Welcome to Tides and Water Levels

◀ ▶

The rise and fall of the tides play an important role in the natural world and can have a marked effect on maritime-related activities. Here, a ship's crew inspects the hull of their vessel. It became stranded on a sandbar following a rapidly receding tide.

NOAA's National Ocean Service collects, studies and provides access to thousands of historical and real-time observations as well as predictions of water levels, coastal currents and other data. Maritime activities throughout the world depend on accurate tidal and current information for safe operation.

In this subject, you will find three sections devoted to learning about tides and water levels: an online tutorial, an educational roadmap to resources, and formal lesson plans.

The Tides and Waters Levels Tutorial is an overview of the complex systems that govern the movement of tides and water levels. The tutorial is content rich and presented in easy-to-understand language. It is made up of 11 "chapters" or pages (plus a reference page) that can be read in sequence by clicking on the arrows at the top or bottom of each chapter page. The tutorial includes many illustrative and interactive graphics to visually enhance the text.

The Roadmap to Resources complements the information in the tutorial. The roadmap directs you to specific tidal and current data offered within the NOS and NOAA family of products.

The Lesson Plans integrate information presented in the tutorial with data offerings from the roadmap. These lesson plans have been developed for students in grades 9–12 and focus on the forces that cause and effect tides, analysis of the variations in tidal patterns and what conditions may cause them, and the effect of lunar cycles on living organisms.

SCiLINKS Selected by Science Educators from NSTA

The National Science Teachers Association (NSTA) has included this online resource in its *SciLinks* database. *SciLinks* provide students and teachers access to Web-based, educationally appropriate science content that has been formally evaluated by master teachers.

For more information about the *SciLinks* evaluation criteria, click here: http://www.scilinks.org/certificate.asp.

To go directly to the *SciLinks* log-on page, click here: http://www.scilinks.org/.

(top)

◀ ▶

search
○ This site ○ NOAA

Tides Roadmap

Tides Lesson Plans

Welcome

What are Tides?

What Causes Tides?

Gravity, Inertia, and Bulges

Changing Angles and Tides

The Frequency of Tides

Tidal Variations

Types and Causes of Tidal Cycles

What Else Affects Tides?

Monitoring the Tides

How are Tides Measured ? Pt. I

How are Tides Measured? Pt. II

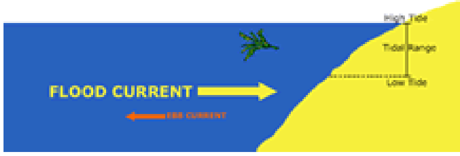
References

Tides and Water Levels

What are Tides?

◀ ▶

Tides are one of the most reliable phenomena in the world. As the sun rises in the east and the stars come out at night, we are confident that the ocean waters will regularly rise and fall along our shores. The following pages describe the tremendous forces that cause the world's tides, and why it is important for us to understand how they work.



As the tides rise and fall, they create flood and ebb currents. *Click the image for an animated view.*

Basically, tides are very long-period waves that move through the oceans in response to the forces exerted by the moon and sun. Tides originate in the oceans and progress toward the coastlines where they appear as the regular rise and fall of the sea surface. When the highest part, or crest of the wave reaches a particular location, high tide occurs; low tide corresponds to the lowest part of the wave, or its trough. The difference in height between the high tide and the low tide is called the tidal range.

A horizontal movement of water often accompanies the rising and falling of the tide. This is called the tidal current. The incoming tide along the coast and into the bays and estuaries is called a flood current; the outgoing tide is called an ebb current. The strongest flood and ebb currents usually occur before or near the time of the high and low tides. The weakest currents occur between the flood and ebb currents and are called slack tides. In the open ocean tidal currents are relatively weak. Near estuary entrances, narrow straits and inlets, the speed of tidal currents can reach up to several kilometers per hour (Ross, D.A., 1995).

(top)

◀ ▶

search
○ This site ○ NOAA

Tides Roadmap

Tides Lesson Plans

Welcome

What are Tides?

What Causes Tides?

Gravity, Inertia, and Bulges

Changing Angles and Tides

The Frequency of Tides

Tidal Variations

Types and Causes of Tidal Cycles

What Else Affects Tides?

Monitoring the Tides

How are Tides Measured ? Pt. I

How are Tides Measured? Pt. II

References

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NOAA's National Ocean Service | National Oceanic and Atmospheric Administration | U.S. Department of Commerce
http://oceanservice.noaa.gov/education/kits/tides/tides01_intro.html
Best viewed in Internet Explorer 5+ or Netscape 6+.

This animation shows the relationship betwen the vertical and horizontal components of tides. As the tide rises, water moves toward the shore. This is called a flood current. As the tide recedes, the waters move away from the shore. This is called an ebb current. The movement of water toward and away from the shore is illustrated by the movement of the green seaweed.

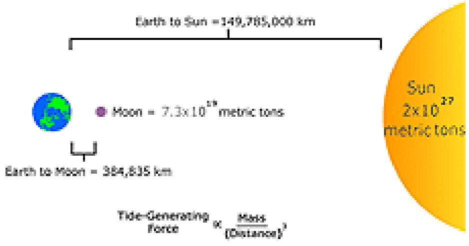
(top)

Tides and Water Levels

What Causes Tides?

Gravity is one major force that creates tides. In 1687, Sir Isaac Newton explained that ocean tides result from the gravitational attraction of the sun and moon on the oceans of the earth (Sumich, J.L., 1996).

Newton's law of universal gravitation states that the gravitational attraction between two bodies is directly proportional to their masses, and inversely proportional to the square of the distance between the bodies (Sumich, J.L., 1996; Thurman, H.V., 1994). Therefore, the greater the mass of the objects and the closer they are to each other, the greater the gravitational attraction between them (Ross, D.A. 1995).



The relationship between the masses of the Earth, moon and sun and their distances to each other play critical roles in affecting tides. *Click the image for a larger view.*

Tidal forces are based on the gravitational attractive force. With regard to tidal forces on the Earth, the distance between two objects usually is more critical than their masses. Tidal generating forces vary inversely as the cube of the distance from the tide generating object. Gravitational attractive forces only vary inversely to the square of the distance between the objects (Thurman, H. V., 1994). The effect of distance on tidal forces is seen in the relationship between the sun, the moon, and the Earth's waters.

Our sun is 27 million times larger than our moon. Based on its mass, the sun's gravitational attraction to the Earth is more than 177 times greater than that of the moon to the Earth. If tidal forces were based solely on comparative masses, the sun should have a tide-generating force that is 27 million times greater than that of the moon. However, the sun is 390 times further from the Earth than is the moon. Thus, its tide-generating force is reduced by 390^3, or about 59 million times less than the moon. Because of these conditions, the sun's tide-generating force is about half that of the moon (Thurman, H.V., 1994).

(top)

search
○ This site ○ NOAA

Tides Roadmap

Tides Lesson Plans

Welcome

What are Tides?

What Causes Tides?

Gravity, Inertia, and Bulges

Changing Angles and Tides

The Frequency of Tides

Tidal Variations

Types and Causes of Tidal Cycles

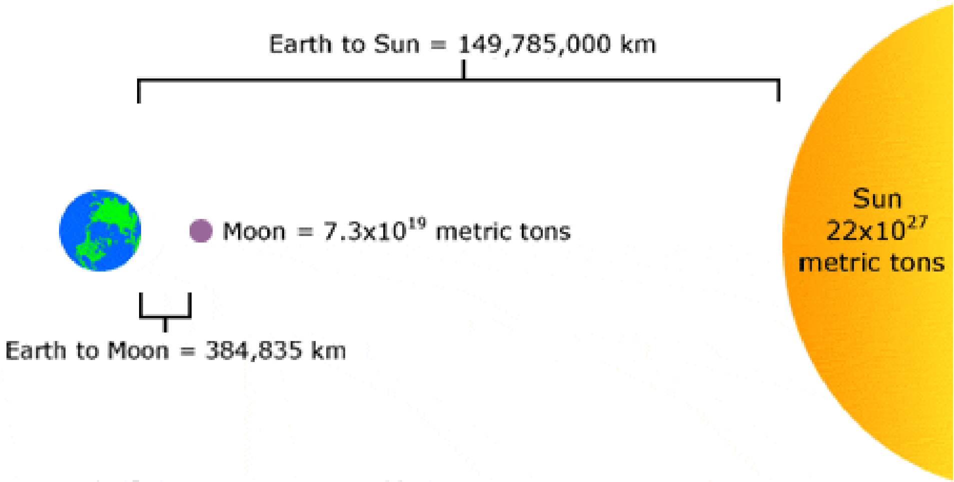
What Else Affects Tides?

Monitoring the Tides

How are Tides Measured ? Pt. I

How are Tides Measured? Pt. II

References



$$\text{Tide-Generating Force} = \propto \frac{\text{Mass}}{(\text{Distance})^3}$$

$$\text{Tide-Generating Force of the Sun} = \propto \frac{\text{Sun's Mass}}{(\text{Sun's Distance to Earth})^3}$$

*NOTE: The sun has 27 million times more mass than the moon and is 390 times farther away from the earth than the moon.

$$(390)^3 = 59{,}000{,}000 \qquad \text{So...} \quad \frac{27\text{ million}}{59\text{ million}} = 0.46 \text{ or } 46\%$$

Therefore the Sun has 46% of the tide-generating force of the Moon.

The relationship between the masses of the Earth, moon and sun and their distances to each other play a critical role in affecting the Earth's tides. Although the sun is 27 million times more massive than the moon, it is 390 times further away from the Earth than the moon. Tidal generating forces vary inversely as the cube of the distance from the tide-generating object. This means that the sun's tidal generating force is reduced by 390^3 (about 59 million times) compared to the tide-generating force of the moon. Therefore, the sun's tide-generating force is about half that of the moon, and the moon is the dominant force affecting the Earth's tides.

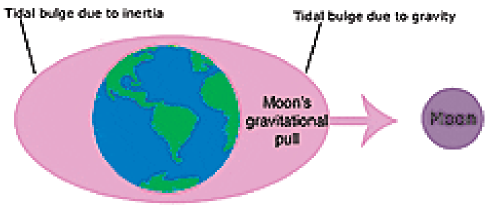
(top)

Tides and Water Levels

Gravity, Inertia, and the Two Bulges

◀ ▶

Gravity is a major force responsible for creating tides. Inertia, acts to counterbalance gravity. It is the tendency of moving objects to continue moving in a straight line. Together, gravity and inertia are responsible for the creation of two major tidal bulges on the Earth (Ross, D.A., 1995).



Two tidal bulges are created on opposite sides of the Earth due to the moon's gravitational force and inertias counterbalance. *Click the image for a larger view.*

The gravitational attraction between the Earth and the moon is strongest on the side of the Earth that happens to be facing the moon, simply because it is closer. This attraction causes the water on this “near side” of Earth to be pulled toward the moon. As gravitational force acts to draw the water closer to the moon, inertia attempts to keep the water in place. But the gravitational force exceeds it and the water is pulled toward the moon, causing a “bulge” of water on the near side toward the moon (Ross, D.A., 1995).

On the opposite side of the Earth, or the “far side,” the gravitational attraction of the moon is less because it is farther away. Here, inertia exceeds the gravitational force, and the water tries to keep going in a straight line, moving away from the Earth, also forming a bulge (Ross, D.A., 1995).

In this way the combination of gravity and inertia create two bulges of water. One forms where the Earth and moon are closest, and the other forms where they are furthest apart. Over the rest of the globe gravity and inertia are in relative balance. Because water is fluid, the two bulges stay aligned with the moon as the Earth rotates (Ross, D.A., 1995).

The sun also plays a major role, affecting the size and position of the two tidal bulges. The interaction of the forces generated by the moon and the sun can be quite complex. As this is an introduction to the subject of tides and water levels we will focus most of our attention on the effects of the stronger celestial influence, the moon.

◀ ▶

(top)

search
○ This site ○ NOAA

Tides Roadmap

Tides Lesson Plans

Welcome

What are Tides?

What Causes Tides?

Gravity, Inertia, and Bulges

Changing Angles and Tides

The Frequency of Tides

Tidal Variations

Types and Causes of Tidal Cycles

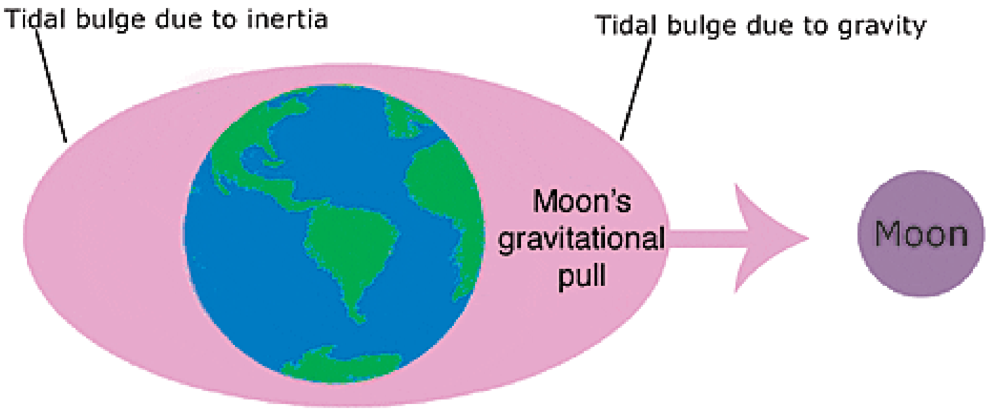
What Else Affects Tides?

Monitoring the Tides

How are Tides Measured ? Pt. I

How are Tides Measured? Pt. II

References



Gravity and inertia act in opposition on the Earth's oceans, creating tidal bulges on opposite sites of the planet. On the "near" side of the Earth (the side facing the moon), the gravitational force of the moon pulls the ocean's waters toward it, creating one bulge. On the far side of the Earth, inertia dominates, creating a second bulge.

(top)

Tides and Water Levels

Changing Angles and Changing Tides

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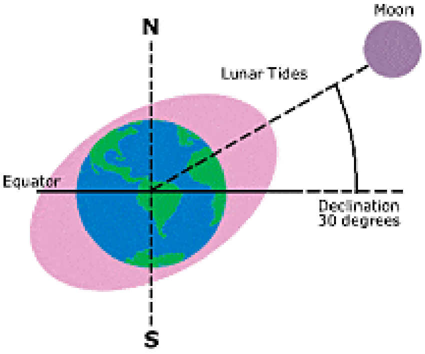
As we've just seen, the Earth's two tidal bulges are aligned with the positions of the moon and the sun. Over time, the positions of these celestial bodies change relative to the Earth's equator. The changes in their relative positions have a direct effect on daily tidal heights and tidal current intensity.



The Earth's tidal bulges track, or follow, the position of the moon and to a lesser extent, the sun. As these two celestial bodies increase and decrease their angles to the Earth, so do the tidal bulges. *Click the image for an animated view.*

As the moon revolves around the Earth, its angle increases and decreases in relation to the equator. This is known as its declination. The two tidal bulges track the changes in lunar declination, also increasing or decreasing their angles to the equator. Similarly, the sun's relative position to the equator changes over the course of a year as the Earth rotates around it. The sun's declination affects the seasons as well as the tides. During the vernal and autumnal equinoxes—March 21 and September 23, respectively—the sun is at its minimum declination because it is positioned directly above the equator. On June 21 and December 22—the summer and winter solstices, respectively—the sun is at its maximum declination, i.e., its largest angle to the equator (Sumich, J.L., 1996).

◀ ▶

(top)

search
○ This site ○ NOAA

Tides Roadmap

Tides Lesson Plans

Welcome

What are Tides?

What Causes Tides?

Gravity, Inertia, and Bulges

Changing Angles and Tides

The Frequency of Tides

Tidal Variations

Types and Causes of Tidal Cycles

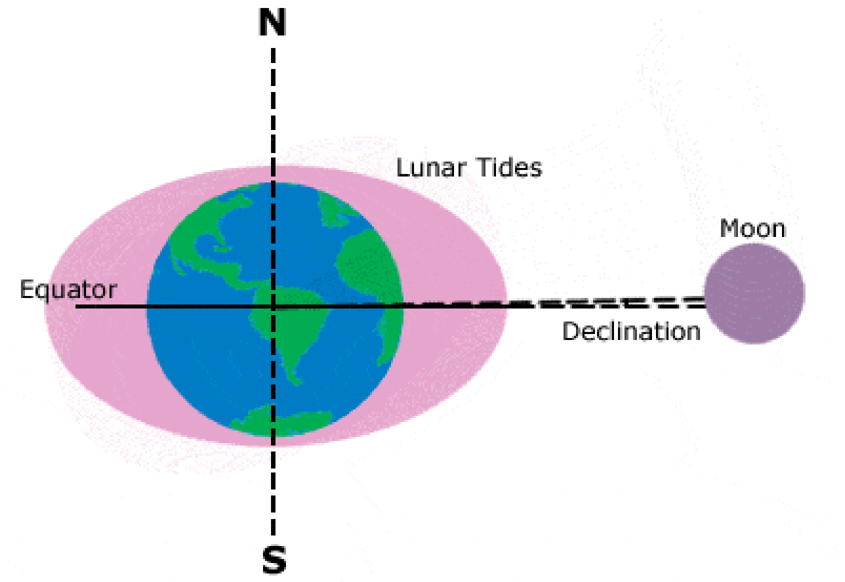
What Else Affects Tides?

Monitoring the Tides

How are Tides Measured ? Pt. I

How are Tides Measured? Pt. II

References



The Earth’s tidal bulges track, or follow, the position of the moon, and to a lesser extent, the sun. As the angles of these two celestial bodies in relation to the Earth increase and decrease, so do the tidal bulges. Here we observe the moon's changing declination to the equator and the effect that this has on the positions of the Earth’s tidal bulges.

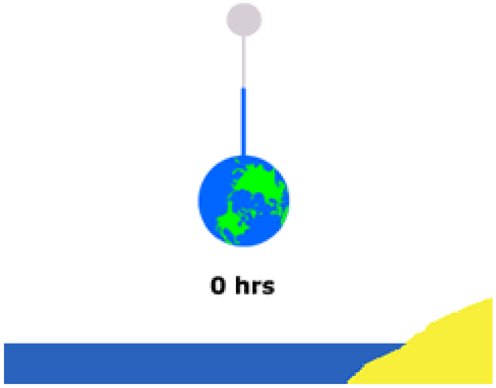
(top)

Tides and Water Levels

Frequency of Tides - The Lunar Day

◀ ▶

Most coastal areas, with some exceptions, experience two high tides and two low tides every lunar day (Ross, D.A., 1995). Almost everyone is familiar with the concept of a 24-hour solar day, which is the time that it takes for a specific site on the Earth to rotate from an exact point under the sun to the same point under the sun. Similarly, a lunar day is the time it takes for a specific site on the Earth to rotate from an exact point under the moon to the same point under the moon. Unlike a solar day, however, a lunar day is 24 hours and 50 minutes. The lunar day is 50 minutes longer than a solar day because the moon revolves around the Earth in the same direction that the Earth rotates around its axis. So, it takes the Earth an extra 50 minutes to “catch up” to the moon (Sumich, J.L., 1996; Thurman, H.V., 1994).



Unlike a 24-hour solar day, a lunar day lasts 24 hours and 50 minutes. This occurs because the moon revolves around the Earth in the same direction that the Earth rotates around its axis. *Click the image to see an animation.*

Because the Earth rotates through two tidal “bulges” every lunar day, coastal areas experience two high and two low tides every 24 hours and 50 minutes. High tides occur 12 hours and 25 minutes apart. It takes six hours and 12.5 minutes for the water at the shore to go from high to low, or from low to high.

◀ ▶

(top)

search

○ This site ○ NOAA

Tides Roadmap

Tides Lesson Plans

Welcome

What are Tides?

What Causes Tides?

Gravity, Inertia, and Bulges

Changing Angles and Tides

The Frequency of Tides

Tidal Variations

Types and Causes of Tidal Cycles

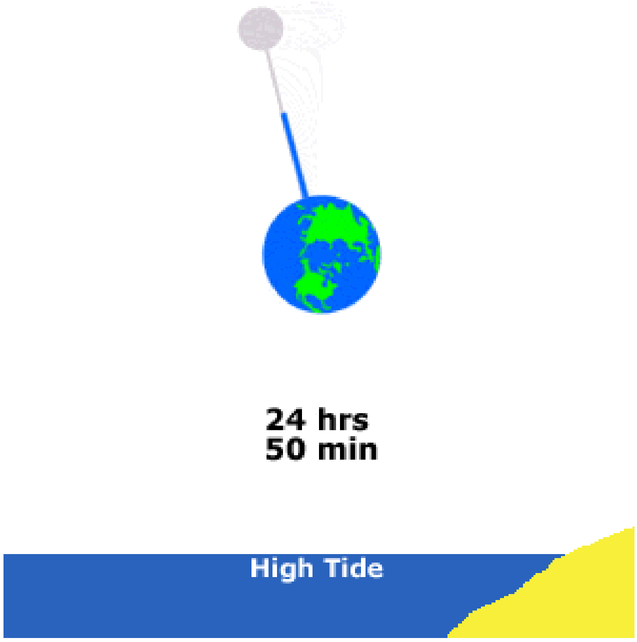
What Else Affects Tides?

Monitoring the Tides

How are Tides Measured ? Pt. I

How are Tides Measured? Pt. II

References



Unlike a 24-hour solar day, a lunar day lasts 24 hours and 50 minutes. This occurs because the moon revolves around the Earth in the same direction that the Earth is rotating on its axis. Therefore, it takes the Earth an extra 50 minutes to “catch up” to the moon. Since the Earth rotates through two tidal “bulges” every lunar day, we experience two high and two low tides every 24 hours and 50 minutes. Here, we see the relationship between the tidal cycle and the lunar day. High tides occur 12 hours and 25 minutes apart, taking six hours and 12.5 minutes for the water at the shore to go from high to low, and then from low to high.

(top)

NOS education discovery kits

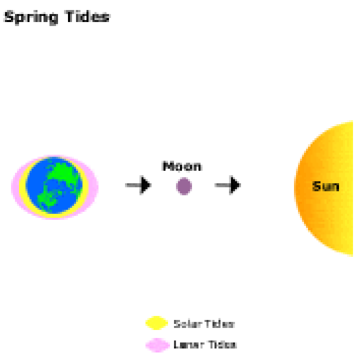
NOS home NOS education home site index

Tides and Water Levels

Tidal Variations - The Influence of Position and Distance

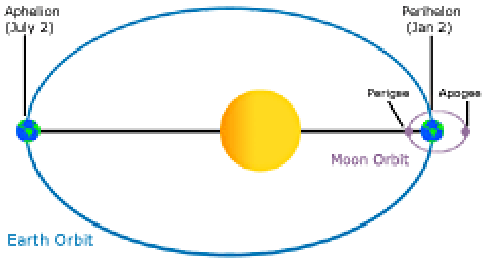
◀ ▶

The moon is a major influence on the Earth's tides, but the sun also generates considerable tidal forces. Solar tides are about half as large as lunar tides and are expressed as a variation of lunar tidal patterns, not as a separate set of tides. When the sun, moon, and Earth are in alignment (at the time of the new or full moon), the solar tide has an additive effect on the lunar tide, creating extra-high high tides, and very low, low tides—both commonly called spring tides. One week later, when the sun and moon are at right angles to each other, the solar tide partially cancels out the lunar tide and produces moderate tides known as neap tides. During each lunar month, two sets of spring tides and two sets of neap tides occur (Sumich, J.L., 1996).



Together, the gravitational effects of the moon and the sun affect the Earth's tides on a monthly basis. *Click the image to see an animation.*

Just as the angles of the sun, moon and Earth affect tidal heights over the course of a lunar month, so do their distances to one another. Because the moon follows an elliptical path around the Earth, the distance between them varies by about 31,000 miles over the course of a month. Once a month, when the moon is closest to the Earth (at perigee), tide-generating forces are higher than usual, producing above-average ranges in the tides. About two weeks later, when the moon is farthest from the Earth (at apogee), the lunar tide-raising force is smaller, and the tidal ranges are less than average. A similar situation occurs between the Earth and the sun. When the Earth is closest to the sun (perihelion), which occurs about January 2 of each calendar year, the tidal ranges are enhanced. When the Earth is furthest from the sun (aphelion), around July 2, the tidal ranges are reduced (Sumich, J.L., 1996; Thurman, H.V., 1994).



The elliptial orbits of the moon around the Earth and the Earth around the sun have substantial effects on the earth's tides. *Click the image for a larger view.*

◀ ▶

(top)

search
○ This site ○ NOAA

Tides Roadmap

Tides Lesson Plans

Welcome

What are Tides?

What Causes Tides?

Gravity, Inertia, and Bulges

Changing Angles and Tides

The Frequency of Tides

Tidal Variations

Types and Causes of Tidal Cycles

What Else Affects Tides?

Monitoring the Tides

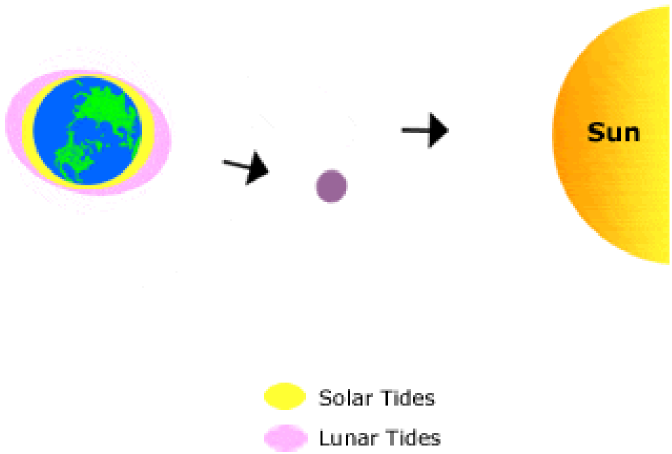
How are Tides Measured ? Pt. I

How are Tides Measured? Pt. II

References

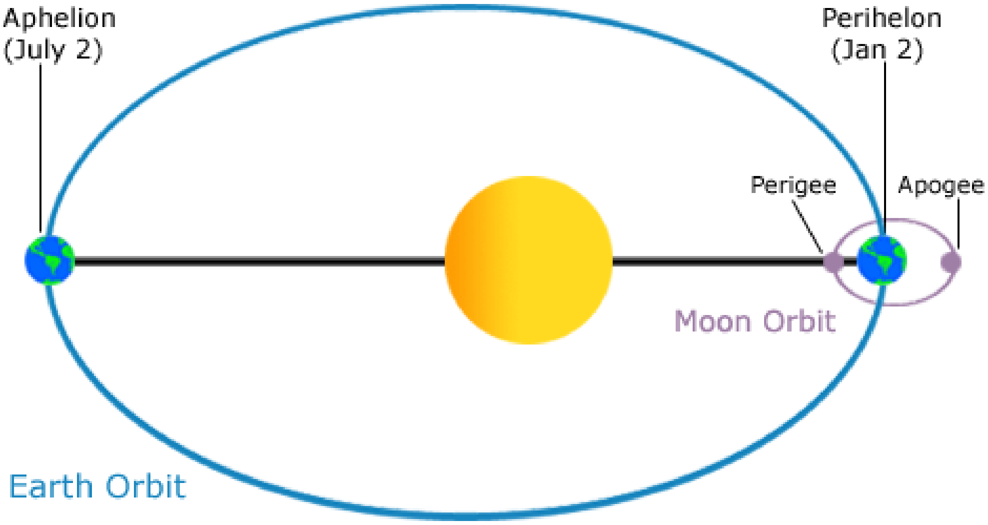
noaa ocean service education

Back



Together, the gravitational pull of the moon and the sun affect the Earth's tides on a monthly basis. When the sun, moon, and Earth are in alignment (at the time of the new or full moon), the solar tide has an additive effect on the lunar tide, creating extra-high high tides, and very low, low tides — both commonly called spring tides. One week later, when the sun and moon are at right angles to each other, the solar tide partially cancels out the lunar tide and produces moderate tides known as neap tides. During each lunar month, two sets of spring and two sets of neap tides occur (Sumich, J.L., 1996).

(top)



The elliptial orbits of the moon around the Earth and the Earth around the sun have a substantial effect on the the Earth's tides. Once a month, at perigee, when the moon is closest to the Earth, tide-generating forces are higher than usual, producing above average ranges in the tides. About two weeks later, at apogee, when the moon is farthest from the Earth, the lunar tide-raising force is smaller, and the tidal ranges are less than average. When the Earth is closest to the sun (perihelion), around January 2 of the calendar year, tidal ranges are enhanced. At aphelion, when the Earth is furthest from the sun, around July 2, tidal ranges are reduced (Sumich, J.L., 1996; Thurman, H.V., 1994).

(top)

Tides and Water Levels

Types and Causes of Tidal Cycles – Diurnal, Semidiurnal, Mixed Semidiurnal; Continental Interference

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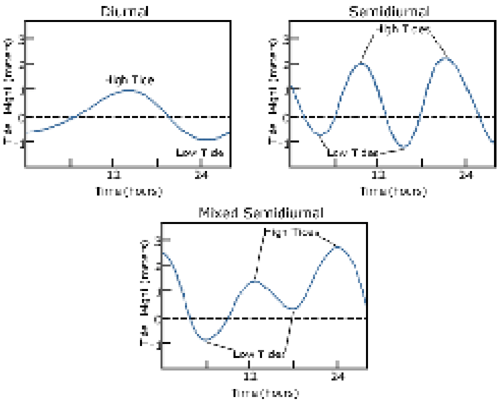
If the Earth were a perfect sphere without large continents, all areas on the planet would experience two equally proportioned high and low tides every lunar day. The large continents on the planet, however, block the westward passage of the tidal bulges as the Earth rotates. Unable to move freely around the globe, these tides establish complex patterns within each ocean basin that often differ greatly from tidal patterns of adjacent ocean basins or other regions of the same ocean basin (Sumich, J.L., 1996).



Depending upon your location on the Earth you may experience Diurnal, Semidiurnal or Mixed Semidiurnal tidal cycles. *Click the image for a larger view.*

Three basic tidal patterns occur along the Earth's major shorelines. In general, most areas have two high tides and two low tides each day. When the two highs and the two lows are about the same height, the pattern is called a semi-daily or semidiurnal tide. If the high and low tides differ in height, the pattern is called a mixed semidiurnal tide. Some areas, such as the Gulf of Mexico, have only one high and one low tide each day. This is called a diurnal tide. The U.S. West Coast tends to have mixed semidiurnal tides, whereas a semidiurnal pattern is more typical of the East Coast (Sumich, J.L., 1996; Thurman, H.V., 1994; Ross, D.A., 1995).

◀ ▶

search
○ This site ○ NOAA

Tides Roadmap

Tides Lesson Plans

Welcome

What are Tides?

What Causes Tides?

Gravity, Inertia, and Bulges

Changing Angles and Tides

The Frequency of Tides

Tidal Variations

Types and Causes of Tidal Cycles

What Else Affects Tides?

Monitoring the Tides

How are Tides Measured ? Pt. I

How are Tides Measured? Pt. II

References

(top)

This map shows the geographic distribution of different tidal cycles. Coastal areas experiencing diurnal tides are yellow, areas experiencing semidiurnal tides are red and regions with mixed semidiurnal tides are outlined in blue. *Click the image for a larger view.*

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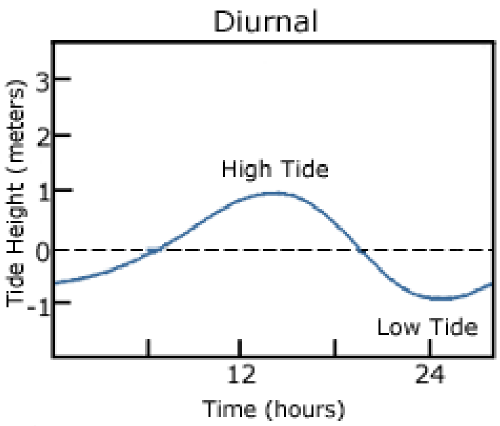
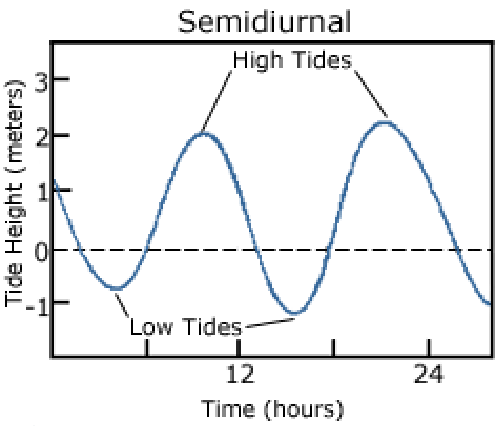
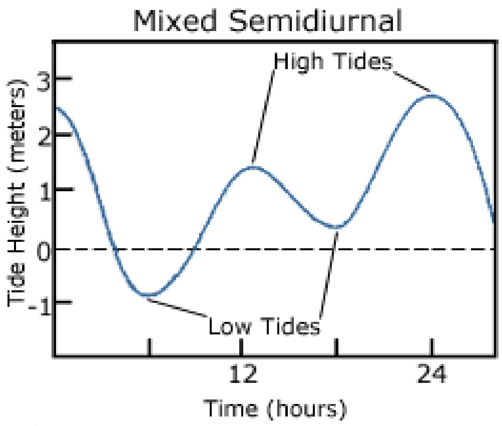




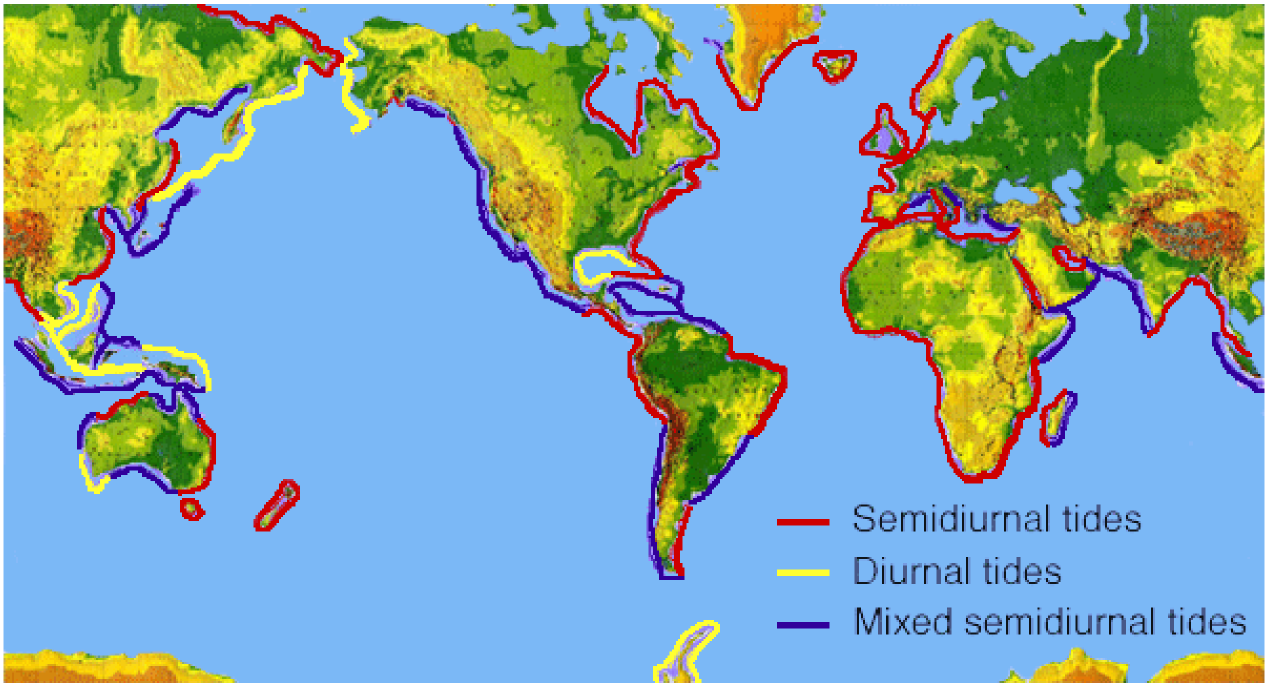


Diurnal tide cycle (upper left). An area has a diurnal tidal cycle if it experiences one high and one low tide every lunar day. Many areas in the Gulf of Mexico experience these types of tides.

Semidiurnal tide cycle (upper right). An area has a semidiurnal tidal cycle if it experiences two high and two low tides of approximately equal size every lunar day. Many areas on the eastern coast of North America experience these tidal cycles.

Mixed Semidiurnal tide cycle (lower middle). An area has a mixed semidiurnal tidal cycle if it experiences two high and two low tides of different size every lunar day. Many areas on the western coast of North America experience these tidal cycles.

(top)



Tides establish complex patterns within each ocean basin that often differ greatly from tidal patterns of adjacent ocean basins or other regions of the same ocean basin (Sumich, J.L., 1996). This map shows the geographic distribution of different tidal cycles along the earth's coastlines. Areas experiencing diurnal tides are marked in yellow, areas experiencing semidiurnal tides are drawn in red and regions with mixed semidiurnal tides are outlined in blue.

(top)

Tides and Water Levels

What Affects Tides in Addition to the Sun and Moon?

◀ ▶

The relative distances and positions of the sun, moon and Earth all affect the size and magnitude of the Earth's two tidal bulges. At a smaller scale, the magnitude of tides can be strongly influenced by the shape of the shoreline. When oceanic tidal bulges hit wide continental margins, the height of the tides can be magnified. Conversely, mid-oceanic islands not near continental margins typically experience very small tides of 1 meter or less (Thurman, H.V., 1994).

The shape of bays and estuaries also can magnify the intensity of tides. Funnel-shaped bays in particular can dramatically alter tidal magnitude. The Bay of Fundy in Nova Scotia is the classic example of this effect, and has the highest tides in the world—over 15 meters (Thurman, H.V., 1994). Narrow inlets and shallow water also tend to dissipate incoming tides. Inland bays such as Laguna Madre, Texas, and Pamlico Sound, North Carolina, have areas classified as non-tidal even though they have ocean inlets. In estuaries with strong tidal rivers, such as the Delaware River and Columbia River, powerful seasonal river flows in the spring can severely alter or mask the incoming tide.

Local wind and weather patterns also can affect tides. Strong offshore winds can move water away from coastlines, exaggerating low tide exposures. Onshore winds may act to pile up water onto the shoreline, virtually eliminating low tide exposures. High-pressure systems can depress sea levels, leading to clear sunny days with exceptionally low tides. Conversely, low-pressure systems that contribute to cloudy, rainy conditions typically are associated with tides than are much higher than predicted.

The shape of bays and estuaries, geographic location and weather patterns all can affect local tidal intensity. *Click the image for a larger view.*

search
○ This site ○ NOAA

Tides Roadmap

Tides Lesson Plans

Welcome

What are Tides?

What Causes Tides?

Gravity, Inertia, and Bulges

Changing Angles and Tides

The Frequency of Tides

Tidal Variations

Types and Causes of Tidal Cycles

What Else Affects Tides?

Monitoring the Tides

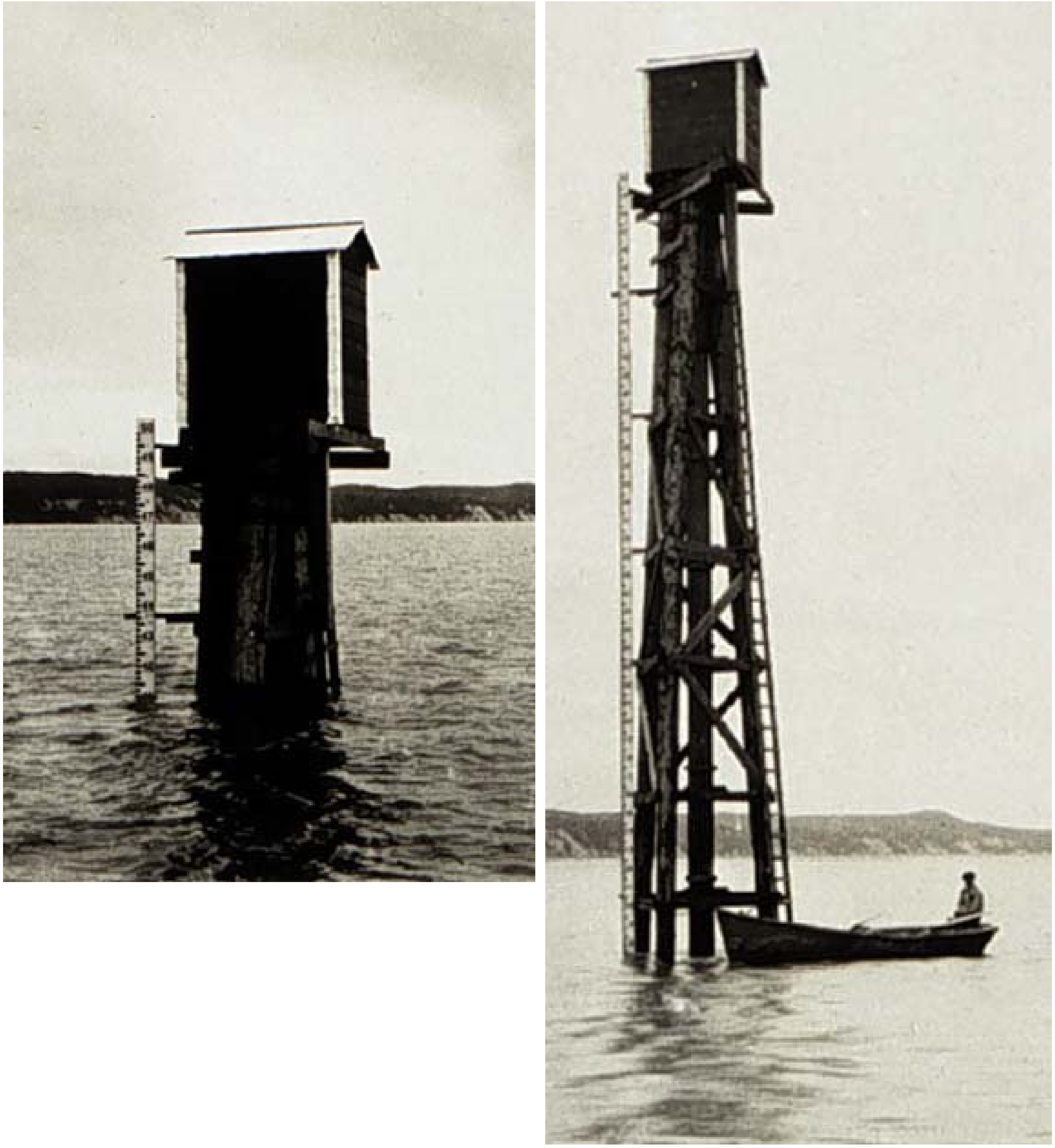
How are Tides Measured ? Pt. I

How are Tides Measured? Pt. II

References

(top)

◀ ▶



The shape of bays and estuaries, geographic location and weather patterns all can affect local tidal intensity. This image of a tidal monitoring station in Alaska taken at high and low tide illustrates the dramatic effect that geographic location can have on tidal range. At increasing lattitudes (as one moves further from the equator and closer to the poles) there often is a dramatic increase in tidal range—in this case, approximately 45 feet.

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Tides and Water Levels

The Importance of Monitoring the Tides and Their Currents

◀ ▶

The ability to predict tides and currents is essential for people who rely on the sea for their livelihood. Knowledge of the marine conditions was critical in transporting these four marine cranes, each 220 feet tall and worth approximately $1.25 million, beneath the Oakland Bridge in San Francisco Bay. *Click the image for a larger view and detailed description.*

Predicting tides has always been important to people who look to the sea for their livelihood. Commercial and recreational fishermen use their knowledge of the tides and tidal currents to help them improve their catches. Depending on the species and water depth in a particular area, fish may concentrate during ebb or flood tidal currents. In some areas, strong tidal currents concentrate bait and smaller fish, attracting larger fish. In addition, knowledge of the tides has also been of interest to recreational beachgoers and surfers.

Navigating ships through shallow water ports, intracoastal waterways and estuaries requires knowledge of the time and height of the tides as well as the speed and direction of the tidal currents. This was particularly critical to sailing ships because they had to take advantage of the tides and currents to manuever correctly. Knowledge of tides and currents is still critical because today's vessels are much larger than the old sailing ships. The depths and widths of the channels in which they sail, and the increased marine traffic leaves very little room for error. Real-time water level, water current, and weather measurement systems now are being used in many major ports to provide mariners and port operators with the latest conditions.

Marine commerce is one area in which tide and current predictions are critical. In June 2002, these four marine cranes valued at $5 million cleared the Oakland Bridge in San Francisco Bay by approximately 6 feet. *Click the image for a larger view.*

Coastal zone engineering projects, including the construction of bridges, docks, etc., require engineers to monitor fluctuating tide levels. Projects involving the construction, demolition or movement of large structures must be scheduled far in advance if an area experiences wide fluctuations in water levels during its tidal cycle. Habitat restoration projects also require accurate knowledge of tide and current conditions.

Scientists are concerned with tides, water levels and tidal currents as well. Ecologists may focus on the tidal mixing of near-shore waters, where pollutants are removed and nutrients are recirculated. Tidal currents also

search
○ This site ○ NOAA

Tides Roadmap

Tides Lesson Plans

Welcome

What are Tides?

What Causes Tides?

Gravity, Inertia, and Bulges

Changing Angles and Tides

The Frequency of Tides

Tidal Variations

Types and Causes of Tidal Cycles

What Else Affects Tides?

Monitoring the Tides

How are Tides Measured ? Pt. I

How are Tides Measured? Pt. II

References

move floating animals and plants to and from breeding areas in estuaries to deeper waters. Oceanographers or atmospheric scientists may study tidal fluctuations to better understand the circulation of the ocean and its relationship to world climatic changes.

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On June 14, 2002, these four industrial cranes, valued at approximately $1.25 million each, arrived in San Francisco Bay from Shanghai, China. Designed to rapidly hoist 40-foot-long containers from super-sized cargo ships, they had to be transported beneath the Oakland Bridge to reach their final destination, the Port of Oakland. The tidal range of San Francisco Bay when these cranes were transported was 4.1 feet and the bridge had a motion of approximately 6 inches. With light chop on the bay and winds blowing at around 10 mph, there was little room for error. With detailed knowledge of the tidal cycle and skillful piloting of the vessel, the cranes cleared the bottom of the bridge by about 6 feet.

(top)

Marine commerce is an area in which tide and current predictions are critical. In June 2002, these four marine cranes valued at $5 million cleared the Oakland Bridge in San Francisco Bay by approximately 6 feet. If you look carefully in the center of the image, you can see a shadowed figure between the crane and the bridge. This is one of the mariners standing on top of the crane and touching the bottom of the bridge as the barge passes beneath it.

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Tides and Water Levels

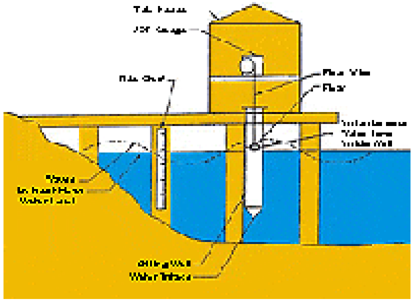
How are Tides Measured? - The Old System

◀ ▶

Since the early 1800s, NOAA and its predecessor organizations have been measuring, describing and predicting tides along the coasts of the United States. The longest continuous sea level records exists for the Presidio, in San Francisco, California. Records for the area date back to June 30, 1854. Today, the Center for Operational Oceanographic Products and Services (CO-OPS), which is part of NOAA's National Ocean Service (NOS), is responsible for recording and disseminating water level data.

This is one of the earliest mechanical pen and ink strip recorders for measuring tidal levels. *Click the image for a larger view.*

In the past, most water level measuring systems used a recorder driven by a float in a "stilling" well. A stilling well calms the waters around the water level sensor. A typical stilling well consisted of a 12-inch wide pipe. Inside the stilling well, an 8-inch diameter float was hung by wire from the recording unit above.



Special tide houses were constructed to shelter permanent water level recorders, protecting them from harsh environmental conditions. *Click the image for a larger view.*

Before computers were used, water level data was recorded on a continuously running pen and ink strip chart. These records were collected by observers once a month and mailed to headquarters for manual processing. In the 1960s, data were recorded onto mechanically punched paper tape that were read into a computer for processing. Water levels were recorded at 6-minute intervals. Observers maintained and adjusted the clocks, and calibrated the gauges with the tide readings. Tide stations were visited annually to maintain the tide

search
○ This site ○ NOAA

Tides Roadmap

Tides Lesson Plans

Welcome

What are Tides?

What Causes Tides?

Gravity, Inertia, and Bulges

Changing Angles and Tides

The Frequency of Tides

Tidal Variations

Types and Causes of Tidal Cycles

What Else Affects Tides?

Monitoring the Tides

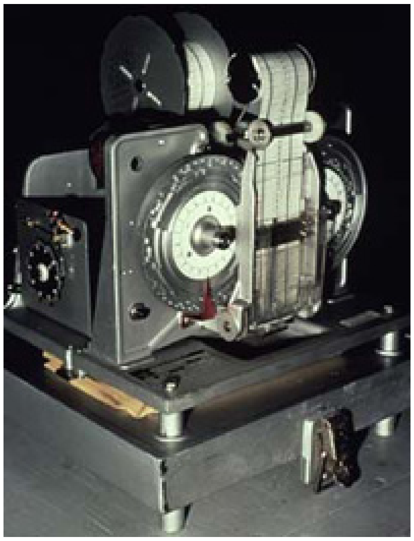
How are Tides Measured ? Pt. I

How are Tides Measured? Pt. II

References

houses and clean biological fouling from the underwater surfaces. During these annual visits, the components and support structures also were checked for stability.

Although these systems worked well, they had their limitations. Stations were subject to recording errors and marine fouling, and were constantly in need of maintenance. In addition, the measurement and data processing equipment could not provide users with information until weeks after the data was collected.



This is a mechanical “punch” recorder that was brought into service when computers first became available for analyzing tidal patterns. *Click the image for a larger view.*

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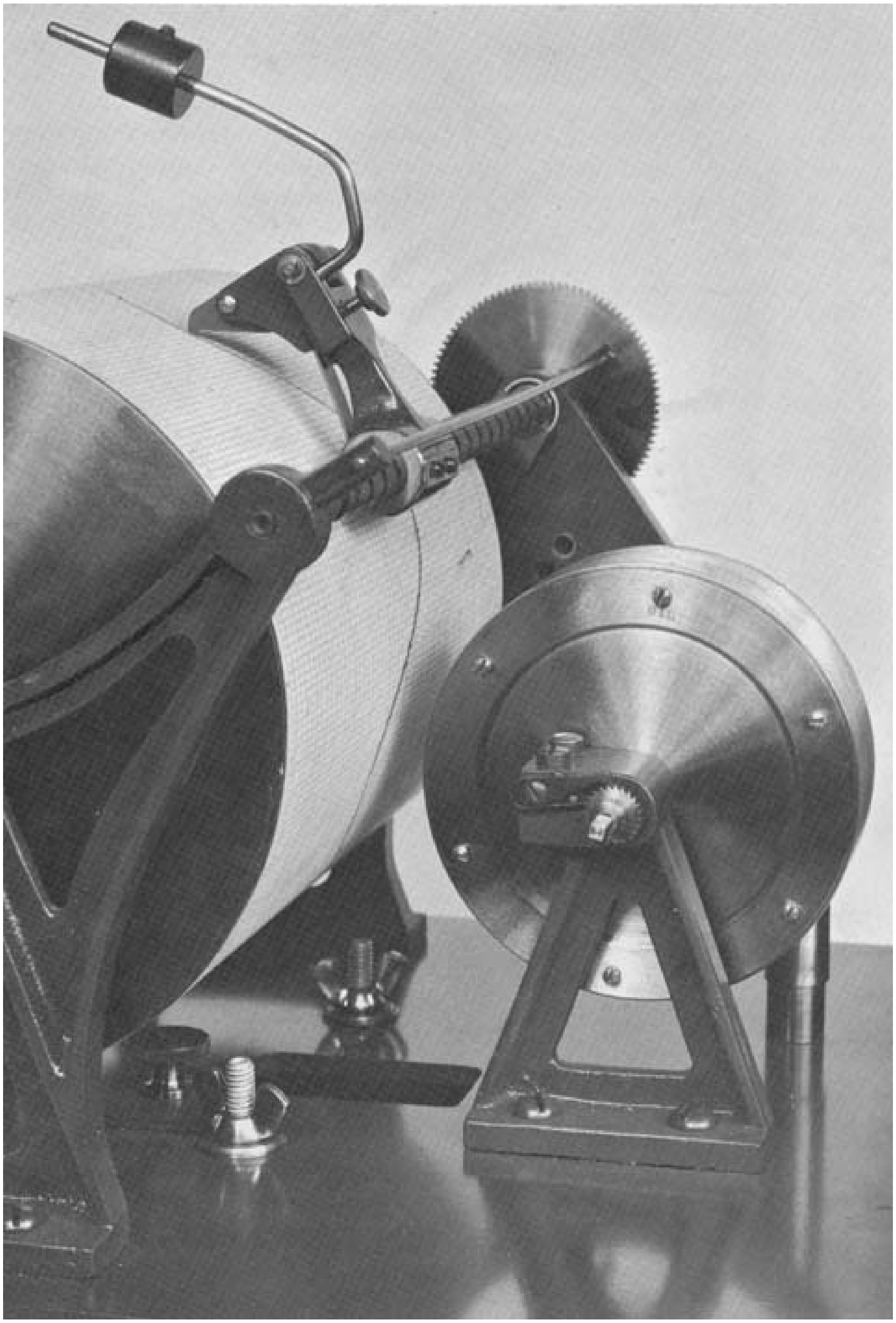
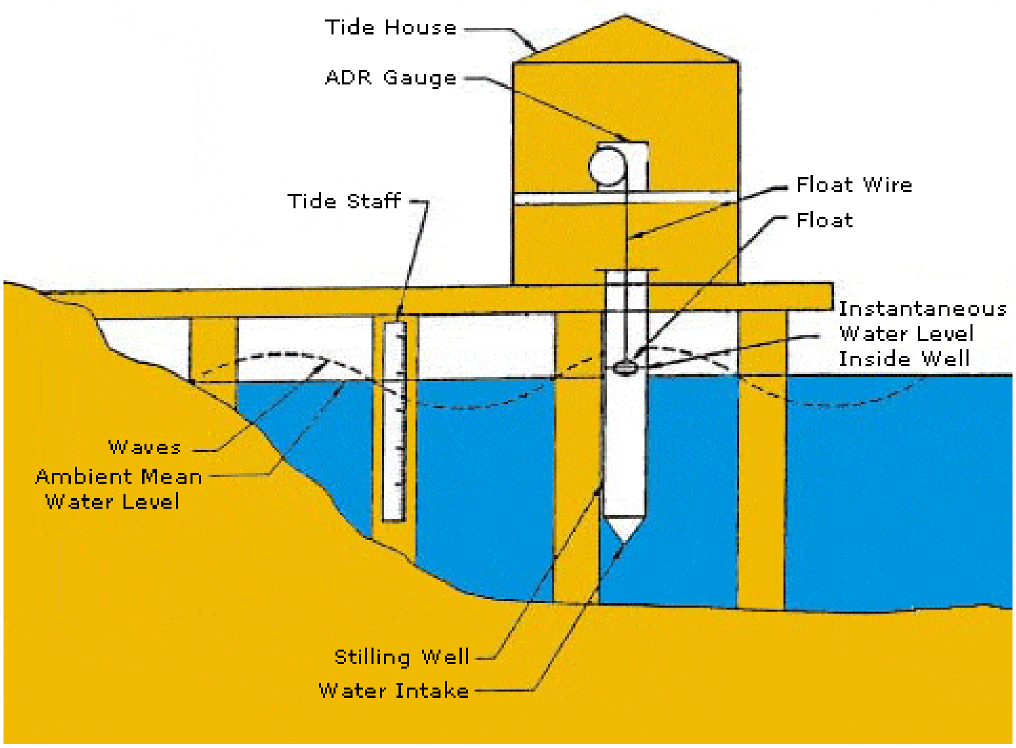


This is a close-up of one of the earliest mechanical pen-and-ink strip recorders. In the upper left part of the image, we can see the stylus marking water level data onto the paper recording strip as it slowly rotates in time with an internal clock. These innovative devices required continuous monitoring and maintenance. All of these mechanical recorders have been replaced with electronic devices that are much more accurate and require less maintenance.

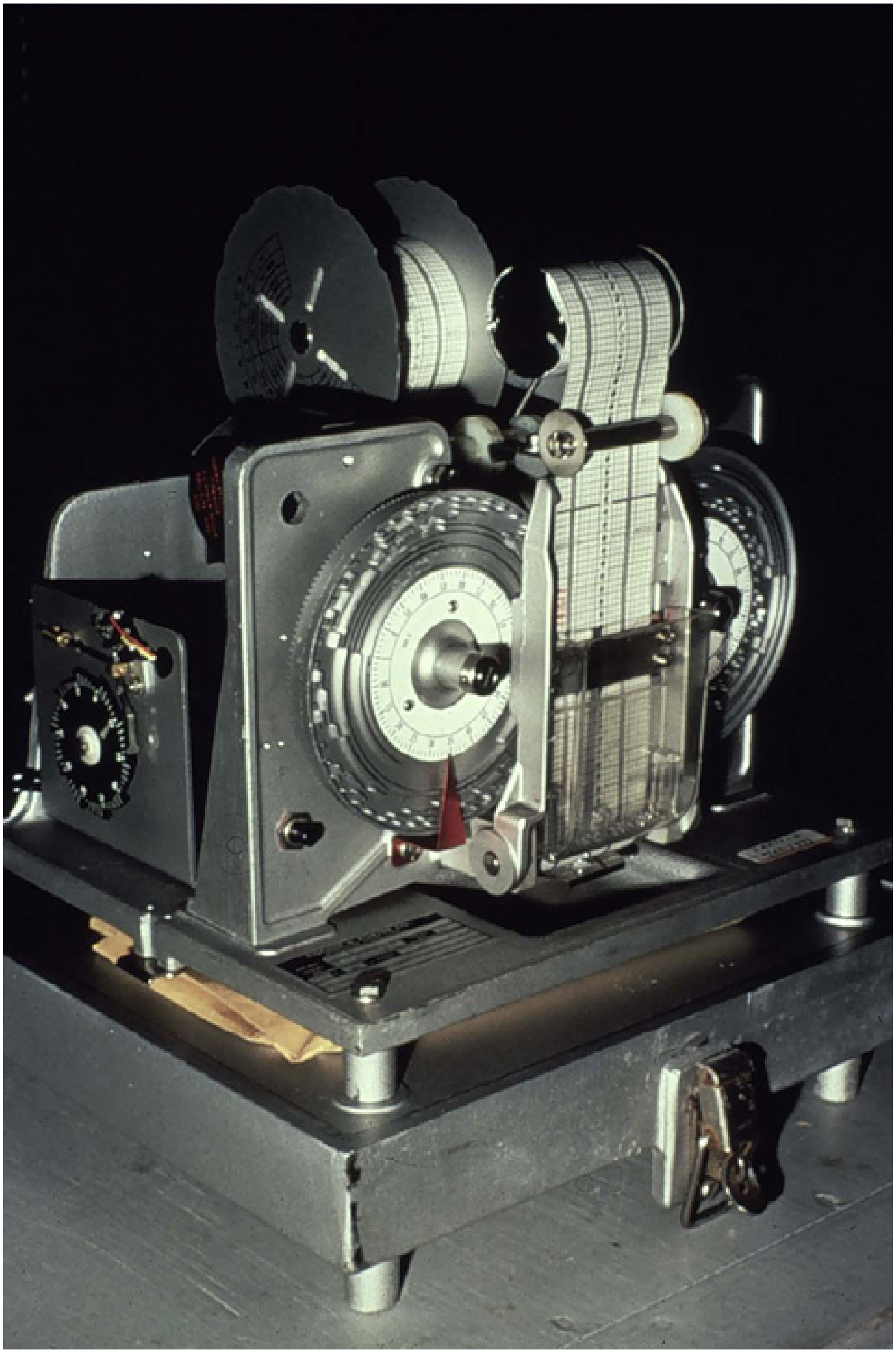


Special tide houses were constructed to shelter permanent water level recorders, protecting them from harsh environmental conditions. In this diagram, we can see how the analog data recorder (ADR) is situated inside the house with the float, and the stilling well located directly beneath it. Attached to one of the piers pilings is a tidal staff. Essentially a giant measuring stick, this device would allow scientists to manually observe the tidal level and then compare it to the readings taken by the analog recorder.

(top)

noaa ocean service education

Back



This is a close-up view of the early analog to digital “punch” data recorders that replaced the earlier pen-and-ink strip recorders. These devices would literally punch a hole into a specially marked strip of paper every six minutes, recording the tidal level at that time. At regular intervals, the paper strips would be removed from the devices and fed into electronic computers. The punches from the strips would be analyzed and graphed. These devices were the precursers to today's advanced electronic monitoring systems. Although more accurate than the older pen-and-ink recorders, they still required frequent maintenance and adjustments.

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Tides and Water Levels

How are Tides Measured? - The New System

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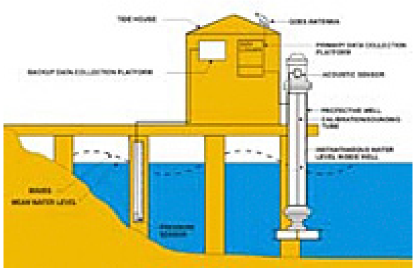
Advances in technology have helped solve many of the problems associated with the old tidal recording systems. Microprocessor-based technologies allow for customized data collection and have improved measurement accuracy. While older tidal measuring stations used mechanical floats and recorders, a new generation of monitoring stations uses advanced acoustics and electronics. Today's recorders send an audio signal down a half-inch-wide sounding tube and measure the time it takes for the reflected signal to travel back from the water's surface. The sounding tube is mounted inside a 6-inch diameter protective well, which is similar to the old stilling well.



Tide houses continue to be built and used to protect equipment from the elements. *Click the image for a larger view.*

In addition to measuring tidal heights more accurately, the new system also records 11 different oceanographic and meteorological parameters. These include wind speed and direction, water current speed and direction, air and water temperature, and barometric pressure.

Like the old recorders, the new measuring stations collect data every six minutes. However, whereas the old recording stations used mechanical timers to tell them when to take a reading, timing is controlled on the new stations by a Geostationary Operational Environmental Satellite (GOES). The stations also use these satellites to transmit their data hourly to NOAA headquarters. In the event of a storm, the stations can be programmed to transmit their data every six minutes. Field teams can quickly check and maintain the systems using laptop computers. In addition, all of the raw and processed data are available over the Internet.

A monitoring station attached directly to a pier. *Click the image for a larger view.*

search
○ This site ○ NOAA

Tides Roadmap

Tides Lesson Plans

Welcome

What are Tides?

What Causes Tides?

Gravity, Inertia, and Bulges

Changing Angles and Tides

The Frequency of Tides

Tidal Variations

Types and Causes of Tidal Cycles

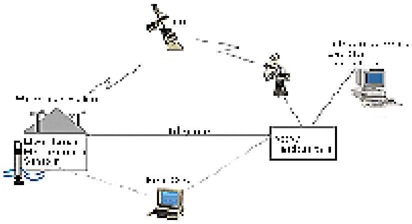
What Else Affects Tides?

Monitoring the Tides

How are Tides Measured ? Pt. I

How are Tides Measured? Pt. II

References



Today, tide monitoring stations are very accurate, require little maintenance, and are part of a larger nationwide network. *Click the image for a larger view.*

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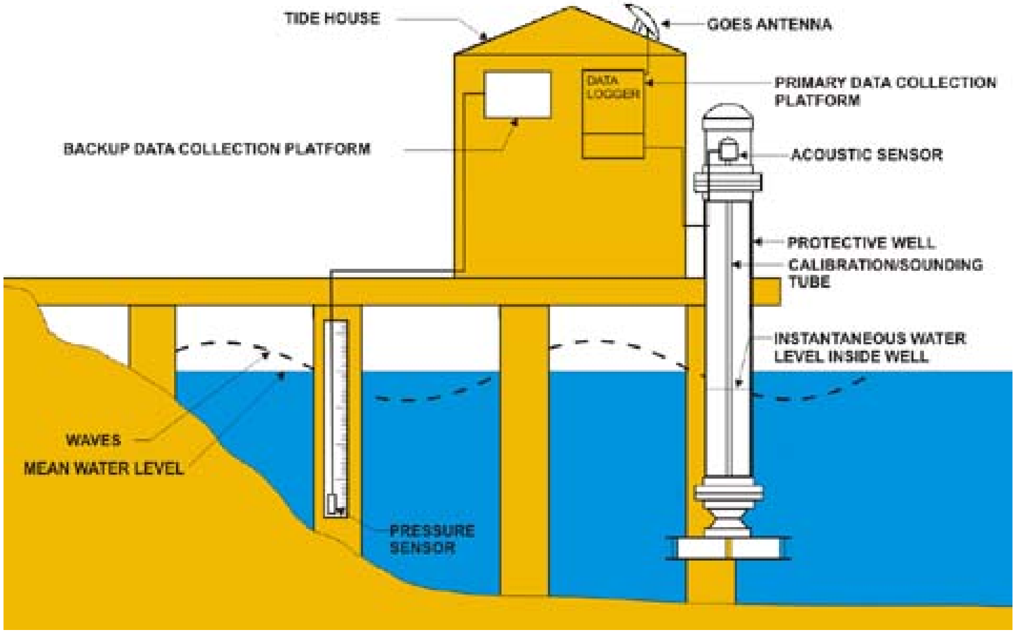
(top)

noaa ocean service education

Back



While similar in design to older tide houses, these newer enclosures are designed to protect sensitive electronics, transmitting equipment, and backup power and data storage devices. The older stilling well has been replaced with an acoustic sounding tube and the tidal staff with a pressure sensor. The new field equipment is designed to operate with the highest level of accuracy with a minimum of maintenance, transmitting data directly back to NOAA headquarters for analysis and distribution.

(top)

noaa oceans and coasts

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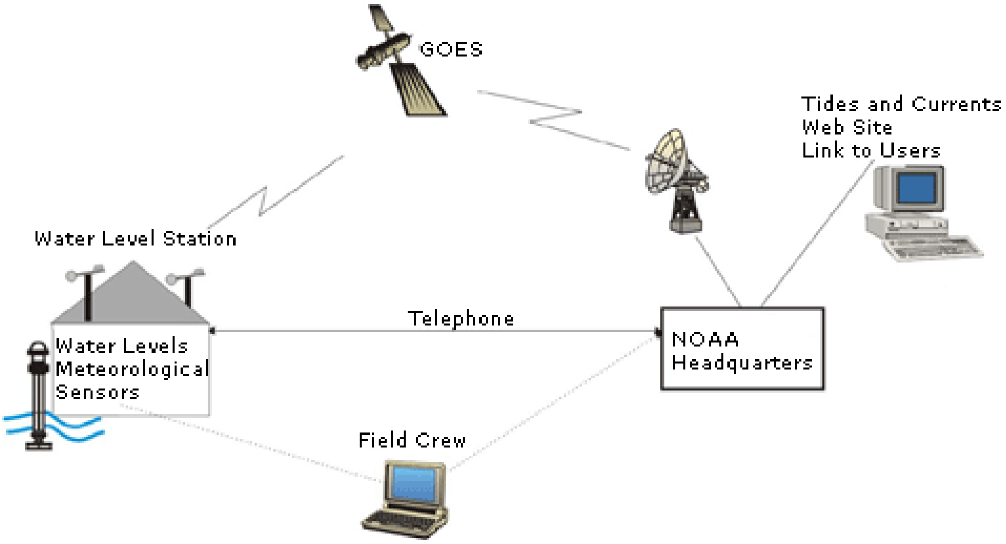
http://oceanservice.noaa.gov/education/kits/tides/media/supp_tide11a.html
Best viewed in Internet Explorer 5+ or Netscape 6+.

Not all monitoring stations are housed in protective enclosures. This water level and meteorological recorder is attached directly to a pier. On the far left is the acoustic sounding tube and sensor. Rising up from the piling is a solar cell, and above that, a satellite transmitter. The remainder of the recording electronics are housed in a small weatherproof box (open).



The earliest tidal monitoring stations were small and self-contained, but they required frequent visits for maintenance and adjustment. Today, stations are still self contained but are very accurate, require little maintenance, and are part of a larger nationwide network. Today, data are transmitted to NOAA headquarters via satellite shortly after they are collected. After rapid computer analysis, the data are immediately posted to one of several Web sites where they can be universally accessed. With these systems in place, scientists can run diagnostic checks on the equipment without needing to travel into the field. This saves both time and money.

(top)

Tides and Water Levels

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(top)

search

○ This site ○ NOAA

Tides Roadmap

Tides Lesson Plans

Welcome

What are Tides?

What Causes Tides?

Gravity, Inertia, and Bulges

Changing Angles and Tides

The Frequency of Tides

Tidal Variations

Types and Causes of Tidal Cycles

What Else Affects Tides?

Monitoring the Tides

How are Tides Measured ? Pt. I

How are Tides Measured? Pt. II

References