

**U3A Port Fairy
Science...naturally!**

The Tides

Ross Knudsen, June 2020



A very high tide on East Beach, Port Fairy in May 2020. Vigorous Autumn storms had eroded about two feet of sand from the beach which allowed water to reach the height it did. A combination of moon position, storm surge, and the season, account for higher tides along our coast.

The Tide

*The ebb of tide reveals the sand
On beaches clean and wide.
In nature's way the waters rise
And does the beaches hide. R.K.*

We are all familiar with the constant movement of the tides. In this presentation, I shall provide you with some information on just how it works.

A request came to me to make it 'really scientific' – so I shall compromise a little and keep it to a reasonable level for understanding. That way everyone can get the basics or a little more.

What are tides? – by definition:

Tides are periodic, short term changes in the height of the ocean surface at a particular place, caused by the combination of the gravitational force of the moon and sun and the motion of the Earth.

Some of you have travelled to other parts of Australia and the world, and perhaps witnessed, not only the tides, but the variation in tide height. Along with that, you may have wondered why they vary in height in London, Rome, Bali, Christchurch, Broome, Perth, Cairns as opposed to the tidal range you see here in Port Fairy. Some tide ranges are quite enormous, whereas others, not so much.

Although tides are predictable events, they occur at different times each day. More on this later.

You may also remember from an early age that the moon has a lot to do with the tides and it was **only** the moon responsible for the ebb and flow due to its gravitational effect on the Earth. There are at least 140 tide-generating and tide-altering forces and factors, and their interactions are complex. Too many to mention here. Besides, that would be getting too scientific!

The main factors include:

- Our sun
- Centrifugal force – due to the Earth's rotation
- Meteorological effects – barometric pressure, effect of wind
- Storm surges
- Seasonal changes
- Latitude – just where you live on this planet
- The depth of the ocean, bays and inlets
- The location and shape of bays, inlets
- Declination of the moon (its relative angle north and south of the equator) see **Figure 1**
- Tidal friction – long term effects

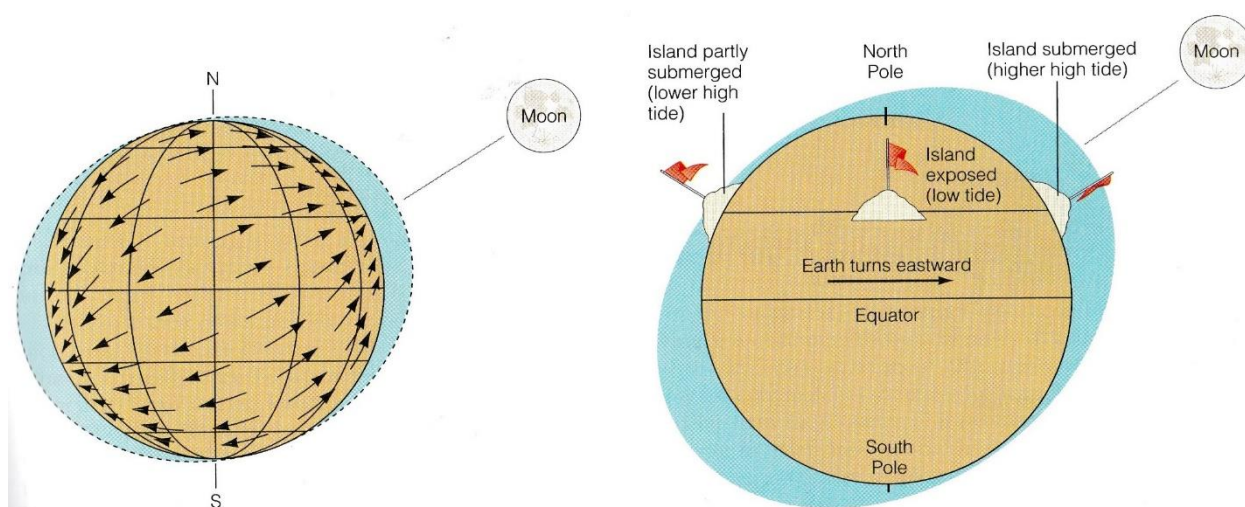


Figure 1: The declination of the moon in this image is high and so the tidal bulge follows the moon. As the moon's declination lessens towards the equator, and then south of the equator, the tidal bulge again follows the moon. Hence another factor in the ever-moving tidal ranges at different locations on Earth.

The opposite bulge is due to the centrifugal force of Earth's rotation.

Gravity and centrifugal force cause the ocean's surface to bulge. Tides occur as Earth rotates beneath the bulges. Generally, there are two high tides and two low tides during the day. The two high tides (bulges) oppose each other, likewise the two low tides oppose each other between the bulges of high tide. Whilst the moon is doing its bit to attract the oceans towards it on one side, centrifugal force is doing its bit on the opposite side of the planet. The

wave crests and troughs that cause high and low tide are actually very small. A 2-metre (7 foot) rise or fall in sea level is insignificant in comparison to the oceans great size. Earth rotates between the bulges (tide wave crests) at about 1600 kilometres per hour at the equator.

This is a simplified explanation and would seem fitting in a state of equilibrium. That state being, there are no land masses, and the oceans being the same depth.

Further explanation of the many other factors or complications that influence our tide's times, frequencies, and heights.

- The land masses (continents) get in the way of the normal motion of the tide wave crests and of course, the oceans vary in depth.
- The **lunar tides**, tides caused by gravitational and inertial* interaction of the moon and Earth, complete their cycle in 24 hours 50 minutes.
- Inertia is a force driving the moon forward. Earth's gravity is pulling the moon towards it. Both forces are in equilibrium and the combined effect provides the moon's stable orbit around the Earth. The same applies to Earth around the sun.
- The high tides arrive 50 minutes later each day.
- Now we add some meteorological effects such as low barometric pressure and prolonged strong winds which could mean a difference between predicted tide heights and times.
- Storm surges are an abnormal rise in sea level over and above the normal tide levels. They are caused by strong winds piling the ocean's waters up against the coast due to cyclones or areas of deep, atmospheric low pressure. These are known as **meteorological tides** caused by weather.

Did you know?

The **Inverse Barometer Effect** is an adjustment of the sea level to changes in barometric pressure. An increase of barometric pressure of 1 mb (millibar), corresponds to a fall in sea level of 1 cm (centimetre). The air indeed has weight.

- The position of our sun – between 23.5 degrees north of the equator (the Tropic of Cancer) and 23.5 degrees south of the equator (the Tropic of Capricorn). Through this variation of the sun's path across our sky, the sun exerts its gravitational force at different times and on different areas of the Earth. This is through our seasons which we know are regular occurrences. This creates a solar bulge (see **Figure 2**)
- Similarly, the moon, as we know, exerts its gravitational force like the sun, however, the moon has a greater range to influence our tides. Where the sun's maximum declination to Earth is 23.5 degrees, the moon's is a hefty 28.5 degrees north and south of the equator. This creates a lunar bulge. (as seen in **Figure 2**)
- The ocean responds simultaneously to centrifugal force and to the gravitational force of both the sun and the moon.
- The moon's influence on tides is about twice that of the sun's. The Earth experiences higher tides at a new and full moon when the sun and moon are aligned. These high

tides are called **spring tides**. They occur at two-week intervals corresponding to the new and full moon. (Please note that spring tides do not only occur in spring of each year.)

- **Neap tides** occur when the moon, Earth and sun form a right angle. High tides are not very high and low tides are not very low. Neap tides also occur at two-week intervals.
- See **Figure 2**

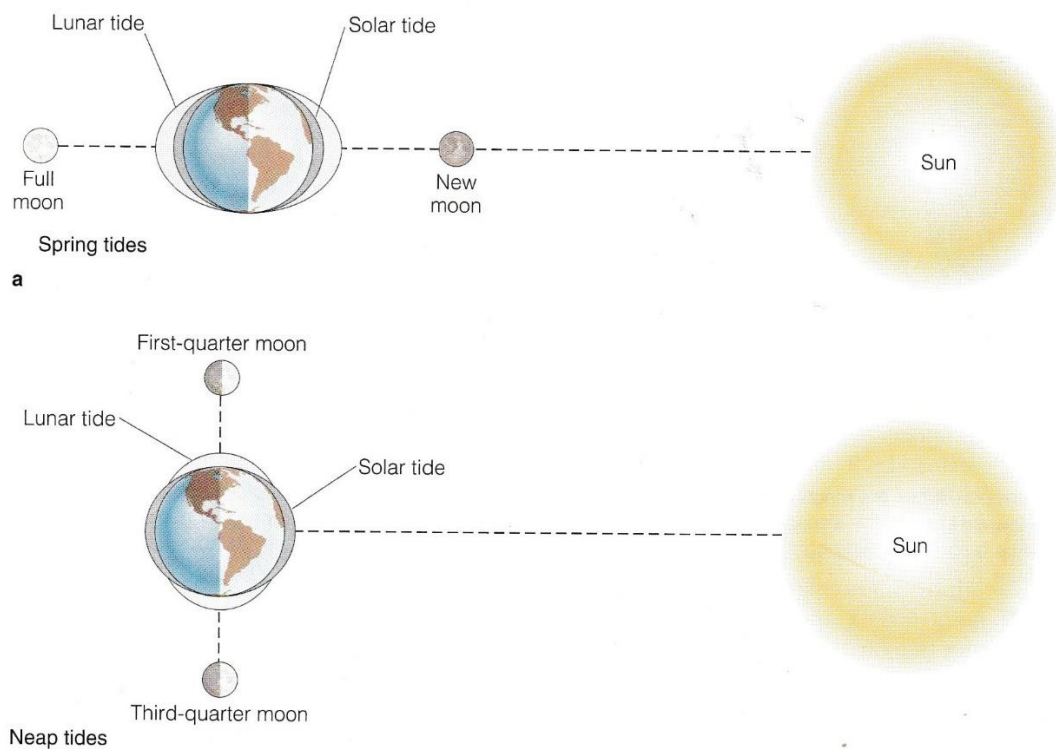


Figure 2: Earth, sun and moon interaction for our spring and neap tides.
Note the position of the tidal bulges around Earth

Another factor to consider whilst on the subject of the moon and sun:

- Both the Earth and moon's orbits are elliptical and not perfectly circular which places each of those bodies, at times, closer to sun/Earth, and further away respectively. The resulting effect is a higher tidal crest (wave). If the sun and moon are over nearly the same latitude, and if Earth is close to the sun, extreme spring tides will result. Earth is closer to the sun during our summer, so our spring tide range is greater. (see **Figure 3**)
- Tides caused by the interaction of the gravity of the sun, moon, and Earth are known as **astronomical tides**.
- The Earth/moon system revolves once a month or 27.3 days, or a cycle of full moon to full moon.

Did you know?

The sun is 27 million times more massive than the moon. Earth is only 81 times more massive than the moon.

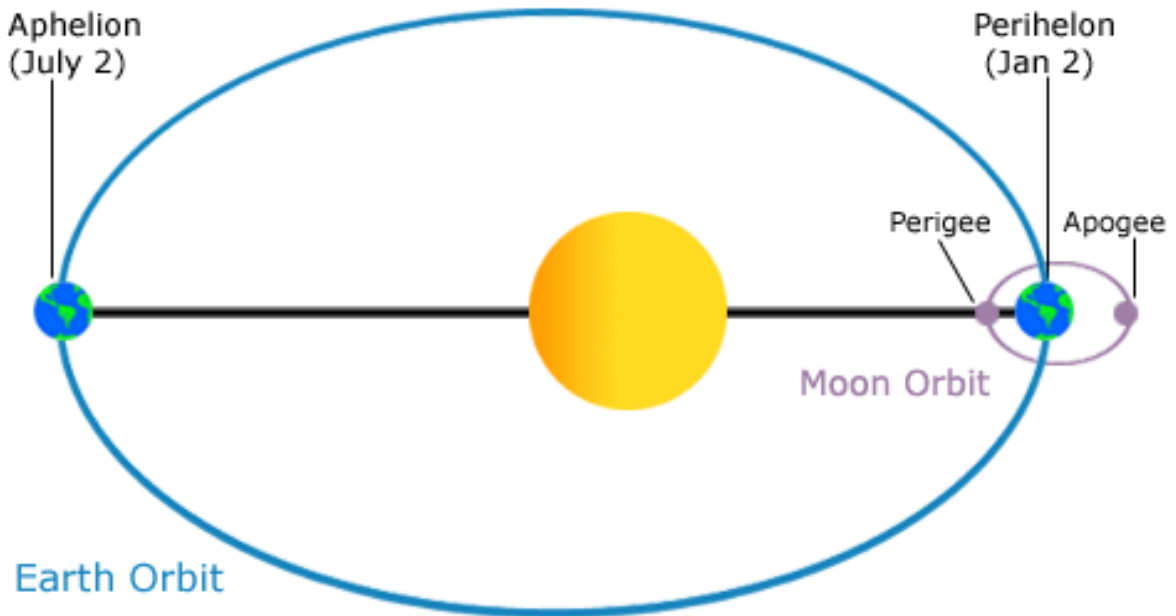


Figure 3 – The Earth and moon's elliptical orbits

I will now touch on tidal range, tidal patterns and amphidromic points.

Tidal Range:

Tidal range is the difference between the maximum and minimum water levels, during a typical tidal cycle. This will determine how much area is above water at low tide and underwater at high tide – the 'intertidal zone'.

The tidal range influences the shape of beaches, as well as the marine life and marine activities in an area (see **Figure 4**).

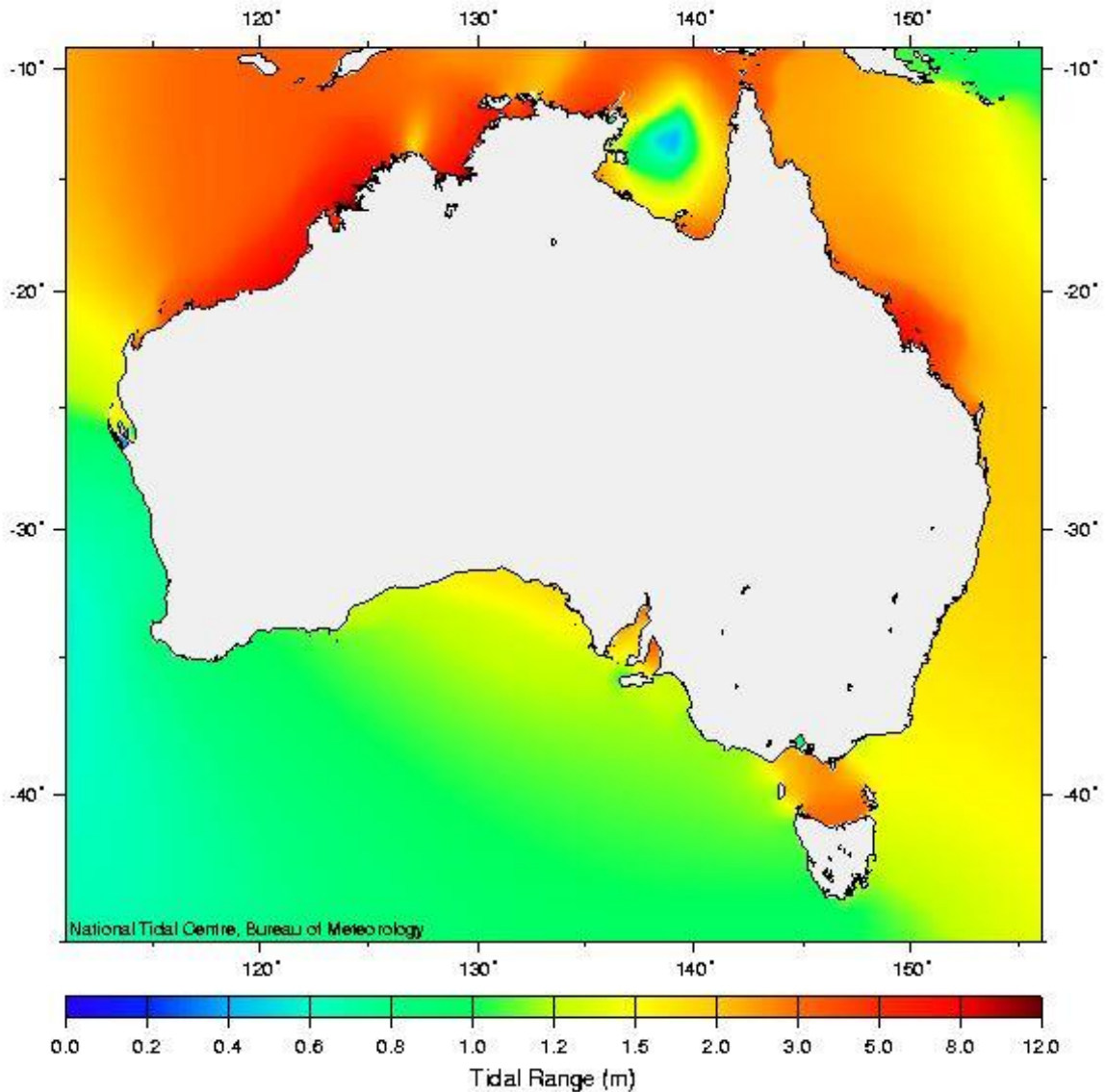


Figure 4: Average tidal range (metres) at spring tides around Australia

Note that Port Fairy's tidal range is around the 1 metre mark

This variation is due to the response of the ocean to astronomical tidal forces, and the shape and depth of ocean basins, bays, and estuaries, which can have a funnelling effect. The spread of tides around the oceans can be thought of as many waves interacting with each other as well as the topography of the ocean floor, with waves undergoing reflection, refraction, rotation, and changes of speed.

Large tides are observed in northwest Australia, in part, because the large width of the continental shelf allows tides to grow larger than they otherwise would if it were a different shape. A similar effect occurs within the southern part of the Great Barrier Reef. Tides are also amplified as they spread into the South Australian gulfs and from either side of Bass Strait.

Tidal Patterns:

Water in large basins can rock rhythmically back and forth in seiches (resonance phenomenon). Though they are small, tidal crests can stimulate this resonant oscillation, and the configuration of coasts around a basin can alter its rhythm.

- For these and other reasons some coastlines experience **semi-diurnal** (twice daily) **tides**: two high tides and two low tides of nearly equal level each lunar day.
- Others have **diurnal** (daily) **tides**: one high and one low
- The tidal pattern is called a **mixed tide** if successive high tides or low tides are of significantly different heights throughout the cycle
- **Port Fairy experiences mixed tides as seen in the chart below**

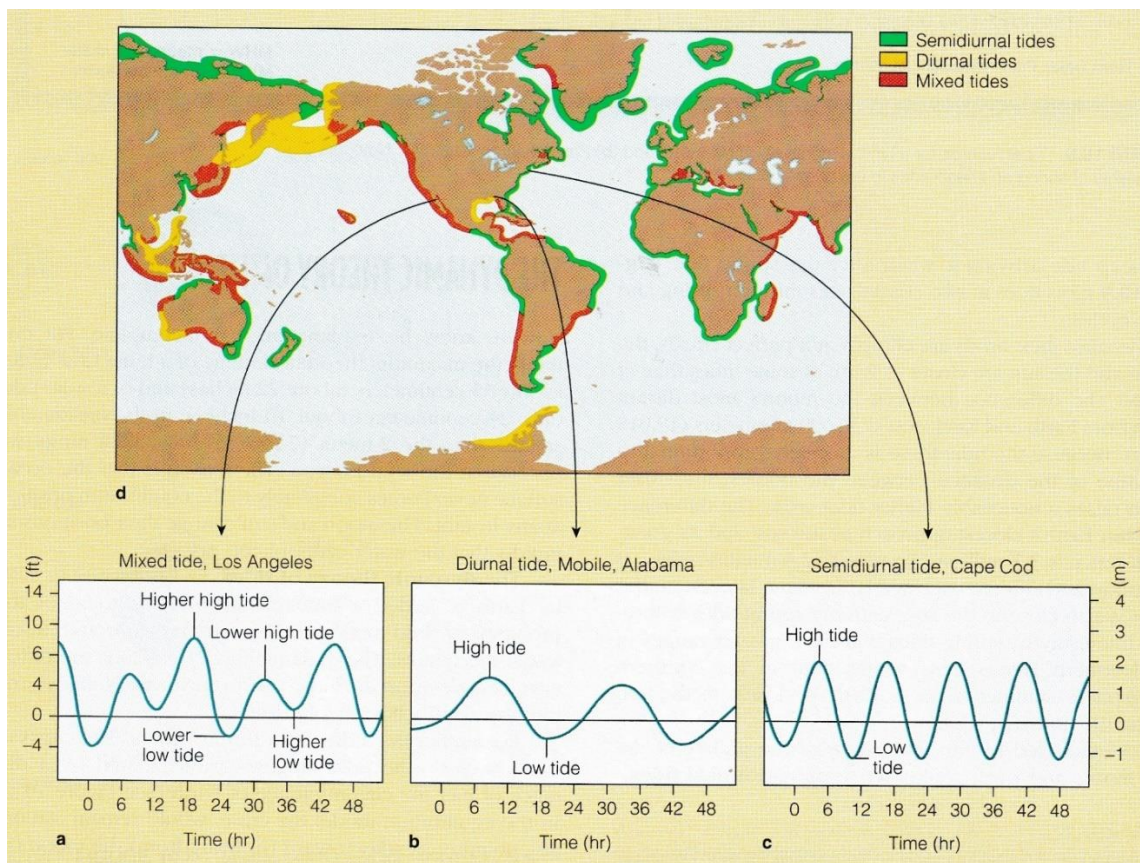


Figure 5: Tidal patterns worldwide

Amphidromic Points:

An **amphidromic point** is a no-tide point (or 'node') in the ocean around which the tidal crest rotates through one tidal cycle. Because of the shape and the placement of landmasses around ocean basins, the tidal crests and troughs cancel each other at these points.

A simple example to demonstrate how this works is to half fill a bath with water, then begin to rock the bath. The water will rock from end to end – high tide at one end and low tide at the other. There will be little or no variation of water height in the middle of the bath. This point or 'node' is the amphidromic point in the bath. The same situation occurs in large inland water storages such as Lake Geneva in Switzerland or Lake Baikal in Russia.

A seesaw is another example: as one end of the seesaw rocks high, the opposite end is low and the point in the middle, that does not gain or lose height, is the amphidromic point of the seesaw.

Tidal ranges generally increase with increasing distance from amphidromic points. About a dozen amphidromic points exist in the world's oceans. The image below shows their locations.

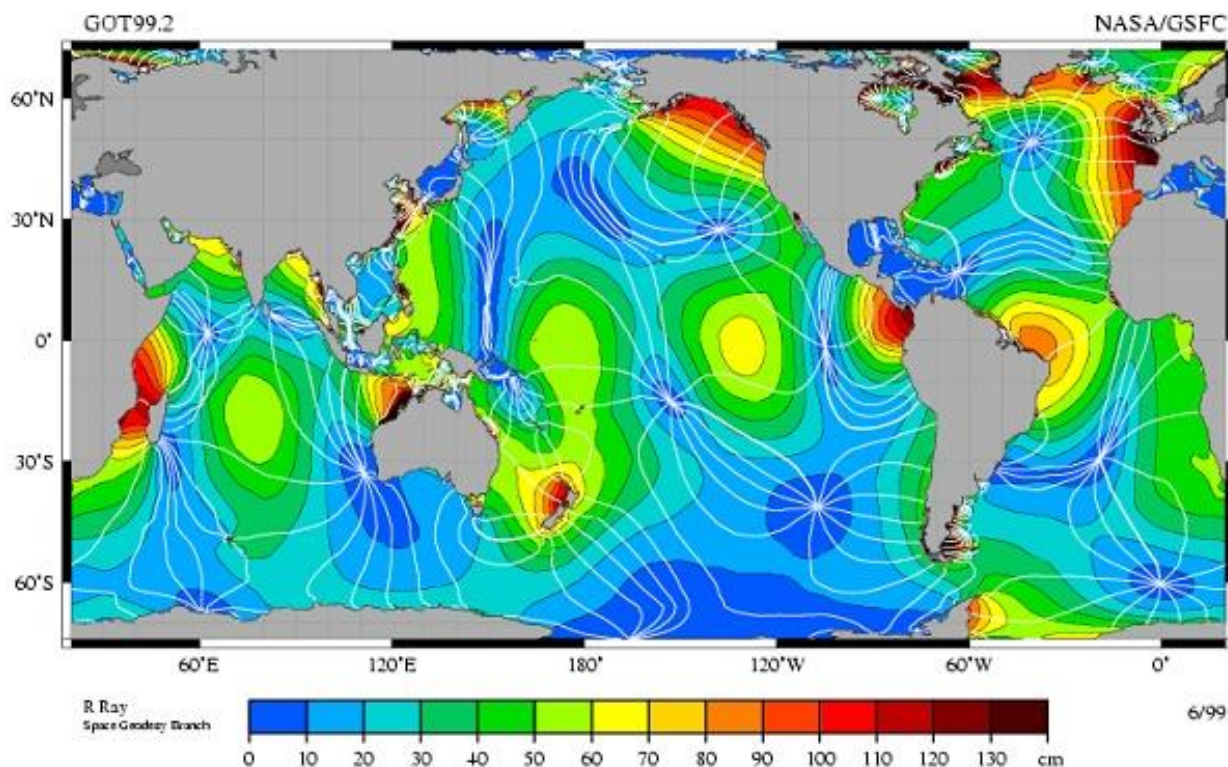


Figure 6: The colours indicate where tides are most extreme (highest highs and lowest lows), with blues being least extreme. White lines radiating from the points (nodes) indicate tide waves moving around these points. In almost a dozen places on this map the lines converge. At each of these places the surrounding colour – the tidal force for that region – is blue, indicating little or no apparent tide. Tide waves move around these points counter-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.

Did you know (technically speaking)?

The current or flow of water we see moving up the Moyne River as the tide is rising is called a **flood stream/flood tide**. The opposite flow as the water recedes is called an **ebb stream/ebb tide**. **Slack water**, a time of no currents, occurs at high or low tides when the current changes direction.

Tidal Friction:

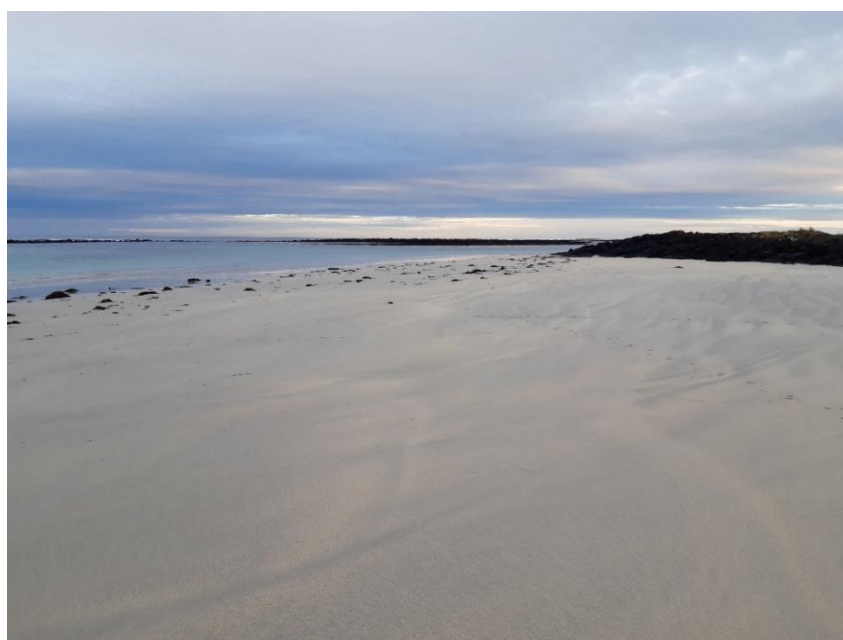
The daily rise and fall of the tides consume a large amount of energy, and this energy is ultimately dissipated as heat. Most of this energy comes directly from the rotation of the Earth itself, and tidal friction is gradually slowing Earth's rotation by a few hundredths of a

second per century. Even such a small change has long-term planetary effects. Geologists studying the daily growth rings of fossil corals and clams estimate that the length of the day has increased, so the number of days in a year has decreased as planetary rotation has slowed.

Evidence suggests that 350 million years ago a year contained between 400 and 410 days, with each day being about 22 hours long; and 280 million years ago there were about 390 days in a year, with each day being about 22 ½ hours long.

Did you know?

A glass of water also has a tide. It is, however, too small to detect. Each molecule of water in the glass responds to the same planetary forces that effect molecules in the ocean.



South Beach, Port Fairy displaying a low, low tide at 8.10am on 27 May 2020



This photo taken 3.58pm on 1 May 2020 at South Beach, Port Fairy.

A combination of a deep low-pressure system just west of Tasmania, storm force winds, and a high tide, culminated in a storm surge bringing water to higher than normal levels.

Summary:

Tides have the longest wavelengths of the ocean's waves. They are caused by a combination of the gravitational force of the moon and the sun, the motion of the Earth, and the tendency of water in enclosed ocean basins to rock at a specific frequency. Unlike the other waves, these huge shallow-water waves are never free of the forces that cause them and so act in unusual but generally predictable ways. Basin resonances and other factors combine to cause different tidal patterns on different coasts. The rise and fall of the tides are important in many physical and biological processes.

Next time you witness the tides, at either high or low stages, you should now be aware of some of the most important influences that make it happen fifty minutes later each day.

It will include the position of the moon, the position of the sun, the season, the weather, windy or calm, the fact Port Fairy experiences mixed tides, the depth of the Southern Ocean and the shape of our coastline and bay. These factors assist in the regular tidal range we experience.

A penultimate note:

Do not confuse tsunamis with tidal waves. They are two separate phenomena.

A 'tidal wave' is caused by the regular motions of rising or flood tides through gravitational attraction.

Tsunamis are caused by landslides, volcanic eruptions or under-sea earthquakes (movement of tectonic plates). Their wavelength is also a dominant factor, having a longer wavelength for the depth of water they travel in.

Final note worthy of inciting intelligent discussion or controversy (straight from the presenter):

The last time the sea-level changes were officially recorded, there was an atmospheric low-pressure system over an extended area which reduced the force applied to the sea surface, therefore raising the sea to an abnormally higher level.

A simple explanation!

So, there you have it.

Sea-level rises associated with climate change is a myth!

It's all to do with weather.

**End of discussion!!!!!!!
controversy!!!!**

Mmmmmm.....but perhaps not the

Acknowledgements and reference sources:

The Australian Bureau of Meteorology

Publication: The Essentials of Oceanography – Fourth Edition by Tom Garrison

Sue Knudsen for her photo on page 10