

Why are there often two high tides a day?

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At many coasts, high water returns roughly twice in a day. At others, one daily high tide dominates, or two successive high tides differ substantially. Any explanation that begins by promising two equal tides everywhere has already lost contact with the observation it needs to explain.

The useful question has two parts. Why does lunar gravity contain a strong twice-daily influence as Earth rotates? And why does a particular coastline respond with its own timing and range? The first concerns differences in gravitational acceleration. The second concerns a moving ocean bounded by continents and a seafloor.

1. The relevant force is a difference

The Moon attracts Earth as a whole, including its solid interior and oceans. If that attraction were exactly the same everywhere, the whole system would accelerate together without the lunar field tending to deform it. Tidal forcing arises because the Moon's gravitational field changes across Earth's extent [1].

The near side is closer to the Moon and accelerates towards it more strongly than Earth's centre does. The far side is farther away and accelerates towards it less strongly. Relative to the accelerating centre, the near-side effect points towards the Moon and the far-side effect points away from it. The latter is not gravity becoming repulsive. It is the difference between two attractive accelerations.

For lunar mass M , centre-to-centre distance d and a small displacement x along the Earth-Moon line, a first-order expansion gives a relative acceleration approximately $2GMx/d^3$. The sign follows x : opposite sides are stretched away from the centre along that line. The expansion assumes $|x|$ is much smaller than d ; it is not an exact formula at arbitrary separation.

This also explains a useful scaling. The main tidal influence varies approximately as inverse distance cubed, whereas ordinary gravitational acceleration from a point mass varies as inverse distance squared. Comparing two bodies' tidal effects therefore requires both their masses and their distances, using the appropriate power. The strongest total gravitational attraction need not supply the strongest tide-raising gradient.

2. Why the simple pattern has two sides

After removing the uniform acceleration of Earth's centre, the leading tide-raising potential has an angular dependence proportional to $3 \cos^2\theta - 1$, where θ is the angle from the Earth-Moon line. Its equal values at $\theta = 0$ and $\theta = \pi$ encode the two-sided character. This is a mathematical statement about the leading gravitational pattern, before asking how seawater responds.

Imagine an ideal equilibrium ocean and a location on the equator, with the Moon also in Earth's equatorial plane. Rotation carries that location through the two aligned directions during one lunar day. A twice-per-lunar-day variation follows. The geometrical symmetry, rather than two different kinds of gravitational force, is the reason the simple picture has two maxima.

That construction deliberately suppresses important complications. At other latitudes and lunar declinations, the path through the pattern differs. The actual water cannot instantly

arrange itself into an equilibrium shape. Continents interrupt motion, and the rotating ocean has its own dynamics. The two-bulge drawing is an entry into the forcing, not a moving map of actual high water at every shore.

3. A lunar day is not exactly a solar day

Earth rotates while the Moon travels along its orbit in the same general direction. A location therefore needs somewhat more than one solar day to return to the same orientation relative to the Moon. NOAA gives the approximate lunar day as 24 hours and 50 minutes [2].

Half that interval is 12 hours and 25 minutes. This is the useful approximate timescale of the principal lunar semidiurnal pattern. It is not a promise that every pair of measured high waters at one harbour will be separated by exactly that interval. The Moon's motion is not uniform in all relevant coordinates, and several tidal contributions combine in the observation.

The Sun also supplies tidal forcing. Contributions with different periods and phases can reinforce or partly offset one another. Thus the height of high water and the interval between successive observed maxima are properties of the combined signal, not just of one isolated sinusoid.

A simple mathematical example makes the distinction concrete. Add two cosine signals of different frequencies. The derivative of the sum vanishes where their slopes cancel, which generally does not coincide with the maximum of either component alone. An observed high tide is a maximum of the total water-level signal. Reading one component's period as an exact timetable confuses the model's ingredients with its output.

4. The coast selects a response

Water movement depends on depth, basin shape, connections to neighbouring waters and Earth's rotation. NOAA distinguishes semidiurnal, mixed semidiurnal and diurnal patterns, and emphasizes the role of ocean basins and continents [3]. These are observed differences that a useful theory must allow.

A semidiurnal coast has two broadly similar highs and lows in the tidal cycle. A mixed pattern has conspicuously unequal successive highs or lows. A diurnal pattern has one dominant high and low. These descriptions concern the resulting water-level record, rather than a change in the fundamental law of gravity from one coast to another.

Timing also requires a dynamical response. The local high tide need not occur when the Moon is directly overhead. Water must move through a connected basin; the relationship between forcing and response depends on that system. A diagram that places a bulge directly below the Moon everywhere omits precisely the information required for a reliable local prediction.

For navigation or a specific coastal visit, a general explanation cannot substitute for local predictions and observations. Here the scientific point is narrower: a forcing with a strong twice-daily component can generate very different local records because the ocean is a dynamical system, not a frictionless film that continually resets its shape.

5. How the explanation is tested

A tide gauge supplies a time series of local water level. Repeated observations allow investigators to distinguish persistent periodic components from weather-related changes and other contributions. The astronomical forcing fixes candidate frequencies; the local record constrains how strongly and with what phase the location responds.

Such a comparison tests more than the statement that the Moon matters. It asks whether the predicted timing and combination of contributions explain measured maxima, minima and changes across successive days. An explanation that only works for one photograph of a beach has not faced that test.

The basic origin of tidal gradients is well established. The simplification lies in replacing a real basin with an equilibrium picture, not in treating the far side as an unexplained exception. Local modelling remains sensitive to geometry, water depth and conditions; uncertainty in a particular prediction does not undo the gravitational mechanism.

There are often two high tides because the leading lunar tidal pattern is two-sided and Earth rotates through it. “Often” remains essential because actual high tides belong to an ocean with boundaries, motion and several simultaneous forcings. The slowing and synchronization of rotation involve energy loss and torque, a separate problem treated in “Why does the Moon show us nearly the same face?”

References

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