Asteroids & Tsunamis

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Big asteroids can be extra deadly when they strike the ocean, carving aquatic craters and sending huge waves in all directions. These tsunami can wreak destruction on shores thousands of miles away. Bad news for people living in coastal areas, but it could be a lucky break for the rest of mankind: The same impact on land would throw dust high into the atmosphere and could block sunlight for many months, possibly causing global starvation and mass extinctions.

Dangerous waves

The surface of water is very good at transferring energy, in the form of waves, across great distances. In 1960, for example, an earthquake near Chile created a series of waves that crossed the Pacific Ocean and killed several hundred people 10,000 miles away in Japan.

These waves, which are generated from a major disturbance to the water surface, are known as tsunami. (Most scientists don't like the popular name "tidal wave" because tsunami have nothing to do with the tides. However, tsunami sometimes surge ashore like a huge, fast-moving tide rather than breaking like a classic surfing wave.)

Tsunami can travel at around 400 mph in deep water. When they reach shallow water they slow down, and that's when the real danger begins. The front of the wave slows first and the effect is like a pile-up on a freeway, with the rear of the wave catching up to the front. The wave increases in height from this bunching effect. The final height of the wave depends on several factors, but the shape of the sea floor has the greatest impact. Estuaries, harbours, cliffs, reefs, and the topography of the continental shelf all play a role.

For a typical shoreline, the final tsunami height is usually about three times its height in deep water, but in some locations the ratio (known as "run-up factor") reaches 40. In other words, a 1-foot wave in deepwater can amplify to a 40-foot wave at a shoreline that is exceptionally vulnerable to tsunami, as are some parts of Hawaii.

Splashdown

If an asteroid collides with the Earth

there is a good chance it will hit an ocean, simply because two-thirds of the Earth's surface is covered by water. A gigantic explosion occurs and the asteroid is pulverised and vaporised, along with a huge volume of water. This creates a crater in the water surface that quickly fills. The filling process generates a series of tsunami that radiate across the ocean. The effect is similar to a pebble thrown into a pond, though with a 50,000-mph impact, we're not talking ripples here.

Based on NASA estimates, about once every 2,000 years an asteroid with a diameter of about 100 yards can be expected to hit one of Earth's oceans. Larger asteroids collide with the Earth much less frequently -- a 500-yard rock from space might hit an ocean once every 80,000 years and a 1,000-yard (1 k) asteroid perhaps once every 200,000 years.

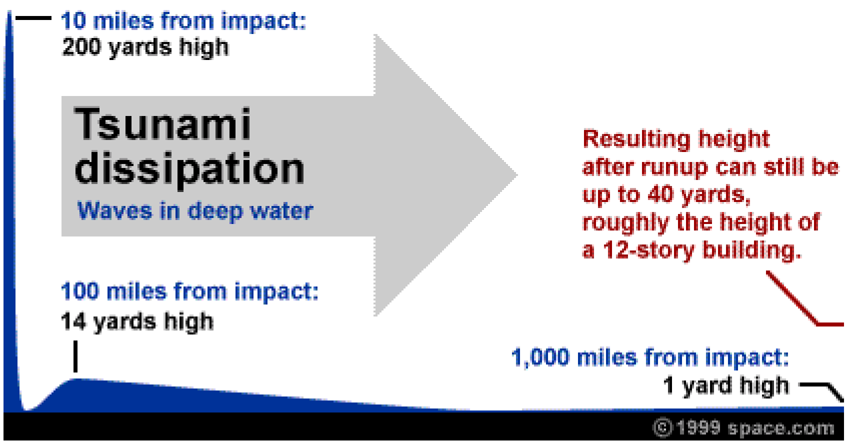
Atomic bombs and ocean impacts

The largest aboveground H-bomb test by the United States was like a firecracker compared to an asteroid impact. That "Bravo" explosion at Bikini Atoll in 1954 was equivalent to fifteen megatons (million tons) of TNT but was only about one-thousandth of the energy of a 500-yard asteroid moving at 50,000 mph.

The Bikini Atoll H-bomb tests enabled scientists to develop computer models of the destructive effects (on shipping) of explosions at the water surface. In the early 1990s these models were applied to asteroid impacts. Initial results suggested that even relatively small impacts could pose a grave tsunami threat over large areas of ocean.

More recent modelling indicates that the tsunami generated by an asteroid impact tend to dissipate, or die out, rapidly (the computer program, developed by Sandia National Laboratories, accurately predicted the consequences of the plummet of Comet Shoemaker-Levy 9 into Jupiter in 1994).

According to this work, a 500-yard-diameter asteroid is predicted to generate a water crater nearly 3 miles in diameter. At a distance of 10 miles from "ground zero" the resulting deepwater tsunami will be about 200 yards high, but by the time the wave has travelled 100 miles it will be reduced to a height of about 14 yards. After 1,000 miles it will have dropped to less than 1 yard in height. Due to the amplification in shallow water, however, this size tsunami could still become a 120-foot wave at a vulnerable shore.



Extra hazard to coastal areas

Due to the extra hazard of tsunami, locations such as Hawaii are at much greater risk from asteroid impacts than inland areas. Rough calculations suggest that a coastal location with a typical tsunami run-up factor of three has about three times the risk of devastation from an asteroid-generated tsunami than the risk of a direct blast to an inland location. Locations with an extreme tsunami run-up factor of 40 have about 70 times the risk compared with an inland location.

People in these vulnerable locations need not lose sleep, however, because the odds of a major asteroid-generated tsunami in any one year are about one in 200,000. On the other hand, as astronomer Duncan Steel has pointed out, asteroid impacts don't run to a timetable like busses.

The estimate of impact tsunami risk is based on the limited search for Near Earth Asteroids carried out so far and assumes that impacts are randomly distributed in time. There is some evidence that impacts may come in clusters (some busses seem to do the same). If this is the case, then it is well worth finding out if we are approaching the next barrage so that coastal areas can be better prepared.

Climate disruption

The comparison between coastal and inland locations is not entirely fair because the biggest danger from an asteroid impact is not from the direct blast but from the after-effects. In particular, the temporary cooling of the Earth due to huge quantities of dust released into the atmosphere from a land impact can disrupt crop production and lead to global starvation.

The giant plumes from the Jupiter impact of Comet Shoemaker-Levy 9 clearly showed how a comet or asteroid tunnels through the atmosphere and creates a temporary chimney. This draws the impact debris into the upper atmosphere. Scientists are only beginning to understand this effect in the case of an impact into Earth's oceans.

An ocean impact by a 500-yard-diameter asteroid will vaporise about 20 cubic miles of water. At first sight this appears to be insignificant since it is less than one tenth of the total amount of water that evaporates from the world's oceans every day (assuming 1 inch of rain over 10 percent of the Earth's surface each day).

Scientists caution, however, that an ocean impact would send the water vapour high into the atmosphere, compared with the lower atmosphere, or troposphere, in the case of evaporation. The upper stratosphere is normally extremely dry and the effects of a sudden injection of a large quantity of water vapour are simply unknown. Other effects of concern are greenhouse warming (water vapour is a strong greenhouse gas) and ozone depletion. Unlike evaporation, an ocean impact would send salt (sodium chloride) into the air. The chlorine in the salt may affect upper atmosphere ozone levels in the same way as chlorofluorocarbons.

The same impact on land would pulverise an equivalent amount of rock (20 cubic miles -- about 1,000 times the volume of the asteroid) and send much of it into the upper atmosphere, where it would circulate around the globe and disrupt agriculture for many months.

A lesson from violent volcanoes

In 1815 a volcano on the Indonesian island of Tambora exploded and produced a crater similar in size to that from a 500-yard asteroid. About 20 cubic miles of ejecta was released (for comparison, the Mount St. Helens explosion in 1980 released about a quarter of a cubic mile of ejecta).

In the case of Tambora, it has been estimated that 10,000 people died directly from the explosion and 80,000 more died in the region from indirect effects, such as starvation. In addition, the ash is thought to have caused the "year without a summer" in 1816, when there were widespread crop failures across *North America*. The final death toll was probably in the hundreds of thousands. A similar event today might kill millions.

Because of the chimney effect, an asteroid impact is much more efficient at sending dust into the upper atmosphere than a volcanic explosion, and the climatic disruption is probably much greater with an asteroid impact. Even so, the events of 1815 serve as a clear warning of the global danger from land impacts by asteroids.

With much less dust released into the atmosphere, an ocean impact will have very different, and perhaps less damaging, effects than a land impact. If an asteroid struck thick ice formations, such as Antarctica or the extensive ice sheets of the last Ice Age, the result would likely be similar to a water impact.

It's possible that our species has been saved from extinction several times because a large asteroid hit the ocean or ice rather than the land. Every million years or so it can be expected that a mile-wide asteroid will hit the Earth. A land impact would probably cause severe climatic disruption and regional extinctions. *If* the global effects of an ocean/ice impact are less severe than one on land, then the impact by a mile-wide asteroid into the ocean might not be as hazardous to life.

Evidence of ocean impacts

Past impacts with water or ice are very difficult to detect, because they leave very little evidence. One such impact is known to have occurred in the South Pacific Ocean, near Chile, about 2 million years ago. This event -- known as "Eltanin" after the ship that discovered the deposits -- involved an asteroid between 1 and 3 miles in diameter that would have created a water crater at least 40 miles across. Tsunami would have swamped coasts around the Pacific and would even have reached some Atlantic coastlines. Assuming a typical run-up factor of three, the coast of Chile would have been inundated by 250-yard-high tsunami. Likely results for other locations: Hawaii 90-yard tsunami (probably higher due to the greater run-up factor); California, 60 yards; Japan and Australia, 25 yards; New Zealand; 120 yards.

Despite this presumed destruction to coastal areas, there is no evidence of global climate change or regional extinctions around this time, when our early ancestors, Australopithecus, were roaming Africa. We don't know whether they would have been wiped out if the Eltanin asteroid had struck land in South America or Africa, instead of splashing into the ocean. To solve that puzzle, to understand which type of impact most threatens our existence, we need a much better understanding of the consequences of asteroid impacts.

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-- Michael Paine

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