Supplementary Information on

SUMATRA-ANDAMAN ISLANDS TSUNAMI EARTHQUAKE

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1. Why were several different earthquake magnitudes reported?

Earthquake magnitude is a measure of the size of the earthquake. The first seismic magnitude scale used is the **Richter Scale**, developed by the American seismologist Charles Richter some 70 years ago. The scale is based on the maximum ground motion recorded by seismographs located within a few hundred kilometers of the epicenter. It is also known as **Local Magnitude Scale** and is the one commonly cited in news and media reports. The Richter Scale, however, cannot accurate measure very large earthquake events because of a phenomenon known as 'instrumental saturation'. That is, above a certain magnitude, the seismometer cannot depict the maximum ground motion with an accurate proportion, inhibiting a proper measurement of the magnitude

Other magnitude scales, such as the ones based on body, surface and coda waves, exist but they all suffer the same general problem of saturation. The magnitude scale able to describe the size of earthquake most accurately is one based on **seismic moment** which is, technically, the product of the area of the rupture plane, the displacement and the rigidity (rock strength) of the plate boundary. The determination of the seismic moment relies on records obtained from a number of distant seismic stations. The magnitude of the Sumatran tsunami earthquake reported initially was 6.4, which was subsequently revised to 9.0 when the seismic moment solution was available.

2. How is a tsunami produced?

An earthquake is **tsunamigenic** if it produces a tsunami. One that produces a much larger tsunami than expected is a **tsunami earthquake**. A tsunami earthquake must fulfill several characteristics. First, the earthquake has to be a sizeable one and occurs in an offshore area. Secondly, the earthquake must have a shallow focal depth and has ruptured through the sea floor. Thirdly, the fault motion has to have a vertical component. In other words, a strike-slip fault with motion only in a horizontal direction is unlikely a tsunamigenic one.

The physics of the production of tsunamis is a bit more complicated than one may think. Tsunami waves behave like surface waves. The vertical displacement in the sea floor creates a sudden uplift or downwarp of the water column over it. The tsunami wave is produced when the uplifted or downwarped water mass rebounds to regain equilibrium.

3. How does a tsunami wave propagate?

Energy propagates outward from the epicenter by means of particle oscillation. The tsunami wave behaves essentially like shallow water waves, with water particles oscillating in highly elliptical orbits. Tsunami waves can attain a great wavelength, sometimes exceeding several hundred kilometers and oscillation periods from a few minutes to an hour. The propagation velocity is generally related to the water depth of the ocean and is approximated given by $v=\sqrt{(d.g)}$ in which v is the propagation velocity, d the water depth and g gravitational acceleration. For the Indian Ocean with an average water depth of about 4 km. The velocity was about 700 km/hr. If you were on a boat in the ocean, the tsunami wave, which might be only up to 2-3 m high, would sweep past you within less than a second. You would only feel a sudden jolt, hardly noticing the passing-by of the tsunami wave.

Because of the little shear resistance of air and water, tsunami waves can travel great distances with a little loss of energy. The energy is also concentrated in a zone elongated in the same direction as the strike of the fault that produces the tsunami waves. Since the fault causing the Indonesian tsunami strikes in a NNW-SSE direction, coastal regions located at right-angles to the fault, e.g. Indonesia, Thailand, Maldives, and Sri Lanka, had suffered the greatest damage.

4. How does a tsunami wave produce such a great destruction?

A tsunami wave becomes destructive when it approaches the shore. Because the waves have a very deep wave base, its velocity is very sensitive to changes in the seabed bathymetry. As the wave reaches the continental shelf, the shallowing seabed produces resistance to the wave propagation and,

as a result, the wave slows, causing the tsunami wavelength to decrease rapidly and water to pile up, resulting in the heightening of the wave crest. The greatest damage occurs after the wave 'breaks', when the oscillatory motion of water particles is disrupted and becomes transverse in nature. This is deadly as the water washes ashore at a great speed. The destructive power of the tsunami wave is often described by the maximum run-up which is the height of the tsunami wave as it approaches land.

5. Can tsunamis be monitored?

Yes. Sea level in the Pacific Ocean is continuously monitored by **ocean bottom pressure sensors** for abrupt sea level changes. The fluctuations in the sea level in the open sea caused by the tsunami wave can be minuscule, ranging from a few centimeters to several meters. These sensors can acquire data at a rate of twice per minute. The data are transmitted to receivers mounted on nearby buoys and relayed to tsunami monitor centers via satellites. **Tidal gauges** installed in the coastal areas are also used to monitor abrupt changes in the sea level caused by onset of tsunami waves.

6. Have there been tsunamis in the vicinity of Hong Kong in recent years?

A number of tsunamis were reported to have hit various regions of Taiwan over the last hundred years. For Guangdong, the most significant tsunami event was probably the one caused by the **1918 Nanao Earthquake** (M=7.3) near Shantao. It was reported that over 500 houses along the coast were destroyed by waves possibly as high as 7 m.

7. Is Hong Kong also exposed to tsunami risk?

The answer is yes. In fact Hong Kong is located in the **Southeastern China Active Seismic Zone**, which is capable of generating large earthquakes. This zone may represent a plate boundary between the South China Block in the north and the Sunda Plate in the south. The estimated motion may be as great as 0.5 cm/year. This does not seem to be a significant motion but the zone has already produced 4 magnitude 7 or above earthquakes during the last 400 years. In addition, large tsunamigenic earthquakes that occur in the Philippines, Taiwan, New Guinea or Indonesian region can still possibly affect Hong Kong. Bear also in mind that earthquakes are not the only reason for tsunamis. Volcanic eruptions, landslides and even a meteorite impact in South China Sea are also capable of producing tsunamis. It is not impossible for a large landslide occurring by the coast to produce a megawave that causes some devastating destruction.

8. Where can I study about earthquakes and tsunamis in Hong Kong?

The **Department of Earth Sciences** of the University of Hong Kong offers the only Earth Sciences degree programme in Hong Kong. In the course Physics of the Earth, we devote about 6 weeks to seismology. Students learn to read seismograms, determine the time, location and magnitude of earthquake events, and calculate other earthquake parameters. In the courses Earth Dynamics, Structural Geology, and Regional Tectonics, students learn about plate tectonics theory, geological processes at plate boundaries and the tectonics of the Southeast Asian region.

FOUR COMMON INDICATORS OF A POSSIBLE TSUNAMI

- feeling a reasonably strong nearby earthquake
- seeing the sea recede and expose the ocean floor
- witnessing an approaching wall of water
- hearing a loud roar like a train

WHAT TO DO

- walk steadily to higher ground or to safer elevations
(even if that means losing sight of this geological event)
- tsunami attack can often occur 30 or more minutes following the earthquake
- remain on high ground or at safe elevations for several hours until local disaster officials give the clearance
- tsunamis are often composed of three or more waves, with the second or third wave being the largest
- the largest wave can strike an hour or more after the first wave

For further information, please feel free to contact the Department of Earth Sciences of the University of Hong Kong by phone: 2858 1084 or email: earthsci@hku.hk; or visit our website at www.hku.hk/earthsci.