Natural Hazards
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Lecture – 37
Introduction to Tsunami

Welcome back. So, this is our last topic in Natural Hazard, one of the most important one.

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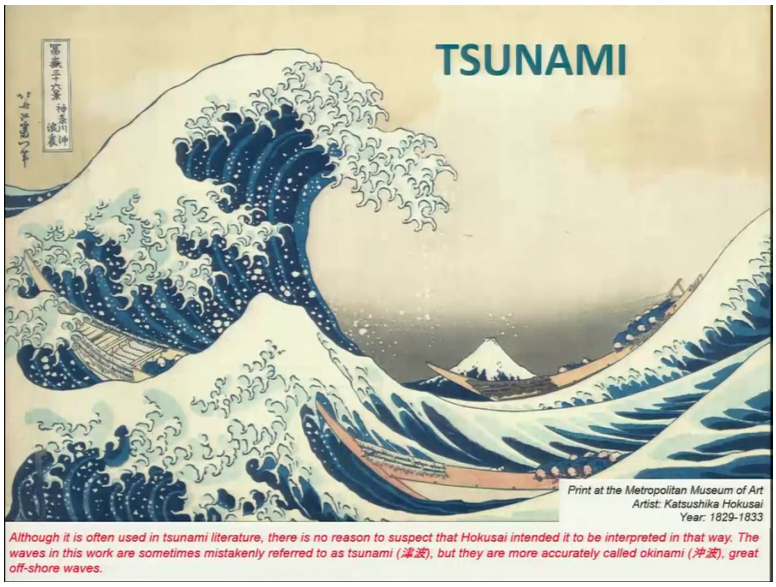

Since most of us mainly the people who were who were staying along the east coast and the west coast of Indian mainland, were surprised and even the people from Andaman, were surprised and shocked to have 2004 tsunami, but I would say that this is not the first time so tsunami has occurred in this region.

We have signatures that in passed also during recent historic past also this region has experienced much larger tsunamis. Then what we experienced in 2004; that was the source was from Banda Aceh Indonesia, but even we can have a similar large magnitude or maybe more damaging tsunami, if it is triggered along the Andaman Islands. And we have evidence not in the past such tsunamis have occurred.

Now, in most of the literature and on any website dealing with the institutions dealing with Natural Hazards and all that you will find so this picture which is a commonly

confused or maybe has the taken up as in that the artist, who wanted to show a sort of an huge or great of survive has been taken as in tsunami wave.

So, Hokusai never thought of that this picture or the sketch; which he is preparing will be used or interpreted as in tsunami wave, but of course, it is it its tried to show he has tried to show that the giant or the great offshore waves, have even much more greater than the Fujiyama, which has been shown here.

Let us move ahead and see what best we can learn out of the experiences, we had recently from Andaman from Tohoku Japan and again from Indonesia.

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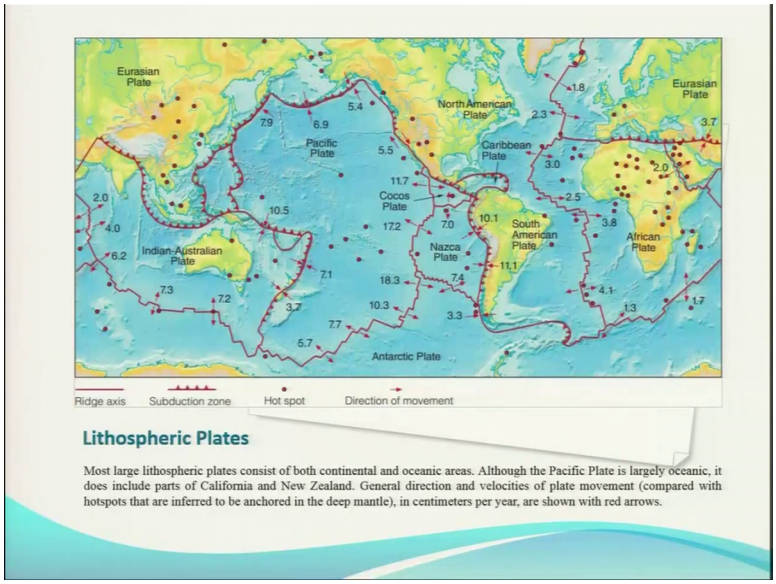

So, as we discussed in the beginning and some part we have already discussed in the other course about the plate tectonics. So, everywhere you will not take experience or expect the tsunami to occur, but there are typical zones which are the subduction zones mainly, where the oceanic plate is subjecting below the continental plate. We will have the greater chances to trigger tsunami.

So, one such zone; which I am right now pointing out lies in the domain of Indian subcontinent. So, we have like a chance of having the great tsunamis along this belt as well as which is not shown here, there is a macron subduction zone. Which is also another who enable area or the area which can trigger large magnitude earthquakes, as well as the tsunamis, but it will known be as large as what we have experienced here.

So, in short like if the tsunami has been triggered along this location it is not that only this location or the area adjoining this will be affected, but the region. So, it will be short of what we call is transporting tsunami.

So, we will be talking about one of the example of 1960 tsunami of Chilean, which was triggered by one of the largest earthquake, of magnitude 9.5 and which affected that was in 1960, that affected the whole region in the pacific area. So, the point is that the even if you are sitting away from the from the subduction zone. Because this is the area which is tectonically active and for example, we are sitting on the east coast and the Sri Lankan part here, and the region on this side of course, will be the area close to it will be affected, but even the area which is sitting away need to be alert from such hazard.

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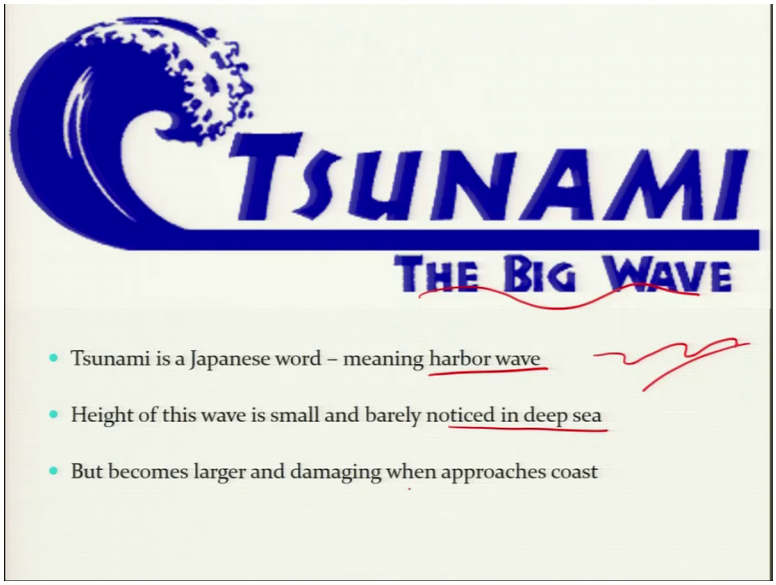

So, if you come as in definition this word tsunami; it came definitely from Japan, which means an harbor wave. So, this was which we have been using in our literature as well as our research. So, the height of the tsunami wave is small and barely noticeable in the deep sea. So, few important things here, but becomes larger and damaging, when it approaches the coast.

So, it will have an very large wave length in the ocean, but it has approaches the coast then this will become and the then it will become; like more damaging as it reaches the coast and the height also goes up.

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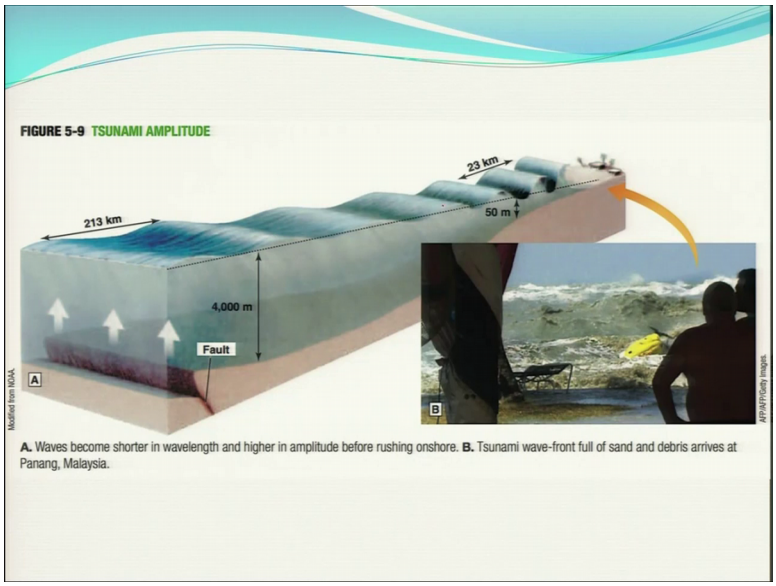

So, it is barely noticeable in the in the ocean. So, if you are sailing on this region, then you will be able to just move very smoothly over the crust and the trough of the tsunami which the wavelength can be of hundreds of kilometers ok. So, here it has been shown like for example, 200 kilometers of wave length, but is of course, it as it reaches the coast it will stack up one by one and the is of course, is the this will the height it will result in to the increase in height. So, the amplitude we will increase at is it reaches the coastal area and it will be more damaging.

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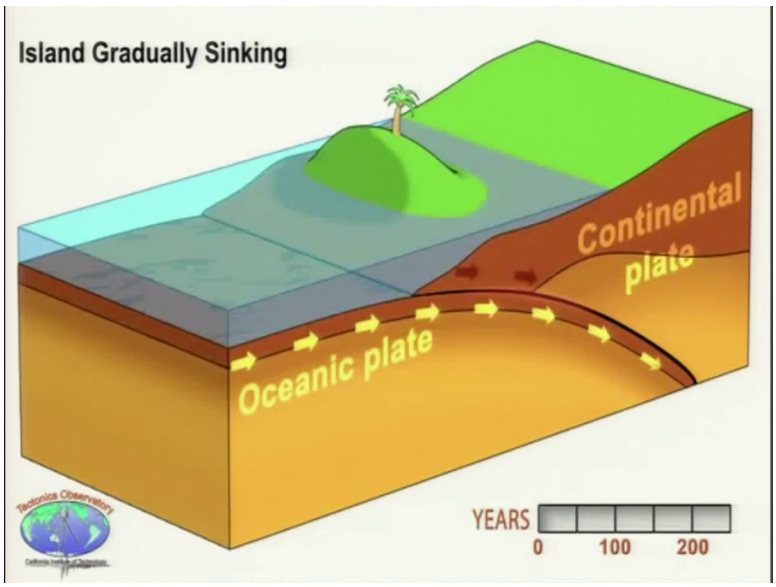

So, if you look at this small cartoon what does it explain is that you have an subducting plate, that is your you take as an oceanic plate and then the overriding plate, is your continental plate. So, this phenomena is not happening quickly, but it will it keeps going on for several years.

So, what is like we have learned from the tectonic deformation, that there is an ongoing deformation which keeps going between the two plates here. And this we will result into the deformation of the overriding plate. So, the land level change will occur over the time it may for it may be for 500 years or 600 years for example, in the Andaman region and the Sumatra region, what recurrence we are getting is around; 400 to 500 even years to have the similar magnitude tsunami, how similar magnitude earthquake which can create or trigger damaging tsunami. So, this plate which is riding own non top of it partly covered by the ocean water, we will deform and there will be land level change.

So, one what best we have done now is that the scientists or the people who are working in this domain have kept like or installed permanent GP has stations, which can help in understanding that what is the rate of deformation in this area and based on that, what is the amount of strain which is getting accumulated in this region and when next earthquake can be triggered.

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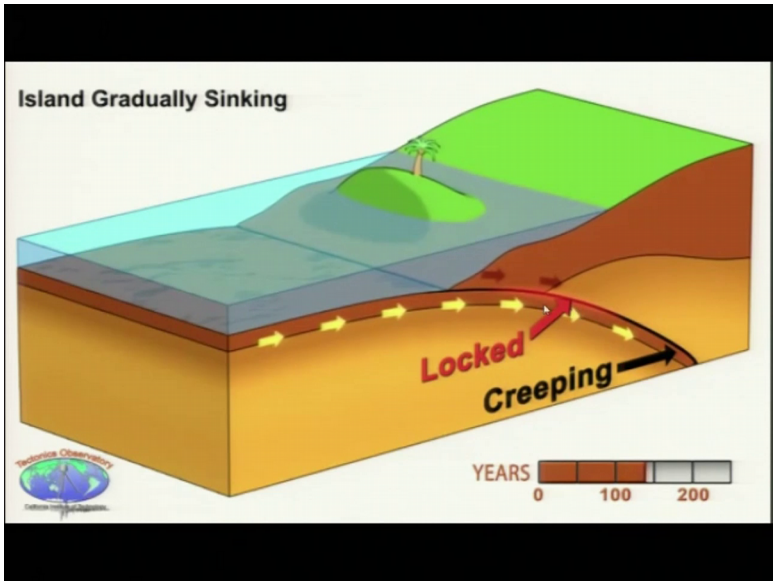

Or so if you look at this kindly watch carefully, what is happening here you can easily make out. So, there is in locking which we will of course, result into the deformation of this one.

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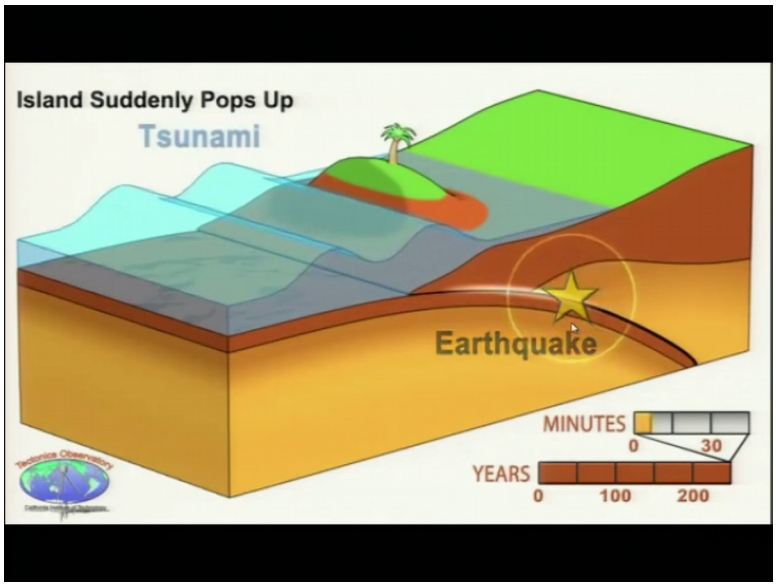

And then what we see is that this island is sinking down and when this was released it resulted in two then uplift.

So, it has come back and the waves were been generated. So, it this is this basically talks about that sudden release of the energy and the disturbance which has disturbed the water column and which definitely will result in to the generation of the waves and those waves are your tsunami waves. And which will definitely affect the whole area, in the adjoining region. So, again I am playing and you can watch it carefully.

So, it is going down and then it will be released. So, this sudden release is your earthquake here. So, this earthquake has triggered the sudden displacement of the water column which has created a tsunami wave.

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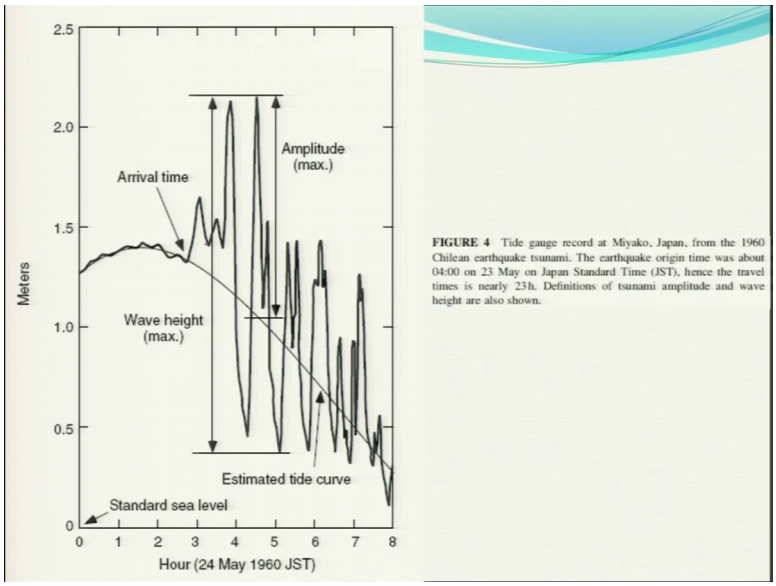

FIGURE 4 Tide gauge record at Miyako, Japan, from the 1960 Chilean earthquake tsunami. The earthquake origin time was about 04:00 on 23 May on Japan Standard Time (JST), hence the travel times is nearly 23h. Definitions of tsunami amplitude and wave height are also shown.

So, if you look at this is the, this example is from the Miyako, Japan, but the tsunami which was recorded here. I was from 1960 Chilean earthquake tsunami. So, this clearly suggests that, there was no earthquake shaking or seismic shaking in Japan, during the this time, but the tsunami reached Miyako island and which affected this area, and this was been recorded. So, this is a normal estimated tide curve and the arrival time of the tie the tsunami was marked by this. So, high very high amplitude we were been recorded. So, this is a maximum amplitude whereas, this is the your estimated tidal curve.

So, tide gauging stations can help us in identifying, if there is sudden change in the in the arrival or is there any disturbance in the tides.

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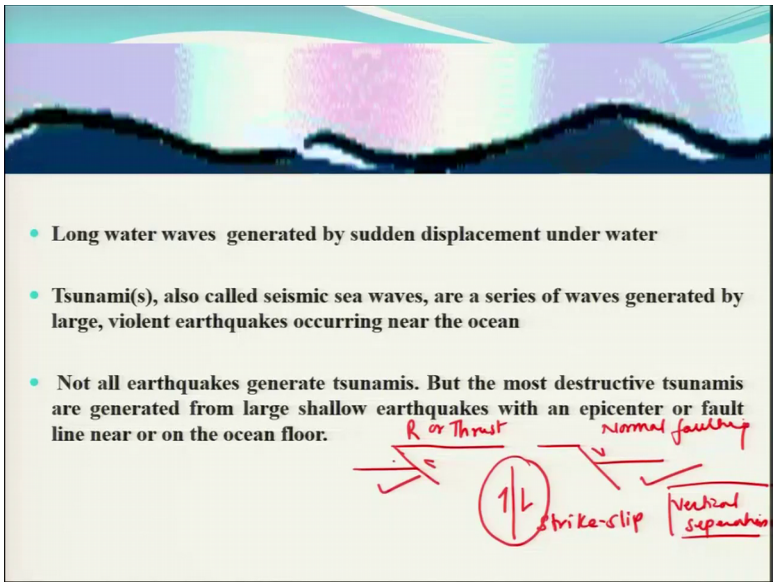

So, long water wave generated by sudden displacement underwater. So, what we saw in this the cartoon, it shows the displacement along the 2 plates or the fault, which disturbed the overlying water column. So, tsunamis also called as seismic sea waves because they are related mostly most deadly tsunamis are due to the seismic events. And Rn are a series of waves, generated by a large violent earthquakes occurring near thee near this ocean, not all earthquakes generate tsunami.

Now this is again based on that what type of displacement will take place, either the displacement is reverse type where the plate has moved up along the fault or the displacement is certain normal along the normal's faulting or the moment is along the like, for example, strikes left.

So, reverse faulting or you can say thrust faulting and the normal faulting and strike slip. Now it was been believed until now, I am still the groups are working on this, but mostly when we say the reverse faulting then 1 block has moved up with respect to another one and here one block has moved down with respect to another one. Whereas, in this case that is in strike slip not much of the vertical displacement you will be able to observe.

So, in these two cases either reverse fault or thrust faulting and normal faulting you will have vertical separation. Where as in strike slip motion or strike slip deformation not much will be the component of vertical separation.

But that has proved things wrong, in terms of like if we consider the recent Paulo tsunami of 2018, but nevertheless the displacement or the deformation triggered the landslide. I will talk to talk about that in the next coming few slides, or maybe in the next lecture, about that what happened exactly during the Paulo tsunami.

So, mostly if we have this 2 type of moments, we expect there will be an huge tsunami. Otherwise, if you are having this, then you may say that it may or may not be depending on the vertical separation.

So, the vertical separation during an earthquake is extremely important, because that will result into the displacement of the water column.

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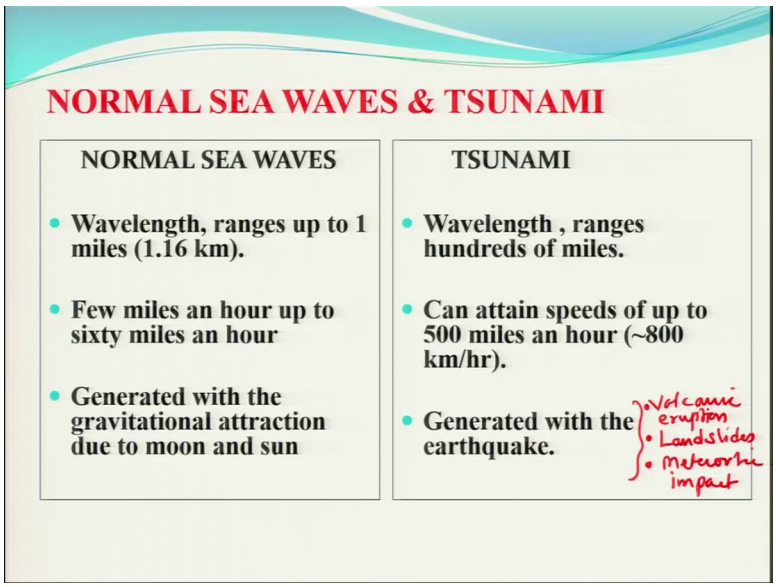

Now, if you differentiate between the normal sea waves and the tsunami waves and there are major difference we can look at quickly. So, normal sea waves and tsunami waves, the wavelength range up to 1 mile or around 1.6 kilometers, where is in the case of tsunami, it will be of 100s of miles a sphere, we are looking at 1 of the example ok. Few miles an hour up to 60 miles an hour the this will be the speed which will be seen in case of the normal sea wave, but in case of the tsunami sea wave it can attain the speed as high as the plane right, almost like 800 kilometers per hour or more.

Generated with the gravitational attraction, due to moon and sun and these are generated with the earthquakes. Nevertheless along with this we have we can expect and tsunami

because of the volcanic eruption, then we have landslides or if you are having meteoritic impact. So, these are a few more reasons for creating tsunami. Because this will also this phenomena or the process will also affect the water column, or disturb the water column because of its sudden impact.

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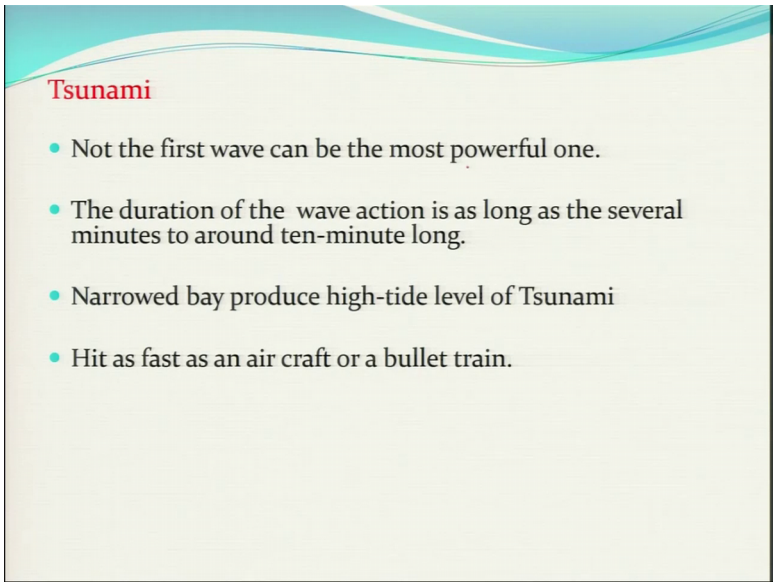

So, coming to this point here, not the first wave can be most powerful and many people who are staying close to the coastlines. They never understand that whether the flooding; the local flooding which is taking place is related to the tsunami or something else ok. And this same was experienced, in 2004 tsunami by people who stayed in Carnac over.

So, they would never realized that this was the inundation, which took place suddenly; was due to the tsunami, but nevertheless they experienced very strong ground shaking. So, that was one indication that there could be an tsunami. And the duration also can be shorter for a several minutes or it can go up to 10s of minutes. And in the areas where you are having the bay, which are narrow areas one can expect the high tide levels of tsunamis, hit as fast as aircraft or a bullet train.

So, these are few things; which we should keep in mind that we should not underestimate the sudden change in the tide level or maybe the water level close to the coast and we should keep in mind that it will be quite powerful.

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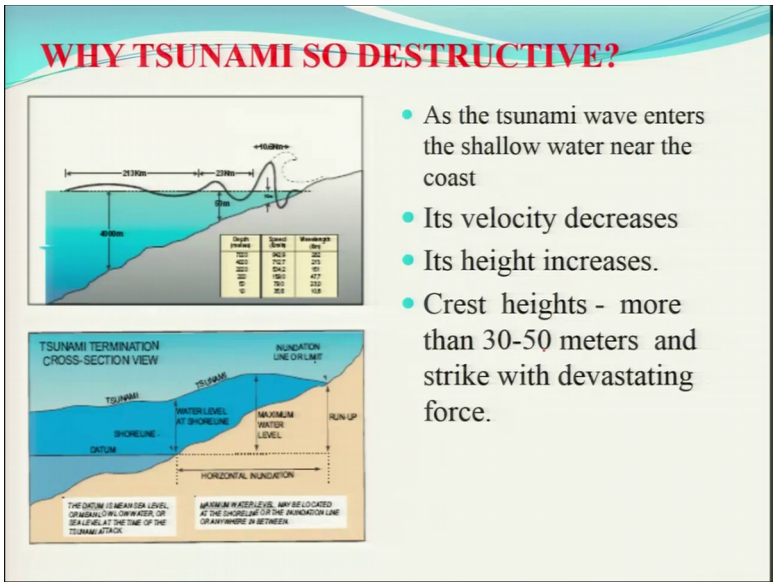

So, why tsunami is so destructive the reason as that as the tsunami waves enter the shallow, water near the coast either it is bay area or what, its velocity decreases, but at the same time its heights increases ok. So, you in the ocean you will have an very large wavelength. So, the amplitude will be not as high as what we see here, close to the coast, but it will be very shallow and it will be barely noticeable, but as it moves and climb up the coastal regions, it starts stacking up and that can result in to the increase in height as well as the run of and the region. So, crust height more than 30 to 50 meters and the strike with devastating force; in this was been noticed in one of the region in Indonesia, in 2004.

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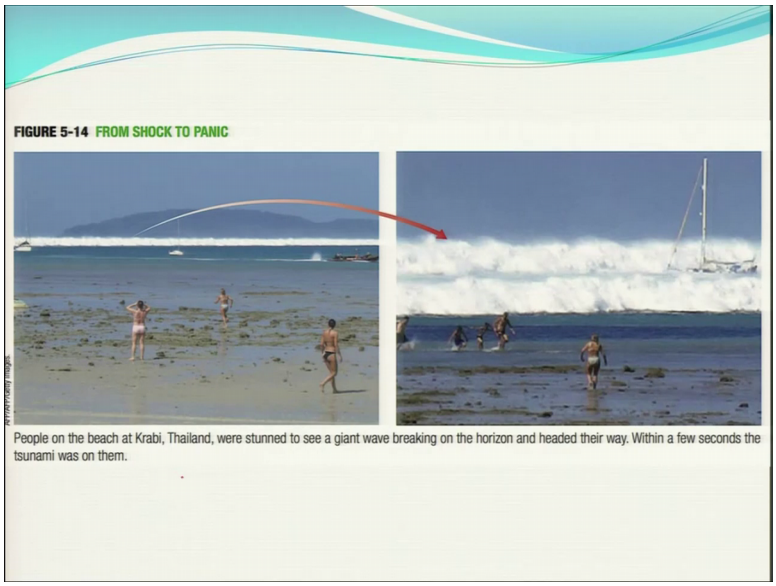

So, if you see it will be like in sea wall, which is traveling towards the coast ok, and may. So, I do not know what must happen to these people of course, they might have stop swept away during this one. This is from the Krabi tsunami, Thailand area of 2004 tsunami.

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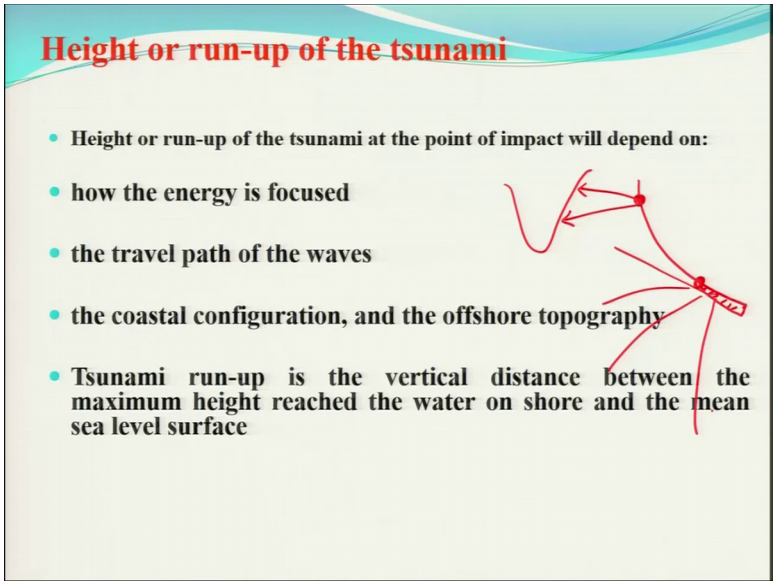

So, the height or run up is another important factor. Which we should keep in mind and usually, what we do is what the tsunami geologists that they will go back into the field,

during the to or after the tsunami and then try to measure all these heights and drops and all that big, which are important for modeling as well as for the future hazard assessment.

So, run up of the tsunami at point of impact will depend on how the energy is focused, from where the tsunami waves will be coming or it expected and 2nd is the travel path of the waves ok. How they are traveling, what is the configuration of the coastal region because, this will again depend on the on the offshore topography.

So, if you are having sitting on very high grounds, then you will not be affected, but if you are for example, you are having in very shallow bay area is then you will have different wave height. So, the energy focused from where it has been triggered for example, if you are having the Indian continent and then you are having the subduction zone sitting here. Then if the tsunami is triggered from this region, then it will be focused it will travel in this direction and all direction here, but if it is it is over here then it will be very straight reaching this place ok. So, the energy how energy is focused and what will be the travel path because, travel path will also reduce the impact if you are having it a longer travel path, if you are having shorter travel path that will be.

So, these are few things which are important. Then coming to the tsunami run up is the vertical distance between the maximum height reached the water on shore ok. So, on shore that what we were looking in the up and the next slide also we will explain this, on shore how far it has reached and the and the mean sea level surface, this is the mean sea level surface will be at the time when the tsunami was triggered because, we have the tidal charts with us we can go back and try to see that and try to look at that what falls exactly they run up with respect to the sea level, mean sea level at that point of time.

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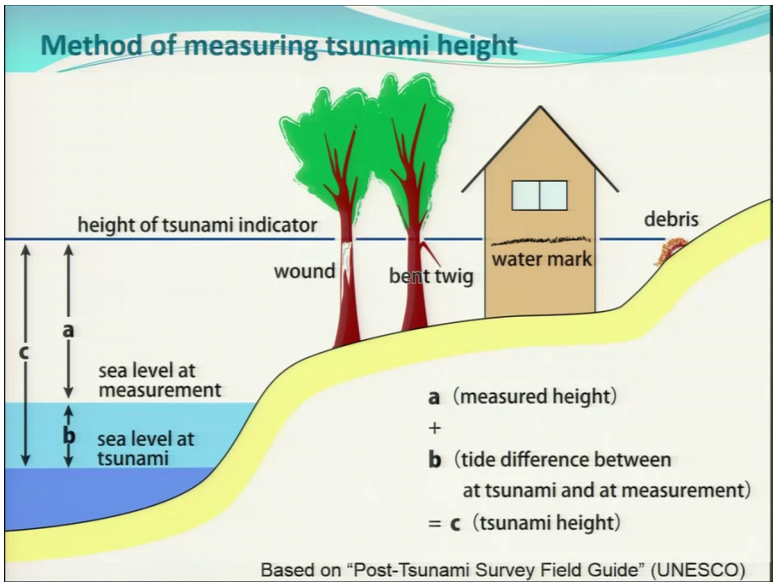

So, if you consider this the method of measuring the tsunami height then what you have is finally, the sea is your tsunami height. Where a and it can be given as a plus b is equal to c, that is the tsunami height, a is the major height. Now the measure height is at the time of the tsunami. So, this is the measure height and then b is your tidal difference between the measure height at tsunami and at the time of the measurements because, you will not be measuring at the time of and tsunami has occurred, but based on the height of is marked ok. That is based on the; this is the sea level at the time of the tsunami, this was ok, and then this is your height of the or the at the time of your measurement.

So, that will give you the inundation height or run up height ok. And one can also look at which can be easily one can find that is one is the watermark and also the wounded trees of and the bent twigs, these are few things which we usually take in if at all this house is survived, then we can say and also because, the tsunami waves will carries the debris either it is planted debris or some other things which will be found very far off inland. That can be taken as an indication of the tsunami wave.

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A. The coastal area of Meulaboh, Indonesia, before the tsunami. B. After the tsunami, nothing remains of most houses. Distinctive buildings in the upper right part of each image can be matched.

So, picture from Indonesia again, 2004. So, you can compare both the satellite data, this is from Google earth and what exactly. So, this is the only 2, 3 houses is cluster was left out, the rest house completely destroys or why wiped off.

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So, if you look at the run up how it looks like. So, in this video you will be able to understand that if you are the first wave may not be very powerful and you may have the negative wave. So, in this video what it is been shown is that, the first arrival of the first wave was negative. Hence, it went back.

So, in some of the events or the tsunami and earthquake events, what people did was that when the sea receded because of the negative wave, they went into the sea and that recede can be up to kilometers ok. So, in case of Andaman also few people they observe this negative wave.

So, what you are going to get like, if you are having this wave ok. So, either you are going to get this one or this one you never know. But, so if you are having a negative wave; that will recede because as commonly seen during the type of if you look and go to the beach or the close to the ocean you will find the way it comes and goes back wave comes and goes back.

So, that will with the way wave recede will be your negative one, and that what happened in 2004 in some places. So, if you look at this one the first wave of course, was not so powerful, but the rest it.

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So, this is the recede of the ocean exposing the area.

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And then the next wave inundated; the area completely and again went back ok. So, this is this again we will depend on the amplitude of the wave, and of course, the configuration of the coastal region. So, I will stop here and we will continue in the next lecture.

Thank you so much.