# Natural Hazards
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## Lecture – 41
## Tsunami Modelling

Hello all. So, today we will start a new topic regarding tsunami. So, as in the previous class, I am shows that I taught about you some of the definition and concept regarding tsunami. This class will be all about Tsunami Modelling. If we means if we talk about tsunami modelling, it means here we here we are going to simulate the tsunami, in the form of its wave height. It is travel time means how much time it is taking to reach a coast where it has been means from place of it is generations towards the coastal areas nearby or some far. And on the basis of that it has been divided on near shore and far shore tsunami.

So, this modelling part helps in 3 ways it helps in prebateness, it helps in formulating some mitigation measures. And then which in all about lower the risk. And this all can be grouped into what we call it making in an hazard assessment map regarding the tsunami. So, I am sure sir is explained you about tsunami and some of the concepts behind it and definition, but to fresh up we will go with the. So, first we will talk about what is tsunami, is just only to brush up the knowledge. So, that we can move to modelling part and you can easily relate how we are coming to from tsunami how we are modelling the tsunami. So, what is tsunami?

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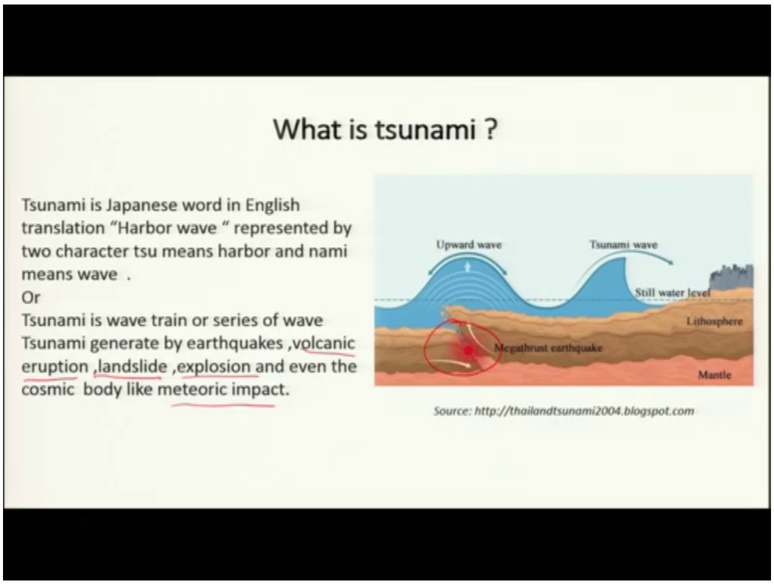


So, tsunami is the Japanese word in English translation means harbor wave, represented by 2 character tsu means harbor and nami means wave. Or it can also be called as a wave train or series of wave tsunami generated by earthquake. Means as sir is already talked about that tsunami can be generated through various sources. It can be from it earthquake, it can be from volcanic eruption or it can be from series of landslide on or mega landslide in this submarine mean in the underwater in the ocean or it can be by nearby explosion. And even cosmic body like meteoric impact which as a very rare case it can also a generate tsunami.

So, here is the schematic diagram of tsunami this tsunami is generated by the earthquake as you can see here. And after the earthquake the energy get released and it is transport it is energy in the water lying above the water column and it generates the wave. And this waves travel towards the coastal areas and forms the tsunami wave.

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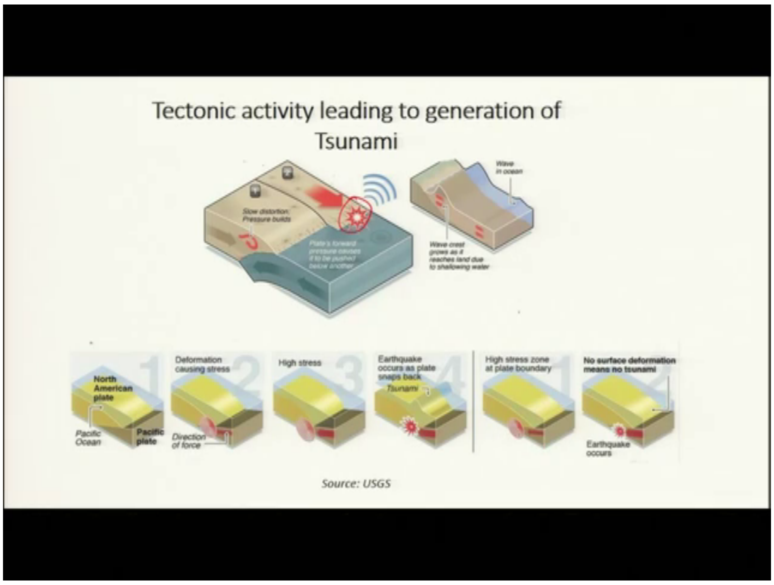


So, here we will talked about a tectonic activity leading to generation tsunami as in the previous slide, we have seen how the earthquake has created tsunami this on the generalized part. As you can see here slab is subducting and one is slab is overriding it. And then there is an earthquake it generates the tsunami. And this is the other step how does tsunami gets generated, means as you can see the North American plate is the overriding plate on the pacific plate the deformation and here the deformation is taking place between these 2 plates, which is causing stress.

If there is a high stress leading to the slip then that slip is turn into a form of energy, which will create the earthquake and that earthquake occur as a snaps pack, which generates the energy and is transformed it transported into the water which creates the waves. These are the highest stress zone at plate boundary where the earthquake and then tsunami are generated.

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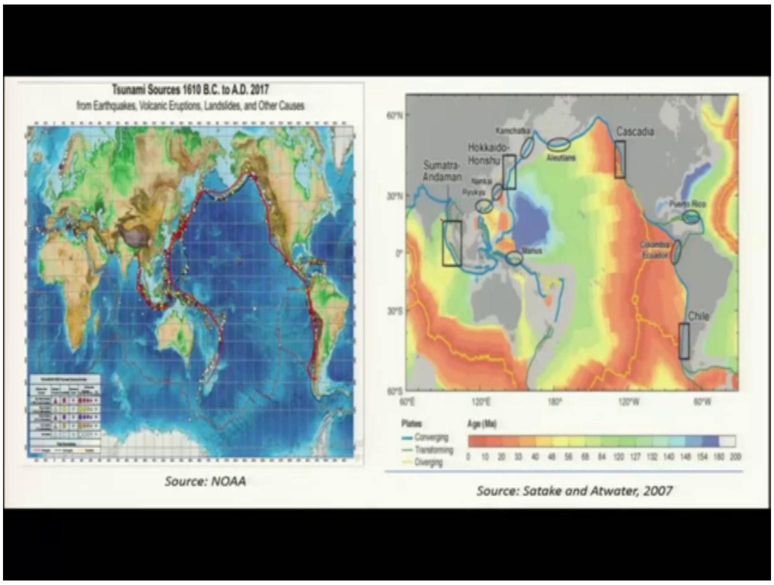


So, here is the map of the world; where we can see the tsunami prone areas, which is this as you can see the subduction zone where the potential where it has the potential of generating tsunami. Of course, by volcanic eruption or the earthquake or maybe both here is our Arakan Andaman Sumatra subduction zone. Where we have experience it is recently 2004 Indian ocean tsunami the most devastating one after the 1960 Chilean tsunami Chilean earthquake and tsunami.

Here are the subduction zones which has the potential of creating or generating the tsunami the Chilean subduction zone. The Columbian Ecuador the Puerto Ricco subduction zone, the Kamchatka subduction zone. So, as already told you about Sumatra Andaman and above it is Arakan. So, these are the subduction zone which has the potential of generating tsunami.

And as I was talking about some near shore and far shore tsunami. So, as we have seen in the 2004 Inca generated near the Indonesia, the epicenter of Banda Aceh. It was the fastest tsunami for the our Indian subcontinent ok, but if that kind of earthquake would have happened near the Andaman area, then the devastation would be more than what we have seen in 2004. So, in the form we were some about lucky that the epicenter was far away from Indian subcontinent, but not as lucky as deformation is still happening in this area and we can expect an earthquake and mega tsunami in near future.

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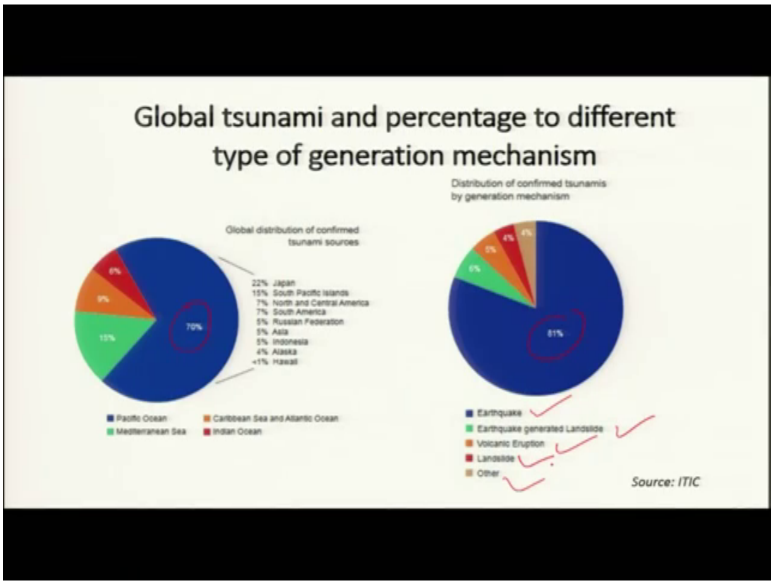


So, in this we will talk about global tsunami and percentage with different type of generation mechanism. Means as I have already told that tsunami is can be generated from different sources. It can be from earthquake, it can be from volcanic eruption it can be from series of landslides. So, in this diagram you can see it is showing the distribution on tsunami around the world.

The area which is experiencing more amount of tsunami it has been shown here. So, you can see the 70 percent is hold by the Pacific Ocean. In that Pacific Ocean comes the Japan, South Pacific Islands, North and Central America, South America, Russian federation, Asia in which our Indian subcontinent, Indonesia and other countries in the Southeast Asia comes which is already Indonesia, so, and Alaska and Hawaii.

And other 6 percent is by the Indian ocean 9 percent by the Caribbean Sea and Atlantic means, this area experience less number of tsunami then the Pacific Ocean. Now here is the diagram you can see the mechanism from which tsunami can be generated. And as you can see the most of it is constituted by the earthquake. 81 percent of tsunami are generated by the earthquake, then we can 6 percent is constituted by our earthquake generated landslide as.

And then 5 percent is by volcanic eruption as we can see in the recent Anak Krakatoa volcanic eruption has generated tsunami due to the after the volcanic eruption series or landslides occur in that area, which generated the tsunami in the nearby countries or the areas. And these 4 percent is causing only by the landslide. And 4 percent maybe other sources for example, meteoric impact and some other mechanisms.

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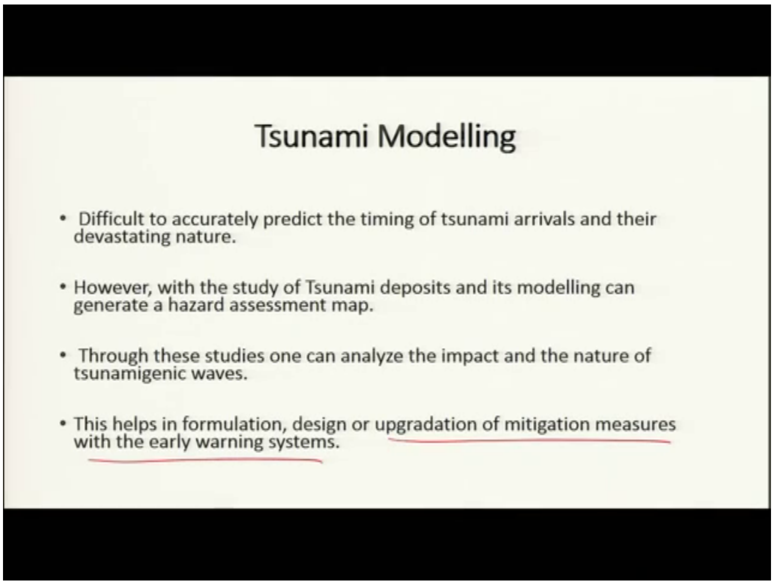


So, here comes this tsunami modelling part. So, after getting the concept of tsunami and definition of some of the tsunami related words, here we come to the modelling part. As I have already explained in the start the modelling is now a days very means it is a need of time. So, that we can lower the risk by having a well preparedness by having some mitigation measures and in on all that we can prepare our hazard assessment for the area.

So, as you can see here as you can see that it is difficult to accurate to predict the timing of tsunami arrivals and their devastating nature. So, here comes the modelling part means. We cannot predict when it is coming, but from the model we can lower the risk means, we are it going to be tsunami where it going to be very much effective or where it is very less effective those areas can be categorized and on that basis we can lower the risk in that area. However, with the study of tsunami deposits and it is modelling can generate a hazard assessment map.

Though this studies one can analyze the impact and the nature of tsunamigenic waves. So, from this studies, what we can analyze means? How the past tsunamis has behaved? What was it is wave height how much time it has taken to reach the coast and what was the inundation? How much it has inundated in the coastal areas? On the basis of that we can prepare an hazard assessment map. And we can demarked those areas as a hazard as a tsunami prone areas where no construction should be allowed or very means restrict constructions should be allowed in those places. This helps in formulation design upgradation of mitigation measures with early warning systems.

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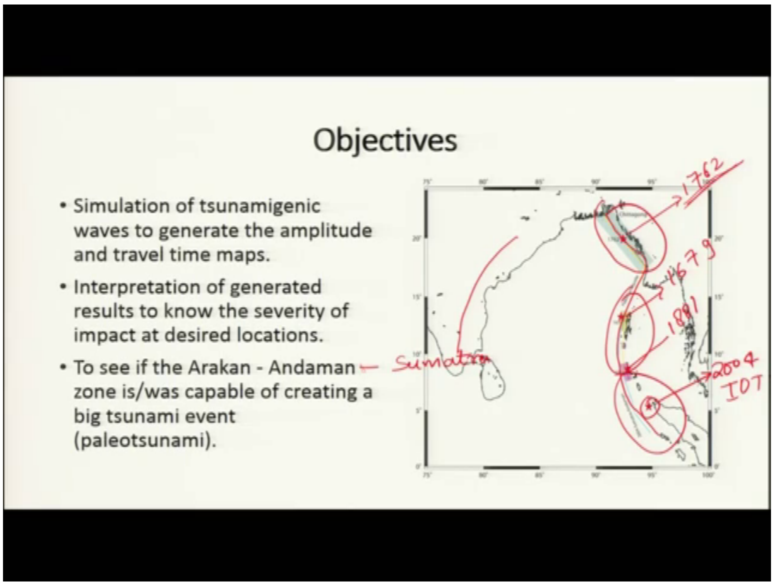


So, here comes the objective, why we need to model the tsunami. Simulation of tsunamigenic waves to generate the amplitude and travel time maps. As I am simultaneously just saying that we need to generate the amplitude the wave height and the travel time maps. So, it is from this modelling part of it generate those parameters which is very helpful in our in order to study the tsunami. Interpretation of generated results to know the severity of impact at desired locations. When the location which are near to the tsunami source, which is a near to the subduction zone which are prone to; which are prone to earthquake and then generated tsunami it can be marketed and we can lower the risk in those areas.

To see means if Arakan Andaman means as people as we are living in the Indian subcontinent. So, we need to study this subduction zone that Arakan Andaman and also the Sumatra zone. As it is capable of creating big tsunami event which we have already seen in 2004. So, here I am going to get into some of the case study which I personally have carried out in my lab. And I am going to show some results that how I have generated the tsunami waves the travel time maps and we will interpret on the basis of those that how much our east coast of India is prone to tsunami. And it is need of time because some of the because we are the developing country population is at a very fast rate. And so, we need to study days and minute to prepare some hazard assessment map of that area. So, that the risk from the tsunami the devastation from the tsunami can be checked.

The risk can be reduced. So, this is the map which shows the Arakan part the Andaman part and the Sumatra part. This is the subduction zone which is in some acquitting nature. And here is the epicentre of 2004 Indian ocean tsunami. And few more tsunami has also has also been marked here as you can see this is the 1881 tsunami. This is the 1679 tsunami and this is the Arakan tsunami of 1762. This tsunami this 1762 tsunami was underestimated and later it has been studied by camions which we will discuss in the following slide.

So, as you can see series tsunami once have has occurred. And it and how much we are this our in east Indian coast this coast of India is prone to this events. We have very less information observable information or the model information of this tsunami, that what they have caused at that time the kind of devastation they have caused in this region in our east coast of India. So, I am trying to study and I am trying to come up with some hazard assessment map of this area. So, that ultimately we can check those events the tsunami which are coming and we can lower the risk in this area.

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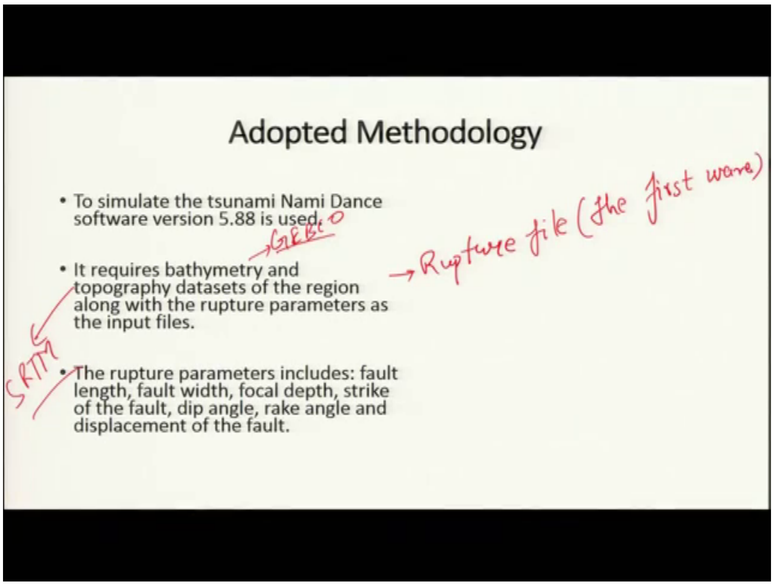

So, what methodology I adopted for the modelling part is that to simulate the tsunami I used software Nami dance the version was 5.88. It requires to generate the tsunami, first we required is the bathymetry map and the topography map topographic data sets bathymetry map, I downloaded from GEBCO. And this topographic dataset I downloaded for I downloaded from earth explorer USGS a certain data have been used in this model data.

So, it requires bathymetry and topographic datasets of the region along with the rupture parameters as the input file. So, first we input these 2 file in our nami dance software. And then we generate the rupture file the first that is the first wave. Which occur during the volcanic eruption induced landslides or the earthquake.

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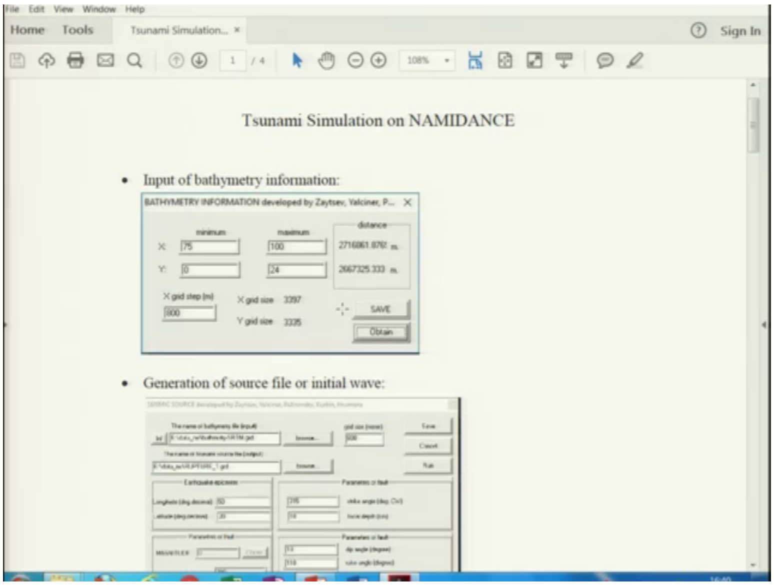


So, here are some snapshot from that software Nami dance. So, what we first do is 2 input the bathymetry information. Bathymetry information means the information about the area in which you are working, I am working as I am working in the Andaman Arakan Sumsatra part so I will give the lat long of that area. And then I will get the first rupture wave of that area. And that rupture wave will be act as a source file in the generation of other initial waves or the wave train of the tsunami due to this earthquake or the landslide.

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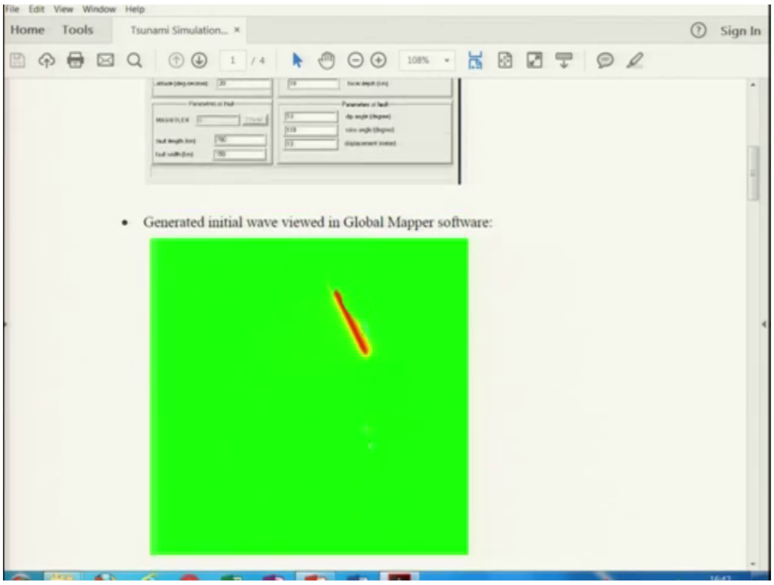


So, we take the assertive data and the GEBCO data in the first part. Then we input the rupture data what we have generated from here. And then we set the grid which is 800 here and then we get give the parameters the fault parameters. Here the strike angle of the fault has been given which is 315 then the focal depth in kilometer which is 10 and the fault length the length of the fault which I have given here around 700 kilometers. The width of the fault is given is 150 kilometers and the other parameters regarding fault is dip angle this 10 degree then rate angle which is 110 then the displacement how much displacement has been taken during the earthquake.

Which at last generated the tsunami it is about 10 meter. When we do all this thing then it takes around 4 to 6 hours of simulation and the first what we get is the this wave. As you can see this is our first wave which is generated during the tsunami.

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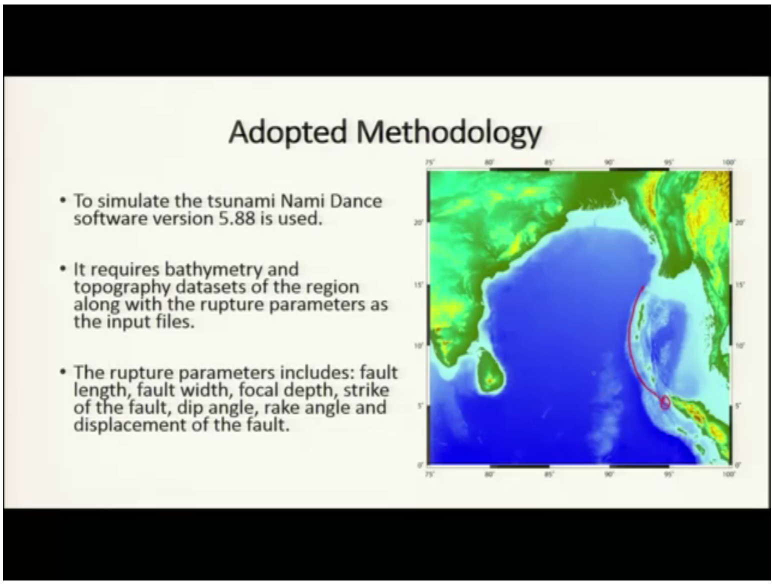


And then which generate series of files after giving the fault parameters which is the fault length fault width focal depth strike of the fault dip angle rake angle displacement of the fault which is about 10 metre. In this area that is Andaman Sumatra, which was the here was the epicentre of that earthquake. And this is the rupture created by this earthquake which was around 1300 kilometer. So, we gave those parameters and generated the tsunami in this whole area. And we see how much time it has taken to reach this part this coastal part of India.

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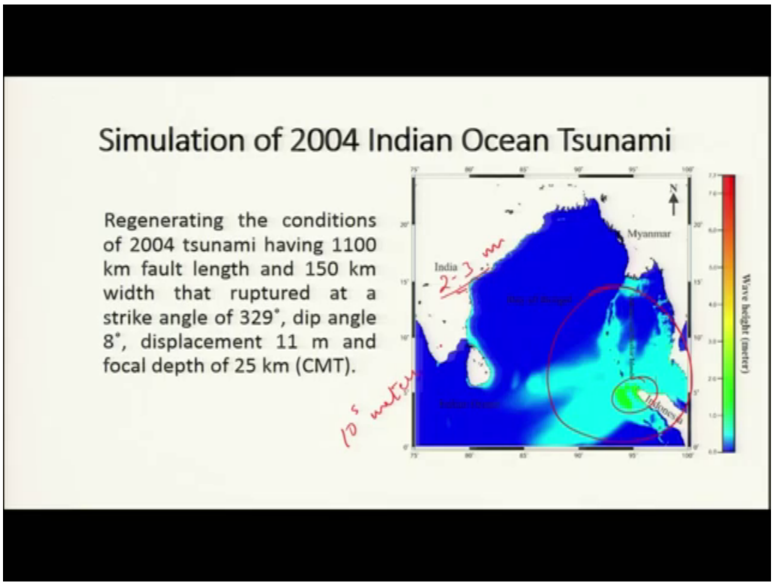

So, as I have told that we are simulating 2004 Indian ocean tsunami. So, this was the tsunami which was generated during the 2004 Indian ocean earthquake. Regenerating the condition of 2004 tsunami having 1100 kilometer or 1300 kilometer for length and 150 kilometer width of the fault that ruptured at an angle of 329, these are the fault parameters.

Which I have given in the name dance software to generate a tsunami and you can see the wave height of this tsunami in the Indian ocean was (Refer Time: 19:53) it was around 3 to 4 meters in this area which was the epicentre of the 2 104 Indian ocean tsunami. And the Indian sub-continent you can see it was around 2 to 3 meters this part receive the tsunami of 2 to 3 meters. And it depends on the height and low tat condition also. This is the height of the tsunami wave, but if it came around the height and condition then that can reach up to 10s of metre. And can create much more devastation in this area, in the Indian this part of the Indian subcontinent.

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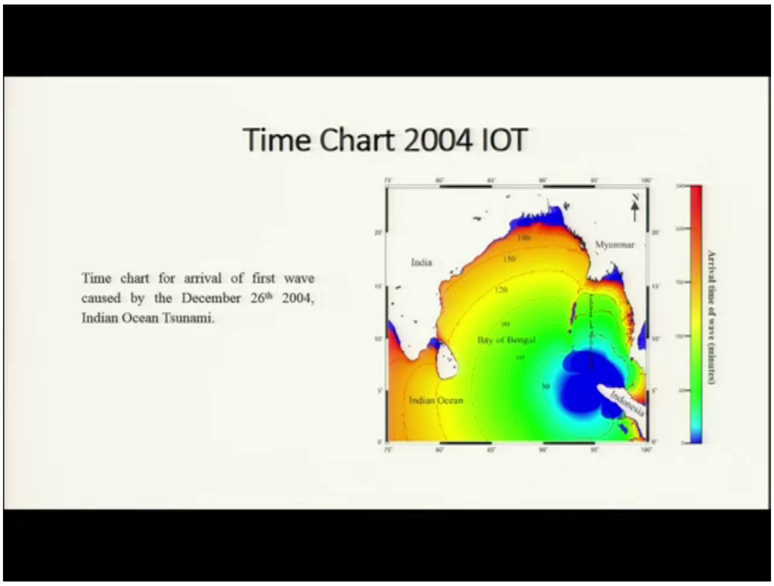


So, here is the time chart of the Indian ocean tsunami of 2004. So, as you can see it took around 180 minutes or around 150 minutes to reach the Indian ocean part, but only 10 to 20 minutes, it takes to reach the epicentre pollution that is in Indonesia. So, after modelling the data what we have done? We have the observed parameters of this 2004 Indian ocean tsunami. So, we need to validate our model data.

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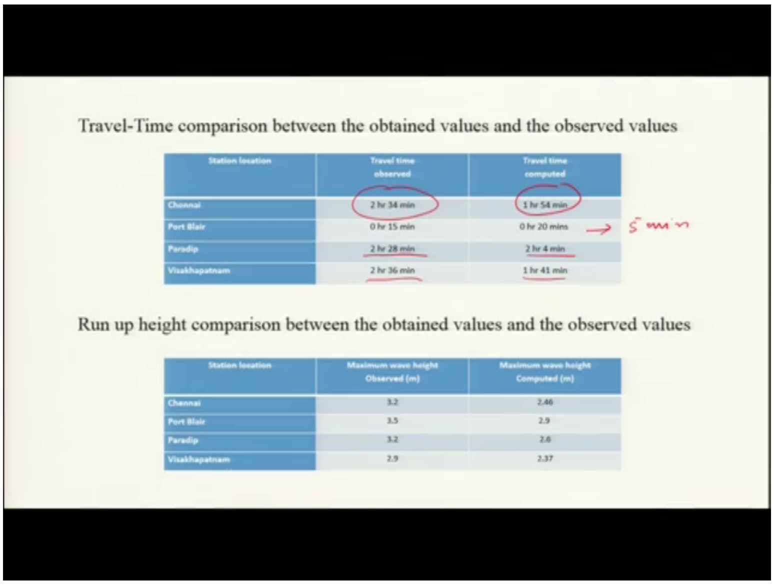


So, what we have done is that we have compared the travel time comparison between the obtain values and the observed values. So, as you can see these are the got stations which we need to put in the modelling part.

So, as you can see Chennai port Blair Paradip and Visakhapatnam. So, in Chennai the tsunami the observed time was 2 hour 34 minutes, but the model part gave us around 1 hour 54 minute. So, this kind of differences are coming because the model data did not take the account of the (Refer Time: 21:46) or the coastal morphology of that area, as it changes from place to place. So, it is approximating those things. So, we need to just verify those errors. So, we cannot get the actual numbers, but near to that value we can get from the model data.

So, as you can see around 2 hours, 2 when half hours it is taking to reach in the observed part, but what we have computed it is around 2 hours. So, only 30 minutes around information kind of error we are getting, so, that we can input in our hazard assessment map. And where as in port Blair it was we find that only 5 minute difference was there between the observed data and the computed data. And here is the Paradip and Visakhapatnam. So, from here we can see that near about our model data is kind of giving the near about results which was observed during the Indian ocean tsunami of 2004.

So, this was the run up height which we called as the wave height that struck the east coast of India and Andaman part. So, after computing travel time comparison map we computed the run up height the wave height of the tsunami which struck the east coast of India and Andaman part. So, as you can see the Chennai port Blair Paradip and Visakhapatnam are the (Refer Time: 23:25) location for our model data. And the observed height was around 3.2 metre in Chennai and computed height was around 2.46 meters.

Means it is near about same and the port Blair actually 3.5 metre the computed was 2.9 Paradip observed was 3.2 metre and the computed was 2.6 Visakhapatnam 2.9 and the computed was 2.37. So, near about our wave height of the model that is also collaborating with the observed data of the Indian ocean tsunami of 2004. So, as now our model data is validated we can use this modelling of we can use this parameters to generate few more tsunami which has occurred in that area. As I have shown that the 1762 tsunami the 1881 tsunami and other tsunami in anywhere in the world after validating our modelling part.

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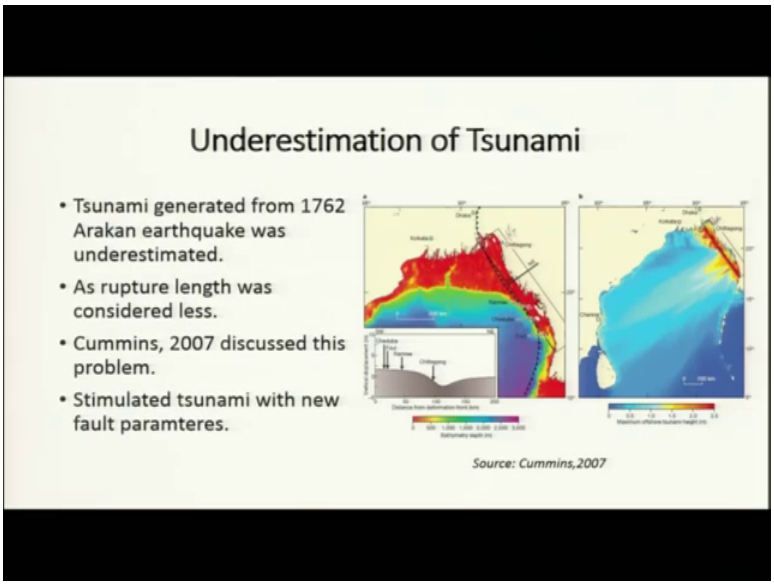


So, as I have already told you that there was an underestimation of tsunami in of 1762 the Arakan tsunami of 1762. So, there was a paper in nature by Cummins which carried out this study of this 1762 Arakan tsunami and we come up with that. Firstly, the authors were on the basis of observed data they are saying that there was small island Ramree they said that rupture after the 1762 earthquake in this area rupture was only up to this part.

But other observations from the inland of the Bangladesh near a Dhaka and Kolkata, this is that the they have experienced means the observation of people at that time it was that they have experienced steam tsunami wave up to upward in the upstream part of the Padma river upto the Dhaka Chittagong part and somewhere near the Kolkata. So, he thought that might be this earthquake was underestimated the rupture land was way more than it has been observed that it has been manuscripted. So, he model that data and has generated the tsunami waves as you can see that the Indian part has experienced up to 2 meter of wave during the 1762 earthquake and tsunami generation of Arakan.

So, with this modelling part, we can recheck the paleo tsunamis. And come up with some more information which has been not manuscripted at that time. So, the modelling part is very very important in the study of tsunami. And with that we can what we can do is that we can prepare some hazard assessment maps in that we can market those areas. Where the tsunami can come and we can give some give the authority some information about that this area cannot be allowed for construction or any other anthropogenic activity.

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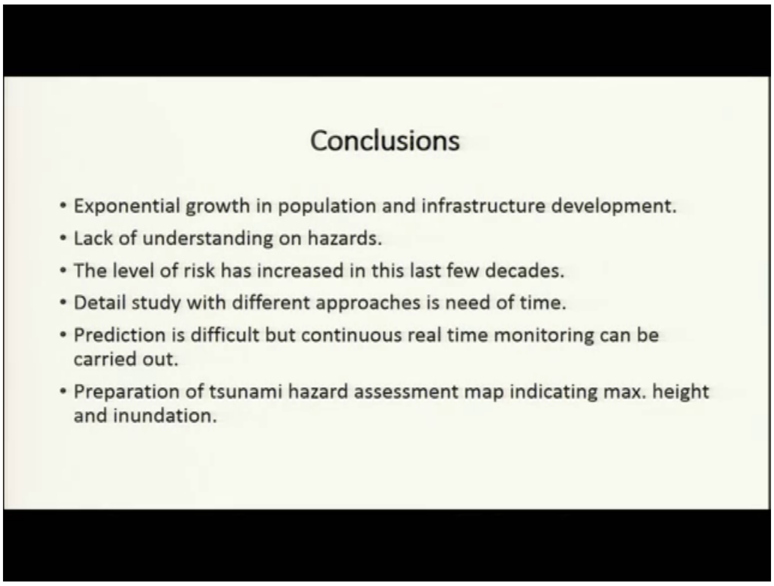


So now the conclusion. So, as in India we are saying the exponential growth in population and infrastructure development. So, this kind of modelling is need of time. Lack of understanding on hazards as you can see the underestimation of an 1762 tsunami that has been recalibrated they studied by Cummins. The level of risk has increased in the last few decades, with the exponential growth in population and the infra structure development. Detailed study with different approaches is need of time means which and that different approach it is can be tsunami modelling or the study of the tsunami deposits. I am sure Sarus thought you.

And then come the prediction how where the prediction difficult, but continuous real time monitoring can be carried out and that can be used in the modelling part. And we can further improve our model data. Then comes the preparation of tsunami hazard assessment map which I am saying again and again. And with this we can come up with some maximum height and inundation. So, that it can give a solid ground to or hazardous assessment map and we can give this information to our authorities.

So, that tell risk means we cannot totally reeducate the hazard, but we can lower the risk. So, after this I am sure that you will know how the modelling part is very important and with this we can help in many other ways to reduce the hazard.

Thank you.