# Introduction to Engineering Seismology

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## Lecture - 45
## Global Equation Model

Vanakkam. We will continue our lecture on engineering seismology. So we have been discussing about the seismic microzonation and then we also seen different component and then different work done in India in the name of microzonation. So we have been highlighting that, even though a microzonation is needed to classify, delineate the cities, which has a different hazard potential, but the work complete microzonation was done only for the few cities in India, which has been realized by the ministry, particularly Ministry of Earth Sciences.

They have taken up initiative for the microzonation of Indian cities, which has a large number of population. The cities, which is exceeding the some x, I think 5 lakh and above cities they identified and then they have taken up, so that the uniform microzonation procedures will be adopted all the location, get a more reliable robust microzonation map. Presently, microzonation of Bangalore, Delhi, Guwahati, are the more classical work, which is completed and we have taken as a reference for the microzonation related studies in India.

With this context, we also want to discuss what is the global macrozonation level and what is the Indian status on macrozonation level. So the work, which I am going to discuss this class and next class will be basically accessed from the global earthquake analysis, which is done by the different scientist group all over India.

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https://www.globalquakemodel.org/gem

https://maps.openquake.org/map/global-seismic-hazard-map/#2/35.7/59.4

https://maps.openquake.org/map/global-exposure-map/#4/12.73/84.61

https://maps.openquake.org/map/global-seismic-risk-map/#3/3.22/59.52

https://maps.openquake.org/map/covid-19-2020-05-20v3-grm/#2/34.9/0.0

https://www.usgs.gov/natural-hazards/earthquake-hazards/seismic-hazard-maps-and-site-specific-data

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You can see these websites to get more information about the microzonation. When I talk about this website, I also need to highlight that the microzonation map, even though many of the microzonation map produced in the lower scale and then maybe the accurate way, there is no iterative map or the user interaction map, which is one of the basic essential requirement for any mapping entity, because the user interface means like, when I zoom into the particular location, I should get the details of the map.

This microzonation studies published by the different people earlier is available as a report, map, but not a website user interface map. So I think the NDMA and MOES, they are planning to create such kind of maps, which will be useful for all the people in India as well as outside India. So that map; how it will be? If you know this map, then you can know how that map will be on this. So the global earthquake model initiated by a group of scientist.

Then, they gathered from each region and tried to generate map in the similar form throughout the world. That was one of the classical way. So I told you that all these information what I am going to discuss today and tomorrow on this topic is actually taken from the website, which I have shown you previously like all these websites, which we have taken. So I acknowledge those people and I also say that these materials are only used for the teaching purpose to explain students, how they are done and what was the highlight of this work. So that is the reason I have been quoting this website. Thanks for providing this material in the website, where people, teachers, students can benefit out of this kind of materials.

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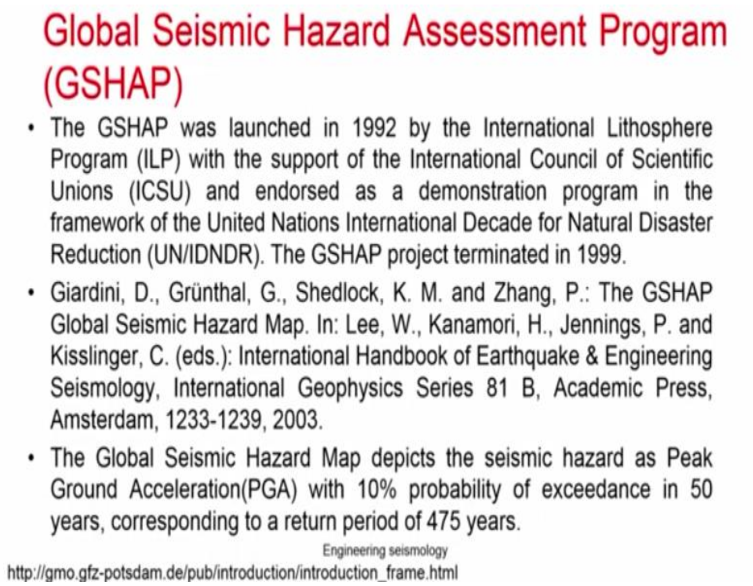


The global seismic hazard assessment program is not the new one. This was actually started in 1991 by The International Lithosphere Program. That was the first global level attempt to prepare a seismic hazard map of the entire globe. So, earlier people are very pioneer on this area. They may concentrate on preparing hazard map on their own region, not for the entire globe. So the group of scientist tried to come together, then they started International Counsil for Scientific Union.

They endorsed and demonstrated the framework for the United Nations International Decade for Natural Disaster Reduction and then they started a GSHAP project this is a global seismic hazard assessment program in 1992. So this was actually the group of scientist who are involved on this basically. These are all the group of scientist; they involved on that and tried to get a map of the entire globe.

So basically, they produced global seismic hazard map, which depicts the seismic hazard as a peak ground acceleration with 10% probability of exceedance in the 50 years corresponding to return period of 475 years. So this we will be understanding when we are taking about the probabilistic seismic hazard analysis. So right now only remember what they have taken.

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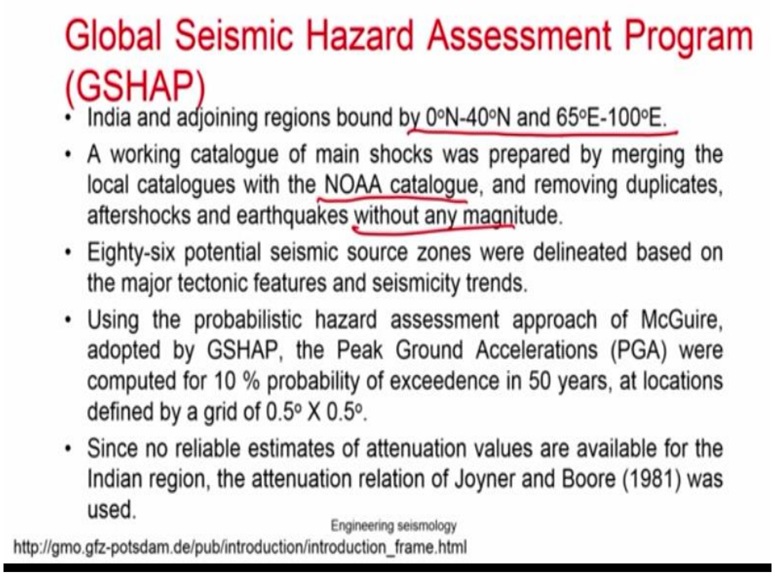


So this they have done for the entire globe. So let I focus only on the Indian context. India and adjoining regions bound by this much latitude and longitude has been taken. A working catalogue of main shocks was prepared by merging the local catalogue with the international catalogue produced by removing the duplicate aftershock and earthquake with different magnitude. We told that the foreshock, aftershock should be removed for any analysis.

So removing of that kind of foreshock and aftershock is actually a decluttering process, which we will discuss in the later stage, but just we discussed earlier, the foreshock, aftershock are removed and then they delineated the seismic source. So, 86 potential seismic source zones were delineated based on the major tectonic features and seismicity trend in India. That, we will see what are those 86. So using the probabilistic seismic hazard analysis, which was developed by the macro and adapted by the GSHAP.

Basically, those GSHAP group suggested to use the similar kind of package. So they tried to estimate PGA, peak ground acceleration with 10% probability in 50 years exceedance for the grid size of so much. They mapped that and then, they have taken that map as a global seismic hazard map for India to represent the global scale. So here, you can see that they use, they said that there is no reliable estimate of attenuation values are available for Indian region during 1992.

The attenuation relation of Joyner and Boore was used. So now, you may understand that when we talk about the Jabalpur microzonation work, I also told that they were used Joyner and Boore ground motion prediction equation or attenuation relation. You can see, here also they use. So if you want to get more information about that, you can visit this website about this.

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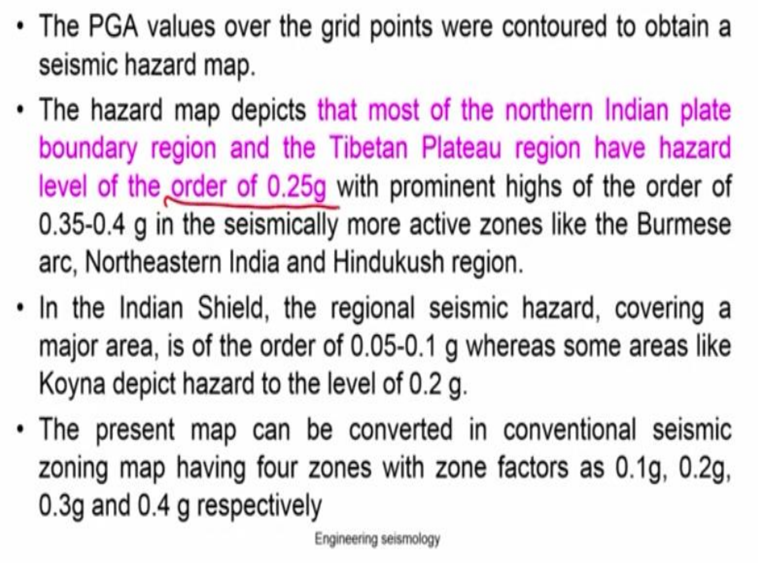


So this is basically what they did. They estimated each grid PGA and then mapped the PGA as a contour and then the most North Indian plate boundary region and Tibetan plate region having the hazard value of so much. So with predominant high in the order of so much in the seismically more active zone with Burmese arc and Northeast Indian and Hindukush region. So these are all the value they got so much.

The Indian shield; the regional seismic hazard covering the order of so much, whereas some areas Koyna and hazard value of so much 0.2g. The present map can be converted into conventional seismic zonation map, the fore zone where the hazard value was so much and so much shown. So this is how this was comparable with the present zonation map.

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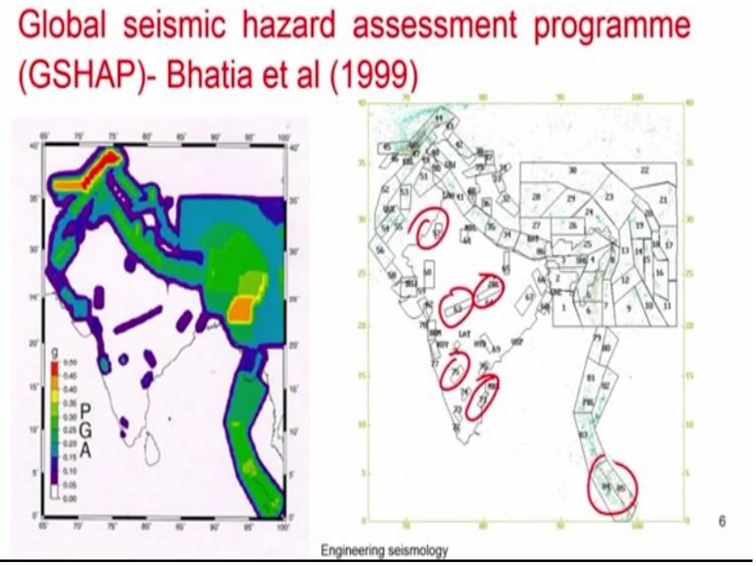


So this is basically the 86 potential seismic zone, you can see. So like that, a different potential seismic zone. So they considered the entire India plus Bangladesh, this side Nepal, so this side even a part of Pakistan has been clubbed together. So this is a so zone they consider. So using this, they used, as I said that, Joyner and Boore equation 1981, they used that equation and then they tried to estimate PGA.

As you know that the GMP or predicted equation is the function of any ground motion parameters. So this is the function of PGA. So they estimated the PGA, then using the probabilistic seismic hazard analysis and then given a map. You can see here. These are all the places, where they have given a g value of 0.5 and above, this one. So these are all the places where the g value of 0.3 and above and these are all the places even the g value of less than 0.5.

You can see Bangalore, South India, Bangalore you can see the very low seismic hazard. So Delhi, I think this is may be Delhi, where you can see the hazard values are close to around 0.15 to 0.12. So that is the global seismic hazard map prepared first time by the global community with support from the Indian author. The work was carried out by NGRI, the scientist called Bhatia et al. These publications are available. Bhatia et al, 1999 work you can see.

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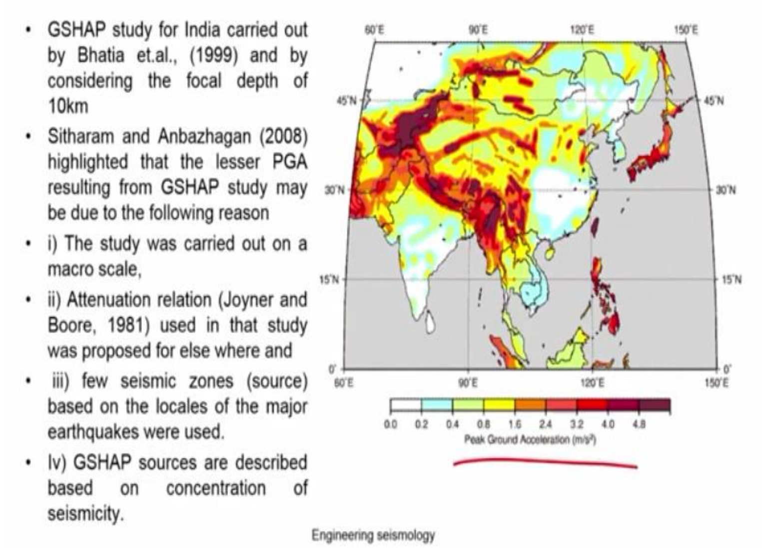


This is the global level hazard. This is basically the hazard distribution map. Here, the PGA is in the meter per second square. Previous one, what we have shown in the g zone, you can see this is the map, which is given for Asia region, where the Indian data has been merged with other region, they prepared. You can see the acceleration, expected meter per second square. So Bhatia et al considered the Joyner and Boore ground motion prediction equation and focal depth of 10 km.

So the 10 km focal depth throughout India is actually very low value, but inspite of that, the hazard values estimated are having a very low PGA or very low acceleration. You can see which is not basically appropriate. So this work was reviewed by me and then we also published a paper when we were talking about that. So we highlighted that what was the reason to get a low hazard value, that is you can see that Sitharam and Anbazhagan 2008 paper, where the lesser PGA resulting from the GSHAP study may be due to the following reason.

One is that the study was carried out on a macro scale. The scale of the study was very large. The attenuation relation, basically Joyner and Boore 1981 used in the study was proposed elsewhere and that is not applicable to the entire Indian region. As we have talked about the Indian region, we have been discussing about the plate boundary. So we have been discussing the plate boundary here, so this was somewhere the plate boundary. This is the plain.

So this is we have seen that there is a plate boundary, intraplate earthquake, inter and then intra, the earthquake on these places even mid plate somewhere in this area. So considering all of them is similar and using same ground motion prediction equation is not appropriate. That was highlighted by our research team and more further we also found that the few seismic source based on the local and major earthquakes were used.

So the number of sources has been taken based on the past earthquake. You can see that they found that there is no seismic source on these areas. There is no seismic source on this area, this area, no seismic source. So basically the active fault study, the fault activity, the seismic activity potential may cause future earthquake is not explicitly modeled in the GSHAP map generated by the Bhatia et al 1999, so that is the message we can take from here.

So that is why the source are described based on the concentration of seismicity. So they have taken a past seismic record and consider that the sources are only located on those location. As we told that, India is recording from 1960. That means, we have only data when this map was carried out, we have only less than 40 years earthquake data. So these data may not be sufficient to really delineate a source.

They should consider some of the advanced technology like satellite based image or the deep geophysical survey and geological studies and then delineated the active source and if they consider, then the map value what they have given will be different than the map what it was produced. So this was the first geological seismicity integrated hazard analysis done for the global seismic hazard program by the Indian contributors, particular Bhatia et al.

But at that time, this work itself was more appreciable way, because in 1992 or 1995, very few people worked in India on seismic hazard analysis. There was no people to teach this kind of subject. As I told you that the earthquake geotechnical engineering is origin after Bhuj 2001 earthquake, the first earthquake geotechnical engineering subject, where the amplification, liquefaction, ground shaking hazard has come into teaching level after the Bhuj earthquake after 2004.

Before that, no such kinds of things were there. Only there are 2 agencies, we use this kind of study, one is by the earthquake engineering department at Roorkee, and then the NGRI, National Geophysical Research Institute, they only do. So Bhatia was part of NGRI; they did this work, which was appreciable at that point of time and may be the more depth of information should be handled in producing that map, which might have been more useful

But anyway, that was anything, which happens in this region as I told you that, anything which happens with respect to seismic hazard estimation, seismic source characterization, seismic microzonation has to be reviewed at every 5 years interval and updated. It has to be frequently need to be updated with interval spacing. So after this effect, there is no such kind of any attempt has been done in the national level to cover a very big, large area.

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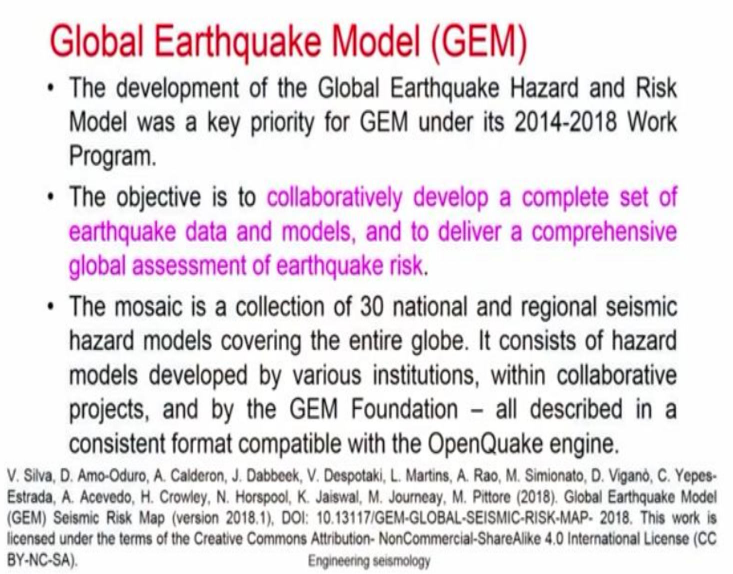


Then, there was a group, which was started working on this during the 2014, which is called global earthquake model. So this was the second global level seismic hazard mapping. So this was done by the global earthquake hazard and risk model. So key priority was GEM. It was called GEM, where to take a seismic hazard analysis of the entire globe and publish that map, so that we would know that on today, as on 2018 or 2019, what was the hazard status of the entire globe.

By 2014 we had at least reasonably good seismic data in the globe, because there was a global seismic network, which we have seen; the global seismic network and regional seismic network established. So the objective is to collaboratively develop a complete set of earthquake data and models and to deliver comprehensive global assessment earthquake risk map of the entire globe and each country wise.

The mosaic of collection of 30 national and regional seismic hazard models covering the entire globe in consistent with hazard models developed by the various institutes in the country within the collaborative projects and by GEM foundation, all described in the consisted format compatible with the OpenQuake engine. So where this map is actually more interactive in nature. So this map and about the report can be found in this reference those who are interested to get more information about that, you can browse this page and get the information.

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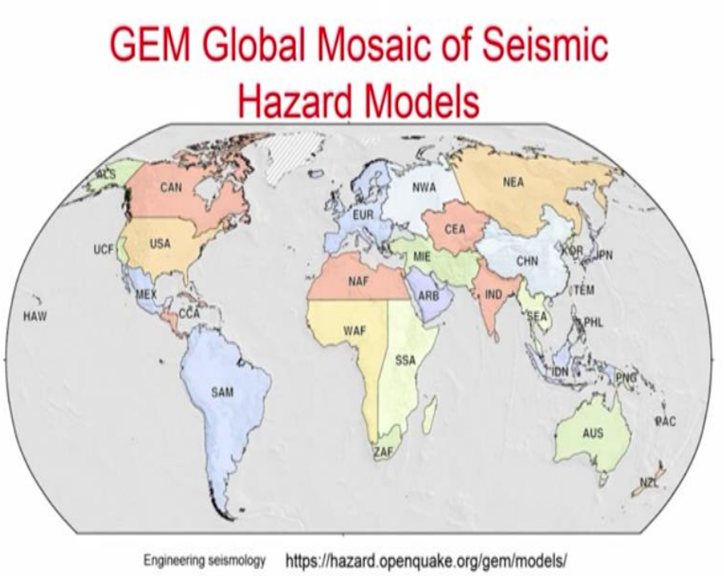


The entire globe, they divide depending upon the research group involved. So basically, the colour of code indicates that the same research group has been handled all these countries. For example, India, then this one, Canada and NAF handled by the similar group of people. Similarly, USA and NES are handled by the similar kind of group. South America, and then Europe and then the Arabian region are handled by the similar group, where the group of scientists work into that.

Australia and see, all those people are actually basically same. Somehow, if you see this mapping, the colouring scheme, you can also understand that these regions, basically similar kind of seismo-tectonic in nature. That also you can get some extent from this. So this information are compiled from each country and each research group and finally they produce seismic hazard map at global level.

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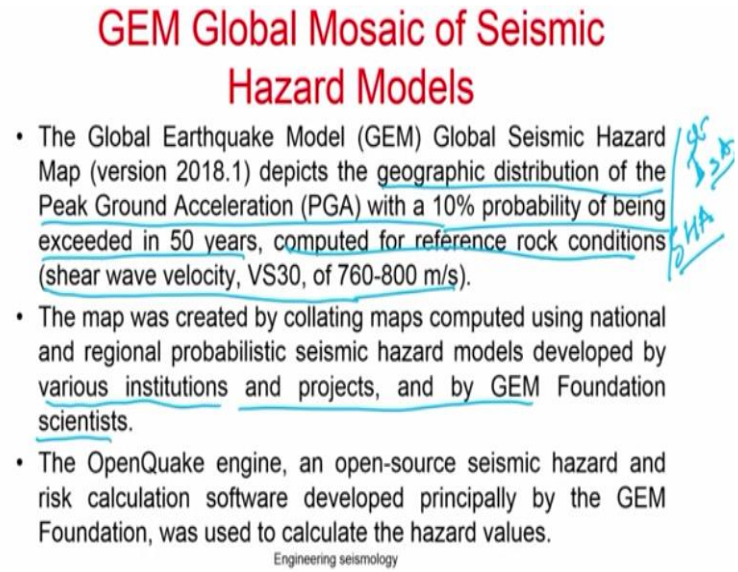


So the GEM global mosaic of seismic hazard model, the global earthquake model GEM, global seismic hazard version 2018, basically the year, 1 is actually the first version, depicts a geographical distribution of the peak ground acceleration with 10% probability being exceeded in the 50 years, computed for the reference rock conditions with VS30 of so much. So you can see that they have done basically seismic hazard analysis using the probabilistic approach, which is the first step in the seismic microzonation.

That is what is there. They considered this hazard value at the bedrock level. So the map was created by collecting the map computed using the national and international probabilistic seismic models, developed by the various institute and project by GEM foundation scientists. The group of people, who are there, they talk with each country who are working in this area. So the OpenQuake engine or open-source seismic hazard and risk calculation software developed principally by the GEM foundation and used to calculate the hazard values at all the places.

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- A smoothing methodology was applied to homogenise hazard values along the model borders. The map is based on a database of hazard models described using the OpenQuake engine data format (NRML); those models originally implemented in other software formats were converted into NRML. While translating these models, various checks were performed to test the compatibility between the original results and the new results computed using the OpenQuake engine.
- Overall the differences between the original and translated model results are small, not withstanding some diversity in modelling methodologies implemented in different hazard modelling software.
- The hashed areas in the map (e.g. Greenland) are currently not covered by a hazard model. The map and the underlying database of models are a dynamic framework, capable to incorporate newly released open models. Due to possible model limitations, regions portrayed with low hazard may still experience potentially damaging earthquakes. The GEM Foundation plans to release future updates of this map on a regular basis as new information becomes available.

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So the smoothing methodology was applied to homogenise hazard values along the model borders. So the map is based on the database of hazard model described using the OpenQuake engine data format, NRML, it is called. Those models originally implemented in other software formats were converted to this format, while translating these models, various checks were performed to test compatibility between the original result and the new result computed using the OpenQuake engine.

So overall the difference between the original and translated model results are small, not withstanding some diversity in modeling methodologies implemented in the hazard modeling software. So they have seen that even though the work was done at regional level individually, they club together all the data and see that these maps are representing the same original research and also it is uniform throughout the world. That was the main priority.

The hashed area in the map, the Greenland are currently not covered hazard model. So the map underlying database models are dynamic framework. It is capable of incorporating a new release open models. Due to possible model limitations, regions portrayed with low hazard may still experience a potentially damaging earthquakes. So they say that, this model, whatever the model they use in some of the places, the lack of proper model and lack of data.

That means, it may have shown in the map a low seismicity or low PGA value, but there may be potential damaging earthquake can be expected in this region. So that is what I told you that none of world area is free from earthquake, only you have the lack of data. You cannot claim that this is more accurate. There may be earthquake, which you can expect in those regions. The GEM foundation plans to release future update of this map on regular basis as on the new information and data are obtained.

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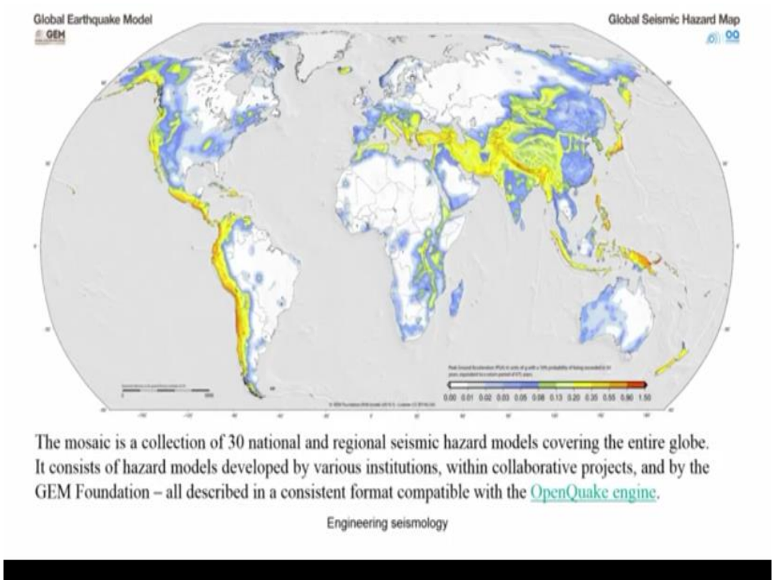


So basically, they develop a model and then they consider all the information considered in the developing model as an entity, where if you key the new information, the map will change automatically. So this is the global earthquake model. So this is the mosaic of 30 national and regional hazard models covering the entire globe. The consisted hazard model developed by the various institutes collaboration. You can see this is the map.

So here, basically you can see the hazard distribution at different places. You can see that overall the plate boundaries you have more seismic hazard, when compared to the non-plate boundary regions. You can also see the PGA distribution. This is actually the peak ground acceleration in the unit of g with 10% probability being exceedance in the 50 years equivalent return period of 470 years. As I told you that the map is more interactive in nature.

So this is actually the image file what I got from the website and put it here. If I go for the website, the same thing, you can go for the website.

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This is basically the website where your maps are published. So if you want image file, you can take it from here by registering your email and other details. So if you want to see this map, go to the hazard viewer. So we understand how this map was prepared. You can see now, I can get a map at different places what I want to see. See Mandya, Bangalore. So Bangalore, what is the hazard value? So this is Bangalore is in a dark colour, I mean green colour.

So the green hazard is actually, how much is the green hazard legend? Let us see the legend here. So you can see, this was about 0.08 to 0.13. So you can see the difference, which is previously what we discussed.

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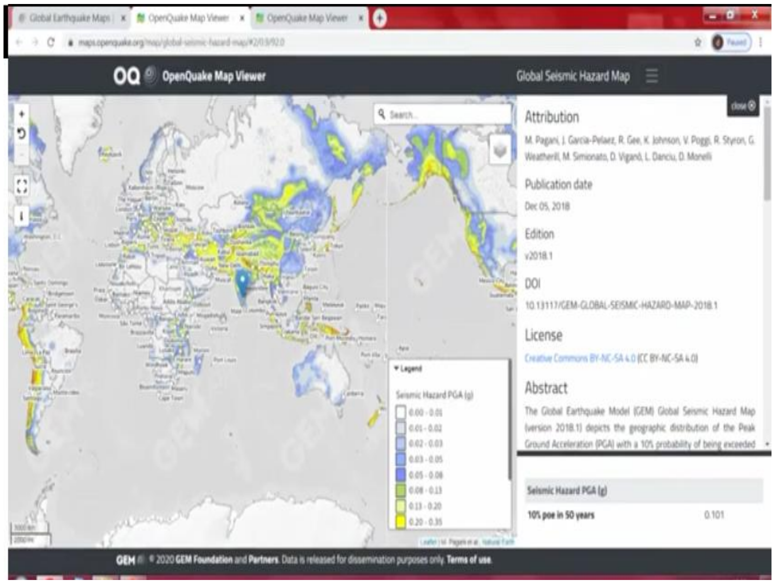


He mapped most of the Southern India as a region with less than 0.05 g. here you can see that in Bangalore, where we have seen Bangalore and then the other part, you can see the values. You can see the hazard values, even this is the Koyna region.

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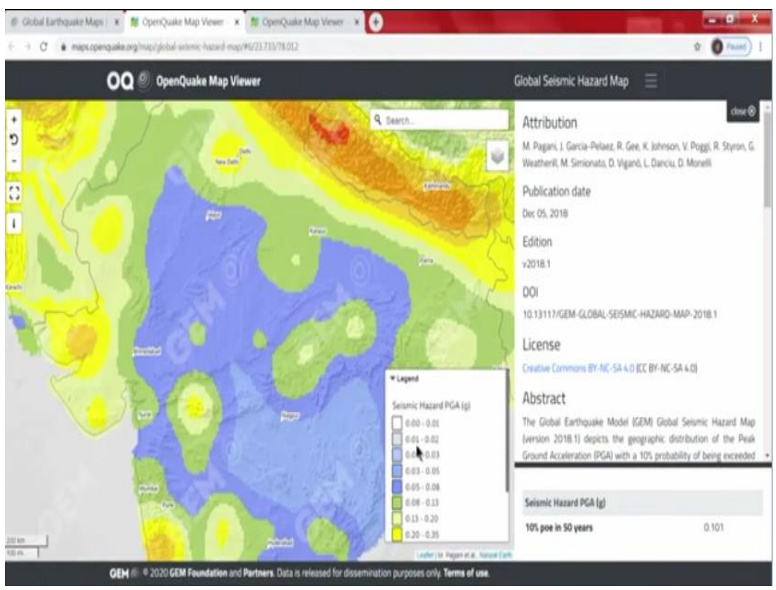


You can see Mumbai, Koyna region, Hyderabad, even you can see there is a lowest hazard value mostly expected was more than 0.01g. So the highest hazard value, which is expected at this very dark red region, where you can see around this close to 1 g, that is on the plate boundary. So these kind of interactive way, you can get information, what do you want.

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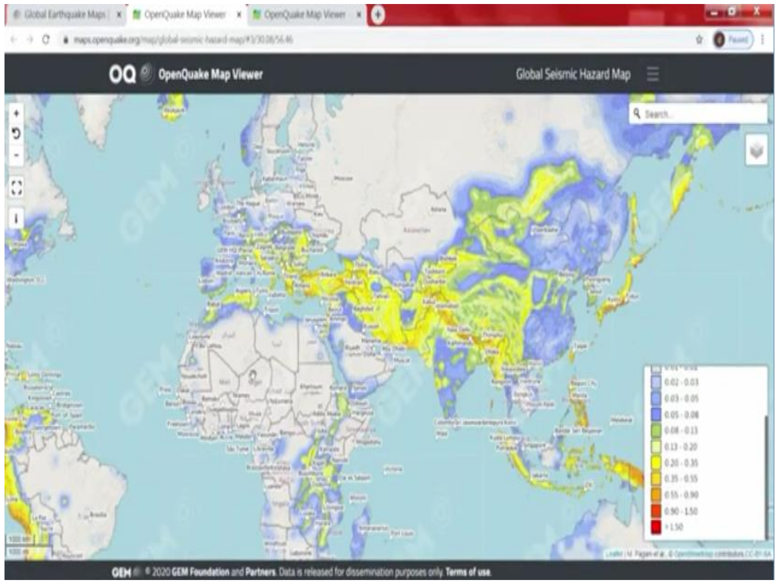


So you can also get the different colours, you can get. Like this, you can create a different interactive way. So that is the one beauty of this map. So you can get a hazard map of this one. You can also zoom in, zoom out and then you can also get information of what you want. You can see the map, which is interactive in nature. So this kind of map is needed for each city, but this is the global scale. So the India variation they have shown, but city variations are not shown.

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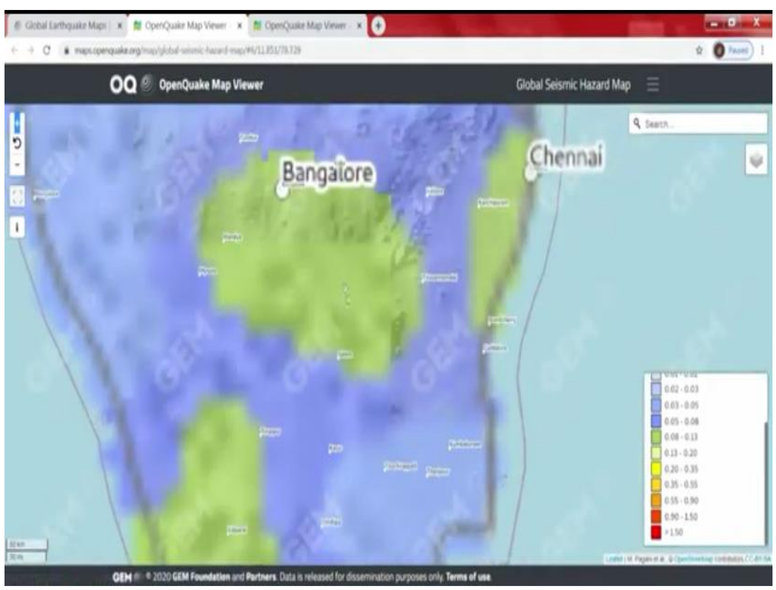


For example, if I want to go inside Bangalore, I think I cannot go beyond some zooming level. So highest level I can zoom is only this much, where Bangalore is shown only as a point. So it is not gone beyond this information, but now the microzonation map, they give, they should create a similar kind of map and then if we zoom into Bangalore, I am giving you the example, IISc, should know what is the hazard? I should know what is the hazard at the JP Nagar?

I should know what is the hazard at the majestic? I should know what is the hazard at airport? I should know what is the hazard at electronic city. Such kind of a minor variation zoomed in value should be available part of the microzonation mapping. So I think the MOES work what they are going to do, they are going to achieve these kind of things in their studies. That is what they are working towards. So this hazard map, it is not only end up mapping PGA.

So this way this is like global scale, somebody want to locate, what is my hazard value. So they will get from here and maybe that can be taken as a reference to do some kind of calculation or anything what they are looking for, but this microlevel information is not there, only macro level you get and it is a very interactive way and they said that these maps could be capable of updating frequently by changing the model as well as the data. How these maps are useful?

Why they developed this map, which we are going to discuss in the next class. This is the macrozonation like a global or continent or country wise zonation map, which is available as on now, which is like maybe the better way to represent as India, but locally city wise represented may not be possible, but why they do it on larger scale and what is the importance of that, what additional input they develop part of this, we will be going to discuss with continuation of this class in the next class. Thank you very much for watching this video. We will meet in the next class on discussing, continuing this GEM model and related results. Thank you very much.