**Remote Sensing Essentials**
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**Lecture – 46**
**SAR Interferometry (InSAR) Technique-02**

Hello everyone and welcome to the new discussion, which is basically part 2 SAR interferometry technique and very briefly first, we will see this figure again.

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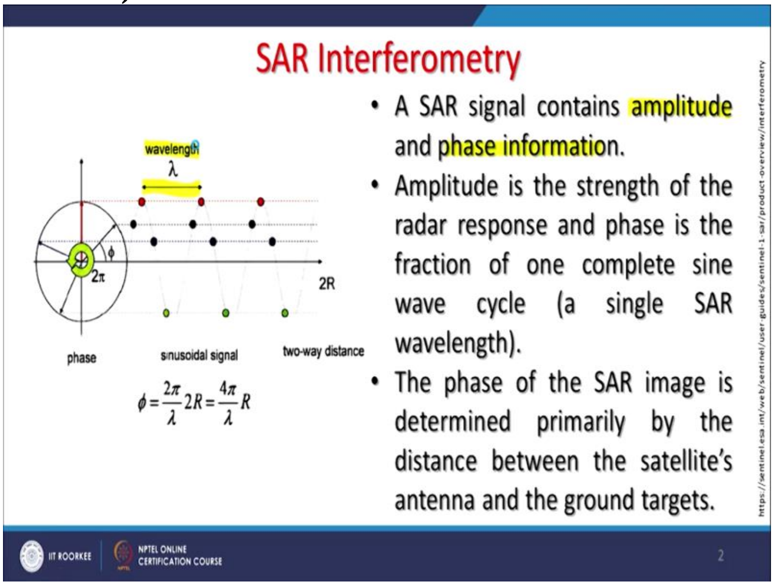


As earlier also while discussing microwave remote sensing active microwave remote sensing we discuss this figure, but very briefly I will bring that in SAR interferometry these SAR signals basically, as also discussed that they contain basically the amplitude and phase information and this amplitude and basically shows the strength of the radar response. And phase is the fraction of one complete sine wave which we are seeing here one complete sine wave cycle as a single SAR wavelength.

So, when it complete sine wave is there that becomes the; our wavelength here that we are seeing here and in this phase of the SAR image determined and basically primarily by the distance between the satellites antenna and the ground targets. So, this phase is basically based on the how far the antenna is between the target and antenna. So, based on that it is discovered.

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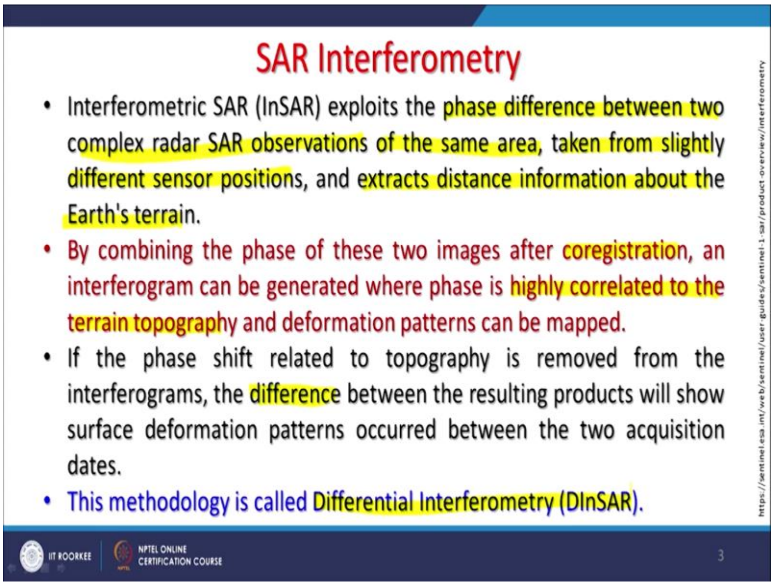


Now interferometric because if ground deformations has taken place, then there should be some phase difference if no ground deformations have taken place, then we will not be seeing those differences. So, what we but it explains basically the phase difference between the 2 complex radar observations. Complex through complex numbers analysis first, so that you are having a pair in between the some changes might have occurred.

And these changes will bring the phase difference between these 2 scenes and that can be exploited to generate interferograms. And then of course, it has to be of the same area and taken from slightly different sensor position, because it is not possible all the time. To have exact position of the sensor or platform in a space. So, even if there is a reasonable baseline perpendicular baseline distance is there, it is not a problem is still interferogram can be derived or can be extracted and this extract distance information about the Earth’s terrain.

So, this way we can exploit SAR interferometry. Now when we combine the phase of these 2 images or appear after co registration. Earlier also I mentioned that this co registration is very important, if 2 scenes have been just co registered nicely, then these will produce good results. So, after this co registration interferogram can be generated where phase is highly correlated to the terrain topography. Generally this is the situation that our phases are related the terrain topography and deformation patterns then can be mapped.

Because if the phases shift a topography is removed from the interferograms, the difference between the resulting products will so, surface deformation pattern. So, in SAR interferometry, what we do first we also generate a digital elevation model using that pair of the same area. And that digital elevation model is then used to subtract from under interferogram. And that is why and this we say as differential interferometry or DinSAR also, so basically it is not purely InSAR for ground Information Studies, it is basically DinSAR,

I will explain again that a pair is taken first a digital elevation model of the area is estimated are derived and that digital elevation model is used later on to subtract from interferongrams and then you get a product. Which is will have no effect of topography or minimum say minimum effect of topography and through this subtraction and then the product is called differential interferometry or differential interferograms. Let me give you one example.

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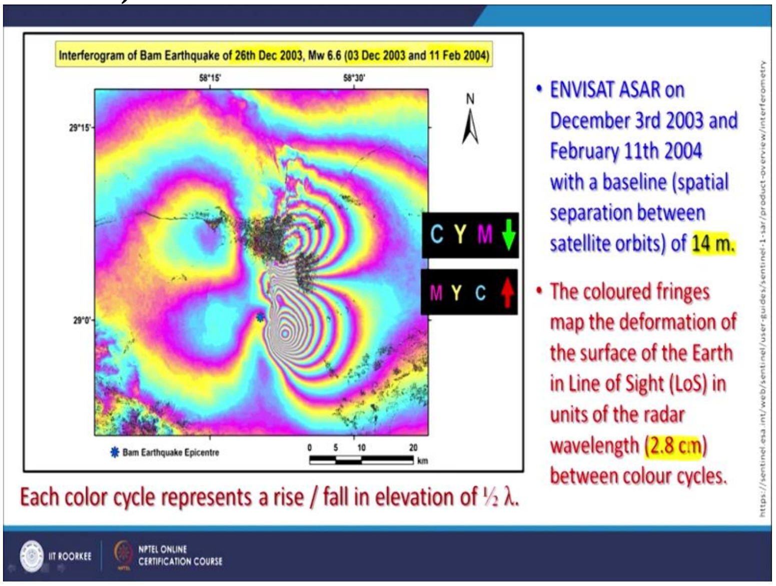


Which is one of the very beautiful example and ground deformation induced by an earthquake event which occurred on 26 December 2003. And a in Bam place name is Bam Iran and the magnitude was 6.6. The 2 scenes to a pair has been taken and the 1 scene of third December 2003 and another one of 11th February 2004. And this is of course, the ENVISAT is our data. And the here and the baseline and difference was only have 14 meter which is very good for driving such interferograms and this ENVISAT data and was implied.

And these deals are interferogram was generated and as discussed in the previous discussion, that these fringes and color of these fringes, the changes in colors or pattern of these colors can be used to count number of fringes 1. Not only that, but we can also know whether there is a subsidence or upliftment due to that particular earthquake event. Like for example, if I get a fringe color pattern like cyan, yellow and magenta, then it is concluded that there is subsidence occurred between those 2 dates for which we are having a pair.

And if magenta yellow and cyan pattern is observed, then it is upliftment. Now the question would be from where I should come from outside or inside so, it is counted from inside. So, if I here, start counting that I will get first the; you know these patterns, like for example here, I am getting cyan, yellow and magenta.

And here I am getting if I start from there, that I am getting magenta, then yellow and then cyan. So, that means, the lower part has got upliftment the upper part has got the subsidence that we will see through the deformation map as well. Now, these colored fringes as you are seeing, they are basically representing the ground deformation in the line of sight in the units is also discuss that the C band was used.

So, it has the 5.6 a centimeter wavelength, half the wavelength will 1 fringe will represent half the wavelength why half that we have already discussed in previous discussions. And this half wavelength is so these numbers of fringes are counted and then multiply by half the wavelength.

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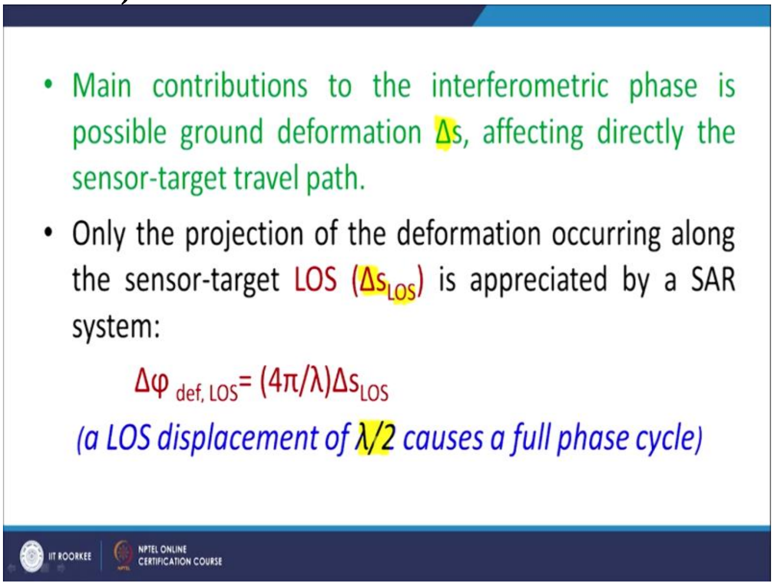


And you get that total information about the deformation. So, the basically in the main country would the contributions to interferometry phase is the possible ground deformation that is delta S affecting directly the sensor target travel path. So, I think that if between those 2 dates when those 2 scenes we are required, if some ground information has occurred. Then that can be detected very easily.

So, the only the projection of the deformation which is occurring along the line of sight a LOS that is delta S LOS is appreciated by a SAR system it is not the real it is not the real deformation which has taken place but the deformation in the line of sight though by using further processing we can create exact formation as well. Now, this LOS line of sight displacement of half of wavelength causes a full phase cycle.

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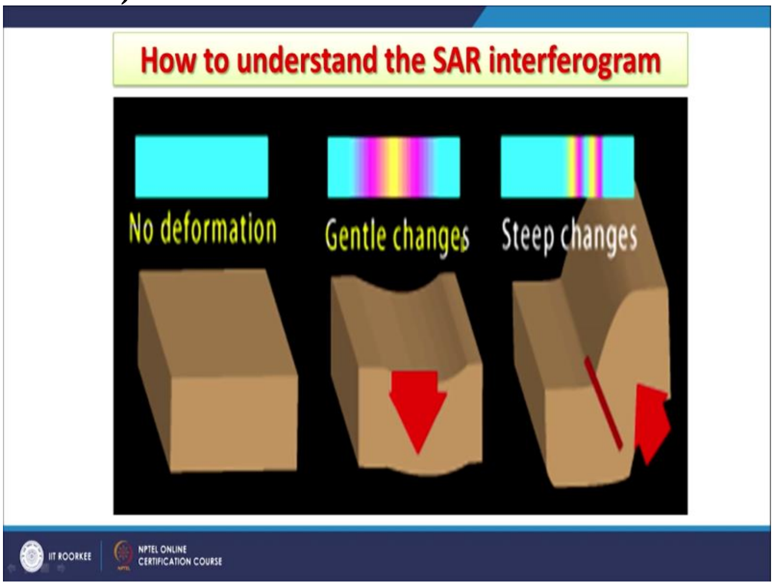


So, that way for example, this example we have seen little differently that when no deformation is there, like in this one on the left image, then and no fringes will be observed in interferogram, but it has some gentle deformation has occurred in this case is subsident, this is the pattern which will you will see and if steep changes have occurred, we might see even 2 fringes like here, the example here.

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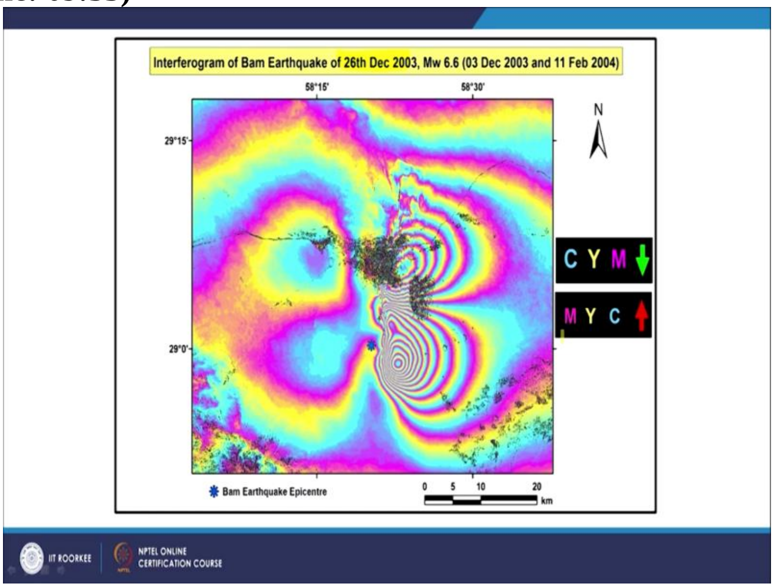

So, when we take this back again this interferogram of this now, we can interpret that in which part of a this interferogram the subsidence has occurred, in which part the upliftment has occurred between these 2 dates. And we know between these 2 dates, one big earthquake has also occurred. So, we can attribute very confidently that these ground deformations are because of that particular earthquake.

Now, there is one coherency part I would like to also discuss, what you are seeing here these spackled black dots speckle these are the incoherent areas within this. And also on the edges in the southeast or in the southwest direction in the edges also you are seen black dots clustered black dots, and these are the built up areas and because of that big earthquake. These buildings or houses got completely damaged and because of that, the coherency for these areas could not be achieved through this interferogram analysis.

So, those areas will appear without any fringes, but the areas be which had the good coherency are showing very clear cut for you. This is one of the best examples of and DinSAR interferometric technique for earthquake studies. This is that the ground information which I was mentioning.

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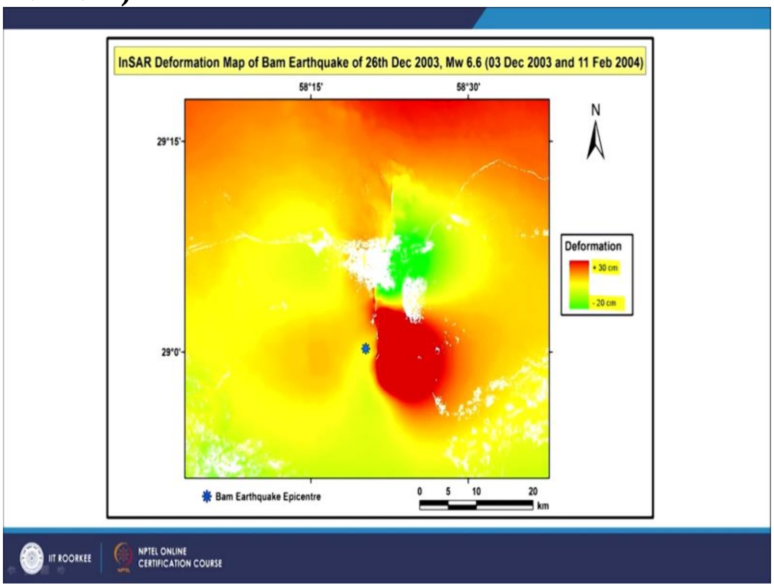


That this top part here and then when we get this color pattern the cyan and yellow and magenta on the top part we get the subsidence and reverse to this pattern is what we get the upliftment. So, the lower part of this area got uplifted by about 30 centimeter and whereas, the upper part, this green area is subsided by 20 centimeter. So, what we can say that total the deformation. Which was induced by that Bam earthquake of 26 December 2003 between these 2 dates is about of 50 centimeter, half a meter, deformation has taken place.

Some areas have gone down, maximum by 30 centimeter some areas have got uplifted by some areas have gone down by 20 centimeters, some areas have got uplifted by 30 centimeters. So, that; kind of deformation estimations are possible through DinSAR technique. Which otherwise there are no other techniques which can give us such kind of accurate information about the deformation. So, this kind of deformation estimations have become nowadays more or less is standard in almost each.

And every earthquake because the data is now available regular data is available and people once the earthquake over people and analyze and of course, in this one in the formation map. Wherever the was not there due to the damage to the houses or building or structures those areas in deformation maps are seeing no changes that means they are appearing as white and no changes in terms of because the coherency could not be achieved there.

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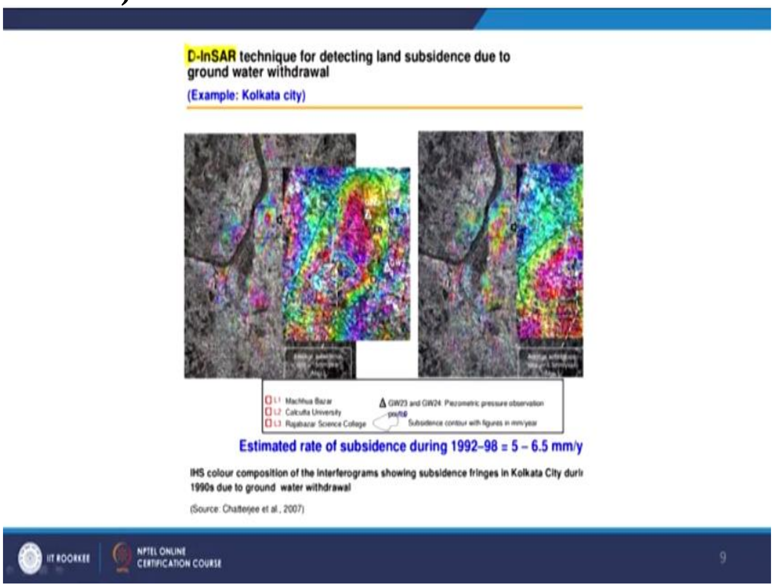


There are some other also examples of DinSAR technique which is detecting and the land subsidence and this example of course, from the Kolkata city. And due to over withdrawal of and groundwater, as you can see here, and that of course, these kind of deformations are very slow as compared to earthquake induced deformations and therefore, very clear cut or multiple fringes may not be possible between these 2 dates.

But none the less, the deformation of millimeter estimated rate of subsidence during 1992 to 98 pass between 5 millimeter to 6.5 millimeter, that kind of range of deformations have been observed between those 6 years. So, this kind of DinSAR or SAR interferometry technique can be implied wave deformations have occurred when we adjust 2 successive overpasses like an earthquakes.

Or there mine deformations which are very slow, like in case of subsidies due to maybe groundwater, subsidence due to mines or maybe some landslide activities in the mountainous regions. So they are these things can really very accurately, unbiasedly can estimate the deformations which are taking place.

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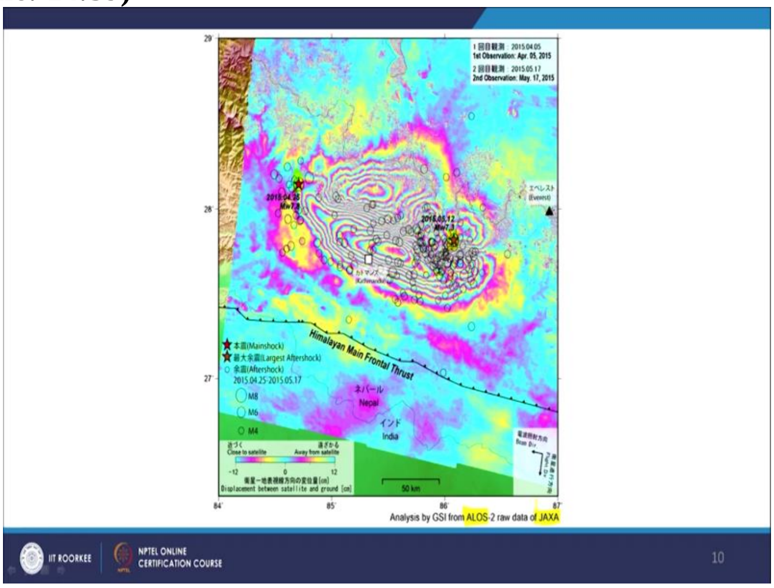


Now, I bring another example from earthquake and which has occurred in Nepal and there are 2 basically 2 earthquakes have occurred. One is occurred on 25th of April 2015. Another one occurred on the 12th of May 2015. And see the fringe is which you are seeing very close fringes in a small area, we are observed this data analysis for this interferograms ALOS PALSAR.

Data was used and is no more data available neither sentinel. So, last ALOS PALSAR data was used and this product was generated by agency of Japan a space agency which is JAXA. So, here we can clearly estimate how much deformation and wave deformations have taken place induced by these 2 earthquakes that kind of accuracy cannot be achieved by any other method except in and this through SAR interferometry technique.

Now, there is another technique which is also now available, which is the basically you can say the next step DinSAR SAR interferometry or InSAR that is persistent is scattered interferometry or InSAR we call it PSI.

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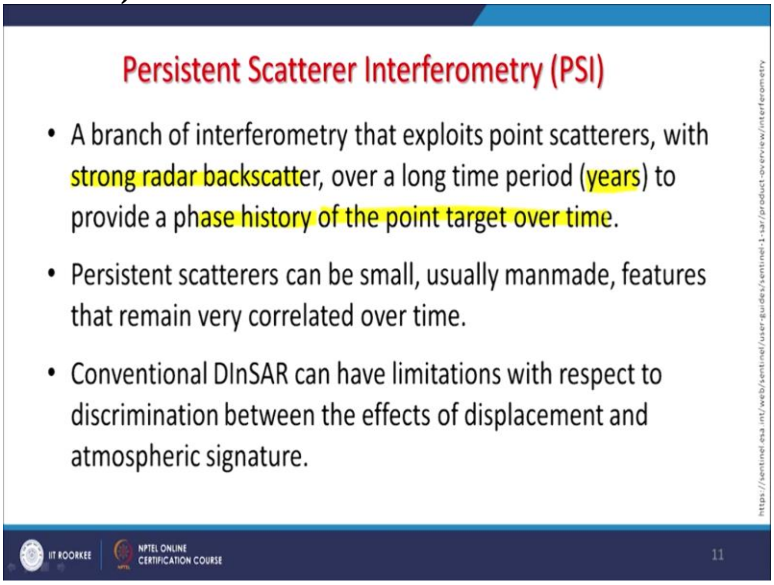


So, basically this is a branch of interferometry and that exploits the point is scatters instead of looking for you know and the fringes is here inducible points are used. So, point scatters are exploited with stronger radar backscatter which may be giving better or a strong backscattering over a long time period, that line time period might be years; because a lot of data is available successive data is available.

And then if we imply this technique through these stronger radar backscatter for a long period, then we can know the history of that point target over time, how it has behaved and this is not I am talking of one point in one area, there might be 100s of such strong radar backscatters and that can give us a and ground deformation or deformations have taken place between and that time period.

So, as it says the persistent scatter that means that those point is scatters continuously are giving and the backscattering that 2 quite strong backscattering and you can and say that something like a corner kind of reflector which always are in giving a strong back scatter. So, these objects are identity or these points are identified through the analysis of several scenes of the same area over a long time period.

And then point is scattered are identified. And based on that, we can estimate how much deformations have taken place so persistent his scatters can be small in numbers usually manmade features that remain very correlated over time. That is the 1 condition if any, I am getting just 1 or 2 persistent scatter then results, I cannot have confidence in them. But if I am having multiple and these scatters.

Then I will have a lot of confidence though the conventional by this technique sometimes is found better because conventional DinSAR are can have limitations with respect to discrimination between the effect of displacement and atmospheric signatures, because between those 2 dates, a lot of atmospheric conditions might change and though we are using long waves.

Generally these should not get affected by because of most flood factors but because of heavy clouds for some other reasons may get affected. So, in PSI, these effects are minimized. Now PSI techniques can overcome and such limitations by relaxing usual baseline and temporal constraints. So, that conditions of baselines is not that big in persistent is scattered and maximizing the number of usable number of usable interferograms.

Because this issue of coherency issue of baseline issue of temporal constraints, the constraints are minimized in PSI. And then these can be used to calculate the mean trends over the time from a large history of interferograms. So, at least 12, 13, 14 scenes are required to develop a PSI interferometry. So, only the targets with the sufficient high coherence are considered in as persistent is scatter resulting in reduced pixel density and that way what happens that we get the scatters these persistence causes but then an image of it then in the study area, maybe just few like here.

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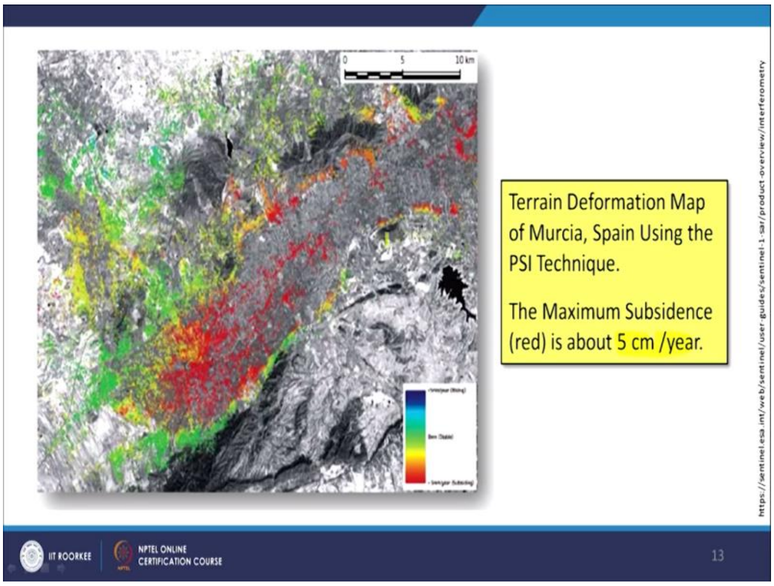


If I take an example of the terrain deformation and which is of a part of this Spain and in which a PSI technique has been used and the maximum subsidence has occurred is about 5 centimeter per year, because it has covered a long time period and therefore, the rate can also be estimated. So, red here as we estimated with and that 5 centimeter per year. The area which are having red persistent scatter or red pixel to call them or swing, whereas, and some are having very little or no changes are there.

Though they are performing as good persistent scatter a good scatter but having here and basically no changes middle, the green 1, are swing and little changes the maximum changes are being shown by these red pixels or red dots. So, in that way also over a time period we can estimate the rate of deformation that maybe subsidence or upliftment does not matter, but rate of deformation can be estimated using persistent scatter.

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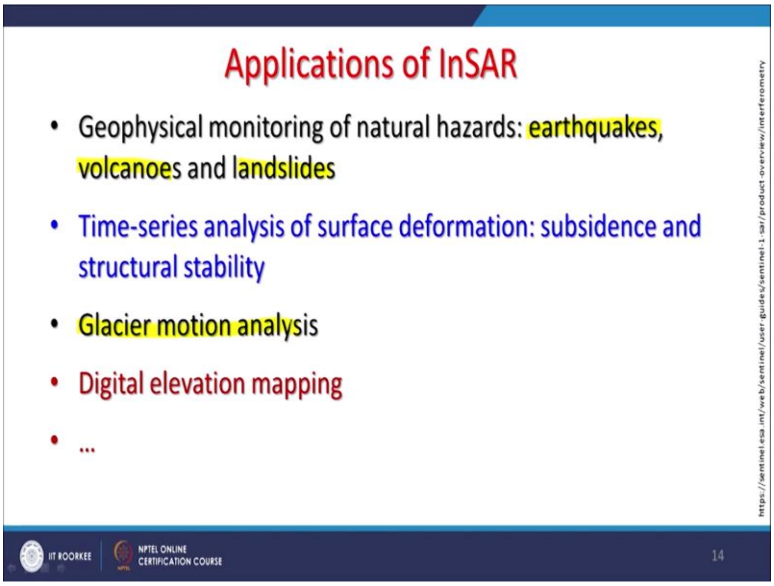


What are the larger some applications we have already touched, but some we will be also mentioning here, applications of InSAR technique DinSAR or PSI all combined together and basically geophysical or, it has it plays very important role and that is the studying the ground deformations and in geology, natural hazards also that we can imply I have shown few examples.

We can implies InSAR interferometry in earthquake related studies or earthquake induced ground deformations, maybe deformation be due to the volcanoes or maybe the deformation due to landslides or over withdrawal of groundwater. So, lot of deformations, which might take place on the part of the land or ground and those deformations, either can be estimated using a pair or rate of deformation can also be estimated to PSI.

Time series analysis of surface deformation that is persistent scattered through persistent scattering or PSI, the subsidence and structural stability can also be estimated, so, there are here a lot of things about some monuments are getting deformed or some other thing or that area is subsiding. Those areas can be studied through PSI. And we can say that whether there is a subsidence or upliftment and if that is there what is the rate also.

And this and this SAR interferometry technique overall whether the DinSAR or PSI can also be used to monitor the glacier motion and how glaciers are moving, what is the rate and so on. Of course, the first application of SAR interferometry is for digital elevation modeling. So, driving digital elevation models one of the best examples is digital elevation models generated using that SRTM mission data and implying DinSAR technique.

So, and this list is not really exhaustive as there can be many applications and lot many new applications are still being developed using these techniques and these datasets, because the reason is now and data is available. And if I talked about the data is basically the sentinel 1 data, it is freely available for the entire globe and therefore, and lot of applications are being developed in this area. So, this brings to the end of this part 2 discussion SAR interferometry. Thank you very much