Global Navigation Satellite Systems and Applications
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Lecture - 17
Global Navigation Satellite Systems (GNSS) Applications – I

Hello everyone and welcome to 17th lecture of Global Navigation Satellite Systems and Applications. So for, we have discussed different segments of different GNSS constellation systems, their advantages and associated errors and how these errors can be removed. Now during that discussion, we have also discussed very briefly about applications; where we can apply the signals which are being received from these GNSS constellations.

But in this lecture and in the next one, we are going to discuss in detail about the applications of GNSS. So, this is part 1. In next lecture, we will be discussing that is part 2.

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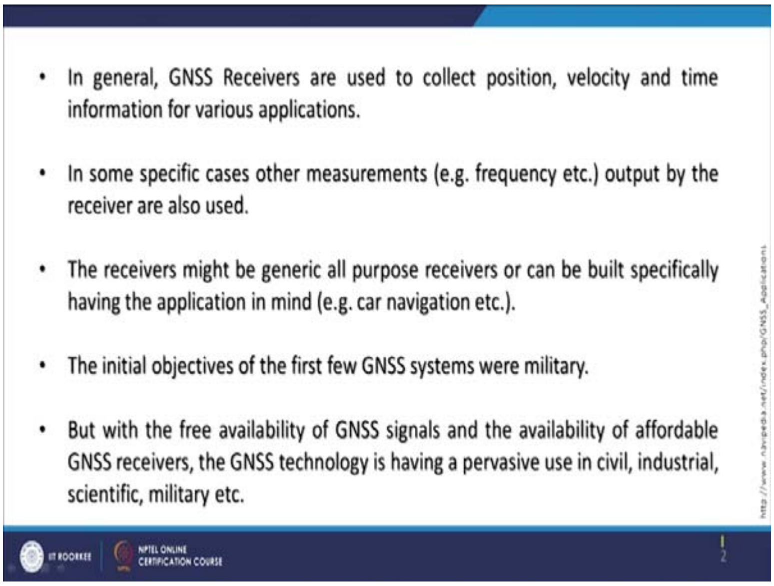

So, as we know that in general what is the purpose of these GNSS receivers is to collect position; basically for positioning and of course, then the velocity can also be estimated and time information which is used for various applications. So, generally this is what the main purpose of GNSS, we also know that there are some applications where frequency based information or the frequency which is available from GNSS systems that can be used for calibration or some other scientific applications.

So, they are also some GNSS applications are there or being developed; lots of new applications are being developed. We are going to discuss in these two lectures the applications which have already been established or are being used. But there are many future applications which are being developed which will be coming also in future. And also we know that the purpose of all these receivers which are built specifically having applications in mind that is initially basically the navigations. And many of such inbuilt navigation systems have already been incorporated in car navigation and etcetera. This is mainly in civilian domain, in military domain of course, there are different application some which we know directly and we will be discussing those as well.

So, initial objectives as we know that the first few GNSS systems like GPS and GLONASS, one from USA and other one from USSR; they were mainly developed for primitive purposes but later on the signals were made available to civilians. So, now different types of services are there for military and civilians.

The other GNSS systems also developed initially for military purposes but when countries realize that there are commercial applications or commercial viability of that one or sustainability of such systems or further development so, the signals are being also provided to civilian domain. So, as you know that most of the signals may not be very precise one but there are because different services are there but the all these signals are freely available from these GNSS constellations.

And in recent years, the receivers have also become very affordable. We know that even GNSS receivers are coming with the not very expensive, a smart mobiles as well. And this technology has pervasive use in civil, industrial, scientific, military and many other applications like games and other things also. So in sports also, it is being used.

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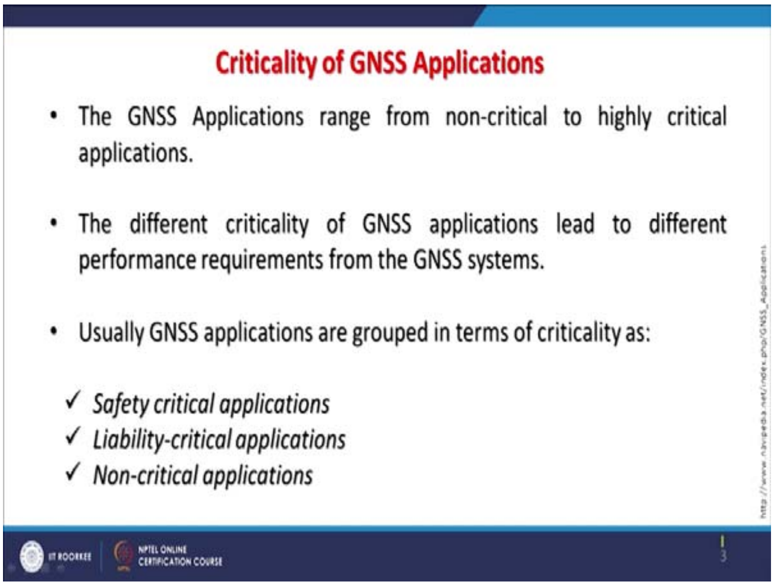

Which are the critical GNSS applications this, now we will be starts seeing but before that there are GNSS applications which range from non-critical to highly critical applications where the system would like to highly reliable on this GNSS applications or this GNSS signals.

So, different critically GNSS applications are there which lead to different performance requirements from the GNSS system. Once we apply these GNSS signals for some critical applications then the reliability or the performance requirements expectations are very high. And definitely because once the system has been put their which has to rely on these signals then everything should work properly. And these are GNSS application, we can group in terms of criticality as safety critical applications and liability critical applications and third one is the non-critical applications. So, we can categorize in these three groups.

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And we will be also seeing that basically for LBS which is Location Based Services are there and these services includes applications that depends on user location to provide service information that is relevant to the user at that particular location where user is situated or standing. This location based services use mobile devices which is very common nowadays with positioning ability to provide the service or information to the user. Like we use the GNSS signals and in the background, we are having a map or a satellite image like Google map and then we navigate using these signals also. But our movement or our services may not be that critical as may be for some construction purpose or maybe for military purposes.

So, there are different types of location based services are there like location based information streams which are required for certain applications, Tourist information that is another very common application of GNSS signals or constellations. And nowadays also, it is being used to manage the fleets by the owners for taxi operators and so on, so for transport on demand etcetera. Transport on demand like these taxi companies OLA and UBER and there are many companies (Refer Time: 07:24) and other things in other countries, they are extensively using not only the GNSS signals along with the GPS and other communication techniques which have been integrated to few applications and then their use have become a very friendly and very extensive also.

And, because of such location based services in transport sector, many times we feel that this taxi services have also become cheaper because they are optimally utilizing all the resources to run these fleets.

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In civilian domain of applications that one of the most uses of GNSS systems with different types of civilian applications are there; like in personal applications which we used for our navigation and other things, road applications are there, aviation applications are there, rail applications; in the rail transport also, they are implying like in India. We know that slowly all engines of Indian railways are being installed with GNSS devices. So, they can transmit their location to a Control Centre so that everyone can know in future hopefully that where that particular train or that engine is standing.

So, this is another application in that one. In road applications, there are two ways it is being used; one for the navigation, another one is sharing the location information. So, in that way if two people are connected to each other then they can share their locations to each other, they can decide for how many hours or minutes they would like to share their location with each other and this is how one can get updated information about a particular person. All this is coming through mobile technology and Google map.

And of course, in maritime applications where in water navigation and other GNSS signals are extensively being used. And also in industry applications like if there are from one point to another point, a fixed transportation is required then vehicles can be programmed accordingly and maybe for large construction industries, GNSS applications are being developed so that many processes can be made automated.

This list is not exhaustive so, there can be a few more applications which has not been listed here but are being developed, they are becoming prudent and few more will come in future in this list. We also used in scientific domain if we talk about that then we also use GNSS signals in surveying and mapping and of course, in GIS also.

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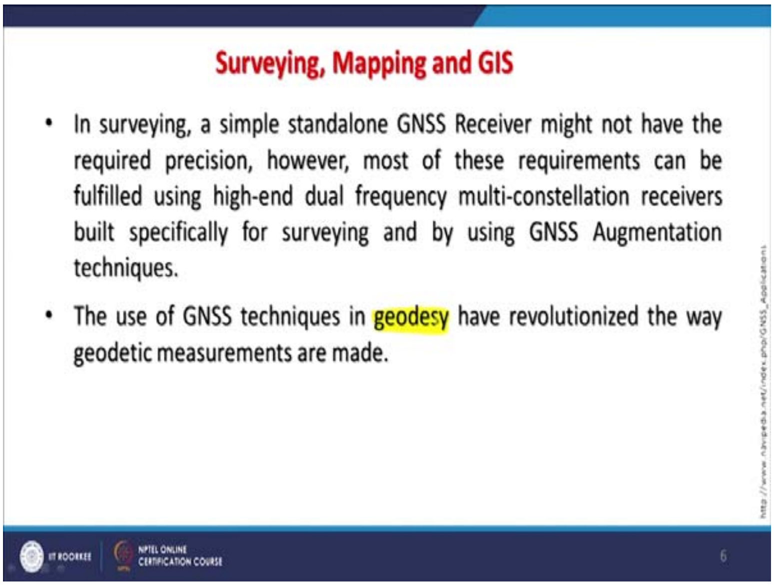

As you know that in serving, you required very precise locations for mapping certain facilities or features, whether it is a topographic surveying or just surveying in urban areas. So, a simple standalone GNSS receiver may not be sufficient to achieve that kind of accuracy which is required for particular kind of surveying.

But surveying like in geological mapping at say 50000 scales, a standalone GNSS receiver might be sufficient which may provide accuracy of 3 to 5 meter. But if one has to go for mapping kind of applications then we require more precise location information and therefore, a standalone GNSS receiver might not be sufficient. So for such requirements, one can go for very high and dual frequency multi constellation receivers or maybe for DGNSS or RTK or some other services which are there like a Satellite Based Augmentation techniques and other. But it depends on what is the precision required. If it is millimetre accuracy is required then there are solutions, if metre accuracy is required then there are solutions. So, all kind of options are available in case of surveying and mapping and of course, in GIS.

One of the very good applications which have been developed which we will be discussing in detail in this lecture is in the application in the Geodesy where crustal deformation studies. The GNSS have been employed; very precise locations are required and differential GNSS have been or RTK techniques have been employed there and by which we have been able to estimate that in which direction, these different plates of earth are moving and what is the velocity and other things so, that discussion will follow soon.

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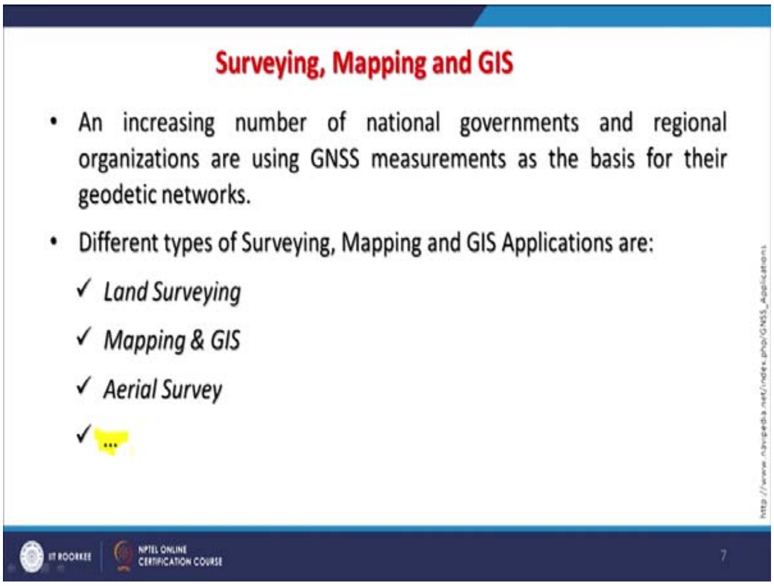

So, we continue on this surveying that increasing number of national governments and regional organizations are now have started using GNSS measurements on the basis of their geodetic networks. You might also know that like you in the sensors department, they too have started in recent years using these GNSS receivers to put a location and then attribute information about associated with that particular location. So, that the database becomes highly reliable, accurate and can be used for various purposes because once a location is attached and that can we attach through these GNSS receivers, then that information really becomes very useful which can be analyzed on a GIS platform and lot of new products can be generated which are being done also.

As mentioned that for different types of surveying, mapping and GIS applications, GNSS receivers are being used like for land surveying, mapping and GIS, aerial survey is also and again this list is not exhaustive. So, lots of applications are also being developed apart from that geodesy which we will discuss in detail.

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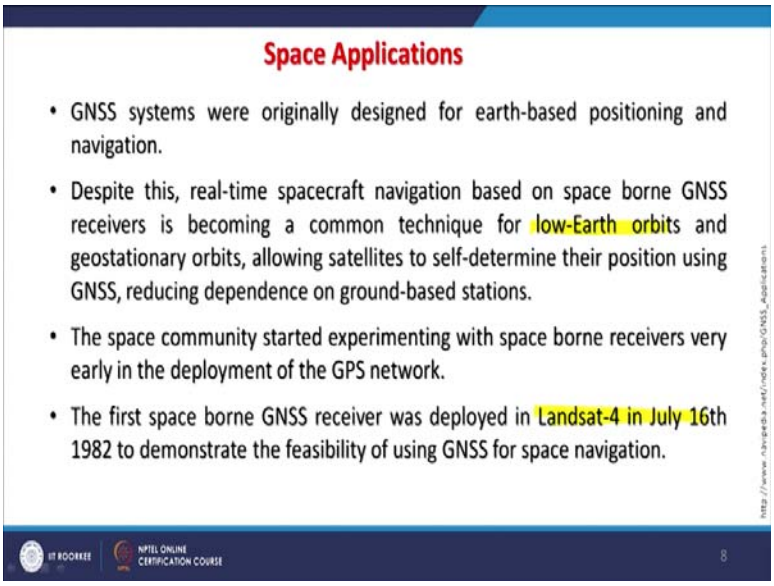

So, GNSS systems are originally as you know, were designed for earth base positioning and navigation. And though that was the main purpose but spacecraft navigation also; they are also using space borne GNSS receivers and which has become a very common way of getting locations. And also using Low Earth Orbits and geostationary orbits satellites of different constellations which allowing satellites to self-determine their position using GNSS.

So, the entire GNSS concept is based on satellites but the other satellites can use these constellations to determine their own position which are not meant mainly for a GNSS constellation but for other purpose; maybe for communication or maybe for spying or you know Low Earth Orbit for high resolution satellite data acquisition and so on. So, for their position determination, the GNSS signals can also be used by satellites, though GNSS itself is a satellite based navigation system.

And if such satellites starts using GNSS signals then their dependency on Ground Stations reduces vary significantly. And of course, the accuracy of their designed orbits; how they have to move and to their designed orbits that can be assessed and they can be put almost automatically in their designed orbit. So, that is a new applications that satellite themselves are using GNSS constellations of a different navigation systems for their own positioning.

And space community started experimenting the space borne receivers very early in the deployment of GPS network and this was done very early when the Landsat - 4 was launched in 1982. At that time, it was tested whether such systems can work in future or not. So, when we discuss the history of development of GPS or overall GNSS, we also touched about that. That first time in 1982, for demonstration and to assess the feasibility of such GNSS systems; at that time only the GPS was there for navigation. This sensor or these facilities was added in Landsat - 4 satellite which was launched (Refer Time: 16:56).

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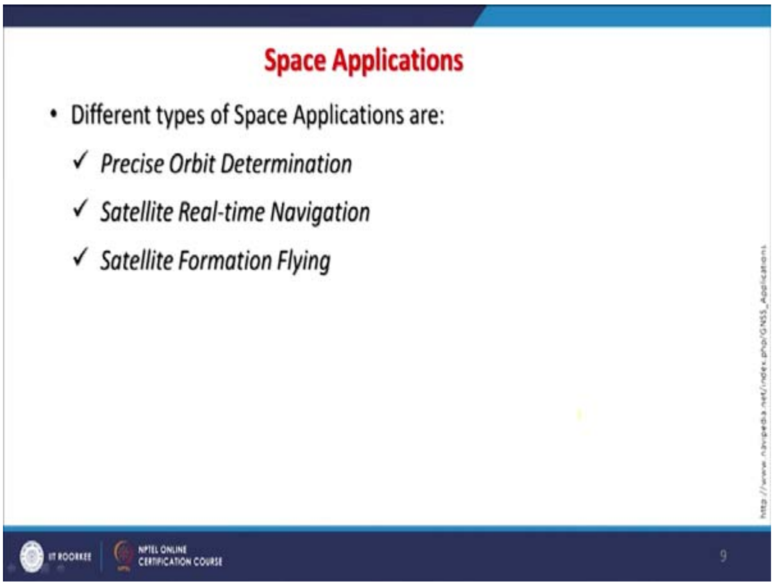

There are different types of space applications like Precise Orbit Determination that is one of the main requirements in space based applications that whether the satellite is orbiting in that designed orbit or not. If not, then how it can be brought back into the precise orbit and Satellite Real-Time Navigation also it can be used, Satellite Formation Flying also it can be used.

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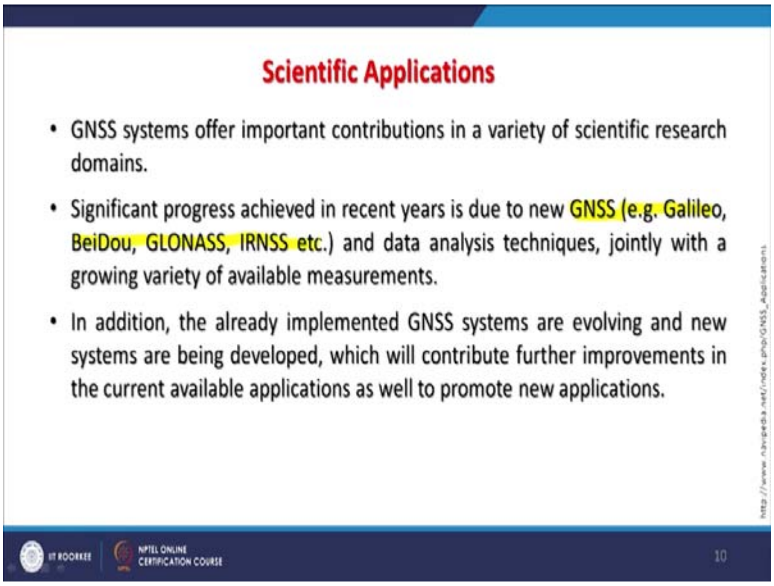

There are various scientific applications which we will be discussing in brief here that for important contributions in a variety of scientific research domains and in recent year's significant progress has been achieved to use new GNSS constellations like GALILEO, BeiDuo, GLONASS, IRNSS or Navic.

And analyze the data available, jointly with a growing variety of available measurements. And additionally, these already implemented GNSS systems are evolving and new systems are being developed. And of course, our position is getting improved; the position information that is mainly XY is getting improved, signals are available in all parts of the world from multiple constellations.

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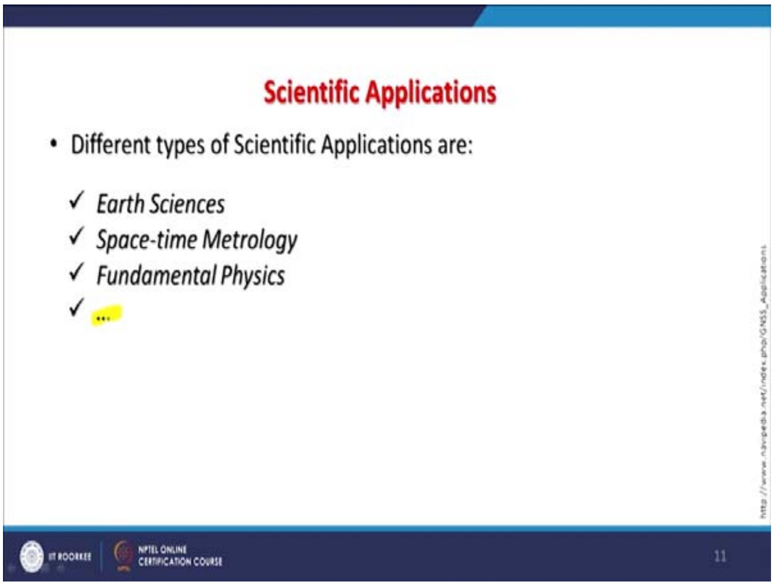

In other scientific applications like in earth science; there is lot of applications of GNSS apart from geological mapping and crustal deformation studies, in mining operations, and many other exploration work where lot of field service are required, these GNSS receivers are being used extensively. A space-time metrology also in a scientific domain that is being used, in fundamental physics also it is being used to you know study the delays in the ionosphere and troposphere and what is the behavior of these waves in these layers of the atmosphere and there it is being used. And as it is shown through 3 dots that again, this list is not exhaustive; there are many other applications which are under development and soon they will be come in this list also.

And in particularly in earth science is because I come from earth science domain. So, I am going to discuss in little bit about that part that in where in earth science it is being used.

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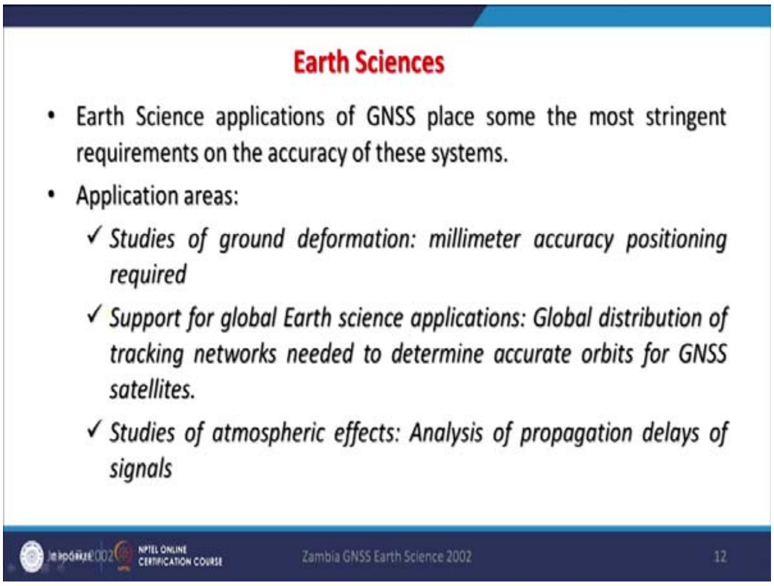

So, as mentioned that this GNSS applications are being used in ground deformation studies and that is where millimetre accuracy positioning is required. And so, highly accurate GNSS receivers are used whether through DGNSS or RTK or SBAS. And there are lots of global distributions of these networks, which are being employed to study these moments of the different plates of the earth including Indian plate.

And this studies of atmospheric effects that I have already mentioned that is sort of not only part of physics but in earth science is also, in the atmospheric science, you can add which is an earth system science. That is how the propagation of these delays through different atmospheric layers; troposphere, ionosphere layer, what is the behavior and delays, these are also being study. Also indicated earlier that such delays are being what the perturbences which occur before an large earthquake event are also being studies through these accurate or DGNSS systems in different parts of the world.

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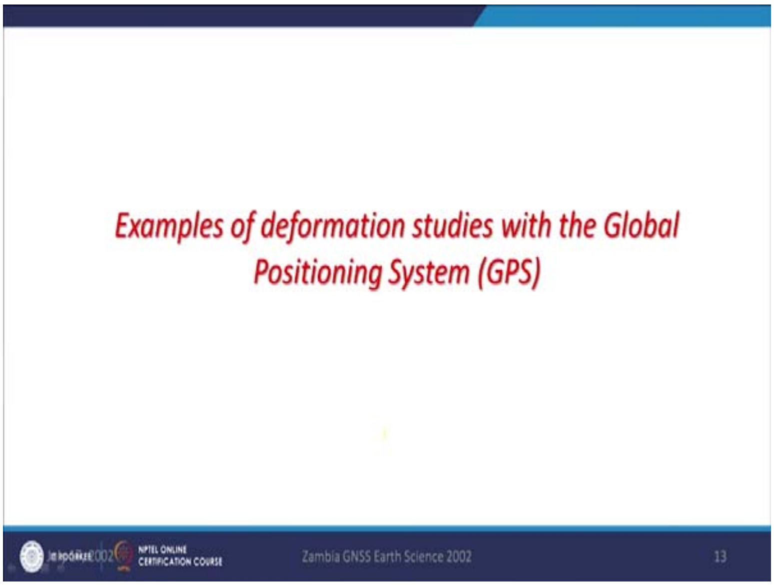

So, one of the examples which I am going to take from earth sciences field which is very-2 popular in that sense and many people understand.

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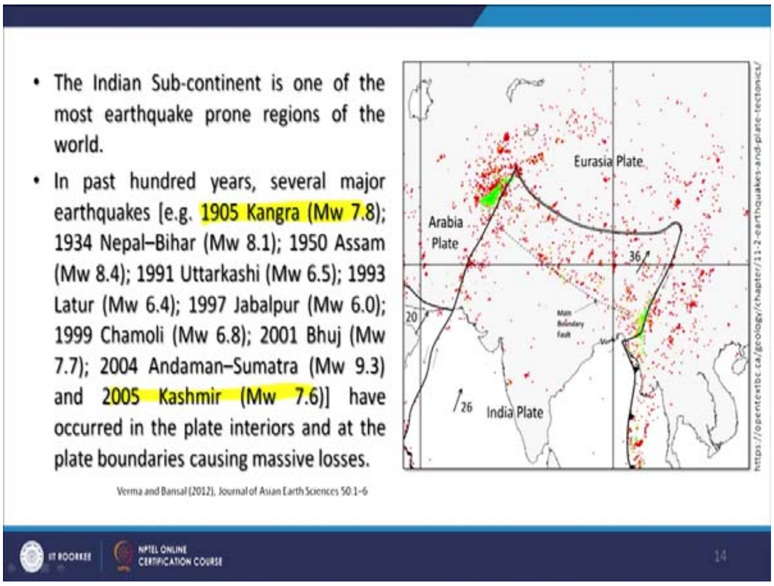

So, in deformation studies, it is being used that as we know that Indian subcontinent is one of the most earthquake prone regions of the world as we can see that all along the Himalayan belt and some other parts in north eastern and western part, we are having occurrences of lot of earthquakes in past 100 years. There is a list says that you know that if we look the past 100 years or so, that we are having a Kangra earthquake of 7.8 and a big earthquake which came in POK 7.6 in 2005 and of course, 2015 earthquakes of Nepal which also part of this Himalayan or Indian plate.

So, it’s seismically very active regions of the world and therefore, it is important to understand that how Indian plate is moving in which direction and where the stresses are being developed, whether they can cause or can bring some earthquake and for that purpose, people are employing these DGNSS systems to study these things that we will see soon.

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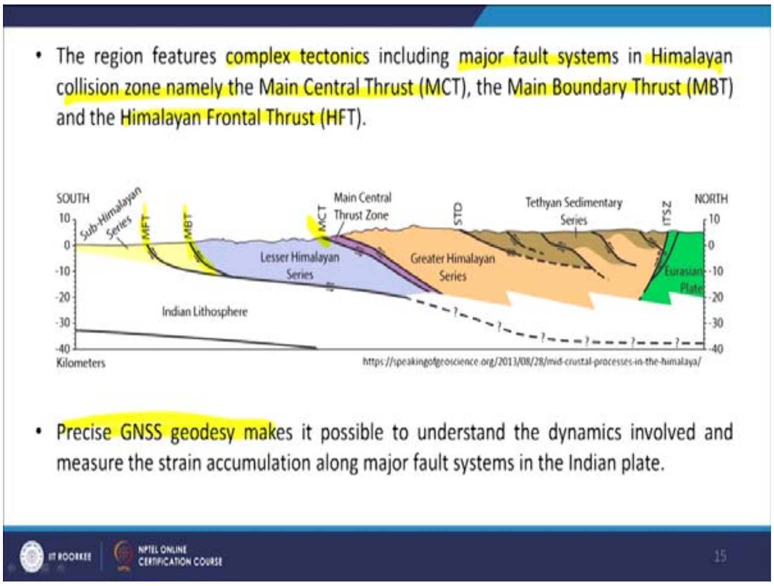

Because it is a highly complex tectonics of Indian plate especially the Himalayan part, large major fault systems are there in Himalayan collision zone and these faults are like Main Central Thrust, Main Boundary Thrust and Himalayan Frontal Thrust.

So, if we go from South to North in the deeper Himalaya, then first we encounter the Himalayan Frontal Thrust, then we encounter the Himalayan MBT Boundary Thrust and then Central Thrust. So, in that way as you can also see in this geological cross section that Himalayan Frontal Thrust or Main Frontal Thrust is here and after this Indo-Gangetic plain, and then MBT is there, then MCT is there and then Indo-Suture zone is also there. So, that is part of a greater Himalaya and Tibet region.

So, as you know that along these faults, the movements occur and whenever there are some moments, earthquake are there. So, precise GNSS geodesy makes it possible to understand the dynamics involved and measure the strain accumulation along major faults systems in Indian plate. That is the main purpose of this GNSS geodesy which has been employed in recent years and lots of such stations have been established all over the India.

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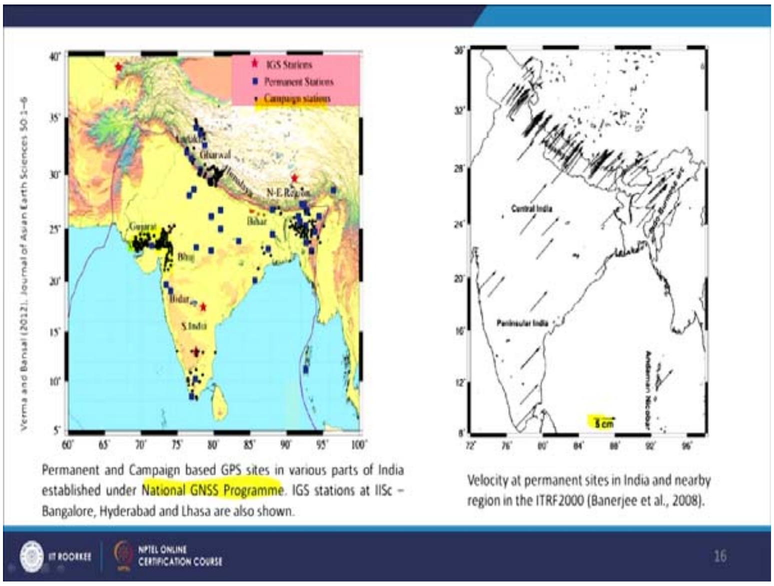

And these triangulation methods along with these observations are being used. So, as you can see that there are various permanent stations spread all over the India. There is a large concentration of these permanent stations in parts of North-East because North-East is seismically very active region as per the seismological map of India. It falls in zone 5, large part of Himalaya also falls in zone 5 and also in Gujarat. And therefore, these monitoring of such zones is very much required and more permanent stations are concentrated there.

And there are several campaign mode stations which have been also shown here. So, under this national GNSS program, this is being done under the ministry of earth sciences. So, by this, so far what we understand that Indian plate is one of the 8 major plates of the world or earth. It is moving towards roughly in the North-East direction with a velocity of about 5 centimetres per year. And where strains are being developed and how they can bring earthquakes and other things, that is a different subject all together. But the main input in such studies is going through these GNSS observations which is being done regularly through these permanent stations and campaign stations as well.

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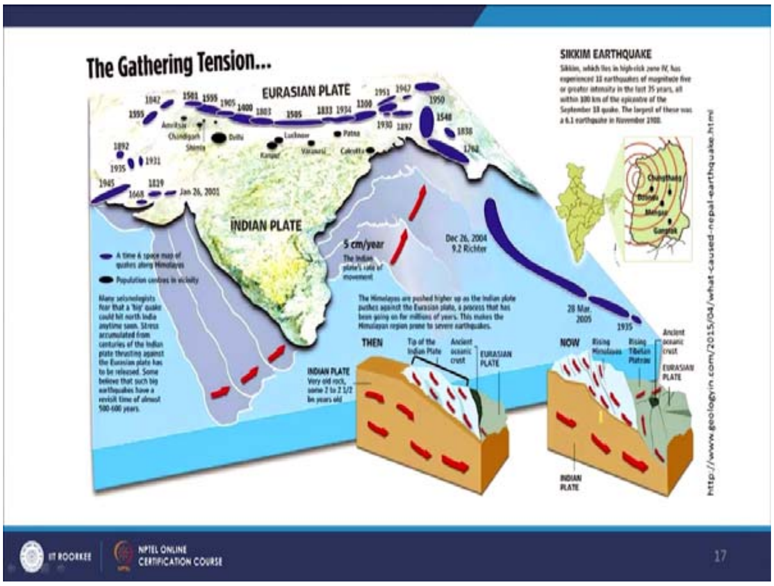

As you know that the tensions are gathering this means by strains are getting accumulated all along these fault lines and whenever there is a rupture and when there is a break, the earthquake occurs and this is what it is shown here in the last; this is the one example of Sikkim earthquake is also shown.

And as we know that recent years, Nepal earthquake has also occur and these are showing that time and space of earthquake along Himalayas. So, there is more a sort of you can roughly say that the more strains are getting accumulated and there are more chances of earthquakes and so on. And what different earthquakes have cause; those things have been indicated in this one. And the velocity of Indian plate is also mention that is roughly about 5 centimetres per year.

Different parts of Indian plate are having some different direction moments and different velocity but overall, the average velocity of Indian plate is towards in the North-East direction roughly and about 5 centimetres per year which is very significant for earthquake related studies. So, this GNSS based geodesy is giving a very significant contribution or input towards seismological studies.

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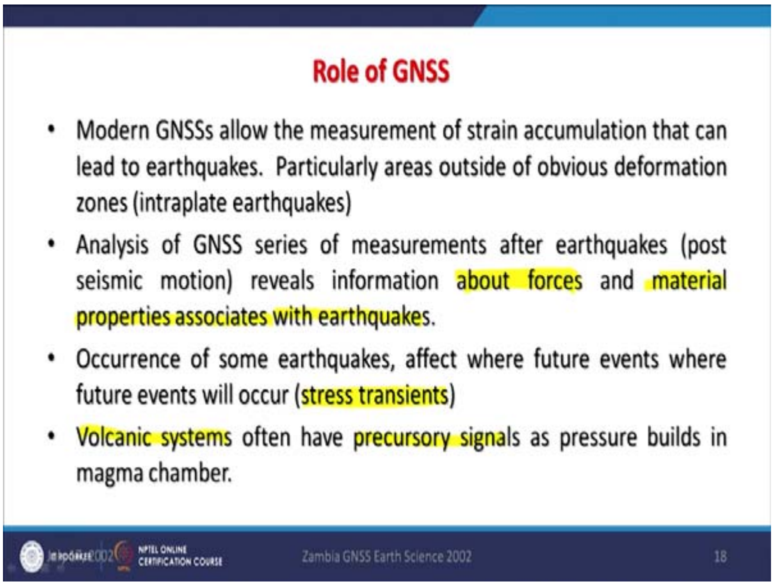

Other roles of GNSS that modern GNSS allows measurement of strain accumulation as just discuss which can lead to the earthquakes, particular areas outside of various deformation zones that is intraplate earthquakes also. And analysis of GNSS series of measurements after earthquakes that is the post seismic motion reveals information about forces and material properties associated with that earthquakes. That means that whenever the large earthquake occurs, scientist also imply; they go in the campaign mode, use the DGNSS systems to understand that where the forces are there and is still continuing and what kind of material properties were associated with those earthquake. So, not only before the earthquake but just after the earthquakes that is post seismic motions are also study during GNSS systems.

And occurrence of some earthquakes effect where future events will occur and that is stress transients also studied. So, one can think is simple measurement through DGNSS; regular measurement, continuous measurements allow to study lot many things about the future earthquake, past earthquake and other things also.

GNSS are also extensively used for to study the volcanic systems especially to understand the precursory signals which might be coming through the volcanoes in future or a sort of dormant volcanoes or maybe active volcanoes. And the pressure builds in the magma chamber when there is a build up if the regular monitoring through GNSS being done, then sometimes even forecast is also possible and which is being done for many active volcanoes of different parts of the world.

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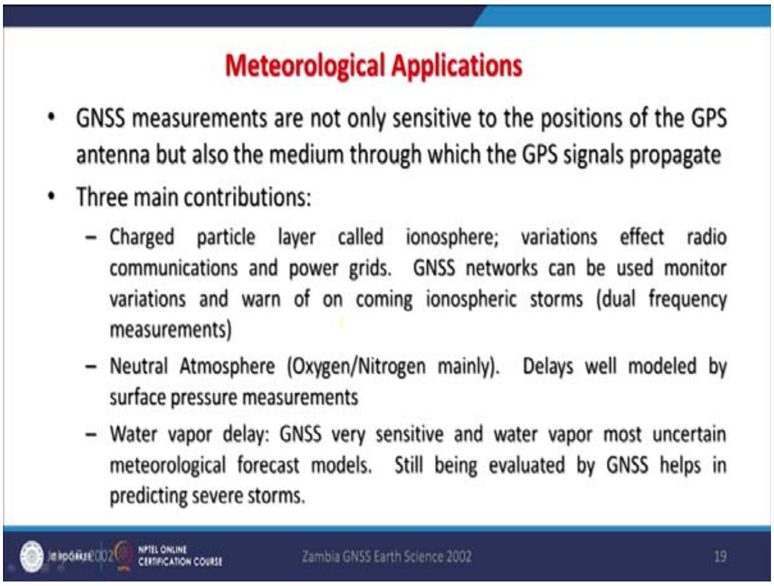

There are meteorological applications and the GNSS measurements are not only for sensitive to positions of GPS antenna but also a medium through which GPS signals or GNSS signals propagates. And we know that there are different layers in the atmosphere which causes delays and by understanding these delays, we can also understand these layers also. So, a kind of inverse studies or inverse modelling is possible which is being done.

And there are three main contributions in meteorological applications of GNSS that is the charged particle layers that is ionosphere, which can be studied where the variations in the radio communications and power grids are there. GNSS networks can be used to monitor variations and warn on the common ionospheric storms for which we require dual frequency measurements.

There is Neutral Atmosphere that is oxygen nitrogen mainly and delays well model by surface pressure measurements. And third one is the water vapor delay; if water vapor is there in the atmosphere then they also causes the delays in GNSS receivers because the signals are very sensitive towards the water vapor. And they bring vapor uncertainty in meteorological forecast model so, for that purpose a GNSS can be implied. To study this and therefore, our meteorological forecast models can be made more accurate and reliable.

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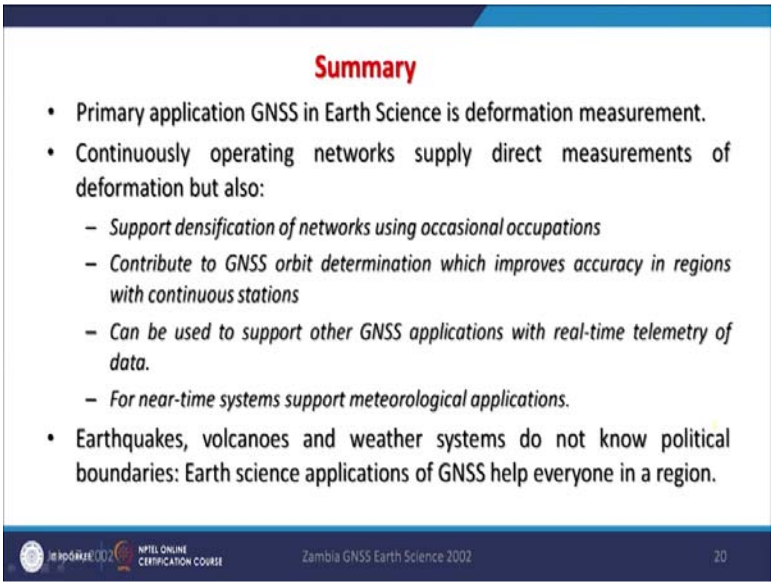

So, in summary what we see that there are primary applications in GNSS in earth sciences that is in deformation measurements, continuous operating networks supply direct measurements of deformation but also support densification of networks using occasional occupations like in posts seismic studies. Contribute to GNSS orbit determination which improves accuracy in region with continuous stations. Can be used to support other GNSS applications with real time telemetry of data that means, that measurements are being done, they are transmitted for some other; for may be a Control Station or some other applications also, so that can be done.

And for near real time system support meteorological applications in which you require very regular monitoring so that can be also done. In earthquakes and volcanoes, weather systems do not know the political boundaries and therefore, the science applications of GNSS can help everyone in a region. So, instead of concentrating mainly in the political boundaries, one can look a system and then can be studied various parameters of these systems in a regional basis can be studies while implying GNSS.

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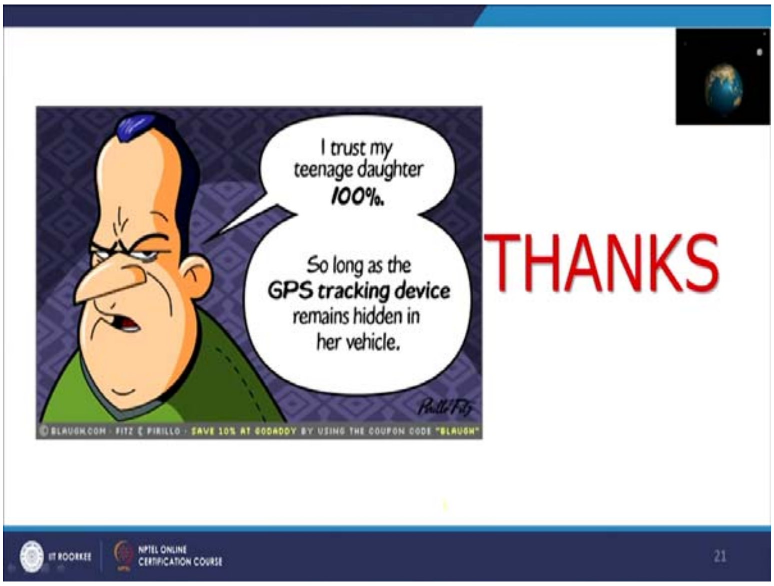

So, this brings to the end of this discussion about the application part 1 and in next lecture, we will be discussing part 2 applications of GNSS. So, as usual again I am leaving with the cartoon for you to smile.

Thank you very much.