Remote Sensing: Principles and Applications
Prof. R. Eswar
Department of Civil Engineering and Interdisciplinary Program in Climate Studies
Indian Institute of Technology Bombay

Lecture-54
Platforms for Remote Sensing Observations-Part-5

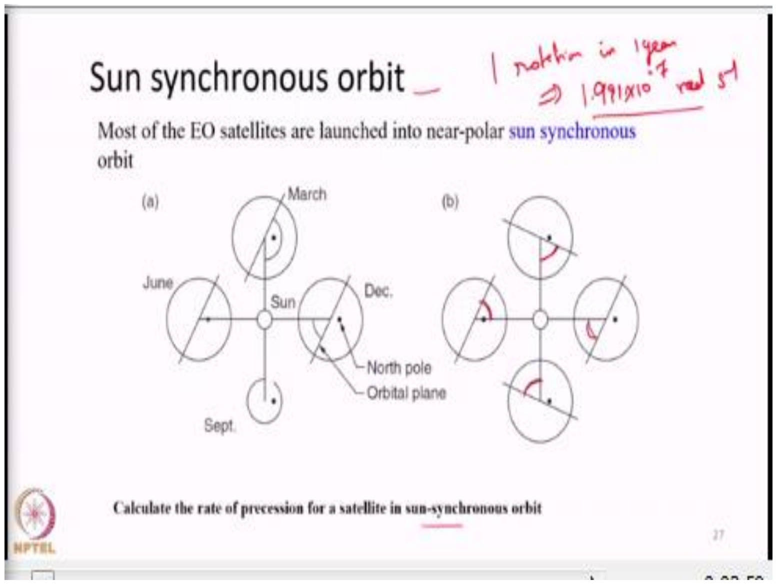
Hello everyone, welcome back to the course. We are discussing about the topic platforms used in remote sensing. And in the last lecture we discussed about near polar orbits in which a special type of orbit called sun synchronous orbit. So, in polar or near polar orbit the satellite will be moving in an orbit that is oriented predominantly in the north-south direction.

So, whenever an orbit is having any inclination other than 0 or exactly 90, the orbit will undergo some sort of precession. So, precession means it will rotate around the earth's polar axis, this will happen because of earth's asymmetry. And we take this to our advantage in launching satellites in orbits known as sun synchronous orbits.

Sun synchronous orbits or those orbits in which if a satellite is placed it will come over a same place in a given direction at a same local mean solar time. Also the angle between the line joining earth and the sun and the orbital plane will remain constant throughout the year. So, we are be adjusting the precession such that the orbital plane completes one rotation around itself in one year. So, that it the angle between earth, sun and the orbital plane will be maintained. We will continue in today's lecture about further interesting topics which helps us to do repeated observations and global coverage.

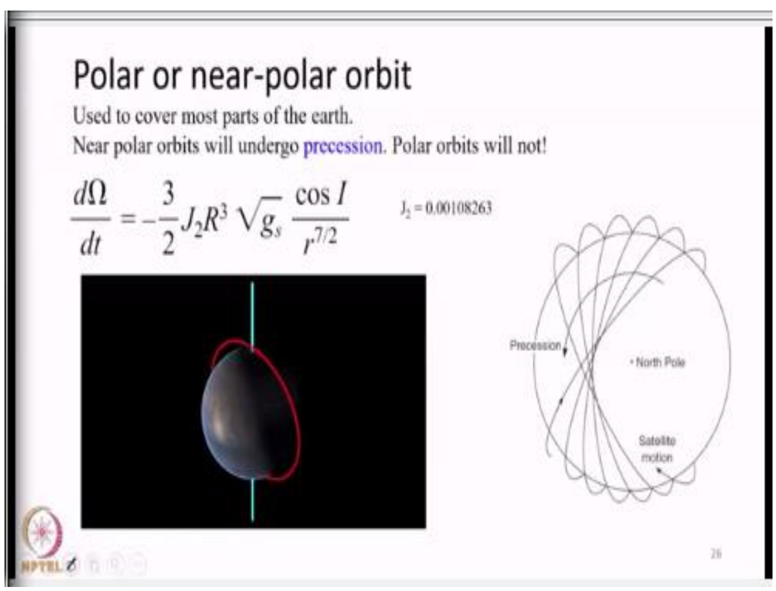
So, the below slide gives you a brief overview of sun synchronous orbits. And as I told you orbits will basically undergo precision and we are taking advantage of this naturally occurring precession and making the orbit to be in sun synchronous. Also like I told you the orbit should complete one rotation around itself in one year which implies the angular velocity at which the orbital plane is precessing will be having a very small value but still having such a value alone will make the orbit precess in a definite rate.

(Refer Slide Time: 02:09)



I actually told you that for a satellite in sun synchronous orbit, the local mean solar time at which the satellite overpasses, will be the same, irrespective of the longitude.

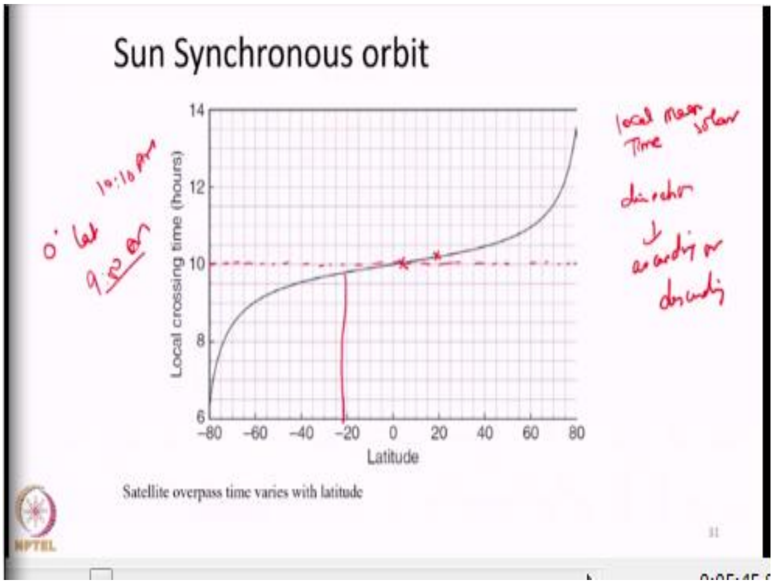
(Refer Slide Time: 02:23)



Just see this particular figure, this tells us for a given latitude and if a satellite is placed in sun synchronous orbit, then the local mean solar time at which the satellite overpasses a particular location and a particular direction whether it is in ascending or descending mode will be the same.

So, here we have given an example of a satellite crossing the equator in descending mode at 10 AM every day.

(Refer Slide Time: 03:29)

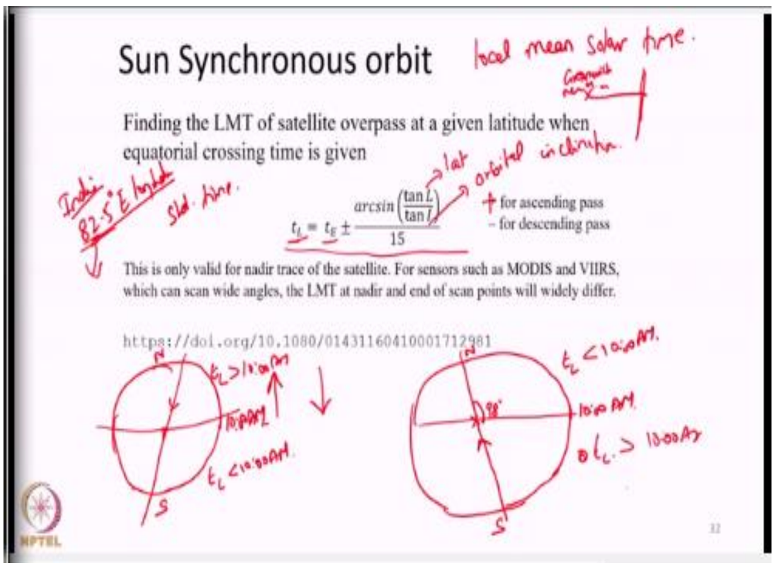


So, I am just drawing this line, so this tells us a particular satellite will cross 0 degree latitude every day at 10 AM, it is irrespective of longitude. Say 0 degree latitude means the equator surrounding the earth. So, whenever the satellite crosses the equator it will cross the equator from north to south in descending orbit. Whenever it crosses the local mean solar time at the place at 0 degree equator will be 10 AM. The time period can be adjusted for different satellites, but just as an example I am telling if a satellite over passes at 10 AM what will happen? Now this overpass time, normally called as equatorial overpass time will vary with latitude. Say for example this satellite will overpass the equator at 10 AM but any other latitudes at higher than 0 degrees let us say 20 degree north latitude.

The time at which it will overpass will be slightly more than that, that is maybe it will take 10:10 AM. On the other hand if it is 20 degree south latitude, then the time period may be around say 9:50 AM at that particular location. So, this suggests the time period at which the satellite will overpass will vary with latitude but at the same time it will be more or less constant.

So, normally if a satellite is launched in near polar sun synchronous orbits, in the orbital parameters you will find a variable called equatorial overpass time where the satellite team will mention at what time the satellite will overpass the equator in which direction in ascending mode or in descending mode. Using that information and assuming a circular orbit unlike a spherical earth, we will be able to calculate at what time the satellite will overpass in a given latitude. Not all places on earth are in equator, at each and every place on the earth the satellite will have one different overpass time which we can calculate knowing this particular equatorial overpass time.

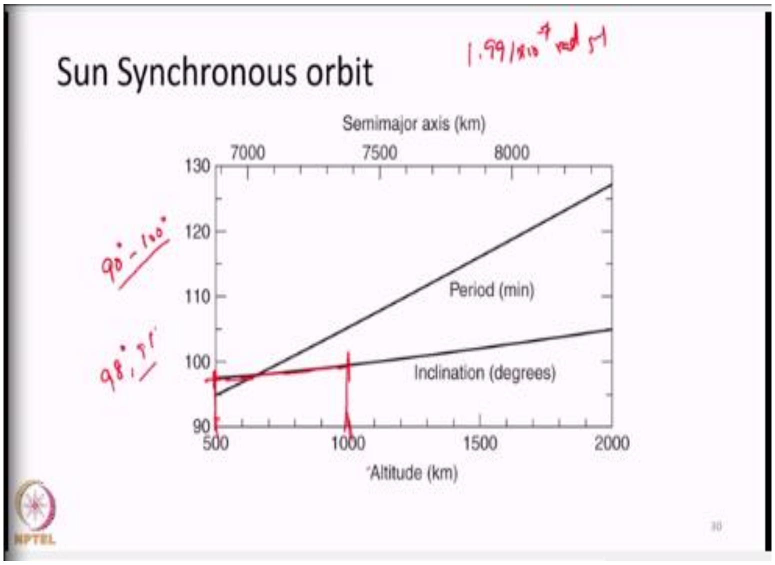
(Refer Slide Time: 06:43)



So, this slide gives a very simple formula for relating the equatorial overpass time with the time at any other latitude. Say it is a very simple one. L is the latitude of the place, i is the orbital inclination, t_E is the equatorial overpass time and t_L is the any latitude in which we are interested upon. So, in this particular equation we have to use plus sign if the equatorial overpass happens in ascending mode or minus sign if it happens in descending mode.

So, this is a very simple formula that helps us to know how orbits or how satellite will overpass or at what time satellite will overpass over a given location. In order to achieve this sun synchronous orbit, we need to adjust the precession rate. The precession rate should match with the earth's revolution time that is the orbital plane should complete one full rotation around itself in one year. So, that precession rate can be changed by changing the orbital inclination and also the orbital height. By playing with these parameters we can change the precession rate and we will adjust the precession rate such that it matches with earth's revolution speed. So, typically for earth observation satellites, we will launch remote sensing satellites normally in the range of 500 kilometers to 1000 kilometers altitude above the earth surface.

(Refer Slide Time: 08:28)



So, just see in this particular figure. So, the normal altitude will be 500 kilometers to 1000 kilometers. For that particular altitude in order to achieve the precession rate that is required that 1.991×10^{-7} radians/second. In order to achieve this precision rate, there is a definite set of inclination that we should achieve in the orbit. So, the inclination should be between say 90 degrees to 100 degrees range, for most of the satellites it will be around say 98 degrees, 99 degrees and so on.

So, if the orbital height is between 500 to 1000 kilometers above the earth surface, then the inclination has to range between these 90 to 100 degrees in order to achieve sun synchronous orbit. Then only the orbital plane will precess with the definite rate at which we will match it with the earth's revolution. This signifies all sun synchronous orbits are near polar orbits, it cannot be polar, it can only be near polar, the inclination will always be greater than 90, 90 to 100 degrees for most of the earth remote sensing applications.

And also the satellite motion will be in retrograde direction, that is orbit will be like this, earth will be moving like this**.** So the satellite will be moving in a net direction opposite to that of earth. If earth is rotating from west to east, the satellite will appear to move from east to west in a retrograde direction, then only this orbital precession will be achieved**.**

But orbital plane itself will rotate in the same direction as that of earth, like the plane in which the satellite is rotating that itself will rotate in the same direction as that of earth. But the direction in which the satellite is moving will be in a direction opposite to that of earth. So, this is what we have to keep in mind when we learn about satellites that are in sun synchronous orbit, all these things should be in our mind when we look at those satellite data and use it in our analysis.

Coming back to this particular equation, like the equation which relates the equatorial overpass time with the time taken at any latitude. Let us say this is the orbit, I told you now the orbital inclination always has to be more than 90. Let us say this is now 98 degrees and satellite is moving in ascending mode. So, this is the normal convention for satellites in polar or near polar orbits, the inclination of the orbital plane will always be measured when the satellite is in ascending mode or in the ascending mode of its overpass, that is the convention we follow, so that is why I am marking it like this. So, here the orbital inclination is given like this, now let us see how this particular time period will vary.

So, satellite is moving in this direction from south to north. Let us say the equatorial overpass time here is for example again 10 AM. So, on all the places in southern hemisphere the overpass time will be greater than 10 AM maybe 10:5, 10:10 and so on. Whereas on the other hand for places in the northern hemisphere the time of overpass will be less than 10 AM. So, this is the case if the satellite is in ascending mode sun synchronous orbit.

Let us consider about the descending mode. For satellite in descending mode orbit has to be drawn like this, north, south, this is the equatorial overpass time. Again let us take the same example of 10 AM. If the satellite is in descending mode then the overpass time for the places in northern hemisphere will be greater than 10 AM, and the overpass time for the places in southern hemisphere will be less than 10 AM.

So, based on this general overpass time or this general equation we can calculate at what time the satellite will overpass our given latitude at which we are interested upon. This will not change with longitude like whatever be the different, different longitudes it will be constant; the time will vary only based on a given latitude. So, for all the places present in a same latitude the overpass time will be the same, that is the characteristics of sun synchronous orbit.

But please remember one thing, the time here we are talking about is mean solar time that is normally taken from the Greenwich meridian. So, we will measure it based on the longitude of the place in which we are located. So, roughly say India has a standard longitude, let us take an example of 82.5 degree east longitude. So, this is the standard longitude for India, so the time in our watches normally will represent the time taken at this particular longitude, as this is the standard longitude for Indian country, but the time what we are talking here is the local mean solar time. That is we have to calculate or we need to know the longitude of our place and for that particular longitude what is the difference in time between the Greenwich meridian and our place**.** Normally 1 degree of longitude from Greenwich meridian will increment the time by 4 minutes, that is the idea.

That is if time is say midnight 12 o'clock in Greenwich meridian at 1 degree east longitude the time will be on 12 hours or 00 hours 4 minutes. At 2 degree east longitude it will be 00 hours 8 minutes and so on. So, that is the general, based on the average rotation speed of earth around the sun. So, this is local mean solar time, we have to calculate it at all the longitudes on which we are located upon**.**

We should not be seeing just the time in our watch; the time in our watch will give us the standard time that is based on the standard meridian for each country. For example as I already told you the standard meridian for India is 82.5 degree east. But when we want to calculate the time in which satellite will overpass, first what we should do is. We should first know the equatorial overpass time, from the equatorial overpass time we should adjust it to our latitude in which we are located or which we are interested upon.

Let us say we are in India, and I am interested in knowing the overpass time of a satellite in longitude around 75 degrees, not in 82.5 degrees. So, the standard time which is shown in my watch I should adjust it, I should bring that to this 72 degrees or 75 degrees in which I am interested upon, that time only I should take. So, there is always a slight confusion between standard time and local mean solar time. Here all the time we are talking about is local mean solar time and not the time shown in our watches. The local mean solar time of a particular place should be calculated based on the longitude of the place at what time. Then only we will be able to calculate the exact time in our watch at will the satellite will overpass, we always have to do this kind of minor adjustments.

So, now what we have discussed is maintaining the same overpass time. But, what are the main aims of launching a satellite in sun synchronous orbit? The main aim of launching a sun synchronous orbit is, to get maximum coverage around the earth that is one major goal. That is from geosynchronous orbit we have already seen, we will not be able to get maximum coverage around the earth. Geosynchronous orbit will be seeing only one particular area of the globe. In order to get a global coverage, naturally the satellite should rotate in a near polar orbit or polar orbit, that is one thing. Second thing is periodic observations, that is we will always want the same location on the earth to be imaged under same sensor, object and sun illumination conditions.

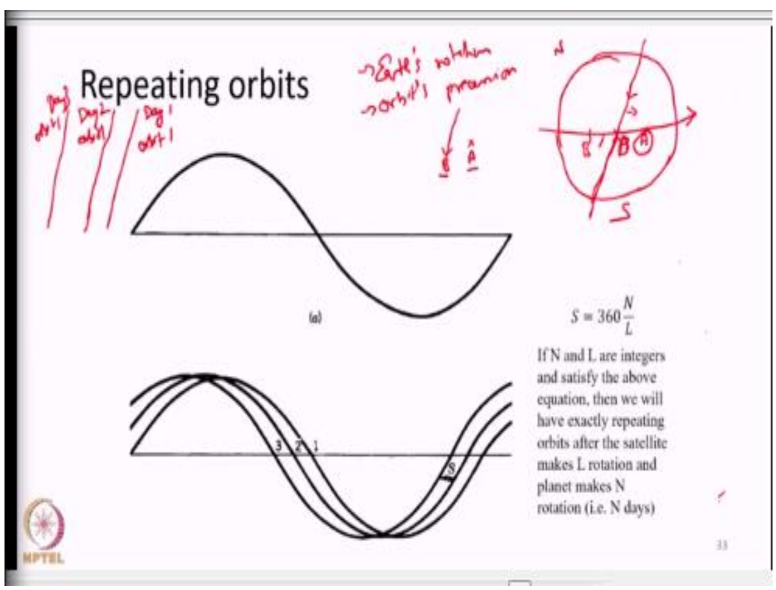
Let us say, satellite is moving in one particular orbit, there is a place underneath it. We will want the place to be imaged with the same orbital parameters, same look angle and everything in a repeated manner maybe once every 2 weeks, once every one month and so on. This is to achieve periodic observations under same conditions, same geometry between satellite, the target. Even the sun synchronous orbit will achieve this more or less like the same conditions of solar illumination, more or less it will vary with season, but we will try to achieve as close as constant solar illumination condition. But this satellite overpass will vary, say for example there is a place here a satellite can see this particular place from nadir or from any other orbit by tilting its camera or by having a very wide scan angle, anything is possible.

Say for example a satellite called MODIS has a very wide scanning angle of around 2300 kilometers. So, same place can be imaged from multiple orbits, when it is directly overhead the place, when it is in an orbit away from it by the scan or when the orbit is placed like here again by the scan. So, by increasing the scan angle also the same place can be image continuously from adjacent orbits that is possible.

But scientists will always aim for achieving repeated orbits after every certain number of days. Repeated orbits means whenever a satellite is moving in the space we can always create a nadir track which we can draw a straight line connecting the satellite and the point on the earth surface. After certain number of days the nadir track should repeat once every 16 days. The satellite should exactly come to the same overhead the same ground point, maybe once every 16 days, once every 24 days and so on. Different, different satellites have different, different characteristic parameter. And as I told you the main aim of doing this is to get repeated observations of the same place with same geometry between the satellite and the point on the earth surface.

So, launching a satellite in sun synchronous orbit will give us a near global coverage more or less. And then it will help us to achieve a higher spatial resolution than what is achieved by geostationary orbit, that is also there definitely because of the lower altitude. Then it will help us to make periodic coverage in a repeated manner of the same place with same geometrical conditions.

(Refer Slide Time: 22:112)



Let us understand how the satellites will trace the ground track. This is equator, the earth is moving in this particular direction north, south, this is the orbit; satellite is in descending mode. Let us say the satellite is starting from here, it is moving in descending mode, it is going to complete one rotation. When it is going to complete one orbit, the earth would have moved a certain distance. Let us say this is point A, where the satellite started.

So, by the time the satellite completes one full orbit the ground point A would have moved certain distance to its east and a new point from west, point B would have come here. So, the ground track of the satellite is changing because of earth's rotation underneath it, orbit is there but due to earth's rotation the ground track will be keep on changing. So, by the time the satellite completes one orbit around the earth, the ground track would have changed. It would have come to a new location, now the satellite will be overhead a place that is west to its starting location. The orbit will precess in this particular direction same that of the earth**.** So, the net effect will be one due to earth rotation and the other due to orbits precession. The satellite will be now in a spot that is normally to the west of it is starting location.

So, between the first orbit and the second orbit, the satellite would have come to the point that is to the west of its starting point. Similarly third orbit, again the new point where it is starting is further west of its second point and so on; it will always be proceeding like this. Not naturally when you look for many satellites in sun synchronous orbits you can sense this particular pattern. Then let us assume it completed one full day normally a satellite will have a 14 to 16 orbits normally per day**.** This will be not an integer, every day the number will be 14 point some orbit, 15 point some orbit, it is not an integer it will vary, it will have like some fraction, I will tell you why later.

So, let us say one full day has elapsed; earth has completed one full rotation. Now normally what will happen is, now the satellite is going to start its first orbit in day 2, the first orbit in day 2 will most likely will not be in the same ground point A. Say same ground point A is where the satellite started its first or between day 1. It made several orbits with different, different starting points for each orbit.

Now when comes the second day, the first orbit will not start with the same ground point A. Normally scientists will not launch a satellite in such an orbit, it is possible to achieve that, but normally they will not do. It will start again at some other point most likely to the west of this starting point**.** So, every day the new starting point or the starting point of the first orbit will always be different than the starting point of the previous day. This will always be proceeding like this to get a global coverage with high spatial resolution and smaller swath width. So, normally for satellites in sun synchronous orbit, the orbits will be designed in such a manner the ground coverage happens like this.

So, after every time the satellite completes one one rotation, it will move to the west and after one full day it starts a new orbit number 1. In day 2 also the starting point will be different than the starting point on the day 1. After certain number of days, say 16 days the satellite will start its first orbit exactly over at the point A, this is what is called repeated orbits. So, again the entire cycle will go on, again after 16 days satellite will come overhead exactly the same point A when it is starting the first orbit in day 1. So, there is a definite number of cycles, say 16 days once, 24 days once, even some satellite has 90 days once when the orbit track will repeat. This kind of orbit is being designed or placed in order to achieve a global coverage.

So, in this lecture we have discussed again about orbital precession. We also discussed about near polar sun synchronous orbits, the inclination angles. We have discussed about the overpass time conditions at different, different latitude and so on. In the next lecture, we will continue with this topic and finish this particular topic.

Thank you very much.