Remote Sensing: Principles and Applications

Prof. R. Eswar
Department of Civil Engineering and Interdisciplinary Program in Climate Studies
Indian Institute of Technology Bombay

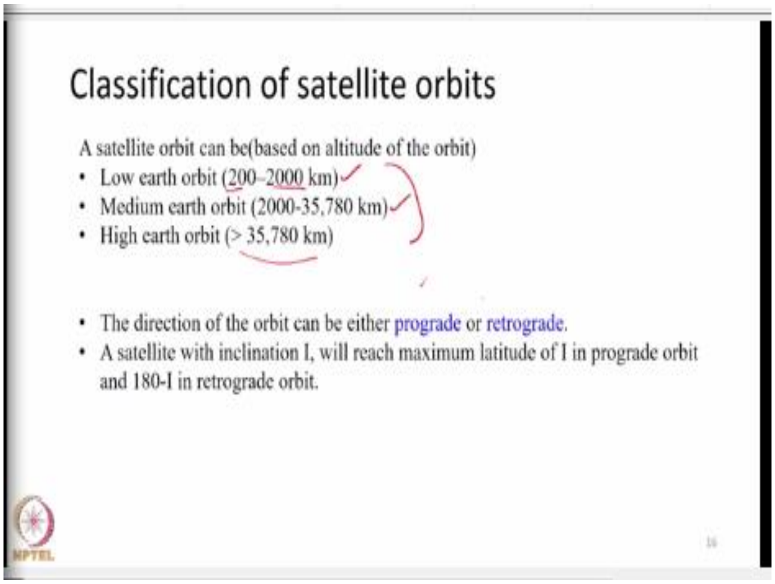
Lecture-52
Platforms for Remote Sensing Observations-Part-3

Hello everyone, welcome to the next lecture in the course remote sensing principles and applications. We started discussing about the various remote sensing platforms from which we can observe the earth surface. We discussed about ground based platforms, aerial platforms and space-borne platforms that are satellites. And today in this lecture we are going to continue with that particular topic.

In the last lecture, I told you about satellites, how to calculate or what is the relationship between the orbital height, the velocity with which the satellite revolves around the earth surface and the time period taken for the satellite to complete one orbit around the earth surface. We assume orbit as circular while calculating all these things. And for all practical applications, we can consider the orbits of remote sensing satellites as circular. They are not exactly circular but we can treat them as so. Some minor differences may come between what we calculate and the actual values. And also in the last lecture we got introduced to the concept of inclination of the orbital plane. We call the plane in which the satellite revolves as orbital plane and the inclination of that particular plane with respect to earth's equator as inclination of the orbital plane. And one more concept is orbital longitude or more precisely the right ascension of the ascending node.

So, with this background we will just look deep into the different kinds of orbits available for satellites. So, based on the altitude of the satellite above which it is revolving around the earth surface, we can classify the satellite orbits into three. One is low earth orbit, where the height of the satellite will be something around 200 to 2000 kms over that surface. Then comes medium earth orbit, 2000 to 35,000 kms and a high earth orbit above a threshold of 35,700 kms or roughly 35,800 kms. So, this is based on the orbital height, above the earth surface. Most of the remote sensing platforms or remote sensing satellites will orbit in the low earth orbit, roughly in the range of say less than 700 or 800 kilometers.

(Refer Slide Time: 02:04)



There are certain platforms which are available at high earth orbit around 36000 kilometers, it is called geostationary orbits which we will see later. Similarly based on the direction, we can classify whether the satellite is moving in a prograde direction or retrograde direction. That is earth is rotating in one particular direction, if the satellite also revolves around earth in the same direction we call the orbit as pro grade. If the satellite revolves in opposite direction to the earth's rotation, we call it retrograde**.** So, these 2 are technical terms which we should remember. And based on the orbital inclination there will be a change in coverage of the earth surface.

If a satellite is having an inclination of i degrees and if the satellite is in pro grade orbit then the satellite will cover latitudes between i degree north to i degree south. That is, let us say a satellite in an orbit which is inclined at 55 degrees with respect to equator in prograde**.** Then that particular satellite will cover 55 degrees north to 55 degrees south latitude, it will not cover the entire globe.

The satellite will be able to cover places occurring within this particular band 55 degree north to 50 degree south. On the other hand, if the satellite is in retrograde orbit with a given inclination of i, then the latitudinal coverage will be 180 - i. Let us say some satellites or most of the remote sensing satellites will be in the range of say 98 degrees inclination and it will be retrograde orbit**.** So, with 98 degrees inclination means 180 - 98 will give us 82 degrees.

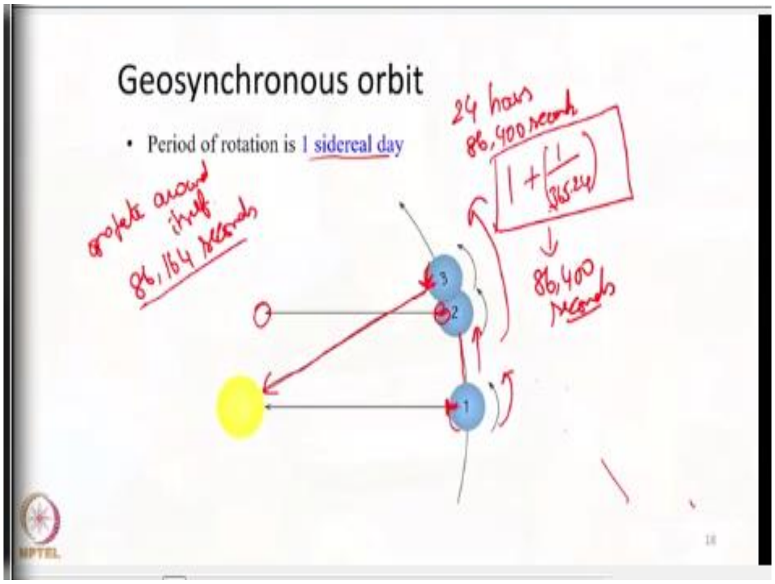
So, those satellites will cover earth surface between 82 degrees north to 82 degrees south, so that is how the coverage will be. So, with respect to direction as well as the inclination the coverage of satellites will vary.

(Refer Slide Time: 05:19)

First we will start discussing about the high earth orbits. One of the major or primarily used high earth orbit is geosynchronous orbit. In addition to geosynchronous orbit we also have what are known as Lagrange points in which satellite can be positioned to observe earth surface, there is actually a satellite which is looking at earth surface from one of the Lagrange points, we will see it in the forthcoming slides.

What exactly is a geosynchronous orbit? A geosynchronous orbit is an orbit in which if a satellite is placed, it will have a orbital period equal to one sidereal day. That is, earth is here let us assume the satellite is here i = 0, let us assume, inclination is 0, it is placed on the equator. If the satellite moves with the same speed as that of earth. Then by the time earth completes one rotation around itself, the satellite will complete one full revolution around the earth and come at the same point. Such satellites are called to be placed in geosynchronous orbits. So, in geosynchronous orbit the time period of one orbit or the orbital period for one revolution of satellite is equal to the time taken for earth to complete one full rotation around itself.

(Refer Slide Time: 06:59)



What exactly sidereal day? Normally we learned that earth takes 24 hours to complete one rotation around the sun. But the actual time taken for the earth to complete one full rotation is actually less than that, why is it happening? Let us see with a small illustration. So, let us say this is earth, let us assume this is the reference point I am taking on the earth surface. Now this reference point is seeing the sun center, now the earth is rotating around itself. At the same time the earth is revolving around the sun in an elliptical orbit, so the earth is simultaneously rotating around itself and also revolving around the sun. But due to earth's motion or earth's revolution around the sun the earth would have moved away from the sun. So, by the time earth completes one full rotation around itself, it will not be able to see the sun because the earth has moved little bit further in its orbit around the sun. The earth should make more than one full rotation around itself in order to see the sun again. So, this time period taken for earth to complete one full rotation around the sun is 24 hours.

So, from this we can infer that the time taken for earth to complete one full rotation around itself is actually less than the time taken to complete one full rotation with respect to sun. So, this basically happens because earth is not only spinning around its axis, it is also revolving around the sun. By the time earth complete one full rotation around itself due to its forward motion in its orbit. It will not be positioned seeing the sun; it will be positioned further away. So, the earth has to make more than one rotation to complete one full rotation about the sun**.** So, in 86,400 seconds earth will complete one full rotation around itself +1 over 365.24 rotation.

But in order to see the sun it is making a slightly more than one rotation in order to see the sun. And that rotation in a day will be 1 by 365.24 because earth takes 365.24 days to complete one full revolution around the sun. So, in order to make this much rotations earth takes 86,400 seconds, this is what we know. The time taken by earth to complete one rotation around sun, so the actual time taken for earth to rotate around itself is what we call the sidereal day and the time taken will be 86,164 seconds. So, the sidereal day for the earth to rotate around itself is actually less than a mean solar day which is 24 hours**.** So, that is the time taken by earth to complete one rotation around sun. So, the orbital period or the rotation time taken for earth is actually one sidereal day, 86,164 seconds only with respect to itself.

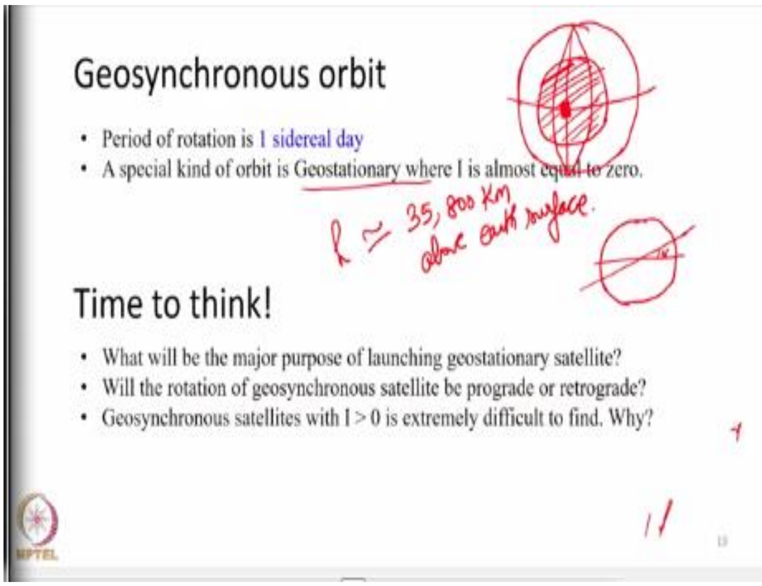
Say for example you can think of a merry-go-round. let us say you are spinning around yourself and also coming in rotation. So, by the time you complete one rotation around yourself you would have moved in the merry-go-round, you will not be able to see the other person. Either you have to tilt your head or go slightly further in order to see the person again. Similar effect, earth is rotating around itself and also it is moving further which is slightly increasing the time taken to complete one rotation around the sun.

So, for geosynchronous satellites, the period of revolution to complete one orbit is one sidereal day 86,164 seconds. By the time let us say earth is here, this is the reference point in earth, here is the satellite. So, the satellite and earth will move synchronously we call it as geosynchronous, geo means earth or related to earth, synchronous means both of them move in tandem.

In this geosynchronous satellite, the satellite revolution speed is synchronized with earth's rotation speed. If the inclination is 0, the satellite is placed exactly over the equator and the direction of motion is prograde. The satellite will appear as if it is constantly overhead over a particular point on the earth surface. Let us say this is one particular city in India, let us say some satellite is positioned over Mumbai.

Mumbai is above 0 degrees north, but let us assume it is placed over a certain location which is at 0 degree equator**.** So, as the earth rotates the speed at which the satellite revolves also will be synchronized. So, the same place in the earth will be seen by the satellite continuously. So, such orbits in which the satellites are placed, they are able to observe the same spot on the earth continuously throughout its lifespan, we call it as geostationary orbit.

(Refer Slide Time: 14:12)



So, a geostationary orbit is a special kind of geosynchronous orbit in which i = 0, means the satellite will be stationed over one particular location on the earth surface. So what will be the major purpose of launching the geostationary satellite? A geostationary satellite should look at the same location again and again. So, the first major purpose for the geostationary satellites were launched was communication. That is in order to achieve global communication through satellites, geostationary satellites were placed in different, different longitudes around the earth**.** So, they will be able to constantly watch over a region throughout its lifespan and relay communication signals. It will not be in a position to see other parts of the globe; it is going to observe only that particular part of the globe.

Such satellites are useful for communication purposes and also lot of weather monitoring satellites are put in geostationary orbits. So, when we want to get data continuously, like there may be a large hurricane going towards a particular country, these weather monitoring satellites may acquire images once every 15 minutes or so. So, for such high temporal resolution imaging people place weather monitoring satellites in geostationary orbits.

So, the major purpose of placing a satellite in geostationary orbit is for weather monitoring applications and also for communication purposes. And nowadays data from weather monitoring satellites are very much useful in remote sensing. India has INSAT-3D meteorological satellites, and KALPANA-1 which are majorly launched for meteorological applications but they also have applications in earth resource like earth surface monitoring for remote sensing.

US has geostationary operational environmental satellite GOES, there are satellite called Meteosat, there are plenty of satellites for remote sensing applications placed in geostationary orbits constantly looking over a particular location on the earth surface. That means it will cover only one region of the globe continuously. Based on the orbital height of the satellite its velocity will vary. So, here we need the velocity of satellite to be synchronized with earth's rotation. So, we can use the earlier equations which we learned in the last lecture using the time period as 86,164 seconds. If you substitute this time period in the equation relating time and velocity as well as the orbital height, we can calculate the height where the satellites have to be placed which is approximately 35,800 kilometers. So such orbits with this much altitude and the satellites having a time period of rotation of one sidereal day is geosynchronous satellites and if $i = 0$ for geosynchronous satellites they are called geostationary.

For geostationary it must be prograde because satellite also rotate in the same direction as of earth, so that it can see the same point. If the orbit is in retrograde then earth will be moving like this, satellite will be moving like this, it will not be seeing the same spot, it will be seeing different, different spots on the earth, normally that will not be done.

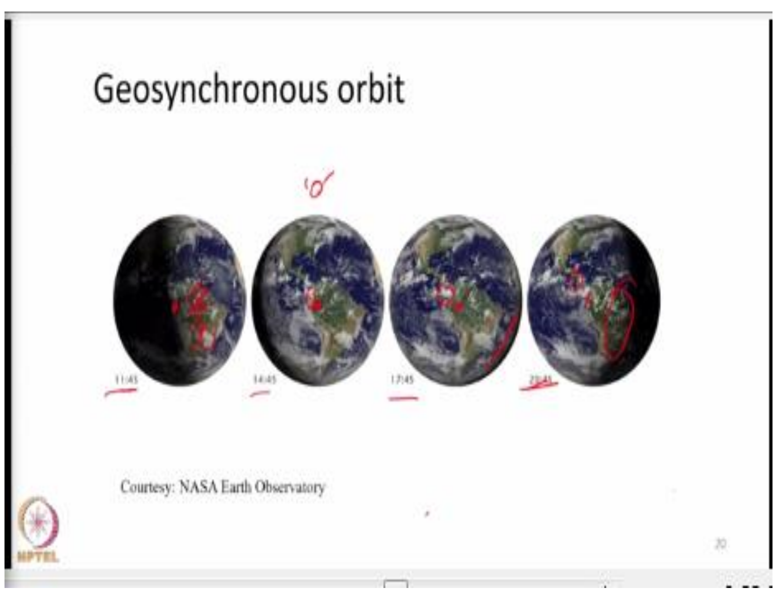
And also if an orbit is in retrograde along the equator then we will call i as 180 degrees as a convention. Geosynchronous satellites with i greater than 0 is extremely difficult to find because the major purpose of launching a satellite in geosynchronous orbit is to achieve this geostationarity, to look at the same spot on the earth again and again continuously. If you put any orbit other than 0, then this geostationary nature will go off.

That is let us say we have a satellite, say this is earth, let us say this is one geostationary orbit and this is the equator let us say i =10 degrees. Even if it is geosynchronous orbit what will happen is, the period of revolution will be synchronized with earth. But as the earth rotates, the satellite due to its orbital inclination will be moving in an inclined plane. Earth will be moving like this, satellite will be moving like this, so essentially what will happen? It will not be stationed over one particular region, it will move from 10 degree north latitude to 10 degree south latitude**.** So the orbit will not be covering one location, it will be covering different, different portions of earth, so the stationarity will be removed from it.

So, normally for remote sensing applications satellites with i greater than 0 will not be launched, they will be launched only in geostationary orbits**.** So, geosynchronous means h = 35800, time period of rotation is one sidereal day. This is geosynchronous general nature, for a geosynchronous orbit to be geostationary i must be equal to 0 in which the satellite is rotating in a prograde direction.

This is a very simple overview of geosynchronous and geostationary orbit. So, as i told the main purpose of launching a satellite in geosynchronous orbit is to produce or observe a same spot on the earth continuously, an example is given in this particular slide, you can see**.**

(Refer Slide Time: 21:56)



A satellite is centered over African continent, so whatever be the time period the satellite is observing the same spot again and again. Say this is morning 11:45 am local solar time, so this will be day time here, sun is here in this direction and this is afternoon. So, this is evening you can see night is beginning to fall and at night 8:45, this is night time here.

So, essentially the same spot will be continuously observed over different, different time period, we can see how clouds are moving in different, different time instances. And these kinds of multi-temporal images even within a day will help us to understand highly temporal or highly varying factors such as cloud formation, hurricane moment and etcetera. Those are all the main applications for launching a satellite in geosynchronous or geostationary orbit.

(Refer Slide Time: 23:00)

So, this is a small video i would like to present where you will be able to see the beauty of the observations from geostationary orbit. So, this video is produced by NASA in order to tell us how season varies basically**.** So, this will again observed over a satellite positioned over African continent, maybe I will just tell the context. And this video is a combination of images acquired by a satellite over one full year at morning 6 AM roughly.

That is same time period in the morning is observed over one full year. The image start date is 10th September 2019, it moves all the way up to next year 11th September 2020; just see how sun's light varies with different, different days. **(Video Starts: 24:13)**

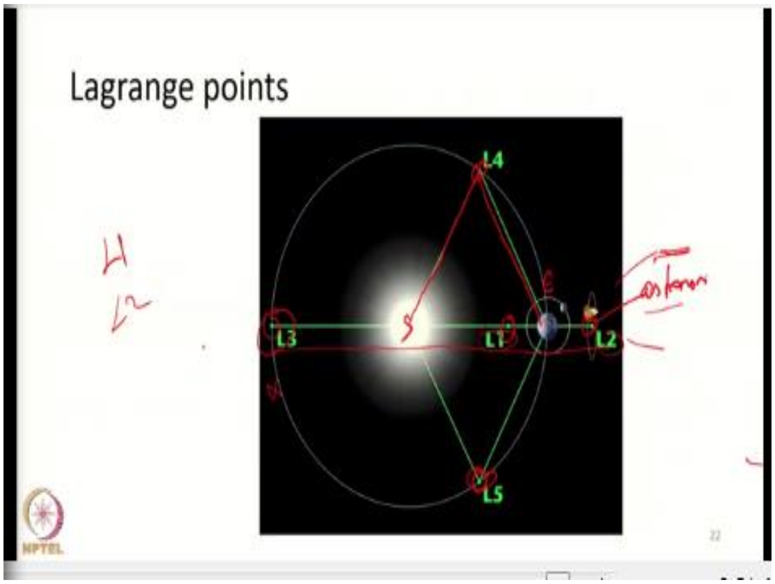
This is actually to depict seasons, you can clearly see how the sun's radiation varies on the earth surface from north pole to south pole. **(Video Ends: 24:28)** This is actually the seasonal effect, how season changes? So, these sort of images, is just not to explain geostationary observation but a way to explain seasons for school kids to understand seasons by NASA. But here I am showing this particular video just to show the beauty of geostationary observations. Same location is observed continuously, we will be able to understand or comprehend many more things. That is the main reason, and also like I told you about vernal equinox when I described about orbital longitude, right ascension of the ascending node. That can also be understood from this particular video.

When the video starts, basically this portion indicates equinox that is this is north, south, east, west. This is one full circle of earth which the satellite is seeing. So, basically on equinox sun will be overhead the equator, so one half of the globe will be exactly illuminated giving rise to equal day and equal night time for places around the equator. So, this time 10th September, we call it as autumnal equinox that is sun is moving from north to south it is crossing the equator during that time that is autumnal equinox. So, that will be indicating the winter season for the northern hemisphere, summer season for the southern hemisphere. Observe this video carefully around this 11th March, when the time period crosses 11th March here again it will cross an equinox.

That is sun is moved from north to south, then again will start moving from south to north, again it will cross the equator. That particular day in which sun crosses the equator once more we call it as vernal equinox, vernal equinox is sun is moving from south to north, you can think it off as it is in ascending motion so that day is vernal equinox. So, this is just to explain those concepts but this kind of observation is possible from geostationary satellites.

We can even learn about different things which we have not seen from any other perspectives. So, the next kind of orbit what we are going to see is Lagrange points. If two bodies are moving with respect to each other due to that combined gravitational effects there will be certain points around their orbit which will be fixed in space.

(Refer Slide Time: 27:37)



Let us say this is sun, this is earth, so earth is moving around the sun in a fixed orbit**.** So, sun will have a gravity, earth also has a gravity. Due to the combined gravity effects there will be certain points and if objects are placed in those particular points those objects will appear in the point continuously. Say sun is here, earth is here, both of them are moving means those 5 points labeled here as L1, L2, L3, L4 and L5. Those 5 points also move with them, such points are called Lagrange points**.** So, there are detailed physical explanation of why these points are there and all, we are not going to discuss in detail about those points. But the one thing what I want to mention is this is because of the combined gravitational effect of two bodies. Not only with respect to sun and earth even with respect to earth and moon, you can fix 5 Lagrange points around it.

So, at those 5 points if you place some objects they will be move along with these 2 objects in tandem. In this 3 Lagrange points L1, L2, L3 they are actually located along the line joining sun and the earth. L1 between sun and earth L2 beyond earth L3 beyond the sun, L4 and L5 are at points on the vertex of an equilateral triangle. This triangle is actually equilateral triangle. So, one vertex is sun, one vertex is earth, one vertex is L5 point. So, totally 5 Lagrange points will be there for a two body system, sun and earth, earth and moon and so on.

So, as the system moves the 5 Lagrange points will also move, among these 5 points L1, L2, L3 are relatively unstable points. That is if you place some object there, very easily they will move out of that particular point. So, we have to maintained some or provide some force to it in order to keep it there, so these points are unstable. But L4 and L5 are highly stable points. If you place certain objects there, it will be remaining there**.**

Normally some kind of asteroids will be coming in and located in the L4 and L5 points because of this combined gravitational effect it is observed. So, this is naturally occurring points, it is not man designated orbit, these are naturally occurring points because of the combined gravity**.** So, if we take a look at this L1, L2, L3 points we can observe earth from L1, L4 or L5 basically, L4 and L5 are like pretty large distances, we will not use. Normally we will use L1 for observing earth and then L2 point is beyond earth. So, this is useful for astronomical applications, there are satellites placed at L2 observing the outer space, L3 we will not use. Because L3 is beyond the sun, so whatever the data collected by this L3 satellite will be very difficult to reach the earth. Since it is at very extremely farther distance sun is in between so we will not get any signal. So, L3 will not be of much use, L4 and L5 are useful for solar observation that is with respect to earth they are very far, we may not get any meaningful data. But they were useful for solar observations and again outer space observations, so these 5 points are called Lagrange points.

So, as a summary, in this lecture we discussed about the classification of satellite orbits with respect to orbital heights. We discussed about geosynchronous orbit and as a special case geostationary orbit, and also we discussed about the Lagrange points. With this we end this lecture.

Thank you very much.