Remote Sensing Essentials
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Lecture-13
Passive Microwave Remote Sensing

Hello everyone, and today we are going to discuss passive microwave remote sensing. And just recall when we have been discussing different types of remote sensing and so 2 types basically, we differentiated, one is active remote sensing and another one is passive remote sensing and active remote sensing as you know purely microwave remote sensing, but in passive under the category of passive remote sensing there is also possibility of having passive microwave remote sensing.

Because objects in natural objects also without having any other source of energy, they also emit energy in microwave part of EM spectrum, though this energy is very, very less compared to other like reflected or emitted energy and this passive microwave energy is very less., So natural objects when they emit that can also be recorded by sensors and they were sensors at a relatively very coarse resolution which we will be discussing soon.

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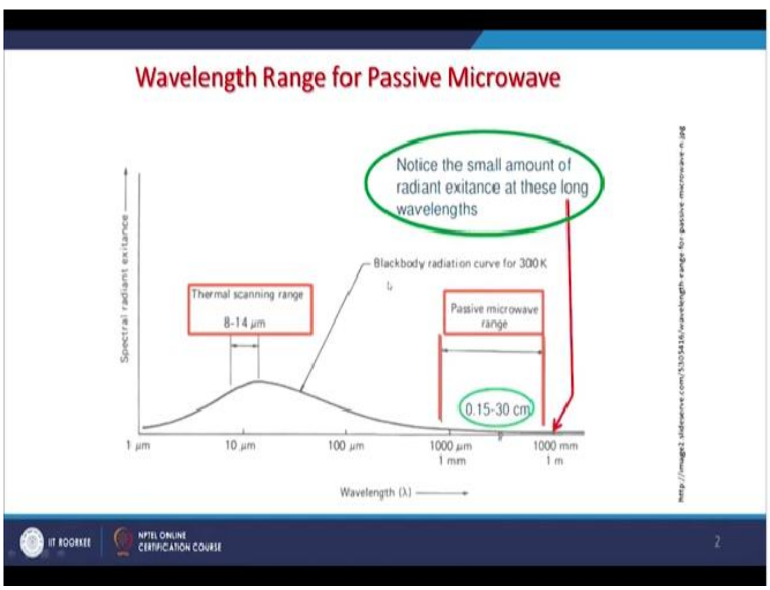

So, what we see here that this part of EM spectrum which is around 8 to 14 micrometer that can be used here. And as you can also see this is the spectral radiance existence and there we see that passive microwave. So, this part is for active microwave or sorry for thermal microwave and this part is for the passive microwave 0.15 to 30 centimeter and there the blackbody radiation curve for this one is also shown that is also shown here.

And so, we can see here that this part of passive microwave signals can be recorded by the satellites. Though we know that this energy is very small in amount and therefore and it is in long wavelengths. So, the problem comes about the space resolution because in order to register a signal into a sensor in that two around 800 50 kilometer away from the earth you require a large area of signals.

And therefore going or adopting for a especially for a very low resolution images, but this has been done in past and we will see that which are those satellites and other things.

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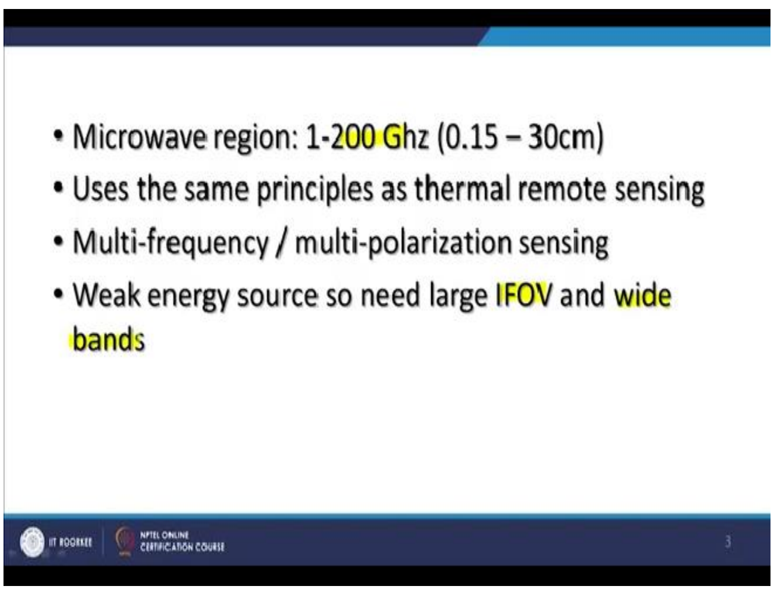

So microwave region in terms of frequency which we discuss here that is 1 to 200 Giga hertz or in terms of length 0.15 to 30 centimeter and this uses the same principles as thermal remote sensing because, as in case of thermal remote sensing objects above absolute zero, emit energy which can be recorded by the sensors which works in the thermal infrared part of electromagnetic spectrum.

So similarly, microwave and also is emitted by some by the objects, but it is a very low energy and nonetheless, that 2 can be recorded, it does not matter how low spatial resolution is. So, there has been sensors, which are multi frequency sensors and multi polarizing remote sensing in microwave passive microwave reason has been done and weak energy source so we need a large IFOV and this is IFOV stands for instantaneous field of view.

And bands also generally are very wide. So because the energy which is being emitted in microwave region by the natural objects is very, very small and therefore, as mentioned that in order to register by sensor in a space, you require a large IFOV instantaneous field of view and that basically directly related with the space resolution and the band also not like very narrow bands you get in visible part of EM spectrum.

But here the bands are very, very and large in that. So, more closely to classical optical and thermal infrared sensors, then radar why because radar is active microwave and whereas a typical visible infrared thermal infrared or passive microwave remote sensing. So, that is why it is specifically this called passive microwave not simple microwave radar remote sensing or active remote sensing.

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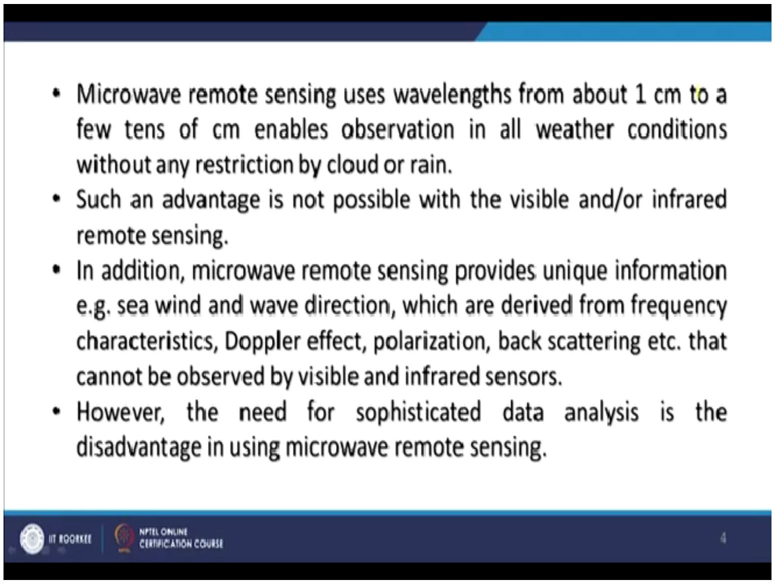

Now, microwave remote sensing uses wavelengths about 1 centimeter to a few tens of centimetre enables observations in all weather conditions without basically restricting by the cloud or rain, because the size of particles are smaller compared to wavelengths, and therefore they do not put any hindrance to these waves, and they can pass through clouds, rain or fog. And such an advantage is not possible as you know with visible or infrared.

Because wavelength is very small. And therefore, these particles are water droplets, they create problem in visible or thermal infrared remote sensing. In addition, the microwave remote sensing also provides unique information and that is a sea wind and wave directions which are derived from frequent characteristics also we use Doppler effect and different polarizations are also possible in combination with microwave remote sensing.

And of course, back scattering etc. So, that cannot be observed by visible or infrared sensors. So, for very special purposes, microwave remote sensing is definitely implied and very useful. However it needs for sophisticated data analysis is the data processing is completely different than data processing of your visible infrared or thermal infrared images or sensors where there you get directly images.

But in case of microwave remote sensing you get the data in waveforms and then processing has to be done so that we get a good informal sort of images.

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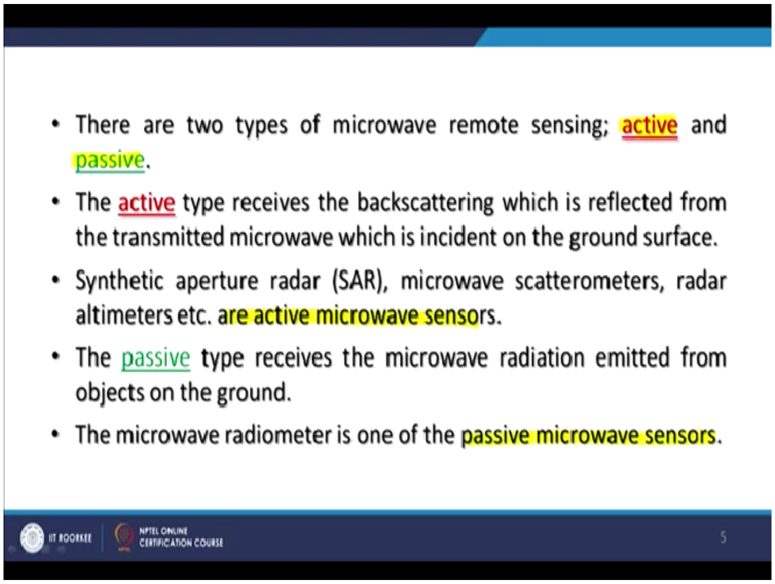

So, that requires intense processing. As I have already mentioned earlier also and today that microwave remote sensing and what overall remote sensing can be divided into categories active and passive, especially microwave remote sensing can also be divided in 2 categories, one is active microwave, which we will be discussing in detail later. And then passive microwave which we are discussing now.

So, the active type receives the back scattering because the satellite or sensor itself the sense the energy or signals pulse towards the ground and whatever is reflected back by or after the attenuation it is received by the same sensor. So, this is basically the transmitted microwave which is incident on the ground surface and best example of this is synthetic aperture radar and there are microwaves, scatterometer, radar altimeters etc.

They are all part of active microwave remote sensing, there are various satellites, we have been discussing few more examples an applications part we will be discussing later about active microwave remote sensing. In case of passive remote sensing which receives the microwave radiation emitted by the objects on the ground itself. So, like an active the signal or pulse has to be sent by the sensor itself, but here the natural microwave emission is recorded that is why it is called passive. So, microwave radio meters is one of the passive microwave sensors in this category.

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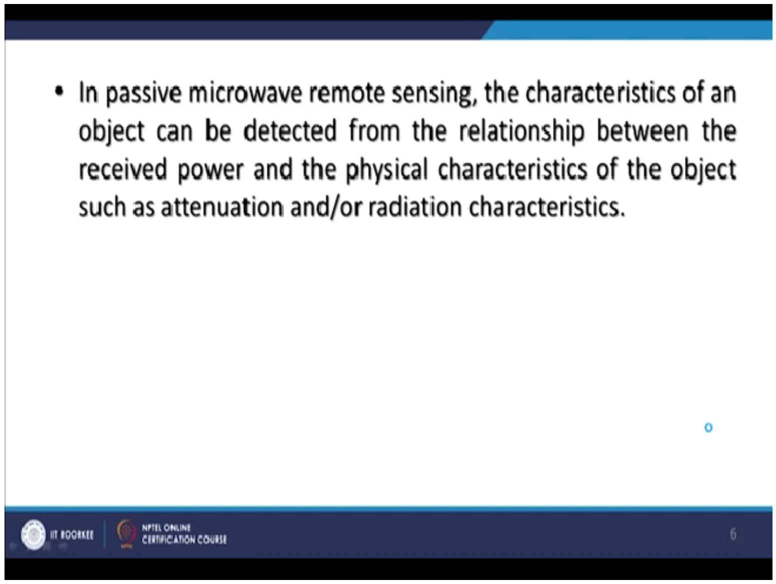

In passing microwave remote sensing the characteristics of an object can be detected from relationship between the received power and the physical characteristics of the object such as attenuation or radiation characteristics. So, why this relation that is exploited.

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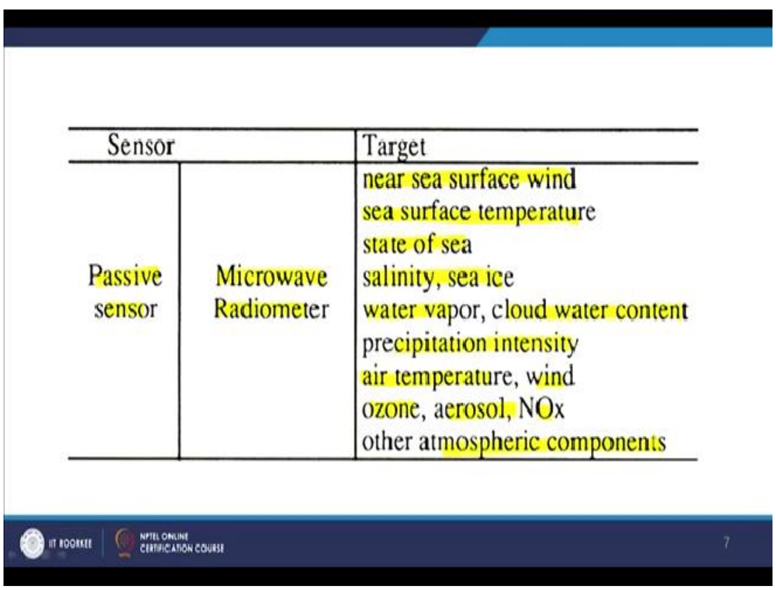

Like here this is passive microwave sensors. So, the main sensor here is the microwave radiometer and what are the targets or where it can be applied. So, near sea surface bands, there it is being used, sea surface temperature or SSD estimations it can be used it is being used and the condition of sea whether it is calm or very volatile that can be seen salinity also or sea ice, water vapour, cloud water contents precipitation intensity.

All these things are being studied using passive microwave remote sensing, air temperature also, wind ozone, aerosol and NO 2 and other atmospheric components are also there, I will be showing example, where passing microwave remote sensing data has been used to even estimate it is not earth in part of Himalaya.

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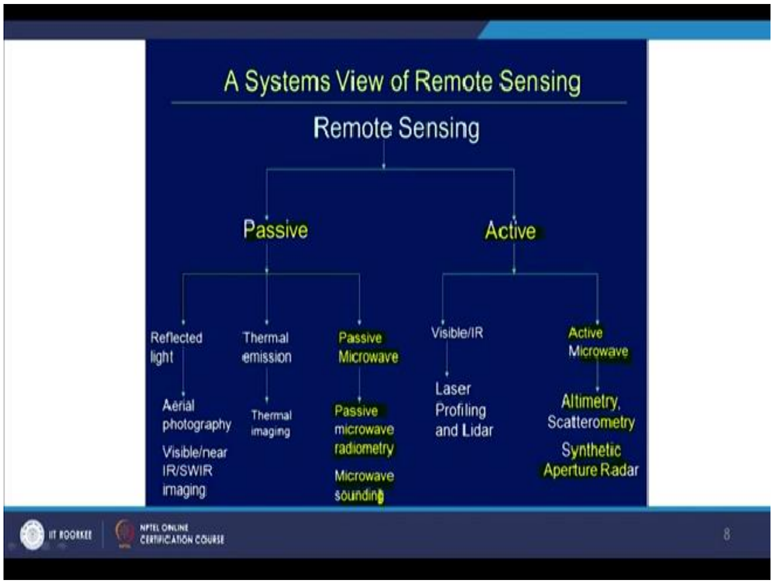

So, various applications are there. And this say we have already touched earlier and that overall remote sensing can be divided in passive and active and when we come for the passive, this is how the passive microwave stands here. In case of active microwave and that is ultimately scatterometry, synthetic aperture radar which is the most common component of active microwave. In case of passive microwave radiometry and microwave sounding, these 2 things are being used in case of passive microwave remote sensing.

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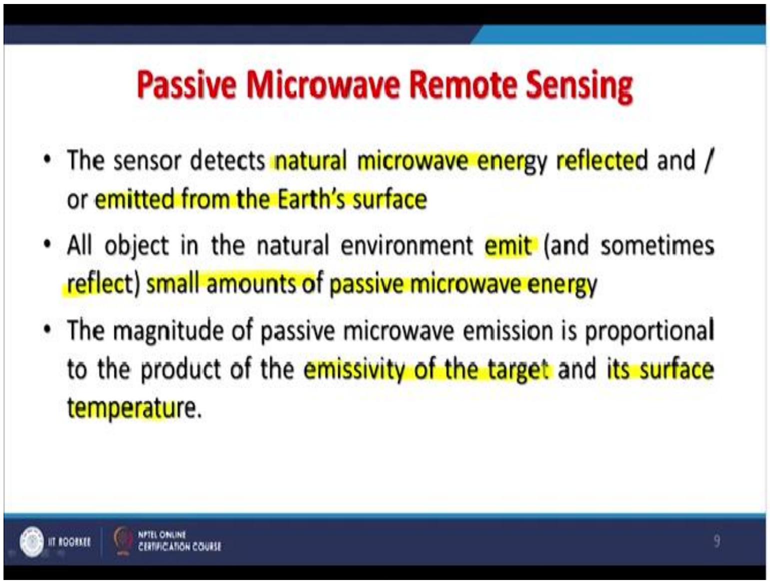

Now, you know what exactly happens in case of passive microwave remote sensing that sensor detects natural microwave energy. The emphasis here is the natural microwave energy, no artificial or synthetic energy sent by the sensor itself, but it is the natural emission in the microwave part of EM spectrum, which is being emitted by different objects or surface of the earth.

So, these sensors on board of satellites are capable of detecting natural microwave energy, which is may be reflected or emitted from the earth's surface, reflected sometimes in natural environment or in atmosphere also, there might be some microwave energy and that is you know that interacts with the earth surface and then again reflected. So, both kind of natural microwave energy can be recorded by the sensors.

And as you know that all objects in the natural environment emit not only the in the thermal infrared part of EM spectrum, but also in the microwave region and sometimes they also reflect energy depending the conditions and very small amount of passive microwave energy. This part I would like to emphasize that very small, the amount of my energy which is emitted or reflected in a microwave region by natural objects is a very tiny amount.

And therefore you require a large IFOV and consequently, you end up with a very coarse resolution images or data. So, magnitude of this passive microwave emission is basically proportional to the product of emissivity of the target and the surface temperature. So, recall these Wien's displacement law and other laws which we have discussed that it will depend basically or it is proportional to the product of the emissivity of the target and its temperature.

So, if temperature is more the emissivity of the target is going to be more you will have more passive microwave energy and therefore, it can be recorded.

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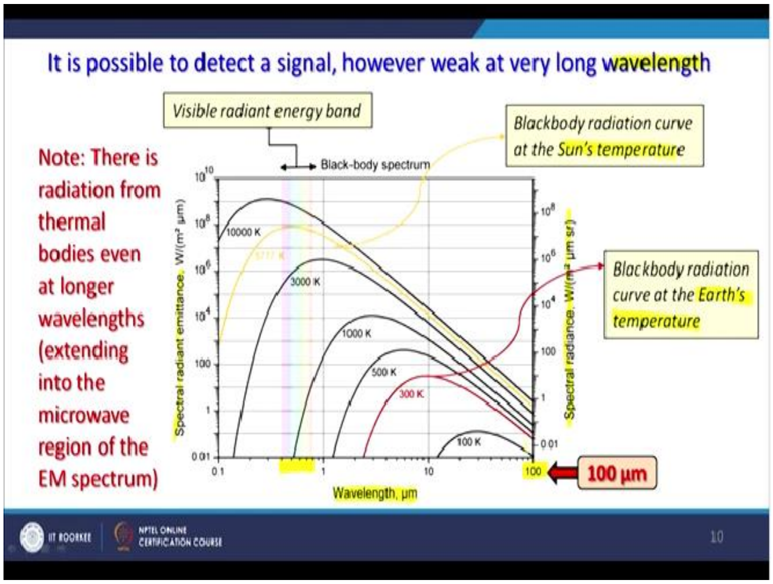

And so, here though as discussed that though the energy might be a very small one in microwave region, but whatever how big it is, but anyway and it is in the long wavelength and it can be recorded by the sensors. As these curves we have already discussed. So, very briefly I will go that on the y axis you are having spectral radiant emitance in watts per square in different wavelengths.

And the wavelength is here and this is what you see that there is a this visible part is shown here. So, see this 300 Kelvin curve and other this that is for an eternal objects on earth's surface. So, this is spectrum radiance, which is again on another axis is there. So as you see that when we go for the lower wavelength we get a high emitance but when we go towards the longer wavelength and especially I am talking about passive microwave region.

Then the energy which is getting emitted, it becomes very small, all these curves though they are very much separated in the visible part of EM spectrum they become almost saying at the end here in 100 micrometer range. So, the energy is very, very low, the weak long wave radiation is there, the visible energy I have already mentioned and blackbody radiation curve is 5777 Calvin or at the sun's sense temperature that is sun temperature is shown yellow.

And then blackbody radiation earth’s temperature. This is the 300 Kelvin is the earth one. So, you can see that even your solar energy or sun's temperature that too becomes a very small when we go towards the long wavelength, this is 100 micrometer thing. So, there is a radiation from thermal bodies even at a longer wavelength and extending into micro region of the EM spectrum and that part of microwave vision is exploded.

And that whole thing we called as a passive microwave. So, passive microwaves sensors use an antenna also called as horn to detect photons at microwave frequencies.

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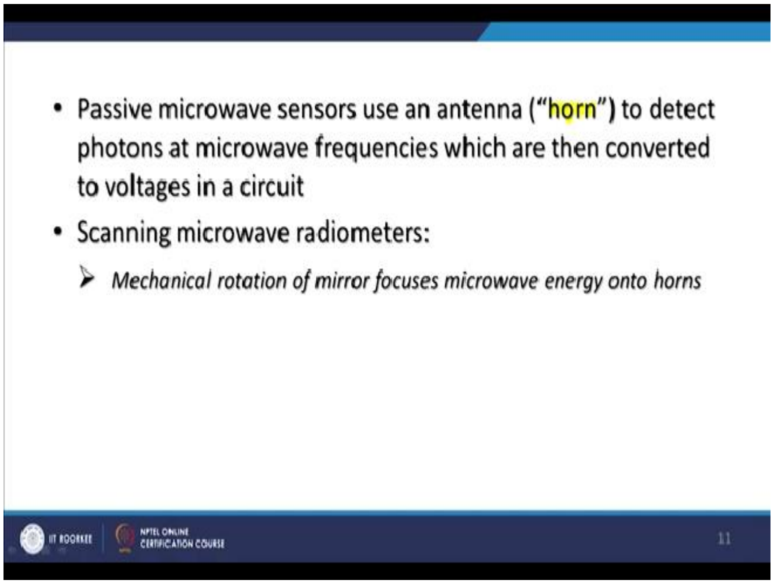

You know longer wavelengths, which are then converted into voltage in a circuit. And so, this is inside a microwave radiometer. And these scanning microwave radio meters there can be of different types one is the mechanical rotation or mirror focuses the microwave energy on 2 horns.

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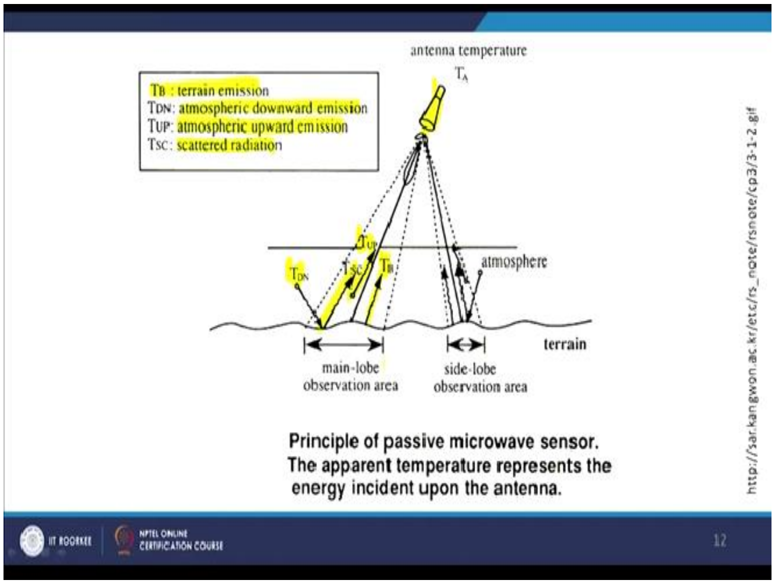

Like this is that horn is shown here. So, the main lobe of observation area and side lobe of the observation area. And so, this is the from the side the horn is detecting. This is from the directly is detecting and basically the TV, the TV component is the come in terrain emission a natural one and then there might be some reflected also and some other type of energy in microwave vision might be available like atmospheric downward emission.

So, TDN is also there, atmospheric downward emission, which later on maybe scattered and that becomes scattered radiation. And of course, then at atmospheric upward emission is also there. That is TUP is the atmospheric one. So this whole area is providing energy not only the terrain emission energy, but energy which is being generated within the atmosphere in passing microwave part of EM spectrum.

So that all is recorded by this horn or antenna. And there might be some energy which might be coming through this side lob way this observation show again atmospheric component is there and natural emission or terrain emission component is all there. So this is how passive microwave and sensors work. Now, what are the current and future polar orbiting microwave sensors are there.

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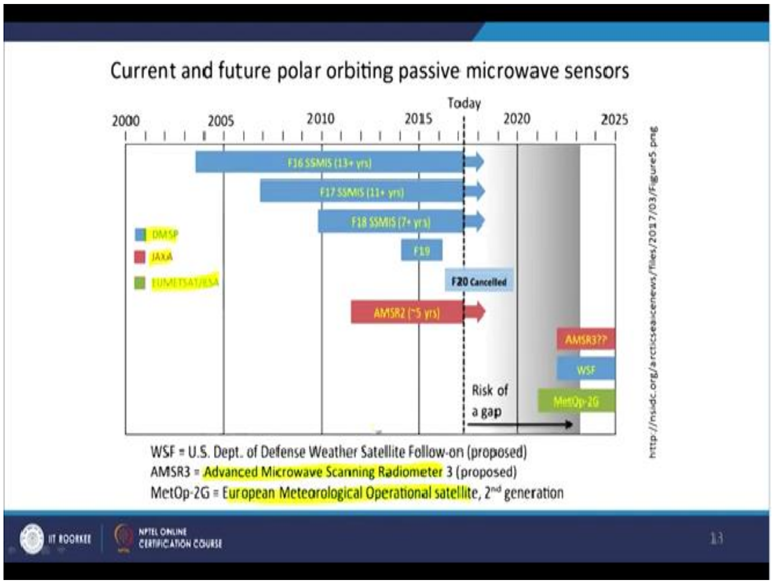

And there is series of satellites DMSP, which carried load of sensors and JAXA is a Japanese agency ah space agency and of course, ESAs also there. So SSMIS they are very popular and they were launched earlier also continuing with that and then you are having a AMSR 5 years life. So various microwave radio meters are there like advanced microwave is scanning radio meter 3.

European mythological operational satellite MetOp is also providing data and others and earlier also the pastor sensors there are also many we are there. So, this in passive micro region they are at least few satellites, which are providing data.

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And a spatial resolution part and we have already discussed, but very briefly I will touch again here that on x axis we are having spatial resolution and here we are a temporary resolution. So, this is the spatial resolution versus temporal resolution that these active SAR and the temporal resolution generally like ESR or Sentinel or Envisat, generally the repeat cycle is about 35 days.

So, if today it has passed over an area, then the satellite will be again coming or revisiting after almost 35 days. And but they were for some time, ERS had 2 satellites in tandem and this time was reduced by half roughly and when we go for the passive microwave, because a spatial resolution is very coarse, very poor, and therefore the repetivity becomes 1 day or 2 days.

So, there is a sort of inverse relation between spatial resolution and temporal resolution, higher the spatial resolution poor the temporal resolution and vice versa is also that higher the temporal resolution and generally you are having a coarser space absolution as depicted here, that passive microwave can have data we can have data almost every day, but in case of active microwave, the temporal resolution is about of 35 days.

So, these are the limitations of active microwave and the same time limitations of passing microwave in terms of spatial resolution and this runs in kilometers.

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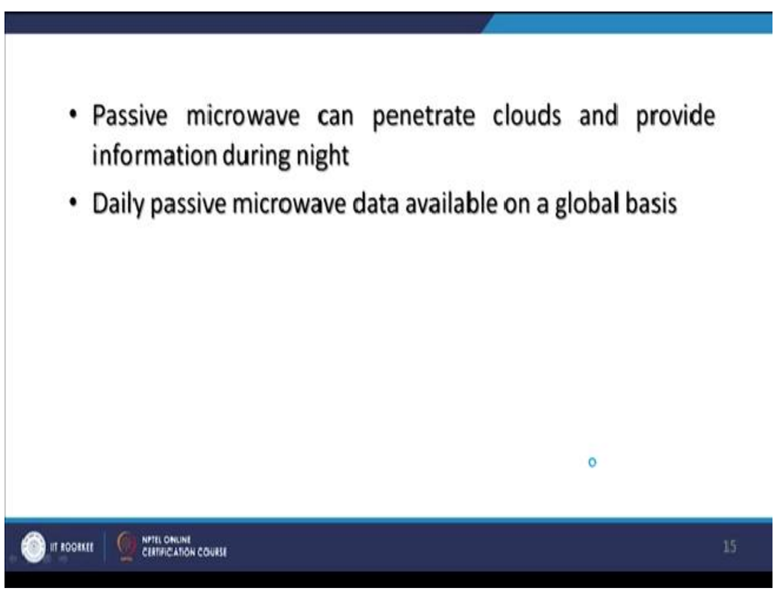

So, that point we will be also coming here and passive microwave can penetrate clouds and provide information during night time as also in case of active microwave because of longer wavelength and daily passive migratory data available on global basis, because, of course, spatial resolution.

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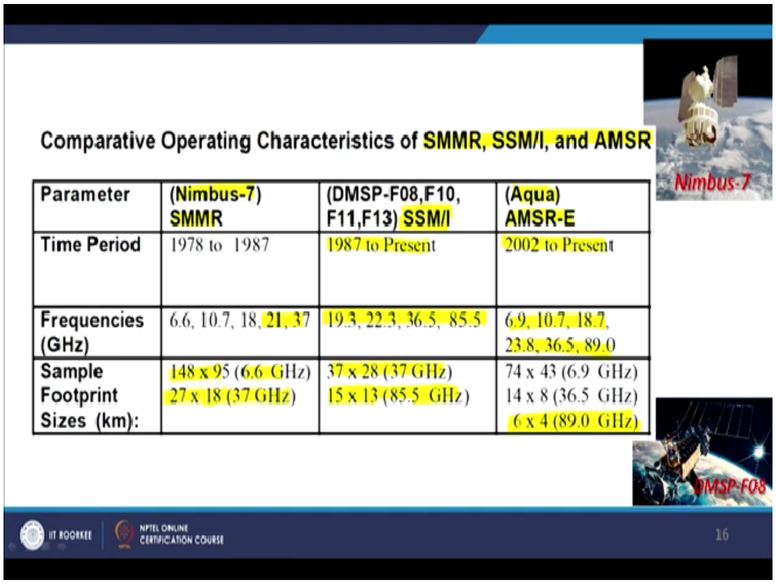

Parameter	(Nimbus-7) SMMR	(DMSP-F08,F10, F11,F13) SSM/I	(Aqua) AMSR-E
Time Period	1978 to 1987	1987 to Present	2002 to Present
Frequencies (GHz)	6.6, 10.7, 18, 21, 37	19.3, 22.3, 36.5, 85.5	6.9, 10.7, 18.7, 23.8, 36.5, 89.0
Sample Footprint Sizes (km):	148 x 95 (6.6 GHz) 27 x 18 (37 GHz)	37 x 28 (37 GHz) 15 x 13 (85.5 GHz)	74 x 43 (6.9 GHz) 14 x 8 (36.5 GHz) 6 x 4 (89.0 GHz)

Now earlier there were many sensors where there are radio meters on various satellites. So, they were 1 satellite Nimbus-7, which had a sensor SMMR and that lasted between 1978 to 87. So, about 9 years it worked frequencies there between these ranges. And now the spatial resolution of footprint was of this size. So quite close resolution data. Then on this DMSP satellite again name you had this SSMI sensor or radio meter that.

So once this SMMR was over, and this started working, and it of course the spatial resolution here is improved and relatively and they were also changes in the frequency and they are generally when we discuss about passing microwave or active microwave we instead of in terms of wavelength we use the frequency and terminology for microwave part of EM spectrum and then of course satellite also Terra and Aqua.

So, both are having MODIS sensors as well. But here we are not discussing MODIS sensor AMSR sensor and as you know that Terra Aqua became operational in 2002. So since then there were series so, like MODIS sensor is continuing so this AMSR also continued and the frequencies are mixed compared to SSMR and SSMI and of course, again see the resolution improvement in resolution is continuous.

So, this is now coming in a relatively higher spatial resolution as compared to between 1978 and 87 which is some applications of passive microwave remote sensing, we have already touched, but now very specifically, we will go word for land.

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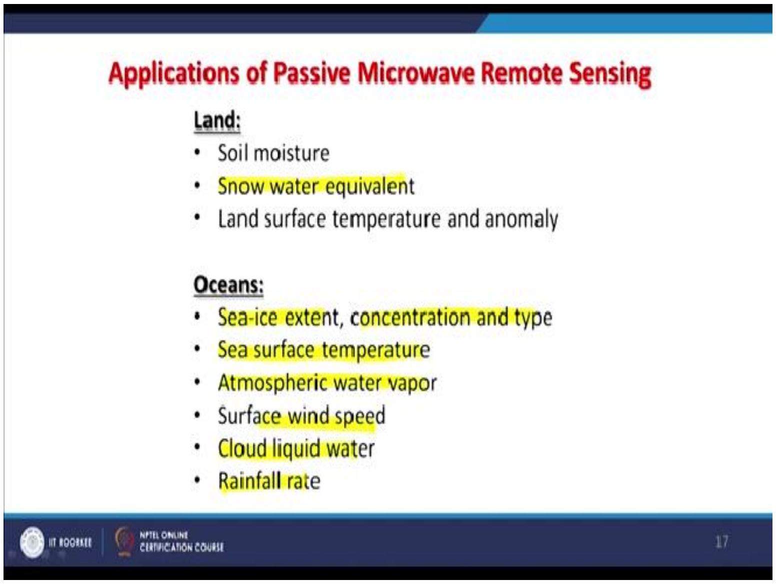

For land applications of passive microwave began use for a soil moisture studies, snow water equivalent and this is what the soil are also use some time back, land surface temperature and anomalies, these can be used and have also been used. Then, this oceans in case of water, you can have ice extent, concentration and other types of ice. Sea surface temperature like land surface temperature can also be used.

Basically temperature estimations are possible with passive microwave remote sensing, then atmospheric water and surface wind speed of the sea surface and cloud liquid water, the rainfall rate or precipitation intensity and they are also it can be used.

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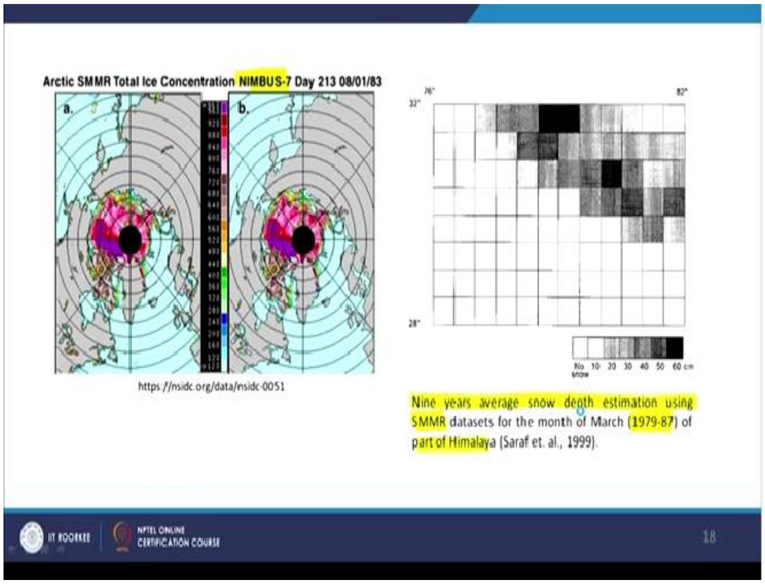

And these are the examples of SMMR, SMMR data and this is what we did 9 years every snow depth estimation or part of Himalaya which we have done between 1979 to 87 which was this SMMR as discussed earlier that it was on the Nimbus-7 satellites and which lasted about 4, 5 years in a space and provided the data. Though the resolution here was about 30 kilometers spatial resolution I am talking about.

But there are no other ways to estimate a snow depth then passive microwave remote sensing, no other technique of remote sensing can work to estimate snow no depth and even in part like rugged terrain like Himalaya, so that that is the only resort or only of option available that we imply adopter passive microwave for such special kind of work. Of course, now as mentioned earlier that now spatial resolution has improved.

So, our estimations of is no death can also be improved in future and once these data sets are implied.

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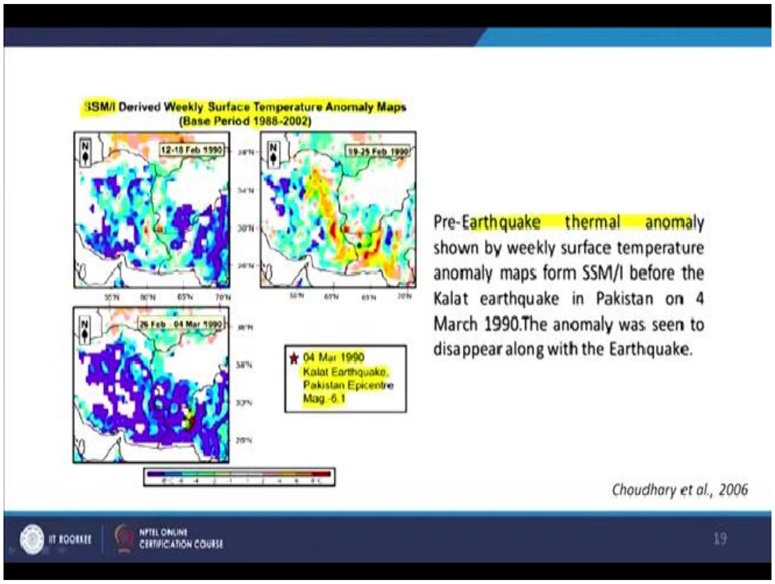

And the biggest advantage is that they are available on regular basis. Also I have discussed that these the passing microwave can we use for these land surface temperature anomaly. So let us see that example also that we have also used to that data SSMI drive the weekly surface temperature anomaly maps, which we are available to us between 1988 to 2000. So, these are the weekly average.

Basically, these are anomaly maps compared with the base period between 1988 to 2002. And if you dig out a weak data compared to average, you get that thing. So, if you put in a time series, like in this example, related with an earthquake, 3 earthquake thermal anomaly, and it was observed that in this case the earthquake occurred on 4th March 1990. And that is falling in the third image and this earthquake centre is shown here.

So, 1 week before this earthquake has occurred, as you can see that a lot of thermal anomaly has been observed. Though the resolution here temporal resolution is weekly data, but if every day basis, the data can be analyzed in time series, estimating first surface temperature, then exactly one can know that when this anomaly was maximum and then what happened after that and then and just before the earthquake and after the earthquake.

Though this study was done based on the believable weekly data but if daily data is available against a base period of between 88 to 2002 or even to current then things can improve. So, this was Kalat earthquake of Pakistan of magnitude 6.1. A identifiable and recognizable pre earthquake thermal anomaly was seen in weekly surface temperature anomaly maps, which were prepared using SSMI data, which is passive microwave data.

So, it is possible though the resolution may be relatively coarse, but it is because that provides the advantage that on daily basis you can have data and it can cover a very large area. So, if application like this one, in order to study the pre earthquake thermal anomalies, we need to cover a large area and therefore for such kind of studies, passive microwave remote sensing can be a very apt data set available to us.

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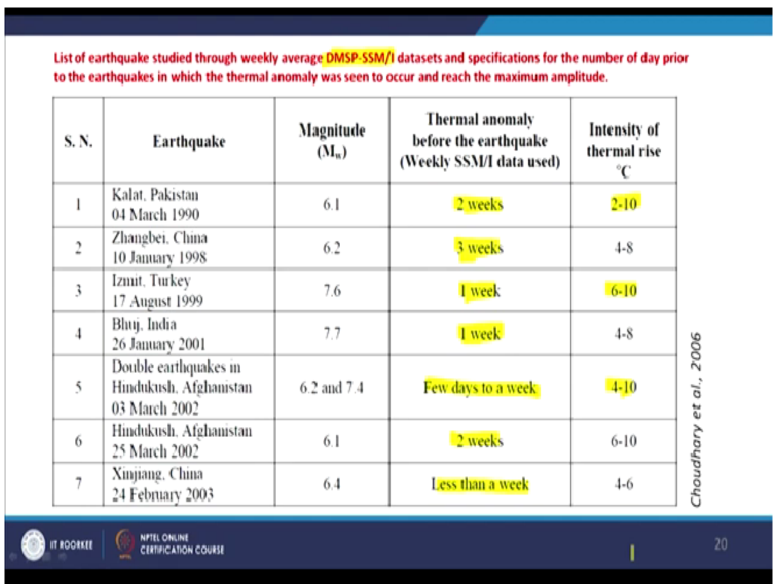
List of earthquake studied through weekly average DMSP-SSM/I datasets and specifications for the number of day prior to the earthquakes in which the thermal anomaly was seen to occur and reach the maximum amplitude.

S. N.	Earthquake	Magnitude (M_w)	Thermal anomaly before the earthquake (Weekly SSM/I data used)	Intensity of thermal rise °C
1	Kalat, Pakistan 04 March 1990	6.1	2 weeks	2-10
2	Zhangbei, China 10 January 1998	6.2	3 weeks	4-8
3	Izmit, Turkey 17 August 1999	7.6	1 week	6-10
4	Bhuj, India 26 January 2001	7.7	1 week	4-8
5	Double earthquakes in Hindukush, Afghanistan 03 March 2002	6.2 and 7.4	Few days to a week	4-10
6	Hindukush, Afghanistan 25 March 2002	6.1	2 weeks	6-10
7	Xinjiang, China 24 February 2003	6.4	Less than a week	4-6

And there are various earthquakes which we have studied using this another set of data from DMSP satellite and the sensor or radio meter was SSMI. This was and you know the thermal anomaly which was detected in Kalat about 2 weeks before in case of January, it was 3 weeks before 1 week because the data was weekly average data. So, we cannot go basically within a week and just some guess can be done that whether few days before the week or so on.

And what was the intensity of rising temperature was 2 to 10 degree, which is very significant, 6 to 10 degree, 4 to 8 degree and so on. So, 7 examples are here, where passing microwave remote sensing data has been employed. So this brings to the end of this discussion about passive microwave remote sensing and there are obviously advantages with passive microwave and that covers a very large area on daily basis data is available though at coarse resolution.

And there are many applications where this data can be implied and some applications where otherwise it is not possible to achieve those results, but implying passive microwave data like in snow depth studies or these land surface temperature anomaly studies a lot of applications, a lot of areas can be benefited. So this brings to end of this discussion. Thank you very much.