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**Lecture-57**
**Applications of DEMs in solar and wind energy potential estimations**

Hello everyone! and welcome to a new discussion on the applications of DEM in solar and wind energy potential estimation. As you know that basically DEM represent terrain and this same terrain can be further analyzed for solar and wind energy potential estimations because as you know that for example, that south facing slopes will receive Sun shine almost an entire day, especially in the hilly terrain like Himalaya.

And that is why, you would also see that lot of developments in the hill regions in past and even in current are all taking place on the south facing slopes. So, south facing slopes are very important from solar energy point of view. But still there are some other directional slopes because every slope is not having a south facing direction. So, there will be some other directions. So how can we estimate what is the potential if at all, a solar power plant has to be established.

This is being done extensively I know in hilly state space mainly in Uttarakhand and lots of such projects are coming. So, how we can exploit digital elevation models in GIS to estimate solar and wind energy but before that very briefly, I will touch about certain fundamentals.

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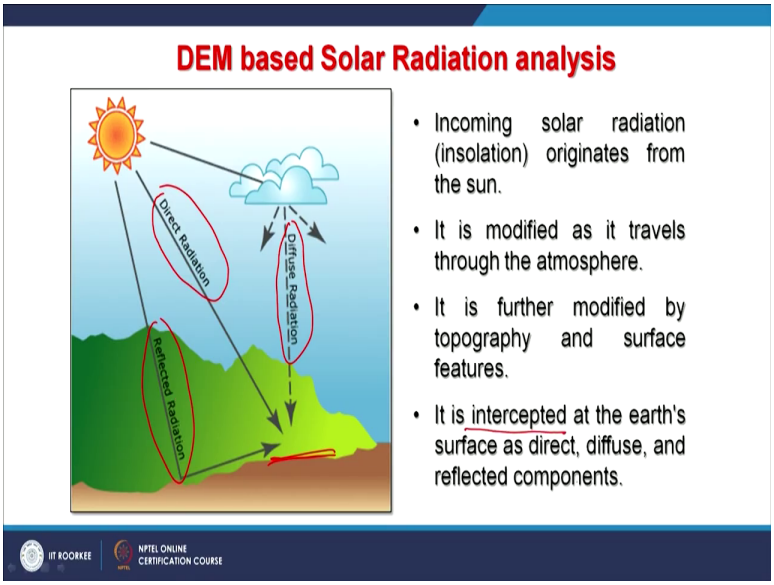


As you can see that of course, the source of solar energy is Sun and that is in two forms; one is in the radiation form which is what it is required for the solar panels and another one is the thermal one which basically provides the heat and that too is being exploited again in hilly regions where you know winters are very cold, for these solar water heater or plants. So, both components of the Solar Energy can be exploited. But where to install, that is what we are going to discuss and what are the complications will arise?

So, if you see that there is a Sun and that energy is available. Theoretically if a sky is clear then the radiation will reach directly to the surface without hindrance but we know that it is not like that. And if it is cloudy or you know some substances are present or gaseous are present in the atmosphere then instead of getting direct radiation, we get the diffuse radiation. And sometimes also in hilly region, we also get a radiation which we can put in a category which is called reflected radiation.

So, this incoming solar radiation or in short, we say insulation provides from the Sun. And this insulation it as you know is modified when it travels through the atmosphere from the Sun towards Earth and also it is modified by the topography as just mentioned so instead of not receiving direct reflection or direct energy, we get the reflected energy. So, it is further modified by topography and surface features.

Surface features might be vegetation, might be agricultural crops or you know soil conditions also and finally, of course the lithology also play part; different types of rocks will behave differently from solar energy point of view. So, the solar radiation which is coming before it reaches to the earth, it is intercepted at various places. Sometimes you get the direct, rarely only in a very special circumstance but generally you get the diffuse one.

And then of course in the hilly parts, you get lot of solar energy through the reflected components.

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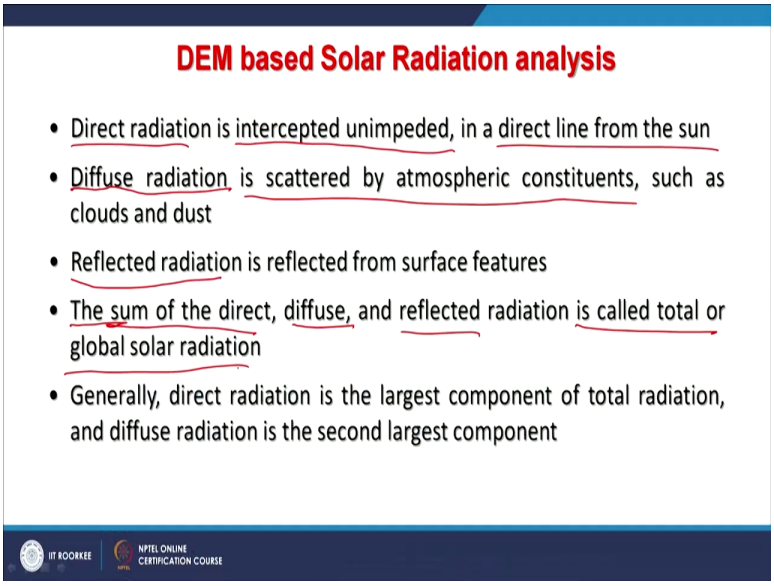


Now this direct radiation as we have just mention that this is intercepted and unimpeded. Basically, unimpeded means that the direct line from the Sun. So, this unimpeded problem will always be there because there is a thick atmosphere between the Sun and the Earth. But if we talk about says Mars or Moon surface where like in Mars, there is a very thin atmosphere and therefore the Solar Energy can reach unimpeded at the surface of the Mars but not like on the surface of the earth.

Because luckily, we are having atmosphere and that atmosphere basically, because of that the life exist on the earth. So, in some way but from solar energy point of view, this atmosphere is a kind of hindrance nonetheless. So, this diffuses instead direct radiation. What we are getting a

diffused radiation which is scattered by atmospheric constituent. There may be many constituents' clouds, dusts, gases and so many other components are there and dust of different sizes; particles of different sizes.

Now third component that is the reflected radiation is reflected from the surface features. And as I have mentioned that in hilly region, this component is also quite significant. Because for solar energy even if the reflected radiation is there, still you can generate some energy. It is not necessary but I mean is that it is not necessary that you should always get a direct sunlight on solar panel then only it will generate energy. You recall the usage of calculators we used to have in which you know a small solar panel used to there. That solar panel or those calculators used to work even in the tube light.

So, small radiation which is required for that kind of operation is available in natural light, may not be directly in the sun. So, the total sum; the sum of the direct, diffusion and reflected radiation which we called as a total or global solar radiation. So, this global solar radiation; lot of these estimations about potential or solar energy can be based on this global solar radiation rather than you know looking for individual components.

Now further that generally direct radiation as you know is the largest component of total radiation because that is how this energy is reaching though in between there is atmosphere but still it is having major role towards the Solar Energy generation. And the second position is hold by this diffuse radiation. And of course, reflected radiation will have the third one.

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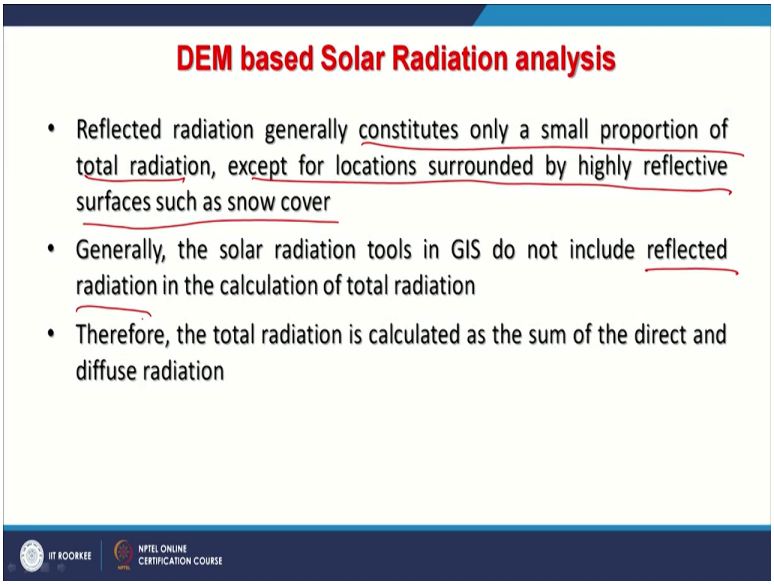


Now, this reflected radiation constitutes only a small portion of the total radiation except for location surrounded by highly reflective surfaces such as a snow cover. So, in these areas which are covered with snow or glaciers where reflection is very high, there reflected radiation can be also of very significant amount. And generally, the solar radiation techniques and tools to analyses in GIS, they do not include the reflected radiation in calculation of solar radiation.

So, obviously it will estimate for a certain location. But whether in real condition, what would happen because what you are doing with GIS is doing a modelling part. So, obviously in modelling and the real world; there are always difference in these models nonetheless and extensively GIS tools are being exploited to get these estimations about potential of solar energy associated with a particular location.

So, what we do? As I have just also mentioned that the total radiation is calculated as the sum of the direct and diffuse radiation.

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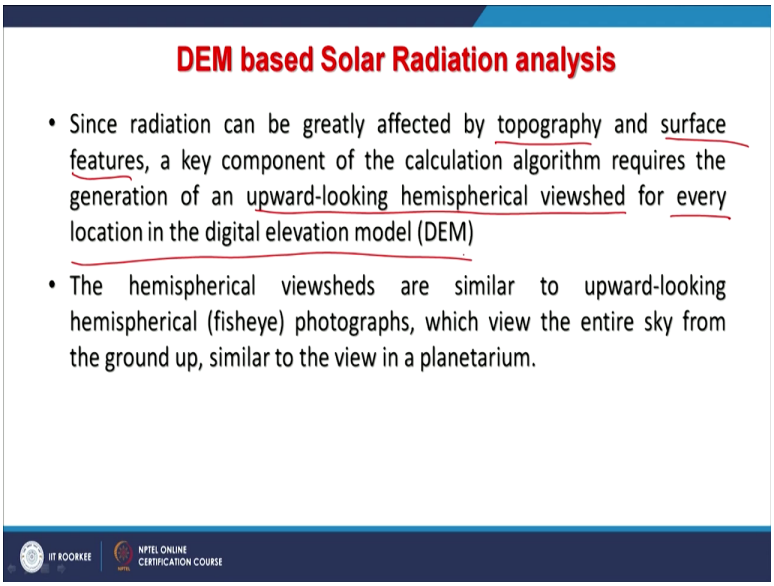


Now this solar radiation calculation for point locations or for an area. we can do it on a GIS platform which will involve 4 steps. The first step is the calculation of upward looking hemispherical viewshed. Viewshed part, we have already discussed. Think a viewshed which is looking towards the sky. That is why the word upward looking and hemispherical because you cannot see the entire hemisphere from a single point or an area.

So, these three words are important that upward looking, hemispherical, viewshed based on the topography. If somebody is located in a valley, this viewshed is going to be very narrow. Though these 2 conditions will be there but still viewshed is going to be narrow. But if somebody is top of the hill or on peak then naturally the viewshed is going to be very high. So, it will depend on the topography. Now what we do? We overlay of the viewshed which will be calculated keeping upward looking and hemispherical on a direct Sun map to estimate the direct solar radiation

And the overly of viewshed on a diffuse sky map to estimate the diffuse radiation. So, we can also calculate not only the direct radiation but also the diffused radiation. And the final step in this solar radiation calculation or analysis on GIS platform is this we repeat this process for every location of interest to produce an insulation map.

So, in that way, we can achieve this estimation of solar energy potential about a location or a particular point or an area. Now as we know that the radiation can be greatly affected by

topography and the surface features. And therefore, a key component in the calculation of this algorithm which requires the generation of upward looking hemispherical viewshed for every location in the digital elevation model.

So, for every location it will be done. Every location here means every cell of our grid; that is Digital elevation model. So, this hemispherical viewshed basically if you think they are similar to the upward looking hemispherical or fish eye photographs; that means a very wide-angle view would be available. Which views, the entire Sky from the ground up similar to the view in the planetarium. If that location for which we are going to do the estimation is open part like on a hilltop or on a ridge but if I am located in the valley then scenario is going to be different.

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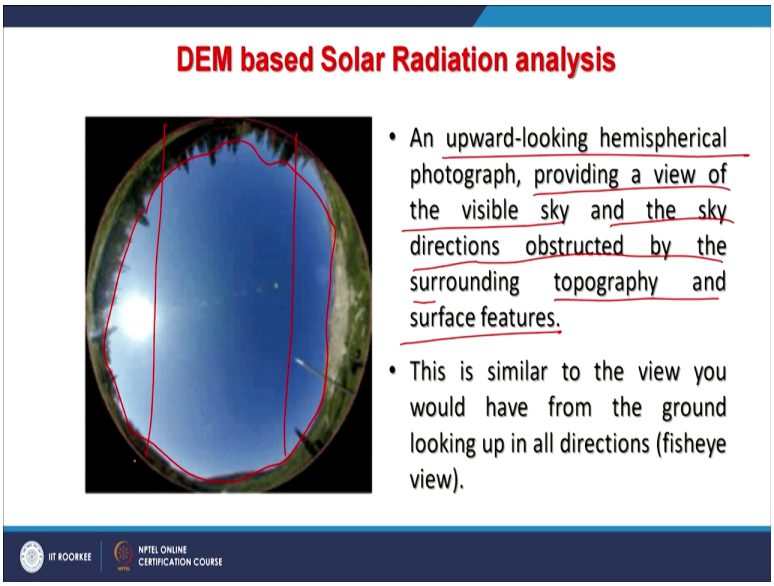


So now, this is what is the fish eye view or upward looking hemispherical photograph was taken keeping the camera on the ground and this is how it looks. So, providing a view of the visible sky and the sky directions obstructed by the surrounding, that is why it was mentioned that not only the topography affects the incoming solar radiation or insulation but also the features.

So, like features, they are also creating hindrance here. So, there are not allowing us to have a complete upward looking hemisphere rather than a hindered one through because of these ground features. So, topography and surface features; they may create problem. If I am in the valley then I might be having this cortile view like this so something like this. Now this is similar

to the view you would have from the ground looking up on all directions; that is the fish eye view.

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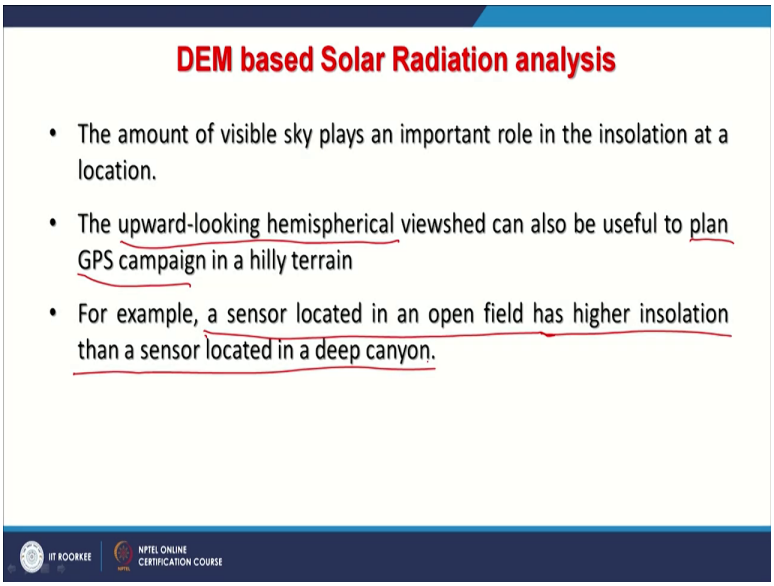


Now how much amount of visible sky plays an important role in the insulation at a location? So, this will play a very important role. Again, this upward hemispherical viewshed can also be used to plant GPS campaign in hilly terrain because for a GNSS or GPS based service, again you require you know sort of in that terminology say sky plot. So, you require an upward looking hemispherical and that should be clear.

As clear the sky would be or sky plot, you would have a better signals or signals from many satellites. So, if somebody is going in hilly terrain and area is fixed, one and you are having a quite reasonably good digital elevation model then before reaching the ground, one can really plan that what is going to be this upward looking hemispherical viewshed for the antenna of your GNSS device or GPS device.

So, there also similar kind of calculations can help this upward looking hemispherical viewshed. So, if a sensor located in open field like in case of GNSS, has a higher insulation then a sensor located in the deep canyon. Now instead of sensor, one can have a solar panel that is also in many ways, a receptor. So, it receives the solar energy. So, if it is kept in open sky or in open

area, definitely it will have more energy which will be reaching to that sensor or receptor or device.

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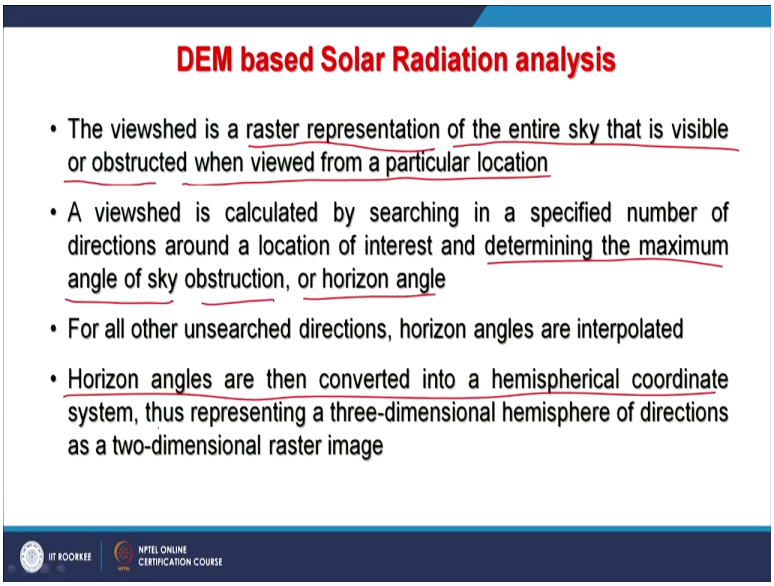


Now viewshed because we are handling in the raster or grid so this viewshed is basically raster representation because the basic input data is digital elevation model which is grid or raster. So, the viewshed is a raster representation of the entire sky that is visible or obstructed when the viewshed and from a particular location. So, you get a complete picture. Now, this is viewshed is calculated by searching a specified number of directions around the location of interest.

Now, one can search the entire sky or one can search in a particular direction. And this will determine the maximum angle of sky obstruction or horizon angle also. Whether parallel to horizon, you can get the signals or energy which is generally not possible. So, what angle you would like? Above horizon 5 degrees,10 degrees, this much. 5 degrees minimum; this cutoff is always required. Otherwise for edges, you will not have anything and for all other these unsearched locations or directions, horizons angles are interpolated.

So, all these things are done. Now this horizon angles are then converted into hemispherical coordinates system and thus representing the three-dimensional hemispheres of the directions of two dimensions raster image.

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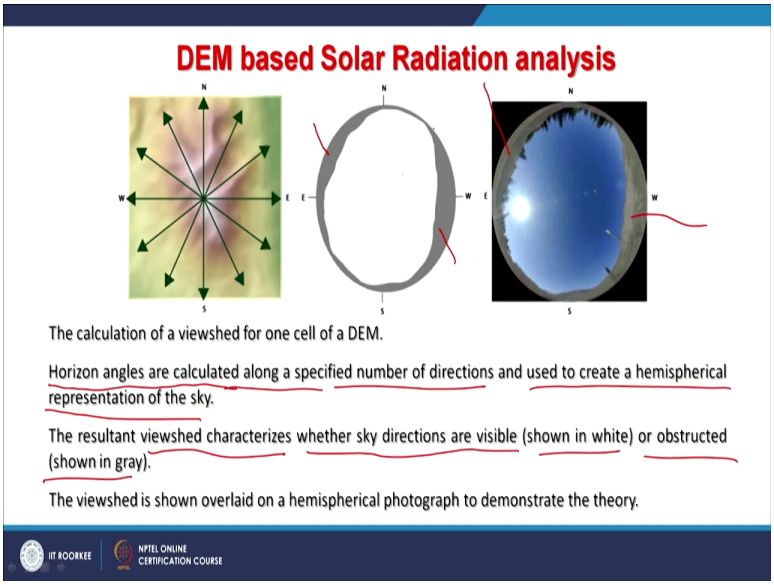


So, when I show the examples, these things will become further clear to us that further raster cell or grid cell of digital elevation model of the viewshed as assigned a value, that will represent the sky direction which is visible or obstructed. And then outputs cell location; that means the rows and columns correspond to the zenith angle, that is θ and this zenith angle is basically the angle relative to straight upward and azimuth angle with reference to the north; that is the α, angle relative to north on the hemisphere

Though it would be in raster form but the representation is little different than what we see. Now, when we involve a digital elevation model and this kind of estimations of solar energy. Here what we are doing that you know, there are so many directions. Instead of 8 directions, now we are having ad 12 direction here. So, for 12 directions, the calculation is being done and based on the location that means because digital elevation model is also providing the information about the terrain and that is why you are seeing that there are some shaded areas and some is the open.

So, that particular location, this is the open areas is having. And if we compared with this camera fish eye view, this is what we are seeing. So, these are the areas where hindrances or ground features are creating problem. So, with this input or start, now we can add a cutoff for this horizon angles which are calculated a specified number of directions whether you want to have all 360 degree or in a specified direction and used to create a hemispherical representation of the sky.

And ultimate you would get a viewshed characterizes whether sky directions are visible; shown in white or obstructed; shown in grey. And this is what here that this white part is completely visible whereas these grey parts are obstructed and this viewshed which you are seeing in the centre is shown over laid on the hemispherical photographs to demonstrate the theory. So, if you are having that fish eye, this is just to check but your estimations in GIS for solar upward hemisphere will provide this kind of output.

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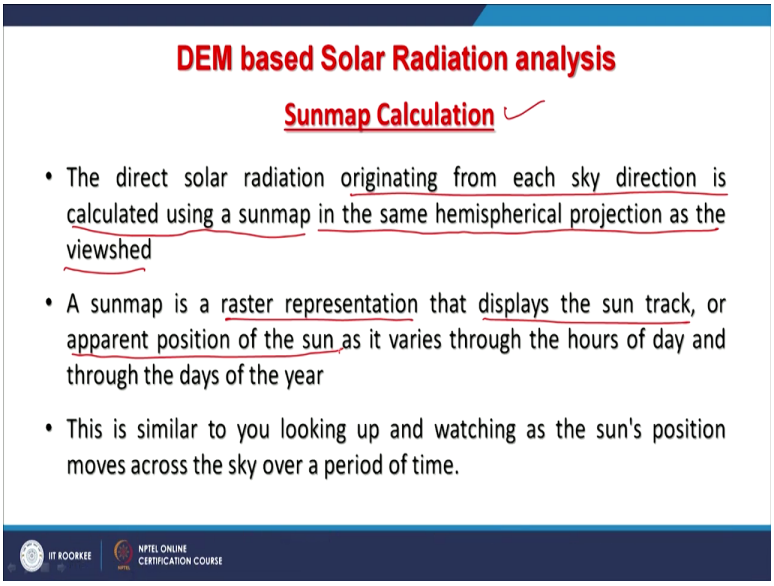


Now further in this calculation, we have to also calculate one important thing which is Sun map calculation. So, after getting this information about how much part is going to be obstructed because of features present or topography then next step is the Sun Map calculation. So, this direct solar radiation originating from each sky direction is calculated using a Sun map. Now remember this thing that the position of Sun is changing.

So, these are all dynamic things so that if we want more accurate estimation against particular location on an area then all those things have to be kept in mind by doing the calculation. So, in the hemispherical projection as the viewshed. Now this Sun map is again, everything is done in the raster. So, sun map is raster representation displaying the Sun track because now we are involving the Sun from morning to evening so that is why I was saying earlier that when you know relative to the earth, the position of the Sun keeps changing because Earth rotates.

So, the Sun track or apparent position of the Sun as it varies through the hours of the day and through the days of the year because seasonal effect will also play a very important role. So, these things are also considered while doing the Sun map calculation. And it is like similar to what you are looking up and watching as the Sun positions moves across the sky over a period of time. So, that Sun map calculation will consider all this; that is in the daytime, how the Sun is changing with reference to that particular location.

And also, in seasons because you know in winter season, Sun is having short distance from the earth and therefore you know there are changes.

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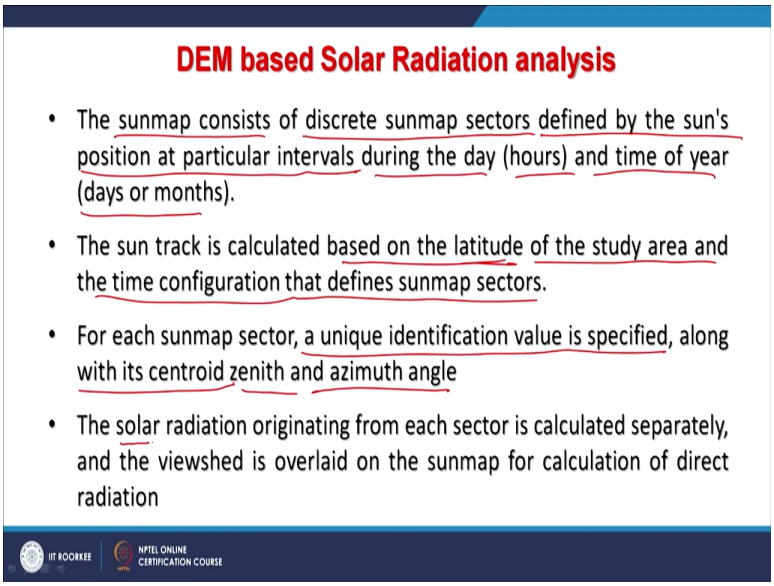


Now this Sun map will consist of discrete Sun map sectors defined by the Sun's position at particular intervals during the day, hours and time of the year. So this much information we will get from the Sun Map. And this Sun track is calculated basically. Sun Map will consists Sun track which is calculated based on the latitude where it is located your area of interest of the study area and time configuration that define Sun maps sectors.

And for each Sun Map sector, there will be sectors not like your cell but sectors in a viewshed and that is hemispherical viewshed or in that projection, a unique identification value is specified along with its centroid zenith and azimuth angle. So this much of information is very much

required because for any that location, then you will get all detail information. And then the solar radiation originating from each sector is calculated separately and then finally the viewshed is overlaid on the Sun Map for calculation of direct radiation.

Why Viewshed is overlaid because the hindrances which were being caused by the ground features or topography, they have to be also discarded because of you do not have the information or sunlight reaching from those area because of vegetation topography and other thing. So, then it is overlaid. So, this is what you are seeing.

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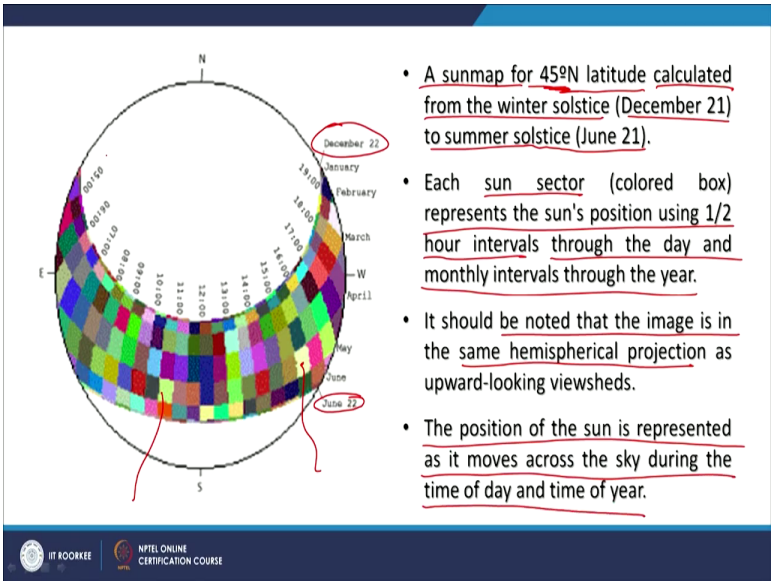


This is a Sun map for North 45-degrees latitude, calculated from the winter solstice; that is the December 21st to the summer solstice; that is June 21st. So, between these as you can also see so after this you are having June 22 and you are having December 22nd. Now in between all the sectors are representing all that information which we have just discussed. Of course, the hindrance part is not yet here; the effect of topography and features which will also come.

So, each Sun sector; these are the Sun sectors which you are seeing here, each rectangle which are different colours represent the Sun's position using half hour intervals. Every half an hour you are having because if we go for less than in this half an hour then you will have you know, maybe of less size of this rectangle or square and so Sun's position using half hour interval; every half an hour, you are having through because if we go for less than this half an hour then you will

have you know may be of less size of these rectangles or squares so Sun's position using half hour interval through the day and monthly intervals through the year.

So, all this information will be generated and here we noted that the image which you are seeing, is the same hemispherical projection of course because we are projecting using this hemispherical concept because the point here is that it is upward looking hemispherical. So, that is why everything will be in the same projection as a upward looking viewshed. Now the position of the Sun is represented as it moves across the sky during the time of the day.

So different timings are there. See this is 0, 0, 50 and then here you are having 19 hours in the evening time. So how it will move; the position of the Sun is represented like this. So, you get both information that in a year, how things will change and, in the daytime, how things will change throughout the day. So, if I take an example of you know, it is given here. So, if I start of course like 10 o'clock; 10 A.M.

Now 10 A.M. say in month of February or March or June or say in the May so that means this is the position of the Sun in the May. So, this is how you will get this Sun map will depict all these details here. Hindrances are not here, that will also come.

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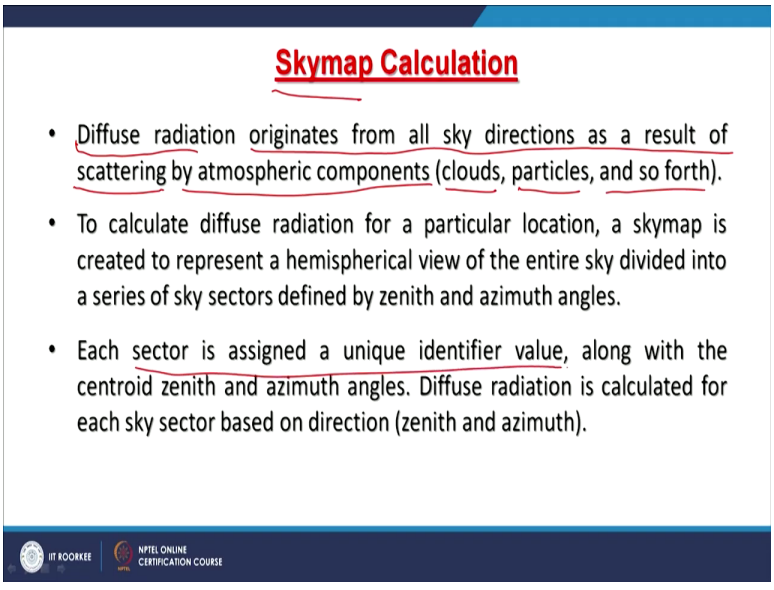

Now sky map; this is the same term which is used in GNSS technology or GPS is that how much sky is open. So, this diffuse radiation originates from all sky directions as a result of scattering by the atmospheric components and these components I have already discussed are like for example clouds, dust particles or gases or other particles also. So, the calculation of this diffuse radiation for a particular location, a sky map is created.

And a sky map is nothing but the upward looking viewshed to represent a hemispherical view of the entire sky divided into series of sky sectors defined by zenith and azimuth angle and that you will see. And each sector is assigned a unique identifier values along with the centroid zenith and this. And this diffuse radiation is calculated for it. So earlier we have been calculating for direct radiation. Now, we are calculating for diffuse radiation because the final product, final calculation has to include both.

Or rather if more accuracy is required, all three components of radiation; that is direct and diffuse and reflected also. But in order to model that reflected part, that is not easy because it depends on the surface condition like given in the example of the snow or Glacier covered areas, the reflection may be different in a forest cover area, refraction may be different in bare grounds; that reflection is going to be different.

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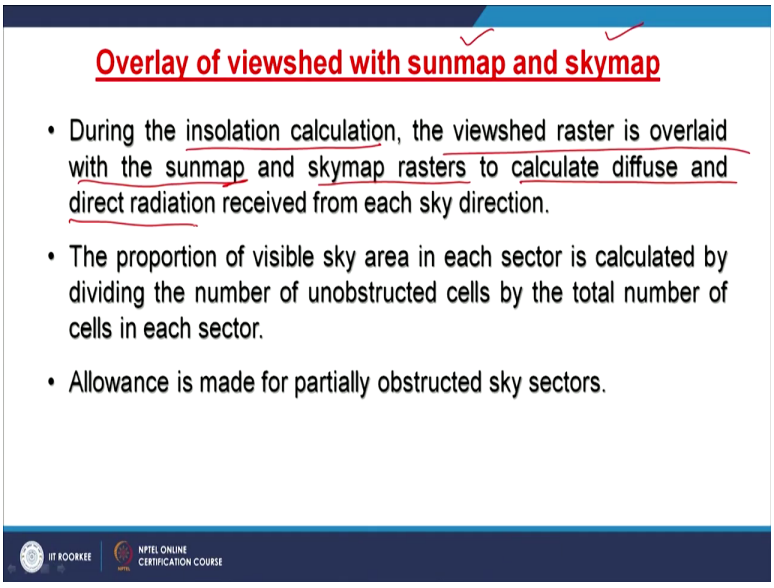

So, for entire 360 degree, a sky map with the sky sector defined by 8 zenith divisions which are there and 16 azimuth division are there. So, one is this division then azimuth division, another one, another one, another one likewise. And 8 means if you start from centre 1, 2, 3, 4, 5, 6, 7, 8 so these are the 8 divisions. So now you are having sky map and you are also having Sun map, you are also having viewshed. Only thing now these things have to be combined now.

So, each colour as you are seeing in the left image, is a sky sector or portion of a sky from which diffuse radiation originate. Just recall that when we have been discussing about direct radiation, we had a limited hemispherical projection for direct radiation because it is not available from all directions. That is why it is just a band in this viewshed available to us. Whereas when we come to this diffused radiation then it is being estimated from all directions.

It is assumed that diffuse radiation will reach from all directions so that is why this kind of calculation is being done. So, now overlying the viewshed; that viewshed which was representing our hindrances with the Sun map and sky map, when we overlay all these three on a GIS platform so that means during the insulation calculation, the viewshed raster is overlaid by the Sun map and the sky map raster to calculate diffuse and direct radiation received from each sky direction.

And the portions of visible sky area in each sector is calculated by dividing the number of unobstructed cells by total number of cells in each sector. And this will basically allow us to made for partially obstructed sky sectors.

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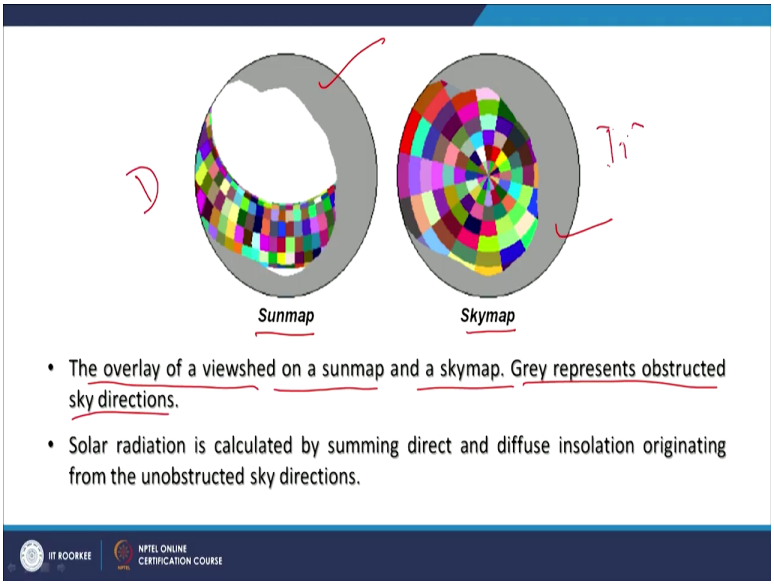


So, this is our Sun map with obstruction information and this is our sky map again with the obstruction information. So, when we overlay all this so overlay of viewshed on a Sun map or in a sky map, of course the grey areas represent the obstructed area. So, solar radiation; this is for the direct and this is for the diffused. Now, the solar radiation is calculated by summing of direct and diffuse radiation. Of course, one more component that is the reflected one but somehow it is not easy in this modelling part to do that.

So that insulation originating from the unobstructed sky directions. So obstructed part is already shown in grayscale. So, whatever the open sky is there or unobstructed sky is there; that is one which we are getting. So, with this, we can get very detailed information about from where the direct solar radiation will be reaching to a particular point location or an area for which the calculations can be done including about the obstructions.

And same with the sky map; from where things would be available and not. And again, you can overlay with the obstruction map also or that viewshed.

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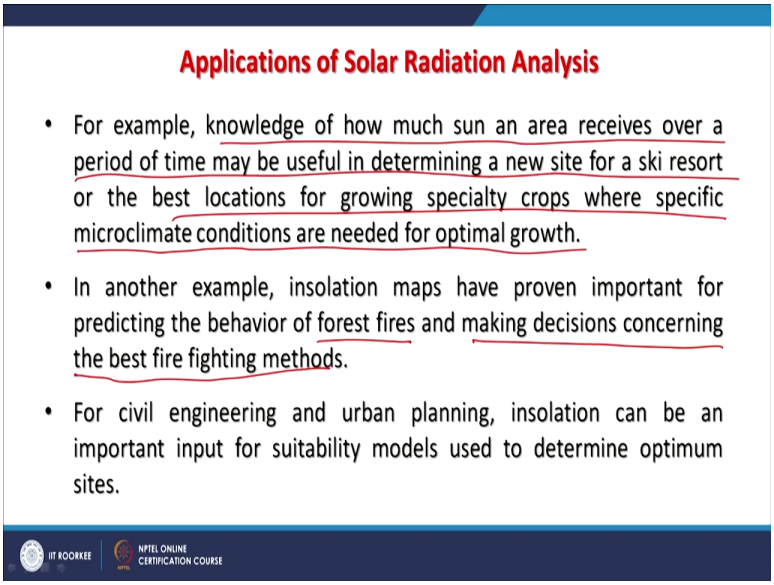


So now what are the applications? Some of the application, we have already touched but nonetheless for completeness, I will go one by one that this incoming solar radiation; that is insulation is basically driving force of the Earth physical and biological system. And knowledge, if we are having good information about any area, this kind of information about direct or indirect solar radiation then that can really help to do lot of other work for energy generation or thermal or other part.

So, the amount of insulation at its specific geographic location is helpful for applications of diverse fields. Even nowadays people who are developing resorts in hilly area, they too are interested to know that how much Sun radiation and when they will get. You know that is very-2 important especially where the cold months are many; you know for about 6 months or 8 months you are having winter and therefore the Sun becomes very-2 important.

So, applications are in the landscape ecology, in the meteorology, even in agriculture because for agriculture practices, you require Sun. So, if somebody is developing a farm like that and in hilly terrain where topography can create hindrance then that modelling can also be done. Of course, environmental modelling, agriculture and forestry, I have just mentioned and solar energy generation estimation, there it is being used maximum.

And of course, for GPS campaign in hilly areas which people can plan before really, they reach to the ground. So, they will know what kind of sky plot or open sky, they will have. What kind of hindrances they are going to have? Of course, this is not an exhaustive list. New applications will keep coming and these one. Now applications of this solar radiation further which we are having that knowledge of how much Sun and area receives over a period of time may be useful for determining new sites for ski resorts.

Because how long, this snow will remain in that area will also depend how much Sun it receives. And best locations for growing specially crops where specified microclimatic conditions are needed for optimal growth. And another example of this solar energy or solar insulation map as that is important for predicting behaviour of forest fire because there are also, it provides heat and that can also create sometimes natural forests fires so that also can be assessed.

And making decision based on that information for the best firefighting method so for that purpose also, it can be done. Now in the civil engineering and urban planning, insulation can be important. Input for suitability model used for determining optimal sides. Nowadays there is a demand for geo-energy or low energy buildings or infrastructure and that in day time for lighting purpose if we can have, wonderful.

Even in cold areas if heating can be avoided or with minimum heating things can be done with the solar insulation, that will be again wonderful. So, lot of now emphasis on that how to design buildings or these Infrastructures which will require the minimum energy and maximum dependence can be made on solar.

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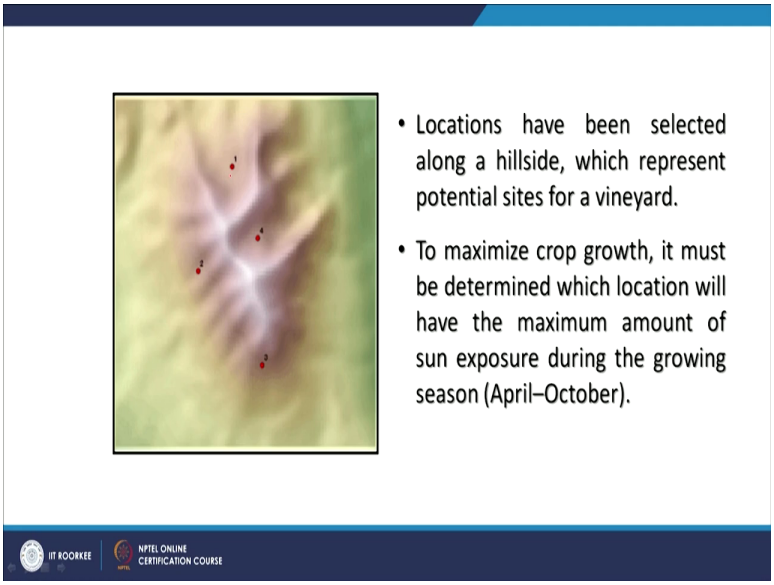


Now if I have to do it on multiple locations, that can also be done like here there are four locations have been chosen and maximum crop growth must be determined.

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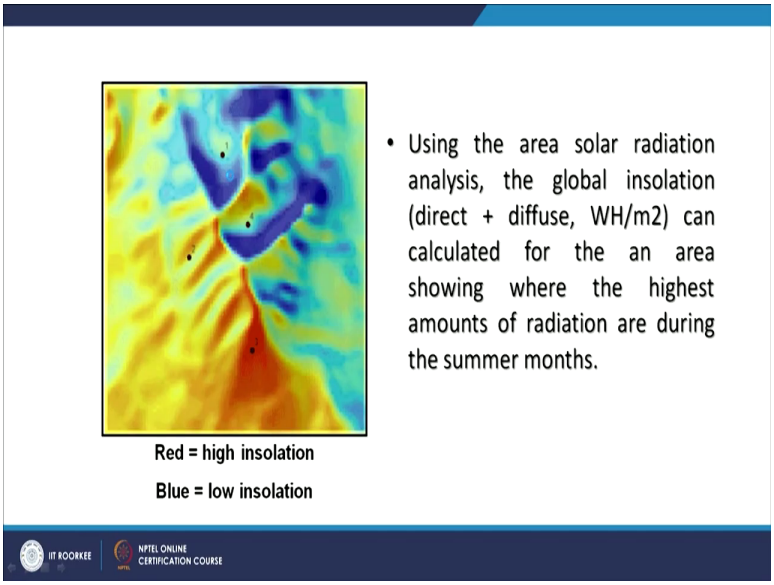


There are many other such applications are there and one can have the direct and diffuse radiation calculation for multiple locations. Of course, the season will also play a very important role.

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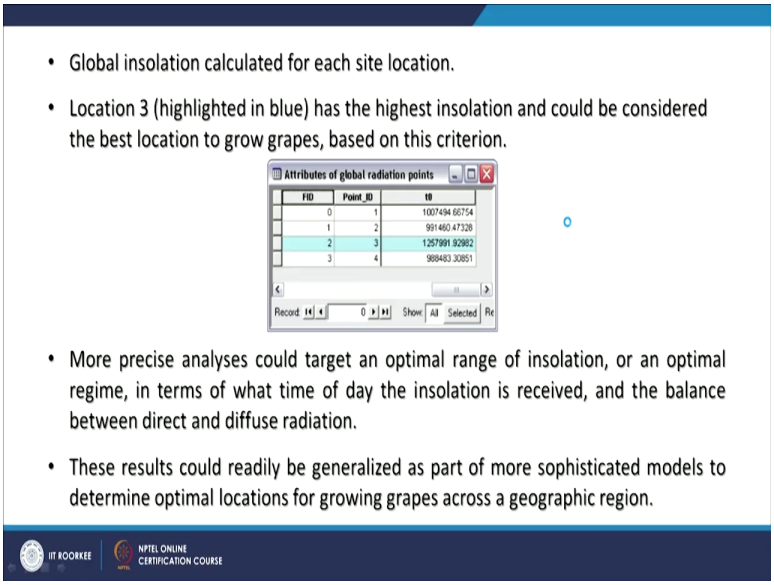


Now, this global insulation calculations for each side located can be done. So, like here, we get the analysis for all these sides which I am just shown in the previous diagram. And if we want more precise analysis, of course always there will be requirement of high-resolution digital elevation model and more detailed information about the features and other things. If that information is available and land use, especially the height of the objects which are surrounding, not only the topography or natural objects but artificial objects.

So, if that information is there, more precise calculation also be done. And basically, all this precise analysis result to readily be generalized by part more sophisticated models to determine optimum location for growing grapes across a geographic region. So, for different kind of crops, the requirement of Sun is different and therefore such things can also be planned.

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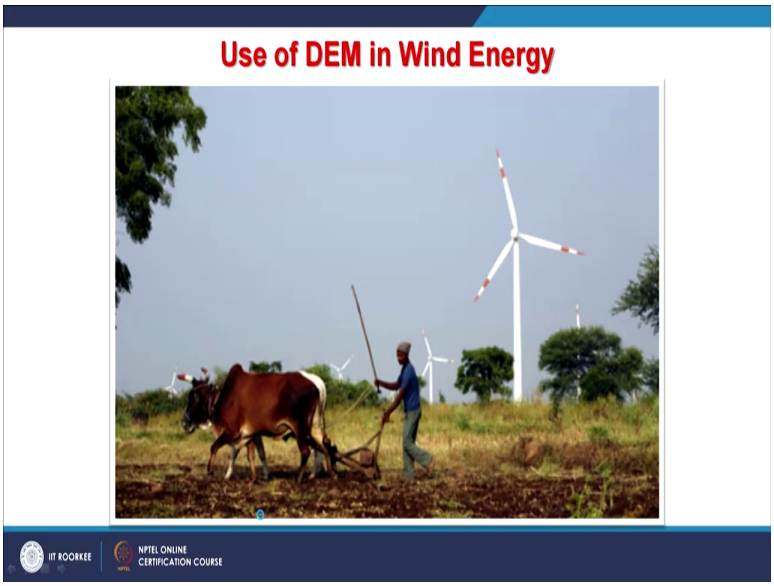


In the last few more minutes, I would like to spend on wind energy because in a hilly terrain again because this topography will play a very important role in case of hilly region. In flat area, things may be different.

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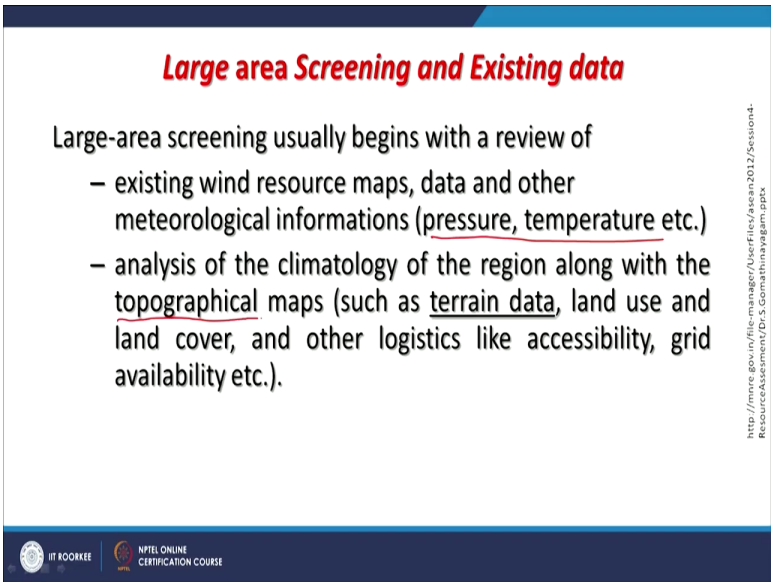


So, wind energy; the larger areas are screening that can be done usually begins with a review of existing wind resources maps, data and other meteorological information. Meteorological information especially about the prevailing wind direction and wind speed and other information's might be atmospheric pressure, temperature etc. And then this analysis of

climatology of a region along with the topography so there come the role of a digital elevation model that terrain data is very much required.

If it is a flat terrain, I am telling that then it may not play a very important role but if it is a hilly region, obviously it will play very important role.

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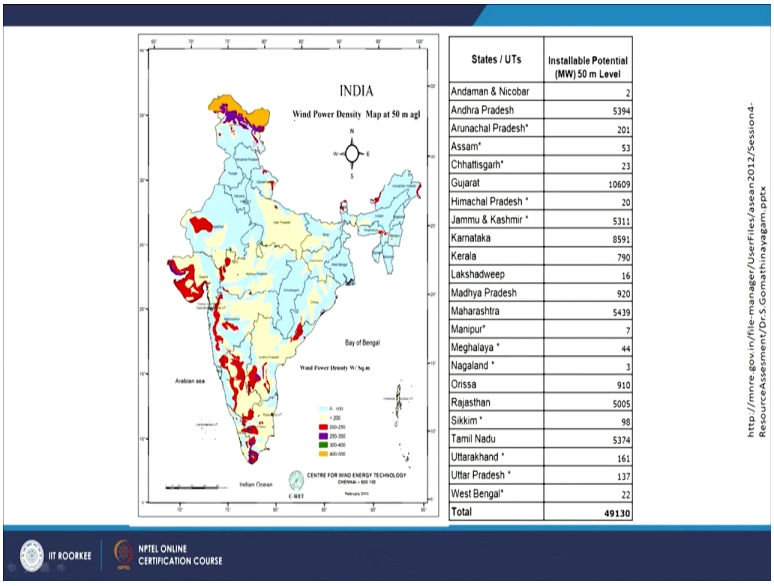


| States / UTs | Installable Potential (MW) 50 m Level |
|---|---|
| Andaman & Nicobar | 2 |
| Andhra Pradesh | 5394 |
| Arunachal Pradesh* | 201 |
| Assam* | 53 |
| Chhattisgarh* | 23 |
| Gujarat | 10609 |
| Himachal Pradesh * | 20 |
| Jammu & Kashmir * | 5311 |
| Karnataka | 8591 |
| Kerala | 790 |
| Lakshadweep | 16 |
| Madhya Pradesh | 920 |
| Maharashtra | 5439 |
| Manipur* | 7 |
| Meghalaya * | 44 |
| Nagaland * | 3 |
| Orissa | 910 |
| Rajasthan | 5005 |
| Sikkim * | 98 |
| Tamil Nadu | 5374 |
| Uttarakhand * | 161 |
| Uttar Pradesh * | 137 |
| West Bengal* | 22 |
| Total | 49130 |

Now this is you know wind power density map or it's a potential kind of thing. So, this is the wind power which is available in different parts of the country. As you can see that the maximum part is available which is the wind which is coming from Arabian Sea. So, you see many parts of Gujarat and then Maharashtra and other states like Tamilnadu and Kerala; all those parts. And also, a large part in Rajasthan; their lots of wind farms have come and there you can see that this is the potential which has been estimated.

Of course, in this calculation, the digital elevation model has played a very important role but if somebody is doing this kind of calculation or estimation for a country level like for India say basically like a continent therefore it must have been done on relatively low-resolution digital elevation model. But for a particular site like if we focus on the Uttarakhand part, there are few areas. So that means that if I want to make sure that if I am going to invest for wind energy in this area, I will do the analysis again with high spatial resolution digital elevation model and then will get more accurate.

But overall a map is quite useful that these are the regions of India which is having a good potential for wind energy.

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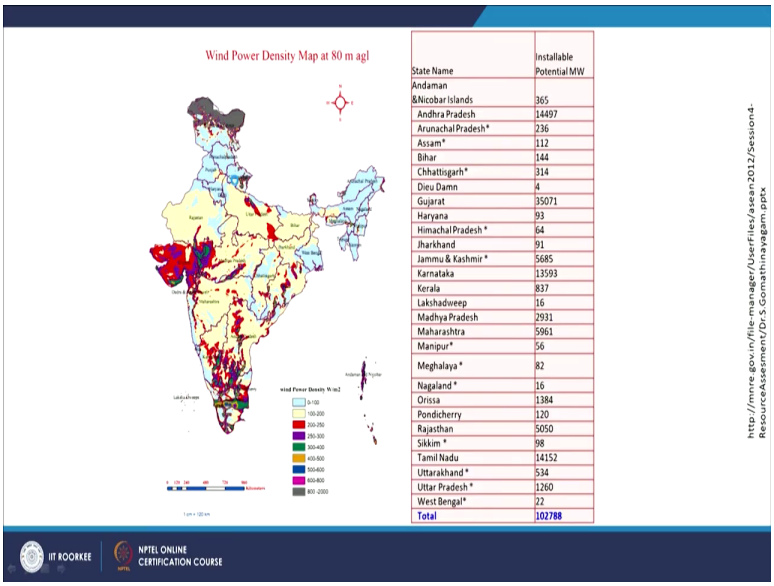


| State Name | Installable Potential MW |
|---|---|
| Andaman &Nicobar Islands | 365 |
| Andhra Pradesh | 14497 |
| Arunachal Pradesh* | 236 |
| Assam* | 112 |
| Bihar | 144 |
| Chhattisgarh* | 314 |
| Dieu Damn | 4 |
| Gujarat | 35071 |
| Haryana | 93 |
| Himachal Pradesh * | 64 |
| Jharkhand | 91 |
| Jammu & Kashmir * | 5685 |
| Karnataka | 13593 |
| Kerala | 837 |
| Lakshadweep | 16 |
| Madhya Pradesh | 2931 |
| Maharashtra | 5961 |
| Manipur* | 56 |
| Meghalaya * | 82 |
| Nagaland * | 16 |
| Orissa | 1384 |
| Pondicherry | 120 |
| Rajasthan | 5050 |
| Sikkim * | 98 |
| Tamil Nadu | 14152 |
| Uttarakhand * | 534 |
| Uttar Pradesh * | 1260 |
| West Bengal* | 22 |
| Total | 102788 |

Similarly, this wind power density map at 80-meter agl (above ground level) is also because these wind turbines; they are generally installed above the ground because at the ground level, the wind energy may be different whereas at 80-meter, the wind energy may be different. So, basically offset in this whole topography has been added because there will be hindrances because of forest or other things so that offset map is also there which is again, it is basically enlarging the area.

So, if you compare the previous maps say if concentrate only on the Gujarat part so at 50-meter ground level, this is the situation and at 80-meter ground level, almost entire Gujarat is having great potential. So, basically the purpose of GIS is to model things, to predict things for different scenarios. Here 2 scenarios; 80-meter and 50-meter. So, if wind turbine is installed at 80-meter height then almost entire Gujarat can be exploited.

So, of course the cost will be different so in the coastal areas, 50-meter height turbine would be sufficient but here it is 80-meter. So definitely at 80-meter, the potential increased significantly in some areas.

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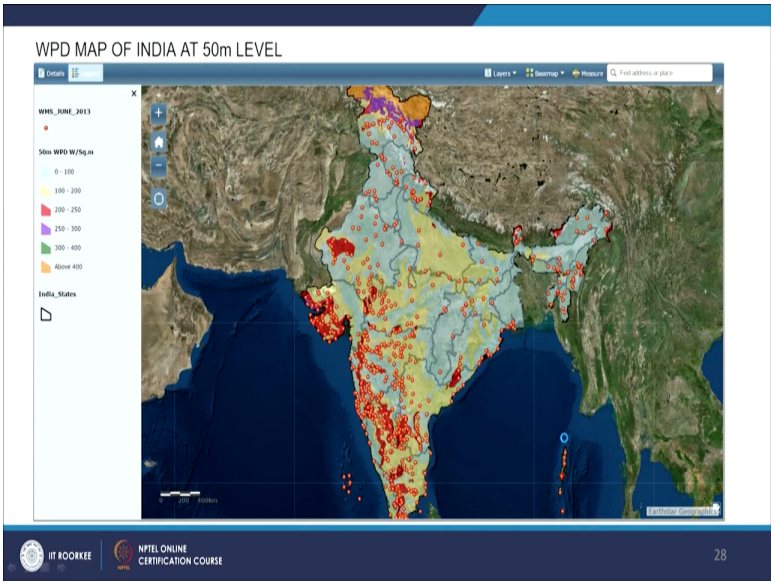


So basically, this WPD (wind power development) map of India at 50-meter level, this you can also see the updated one on the Internet.

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And also, wind turbines are shown here that how the topography affects in certain region. So, topography plays a very-2 important role. As you can see that all Hills are there. So, in order to exploit that wind along the hill or foot hills, this is what the wind turbine have been put there. Even in the valleys, there sometimes this effect is there of energy which I have observed near Lakshman Jhula.

In early morning hours, every day there is a good wind and then by 9 o'clock or 10 o’clock, things settle down. Even if energy can be exploited for few hours in a day, what is the problem because after all it is a free energy; renewable energy. So, wind energy is a very-2 important like solar energy; these are renewable. So, you have got this so much potential in India especially about the Solar. Further it can be exploited by employing digital elevation models and GIS. With this, I end discussion. Thank you very much.