Remote Sensing: Principles and Applications
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Lecture-67
Application of RS in Water Resources Management-Part-4

Hello everyone, welcome to the final lecture of this course remote sensing principles and applications. Here we are going to discuss further about applications of remote sensing in water resource management. So, we already discussed retrieval of evapotranspiration and soil moisture, now we will briefly discuss mapping and monitoring of open water bodies and limitations of remote sensing in water resource management.

The mapping of surface water bodies is one of the vital topics not only for water resource management but also for environmental monitoring. Because with rapid urbanization and encroachments happening, many places are reporting loss of water bodies like number of lakes are shrinking or the aerial expansion of water bodies are shrinking and so, on. So, monitoring this is really vital.

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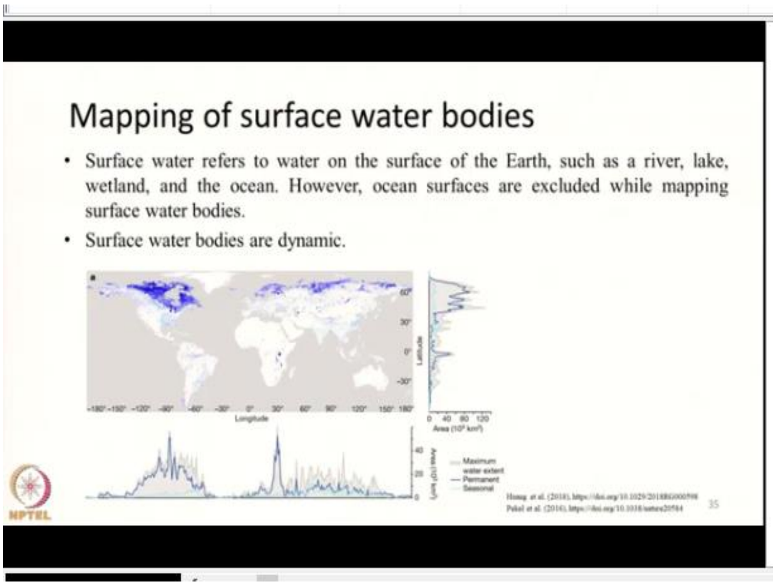

So, surface water refers to what is present on the top surface like rivers, lakes, wetland and ocean, but normally oceans will be excluded when people try to monitor surface water bodies. Because our concentration will be on mapping and monitoring whatever present within land, say inland water bodies or the wetlands basically. So, these surface water bodies are highly dynamic in nature like the lakes aerial extent may change, the depth of water will change everything will happen based on the availability of rainfall, water inflow to the lakes and so on.

So, these are highly dynamic and because of their importance, several studies have been carried out for the mapping of surface water bodies, both at global scales and at local scales. So, we will discuss optical remote sensing for surface water mapping.

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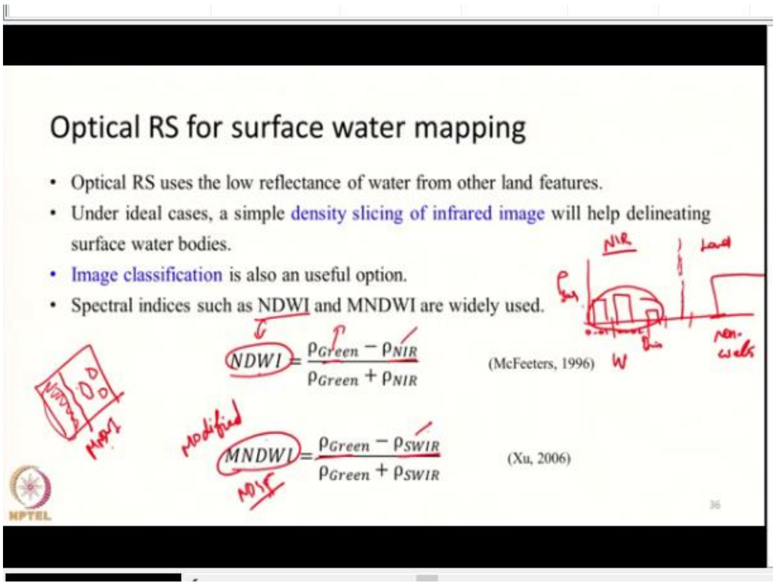

Optical remote sensing uses the large change in reflectance between land surface and water bodies for mapping it. We already know that whenever a water body is present, the reflectance in NIR will be very low. So, we will try to use this equation with the NIR as well as SWIR bands. We will try to use this difference and take it to our advantage for mapping water bodies. So, if all conditions are ideal, we will get a perfect image without any sort of sun glint. Whenever sun is directly overhead of a water body we may get a bright spot on the image. If both the zenith angle of sun and the sensor is more or less the same, then a specular reflection will happen which may actually affect the reflectance that we measure, it will appear like a very bright spot. We call it as sun glint.

If those things are absent and if the image is perfectly clear without any sort of turbidity, then even a simple density slicing of infrared image will help us in delineating surface water bodies. We know land features has higher reflectance in the infrared portion either NIR or SWIR when compared to water bodies. If you plot a histogram which is nothing but the frequency distribution of the DN value, let us say we have surface reflectance, this is the different bins let us say 0 to 0.1, 0.1 to 0.2 and so on. So, we have divided into several bins. In each bin, we will count the number of pixels having a certain range. Let us say water bodies may be falling somewhere here and then land may fall somewhere here. So, it can be clearly delineated water bodies will have lower reflectance and land features will have higher reflectance. So, if you put a threshold, if the reflectance is less than a certain value, then classify the lower reflectance values as water, other values as non water bodies.

That is all water this is all non water, it is kind of a binary map. This is the simplest way in which we can use infrared images for mapping water bodies. This is under ideal conditions, but this may not always work and that is why people have developed spectral indices such as NDWI normalized difference water index relating green and NIR or green and SWIR. This is NDWI or MNDWI, modified normalized difference water index. Water has higher reflectance in green and lower reflectance in NIR and SWIR, using this characteristics, people have developed indices for identifying open water bodies. Again, these indices have proven successful for identifying water bodies; normally they will have positive values for water bodies and negative values for non water bodies.

But the threshold can vary based on region to region and the quality of data we are using. So, these are sort of indices which will directly tell us, whether it is a water body are not. The only problem using MNDWI is if you recall, it has same definition as that of NDSI normalized different snow index. So, if we want to map open water bodies under areas or regions, which also has snow, then both snow pixels and water pixels will be highlighted because of their reflectance characteristics.

Let us say we have an image that has some sort of high mountains containing snow, then there are lower valley portions which has some lakes, if we apply this MNDWI over that portion, since the definition is more or less equal to NDSI both snow pixels and water pixels will be together highlighted Hence, just using MNDWI may not be suitable for such regions; we have to bring other information. Using NDVI or NIR band data may prove worthy in order to delineate snow cover and water bodies in such areas. So, many studies have used such simple indices to a good successful extent for identifying water bodies.

However, one of the major difficulty in using such indices is identifying a threshold, threshold means say less than this value non water body, more than this value water body. So, identifying that particular threshold is of paramount importance and any errors in identifying that threshold may actually lead us to miscalculating the extent of surface water bodies.

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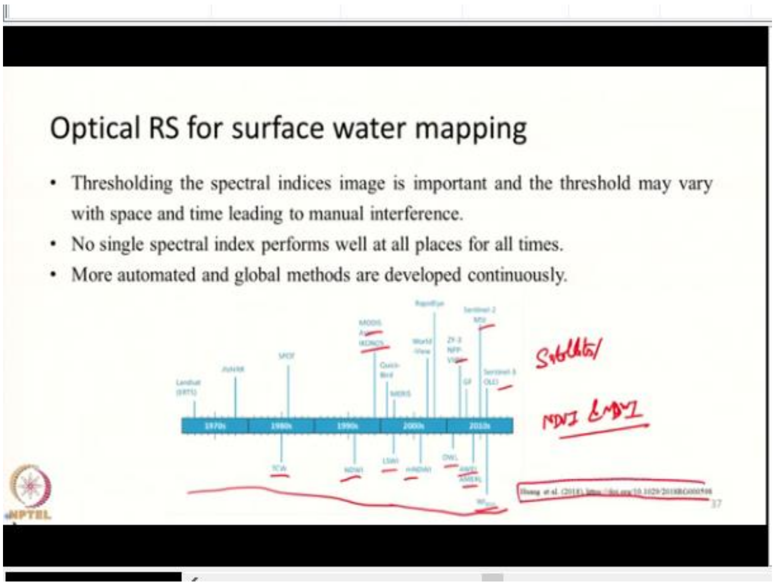

So, this is kind of a manual process and in order to overcome this, several researchers have improved these indices or developed new indices from these reflectance values and this can be seen in this particular slide which shows different indices present on the year in which they were developed. Similarly, what are all the satellites that were launched from which these indices can be obtained.

So, the top part of this line gives the satellites or the sensors which provide the data for the different indices are all given here. And people have even used a combination of NDVI and NDWI in order to retrieve open water bodies. So, there are different ways and different thresholding methods have been used, but only one problem is no single spectral index has been found to perform well globally and at all times.

So, essentially, the studies are regional and global studies have been carried out using some sort of machine learning or AI based tools. Even I told you about a Google Earth Engine platform, which mapped global water bodies using the algorithms present there. So, this field is actually continuously evolving, where people are trying to use the upcoming computing technologies as well as new satellite data for retrieval or for mapping open water bodies.

So, one of the references given here will tell you a broad overview about the subject. And then the global surface water map, which is again published as a paper also uses Google Earth

Engine platform. So, these are some studies which highlight the different ways in which we can map open surface water bodies.

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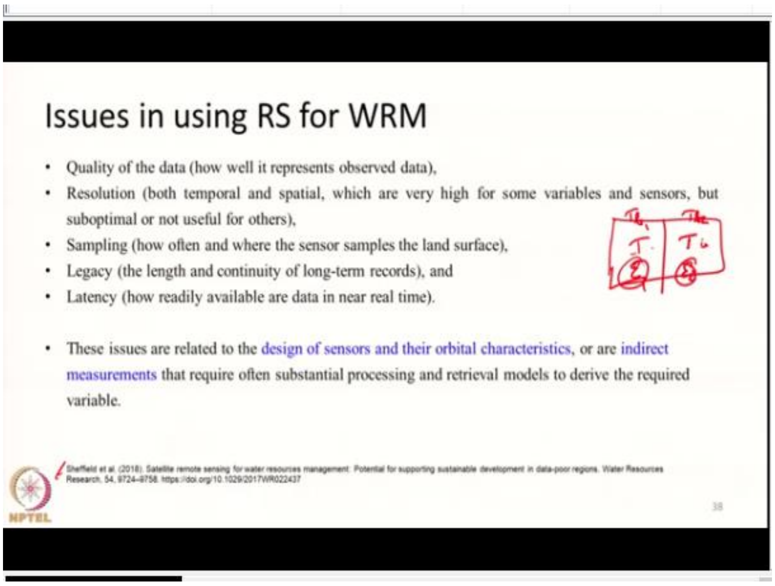

So, in remote sensing for water resource management, there are plenty of applications which we are not covering for the want of time and also for the want of background information that we need to discuss before we go on to the real applications. So, we are kind of wrapping it, but before that we will see the issues of remote sensing in water resource management. The first thing is the quality of data, how well the satellite data matches with the variable that we want. Say we measure reflectance from optical data, temperature from thermal infrared, all these things.

How well it matches with our variable of interest, say if you want to measure precipitation, what wavelength to use and how well those wavelength matches, all these things needs to be observed. Or if you read the review paper given here, in this particular slide, it will tell the different variables and the different satellites available to us. So, from which you can understand retrieval of different variables actually requires different types of sensors like passive microwave, active microwave, thermal, optical and also specific characteristics of the sensors in order to improve the data collection by the satellites along with the variable which we need to measure. So, that is one thing.

Second thing is the resolution both spatial and temporal, how frequently the data is collected? Say soil moisture changes very frequently, can we get it every day or twice a day and so on or at which resolution are we getting, at field scale or are we getting at like 10s of kilometer of resolution. That is again an issue which people are always trying to have. Some data may be very good in quality, but the resolution may not be optimal, the passive microwave retrieved soil moisture or some data will be of very high resolution, but it may not be of good quality due to other error. Say, due to some nature that thermal infrared might not have got the ET properly or the active microwave remote sensing might not have got the soil moisture information properly due to the missing information for other variables.

All these things might have happened. And sampling is how often the sensor sample the land surface, again that is related to temporal resolution, but if the sampling is frequent, we may get frequent data. Even sometimes if you want thermal datasets frequently, maybe MODIS samples earth almost twice a day, two data points we may get or if we combine two MODIS sensors, we may get 4 data points in a day. But the problem is, are those 4 data points are free of cloud, if clouds were present over our study region, then all those 4 points will not be useful to us. So, the sampling as well as the availability of data influences the variable retrieval and our applications.

Then the legacy of data, how long the time series of data we have. Say for some applications like drought monitoring, we need to have a longer time series, but some variables are actually being measured only recently. Say, soil moisture from passive remote sensing using L band radiometers have developed widely from the year 2009 after the launch of SMOS. Before that, there were other satellites that were in orbit, but they were not L band. So, there has always be some sort of mismatch when you try to compare the soil moisture from some other bands with what is returned from SMOS or SMAP. So, the data length is actually kind of a problem. We may be requiring at least 10 years of data, but data may be available once only for 5 years and so on.

The time period between satellite observation over a region and the actual product release for that particular day is called latency. So, for most of the applications, we may be requiring data very soon, like after 2 to 3 days of satellite overpass or for some sort of real life events like floods or droughts, the latency time should be very low, within a few hours of satellite observation, we may need to have data. So, again this latency plays a major role. So, these are some of the things we need to keep in mind while using remote sensing datasets for water resource management.

All these issues are related with the sensor characteristics which means the spatial, spectral, temporal and radiometric nature of sensors along with the orbital characteristics. All these things will influence the type of data we collect, the sampling that we do and also the launch of sensors and the availability of sensors will determine the legacy and so on. And also, only some variables can be directly observed and most of the variables in water resource management cannot be directly observed. We need to do some sort of retrieval process using some sort of modeling.

Both evapotranspiration and soil moisture are not directly observable. We need to use retrieval algorithms and there can be plenty of uncertainties within the algorithm themselves. The data may be of good quality, but the retrieval algorithms may not be performing well. So, again our applications will suffer. So, this is not a simple task. Even though we know this can be used, we need to be really careful in selecting a suitable sensor for our applications.

One very good example is if you look at the overpass time of soil moisture dedicated missions like SMOS or SMAP, they will be over passing in sun synchronous orbit around 6 AM or 6 PM local time not at during midday or early, it will be early morning and then evening. That is because of two reasons; one is to reduce Faraday rotation effect. And other thing is during early morning hours, we have already seen that there will be thermal crossover. During pre dawn early morning hours, the temperature of different objects on earth's surface will be very close to each other and hence thermally they will not be differentiable. At that time these satellites will try to overpass because our aim is to get emissivity. So, if all the objects are at same temperature then the brightness temperature observed will vary only based on emissivity of the object.

Let us say you have a big region. let us assume you have 2 pixels with both of them are at almost similar temperatures, but this gets a brightness temperature T_{B1} and this gets a brightness temperature T_{B2}. If the temperature of them is very close, then the difference in brightness temperature can be directly attributed to emissivities of the pixels. Say this can be dry having a high emissivity; this can be wet having a lower emissivity. So, in order to get this optimal condition for getting emissivity we do this, but if we want to actually get temperature for evapotranspiration mapping, we cannot use this particular data. When all the objects are at same temperature, we need to get proper temperature of the surface or different features present over there.

So, there are different things we have to keep in mind. So, these satellites are dedicated for the application, their orbital characteristics are chosen suitably, but if you want to use some of the satellite in olden days 2000s we had a AMSR-E, it was useful in retrieving soil moisture. But it will overpass at afternoon time, where the temperature will be highly differing, there will be some sort of errors; the wavelengths will not match with L band frequency and so on. So, all these things play a major role in the quality of the data that we get and also the applications we do. So, with this we end this particular topic, applications of remote sensing in water resource management.

Applications of remote sensing are plenty and there can be different fields like geology, urban studies, environmental monitoring, water quality and it is close to impossible to cover all the applications. As I have already told you, when want to discuss applications definitely we need to discuss the background domain information before we go on to that which will require several courses in order for us to cover it. So, the aim of this course is just to provide you a feel for the different ways in which remote sensing datasets can be used. I broadly touch different datasets like optical, how it is used for land use, land cover mapping, thermal data, we discussed about evapotranspiration mapping using surface energy balance equation, passive and active microwave for soil moisture and Lidar, I just briefly mentioned their needs in cryospheric monitoring and vegetation monitoring, topographic mapping and so on.

So, it is kind of extremely broad overview of applications. Some students taking this course maybe from water resource background, some maybe from earth science, some maybe from ecological background and so on. So, combining these remote sensing principles along with your own domain knowledge, I am very sure that you can definitely come up with your own applications, there are plenty of study material available in the internet and also scientific literature is now increasing rapidly. And it is only up to us to choose the best in order for us to develop our own knowledge and get practice.

So, with this we end this particular lecture as well as this particular course. I hope the students would like the course. The contents of the course would have been useful to you. And I wish you all the very best and I appreciate your interest in this course.

Thank you very much.