

## Slide 1 – Title Slide

Hello and welcome to Week 12, part 2 of EGM310: Water Resource Applications. In this lesson, we will learn about how we can use remote sensing to study different aspects of water.

## Slide 2 – Remote sensing of water

Remember that most electromagnetic radiation is absorbed within about 2 meters of the surface of water, depending on the wavelength. For infrared light, there is very little penetration below about half a meter, while for visible blue or green light, we can get penetration down to 20 m depth under the right conditions (normally calm, clear water). Suspended sediments or other particles, or chlorophyll from phytoplankton will determine how much light is reflected, and at what wavelengths. In thermal infrared wavelengths, we can also measure water temperatures, at least at the surface; In microwave wavelengths, we can measure the surface roughness, at least relative to the signal wavelength; we can also learn things about the composition – what other substances might be present on the surface. On land, we can also measure soil moisture.

## Slide 3 – Mapping water

We've discussed this somewhat already last week. One of the ways we can map the extent of water bodies is by calculating an index. The first way that we talked about is the normalized difference water index, or NDWI. This is calculated by subtracting the near infrared band from the visible green band and dividing by their sum – it works, because most land surfaces have higher or similar values of reflectance in the near-infrared and green bands, while water has a significantly higher reflectance in the visible green. The NDWI will have positive values for water surfaces, and negative or near-zero values for most everything else. Built-up areas can pose issues for estimating the NDWI, however, which led to the development of a modified NDWI. In this, the shortwave infrared reflectance around 1500 nanometers is used, rather than the near-infrared. This helps reduce some of the noise, and improve the extraction of water pixels. But, this can pose significant issues with selecting a threshold, which led to the development of the Automated Water Extraction Index, or AWEI. The AWEI combines multiple bands, including the shortwave infrared, near infrared, and visible bands. Each of these methods requires choosing a threshold to classify 'water' and 'not water' – the images I've shown here are all presented using the default values, and you can see from these images that there are significant differences in the areas of water mapped.

## Slide 4 – Water levels

To estimate water volumes, we need to know the surface elevation of the water body. We can do this using satellite altimeters – this could be a radar altimeter, as is used to map the ocean surface elevation; for smaller water bodies, we can also use laser altimeters or LiDAR, including NASA's Ice, Cloud, and land Elevation satellites. The example here shows ICESat-2 data – you can see that the laser can estimate the height of ocean waves, and can even measure bathymetry in shallower waters under the

right conditions. If we also have a digital elevation model, or DEM, we can even estimate things like flood depths and volumes – by mapping the flood extent, we can intersect this with the elevation model to find the surface elevation, and subtract the initial elevation to estimate depth. We can also estimate lake or reservoir volume, especially if the bathymetry is already known.

## **Slide 5 – Example: Floods**

One example application of using remote sensing to study water is in the detection and observation of floods. In February 2020, Storm Dennis struck northern Europe, including the UK and Ireland. It brought high winds and significant rainfall, causing significant flooding over large parts of the UK. This image here shows an area in Yorkshire, with the river Wharfe flowing from the upper left to the lower right, meeting the river Ouse in the lower right part of the image. This image is a false-color composite from summer 2020, and gives an idea of what the area looks like under normal conditions. This image is from February 2020, and shows significant flooding along the river Wharfe and its tributaries. To give an idea of scale, the widest sections of flooding here are about 5-600 meters. As you can see, optical sensors are weather-dependent. Much of the flooded extent in the area is obscured by clouds, which makes mapping the full extent of the flooding difficult. By using SAR sensors, on the other hand, we can map floods under all weather conditions, as clouds are almost entirely transparent in the microwave portion of the electromagnetic spectrum.

## **Slide 6 – Ocean Color**

In addition to mapping the extent of water bodies, we can also learn about their chemical and biological makeup. One common application of this is in estimating chlorophyll-a concentration using the difference in reflectance between the visible blue and green bands. This is often used as a proxy for phytoplankton concentration. The example shown here is a portion of a landsat image showing the southern coasts of Spain and Portugal. You can see the variations of color along the coast here. Some of this variation is due to sediments and turbidity of the water, not directly related to chlorophyll or algal blooms. Using certain sensors, such as MODIS, we can estimate fluorescence – the electromagnetic radiation actually produced by microorganisms in the water. We can see an example of this shown here – the image on the left shows a ‘red tide’ – a type of algal bloom that poses a threat for marine life due to the toxic conditions it can produce. But notice that not all areas of high chlorophyll concentration are due to high concentrations of algae – most of the signal along the coast is related to sediments. The fluorescence shown in the upper right corner of the image removes a significant portion of the non-biological signal – we still see the extent of the algal bloom, but the sediment-related signal is significantly diminished.

## **Slide 7 – Water Quality**

In addition to chlorophyll concentration, we can also estimate other quantities of organic particles suspended in the water column. Generally speaking, we can refer to these as “colored dissolved organic matter” or CDOM. These are molecules that have been leached from decaying organic matter, that change the color of the water. We can relate these to dissolved organic carbon, or other nutrients, to

help study water quality and other aspects of water science. More generally, we can also estimate the total suspended matter – all sediments and organic matter that are suspended in the water column. We normally estimate these quantities using empirical relationships derived from in-situ observations – very often, someone will go out with a boat and take a number of measurements. We can then compare these measurements to our remote sensing observations, working out a mathematical relationship between the field measurements and the remote sensing data, in order to estimate quantities in unmeasured areas, and at different times.

## **Slide 8 – Oil spills**

Another useful application of remote sensing data is detecting and monitoring oil spills. Optical systems can help detect thin films of oil on the water, also known as sheens, as well as thicker layers of oil, known as slicks. Typically, the best results are using wavelengths between 300 and 450 nanometers, which are not always detected by optical systems – the more recent Landsat and Sentinel-2 instruments detect in parts of these wavelengths, but earlier instruments did not. Because of the way that oil interacts with the water surface, we can also detect slicks using active microwave sensors. Thicker deposits of oil dampen waves, changing the texture of the water surface – you can see examples of this in the images shown here. The ocean surface is somewhat rough and bright, while oil slicks appear darker and smoother. Sometimes, we can also see ships that are responsible for the oil slicks.

## **Slide 9 – Summary**

In this lesson, we have discussed how remote sensing provides a powerful tool for monitoring water resources. visible and infrared sensors, or optical systems, can be used to map the extent of water bodies, as well as monitor sediments and water quality. With altimeters, we can get water levels and calculate the volume of some water bodies, in particular reservoirs used as water sources or hydro power. Microwave sensors can be used to detect and monitor floods, or oil spills and other sources of pollution.

## **Slide 10 – Additional resources**

Once again, you can read more about the concepts we've covered in this lesson in the textbooks, Chapter 8, section 7 of Lillesand, Kiefer & Chipman, or Chapter 19 of Campbell & Wynne. I've included links to two websites that go into a bit more detail about mapping ocean color and water quality, as well as two different videos that cover similar topics. That's all for this lesson – I hope you found it interesting, and if you have any questions, please don't hesitate to e-mail me or post in the discussion forum on blackboard. Bye!