Slide 1 – Title Slide

Hello and welcome to Week 4, Part 2 of EGM703: SAR Applications. In this lesson, we’ll look at a number of scientific applications of SAR data.

Slide 2 – SAR Applications

We’ll start off by looking at how we can use SAR for monitoring different hazards such as floods and wildfires. Then, we’ll move on to looking at how we can use SAR to observe surface displacements, before finishing up with applications of oil spill and ship detection.

Slide 3 – Flood monitoring

As we’ve seen in the week 3 practical, calm surface water tends to appear dark in a SAR image – the water’s surface acts as a specular reflector, and directs most of the signal away from the sensor. In the image we can see here, we can see two different polarizations showing a flooded area: on the left, we have the VH polarization, in the middle, the VV polarization, and on the right, the derived flood extents from each. This example is from a study that looked at flooding in the rivers Wharfe and Ouse in northeast England during winter 2015-2016. Of course, the presence of floodwater is not the only reason that a pixel over land might appear dark, but if we compare images from before and during a flood, we can usually detect floodwaters as pixels that become darker. We do have to take some things into consideration – for example, the sensor polarization. As we can see in the image up here, and this graph down here, there are differences in flood-detected areas based on the sensor polarization – in this example, cross-polarized signals tend to provide higher estimates of flood area than vertically-polarized. We also need to consider speckle – the random phase “noise” present in images – we normally want to make sure we do some kind of filtering before we try to classify SAR images. Finally, we can also consider the terrain, as this study did – by considering only pixels that are likely to be flooded (i.e., not at the top of a mountain), we can cut down on false classifications.

Slide 4 – Fire monitoring

In a bit the opposite direction of flooding, burn scars tend to have brighter backscatter than surrounding areas. The example here shows a burn scar from a fire near Tok, Alaska – we can see the unburned forest in the left and right sides of the image, while the burn scar shows up prominently in the center. This happens in part because of a difference in soil moisture between burned and unburned areas – after the fire, we tend to see higher soil moisture due to the loss of vegetation such as sphagnum moss, but also the exposure of more rough areas. This depends on the wavelength of the sensor, though – for example, if we look at the same area using an L-band sensor, we no longer see the enhanced backscatter of the burn scar. This signal is also seasonal – depending on the time of year, the backscatter will be more or less enhanced, as shown in this comparison of an image from May and September 1992. We can also see here how the effects can be long-lasting, with burn scars from multiple fire years visible in the same area, including some as old as 13 years.

Slide 5 – Offset tracking

If we have two or more images separated in time, we can observe "slow" surface motion – for example, the flow of landslides or glaciers. The basic idea of offset is as follows. First, we start with a small sub-region, also known as a template, or chip, of the first image. Starting from the same location in the second image, we search for our reference template by moving it around the second image and calculating the correlation between the two sample chips. The peak correlation generally corresponds to the surface displacement between the two images. With SAR images, we usually correlate using both components of the complex image – that is, we include the speckle, which is why you'll sometimes see this technique referred to as "speckle tracking." We normally use non-terrain corrected images for this, so this technique gives us the displacement in both the range and azimuth directions – in order to transform this to ground coordinates, we have to geocode the offsets using a DEM.

Slide 6 – Glacier motion

Repeat satellite images let us observe the motion of glaciers. For larger displacements, on the order of meters per day, we can use techniques like offset or speckle tracking. For smaller displacements, on the order of centimeters per day or even smaller, we can use InSAR. We can also look at motion on different scales – starting from the scale of individual glaciers, like this animation. This animation shows the onset of a surge at Moršnevbreen, Svalbard – we can see that as the glacier begins to move faster, the surface becomes brighter. This happens because the speedup actually causes the glacier to pull apart and crack, forming crevasses – this even makes it easier for us to observe the motion from space. We can also observe motion on the scale of ice sheets, like this velocity map for Antarctica from the National Snow and Ice Data Center. You can see here how the scale varies from only a few meters per year up to over 1000 meters per year near the coasts – to be able to map both slow-moving and fast-moving regions, we have to combine approaches like InSAR and offset tracking. This is highlighted here for the Amery Ice Shelf region, where we can see slow-moving and fast moving areas in close proximity to each other. When we use SAR images, we also get observations during the polar night and through cloud cover, which is especially useful for studying glaciers that are located at the poles or in very cloudy regions.

Slide 7 – Oil spill detection

In addition to changing the spectral reflectance of water, oil also dampens small surface waves, also known as "capillary" waves, which changes the texture of the surface. In particular, it makes the surface appear much darker, which means that we can use SAR to detect and observe oil spills. In these examples, we can see oil spills highlighted as dark, smooth areas surrounded by somewhat brighter, more "rough" areas of water. We can also see how this long streak is trailing behind a ship, which we can also see in the image. Oops. We do need to be careful about potential "look-alikes" – as with floodwaters, there can be other reasons for there to be dark, smooth areas in a SAR image. For example, some biogenic surface films, which are not human-caused oil spills, can change the texture of the water surface and therefore appear dark; "grease ice", one of the formation stages of sea ice, can cause a similar effect. And of course, we can also have calm, wind-free areas due to different wind patterns – all of these are different things to keep in mind when attempting to classify oil spills.

Slide 8 – Ship detection

As we saw on the previous slide, we can also use SAR images to detect ships – this probably makes some sense, given the initial development of radar technology. Monitoring ships, or maritime activity, is important for monitoring fisheries; surveillance of marine traffic, especially around ports; and for safety operations. With higher-resolution SAR images, we can easily see ships: they show up very brightly, since they are effectively large corner reflectors on a mostly dark background. In the examples shown here from a 2019 study, the authors used an artificial neural network to do both simple classification (i.e., ship/no ship), as well as characterization – what kind of ship are we looking at? As we an see here, different kinds of ships have different signatures in the SAR image owing to their different overall shapes and profiles.

Slide 9 – Summary

As we've seen in this lesson, there are a number of ways that applications of SAR, optical, hyperspectral, and thermal images overlap – we can often use these different techniques in complementary ways.

In general, SAR images are weather-independent: we can make observations despite heavy cloud cover; or even at night, when we have no external source of illumination.

Interpreting SAR images can be quite challenging, but we can still use a lot of the techniques that we've already studied, to help us make sense of what it is that we're seeing.

Slide 10 – Additional resources

As always, I've included links to the different articles referenced in this presentation here – they're also available on the slide notes, and you can find PDF versions of the articles on Blackboard or in the Zotero library. I've also added a few additional papers to the Zotero library that weren't covered here, so feel free to browse those as well. That's all for this lesson – I hope you found it interesting, and you have any questions, please don't hesitate to e-mail me or post in the discussion forum on blackboard. Bye!