Slide 1 – Title Slide

Hello and welcome to Week 4, Part 1 of EGM703: SAR Missions and Data. In this lesson, we'll learn a bit more about SAR data, including some commonly-used SAR missions, and where to find them.

Slide 2 – Week 4 Outline

In the rest of this week, we'll look at applications of SAR data, before learning about InSAR and its applications, and finish up by looking at applications of passive microwave remote sensing.

Slide 3 – SAR Bands

Just like we've seen with the visible portion of the EM spectrum, or the infrared, we can also divide the microwave portion of the EM spectrum into different bands based on wavelength or frequency. The most common ones that we'll run into, in order of increasing wavelength, are: K-band, often divided into Ka, K, and Ku, which ranges from 40-12 GHz, or about 1.5 to 11.1 cm. Next, we have X-band, ranging from 12-8 GHz, or about 2.5 to 3.75 cm. This is followed by C-band, ranging from 8-4 GHz, or 3.75 to 7.5 cm; S-band, 4-2 GHz, or 7.5-15 cm; L-band, 2-1 GHz or 15-30 cm; and finally, P-band, 1 GHz – 300 Mhz, or 30-100 cm.

Each of these different bands has different applications. For example, K band is not commonly used for satellite-based remote sensing, owing to absorption of water vapor at approximately 22.25 GHz (or 1.35 cm). Different frequencies, or wavelengths, have different penetration into vegetation, snow/ice, or other surfaces, owing to the dielectric properties of those surfaces – we can see the example here showing how X-band primarily gives us information about forest canopies, while longer wavelengths, such as L or P-band, give us quite a bit of information about the canopy and tree structure. Ionospheric effects, like we introduced last week, tend to increase with wavelength, which can have implications for spaceborne P-band radar systems.

As we are going to see through the rest of this lesson, the X, C, and L bands are by far the most popular choices for satellite-based microwave remote sensing, though there are plans for a spaceborne P-band sensor currently in the works.

Slide 4 – SAR Modes

Generally speaking, we can divide the ways that SAR sensors acquire images into three main modes, though specific sensors will have their own variations on these basic themes.

The first mode that we'll look at is "stripmap" mode – this is the most basic acquisition mode, where the radar is imaging a single swath parallel to the satellite orbit. This is the mode that we discussed last week when we introduced the concept of synthetic aperture radar. Recall that the range resolution of the sensor depends on the frequency range of the "chirp" sent out by the transmitter, while the azimuth resolution depends on the length of the synthetic aperture, which depends on the length of the physical antenna.

Next up, we have “spotlight” mode, where the beam of the sensor is actually steered forward or backward, in order to extend the amount of time that the sensor looks at a particular spot on the ground. In this mode, the range resolution still depends on the frequency range of the “chirp” sent out by the transmitter, but the length of the synthetic aperture, and therefore the azimuth resolution, is no longer dependent on the length of the physical antenna – in effect, we are able to increase the azimuth resolution of the sensor, by spending longer “looking” at a particular spot on the ground. However, this requires a tradeoff with spatial coverage – we’re not able to image the areas directly before, or behind, the area where we are highlighting.

Finally, we have the “ScanSAR” mode. In this mode, the satellite sends out multiple “bursts” in order to scan progressive “sub-swaths” on the ground. With this, we get increased coverage, or a wider swath, though we lose a bit of azimuth resolution because the sensor does not spend quite as long “looking” at a particular point on the ground. As always, the range resolution only depends on the frequency range of the “chirp” sent out by the transmitter.

Slide 5 – European Remote Sensing Satellite (ERS)

The first SAR mission that we’ll cover is the European Remote Sensing Satellite, or ERS. As you can see from the diagram here, ERS had a number of different sensors, including a microwave sounder, a radar altimeter, and a scatterometer. For now, we’re going to focus on the SAR sensor. The ERS SAR instrument operated at 5.3 GHz, or 5.6 cm wavelength, meaning that this was a C-band radar. ERS only operated in stripmap mode with vertical polarization – the VV here means that the transmitter sends out a vertically-polarized signal, and records only vertically-polarized signals. It had a swath width of 100 km or so, and a ground resolution of about 25 m. Normally, it had a 35-day repeat cycle, meaning that the satellite acquired an image from the same location in its orbit every 35 days. ERS-1 was operative from 1991 until 2000, but it overlapped for quite a while with ERS-2, which was an identical satellite with identical sensors. ERS-2 operated from 1995-2011, and from 1995-1996, it operated in a tandem mode with ERS-1, meaning that it was acquiring images with 1 day separation – using a technique we’ll cover later this week, this means that we can use these images for interferometery. ERS data are all available online from ESA, for free, from the link here – you just need to create a free account. Using your NASA Earthdata account, you can also get a subset of the data, again for free, from the Alaksa Satellite Facility – more on that later.

Slide 6 – Radarsat

The next set of missions that we’ll cover is Radarsat. Radarsat-1 operated at 5.3 GHz, or 5.6 cm wavelength, making this another C-band radar. It operated in a variety of both stripmap and ScanSAR modes – you can see a diagram showing the various modes and beam angles here. It recorded horizontally-polarized signals, had a swath width that varied between 45 and 500 km, and a resolution between 8 and 100 m. The temporal resolution was a 24-day repeat cycle, and it was in operation from 1995 until 2013. You can get Radarsat-1 data from a few places – Natural Resources Canada has a collection of over 36,000 scenes freely available, with more that have not yet been processed.

Radarsat-2 is similar to Radarsat-1 in that it's a C-band radar with horizontal polarization, but it has even more modes, a finer swath width, and potentially higher resolution depending on the acquisition mode. It was launched in 2007, and is still operational.

Finally, we have the Radarsat constellation mission, which is a set of 3 twin satellites with the same specifications as Radarsat-2 – the fact that there are three satellites means that there are more acquisitions, great potential for high-temporal repeats, and even better opportunities for topographic mapping. This mission was launched in 2019, and each satellite is expected to operate for at least 7 years.

Slide 7 – PALSAR: L-band

Moving away from the C-band radars for a bit, we'll take a look at a few L-band radars operated by the Japanese Aerospace eXploration Agency, JAXA. I don't have it on the slide here, but JAXA also operated an L-band radar before this on Fuyo- (better known as JERS-1), which was in operation from 1992 until 1998.

PALSAR (Phased Array type L-band Synthetic Aperture Radar), operated at 1270 MHz or 23.6 cm. It had a few different stripmap and ScanSAR modes, and is the first sensor we've seen that acquired cross-polarized signals: it operated both horizontally- and vertically-polarized signals, and also cross-polarized – the VH and HV, which means it provides a bit more information about the surface characteristics. It operated on a swath width between 20 and 350 km with a spatial resolution between 10 and 100 m, again depending on the mode. It had a much longer repeat cycle than we've seen, 46 days, and was in operation from 2006 until early 2011.

PALSAR-2 is an upgraded version of PALSAR, with higher spatial and temporal resolutions. It was launched in 2014, and is still operational.

You can get PALSAR data from the Alaska Satellite Facility's Vertex archive, linked here – the whole PALSAR archive (not including PALSAR-2) is freely available.

Slide 8 – TerraSAR-and TanDEM-X

Changing frequency once again, we'll take a look at TerraSAR-and TanDEM-X, which are operated by the German aerospace agency, DLR. TerraSAR-operates at 9.65 GHz, or 3.1 cm – this is an X-band radar (as you can hopefully see from the name). TerraSAR-operates in a number of different stripmap, spotlight, and ScanSAR modes, and it acquires both horizontally and vertically polarized signals, as well as cross-polarized signals. The swath width ranges from 10 to 100 km, with a resolution that varies between 1 and 16 m depending on the acquisition mode. TerraSAR-has an 11-day repeat cycle, and has been in operation since 2007.

Since 2010, DLR has operated a twin satellite that operates in a tandem orbit with the original TerraSAR-X. These satellites operate in two different acquisition modes: the bi-static mode, where the two satellites are flying parallel to each other, enables high-resolution topographic mapping; the monostatic mode, where the two satellites are flying in sequence, enables along-track interferometery, which enables both topographic mapping and mapping “fast” surface motion.

While TerraSAR-scenes are not normally freely available, there are occasionally proposal calls from DLR to access images, and the global topographic products generated by TanDEM-are freely-available from DLR.

Slide 9 – Sentinel-1

The final SAR mission we’ll look at is Sentinel-1, which we’ve already seen in the Week 3 practical. Sentinel-1 operates at 5.4 GHz, or 5.6 cm, making this another C-band radar (you might be noticing a pattern). It operates in both Stripmap and ScanSAR modes, depending on where it is acquiring data. It acquires both horizontally and vertically-polarized signals, with a swath width that varies between 20 and 400 km, and a resolution between about 5 and 40 m. Sentinel-1 has a 12 day repeat, though with multiple satellites, the actual repeat time is 6 days for most of the globe. The first satellite, Sentinel-1A, was launched in 2014; Sentinel-1B was launched in 2016, and both are still operational. While currently there are two satellites, 1A and 1B, there are plans to launch Sentinel-1C and 1D in the not too distant future. Sentinel-1 data are freely-available from a number of places; you can find them on the link shown here from Copernicus, but you can also search for them from the ASF archive that I linked earlier.

Slide 10 – Get HyP3!

As you have no doubt noticed, downloading and processing your own SAR data is hard, and expensive, especially in terms of storage and computation. Part of this is because SAR data files are huge, and because they require various forms of geometric correction, which require a lot of processing. One solution is to get hype! The ASF hybrid pluggable processing pipeline, or HyP3, provides free on-demand radiometric terrain correction, InSAR processing, and offset tracking products. All you have to do is order the images from Vertex, select the different kinds of processing that you want, and you can download your analysis-ready data once the processing is finished. If you are interested in working with SAR datasets, especially for your master’s project, I highly recommend looking into this service.

Slide 11 – Summary

In this lesson, we’ve covered how just like we’ve seen with other parts of the electromagnetic spectrum, we can define different microwave bands, which tend to have different applications due to the properties of the signal and how it interacts with Earth’s surface.

In general, SAR sensors acquire images in three main modes, depending on the application or needs of the mission. Individual sensors will have more specific acquisition modes, so be sure to have a look at the documentation for the sensor you’re interested in using.

We’ve seen how there are a number of freely-available SAR datasets available, as well as free processing options: for example, the SNAP toolbox we used in last week’s practical, or analysis-ready data via HyP3!

Slide 12 – Additional resources

I’ve included links to the mission pages for a number of the SAR missions discussed here – ERS from ESA, the Radarsat constellation mission from the Canadian Space Agency, PALSAR-2 from JAXA, TanDEM-via the ESA eo portal directory, and Sentinel-1. There’s also a link to this paper from Krieger et al. that provides the details behind the TanDEM-mission. Finally, there are links to more information about HyP3, including a link to more information about the GIS analysis toolbox. 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!