



SAR for Flood Mapping

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Jet Propulsion Laboratory, California Institute of Technology

Oct. 19, 2022



Training Format

- Three 2-hour sessions including presentations and question and answer sessions
- The same content will be presented at two different times each day.
- Session A will be presented in **English**.
- Session B will be presented in **Spanish**.
 - Session A: 11:00-13:00 EST (UTC-4)
 - Session B: 14:00-16:00 EST (UTC-4)

- Training materials and recordings will be available from:

<https://appliedsciences.nasa.gov/join-mission/training/english/arset-disaster-assessment-using-synthetic-aperture-radar>



Homework and Certificate

- Homework Assignment:
 - Answers must be submitted via Google Form
 - Due Date: **Nov. 17, 2022**
- A certificate of completion will be awarded to those who:
 - Attend all live webinars
 - Complete the homework assignment by the deadline (access from website)
 - You will receive a certificate approximately two months after the completion of the course from: marines.martins@ssaihq.com



Prerequisites

Fundamentals of Remote Sensing:

<https://appliedsciences.nasa.gov/join-mission/training/english/fundamentals-remote-sensing>

Introduction to Synthetic Aperture Radar (Sessions 1, 2 and 4):

<https://appliedsciences.nasa.gov/join-mission/training/english/aset-introduction-synthetic-aperture-radar>

Radar Remote Sensing for Land, Water, & Disaster Applications (Session 2)

<https://appliedsciences.nasa.gov/join-mission/training/english/aset-radar-remote-sensing-land-water-disaster-applications>

SAR for Disasters and Hydrological Applications (Session 3)

<https://appliedsciences.nasa.gov/join-mission/training/english/aset-sar-disasters-and-hydrological-applications>



Training Outline



Oct. 19, 2022

**SAR for Flood Mapping
by Dr. Erika Podest (JPL)**



Oct. 20, 2022

SAR for Mapping Landslide
Motion
By Dr. Eric Fielding (JPL)



Oct. 27, 2022

SAR for Oil Spill Detection
by Dr. Malin Johansson (UiT
The Arctic University of
Norway)



Learning Objectives

By the end of this session attendees will be able to:

- Understand the information content in SAR images relevant to flooding
- Understand the confounding factors in SAR relevant to flooding
- Access, process, and visually interpret SAR data
- Generate a time series flood map using Google Earth Engine



Outline

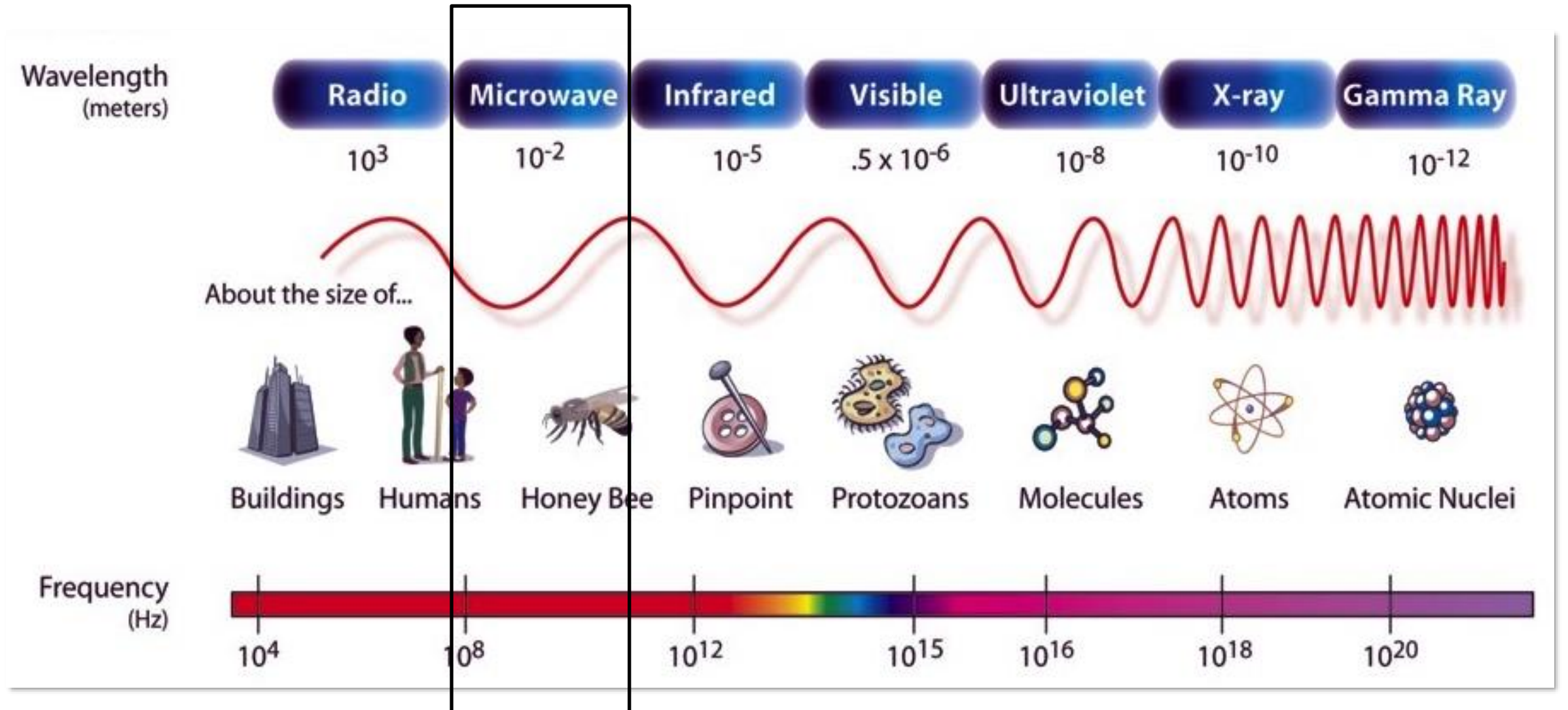
- Radar Overview
 - Radar Signal Interaction with the Land Surface
 - Radar and Surface Parameters
 - Distortions
 - Confounding Factors
 - Available SAR Data
- SAR Time Series Flood Demo
 - Define Area and Time of Interest
 - Visualize the SAR Data
 - Generate Time Series Flood Maps with SAR Data





Radar Overview

The Electromagnetic Spectrum



Advantages/Disadvantages of Microwave Remote Sensing over Optical



Advantages

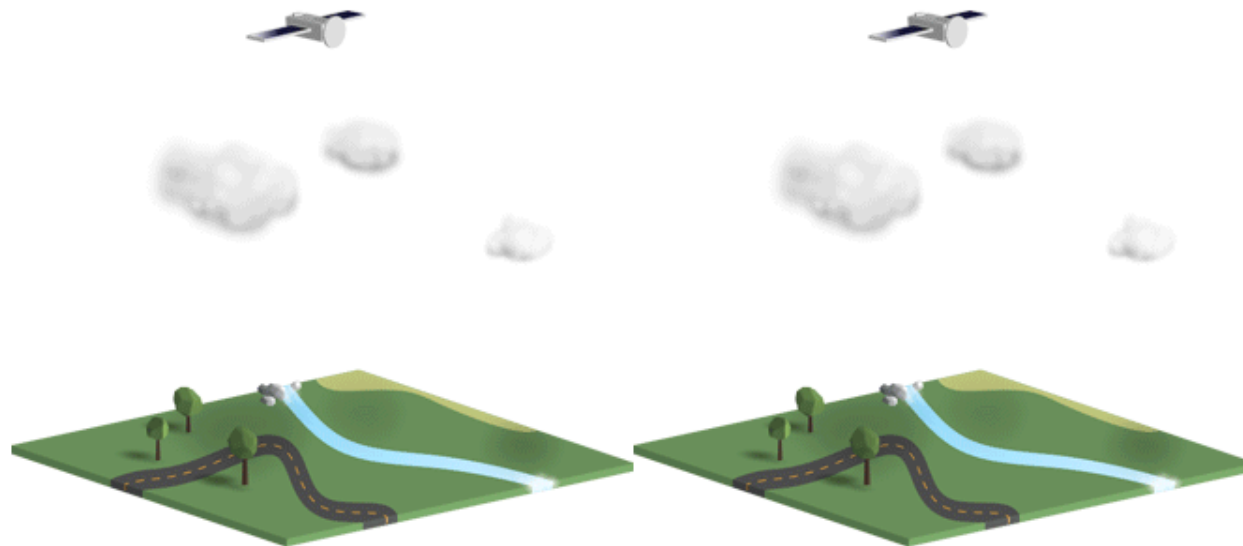
- Nearly all weather capability
- Day or night capability
- Penetration through the vegetation canopy
- Penetration through the soil
- Minimal atmospheric effects
- Sensitivity to dielectric properties (surface wetness or liquid vs. frozen water)
- Sensitivity to structure

Disadvantages

- Information content is different than optical and sometimes difficult to interpret
- Speckle effects (graininess in the image)
- Effects of topography



Active and Passive Remote Sensing



Passive | Sensors detect only what is emitted from the landscape, or reflected from another source (e.g., light reflected from the sun).

Active | Instruments emit their own signal and the sensor measures what is reflected back. Sonar and radar are examples of active sensors.

Passive Sensors:

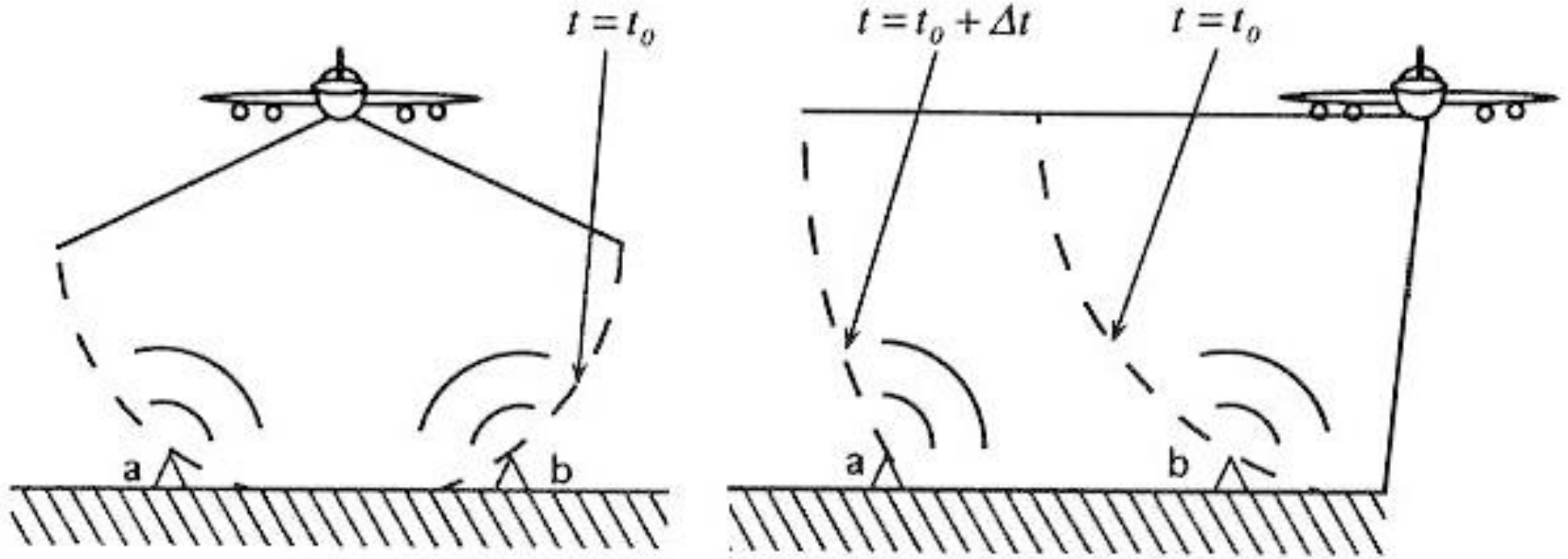
- The source of radiant energy arises from natural sources
- e.g., the sun, Earth, other “hot” bodies

Active Sensors

- Provide their own artificial radiant energy source for illumination
- e.g., radar, synthetic aperture radar (SAR), LiDAR

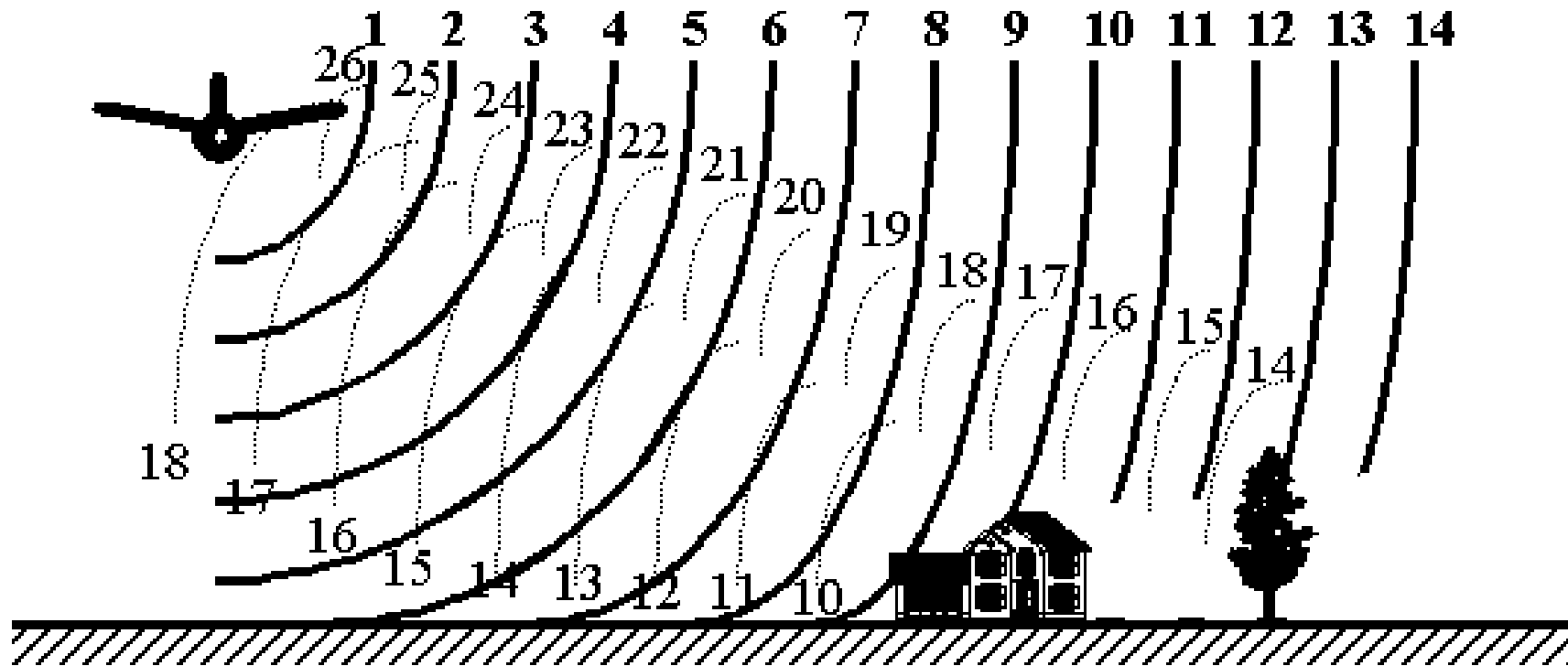


Basic Concepts: Down-Looking vs. Side-Looking Radar



Basic Concepts: Side-Looking Radar

- Each pixel in the radar image represents complex quantity of the energy that was reflected back to the satellite.
- The magnitude of each pixel represents the intensity of the reflected echo.



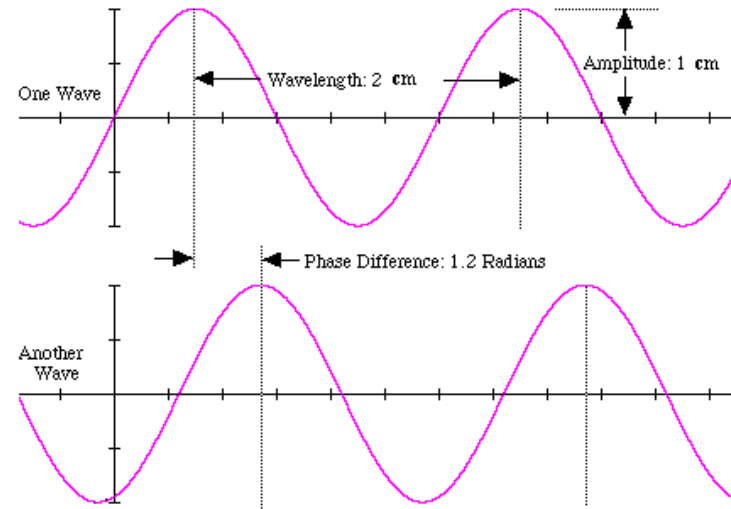
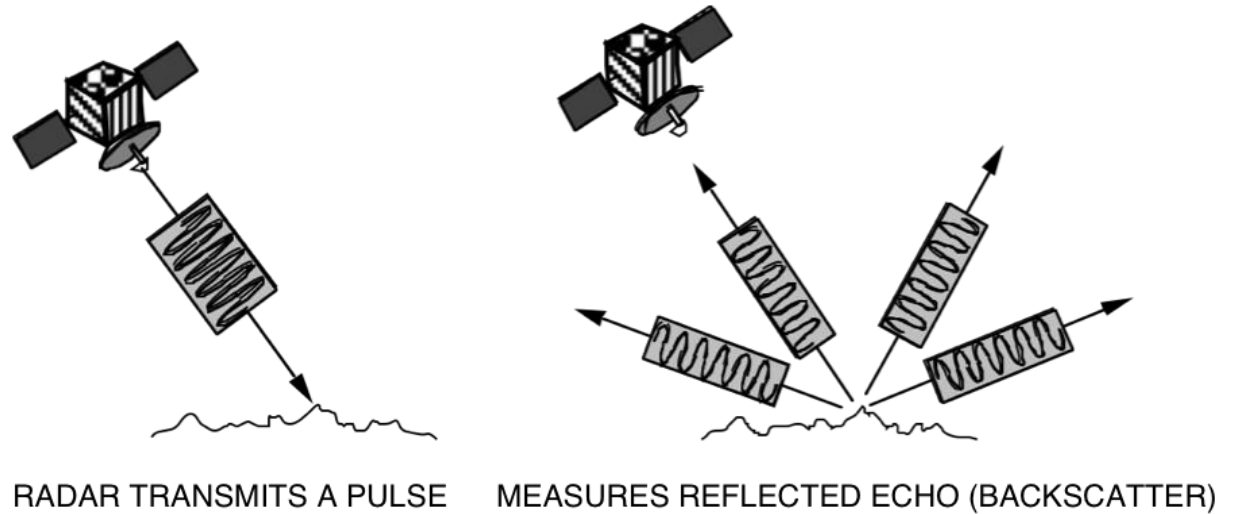
Credit: [Paul Messina, CUNY NY](#), after Drury 1990, Lillesand and Kiefer, 1994

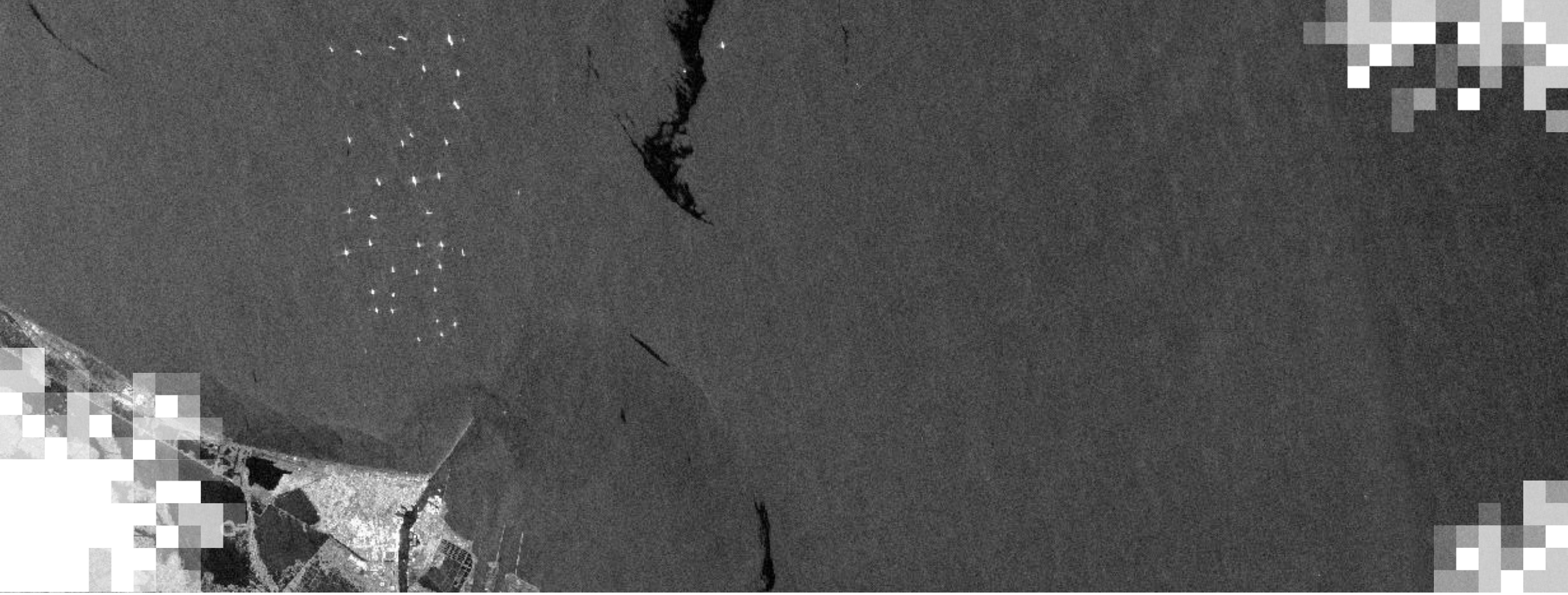


Review of Radar Image Formation



1. Radar can measure amplitude (the strength of the reflected echo) and phase (the position of a point in time on a waveform cycle).
2. Radar can only measure the part of the echo reflected back towards the antenna (backscatter).
3. The strength of the reflected echo is the backscattering coefficient (sigma naught) and is expressed in decibels (dB).





Radar Signal Interaction with the Land Surface

Flooding Definition from a Radar Perspective:

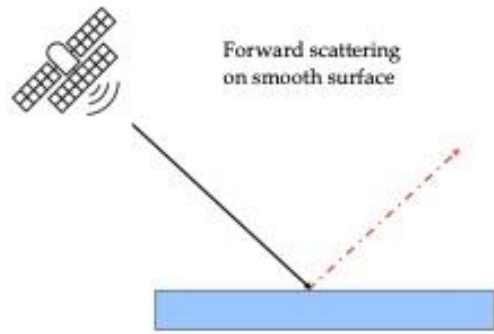
The temporary or permanent occurrence of a water surface:

- Beneath a vegetation canopy (tall or short standing vegetation)
- Without any standing vegetation (referred to as open water)

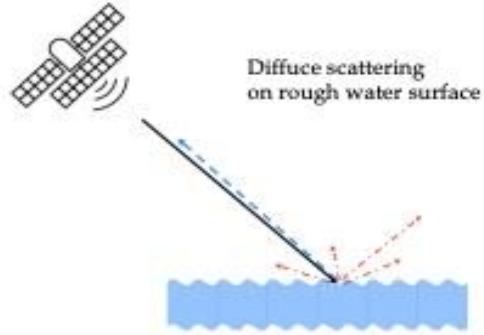


SAR Signal Backscattering Mechanisms

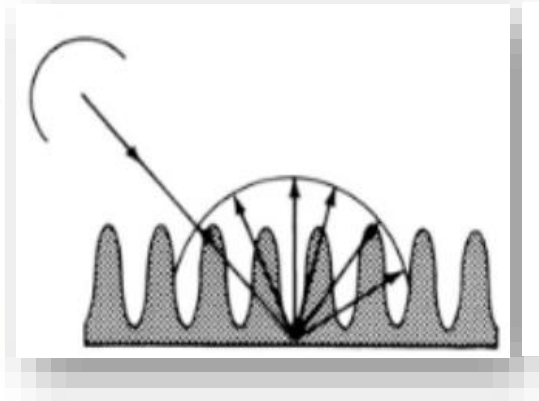
Smooth Surface



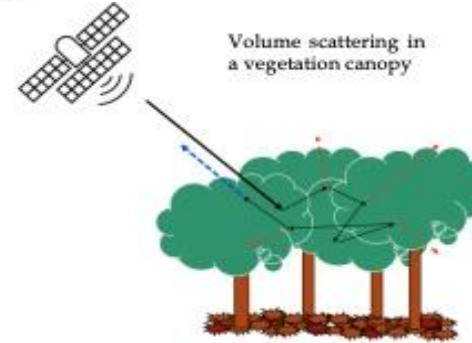
Rough Surface



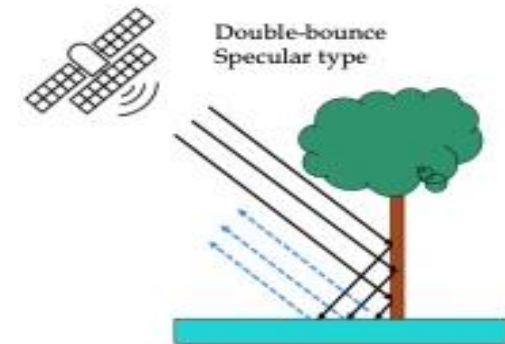
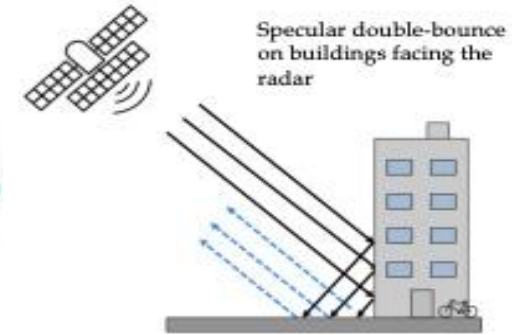
Rougher Surface



Volume



Double Bounce



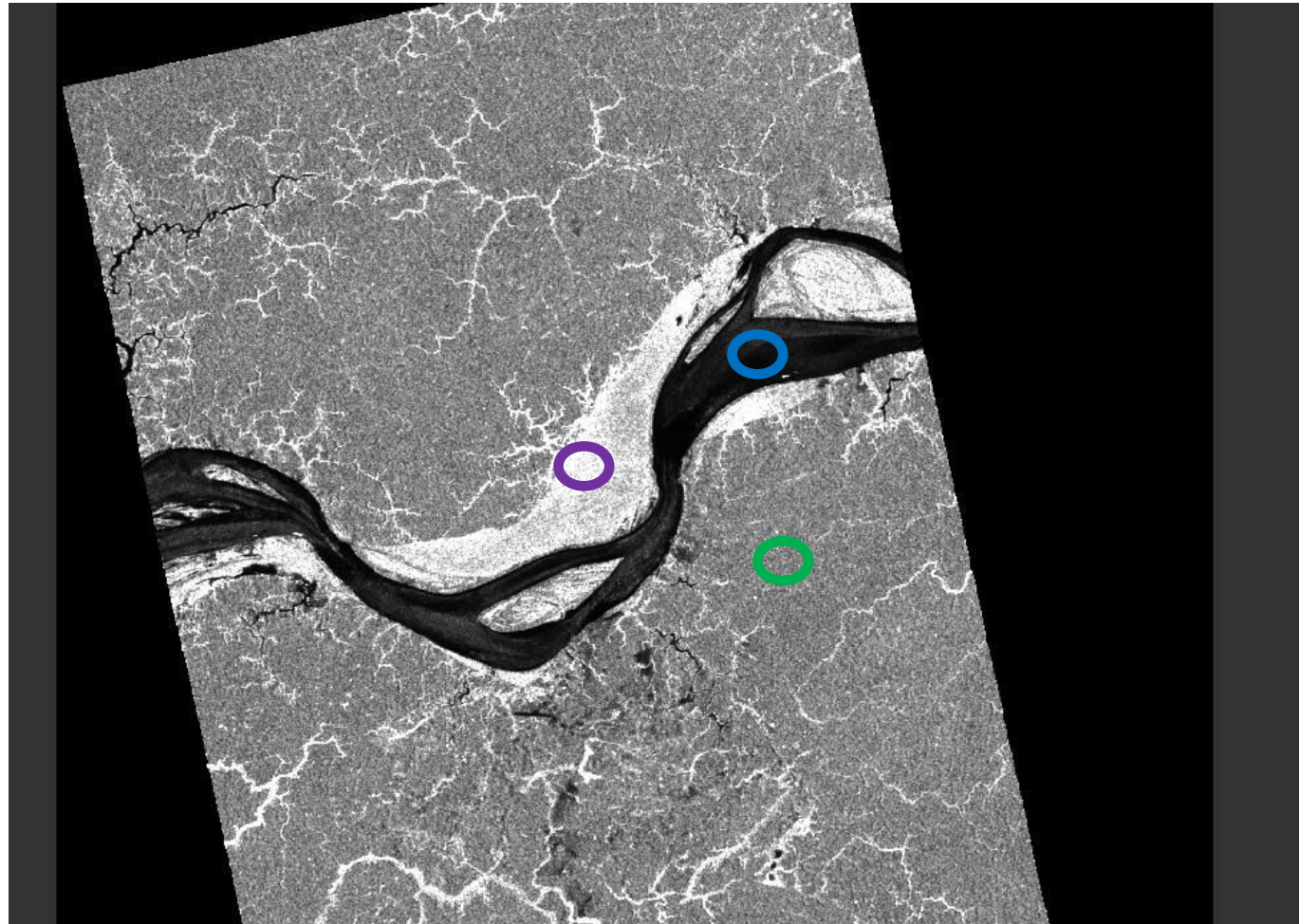
Source: CEOS Systems Engineering Office (SEO)

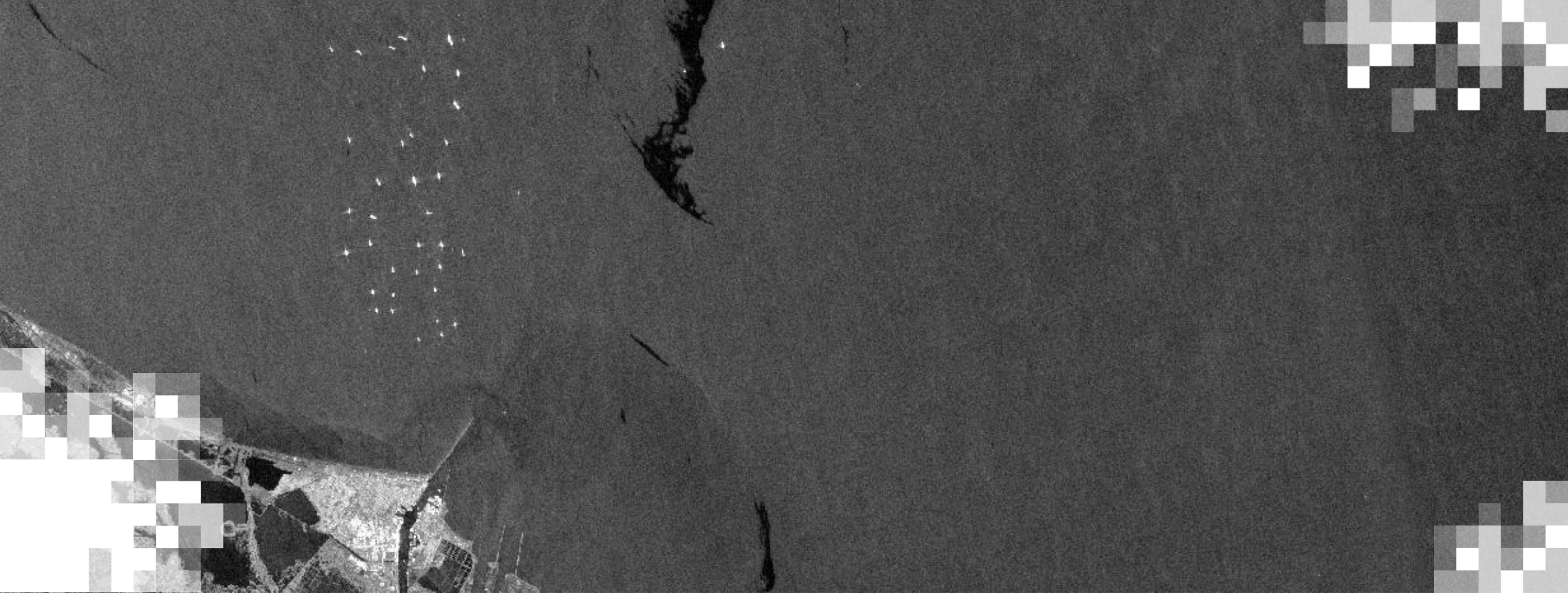
NASA's Applied Remote Sensing Training Program



SAR Signal Scattering Over Inundated Regions

PALSAR Image (L-band) Near Manaus, Brazil





Radar and Surface Parameters

Parameters to Consider for a Land Cover Mapping Study

Radar Parameters

- Wavelength
- Polarization
- Incidence Angle




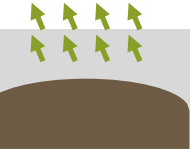
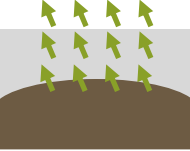
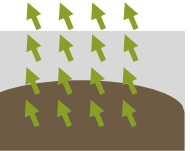
Surface Parameters

- Structure
- Dielectric



Wavelength and SAR Signal Response Over Flooded Vegetation

- Penetration is the **primary factor** in wavelength selection.
- Generally, the longer the wavelength, the greater the penetration into the target.

Vegetation			
Dry Alluvium			
	X-band 3 cm	C-band 5 cm	L-band 23 cm

Band Designation*	Wavelength (λ), cm	Frequency (ν), GHz (10^9 cycles·sec ⁻¹)
Ka (0.86 cm)	0.8 – 1.1	40.0 – 26.5
K	1.1 – 1.7	26.5 – 18.0
Ku	1.7 – 2.4	18.0 – 12.5
X (3.0 cm, 3.2 cm)	2.4 – 3.8	12.5 – 8.0
C (6.0)	3.8 – 7.5	8.0 – 4.0
S	7.5 – 15.0	4.0 – 2.0
L (23.5 cm, 25 cm)	15.0 – 30.0	2.0 – 1.0
P (68 cm)	30.0 – 100.0	1.0 – 0.3

*Wavelengths most frequently used in SAR are in parentheses.



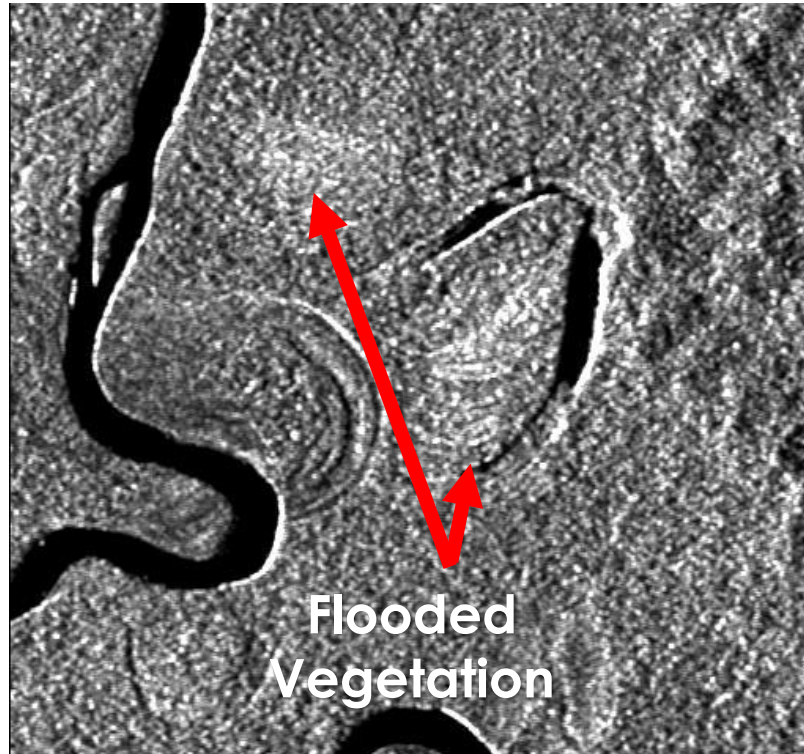
Signal Penetration Over Flooded Vegetation

Multifrequency AIRSAR data in Manu National Park, Peru

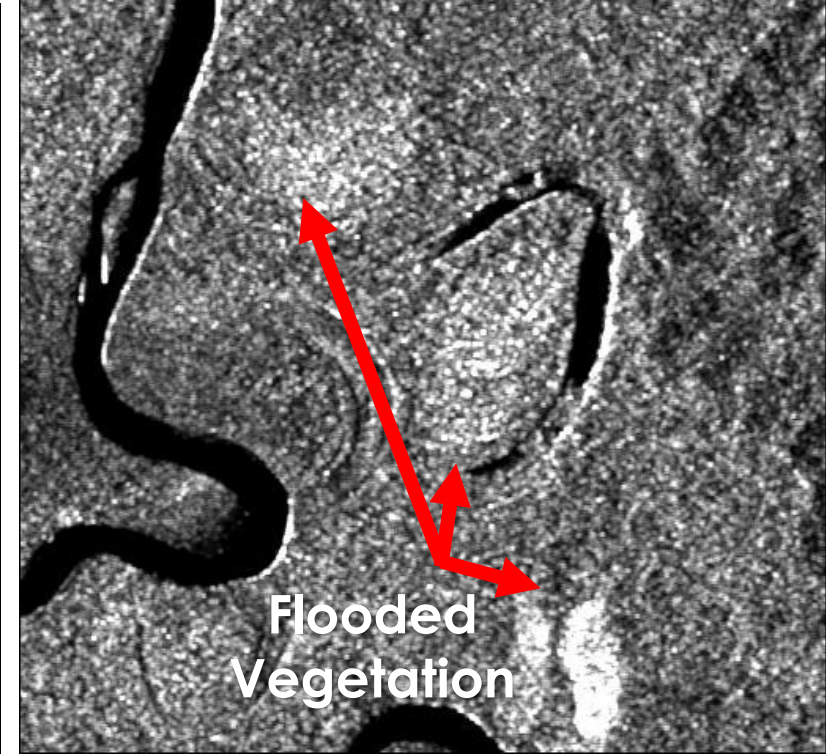
C-Band



L-Band



P-Band



Radar Parameters: Polarization

- The radar signal is polarized.
- The polarizations are usually controlled between H and V:
 - HH: Horizontal Transmit, Horizontal Receive
 - HV: Horizontal Transmit, Vertical Receive
 - VH: Vertical Transmit, Horizontal Receive
 - VV: Vertical Transmit, Vertical Receive
- Quad-Pol Mode: When all four polarizations are measured.
- Different polarizations can determine physical properties of the object observed.

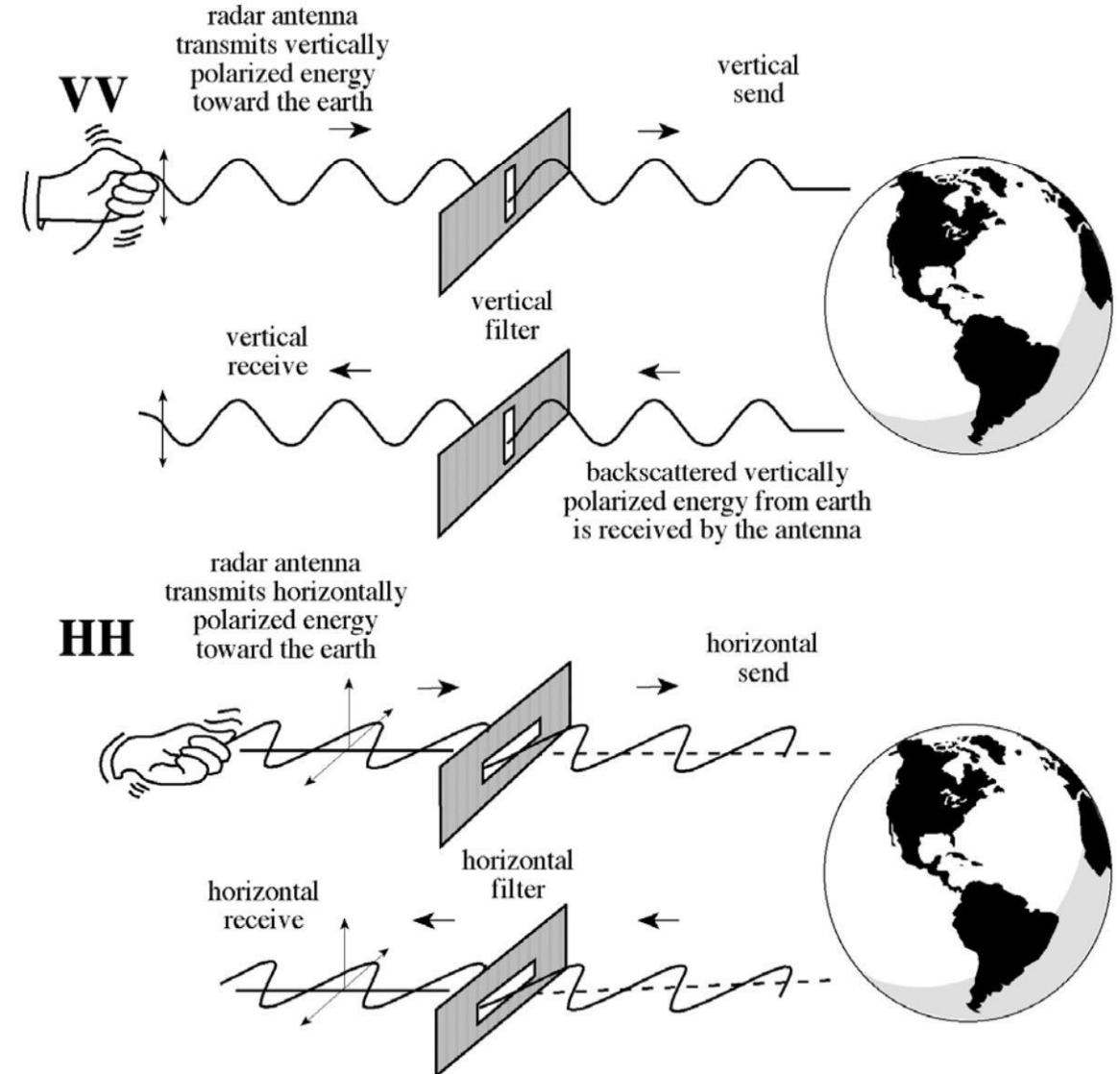
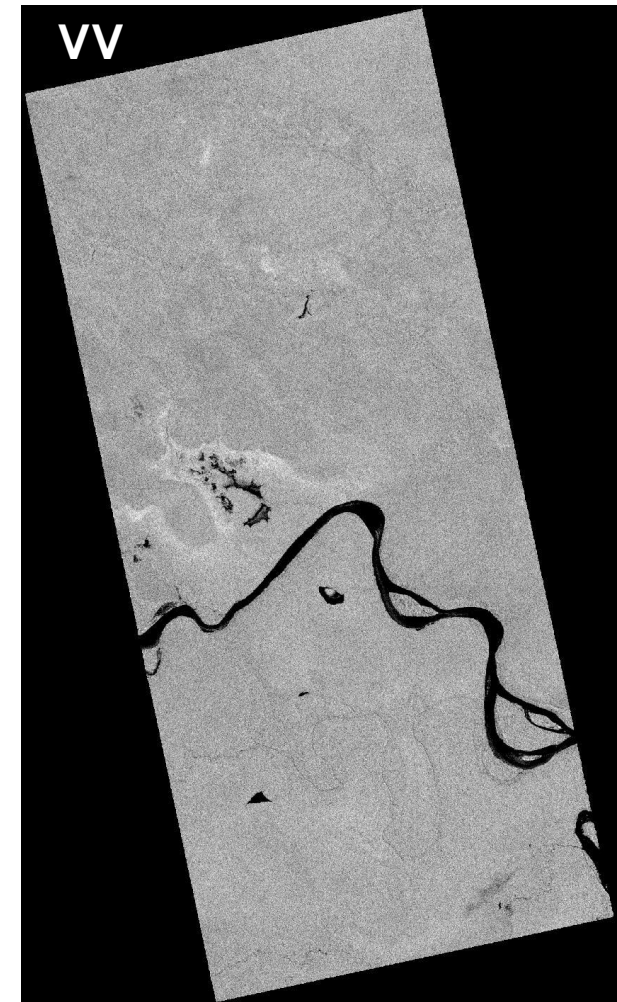
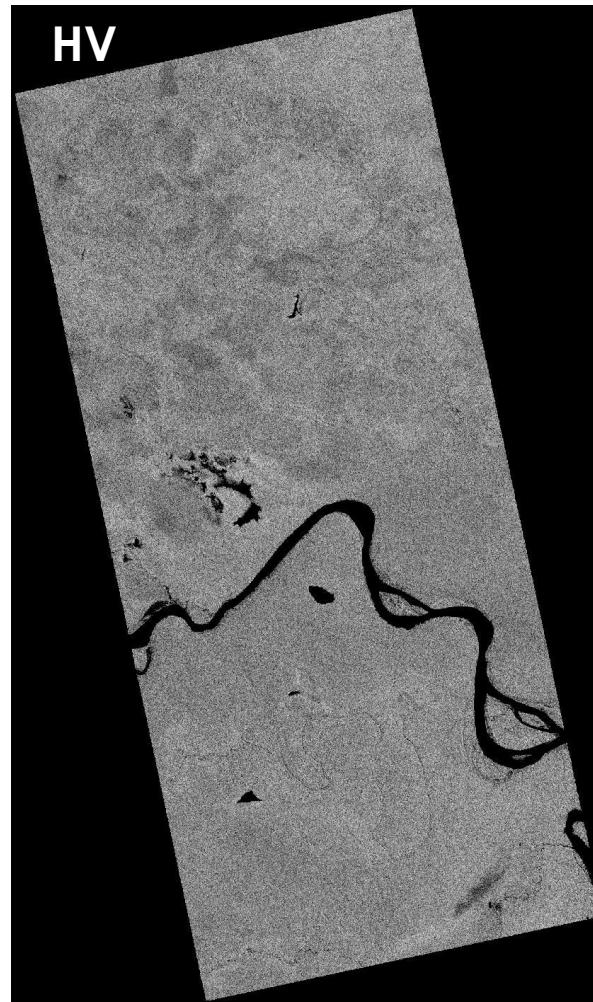
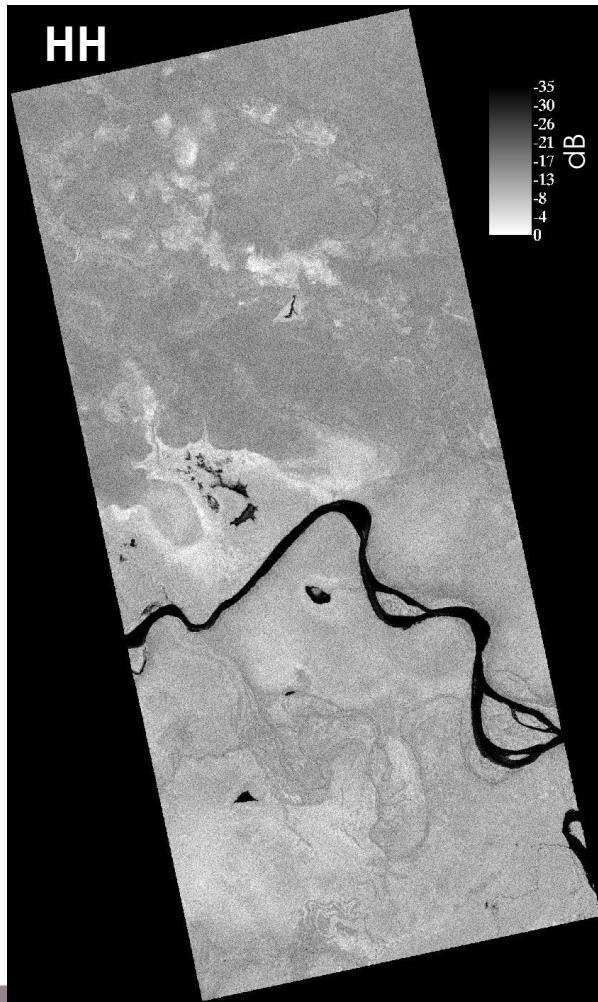


Image Credit: J.R. Jensen, 2000, Remote Sensing of the Environment



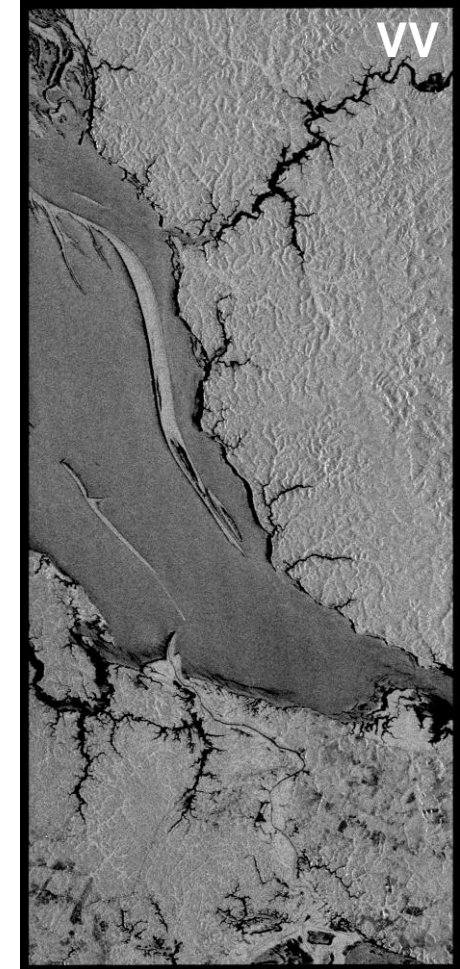
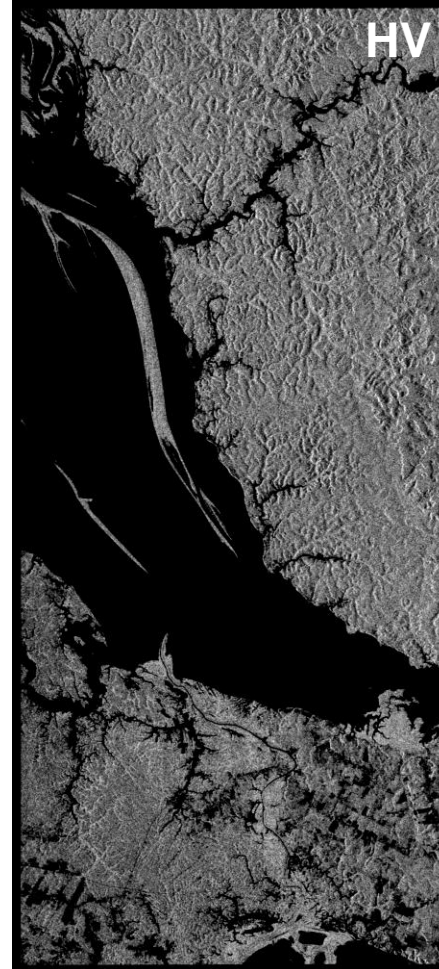
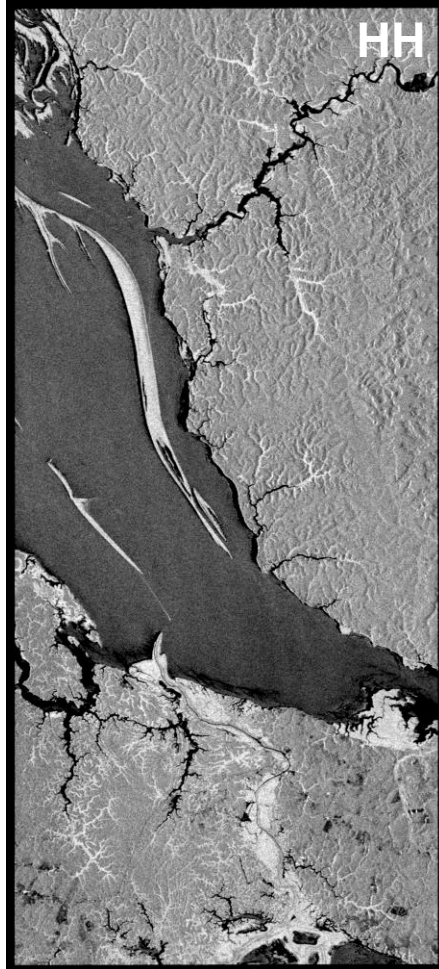
Multiple Polarizations for Detecting Inundated Vegetation

Images from Palsar (L-band) over Pacaya-Samiria in Peru



Multiple Polarizations for Detection of Open Water

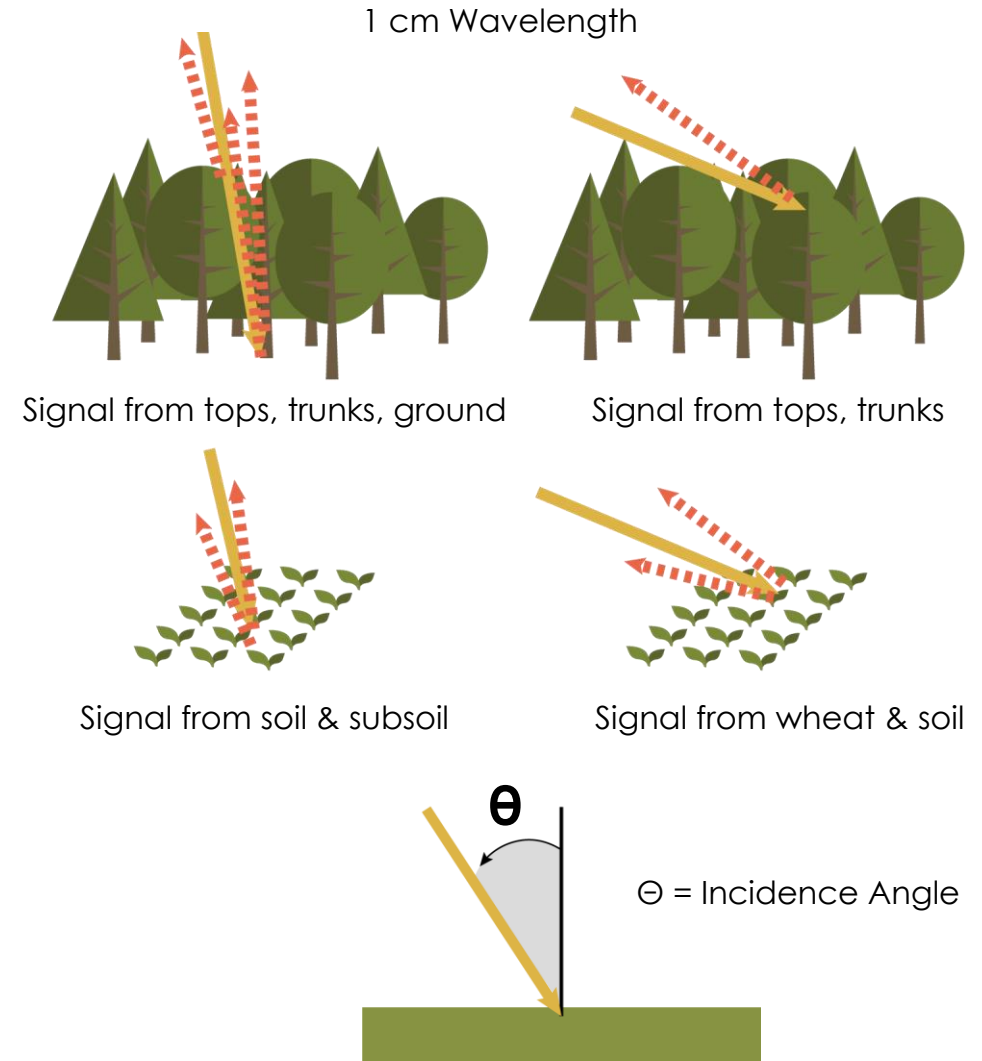
Images from PALSAR (L-band) Near Manaus, Brazil



Radar Parameters: Incidence Angle

Local Incidence Angle:

- The angle between the direction of the incident wave and the Earth's surface plane
- Accounts for local inclination of the surface
- Influences image brightness
- The geometry of an image is different from point to point in the range direction



Images Based On: Top: Ulaby et al. (1981a), Bottom: ESA



Parameters to Consider for a Land Cover Mapping Study

Radar Parameters

- Wavelength
- Polarizations
- Incidence Angle

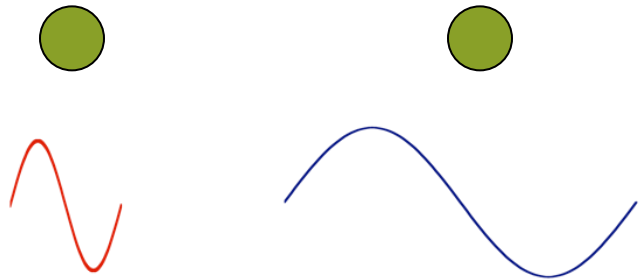
Surface Parameters

- Structure
- Dielectric

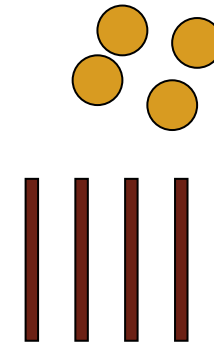


Surface Parameters Related to Structure

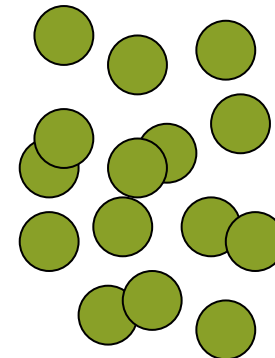
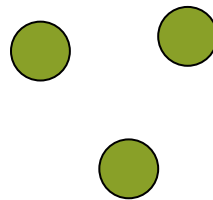
Size Relative to Wavelength



Orientation



Density



Size Relative to Wavelength



Austrian pine



X band
 $\lambda = 3 \text{ cm}$



L band
 $\lambda = 27 \text{ cm}$

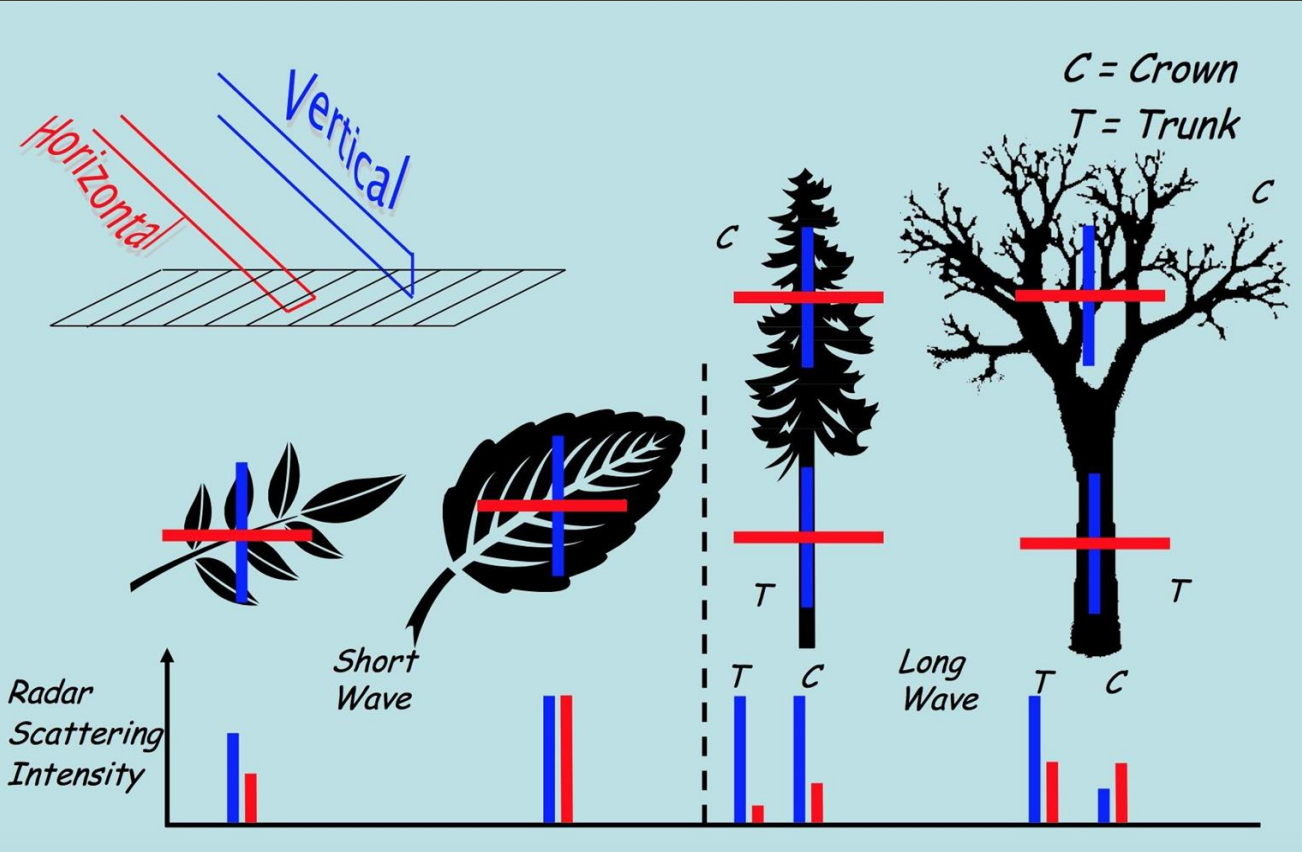


P band
 $\lambda = 70 \text{ cm}$



Size and Orientation

Polarization



Source: Walker, W. *Introduction to Radar Remote Sensing for Vegetation Mapping and Monitoring*

RELATIVE SCATTERING STRENGTH BY POLARIZATION:

Rough Surface Scattering

$$|S_W| > |S_{HH}| > |S_{HV}| \text{ or } |S_{VH}|$$

Double Bounce Scattering

$$|S_{HH}| > |S_W| > |S_{HV}| \text{ or } |S_{VH}|$$

Volume Scattering

Main source of $|S_{HV}|$ and $|S_{VH}|$

Source: SAR Handbook

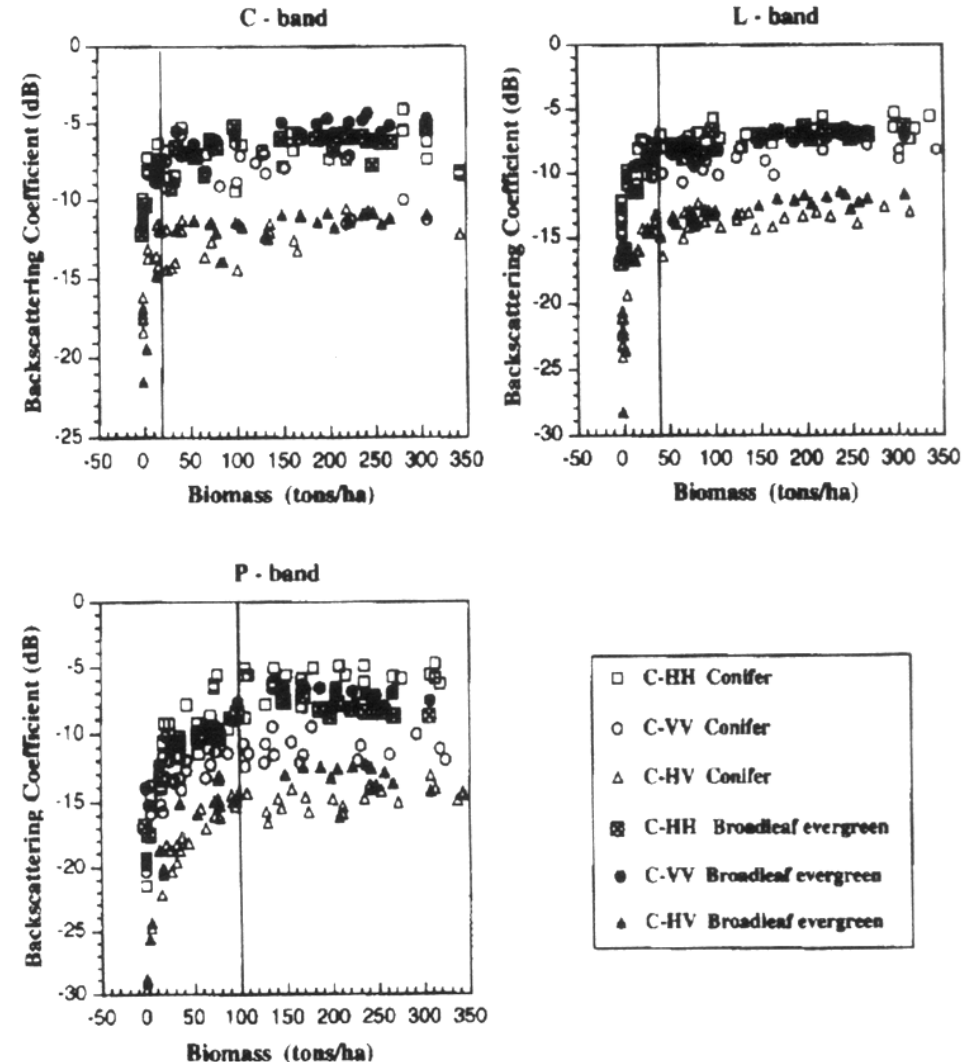


Vegetation Density

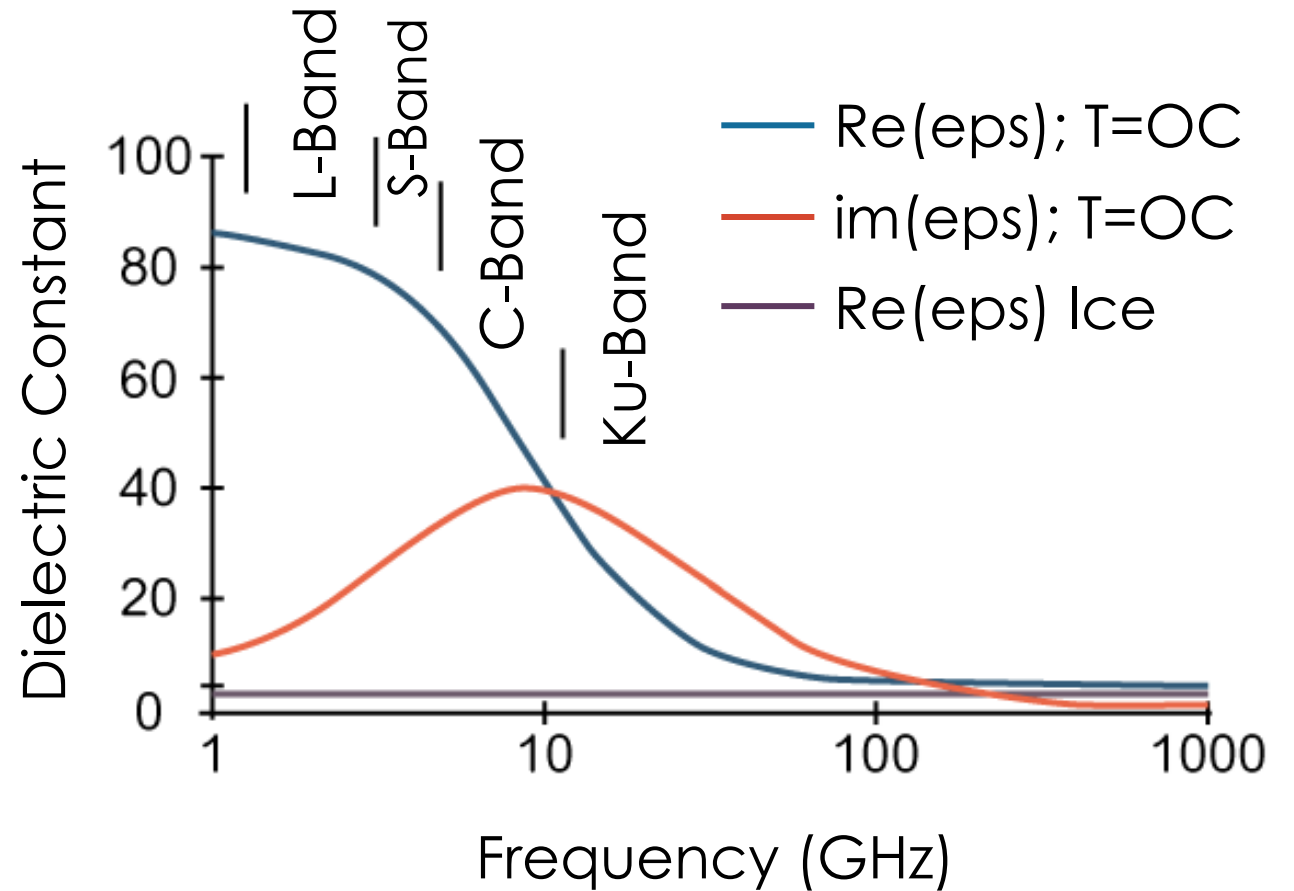
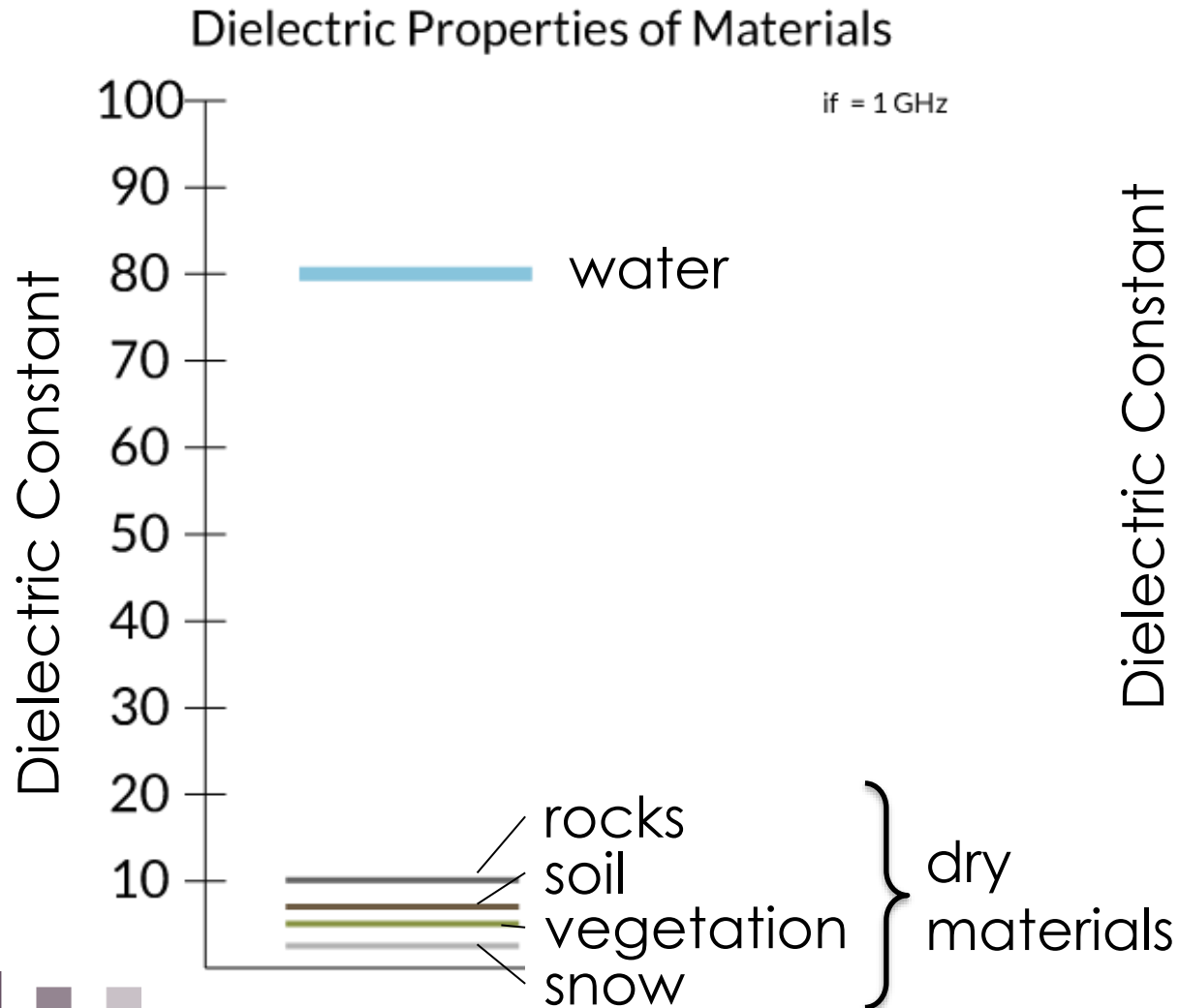
The denser the vegetation, the less likely for the signal to penetrate through the canopy. This is a function of wavelength.

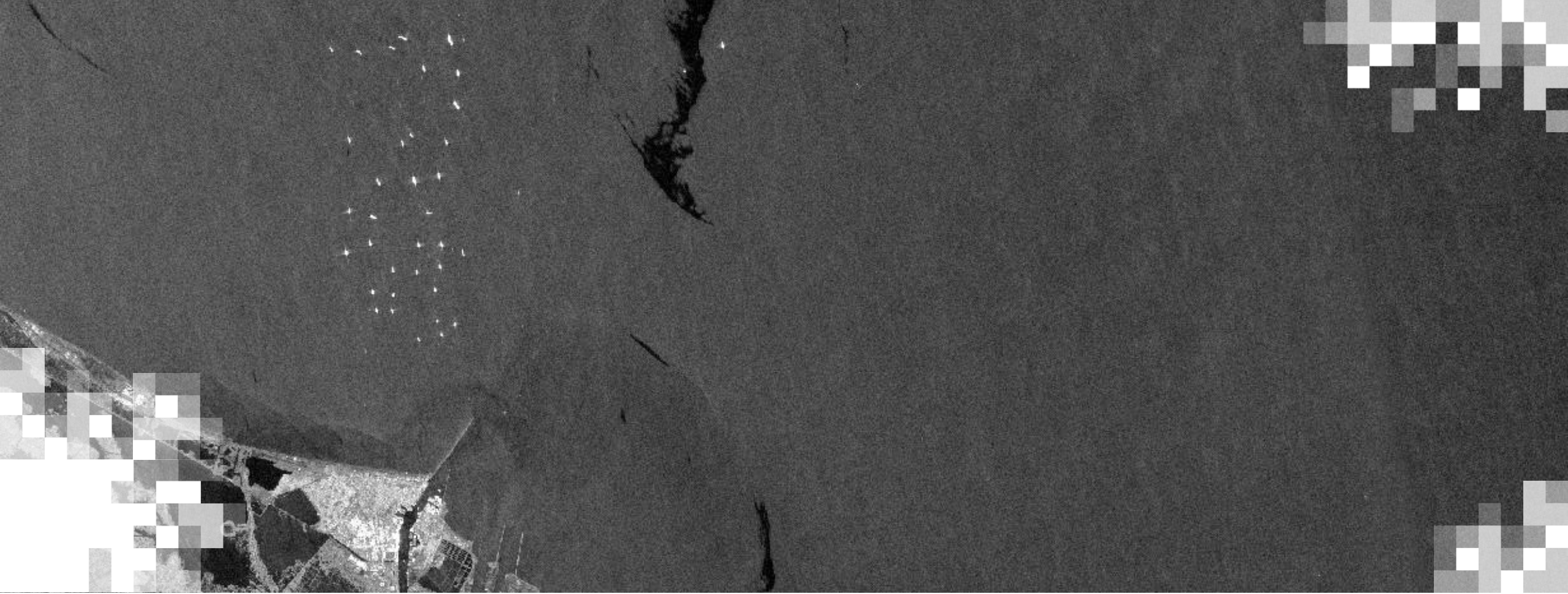
- Saturation Problem - The signal saturates at a certain biomass level, which is wavelength dependent.
- C-band \approx 20 tons/ha (2 kg/m²)
- L-band \approx 40 tons/ha (4 kg/m²)
- P-band \approx 100 tons/ha (10 kg/m²)

Broadleaf Evergreen and Coniferous Forest



Surface Parameters: Dielectric Constant



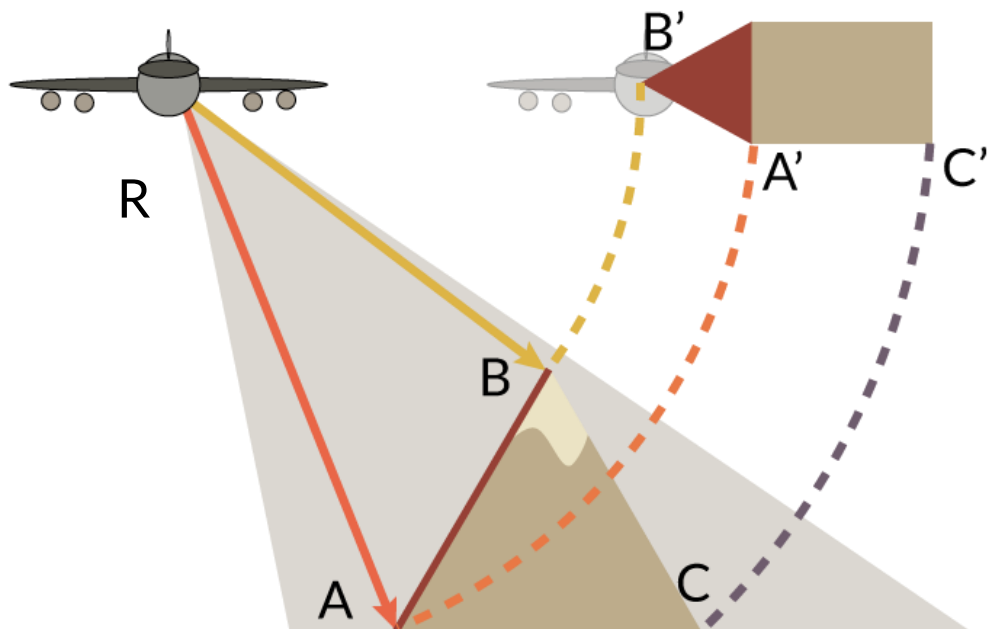


Effects of Topography and Speckle

Geometric Distortion

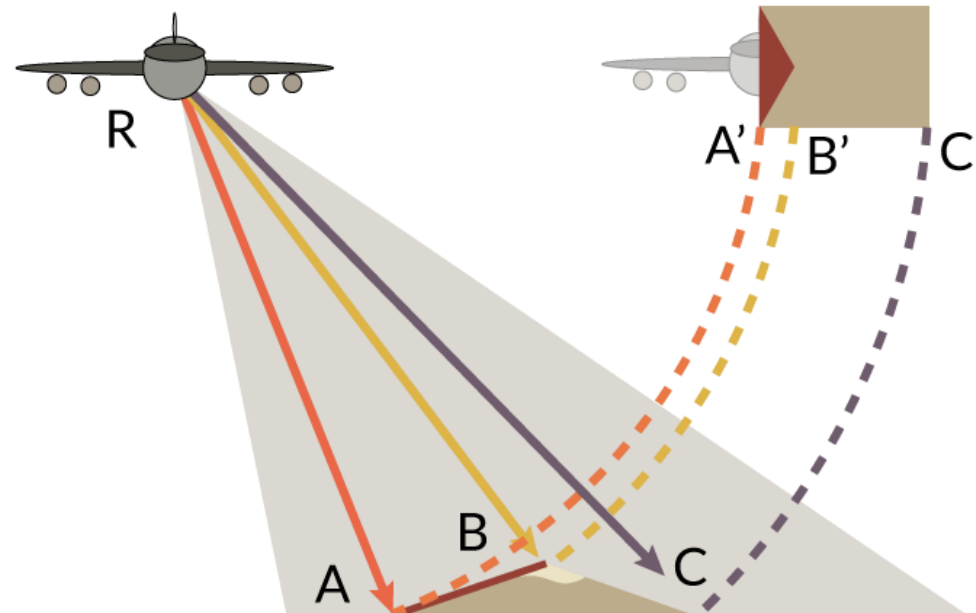
Layover

$$\begin{aligned} AB &= BC \\ A'B' &< B'C' \\ RA &> RB \\ RA' &> RB' \end{aligned}$$



Foreshortening

$$\begin{aligned} RA &< RB < RC \\ AB &= BC \\ A'B' &< B'C' \end{aligned}$$



Images based on NRC images.



Shadow

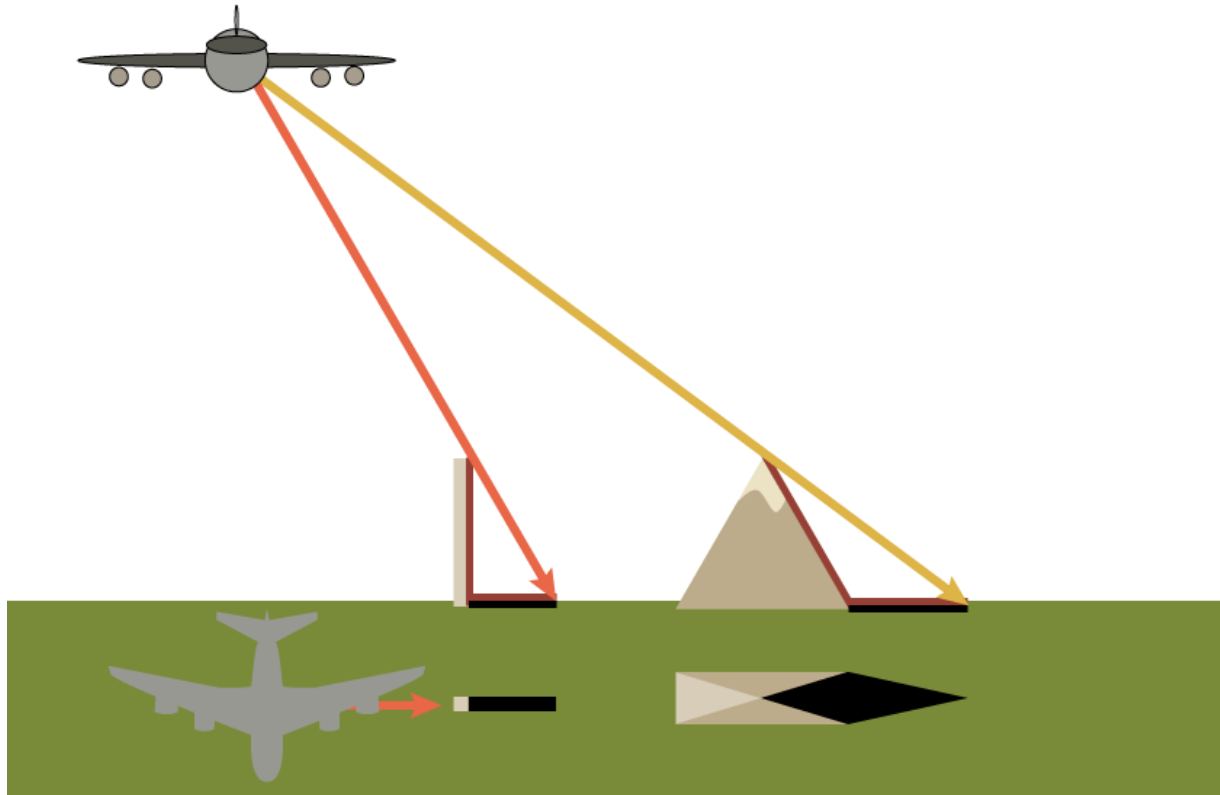


Image (left) Based on NRC



Speckle

Speckle is a granular 'noise' that inherently exists in and degrades the quality of SAR images.

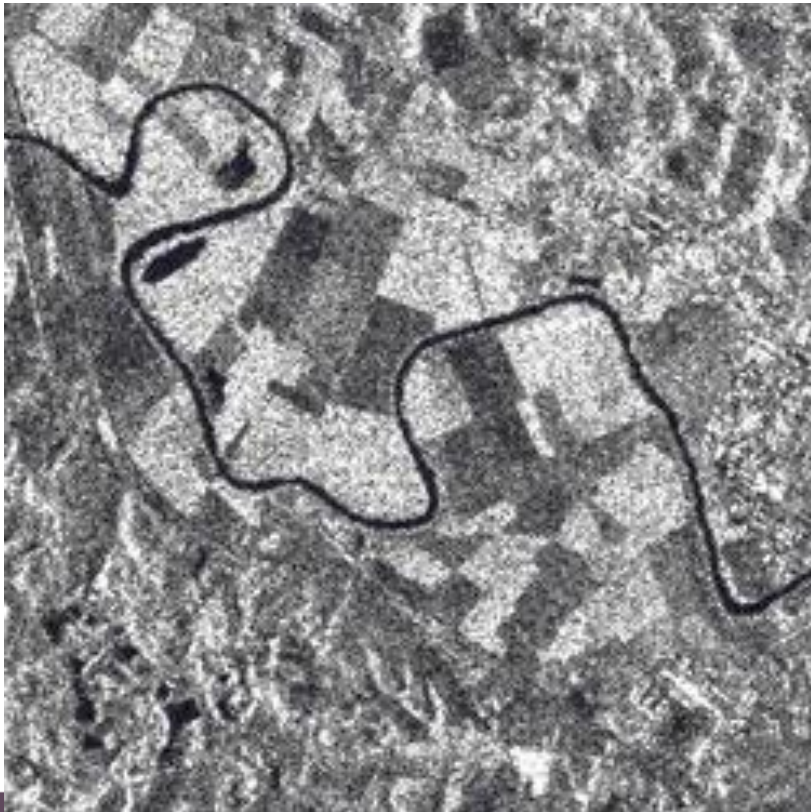
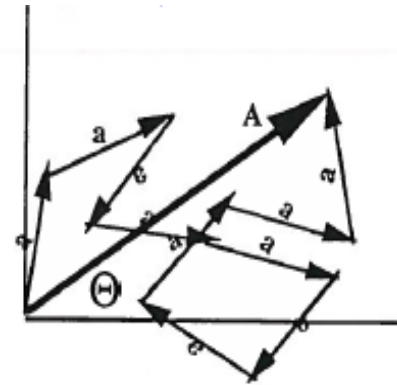


Image Credit: ESA



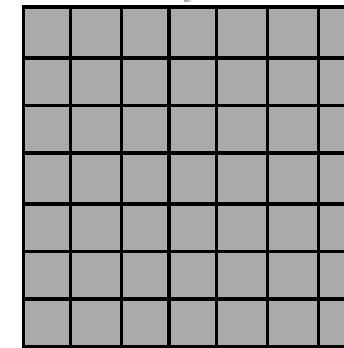
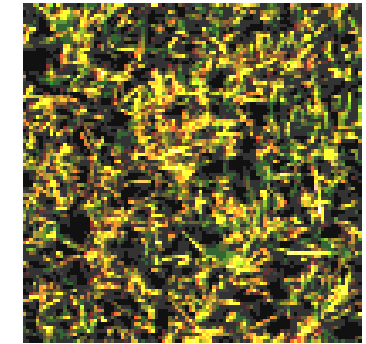
Constructive Interference



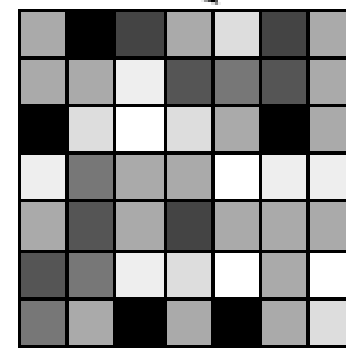
Destructive Interference



Example of Homogenous Target



A



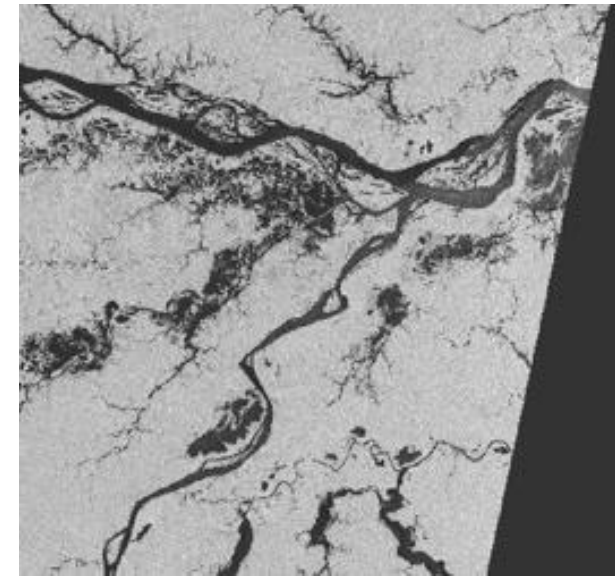
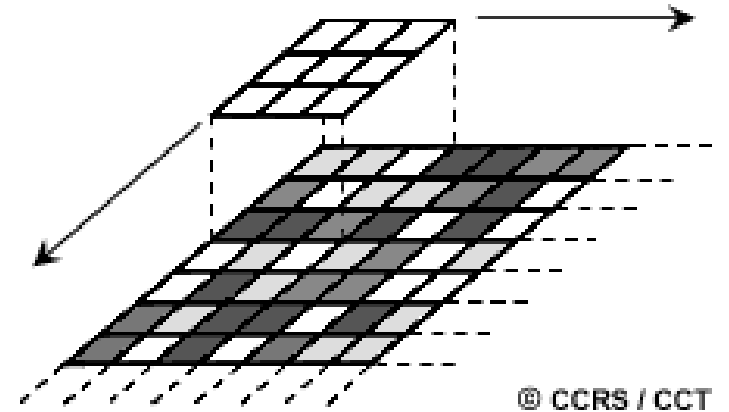
B

Image Credit: Natural Resources Canada



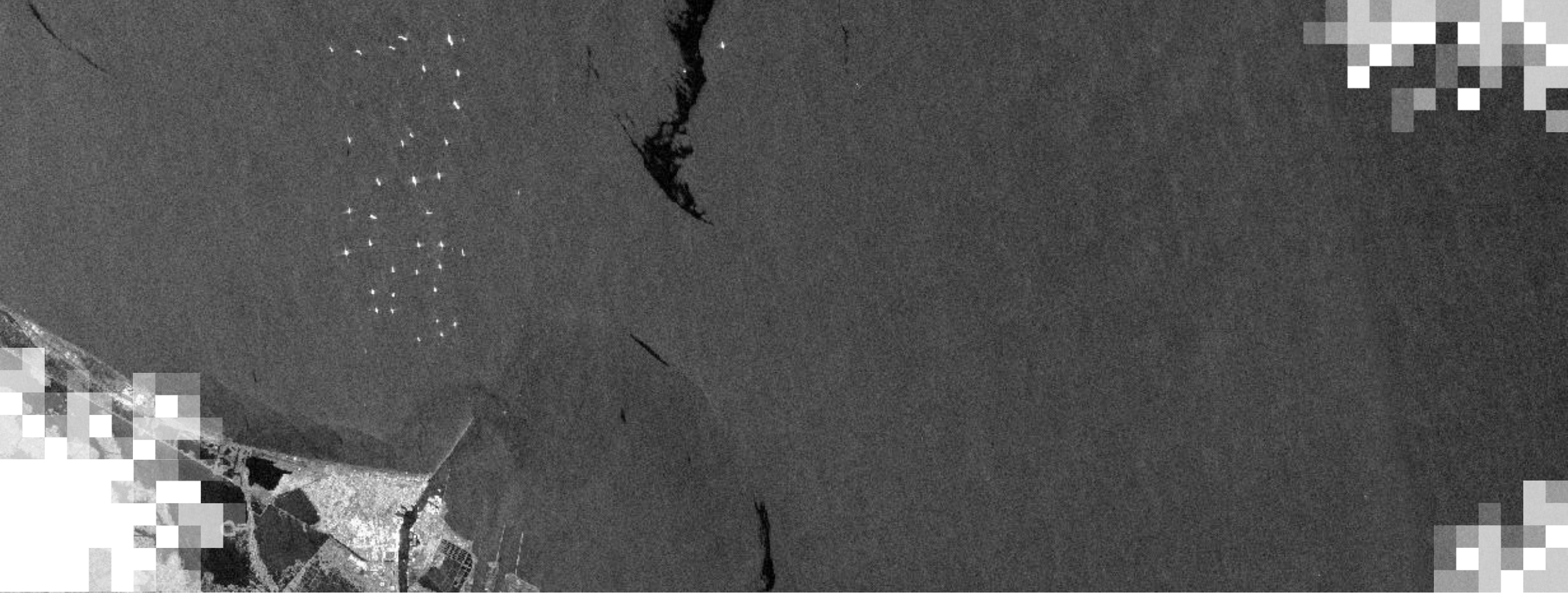
Speckle Reduction: Spatial Filtering

- Moving window over each pixel in the image
- Applies a mathematical calculation on the pixel values within the window
- The central pixel is replaced with the new value
- The window is moved along the x and y dimensions one pixel at a time
- Reduces visual appearance of speckle and applies a smoothing effect



Source: Natural Resources Canada

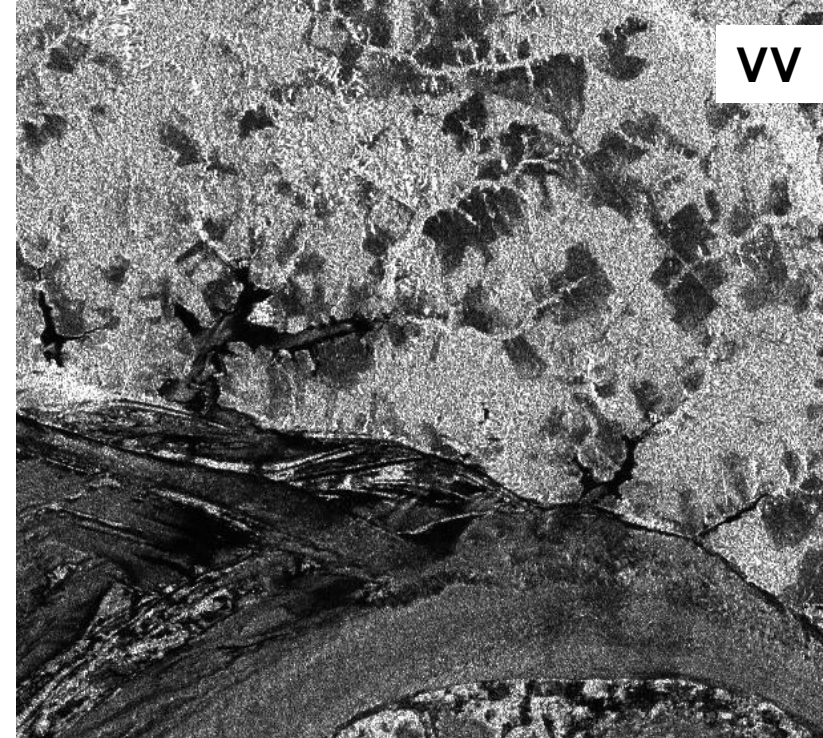
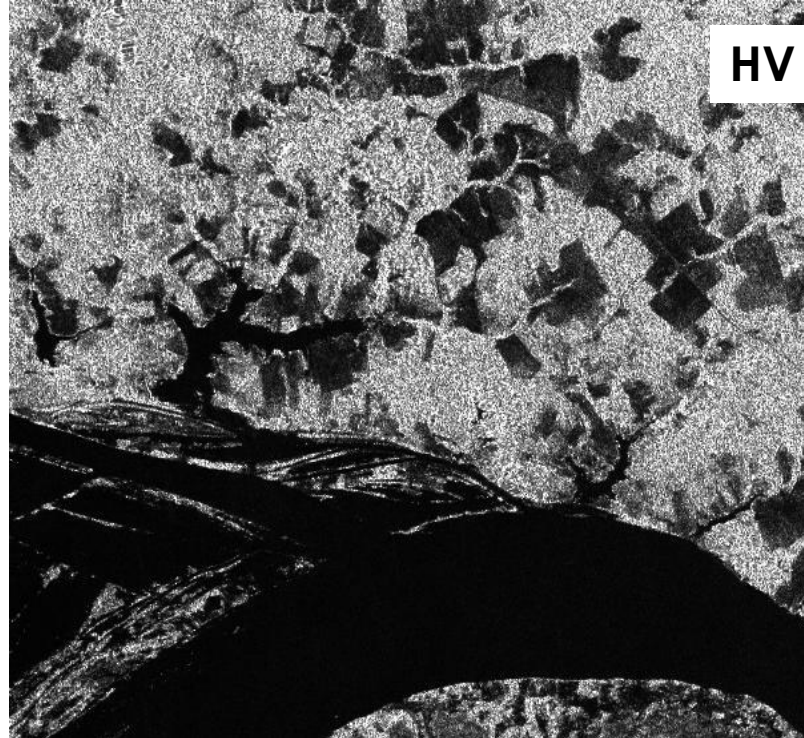
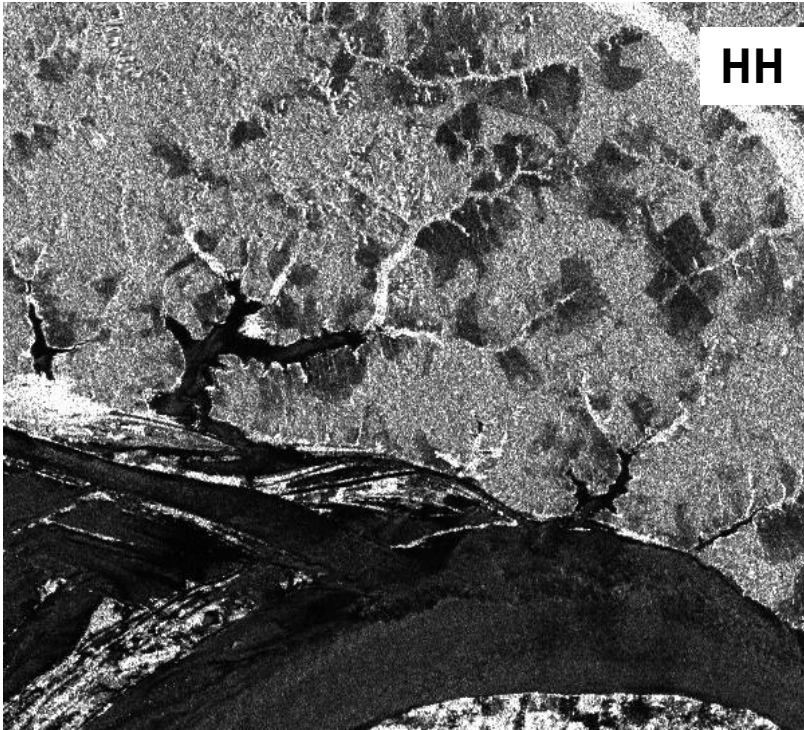




Confounding Factors

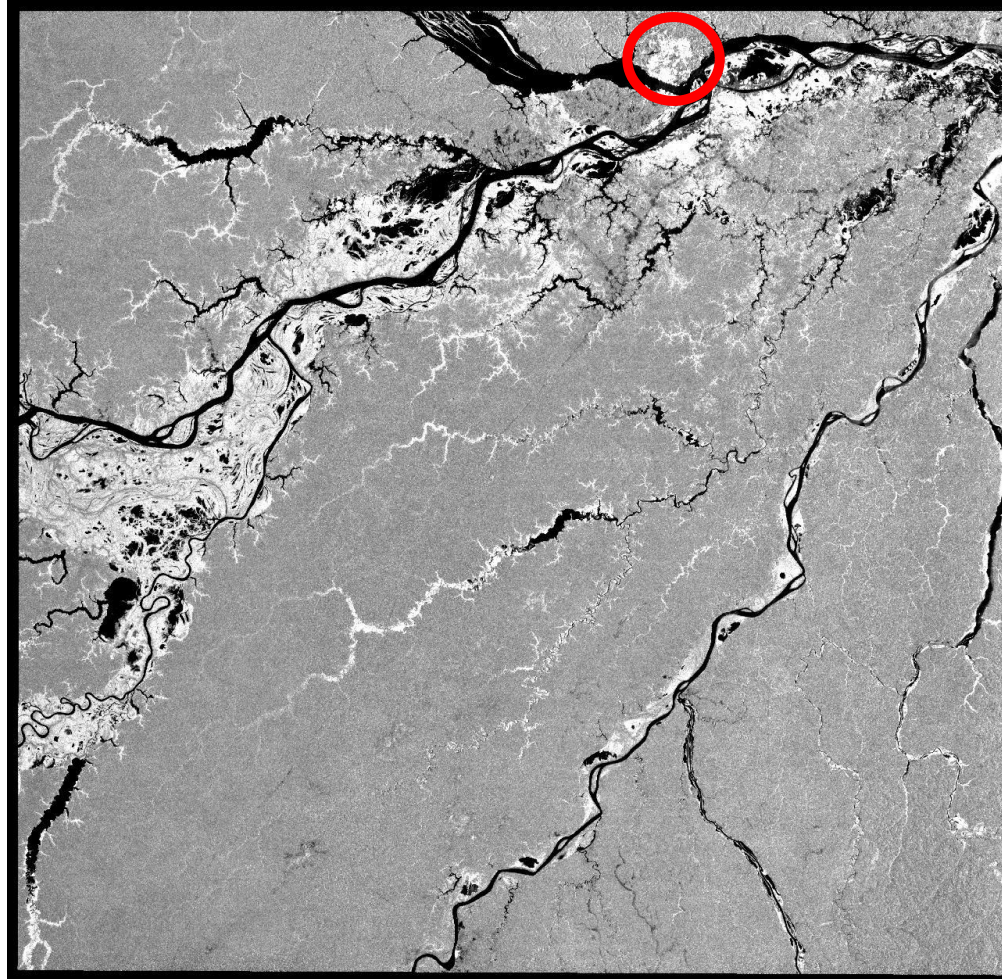
Source of Confusion: Open Water and Low Vegetation

Images from PALSAR (L-band) Near Manaus, Brazil

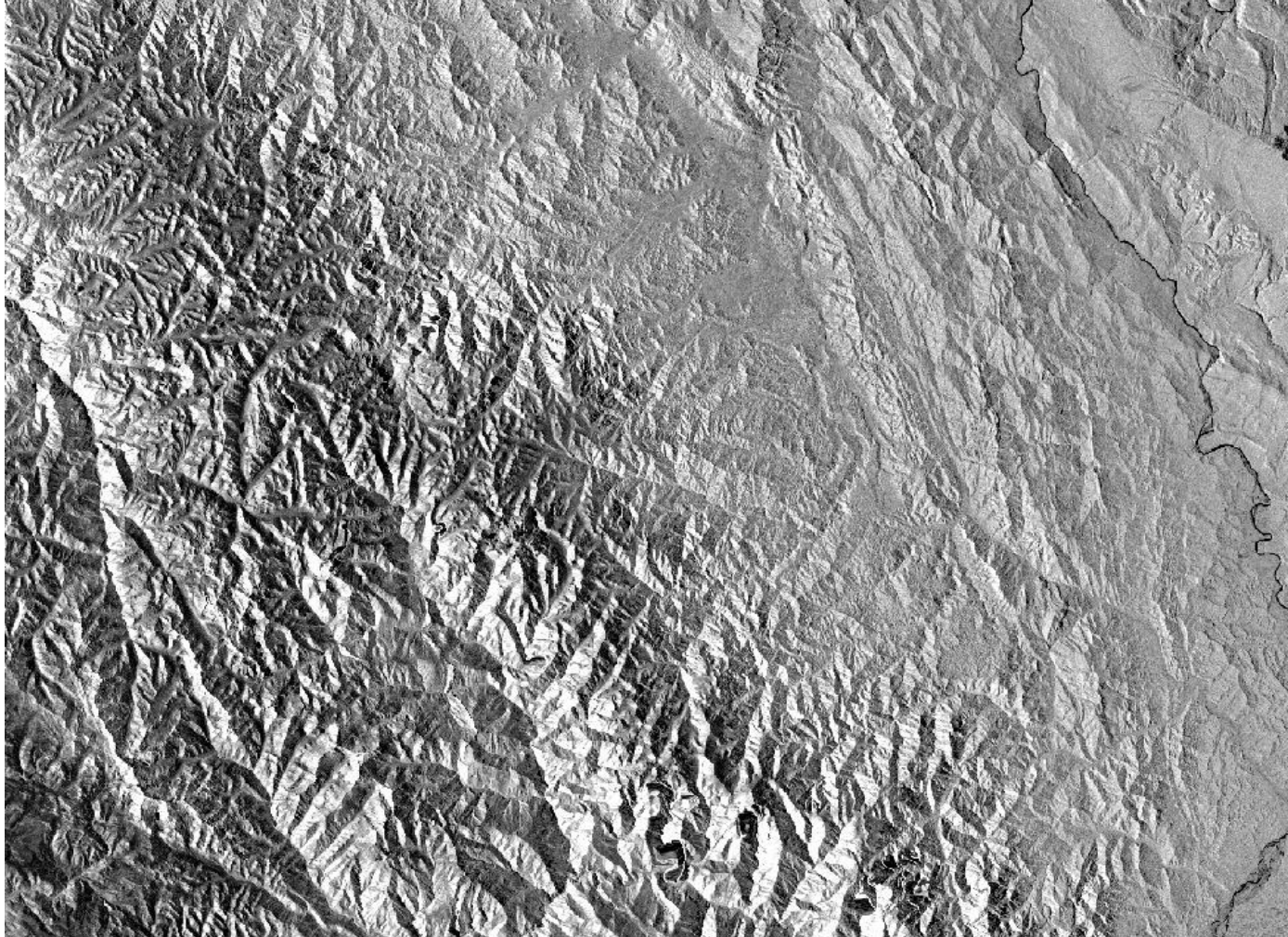


Source of Confusion: Urban Areas and Flooded Areas

Images from PALSAR (L-band) Near Manaus, Brazil



Source of Confusion: Topography and Inundated Vegetation



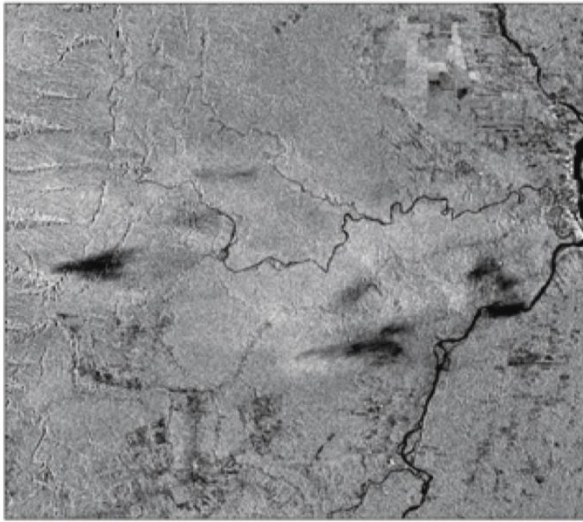
Rain Event and an Increase in Surface Moisture

Sentinell C-Band Data over Ecuador

Band 3: 2016-02-17



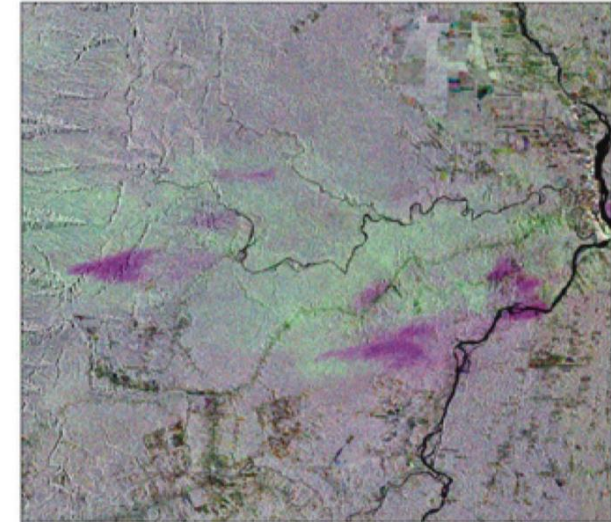
Band 35: 2017-02-17



Band 59: 2018-02-12



RGB: 2016-02-17 2017-02-17 2018-02-12



Source: SAR Handbook, Chapter 2 by Josef Kellndorfer





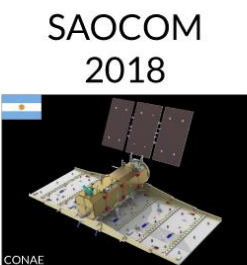
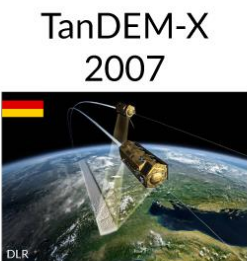
Available Radar Data

Radar Data Available

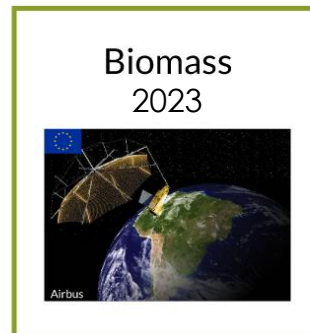
Legacy:



Current:



Future:



Freely Accessible

Image Credit: Franz Meyer, University of Alaska, Fairbanks



Open Radar Data Access: Alaska Satellite Facility

<https://search.asf.alaska.edu/#/>

ASF Data Search Vertex

Search Type: Geographic Search

Map View | Zoom | Layers | Area of Interest

lat 77.6646° lon -163.324°

Satellite	Period	Agency
Sentinel-1 Sentinel-1 includes twin satellites that each carry C-band synthetic aperture radar (SAR), together providing all-weather, day-and-night imagery of Earth's surface. More info	2014 to Present	ESA
ALOS PALSAR PALSAR was developed to contribute to the fields of mapping, precise regional land-coverage observation, disaster monitoring, and resource surveying. More info	2006 to 2011	JAXA/METI
ALOS AVNIR-2 Advanced Visible and Near-Infrared Radiometer (AVNIR)-2 images have removed distortions caused by the sensor and terrain. This allows the overlay of geospatial... More info	2006 to 2011	JAXA
SIR-C (beta) The instrument was flown aboard two the space shuttle Endeavour's missions. The instrument, monitored, and assessed large-scale environmental processes. More info	1994	NASA
S1 InSAR (beta) NISAR-format Sentinel-1 Interferogram (BETA) products are prototype Level 2 NISAR-Format interferometric products produced using the ARIA Science Data System. More info	2014 to Present	ESA
SMAP The SMAP mission provides global measurements of soil moisture and its freeze-thaw state. SMAP measures the amount of water in the top 5 cm of soil everywhere... More info	2015 to Present	NASA
UAVSAR Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) is specifically designed to acquire airborne repeat-track SAR data for differential interferometric measurements. More info	2008 to Present	NASA
RADARSAT-1	1996 to 2008	

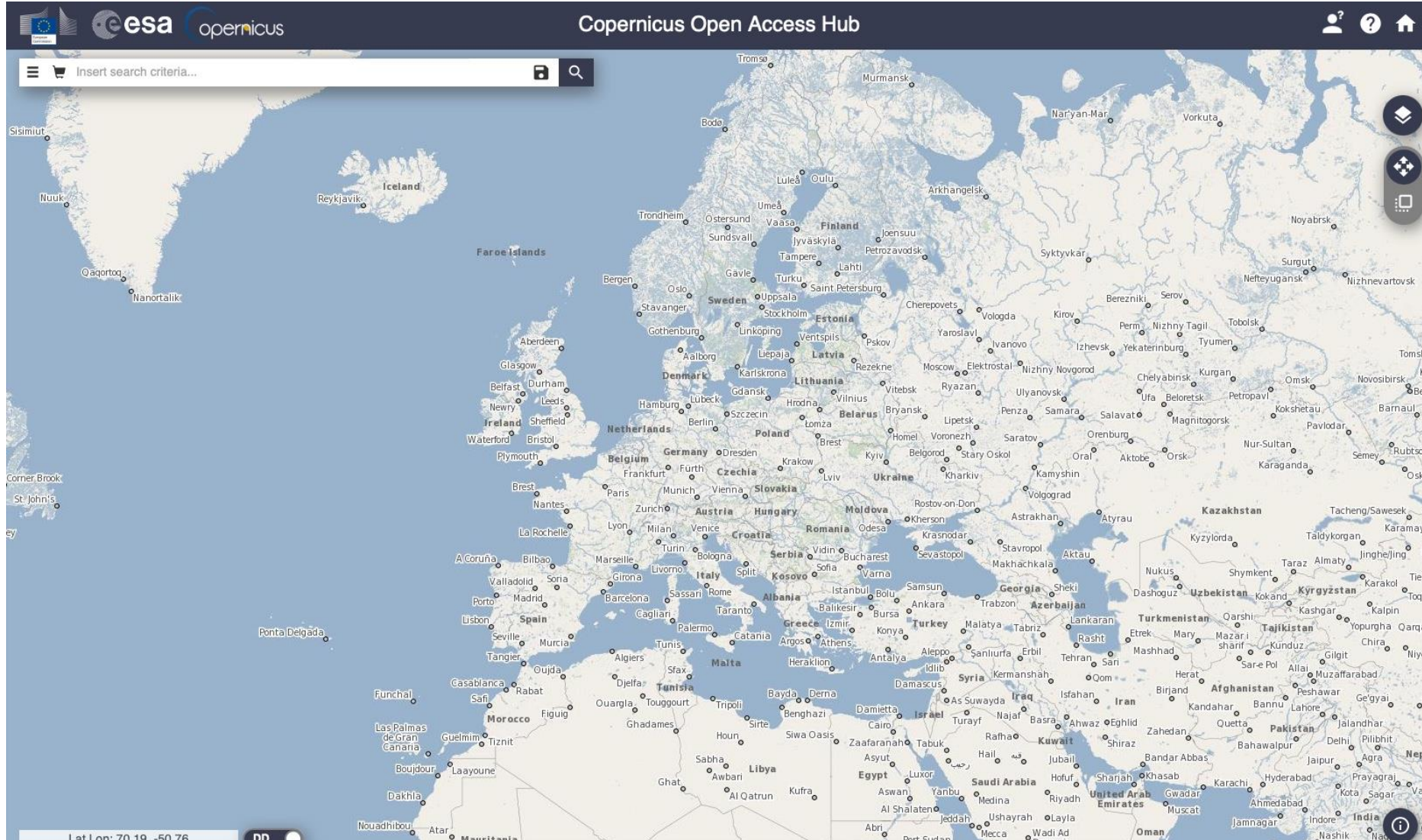
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© 2022 ASF | Contact | Non-Discrimination



Open Radar Data Access: ESA's Copernicus Hub

<https://scihub.copernicus.eu/dhus/#/home>



Open Radar Data Access: Google Earth Engine

<https://developers.google.com/earth-engine/datasets/catalog>

Earth Engine Data Catalog

Search

Home View all datasets Browse by tags Landsat MODIS Sentinel API Docs

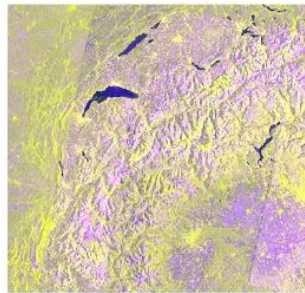
Earth Engine Data Catalog

Earth Engine's public data catalog includes a variety of standard Earth science raster datasets. You can import these datasets into your script environment with a single click. You can also upload your own raster data or vector data for private use or sharing in your scripts.

Looking for another dataset not in Earth Engine yet? Let us know by [suggesting a dataset](#).

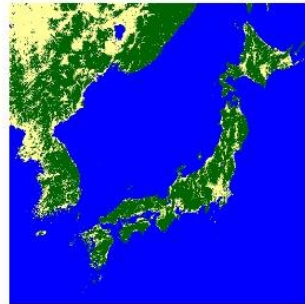
sar

Sentinel-1 SAR GRD: C-band Synthetic Aperture Radar Ground Range Detected, log scaling



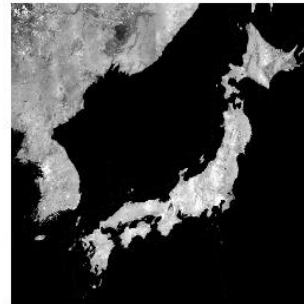
The Sentinel-1 mission provides data from a dual-polarization C-band Synthetic Aperture Radar (SAR) instrument at 5.405GHz (C band). This collection includes the S1 Ground Range Detected (GRD) scenes, processed using the Sentinel-1 Toolbox to generate a calibrated, ortho-corrected product. The collection is updated daily. New ...

Global PALSAR-2/PALSAR Forest/Non-Forest Map



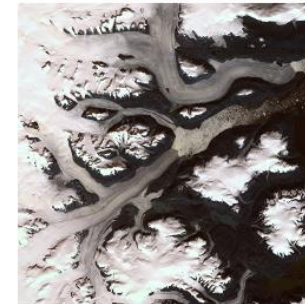
The global forest/non-forest map (FNF) is generated by classifying the SAR image (backscattering coefficient) in the global 25m resolution PALSAR-2/PALSAR SAR mosaic so that strong and low backscatter pixels are assigned as "forest" and "non-forest", respectively. Here, "forest" is defined as the natural forest with ...

Global PALSAR-2/PALSAR Yearly Mosaic



The global 25m PALSAR/PALSAR-2 mosaic is a seamless global SAR image created by mosaicking strips of SAR imagery from PALSAR/PALSAR-2. For each year and location, the strip data were selected through visual inspection of the browse mosaics available over the period, with those showing minimum ...

2000 Greenland Mosaic - Greenland Ice Mapping Project (GIMP)



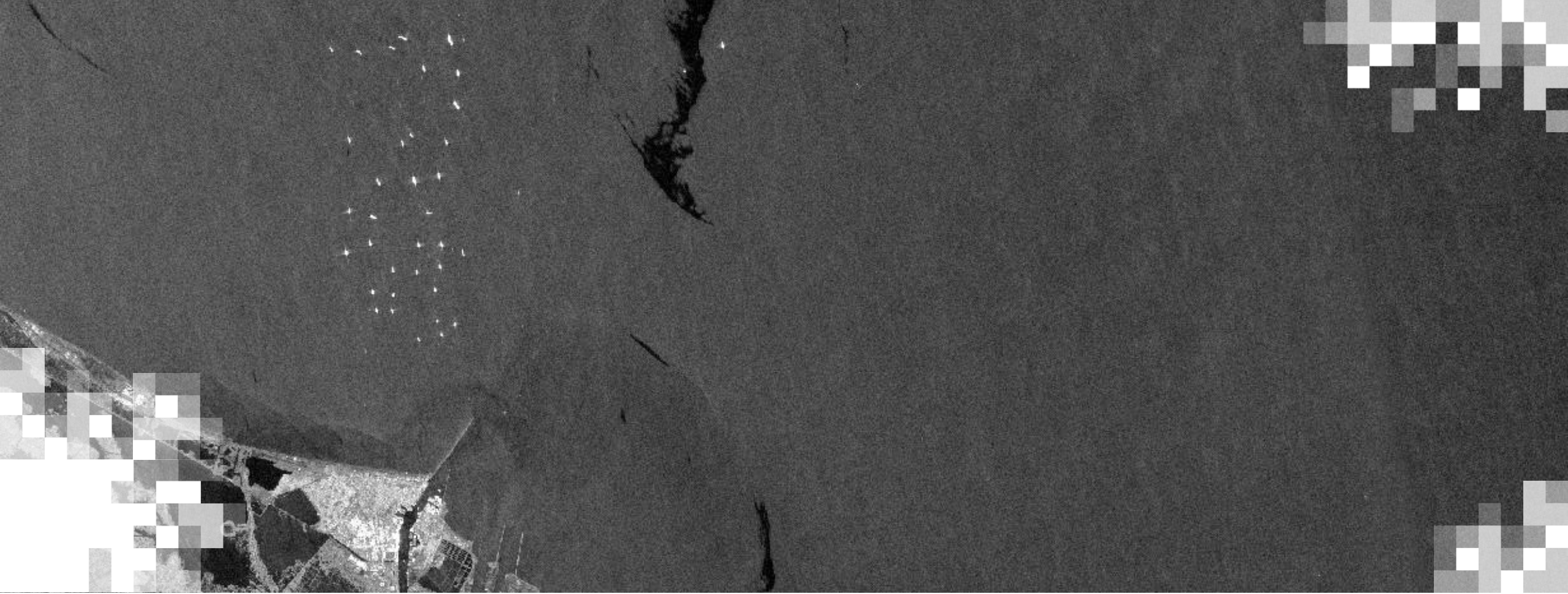
This dataset provides a complete 15 m resolution image mosaic of the Greenland ice sheet derived from Landsat 7 ETM+ and RADARSAT-1 SAR imagery from the years 1999 to 2002. The methods include a combination of image cloud masking, pan sharpening, image sampling and resizing, ...



Processing Steps for Analysis Ready SAR Data

1. Radiometric Calibration
2. Terrain correction using SRTM 30 or ASTER DEM for areas greater than 60 degrees latitude, where SRTM is not available.
3. Speckle Filtering





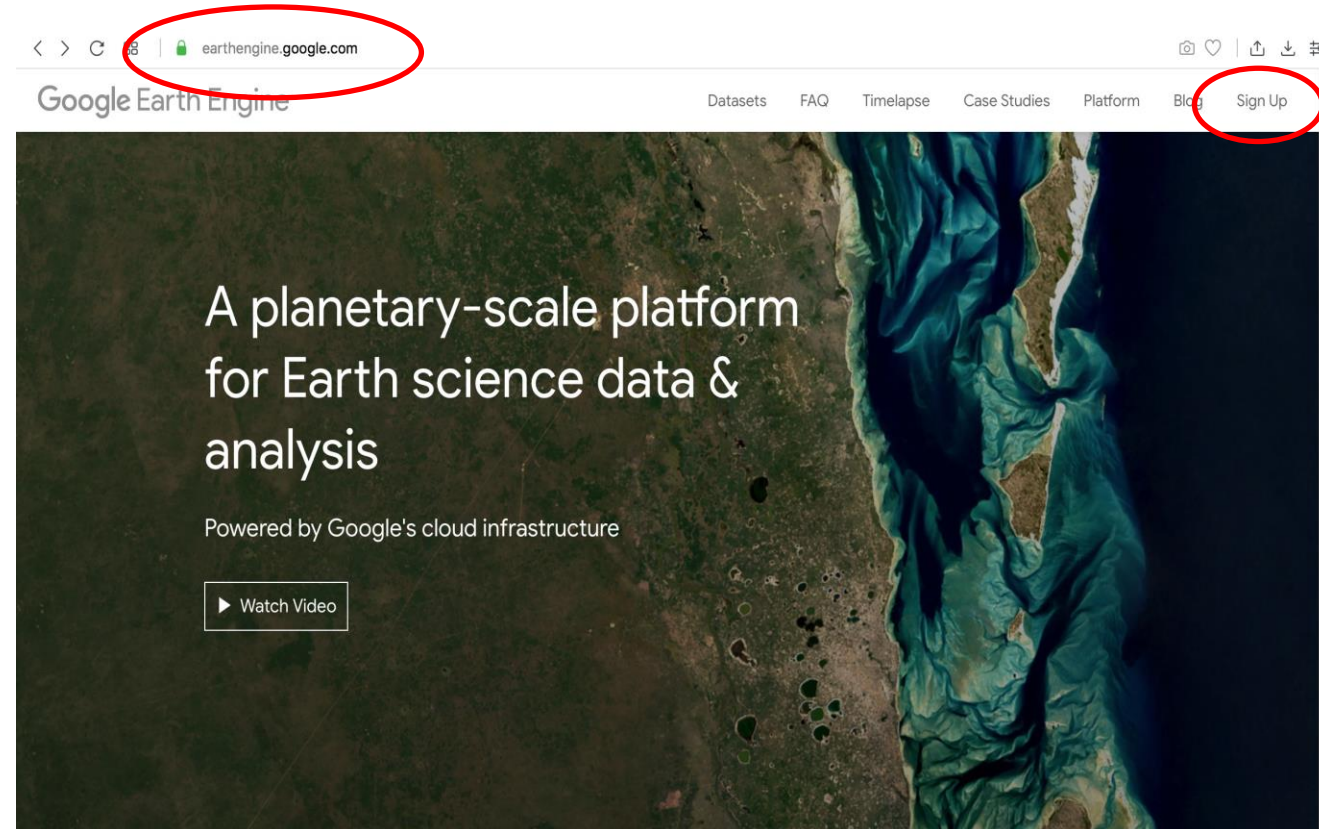
Flood Mapping Demonstration

Google Earth Engine Overview

- A cloud-based geospatial processing platform
- Available to scientists, researchers, and developers for analysis of the Earth's surface
- Catalog of satellite imagery and geospatial datasets (including Sentinel-1):

<https://developers.google.com/earth-engine/datasets/catalog/>

- JavaScript code editor
- Go to Google Earth Engine:
<https://earthengine.google.com>
- Sign up for an account (it's free)



Meet Earth Engine



Google Earth Engine Code Editor

<https://code.earthengine.google.com>

The image shows a screenshot of the Google Earth Engine Code Editor interface. The interface is divided into several sections:

- Search for datasets or places:** A search bar at the top center.
- Script manager:** A sidebar on the left with a search bar and a list of scripts.
- API documentation:** A link in the top navigation bar.
- Asset manager:** A link in the top navigation bar.
- Get a link (URL) to the script:** A link in the top navigation bar.
- Save the script:** A link in the top navigation bar.
- Run the script:** A link in the top navigation bar.
- Help button:** A button in the top right corner.
- Feedback button:** A button in the top right corner.
- Code Editor:** The central area containing a code editor with a JavaScript script for cloud masking.
- Inspector:** A panel on the right for inspecting map elements.
- Console output:** A panel on the right for viewing script execution output.
- Task manager:** A panel on the right for managing tasks.
- Geometry Tools:** A toolbar on the left for map interaction.
- Zoom:** A zoom control on the left side of the map.
- Map:** The main map area showing a satellite view of a coastal region.
- Layer manager:** A panel on the right for managing map layers.

```
1 // This example uses the Sentinel-2 QA band to cloud mask
2 // the collection. The Sentinel-2 cloud flags are less
3 // selective, so the collection is also pre-filtered by the
4 // CLOUDY_PIXEL_PERCENTAGE flag, to use only relatively
5 // cloud-free granules.
6
7 // Function to mask the Sentinel-2 QA band.
8 function maskQA(qa) {
9   // Sentinel-2 QA band.
10  var qa = qa.band('QA10').eq(0);
11
12  // Bits 10 and 11 are clouds and cirrus, respectively.
13  var cloudMask = qa.band('QA10').eq(0);
14  var cirrusMask = qa.band('QA11').eq(0);
15  // Both flags indicate clear conditions.
16  var mask = qa.bitwiseAnd(cloudMask, cirrusMask);
17
18  // Return the masked and scaled data, without the QA band.
19  return image.updateMask(mask).divide(10000)
20   .select(['B4']);
21 }
22
```



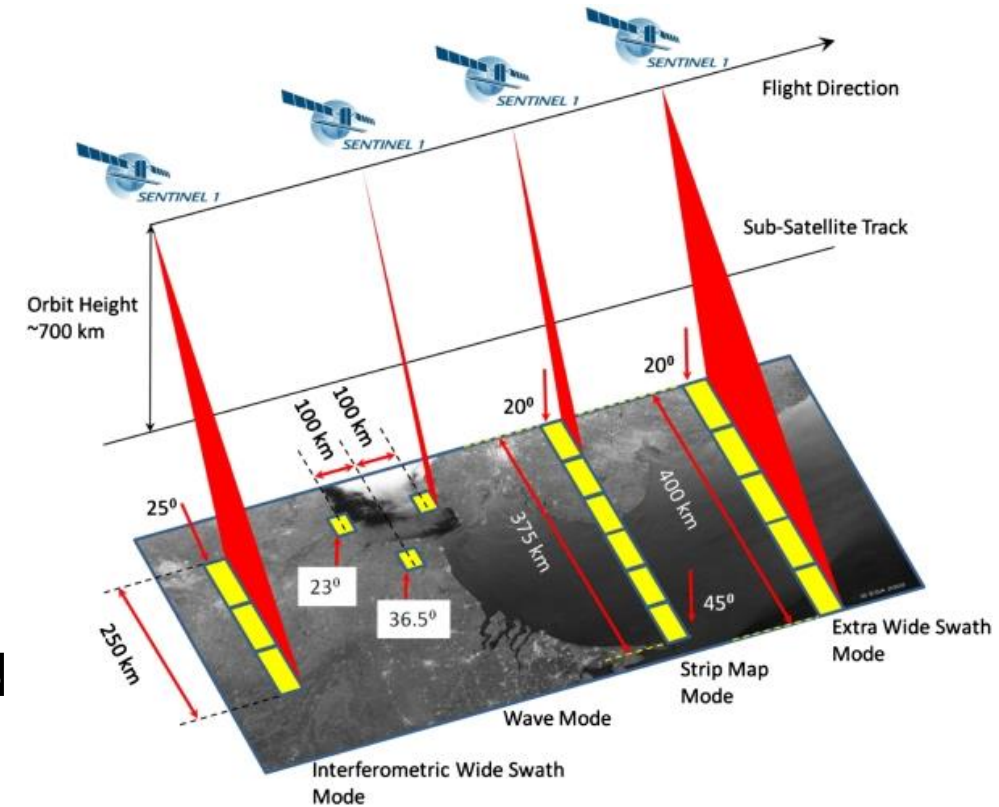
Sentinel-1 Data Review

Two Satellites: A & B

- C-band data
- Each satellite has global coverage every 12 days
- Global coverage of 6 days over the equator when using data from both satellites

Different Modes:

- Extra Wide Swath – For monitoring oceans and coasts
- Strip Mode – By special order only and intended for special needs
- Wave Mode – Routine collection for the ocean
- *Interferometric Wide Swath – Routine collection for land (**this is the one you want to use**)*



Sentinel-1 Catalog

https://developers.google.com/earth-engine/datasets/catalog/COPERNICUS_S1_GRD

Each scene was pre-processed with [Sentinel-1 Toolbox](#) using the following steps:

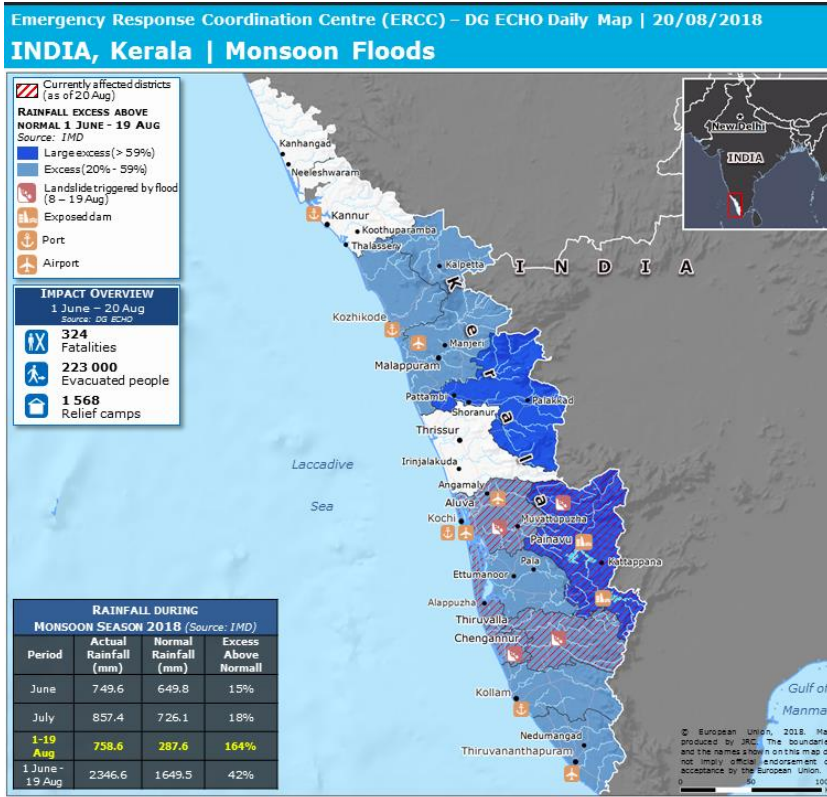
1. Thermal noise removal
2. Radiometric calibration
3. Terrain correction using SRTM 30 or ASTER DEM for areas greater than 60 degrees latitude, where SRTM is not available. The final terrain-corrected values are converted to decibels via log scaling ($10 \cdot \log_{10}(x)$).



The screenshot shows the Earth Engine Data Catalog interface. At the top, there is a search bar and navigation links for LANGUAGE, ALL PRODUCTS, and a user profile icon. Below the navigation bar, the main content area displays the dataset title "Sentinel-1 SAR GRD: C-band Synthetic Aperture Radar Ground Range Detected, log scaling" with a five-star rating. A thumbnail image of a SAR image is shown on the left. To the right of the thumbnail, the "Dataset Availability" is listed as "2014-10-03T00:00:00 - Present", and the "Dataset Provider" is "European Union/ESA/Copernicus". Below this, an "Earth Engine Snippet" is provided: `ee.ImageCollection("COPERNICUS/S1_GRD")`. At the bottom, there are several tags: radar, sar, backscattering, polarization, eu, esa, copernicus, and sentinel.



Flood Case: Kerala Floods, August 2018



[http://www.gdacs.org/contentdata/maps/daily/FL/1000212/ECMD/20180820 Kerala Floods.png](http://www.gdacs.org/contentdata/maps/daily/FL/1000212/ECMD/20180820_Kerala_Floods.png)

Kerala floods: death toll rises to at least 324 as rescue effort continues

220,000 people left homeless and thousands still trapped in southern Indian state after unusually heavy rain



▲ 'Please pray for us': Kerala experiences worst monsoon in nearly a century - video report

<https://www.theguardian.com/world/2018/aug/17/kerala-floods-death-toll-rescue-effort-india>



GEE Code

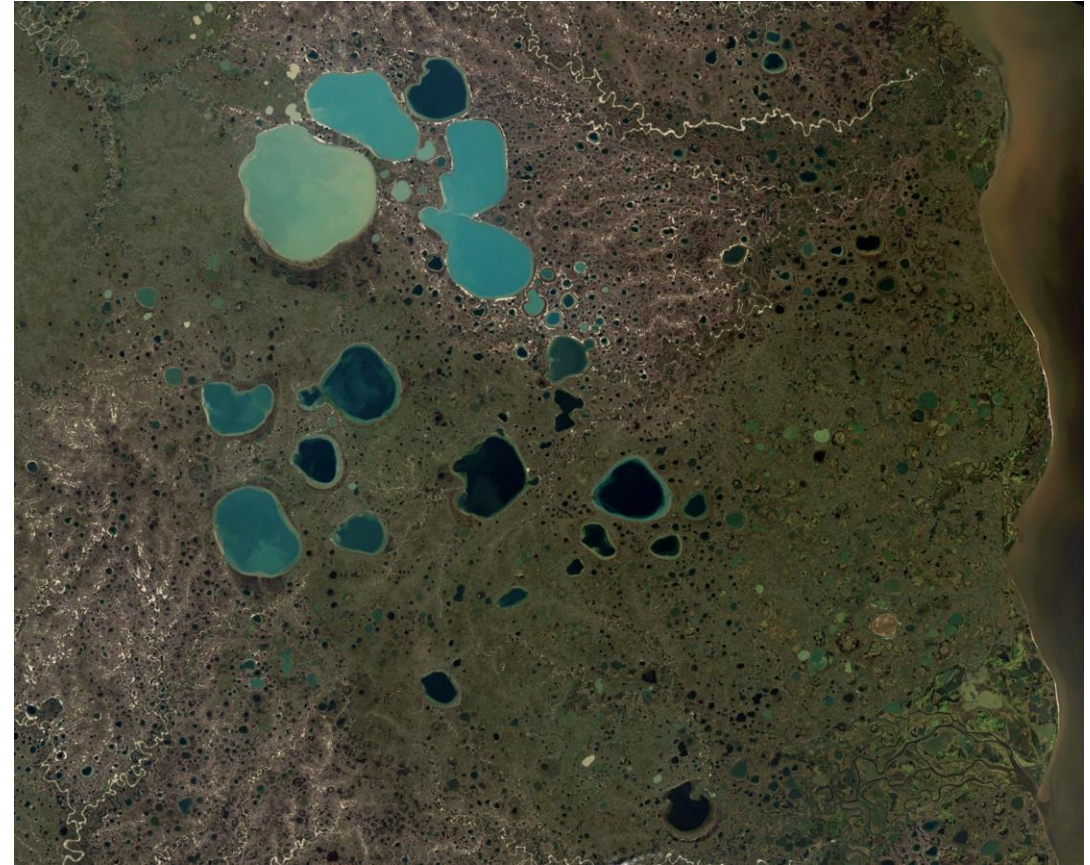
Time Series Flood Mapping:

<https://code.earthengine.google.com/34ef34c863d26bceee24e194d71236e5>



Questions?

- Please enter your questions in the Q&A box. We will answer them in the order they were received.
- We will post the Q&A to the training website following the conclusion of this session.



<https://earthobservatory.nasa.gov/images/6034/pothole-lakes-in-siberia>



Contacts

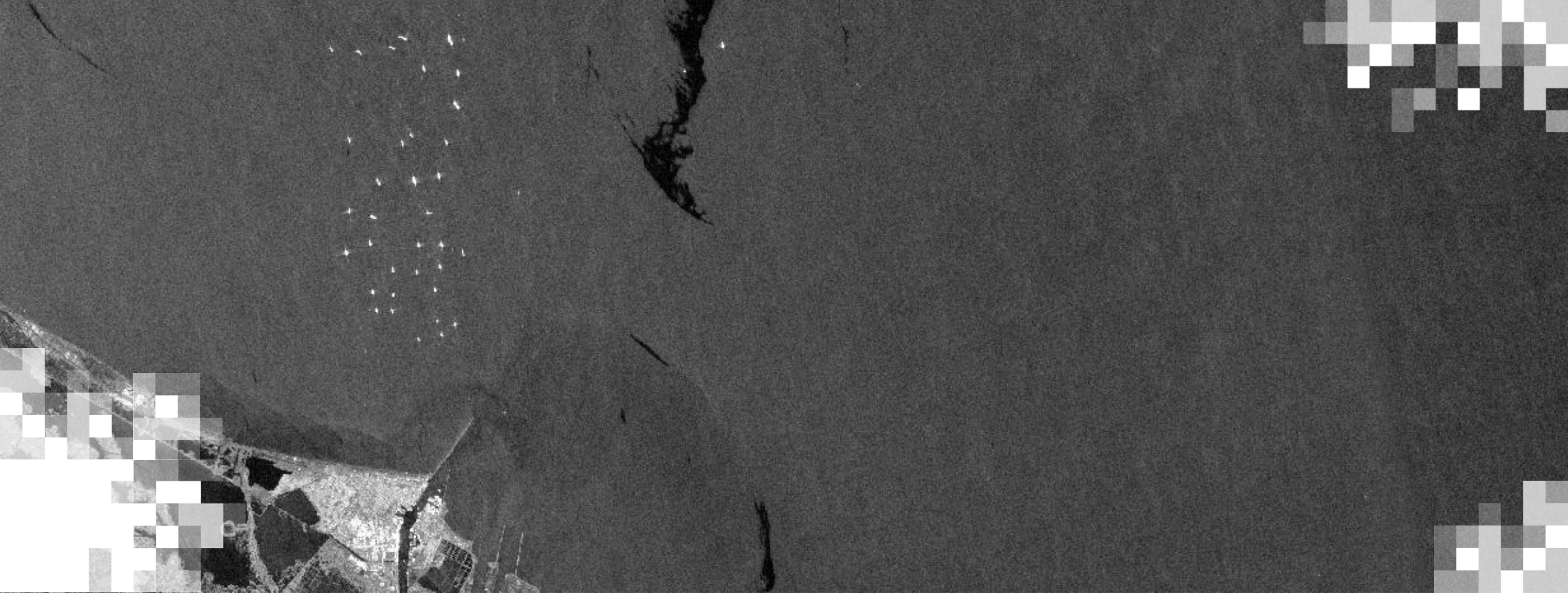
- Trainer:
 - Erika Podest: erika.podest@jpl.nasa.gov
- Training Webpage:
 - <https://appliedsciences.nasa.gov/join-mission/training/english/arset-disaster-assessment-using-synthetic-aperture-radar>
- ARSET Website:
 - <https://appliedsciences.nasa.gov/arset>
- Twitter: [@NASAARSET](https://twitter.com/NASAARSET)





Thank You!





Appendix: SAR Tutorial References and Resources

ARSET SAR Tutorials

Introduction to SAR Webinar Series:

Session 1: Basics of SAR

<https://www.youtube.com/watch?v=Xemo2ZpduHA>

Session 2: SAR Processing and Data Analysis

<https://www.youtube.com/watch?v=OwrLh7pjHRQ>

Session 3: Introduction to Polarimetric SAR

<https://www.youtube.com/watch?v=-xU4oE66pgY>

Session 4: Introduction to SAR Interferometry

<https://www.youtube.com/watch?v=P8lQ7pjkRlw>

ARSET SAR Tutorials

Radar Remote Sensing for Land, Water, & Disaster Applications Webinar Series:

Session 1: SAR for Mapping Land Cover

https://www.youtube.com/watch?v=IDxBgK1VY_4

Session 2: SAR for Flood Mapping

<https://www.youtube.com/watch?v=QKrG5jYZe10>

Session 3: SAR for Mapping Soils and Crops

<https://www.youtube.com/watch?v=yoEu2P1i5xE>

Session 4: InSAR for Earthquake Studies

<https://www.youtube.com/watch?v=P8lQ7pjkRlw>

ARSET SAR Tutorials

SAR for Landcover Applications:

Session 1: SAR for Flood Mapping Using Google Earth Engine

<https://www.youtube.com/watch?v=J5RPibJ8my4>

Session 2: Exploiting SAR to Monitor Agriculture

<https://www.youtube.com/watch?v=vS7r50EbFQY>

SAR for Disasters and Hydrological Applications:

Session 1: SAR for Flood Mapping Using Google Earth Engine

<https://www.youtube.com/watch?v=4Y2giuRPCuc>

Session 2: In SAR for Landslide Observations

<https://www.youtube.com/watch?v=bigoDH9VsiA>

Session 3: Generating a DEM

<https://www.youtube.com/watch?v=9PbFbHqRufQ>

ARSET SAR Tutorials

Forest Mapping and Monitoring with SAR Data:

Session 1: Time Series Analysis of Forest Change

<https://www.youtube.com/watch?v=KitbOq7ARNQ>

Session 2: Land Cover Classification with Radar and Optical Data

<https://www.youtube.com/watch?v=raXA3gnb94Q>

Session 3: Mangrove Mapping

<https://www.youtube.com/watch?v=vaBEHALn-js>

Session 4: Forest Stand Height

https://www.youtube.com/watch?v=RROJ_4Ud78g

Alaska Satellite Facility Resources

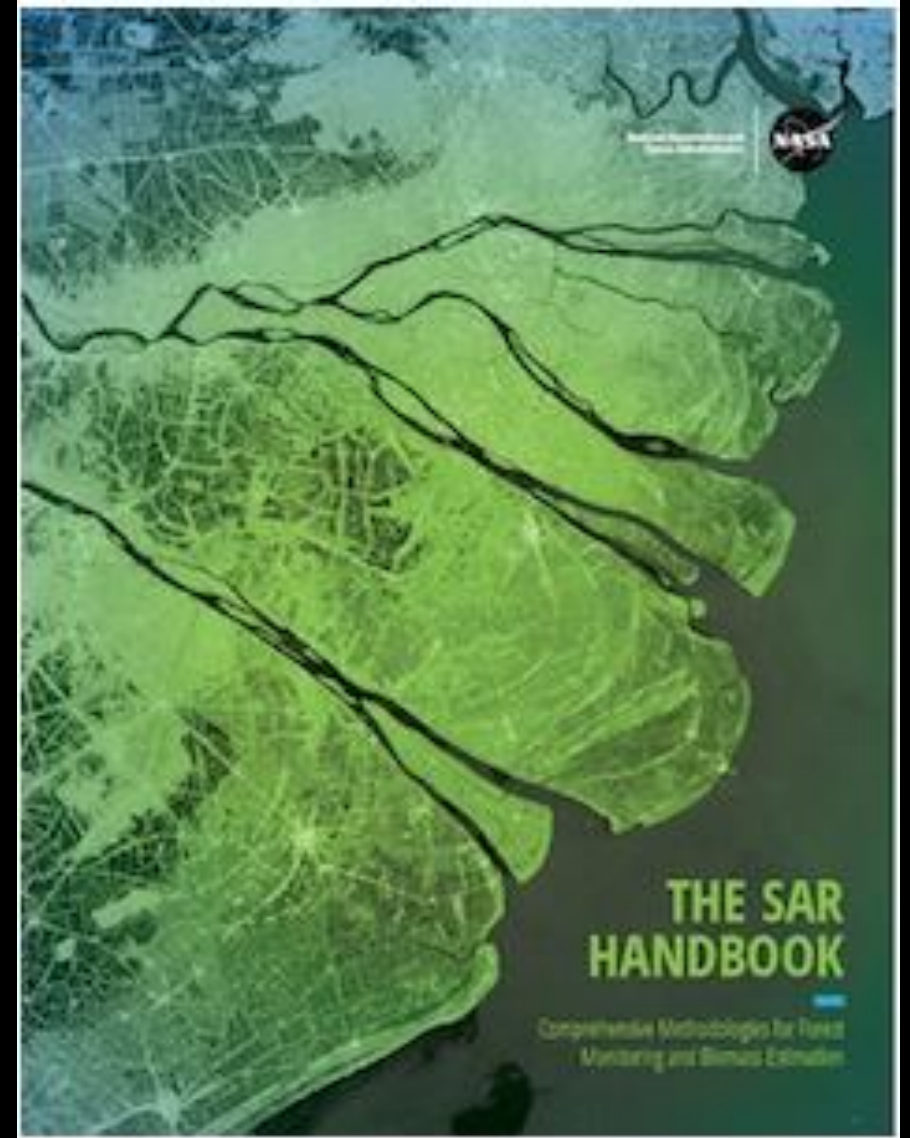
Fundamentals of SAR

Data Tools

Data Recipes

SAR Handbook

Comprehensive Methodologies for
Forest Monitoring and Biomass Estimation



SAR Tutorial References

A Laymans Guide to Interpreting L and C-band SAR:

http://ceos.org/document_management/SEO/DataCube/Laymans_SAR_Interpretation_Guide_2.0.pdf

SAR Tutorials (written):

-A tutorial on SAR by ESA

<http://ieeexplore.ieee.org/document/6504845/?reload=true>

by the EU:

<http://www.radartutorial.eu/20.airborne/ab07.en.html>

SAR Tutorial References

-CRISP Center:

<https://crisp.nus.edu.sg/~research/tutorial/mw.htm>

-Lincoln Lab:

http://www.egr.msu.edu/classes/ece480/capstone/spring12/group05/docs/presentations/TechLecture_Team5.pdf

-INSAR by ESA:

http://www.esa.int/esapub/tm/tm19/TM-19_ptA.pdf

SAR Tutorial References

Fundamentals of Remote Sensing by Natural Resources Canada:

<http://www.nrcan.gc.ca/earth-sciences/geomatics/satellite-imagery-air-photos/satellite-imagery-products/educational-resources/9371>

SAR Tutorial (video)

-Echoes in Space – Radar Remote Sensing by ESA

<https://eo-college.org/courses/echoes-in-space/>

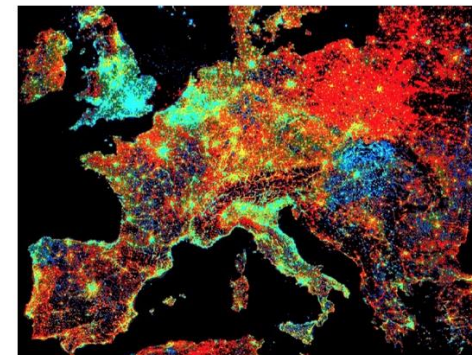
Sentinel-1 Tutorials:

<http://step.esa.int/main/doc/tutorials/>

Google Earth Engine

Cloud Based Remote Sensing with Google Earth Engine

<https://www.eefabook.org>



Welcome to Cloud-Based Remote Sensing with Google Earth Engine: Fundamentals and Applications

This book is the product of more than a year of effort from more than 100 individuals, working in concert to provide this free resource for learning how to use this exciting technology for the public good.

The book includes work from professors, undergraduates, master's students, PhD students, assistant professors, associate professors, and independent consultants.



Sisters of SAR

Sisters of SAR

Email: sistersofsar@gmail.com

Twitter: [@SistersofSAR](https://twitter.com/SistersofSAR)

LinkedIn: [Sisters of SAR](https://www.linkedin.com/company/sisters-of-sar)

The screenshot shows the homepage of the Sisters of SAR website. At the top, there is a navigation bar with the logo and links for 'About', 'Organisers', 'SAR Stars', 'SAR resources', 'Projects', 'Become an ally', and 'Contact'. The main content area features a central image of the Earth with several SAR satellites orbiting it. The text 'SISTERS OF SAR' is overlaid on the image. To the left of the image, the text reads: 'We are Women in SAR amplifying the voices of Women in SAR'. To the right, a list of hashtags is displayed: #SARisbeautiful, #WomeninSAR, #WomeninRemoteSensing, #GoldenAgeofSAR, #RepresentationMatters, #SARisgorgeous, #InclusivityinScience, #DiversityinScience, and #WomeninSTEM. Below the main content area is a purple navigation bar with five buttons: 'Mission' (Our Visions and Goals), 'Organisers' (Our organisers), 'Projects' (Our fabulous collaborations), 'SAR Stars' (Get to know them), and 'Get Involved' (Become an ally). At the bottom, there is a dark blue footer with a logo on the left, a paragraph of text in the center, and another logo on the right.

Mission
Our Visions and Goals

Organisers
Our organisers

Projects
Our fabulous collaborations

SAR Stars
Get to know them

Get Involved
Become an ally

Sisters of SAR is a voluntary initiative that officially launched on Twitter on April 27, 2020. Created and organised by women in SAR, we promote the exceptional advancements in SAR research and engineering around the world while showcasing the accomplishments of other women in our field. In a field historically dominated by men, we help make sure that the voices and work of women no longer go unnoticed.