





Lesson on Synthetic Aperture Radar (SAR) Imagery

Mentors :

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Video/Web-based Lesson by Ms. Lakshmi Muttreja AEOP RESET TA

June 27, 2024 **lak.gdsalwan@gmail.com**

Images : California Science Center (Los Angles) & CRISP

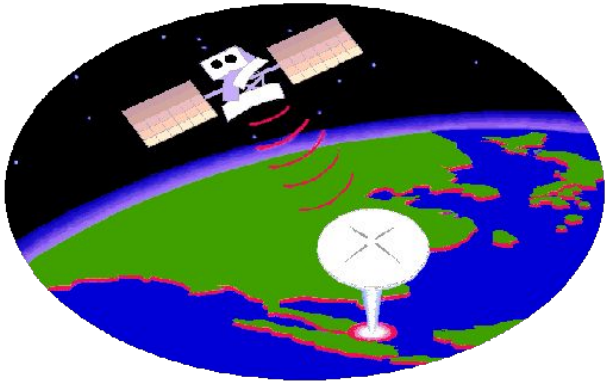
Introduction:

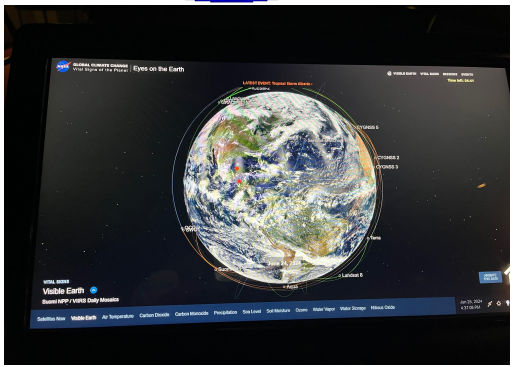
Welcome to my lesson on Synthetic Aperture Radar, or SAR.

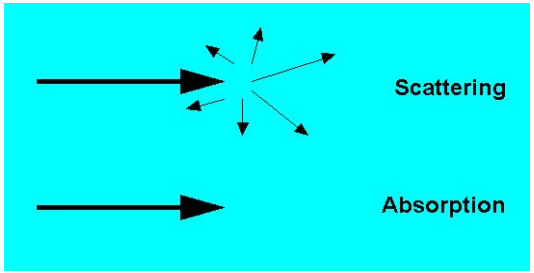
It is a type of radar that creates detailed images of the Earth's surface.

It is used in weather monitoring, environmental studies, disaster management & security.

Let's experience it!

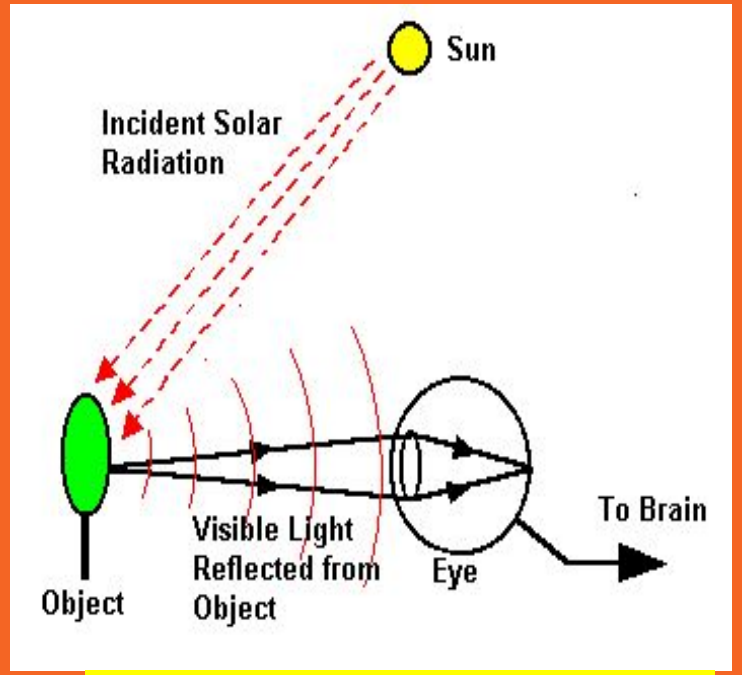




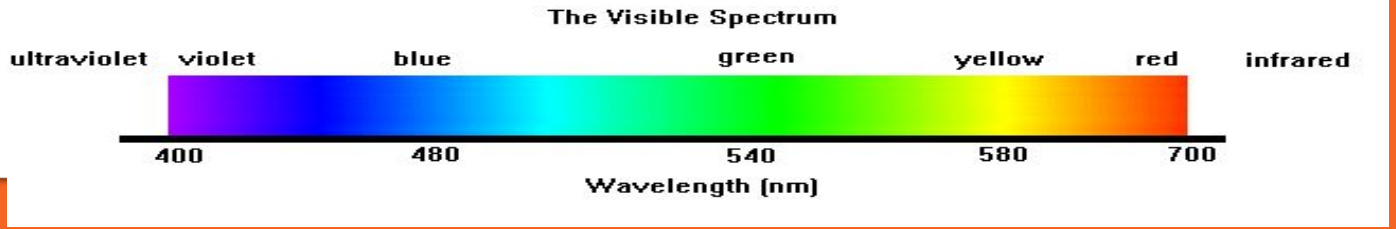


1. What is remote sensing?

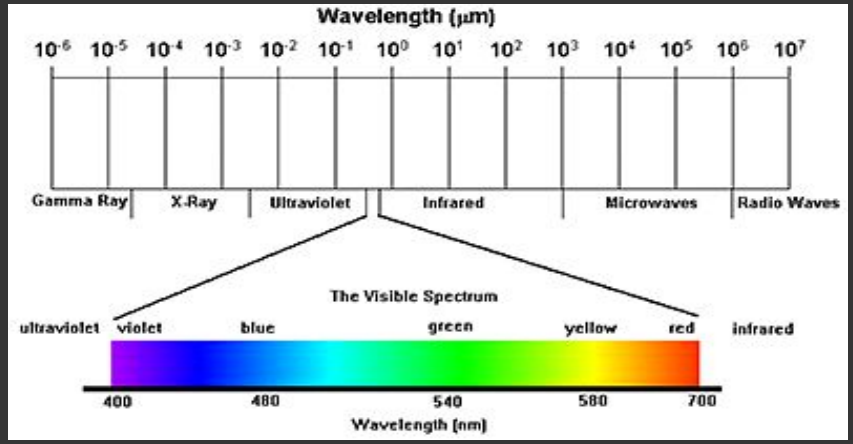
- We feel, understand & interpret our surrounding world through our five senses. Some senses (touch and taste) require direct contact of our sensing organs with the objects. However, we perceive much information about our surrounding through the senses of sight, hearing & smell which do not require close/direct contact between the sensing organs and the external objects. In another word, we are performing **Remote Sensing** all the time.



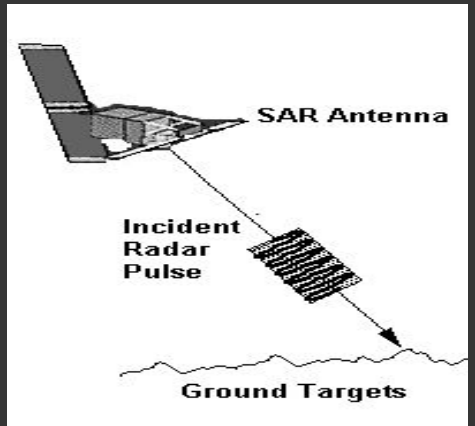
Example: Human Visual System

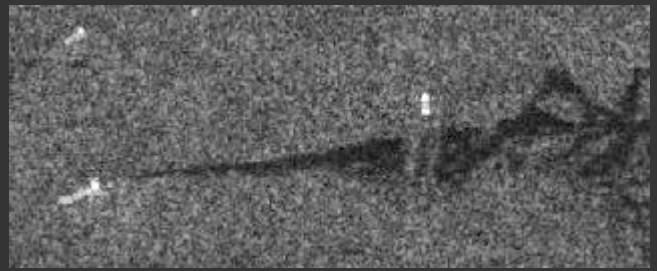


A microwave imaging system which can produce high resolution image of the Earth is the **synthetic aperture radar or SAR**). The intensity in a SAR image depends on the amount of microwave backscattered by the target and received by the SAR antenna. Since the physical mechanisms responsible for this backscatter is different for microwave, compared to visible/infrared radiation, the **understanding & analysis** of SAR images requires the knowledge of how microwaves interact with the targets.



Microwaves: 1 mm to 1 m wavelength. The microwaves are further divided into different frequency (wavelength) bands: **(1 GHz = 10^9 Hz)**

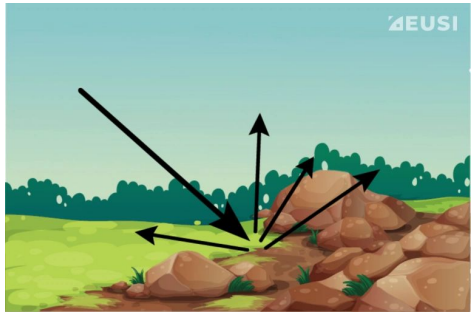




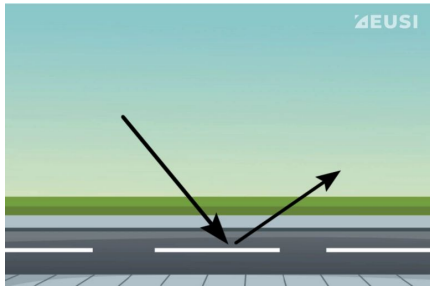
P band: 0.3 - 1 GHz (30 - 100 cm)
L band: 1 - 2 GHz (15 - 30 cm)
S band: 2 - 4 GHz (7.5 - 15 cm)
C band: 4 - 8 GHz (3.8 - 7.5 cm)
X band: 8 - 12.5 GHz (2.4 - 3.8 cm)
Ku band: 12.5 - 18 GHz (1.7 - 2.4 cm)
K band: 18 - 26.5 GHz (1.1 - 1.7 cm)
Ka band: 26.5 - 40 GHz (0.75 - 1.1 cm)

SYNTHETIC APERTURE RADAR (SAR)

SAR (Synthetic Aperture Radar) is a type of satellite imagery using radar waves to map the Earth's surface. The radar transmits electromagnetic waves, they reach the surface and backscatter back to the sensor. Based on the characteristics of the backscattered waves, it is possible to determine the type of the surface of an object and the distance between the sensor and the object.



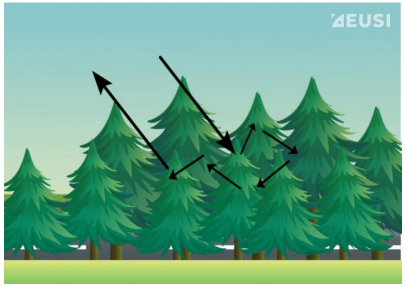
Rough Surface(single bounce)



Smooth Surface(single bounce)



Elevated buildings(double bounce)



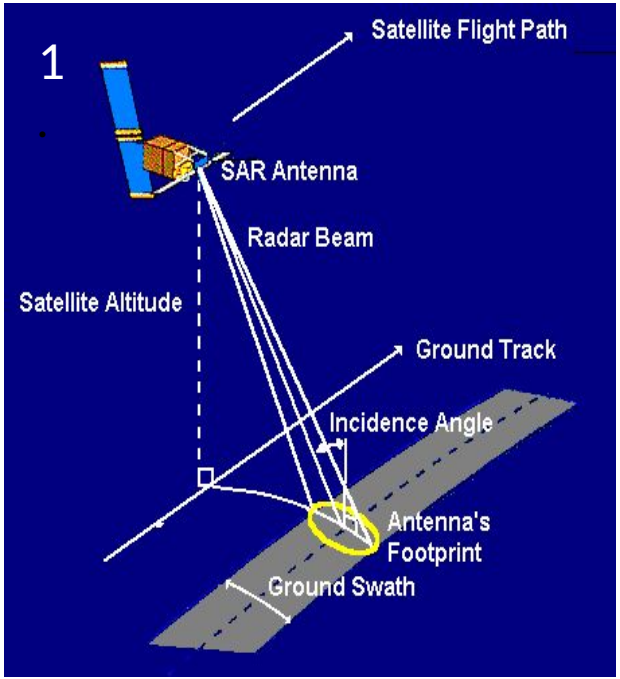
Multiple Diffuse

- Rough surface (for example vegetation): The backscattered waves go in various directions, resulting in a diffuse backscatter.
- Smooth surface (for example water or road): No or little amount of signal backscatters to the sensor.
- Human-made structures (for example buildings): the radar waves double bounce off the surface, resulting in a bright and clear backscatter.
- Objects with several surface layers (for example forest): due to multiple scattering within the object's internal layers, a higher backscatter signal returns to the sensor, and the object appears bright in the satellite image.

KEY SAR PARAMETERS

TARGET AZIMUTH ANGLE

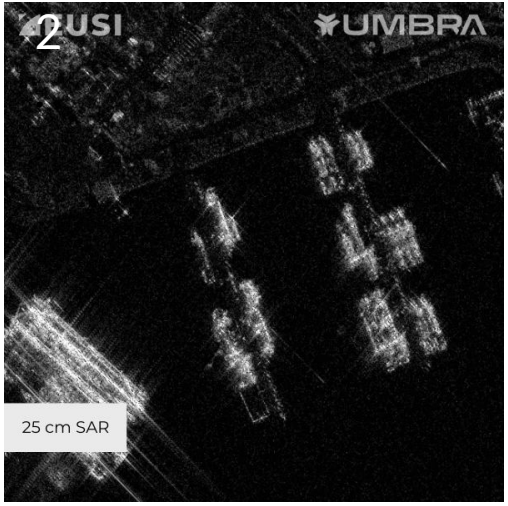
Target azimuth angle is **the angle between the target, the north, and the direction of the satellite**. It's need to determine the location of a target in SAR imagery: together with distance and elevation angle, it helps in accurately pinpointing the position of targets within the image.



1. Imaging geometry for a typical strip-mapping synthetic aperture radar imaging system. The antenna's footprint sweeps out a strip parallel to the direction of the satellite's ground track

GRAZING ANGLE

The grazing angle is **the angle between the surface and the satellite**. It determines how steep or shallow the collection is. Generally, a higher grazing angle provides more image contrast but reduces the amount of access to the AOI. Opposite to the grazing angle is the Off Nadir Angle (ONA)-you can easily calculate the grazing angle as 90° minus ONA.

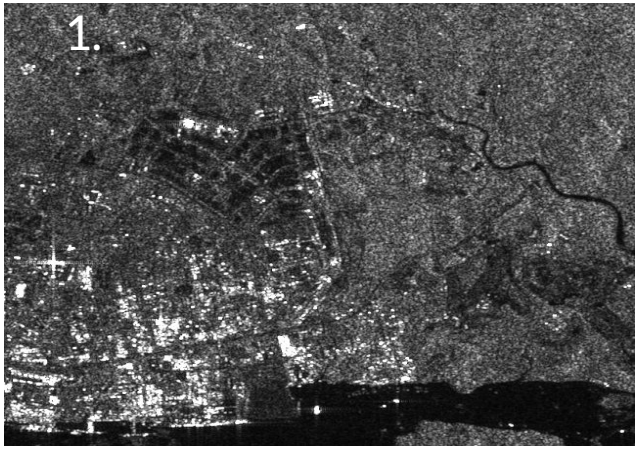


2. Costel area maritime



3.San Francisco US SAR IMAGES

SAR IMAGES

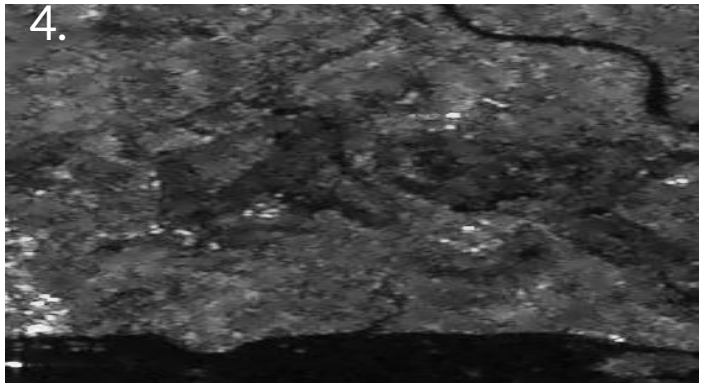


1. ERS SAR image (pixel size=12.5 m)

Difference between images 1 & 2: Calm sea surfaces appear dark in SAR images. However, rough sea surfaces may appear bright especially when the incidence angle is small. The presence of oil films smoothen out the sea surface. Under certain conditions when the sea surface is sufficiently rough, oil films can be detected as dark patches against a bright background.

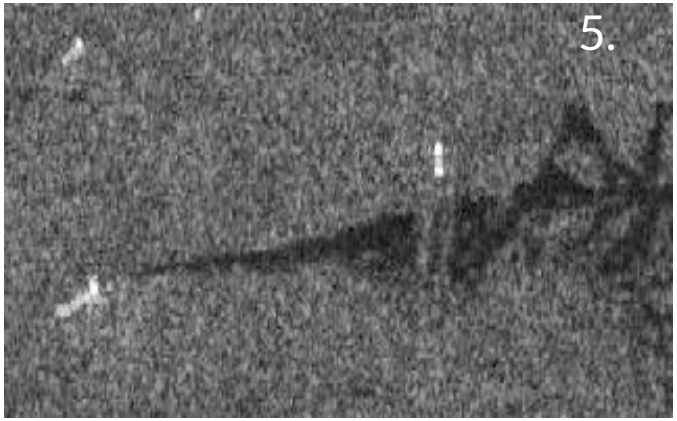


2. The urban area on the left appears bright in the SAR image while the vegetated areas on the right have intermediate tone. The clearings and water (sea and river) appear dark in the image.
3. SPOT Multispectral image in Natural Colour
(pixel size=20 m)

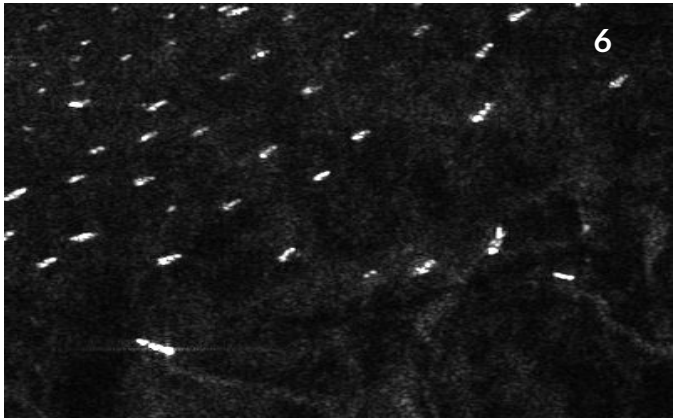


4. This image shows the effect of applying a speckle removal filter to the SAR image. The vegetated areas and the clearings now appear more homogeneous.

SAR IMAGES



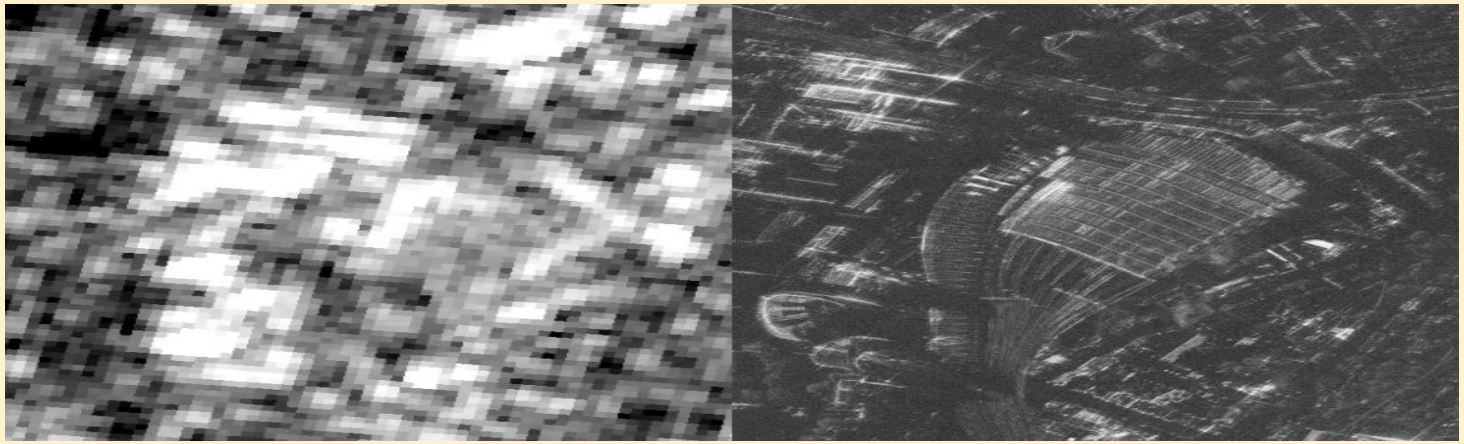
5. A ship (bright target near the bottom left corner) is seen discharging oil into the sea in this ERS SAR image.



6. This SAR image shows an area of the sea near a busy port. Many ships can be seen as bright spots in this image due to corner reflection.

ADVANTAGES, LIMITATIONS AND APPLICATIONS OF SAR IMAGERY

The major benefits of SAR imagery include all-weather imaging, day and night operation, high resolution, the ability to penetrate foliage and soil, high revisit rate, and no sun glint.



Comparison of SAR imagery from Sentinel-1 (10 m resolution) and Umbra (25 cm resolution).

But, SAR imagery has limitations as well. Those include complex interpretation, sensitivity to surface properties, limited penetration depth, the requirement of prior knowledge of the target, and colour information.

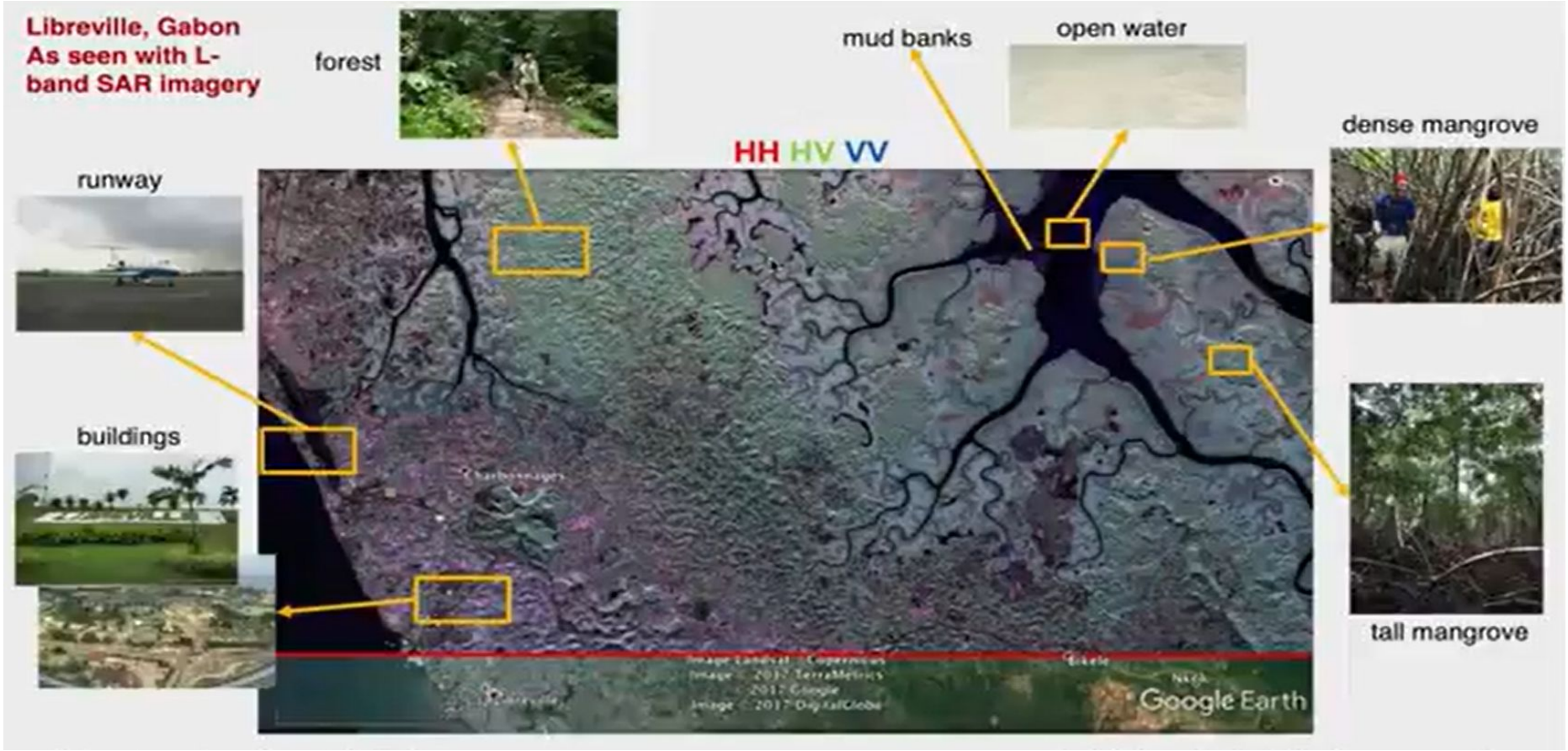
Besides other uses, SAR imagery is a valuable tool for emergency response, defence and intelligence, agriculture, or for example urban planning.

Annotation of OPTICAL IMAGE : Alaska Satellite Source



RESOURCES: youtube videos on NASA ARSET session 3/4

SAR IMAGE: Annotations Optical vs SAR



RESOURCES: youtube videos on NASA ARSET session 3/4

Milestones

1.Introduction

Elaborate & Evaluate

Online tools to explore SAR images and annotate them & attempt quiz.



Engage & Explore

Definition & Principles of SAR
Advantages, limitations & applications of SAR

Examples of SAR & Citations

Great thanks to resources available to make this lesson & Mentors: Dr. Ben, Dr. Kim.

Your Turn! (Quiz)

1. Define SAR?
2. Name the wave used for SAR imagery & why?
3. What are some applications of synthetic aperture radar imagery?
4. Extra Credit: how do you save your house from SAR imagery?

Citations:

I am greatly Thankful to

1. Dr. S. C. Liew *Centre for Remote Imaging, Sensing and Processing National University of Singapore CRISP.*

1. **https://www.euspaceimaging.com/what-is-sar-imagery/**

3.NASA youtube ARSET sessions 1-4.

4. Alaska Satellite source
5. Sentinel: Sandia national laboratories.
6. ICEYE
7. SAR Tutorial by Alberto Moreira, Pau Prats-Iraola, Marwan Younis, Gerhard Krieger, Irena Hajnsek, and Konstantinos P. Papathanass iou Microwaves and Radar Institute of the German Aerospace Center (DLR), Germany
8. Copernicus Open Access Hub
9. MATLAB
10. https://nisar.jpl.nasa.gov/