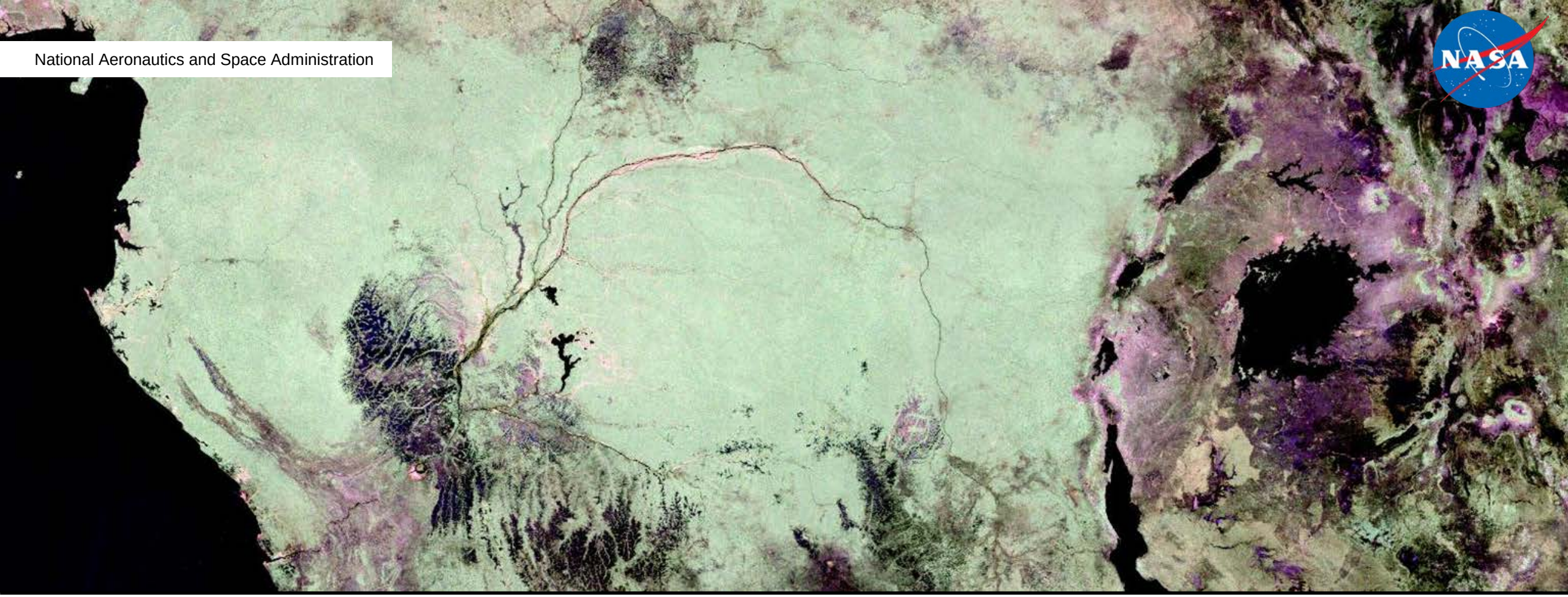
National Aeronautics and Space Administration



SAR for Flood Mapping

Erika Podest

9 August 2018

Learning Objectives

- By the end of this presentation, you will be able to understand:
- the advantages of SAR over optical systems for flood mapping
- the information content in SAR images relevant to flooding
- the limitations of SAR for mapping floods
- the optimal sensor parameters for flood mapping
- how to generate a flood map

Flood Mapping

- the temporary or permanent occurrence of a water surface beneath a vegetation canopy
- water without any standing vegetation

Flood Mapping: Radar vs. Optical

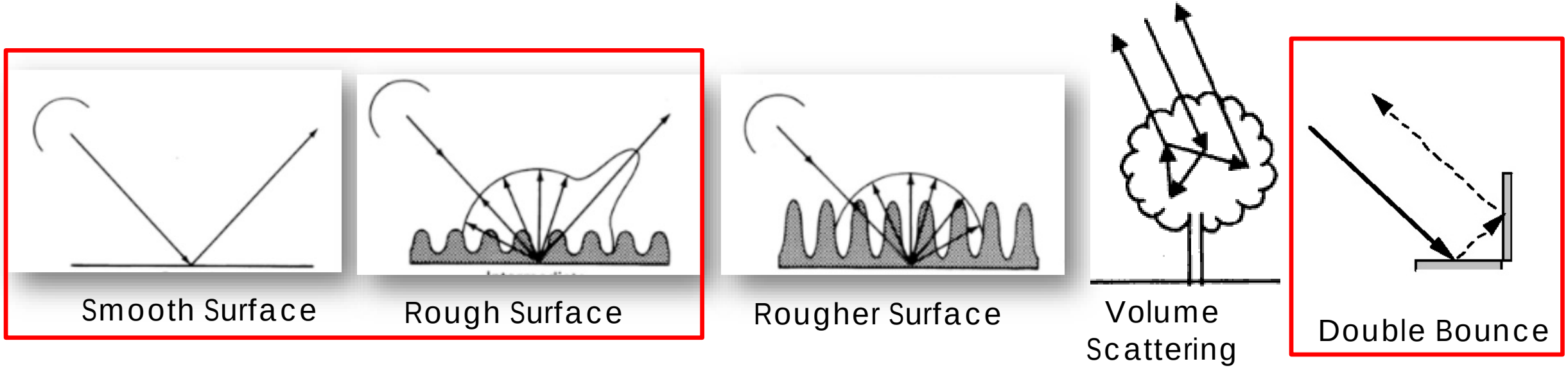
Radar

- Almost all weather capability and day/night capability
- The signal can penetrate through vegetation (wavelength dependent), providing information on inundation state.

Optical

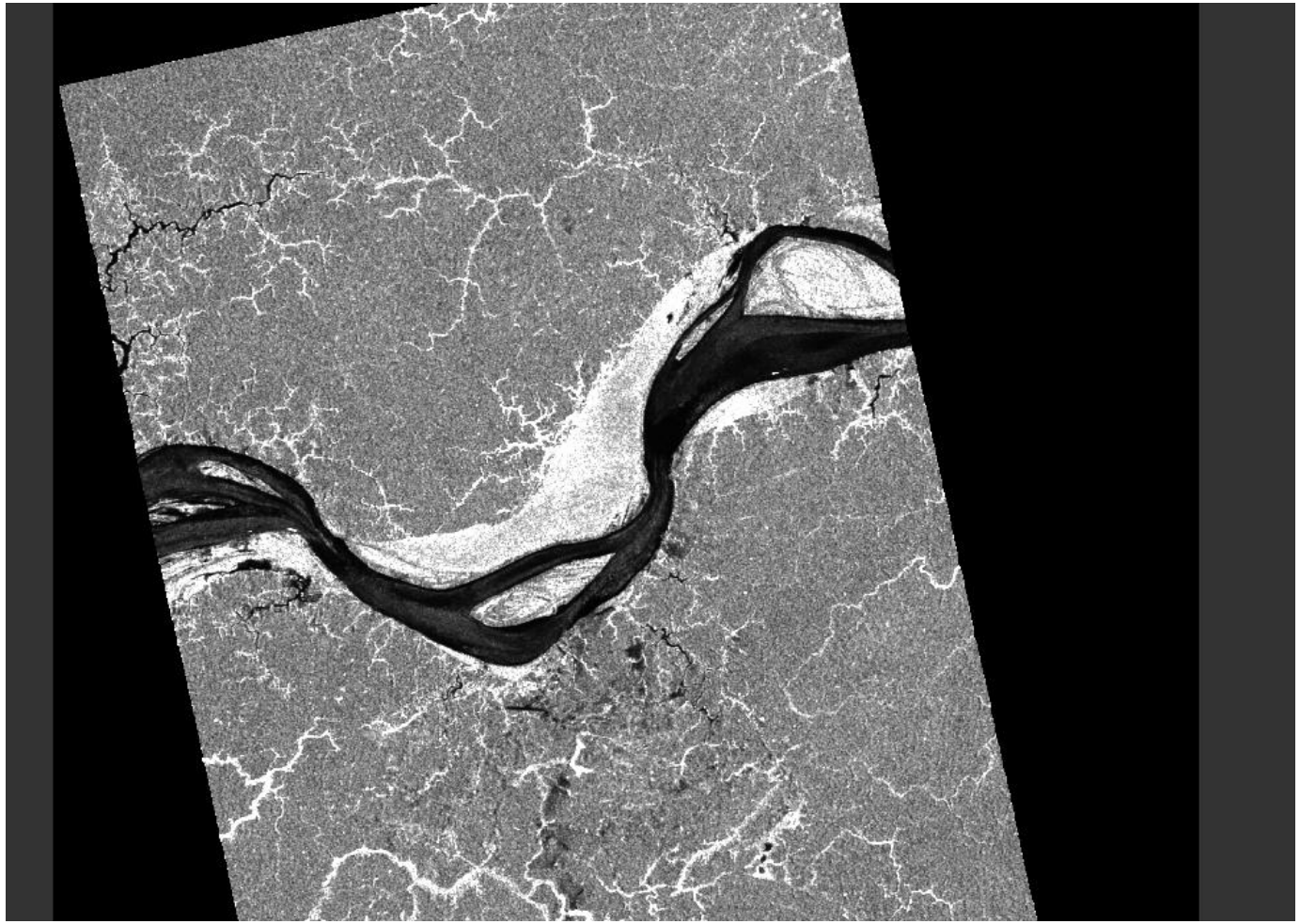
- Hindered by cloud cover and darkness (night)
- Optical sensors only see surface tops, because the canopy blocks the understory, limiting the inferences of flood state in some cases.

SAR Signal Scattering Over Inundated Regions



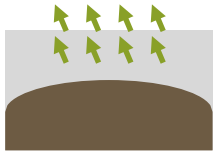
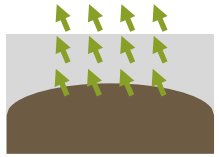
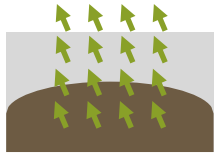
SAR Signal Scattering Over Inundated Regions

Palsar Image (L-band) near Manaus, Brazil



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

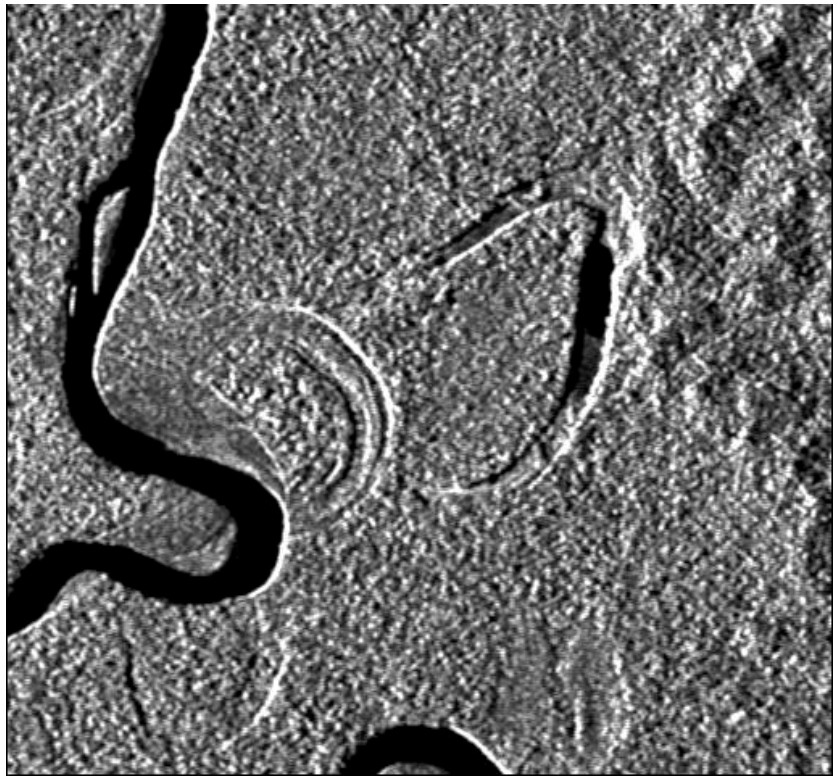
Band Designation*	Wavelength (λ), cm	Frequency (v), GH_z (10^9 cycles·sec^{-1})
Ka (0.86 cm)	0.8 – 1.1	40.0 – 26.5
K	1.1 – 1.7	26.5 – 18.0
Ku	1.7 – 2.4	18.0 – 12.5
X (3.0 cm, 3.2 cm)	2.4 – 3.8	12.5 – 8.0
C (6.0)	3.8 – 7.5	8.0 – 4.0
S	7.5 – 15.0	4.0 – 2.0
L (23.5 cm, 25 cm)	15.0 – 30.0	2.0 – 1.0
P (68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

*wavelengths most frequently used in SAR are in parenthesis

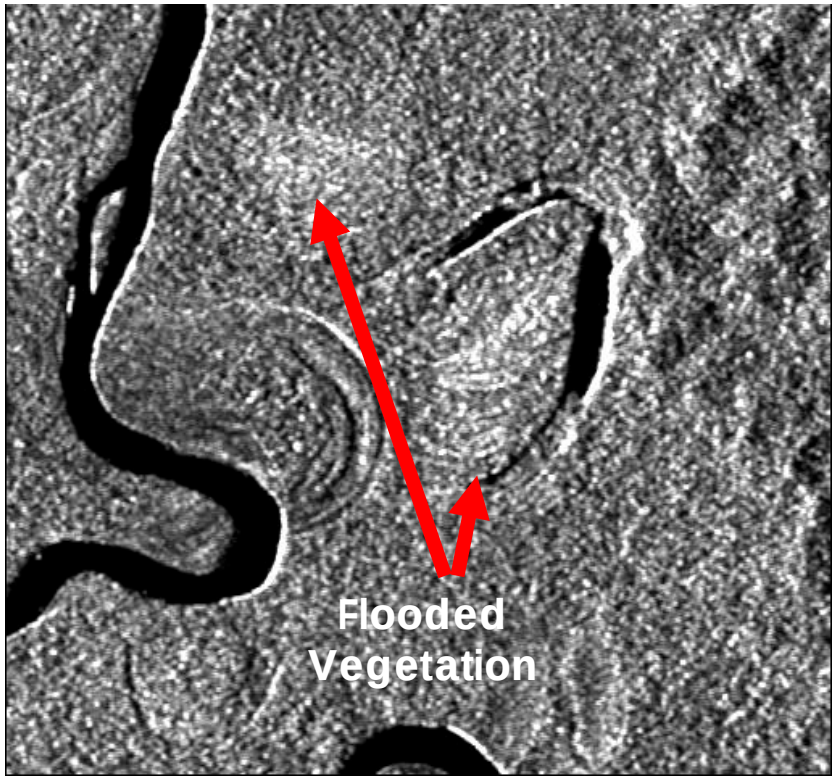
Signal Penetration Over Flooded Vegetation

Multifrequency AIRSAR data in Manu National Park, Peru

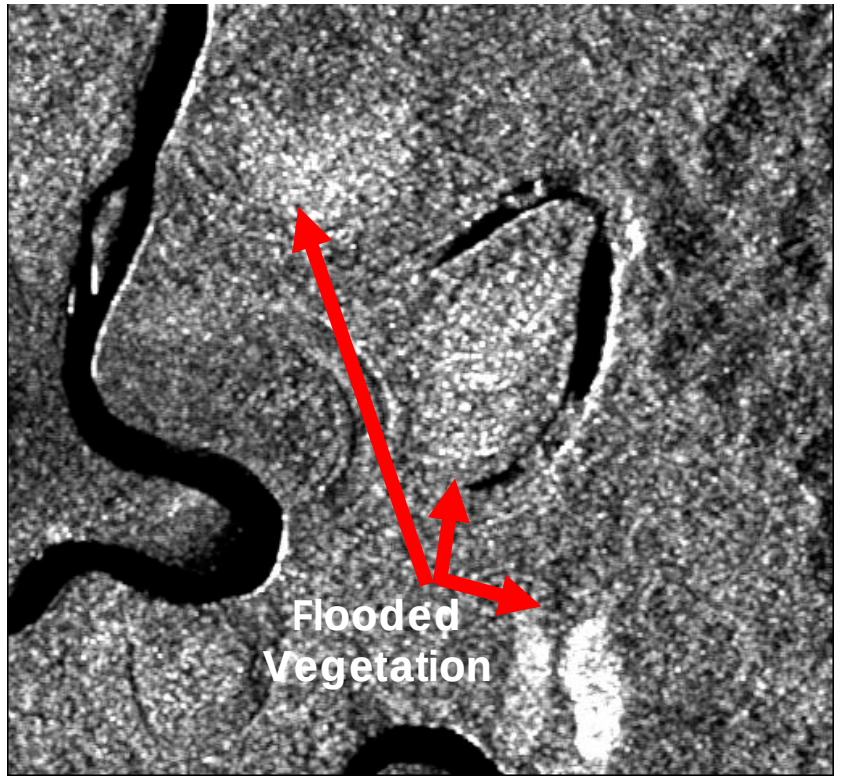
C-Band



L-Band

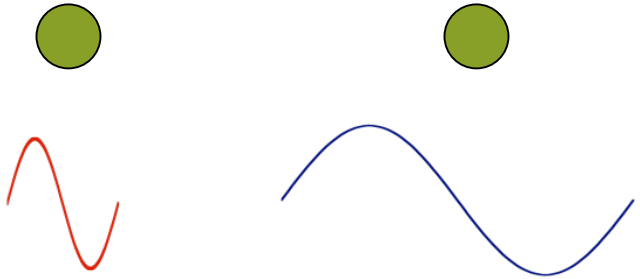


P-Band



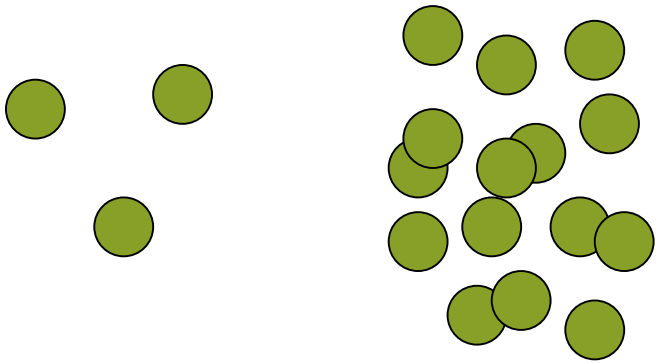
Surface Parameters Related to Structure

Size Relative to Wavelength



Orientation

Density



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

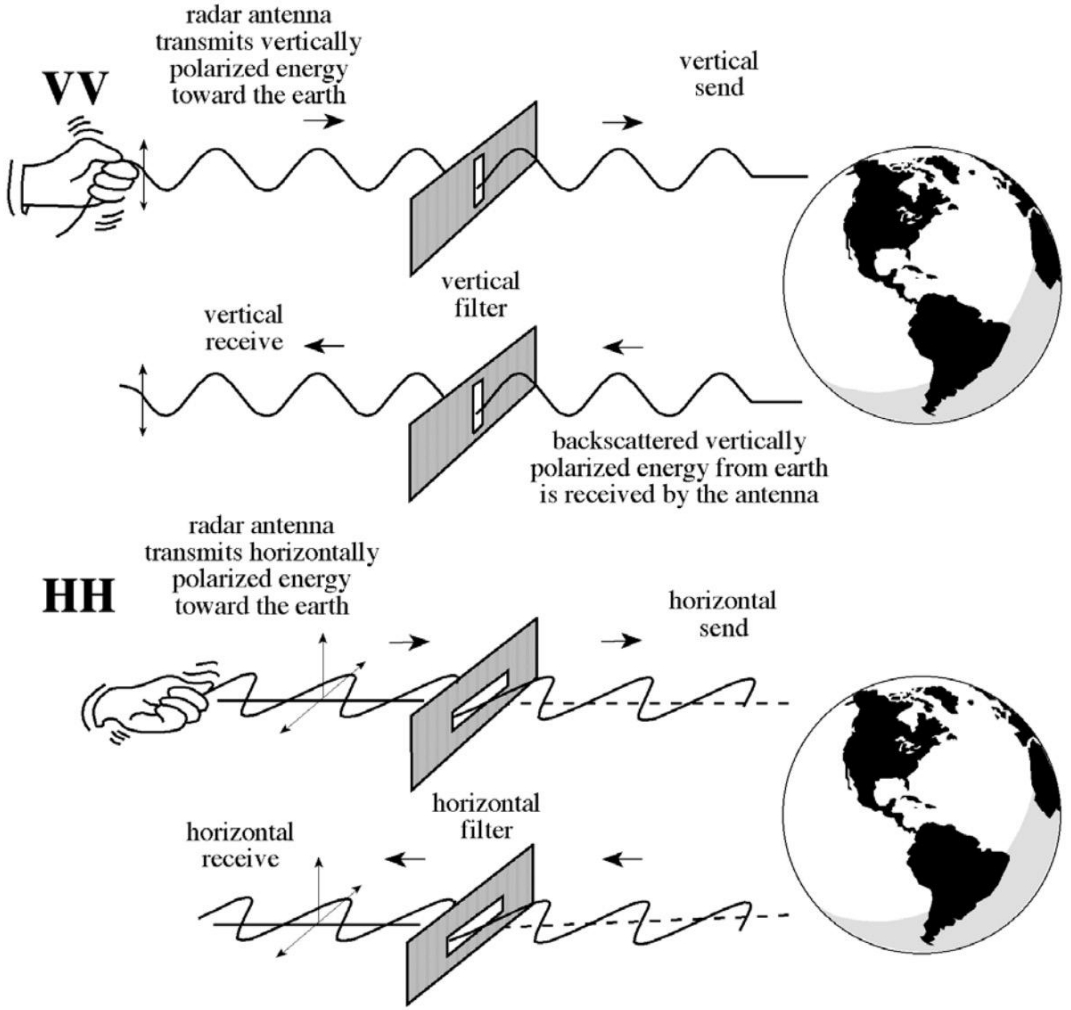
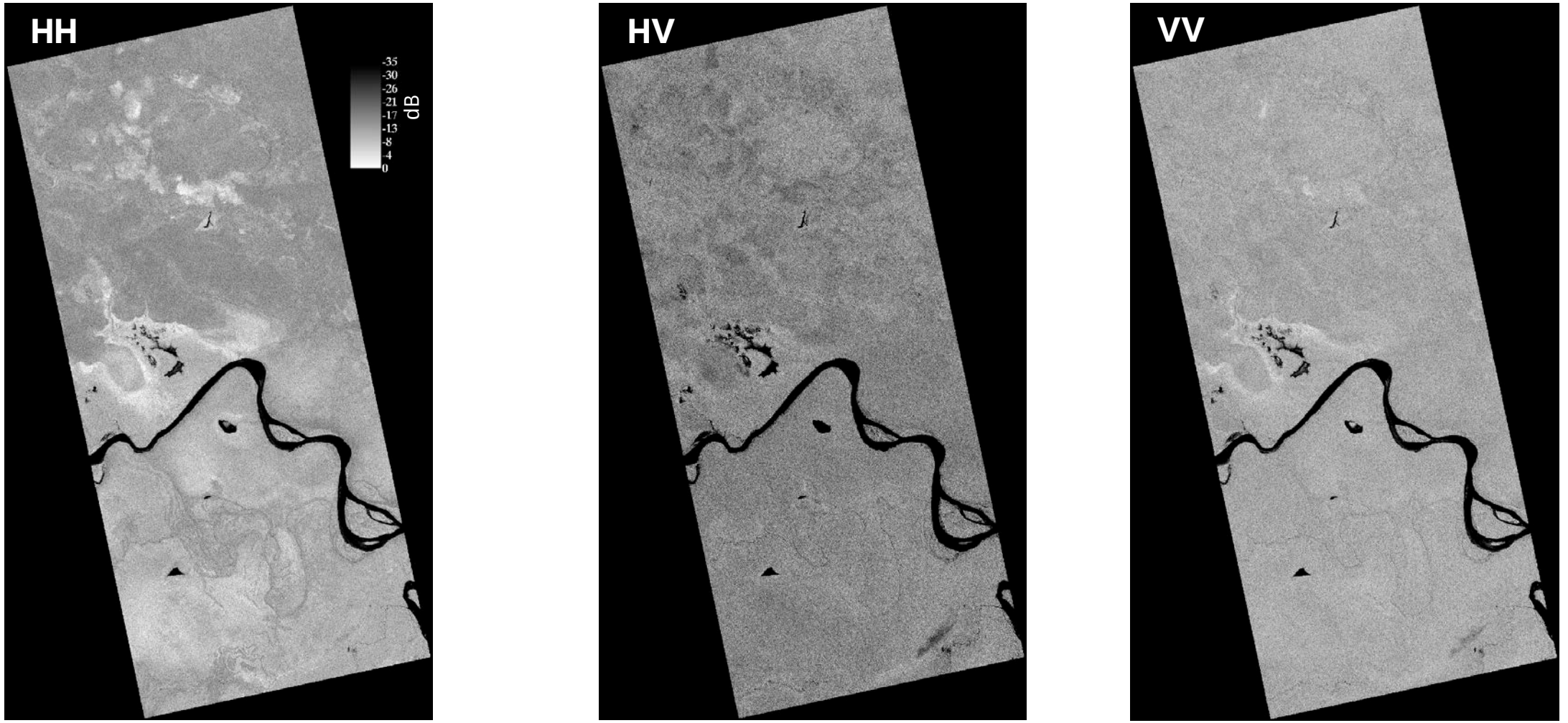


Image Credit: J.R. Jensen, 2000, Remote Sensing of the Environment

Multiple Polarizations for Detection of Inundated Vegetation

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



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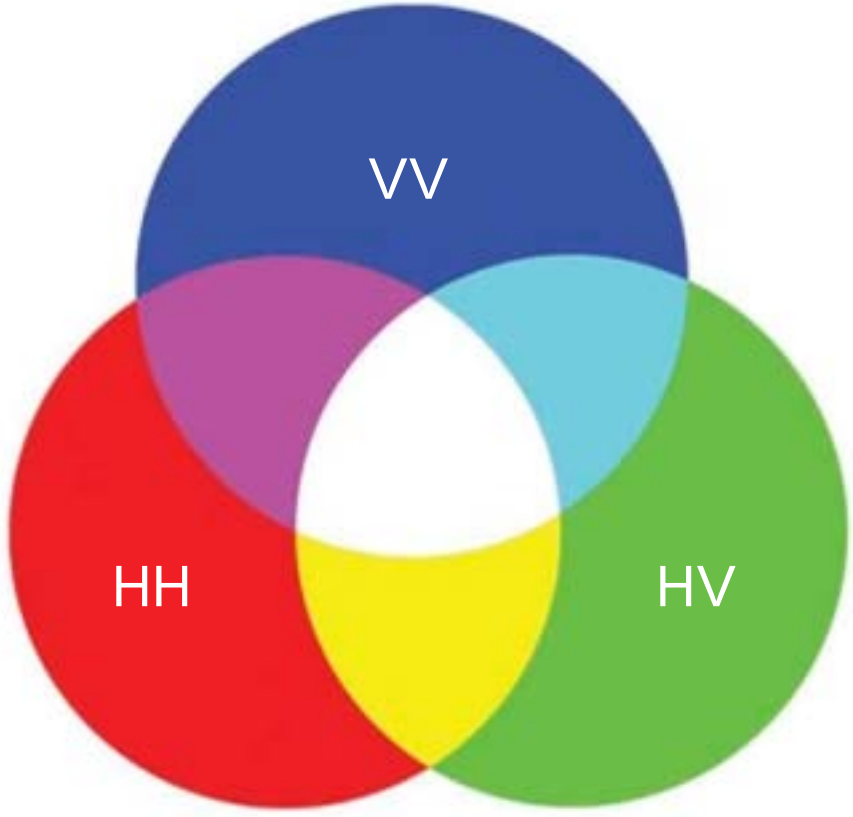
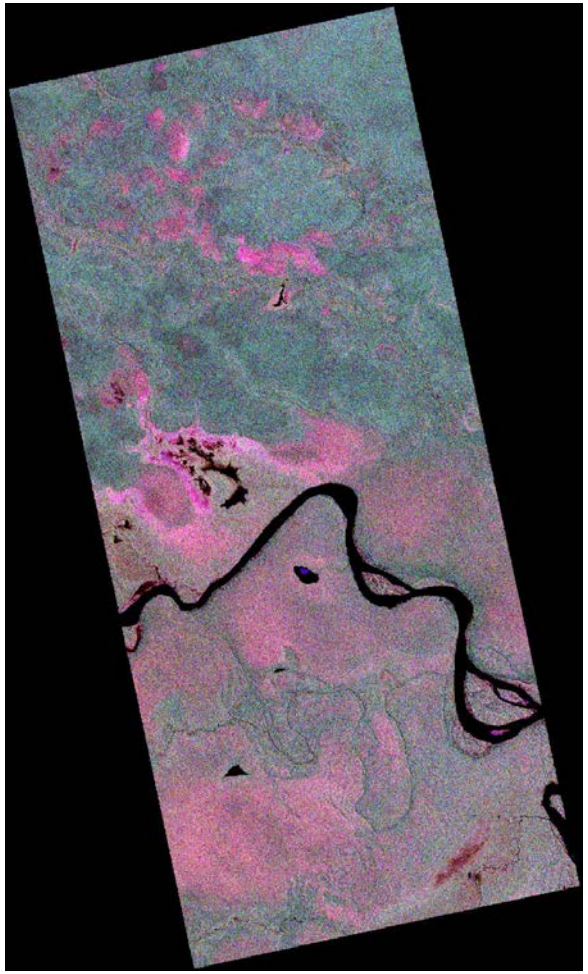
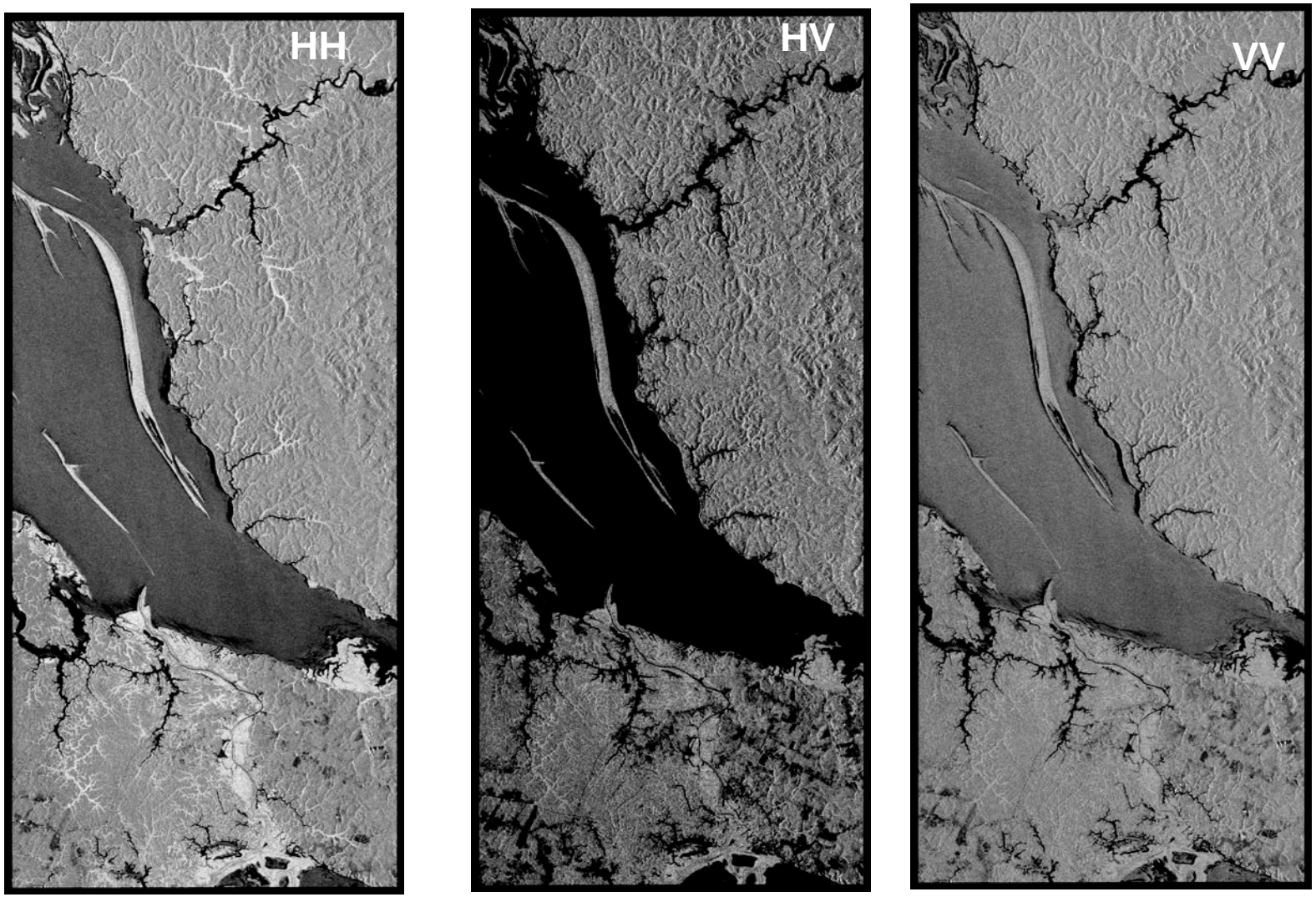




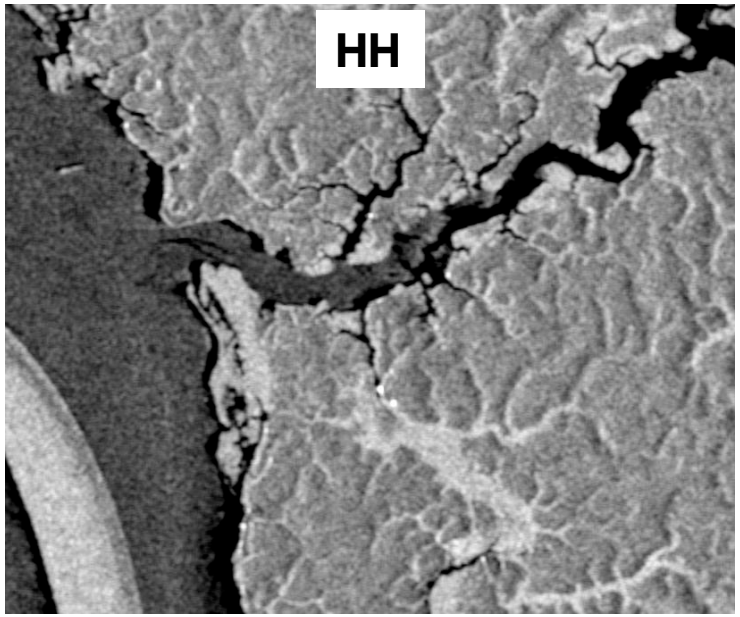
Multiple Polarizations for Detection of Open Water

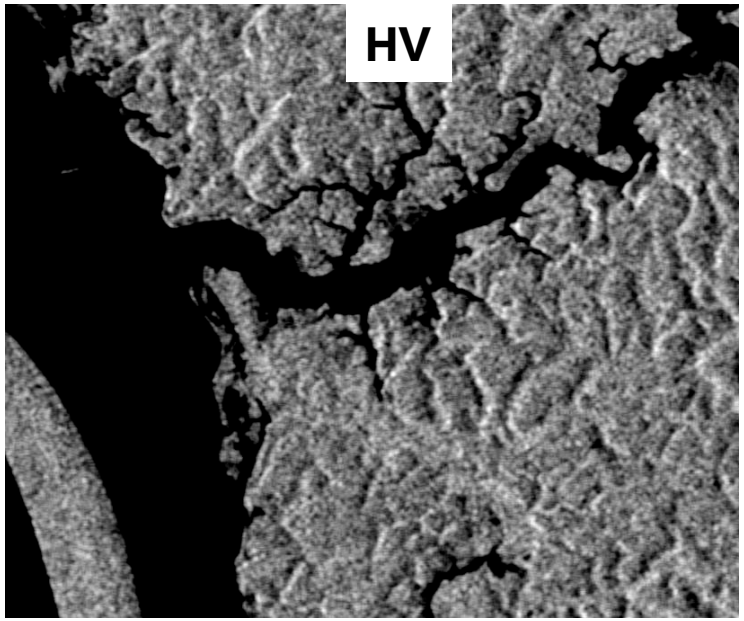
Images from Palsar (L-band) near Manaus, Brazil

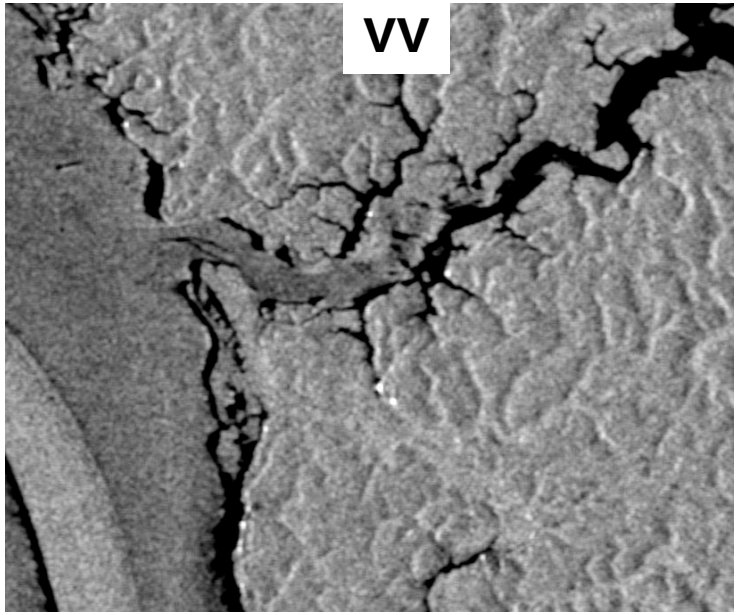


Example of Multiple Polarizations for Flood Studies

Images from Palsar (L-band) near Manaus, Brazil



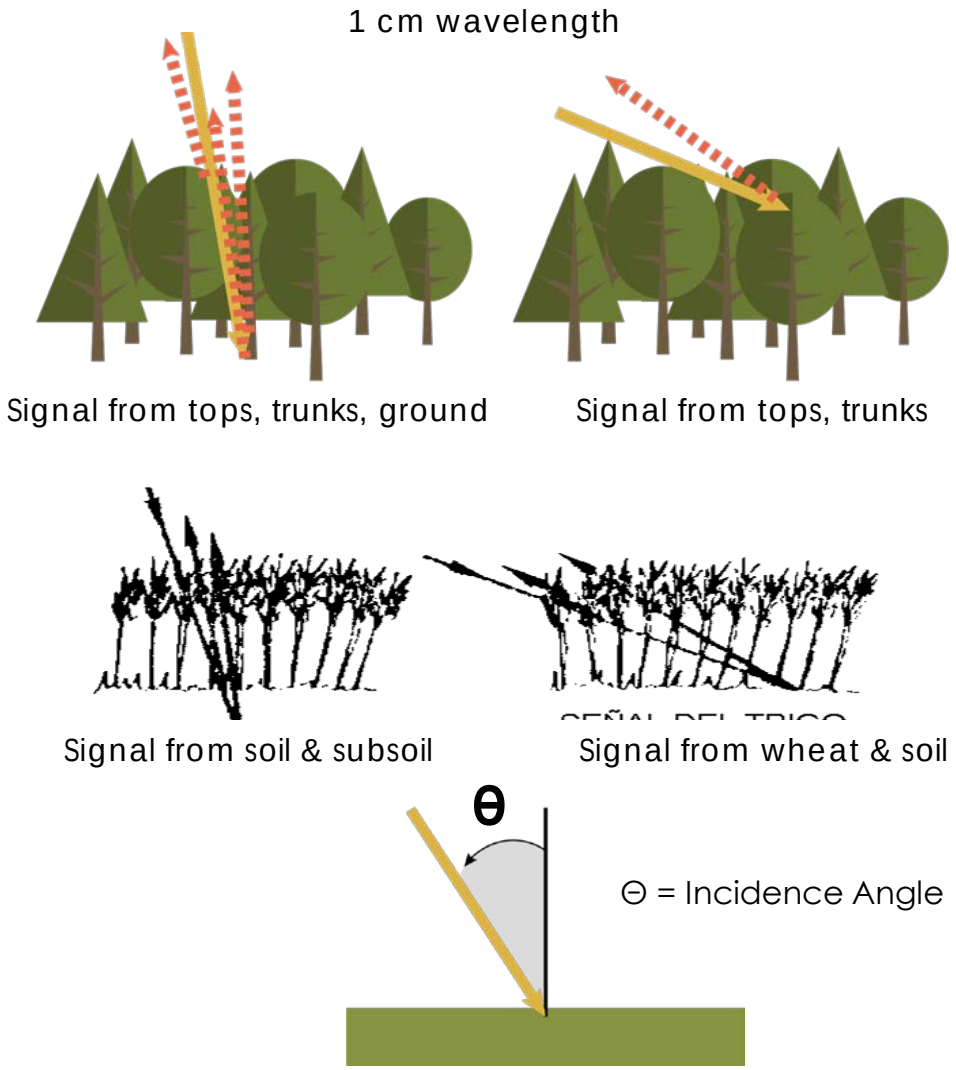




Incidence Angle

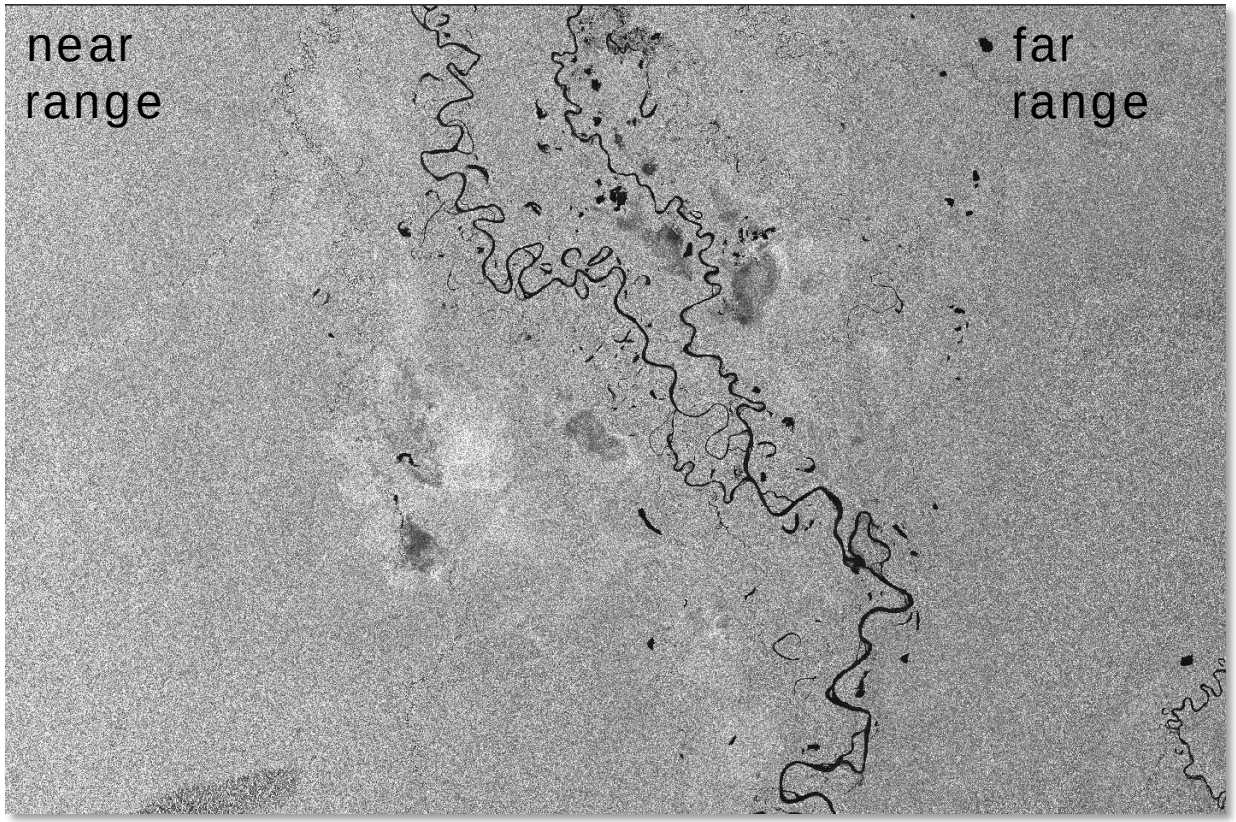
Local Incidence Angle:

- The angle between the direction of illumination of the radar and the Earth's surface plane
- accounts for local inclination of the surface
- influences image brightness
- is dependent on the height of the sensor
- the geometry of an image is different from point to point in the range direction

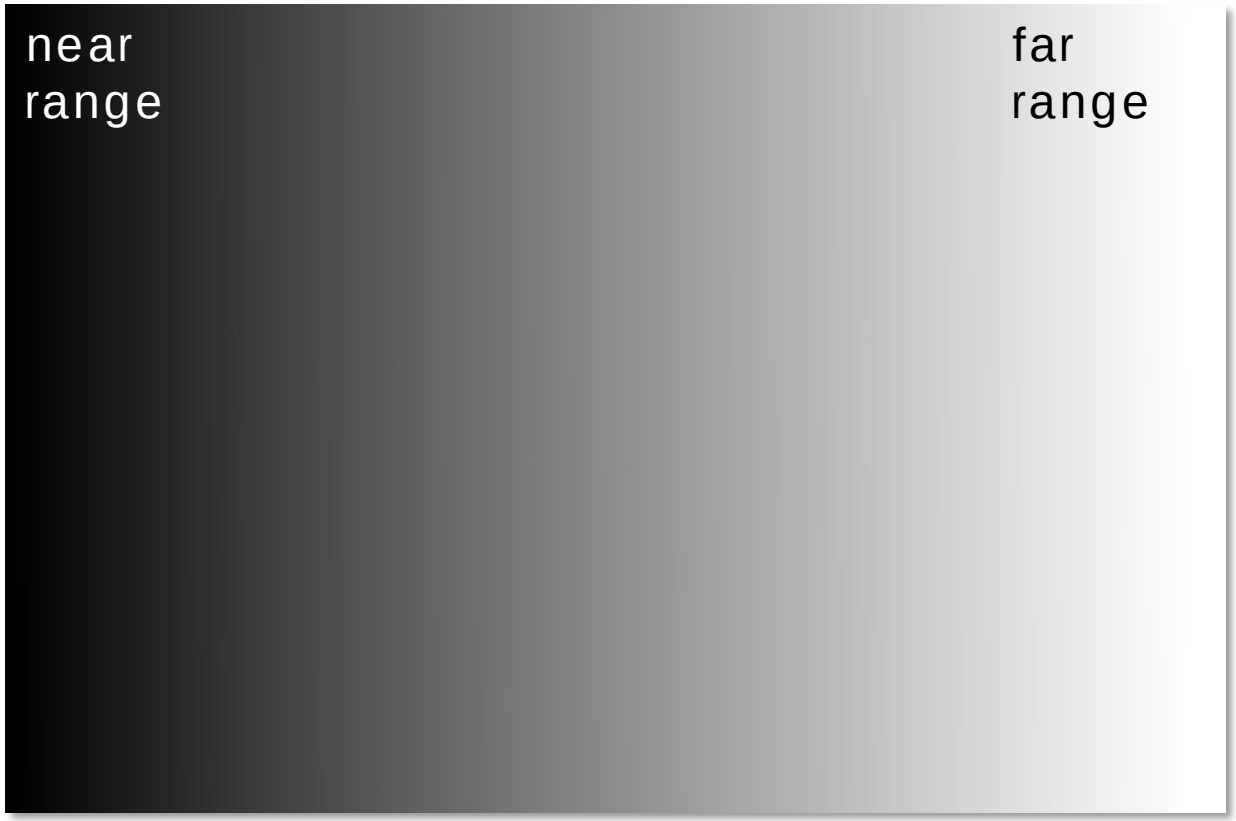


Images based on: top: Ulaby et al. (1981a), bottom: ESA

Effect of Incidence Angle Variation



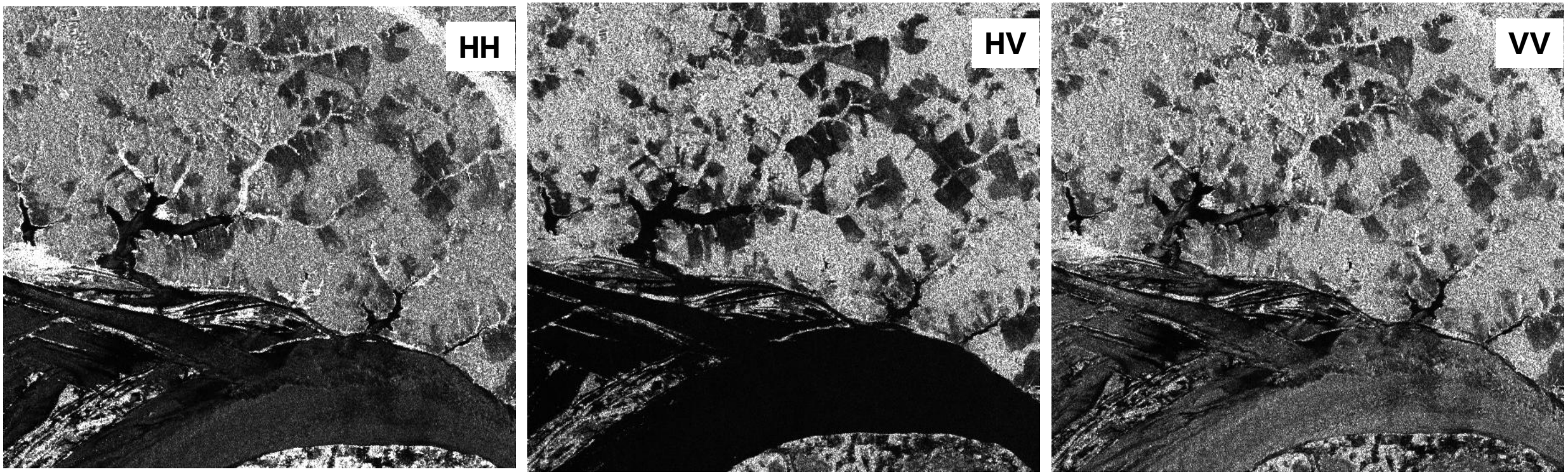
Sentinel-1



30 Incidence Angle (degrees) 45

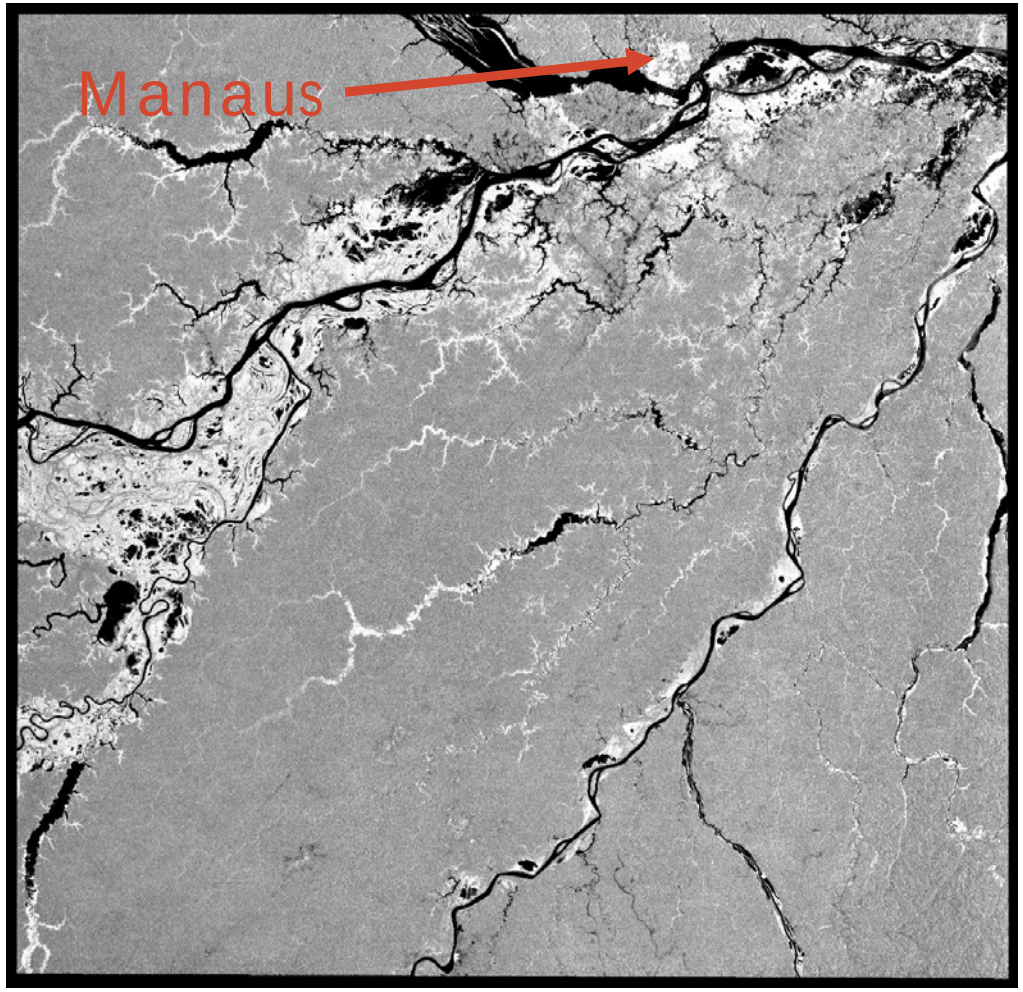
Source of Confusion: Wind

Images from Palsar (L-band) near Manaus, Brazil

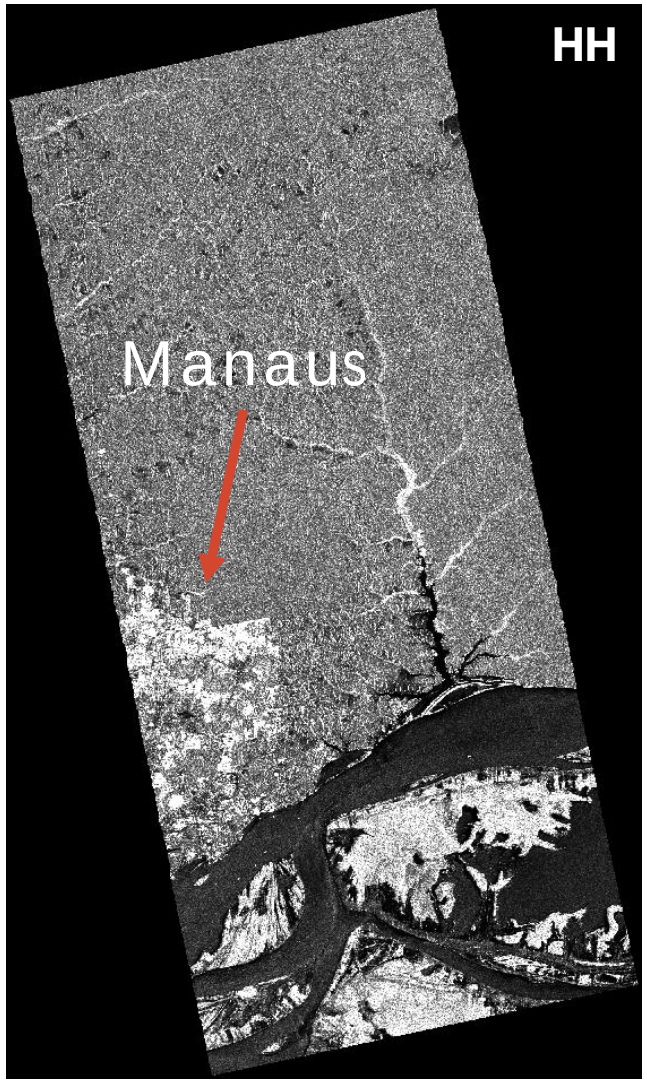


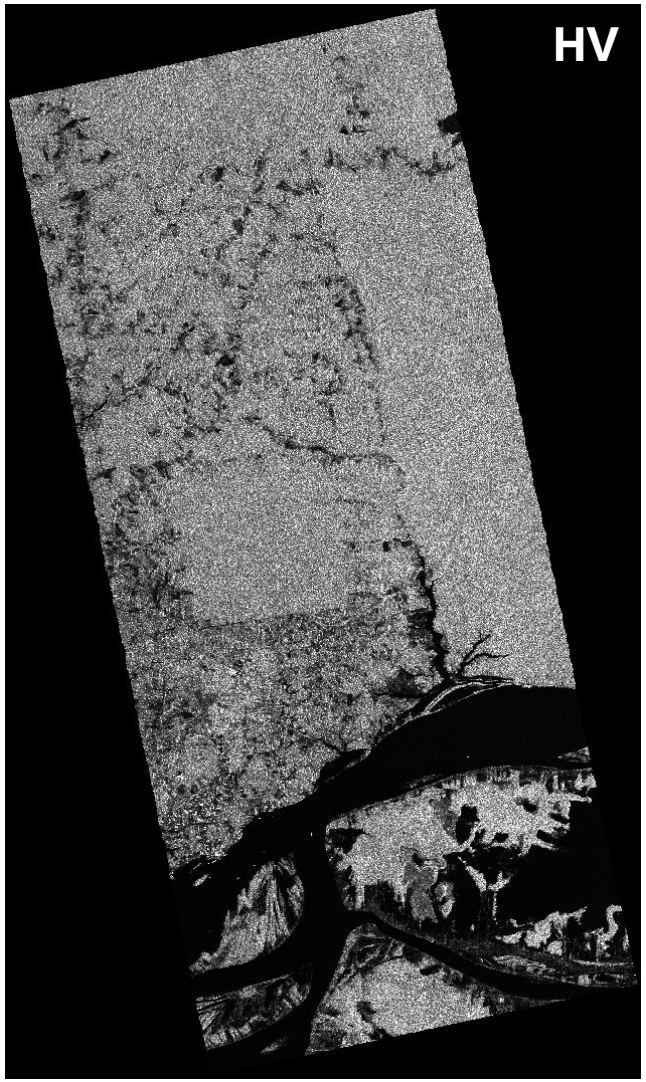
Source of Confusion: Urban Areas

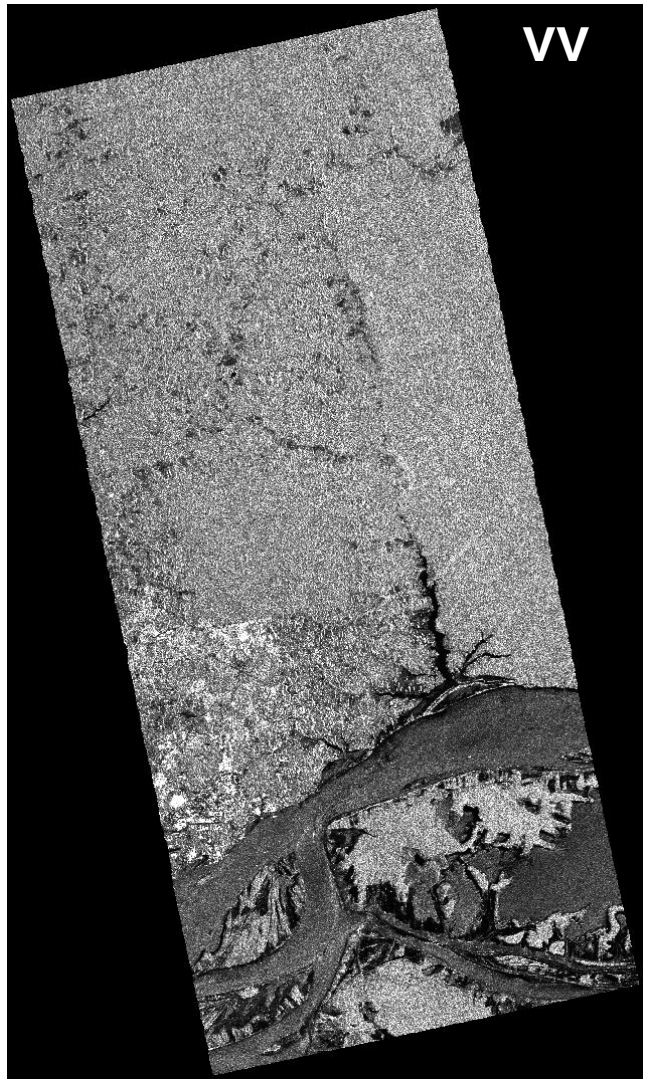
Images from Palsar (L-band) near Manaus, Brazil



Source of Confusion: Urban Areas with Different Polarizations







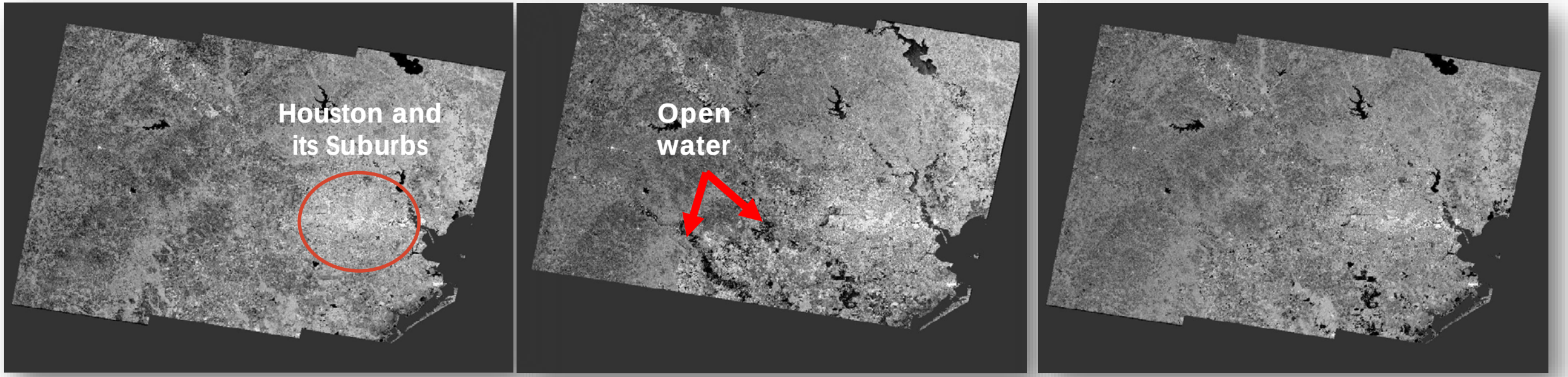
Hurricane Harvey in Houston Texas – August 2017

Sentinel-1 Images (VV)

Aug 18, 2017
(Before the Event)

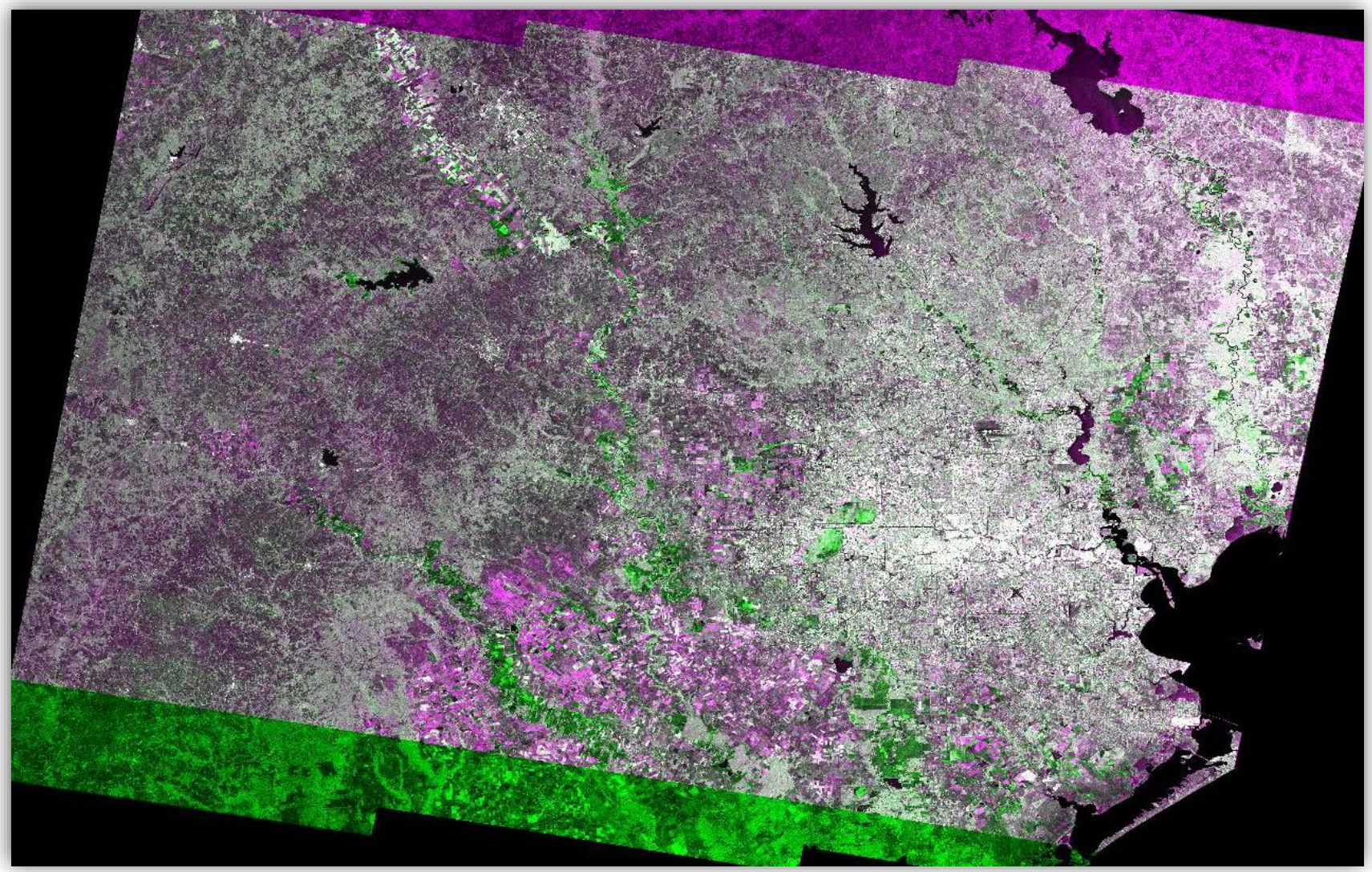
Aug 30, 2017
(During the Event)

Sep 5, 2017
(After the Event)



Hurricane Harvey in Houston Texas - Before and During the Event

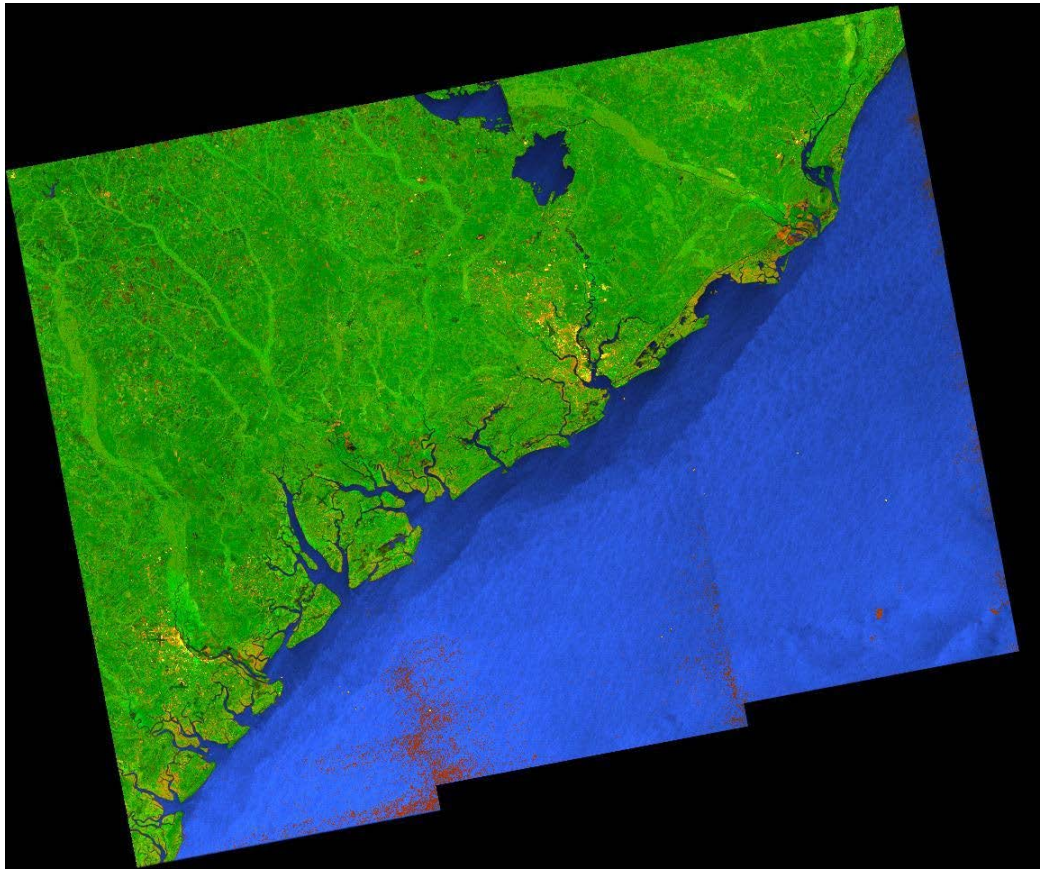
Sentinel-1 Radar Images, RGB: Aug 30 (R), Aug 18 (G), Aug 30 (B)



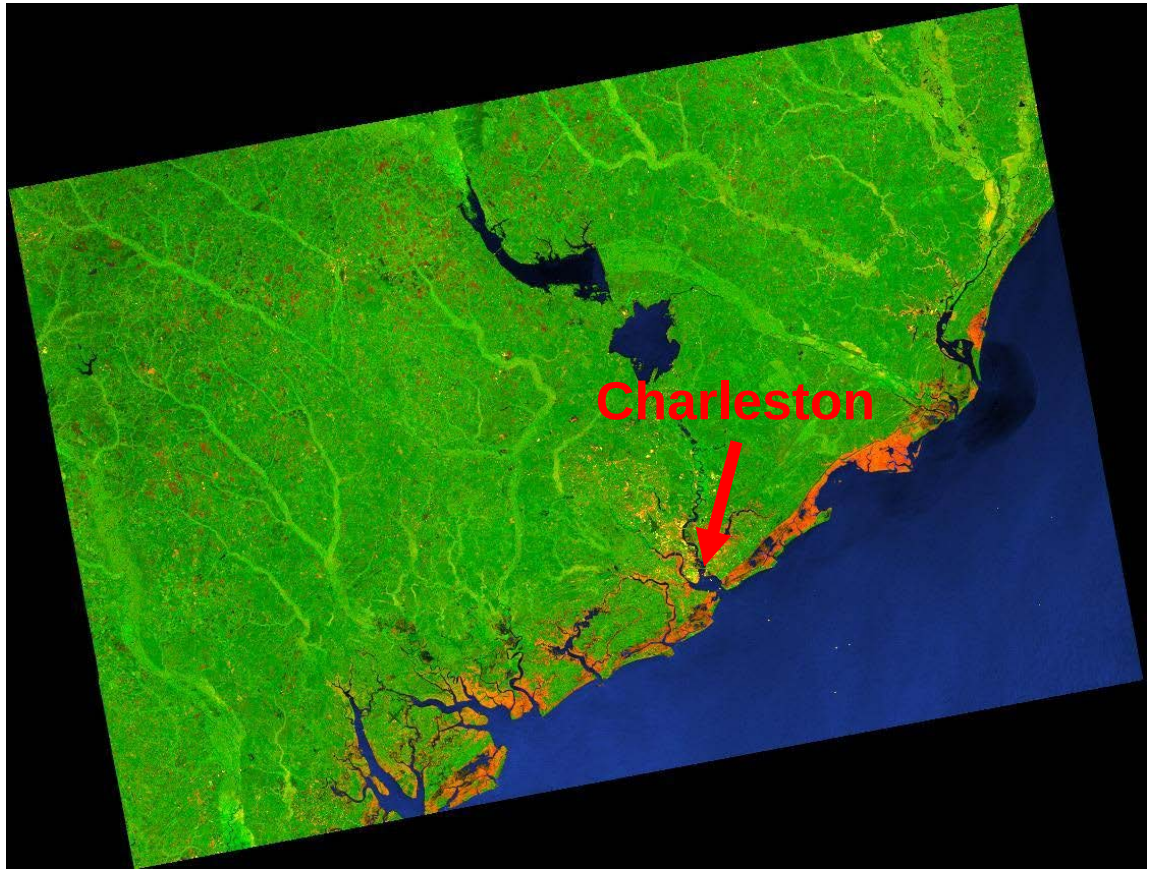
Hurricane Matthew on the East Coast of the U.S. – Coastal Flooding

Sentinel-1 Radar Images (R-VV; G-VH; B-VV/VH)

Oct 4, 2016
(Before the Event)



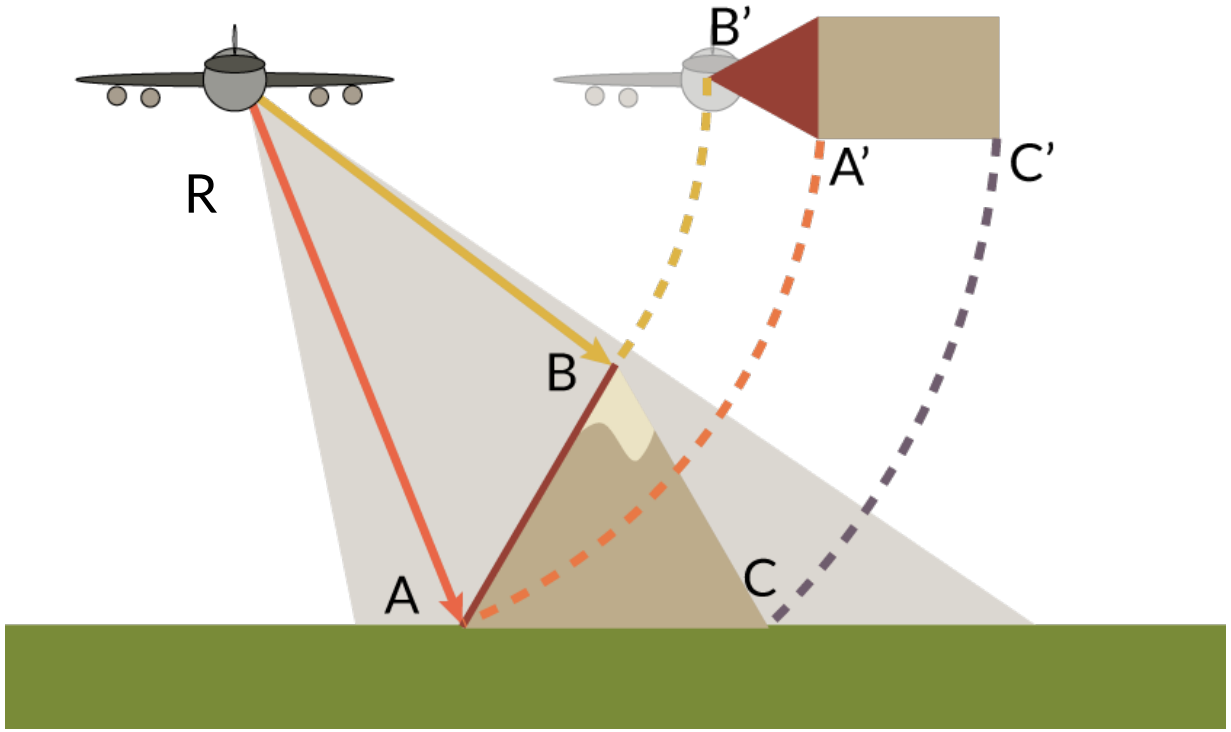
Oct 16, 2016
(After the Event)



Geometric Distortion

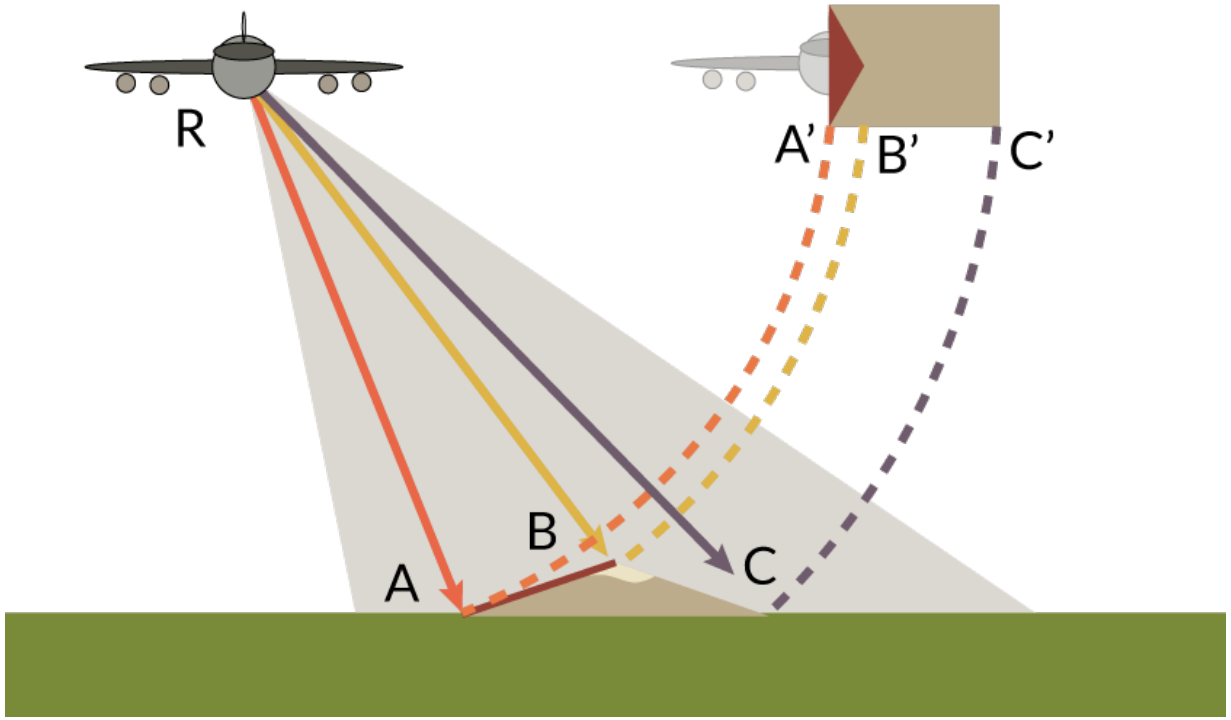
Layover

AB = BC
A'B' < B'C'
RA > RB
RA' > RB'



Foreshortening

RA < RB < RC
AB = BC
A'B' < B'C'



Images based on NRC images

Shadow

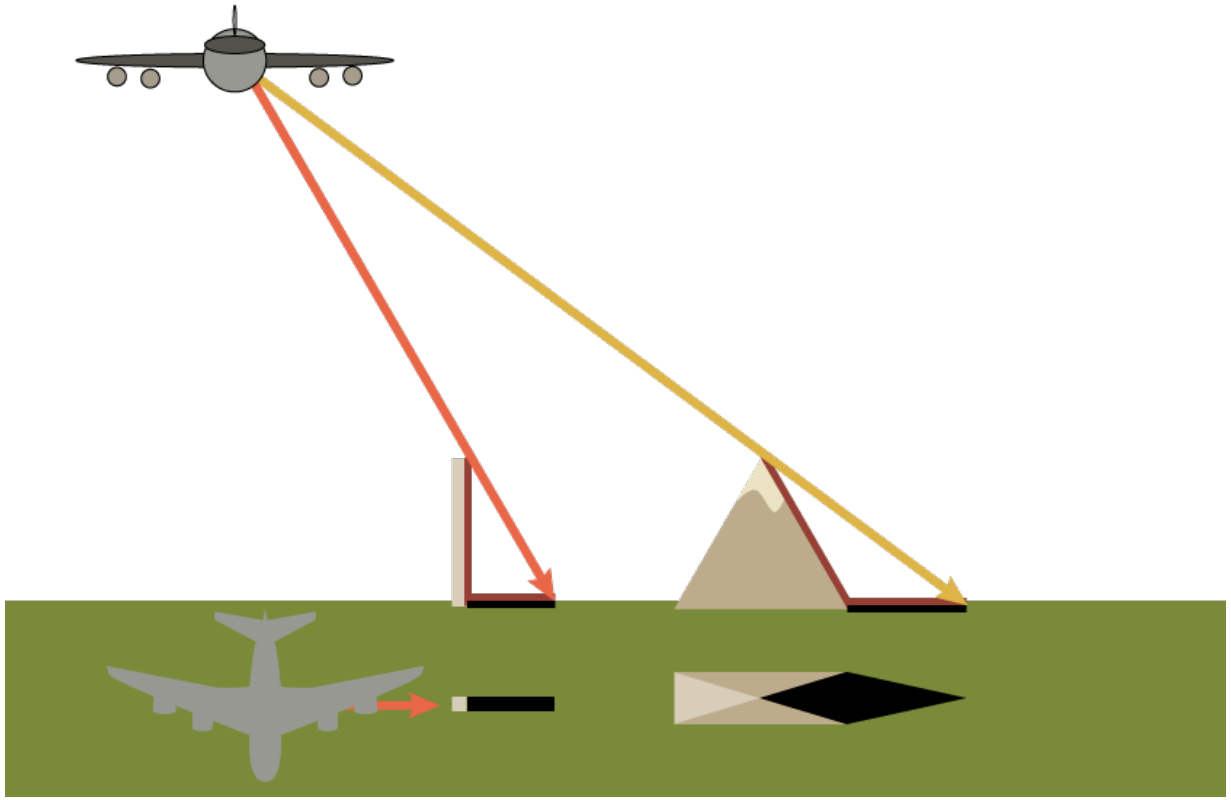
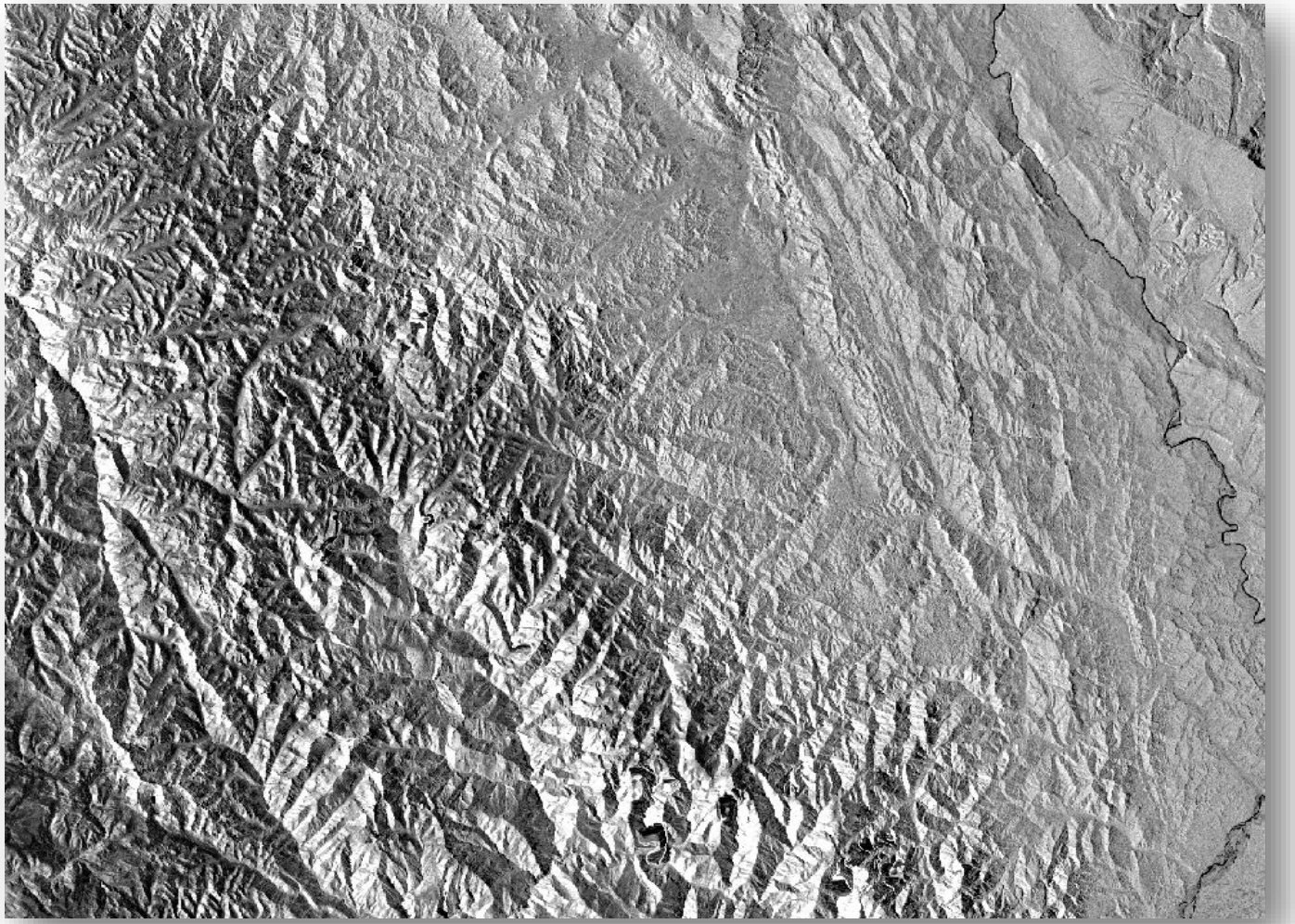


Image (left) based on NRC

Radiometric Distortion

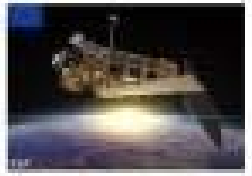
Sentinel-1 Radar Image Over the Andes

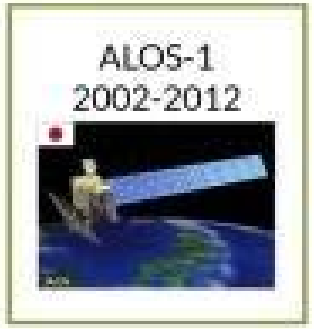


Images based on NRC images

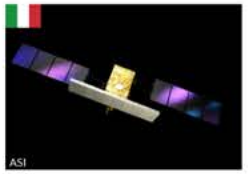
Radar Data from Different Satellites

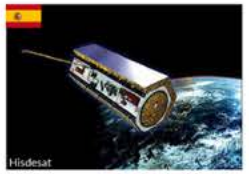
Legacy:



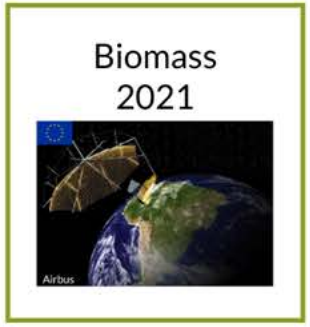


Current:





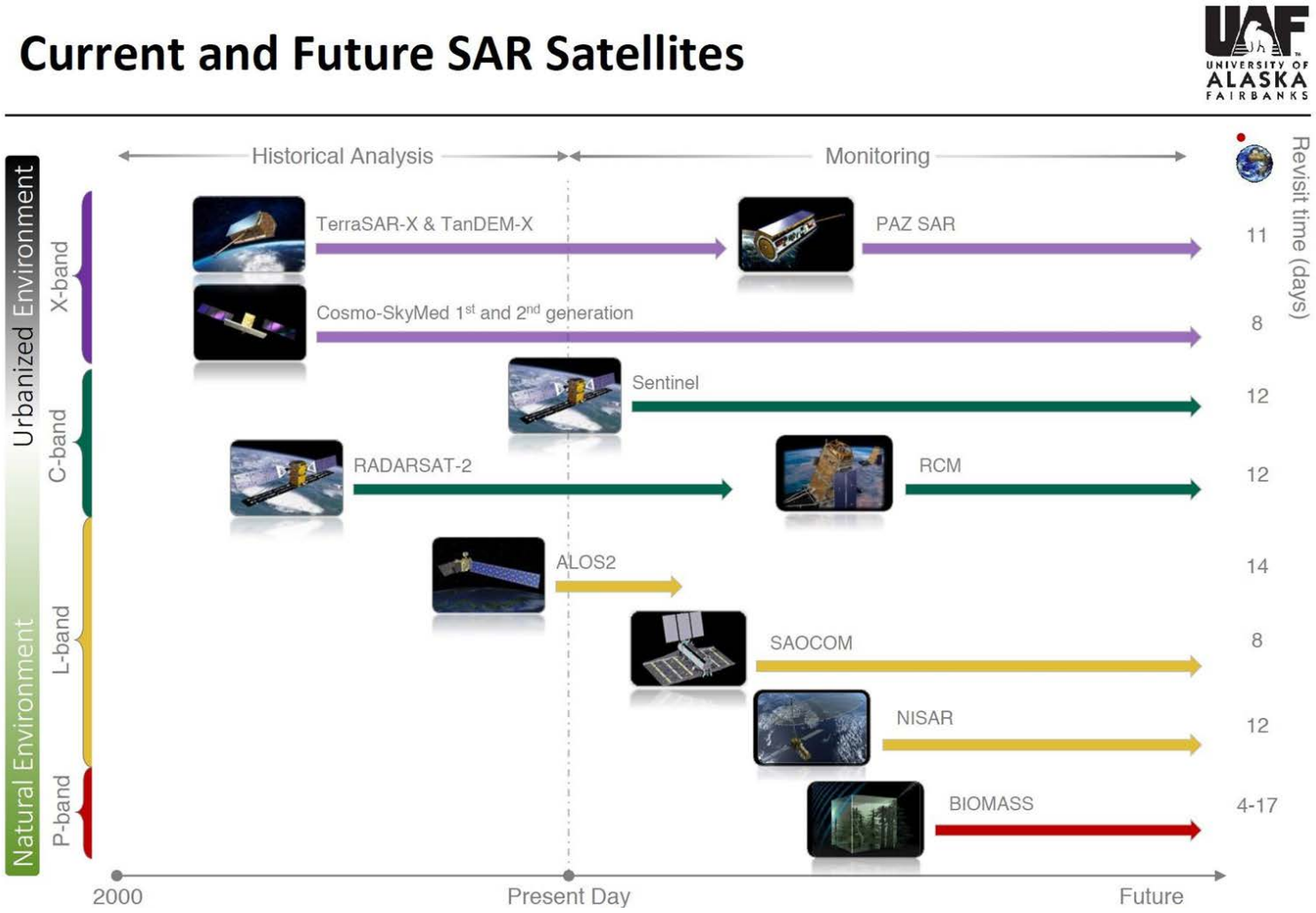
Future:



freely accessible

Credit: Franz Meyer, University of Alaska, Fairbanks

Current and Future SAR Satellites



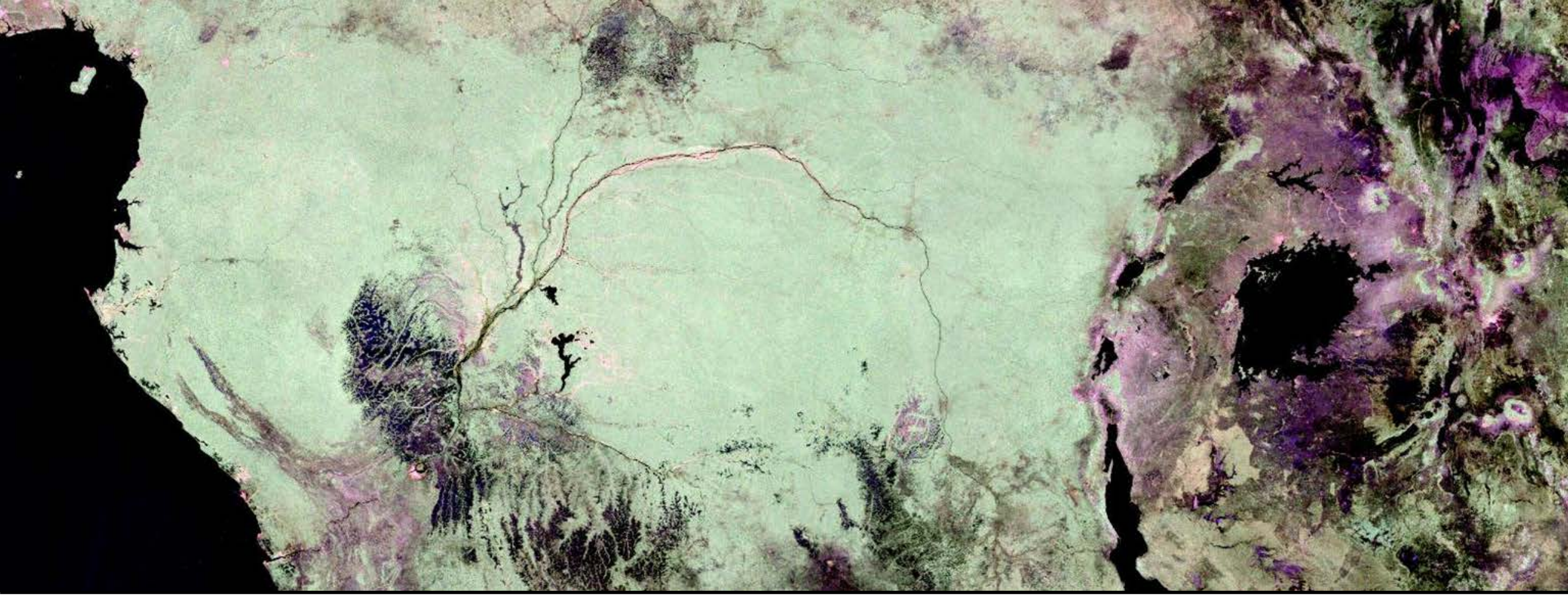
Credit: Franz Meyer, University of Alaska, Fairbanks

NASA-ISRO SAR Mission (NISAR)

- High spatial resolution with frequent revisit time
- Earliest baseline launch date: 2021
- Dual frequency L- and S-band SAR
  - L-band SAR from NASA and S-band SAR from ISRO
- 3 years science operations (5+ years consumables)
- All science data will be made available free and open

NISAR Characteristic:	Would Enable:
L-band (24 cm wavelength)	Low temporal decorrelation and foliage penetration
S-band (12 cm wavelength)	Sensitivity to light vegetation
SweepSAR technique with Imaging Swath >240 km	Global data collection
Polarimetry (Single/Dual/Quad)	Surface characterization and biomass estimation
12-day exact repeat	Rapid Sampling
3-10 meters mode-dependent SAR resolution	Small-scale observations
3 years since operations (5 years consumables)	Time-series analysis
Pointing control < 273 arcseconds	Deformation interferometry
Orbit control < 500 meters	Deformation interferometry
>30% observation duty cycle	Complete land/ice coverage
Left/Right pointing capability	Polar coverage, North and South
Noise Equivalent Sigma Zero ≤ -23 db	Surface characterization of smooth surfaces

Courtesy: Paul Rosen (JPL)



Hands-on Exercise