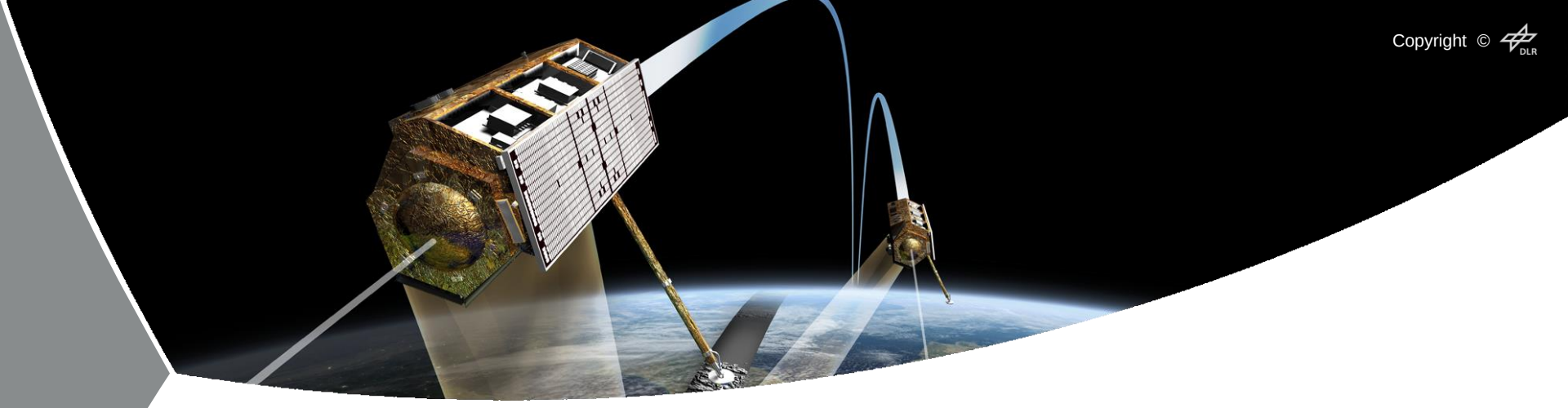

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SAR Remote Sensing

An Introduction

Prof. Dr. Christiane Schmullius, Dr. Christian Thiel, Robert Eckardt, Mikhail Urbazaev

Dept. of Earth Observation, Friedrich-Schiller-University Jena

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ZEISS Bau-15, 1915

Participants of the 1st „Summerschool on Stereophotogrammetrie“, Jena, 4.-9. Oct.1909

(Quelle: Sonderdruck der PFG, Jg. 1999, Heft 5)

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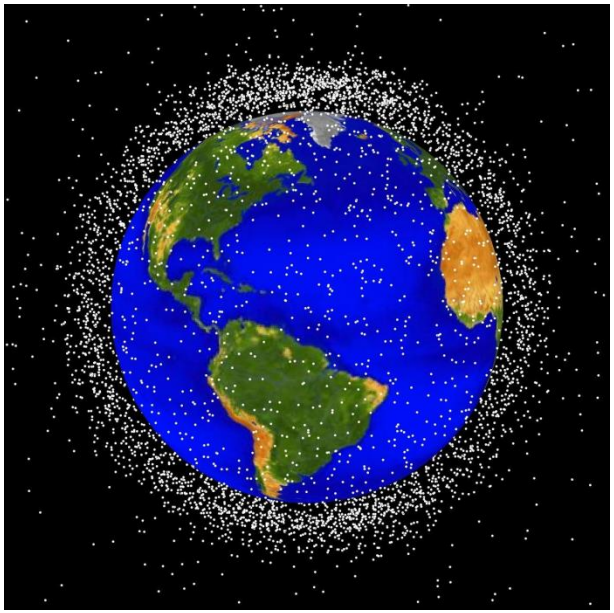
Contents

- What is Remote Sensing/Earth Observation?
- Active Radar Remote Sensing
- Summary

What is Remote Sensing/Earth Observation?

- ***Remote sensing (RS)*** (or Earth observation - EO) refers to ***obtaining information*** about objects (or the Earth's surface) ***without being in direct contact*** with the object or area.

http://freeda.files.wordpress.com/2007/10/sv003.jpg



http://www.nhn.ou.edu/~jeffery/astro/earth/orbital_debris.jpg

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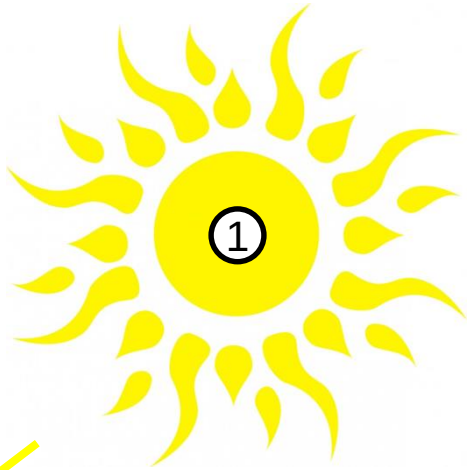
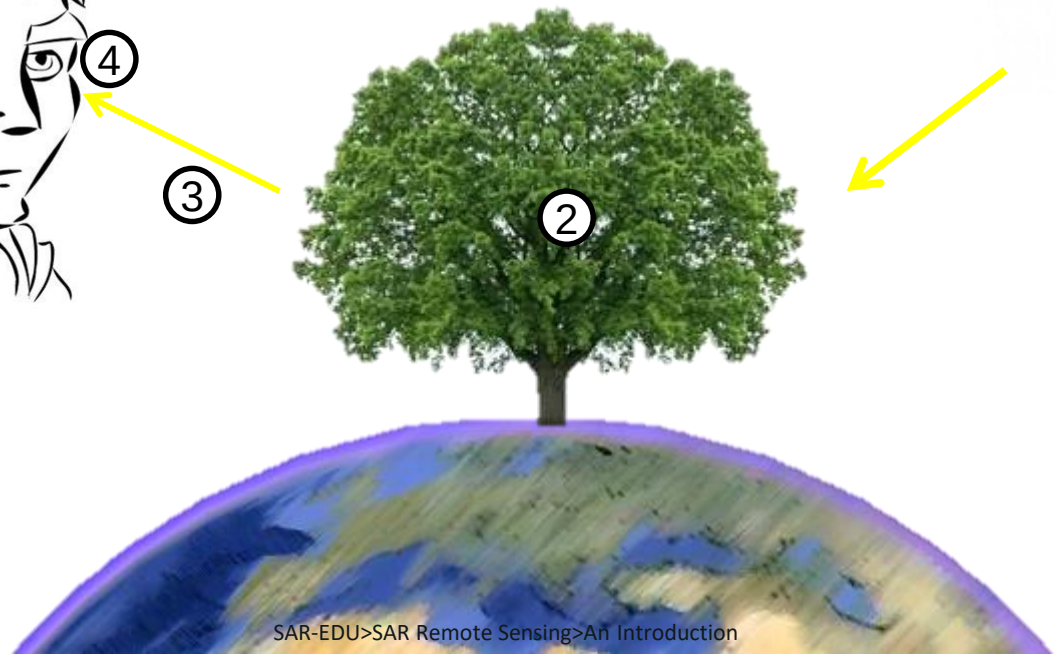
What is Remote Sensing/Earth Observation?

Components of the remote sensing process

1. Source of electromagnetic energy
2. Interaction with the object
3. Radiation back to sensor
4. Reception of radiation by sensor
5. Interpretation and analysis





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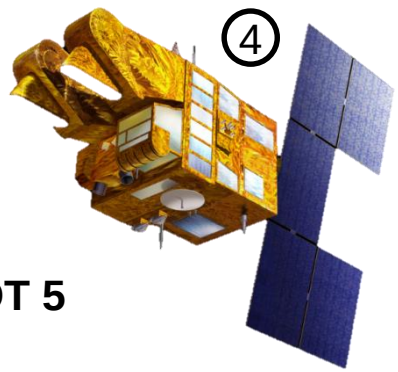
What is Remote Sensing/Earth Observation?

Components of the remote sensing process



5

SPOT 5

Optical satellite
visible part of the spectrum

energy scattered off the leaf is dependent on:

The "**greenness**" of the leaf as a function of the amount of chlorophyll, which absorbs the energy that is needed for photosynthesis

1. Source of electromagnetic energy
2. Interaction with the object
3. Radiation back to sensor
4. Reception of radiation by sensor
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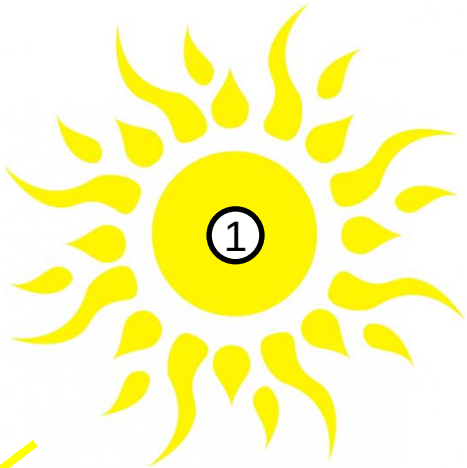
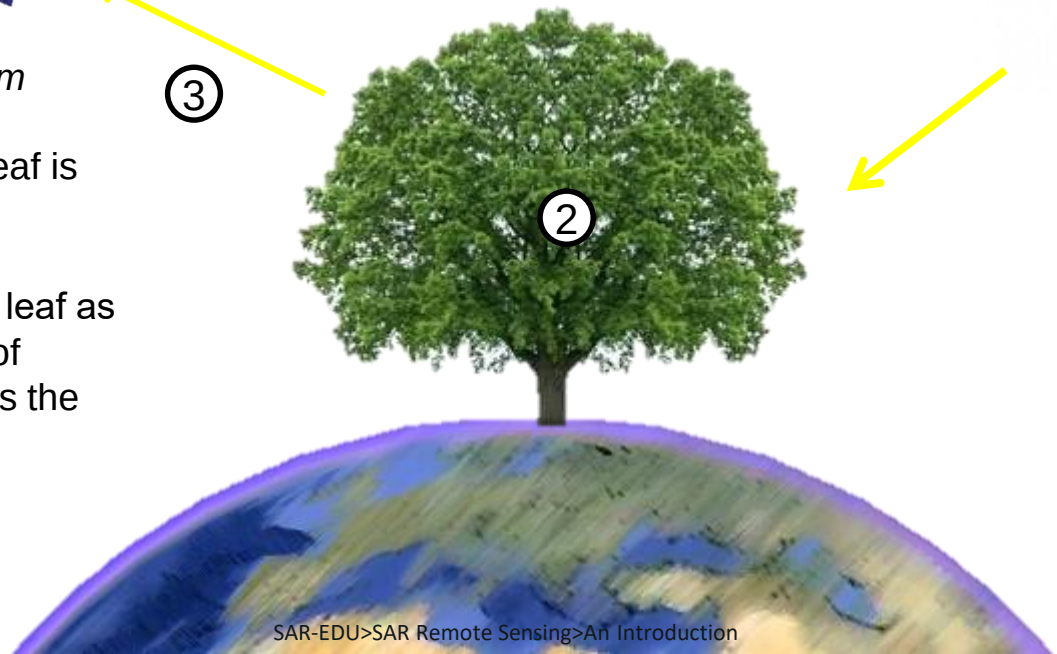


3



SAREDU Remote Sensing Education Initiative

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What is Remote Sensing/Earth Observation?

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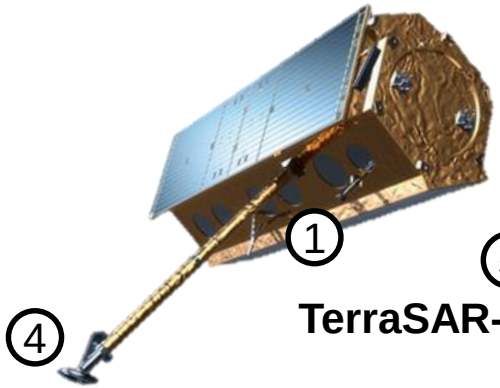
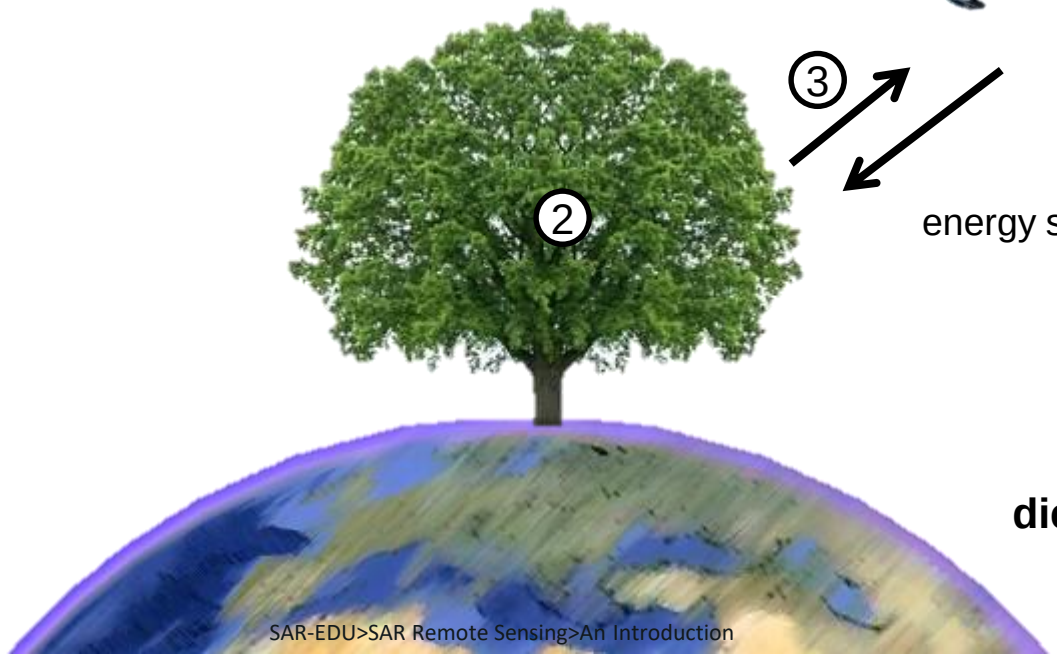


TerraSAR-X

Radar satellite
microwave part of the spectrum



energy scattered off the leaf is dependent on:

size
shape
orientation
dielectric properties

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What is Remote Sensing/Earth Observation?

Source of electromagnetic energy

Passive remote sensing systems:

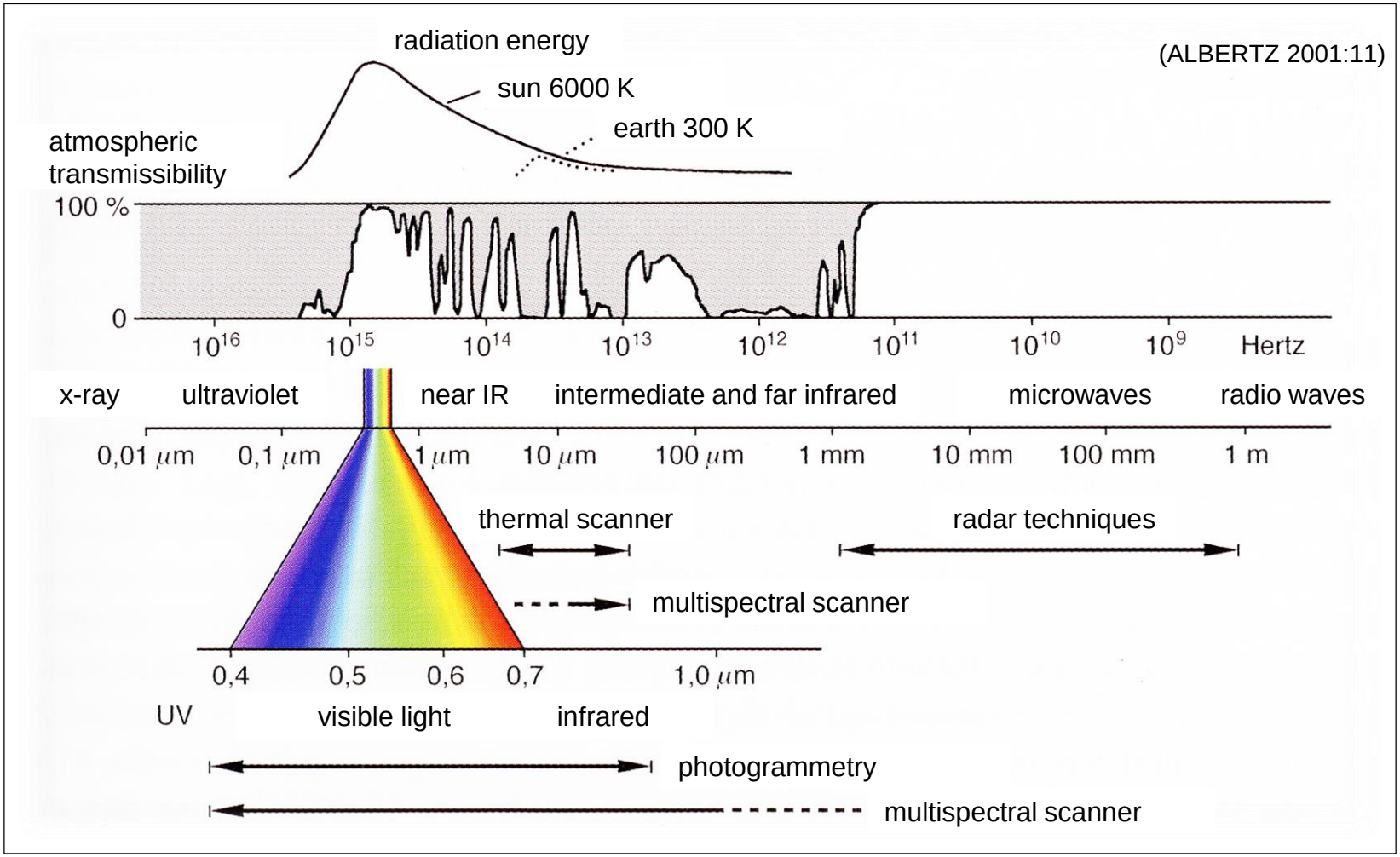
- Detect the **reflected** or **emitted** EM radiation from natural sources
- **Some of the images represent reflected solar radiation in the visible and the near infrared regions of the EM spectrum**
- **others are the measurements of the energy emitted by the Earth surface itself i.e. in the thermal infrared wavelength region**

Active remote sensing systems:

- Detect **reflected responses** from objects irradiated by **artificially-generated energy** sources
- **energy is transmitted from the remote sensing platform**
- **measurement of relative return from the Earth's surface**

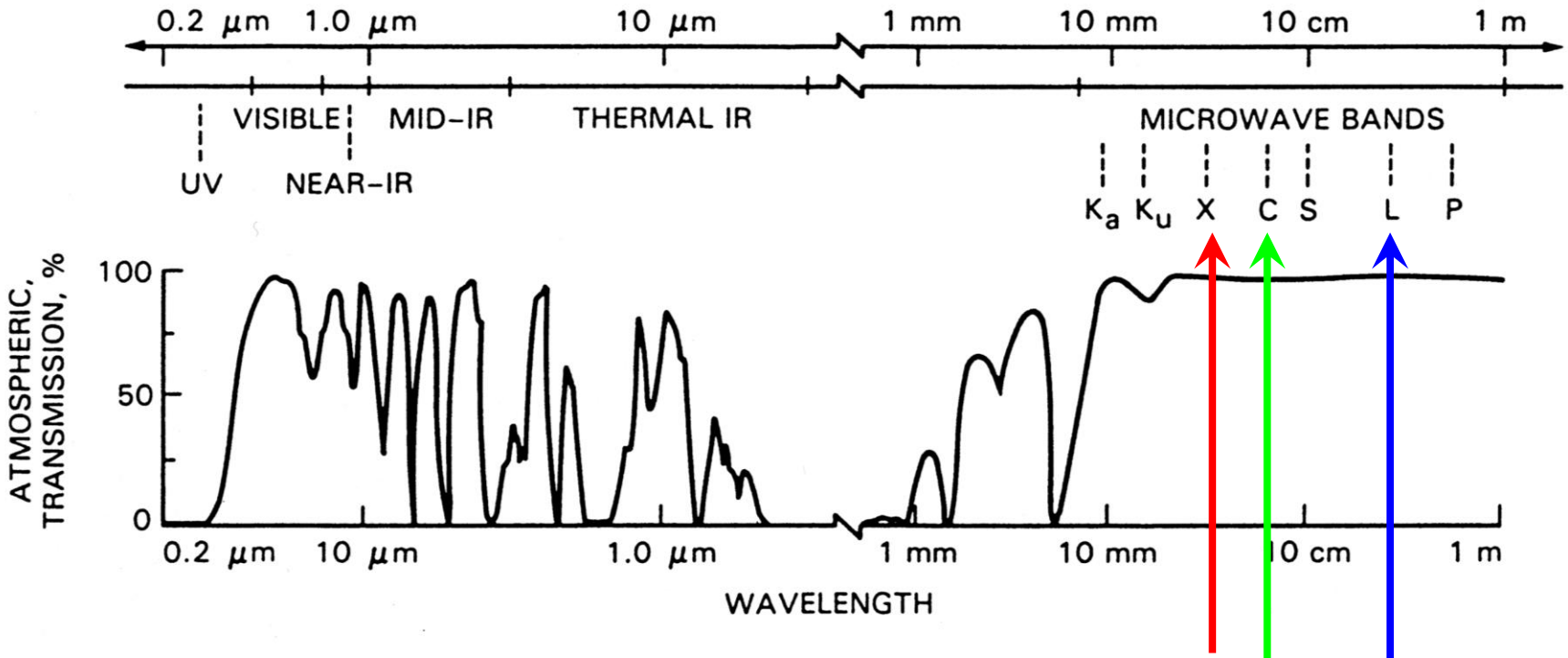
What is Remote Sensing/Earth Observation?

Source of electromagnetic energy



Active Radar Remote Sensing

Interaction with the object



TerraSAR-X

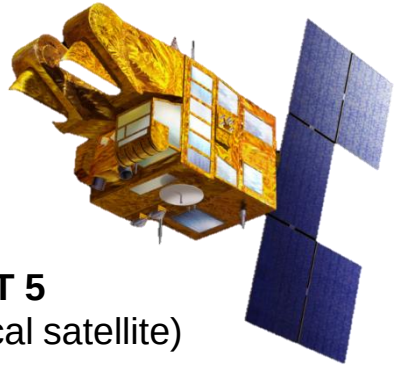
ENVISAT, RADARSAT, ERS1&2

ALOS, JERS1

Radar bands and transmission of Radar through the atmosphere (WICKS 2006:o.S.).

What is Remote Sensing/Earth Observation?

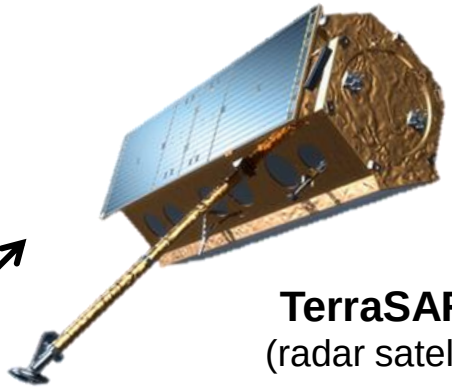
Source of electromagnetic energy



SPOT 5
(optical satellite)

passive

active



TerraSAR-X
(radar satellite)

Further Examples:

Non-imaging: radiometer, magnetic sensor

Imaging: cameras, optical mechanical scanner, spectrometer, radiometer

Further Examples:

Non-imaging: altimeter, laser

Imaging: Real Aperture Radar, Synthetic Aperture Radar

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What is Remote Sensing/Earth Observation?

Interaction with the object

SPOT 5

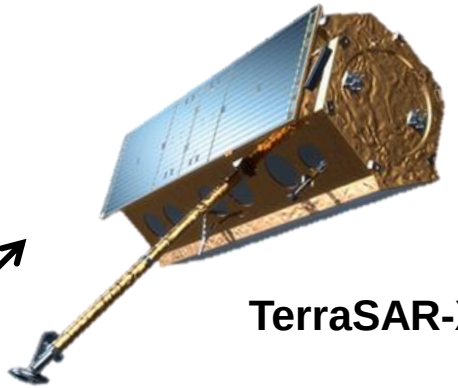
Optical satellite
visible part of the spectrum

energy scattered off the leaf is dependent on:

The "greenness" of the leaf as a function of the amount of chlorophyll, which absorbs the energy that is needed for photosynthesis

optical

radar



TerraSAR-X

Radar satellite
microwave part of the spectrum

energy scattered off the leaf is dependent on:

size
shape
orientation
dielectric properties

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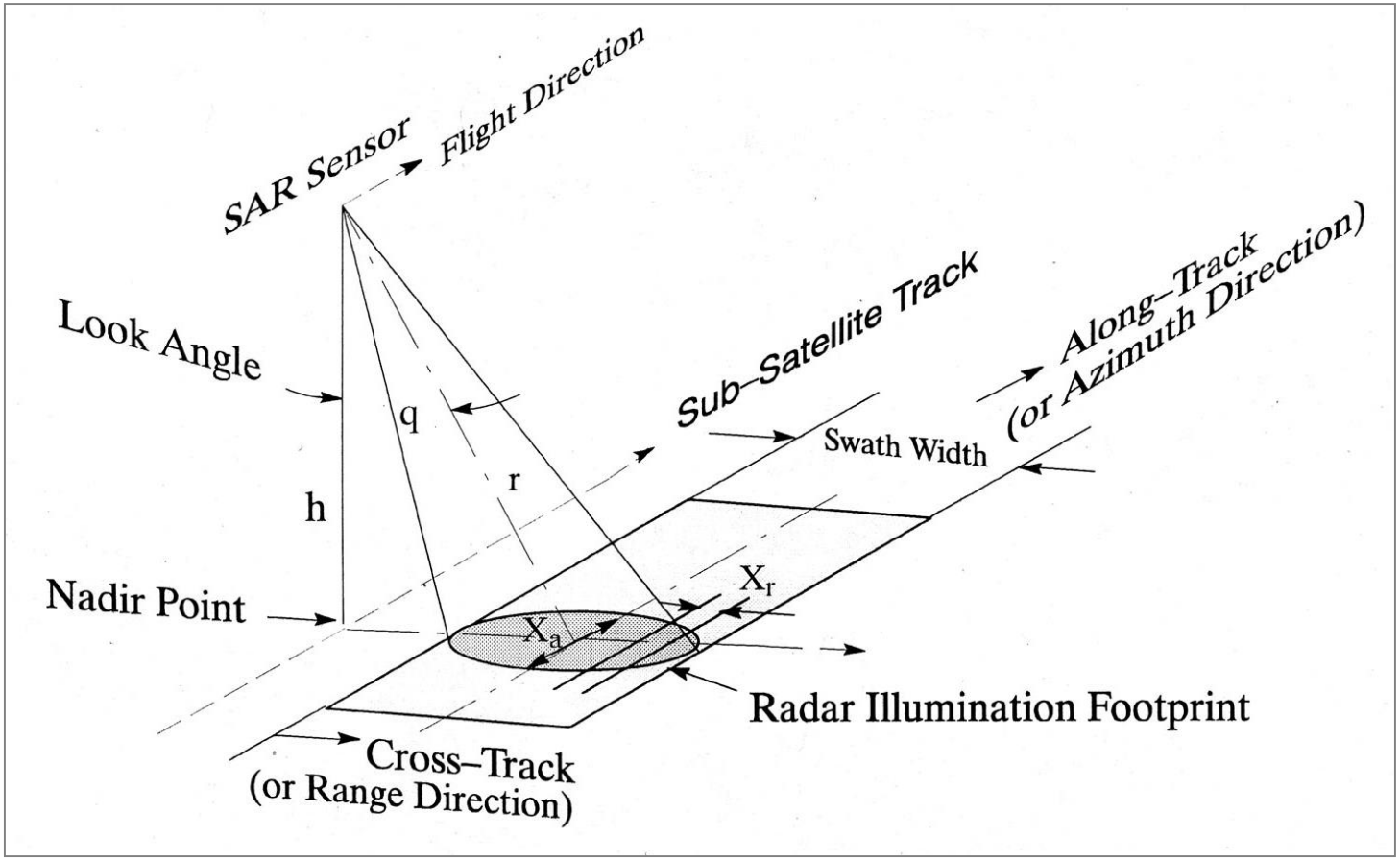
Active Radar Remote Sensing

Interaction with the object

The Radar Concept (after ROSEN 2004:o.S.).

Active Radar Remote Sensing

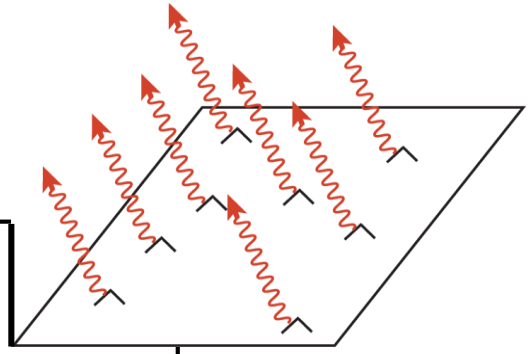
Interaction with the object

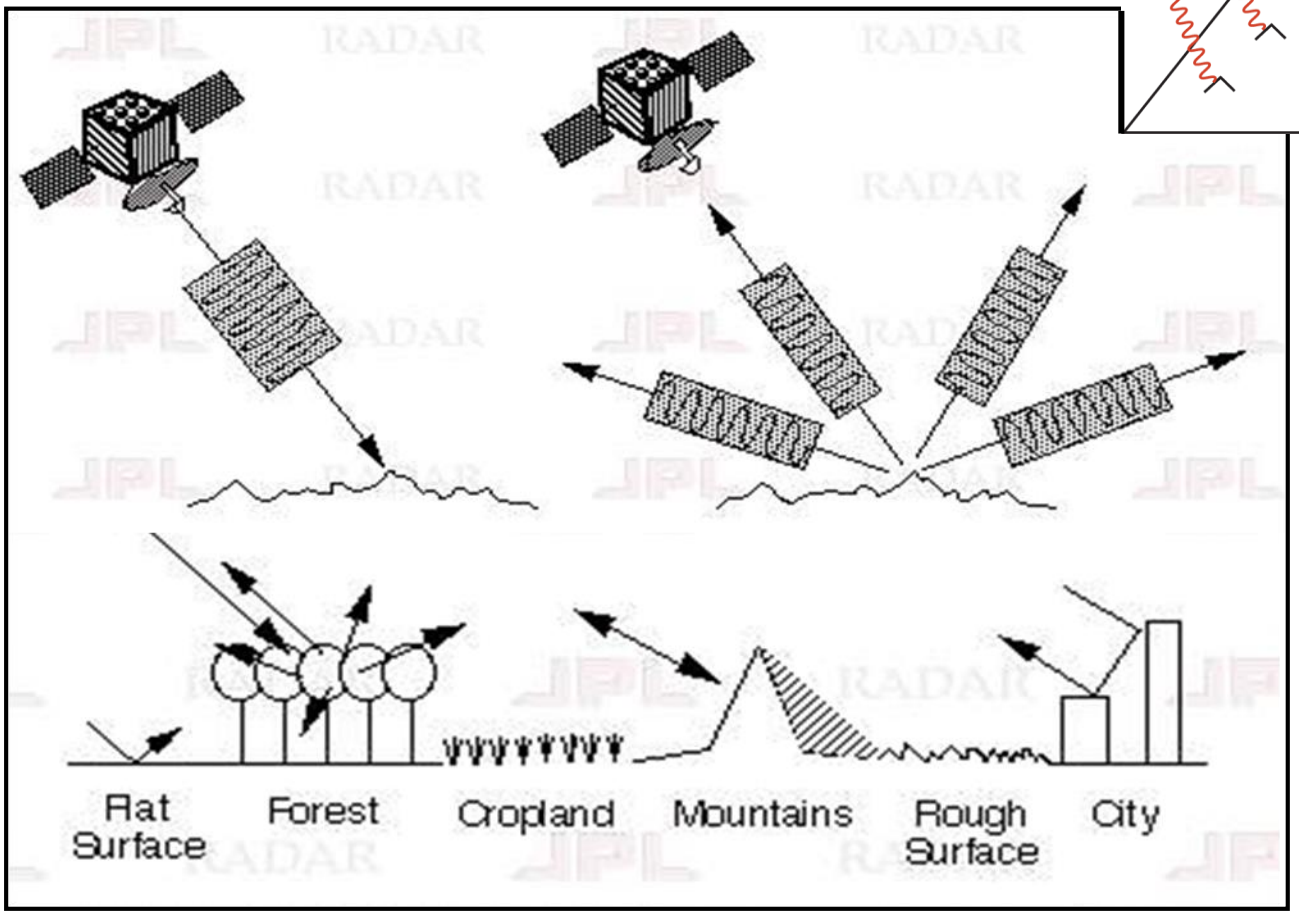


Side-looking SAR geometry.

Active Radar Remote Sensing

Interaction with the object





The Radar Concept (WICKS 2006:o.S.).

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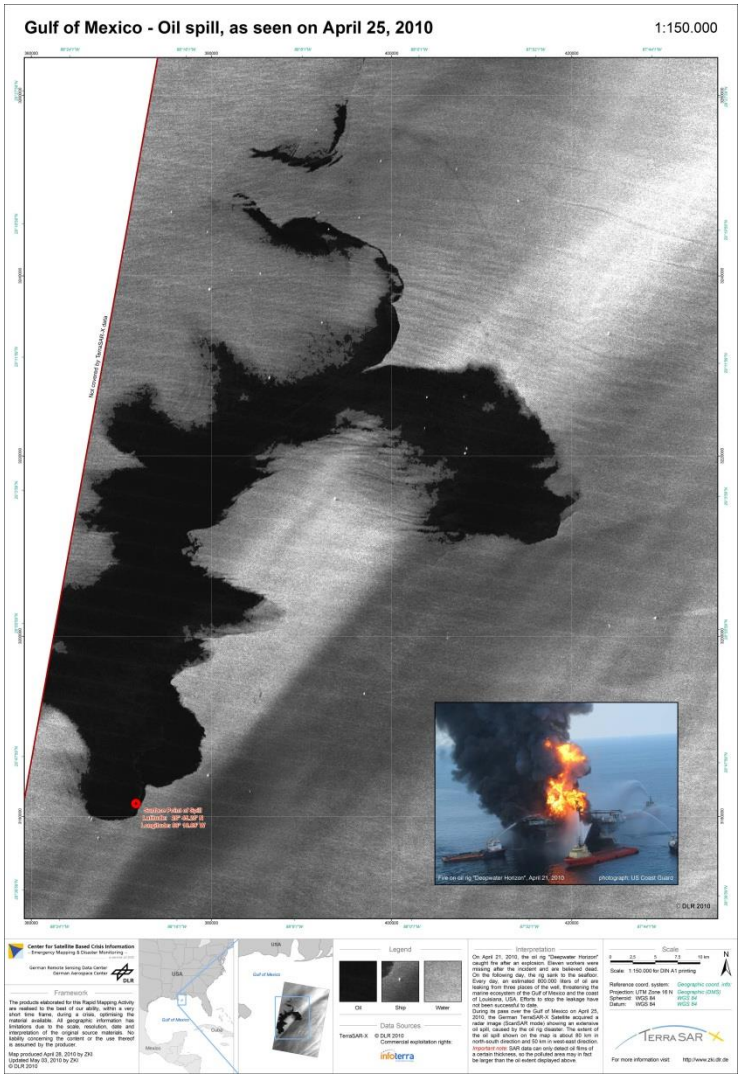
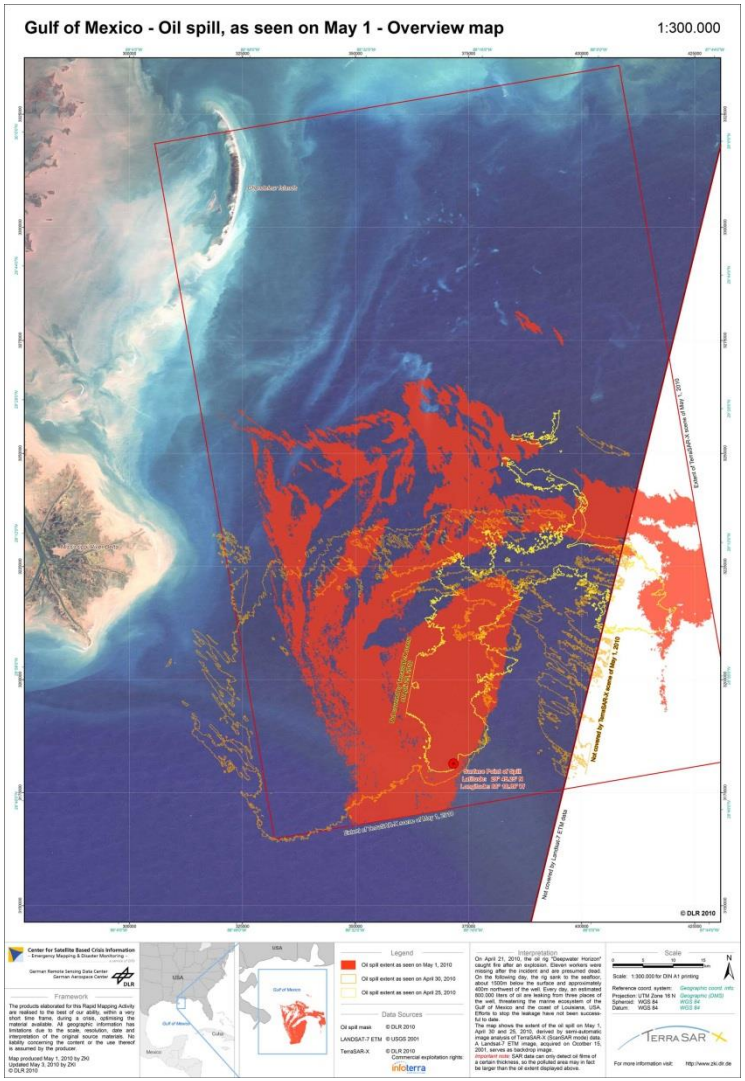
Applications





Rapid situation analysis

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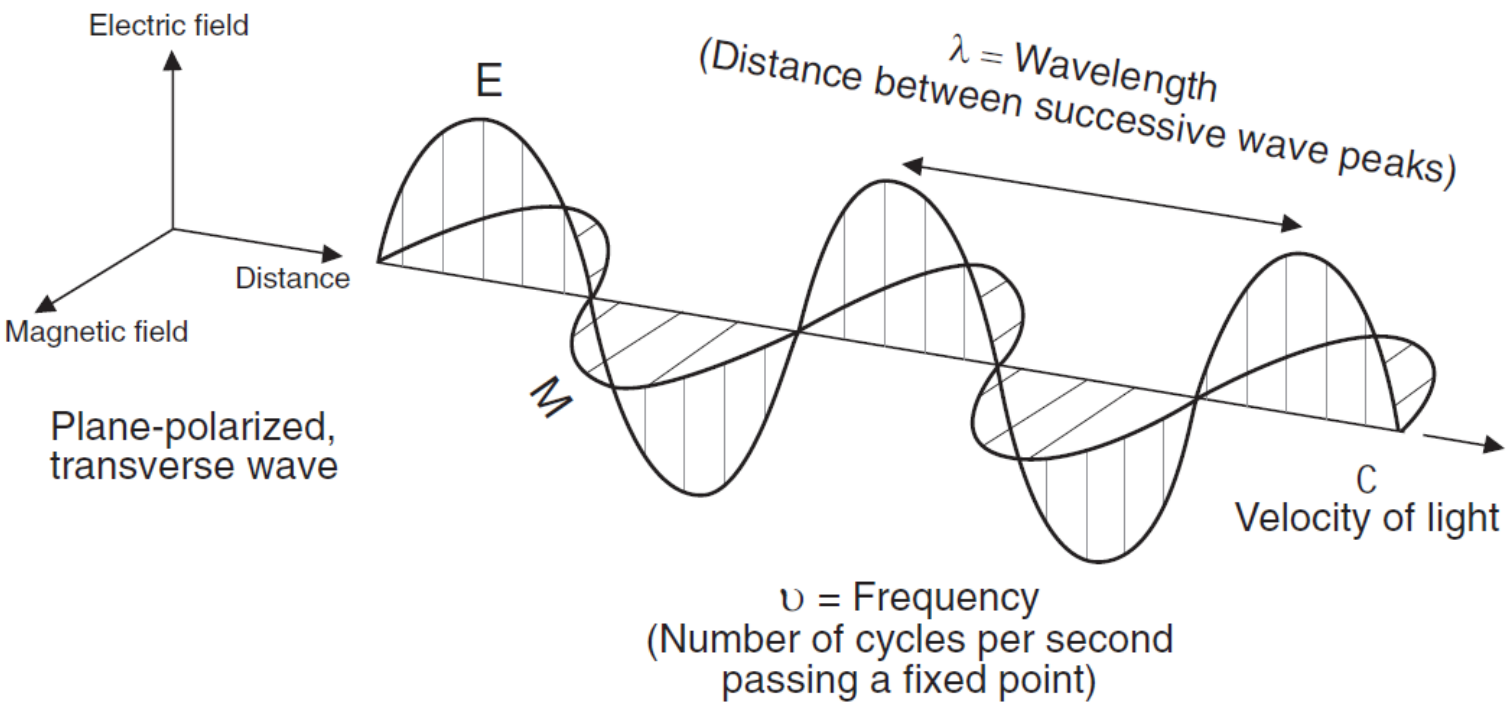
Active Radar Remote Sensing

Interaction with the object

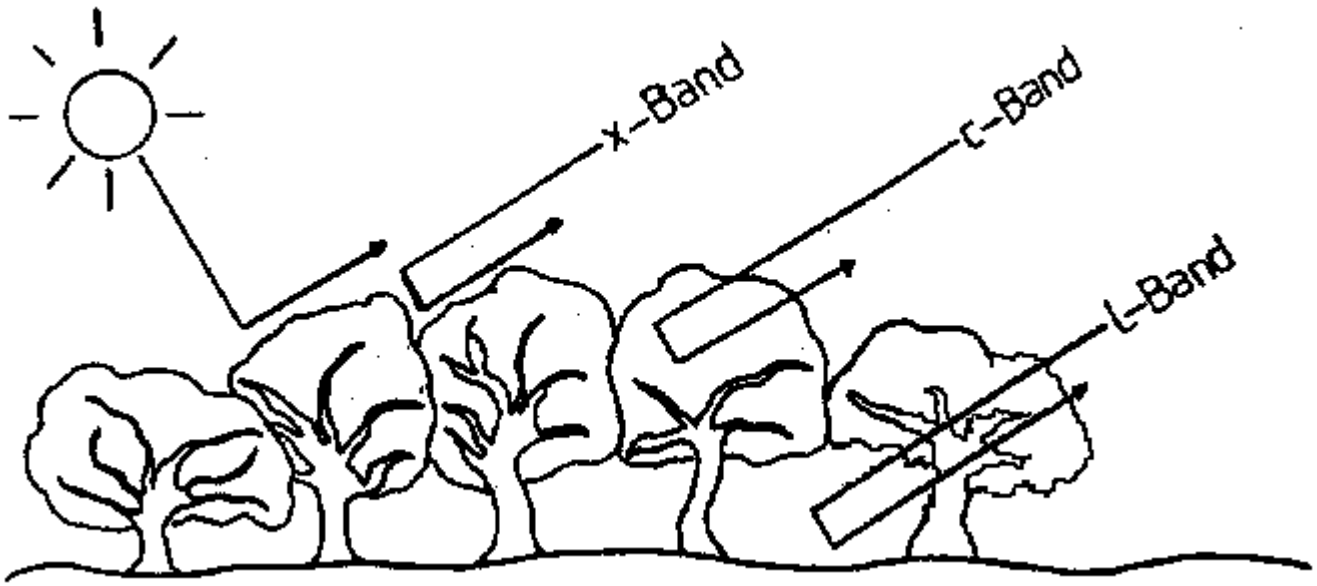
$$c = \lambda \nu \qquad c = 3 \times 10^{8}\ \mathrm{m\ s^{-1}}$$



Wave Theory and Polarization
(David P. Lusch, 1999).

Active Radar Remote Sensing

Interaction with the object



Penetration depth of microwaves in X-Band, C-Band, L-Band (Uni Siegen).

What are the scatterers in the volume scattering?

Austrian pine | **X band** $\lambda = 3$ cm | **L band** $\lambda = 27$ cm | **P band** $\lambda = 70$ cm | **VHF** $\lambda > 3$ m

The main scatterers in a canopy are the elements having dimension of the order of the wavelength

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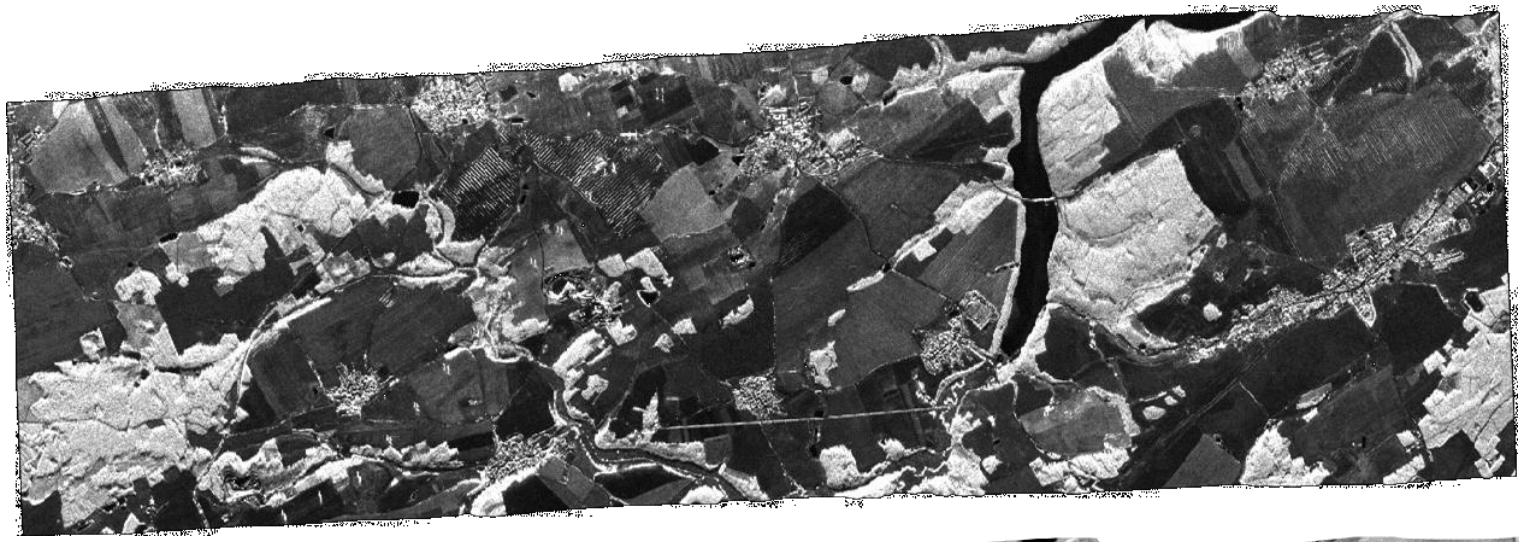
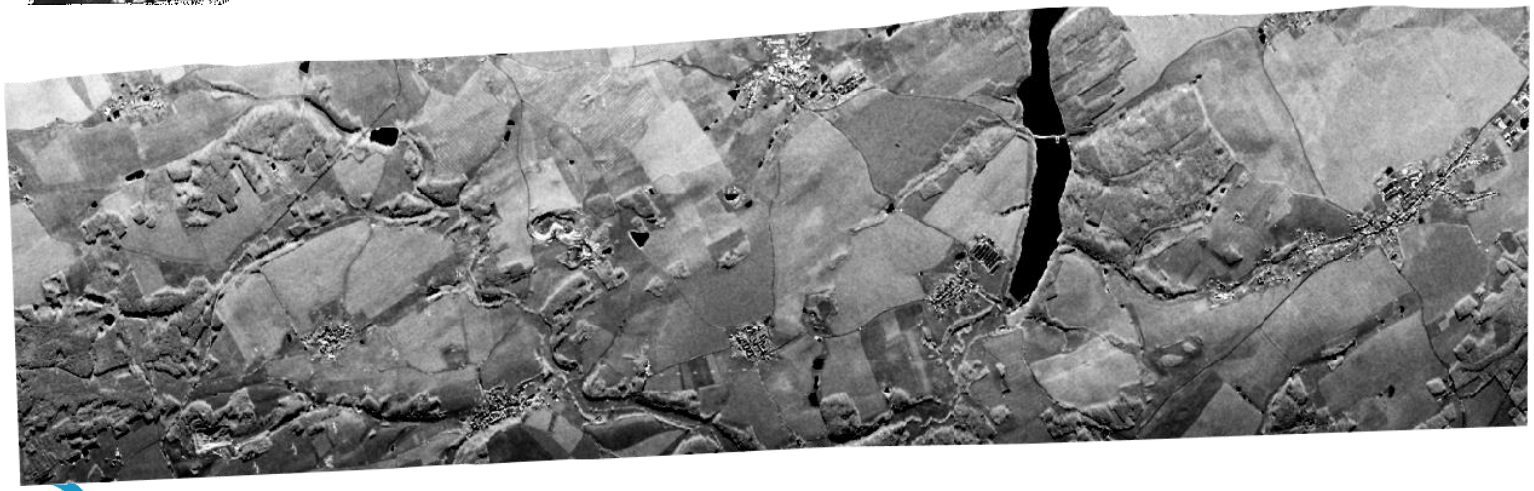
Impact of SAR Frequency



L-band



X-band

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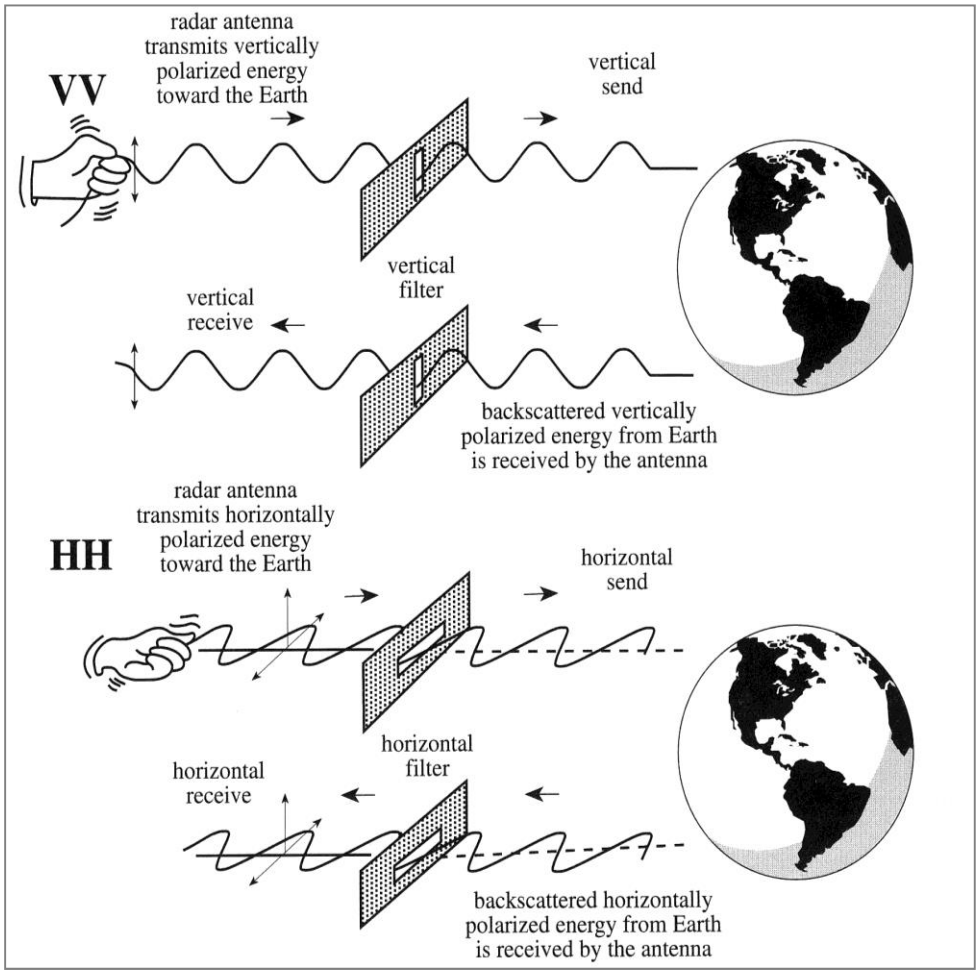
Use of polarized waves



Polarisation (Jensen, 2000).

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Use of polarized waves (Example L-band)

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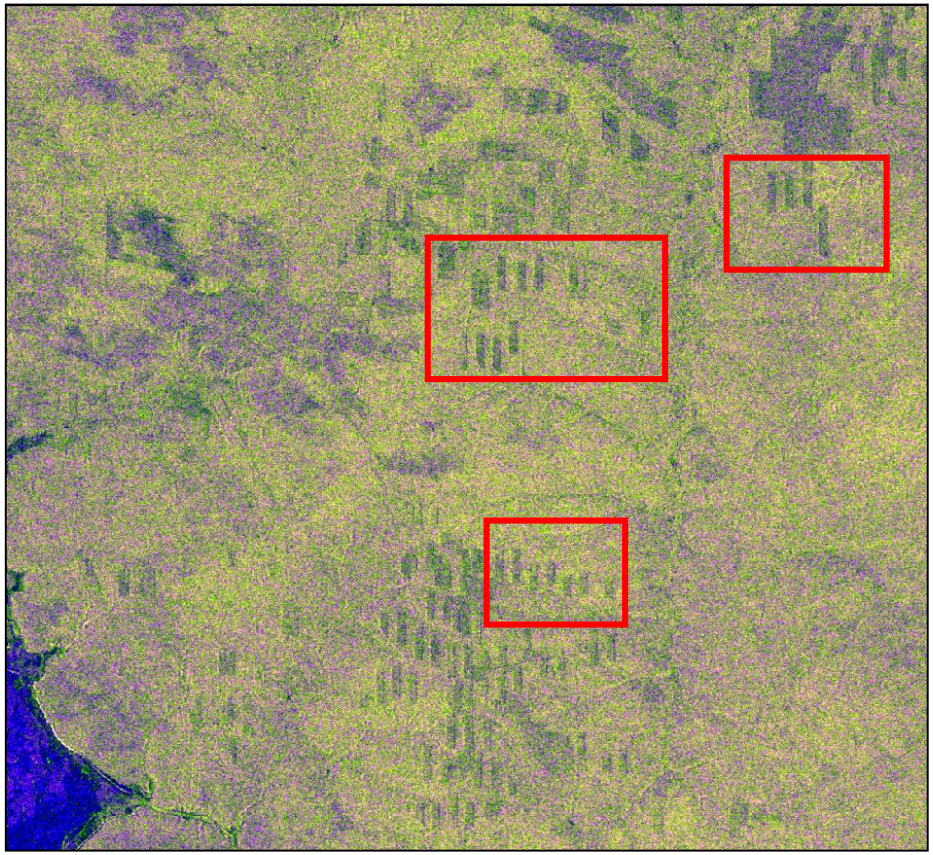
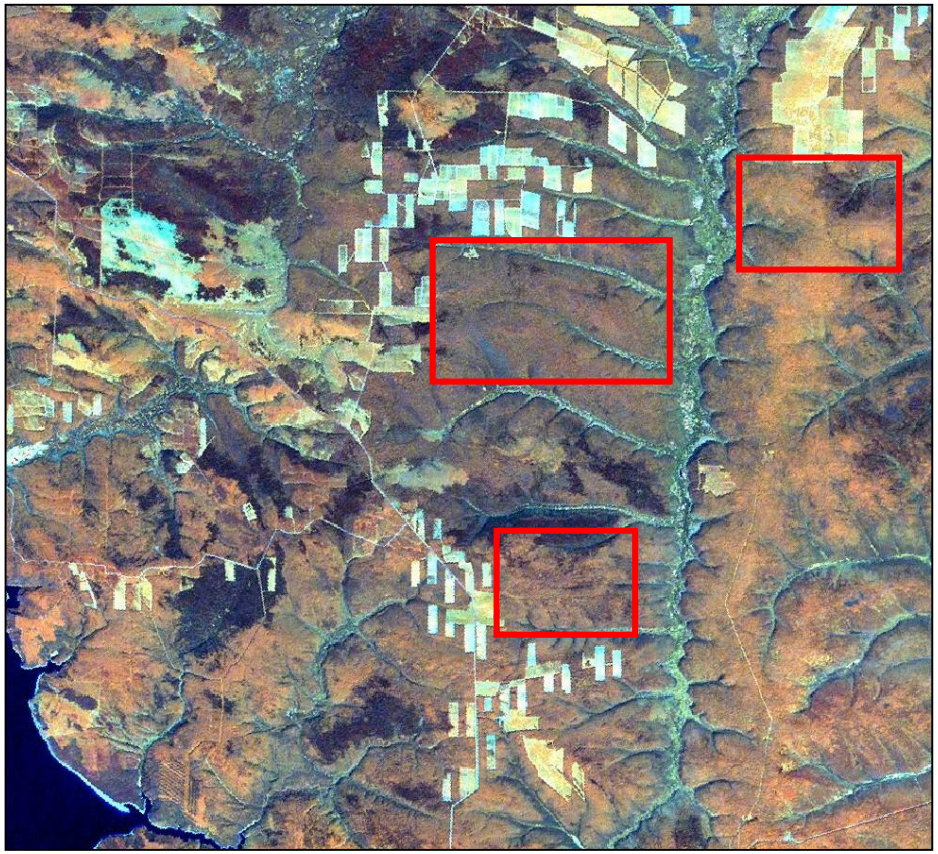
Applications

Detection of Change



ASAR APP (HH, HV, HV/HH), Siberia 2006



Landsat (4, 5, 3), Siberia 1990

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Active Radar Remote Sensing

Advantages

- ***all weather*** capability (small sensitivity to clouds, light rain)
- ***day and night*** operation (independence of sun illumination, active instruments with own source of energy)
- ***no effects of atmospheric constituents*** (multitemporal analysis)
- sensitivity to ***dielectric properties*** (water content , biomass, ice)
- sensitivity to ***surface roughness*** (ocean wind speed)
- accurate measurements of ***distance*** (interferometry)
- sensitivity to ***man made objects***
- sensitivity to ***target structure*** (use of polarimetry)
- ***subsurface penetration*** (the longer the wavelength, the higher the transmission through a medium)

Active Radar Remote Sensing

Inconveniencies

- ***complex*** interactions (difficulty in understanding, complex processing)
- ***speckle*** (difficulty in visual interpretation)
- ***topographic effects***
- etc.

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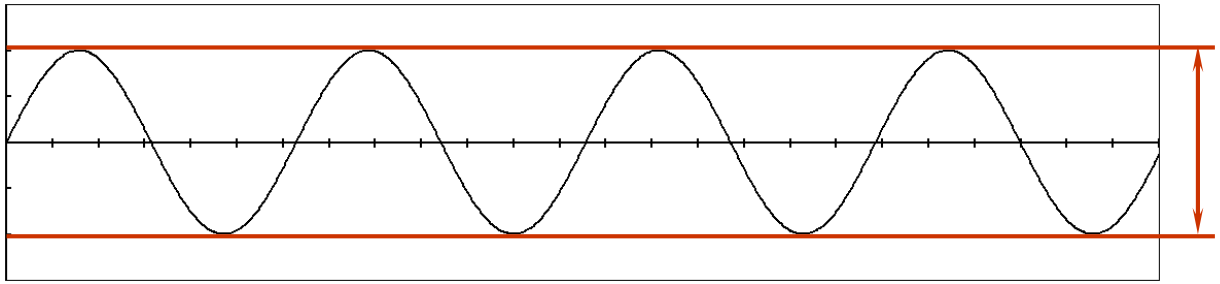
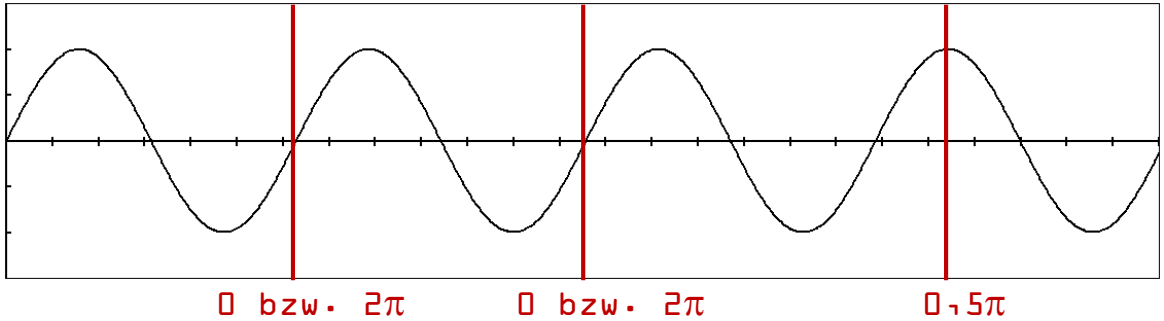
Active Radar Remote Sensing

Parameters measured by SAR

1. Amplitude



2. Phase [0, 2π]



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Speckle "Noise"

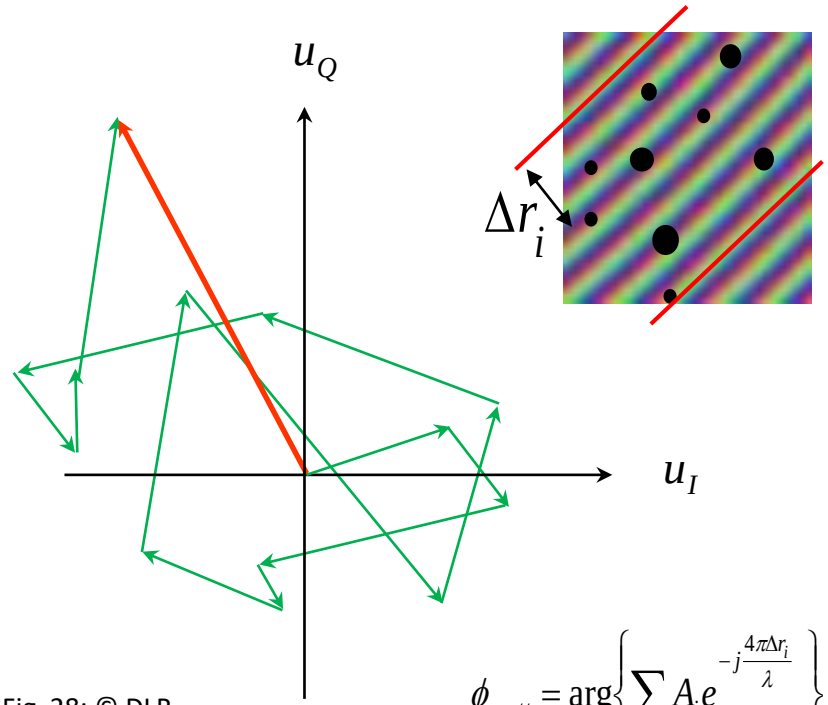


Fig. 28: © DLR

$$\phi_{scatt} = \arg\left\{ \sum A_i e^{-j\frac{4\pi\Delta r_i}{\lambda}} \right\}$$

- Random positive and negative interference of wave contributions from the many individual scatterers within one resolution cell
  - varying brightness from pixel to pixel even for constant σ_0
  - granular appearance even of homogenous surfaces

Copyright © DLR

Example for Bayesian Speckle Reduction

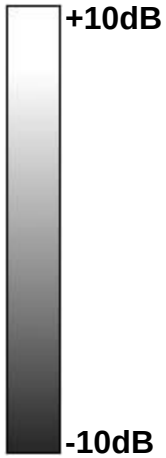
original SAR image

SAR data © AeroSensing GmbH

speckle filtered
Bayesian algorithm

Copyright © DLR

Speckle Reduction by Temporal Multilooking (ERS)

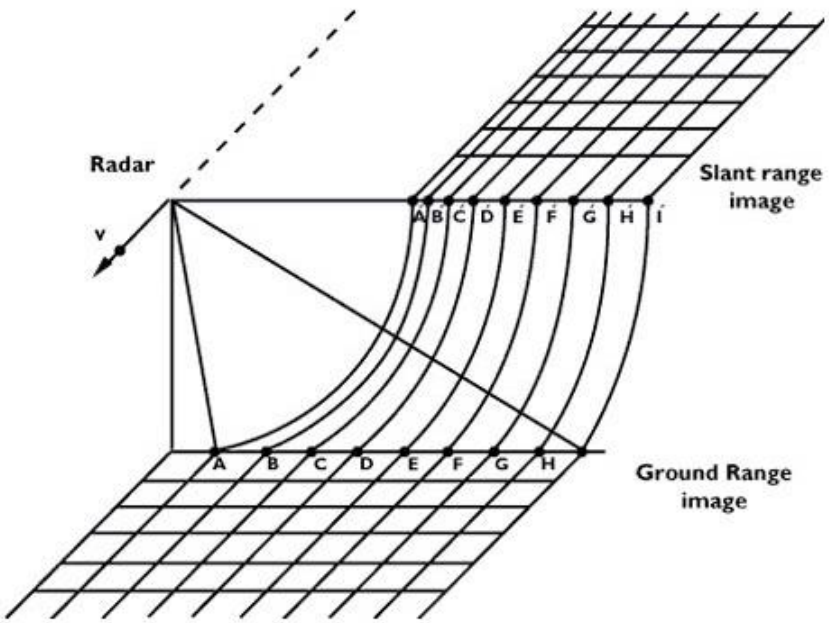


5 spatial looks
20 x 20 m ground resolution
2 dB radiometric resolution

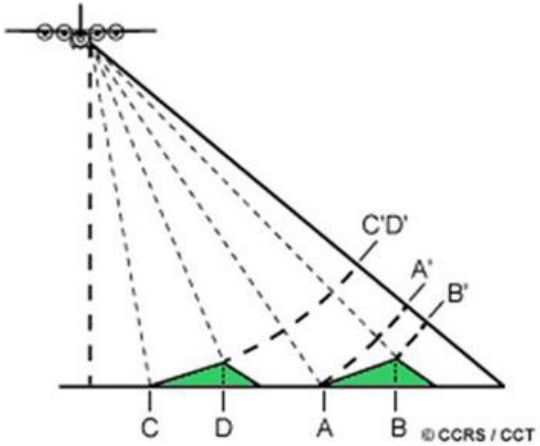
320 spatio-temporal looks
20 x 20 m ground resolution
0.3 dB radiometric resolution

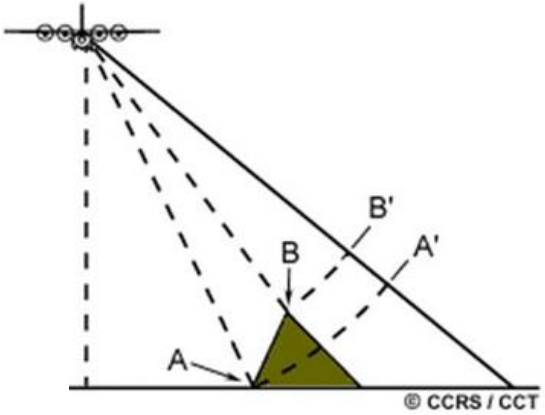
Active Radar Remote Sensing

Interaction with the object



Slant-range vs. ground range radar image geometry (ESA).



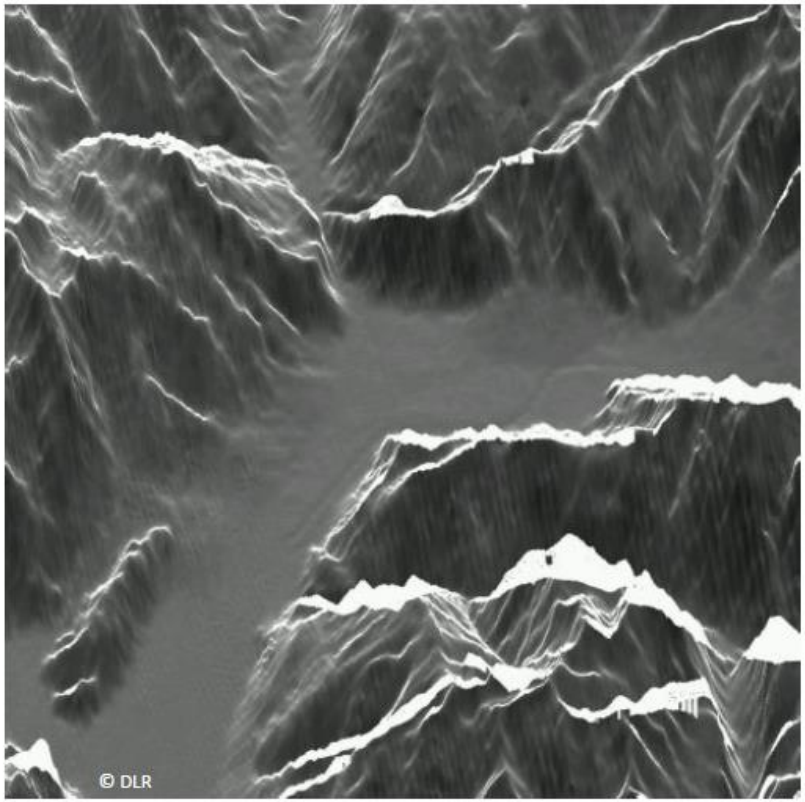


Foreshortening (top) and layover (bottom) caused by terrain relief (NATURAL RESOURCES CANADA).

Copyright ©

Layover Mask Computed from DEM

100m DEM

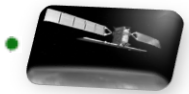


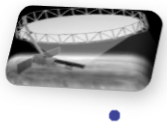
simulated ERS-Image
white: lay-over

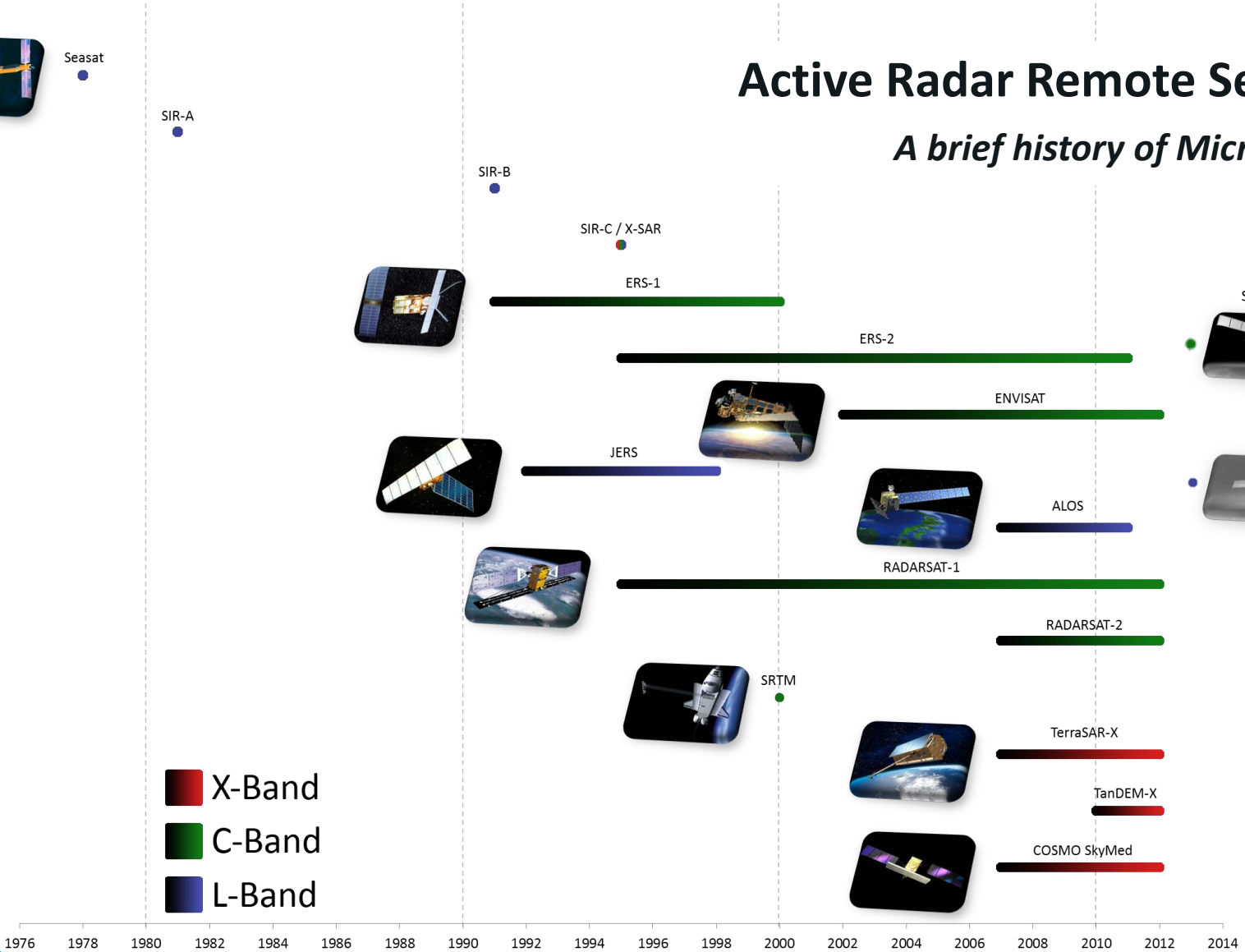
Copyright © DLR

Active Radar Remote Sensing

A brief history of Microwaves







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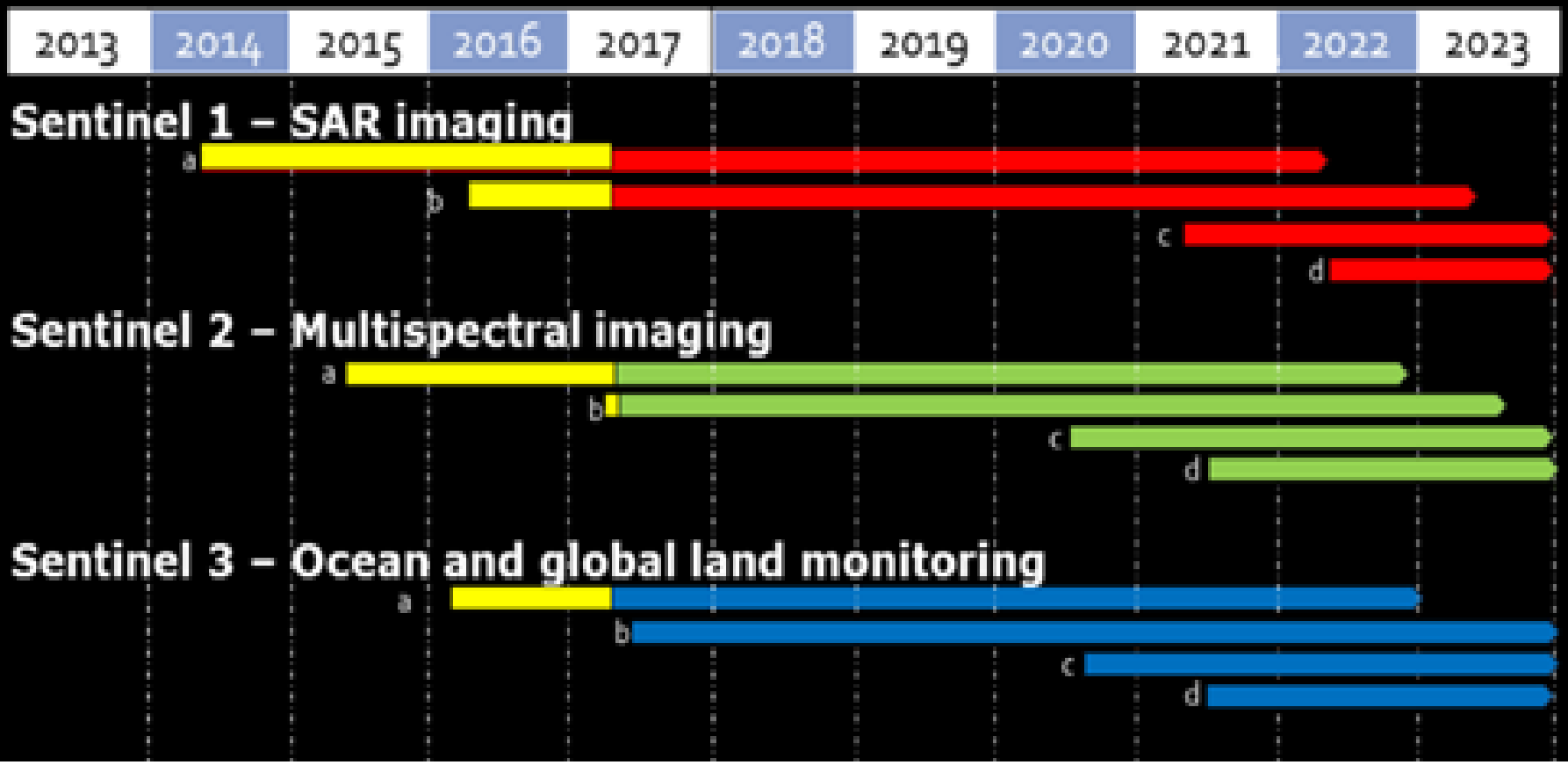
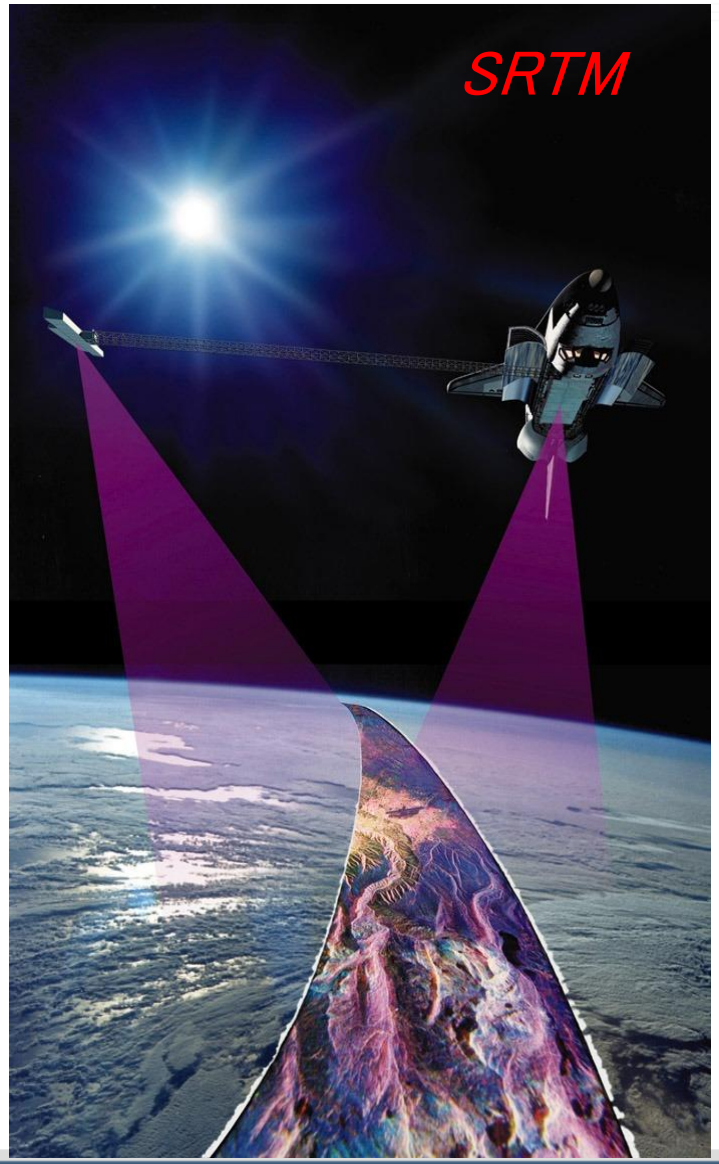
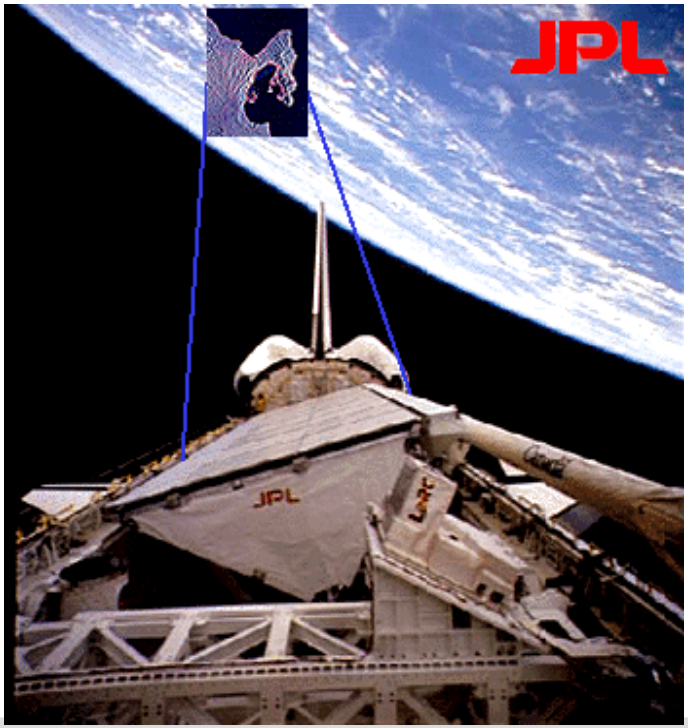
The Copernicus Sentinel Missions

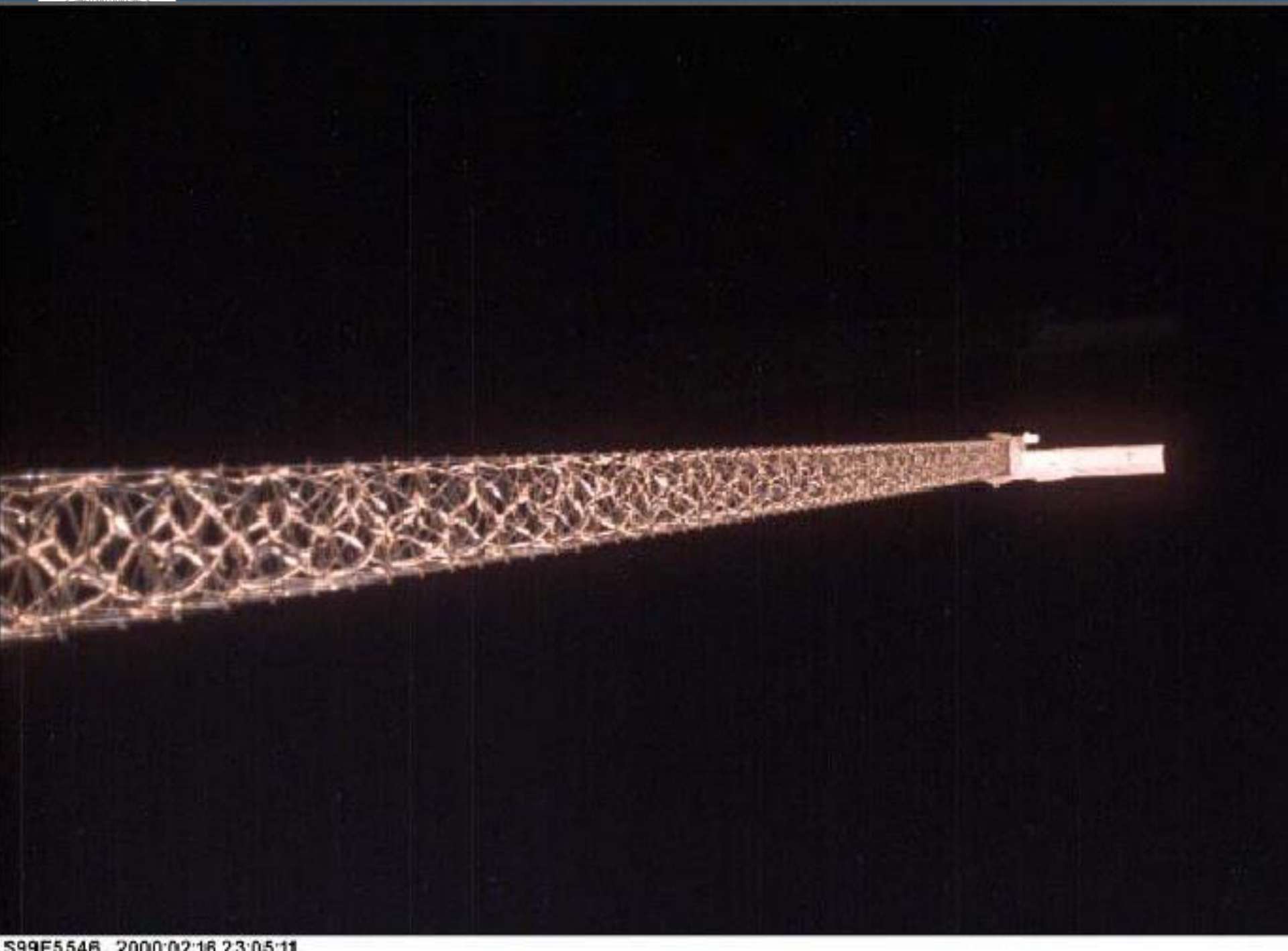


The Radar Era starts:

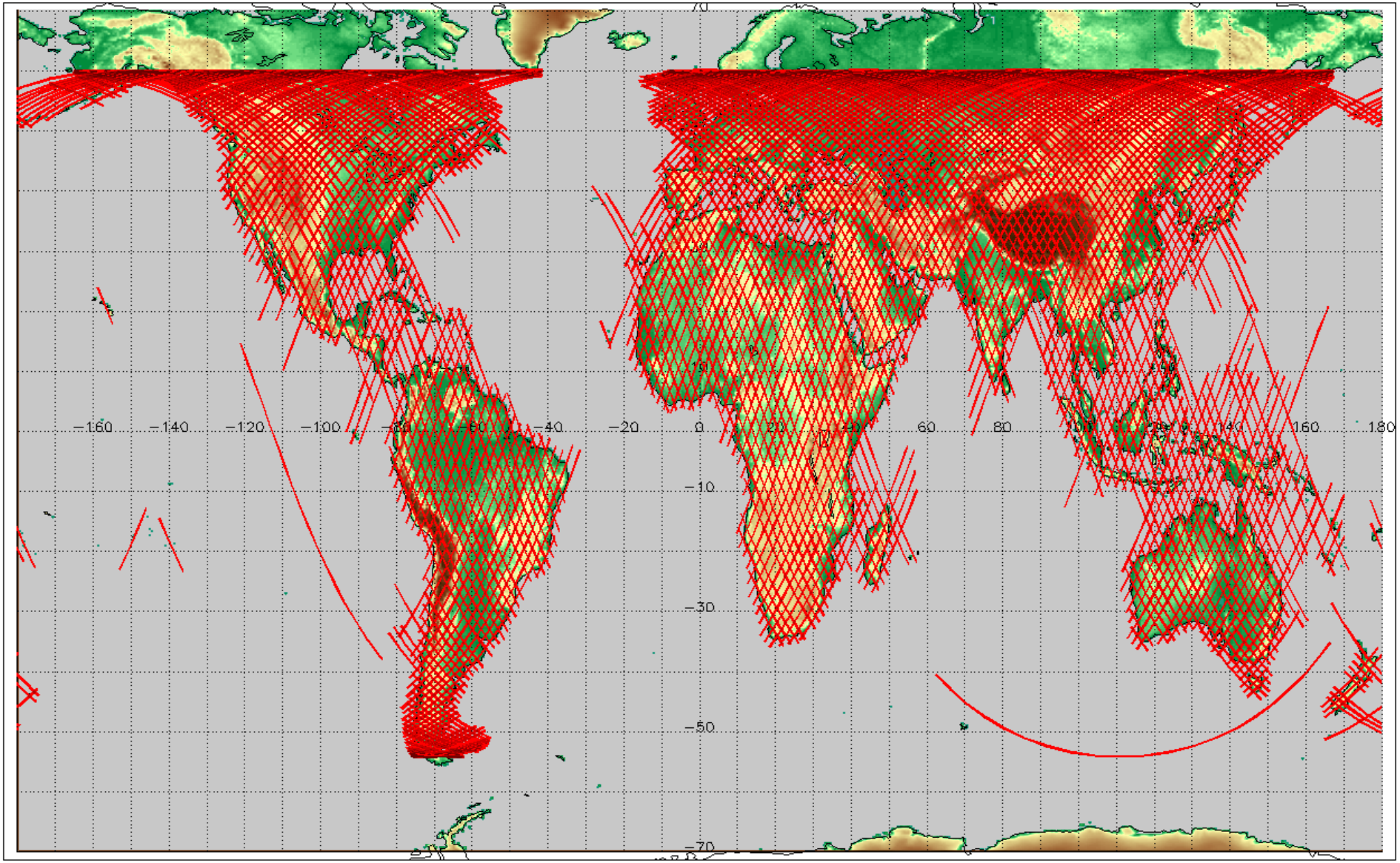


- **SIR-A (1981)**
- **SIR-B (1984)**
- **SIR-C/X-SAR (1994)**
- **SRTM (2000)**



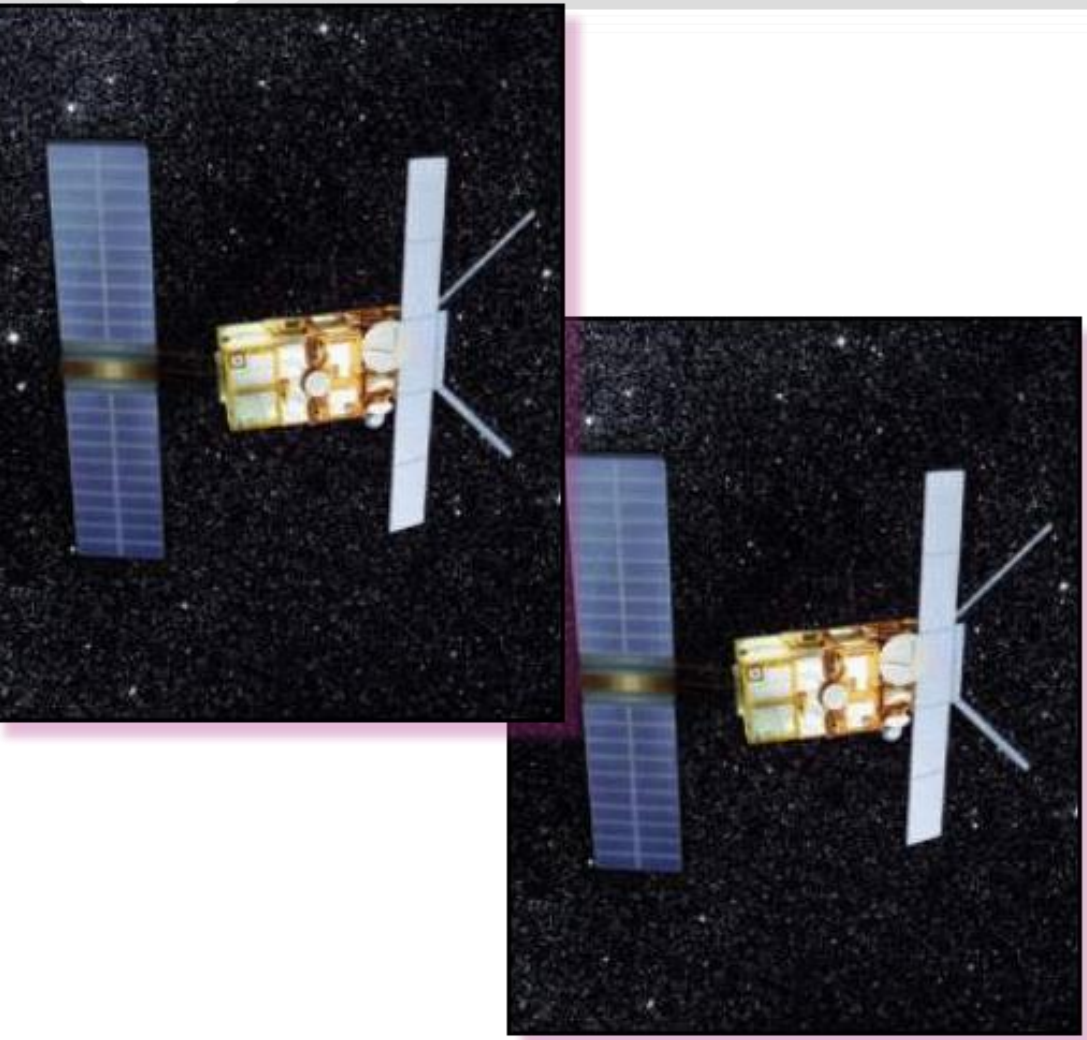

S99E5546 2000/02/16 23:05:11

X-SAR SRTM Coverage : 64 Mio km² of land



Overlaps: 1x 2x 3x or more
D:\mpuser\x\PLOTS\post_mission_cov_02.gif created 10-MAR-2000 12:34 GMT
G/T: 0/11:45:00.0 to 9/18:10:00.0

The „Twin Mission“



- Height: 785 km
- Incidence angle: 23°
- C-band, VV-Polarisation
- Swath width: 100 km
- ERS-1 operated 1991-2000
- ERS-2 operated1995-2011
- Repeat pass cycle: 35 days
- ERS-1/2 ”Tandem mission”
- 1 day interval between passes

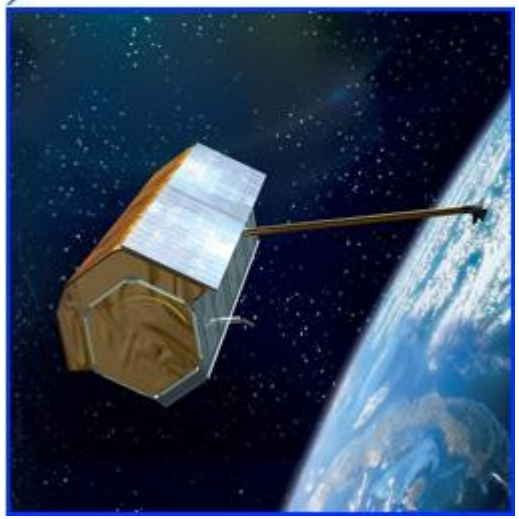
→ Repeat pass interferometry

The ENVISAT Mission:

Polarimetry! Resolution!

PALSAR
L-band

+



Fine Resolution Mode
8.0-60.0 deg.
HH or VV / HH+HV or VV+VH
7.0-44.3m / 14.0-88.6m
40-70km / 40-70km

ScanSAR Mode
18.0-43.0 deg.
HH or VV / 100m / 250-350km

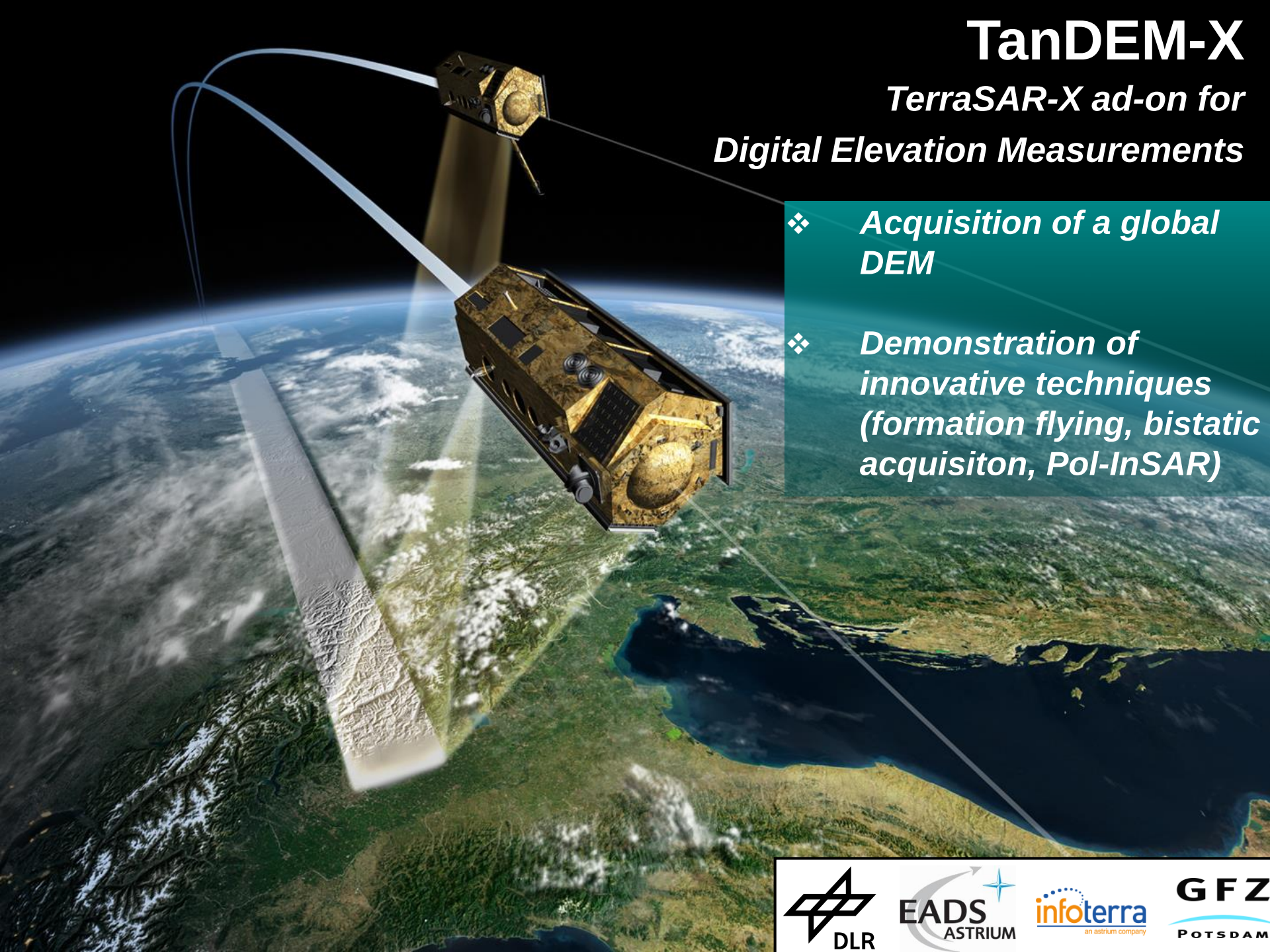
Polarimetric Mode
8.0-30.0 deg.
HH + HV + VH + VV
24.1-88.6m / 20-60km

Standard Imaging Mode

	Spotlight	StripMap	ScanSAR
Geometric Resolution	1 m	3 m	16 m
Image Swath Width	10 km	30 km	100 km
Maximum Length per Image	5 km	3000 km	3000 km

TanDEM-X

TerraSAR-X ad-on for Digital Elevation Measurements

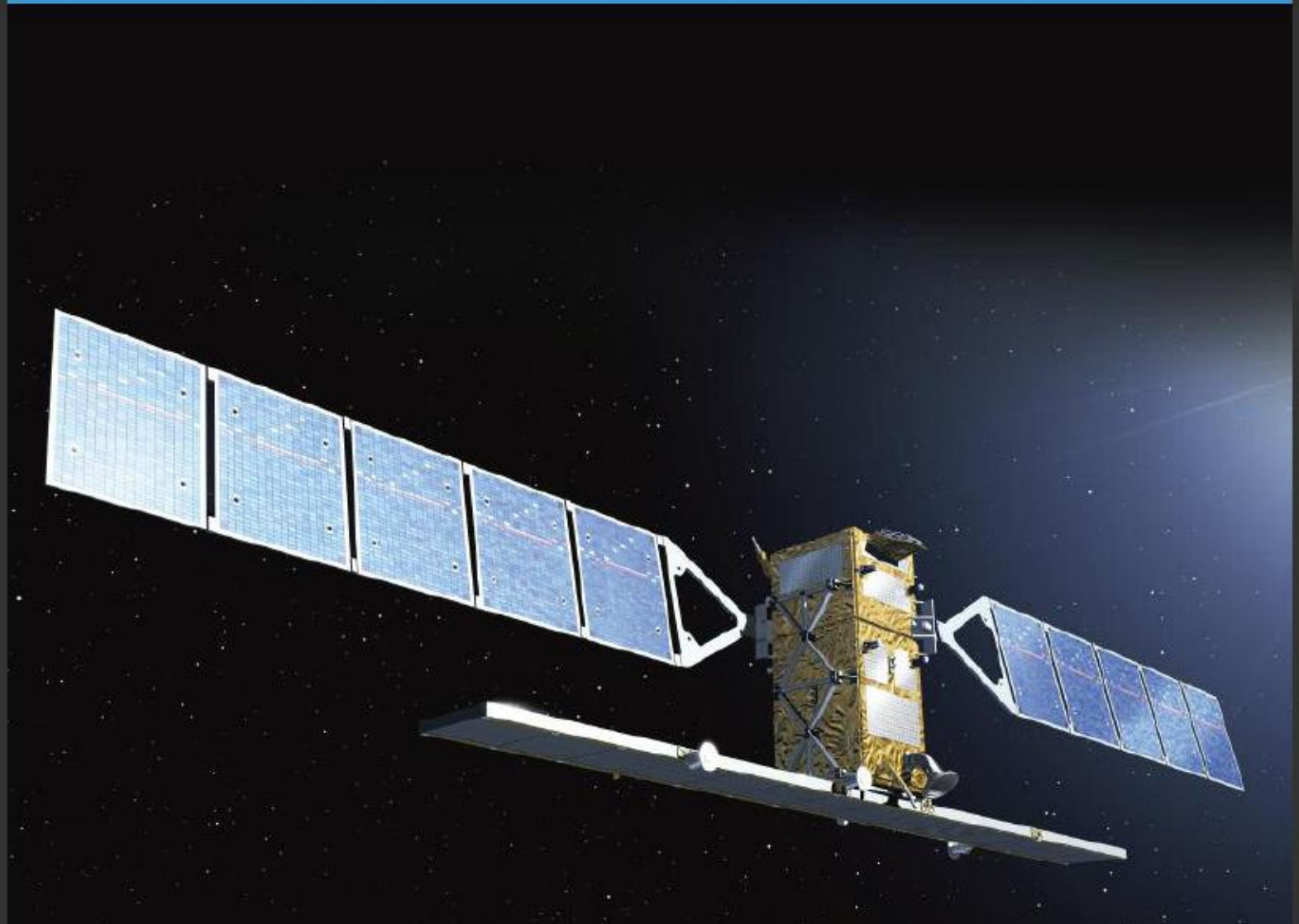


- ***Acquisition of a global DEM***
- ***Demonstration of innovative techniques (formation flying, bistatic acquisiton, Pol-InSAR)***

DLR EADS ASTRIUM infoterra an astrium company GFZ POTSDAM

sentinel-1

→ GMES RADAR MISSION FOR LAND AND OCEAN SERVICES



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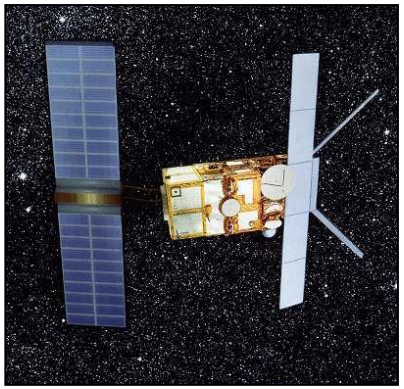
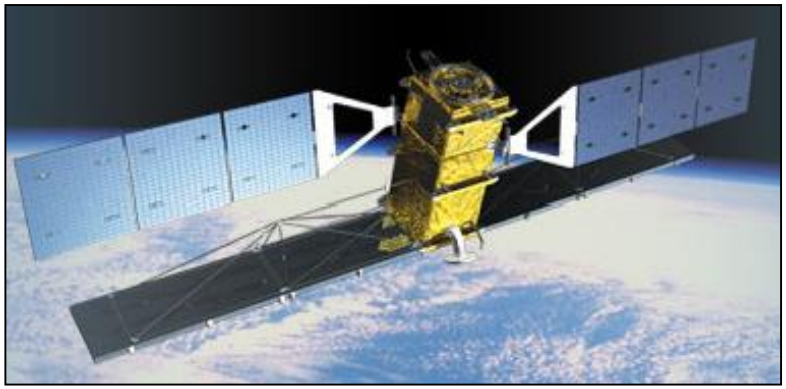
Active Radar Remote Sensing

Examples of satellite based radar sensors



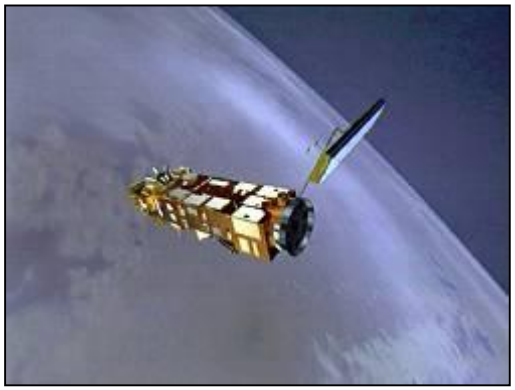
ERS-1, 2

JERS-1

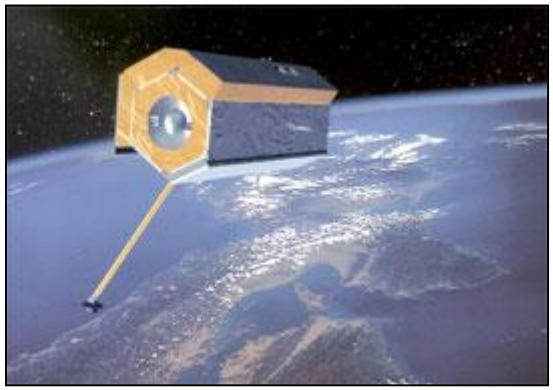


Radarsat 1, 2

ALOS (PALSAR)



Envisat (ASAR)



TerraSAR-X

Summary

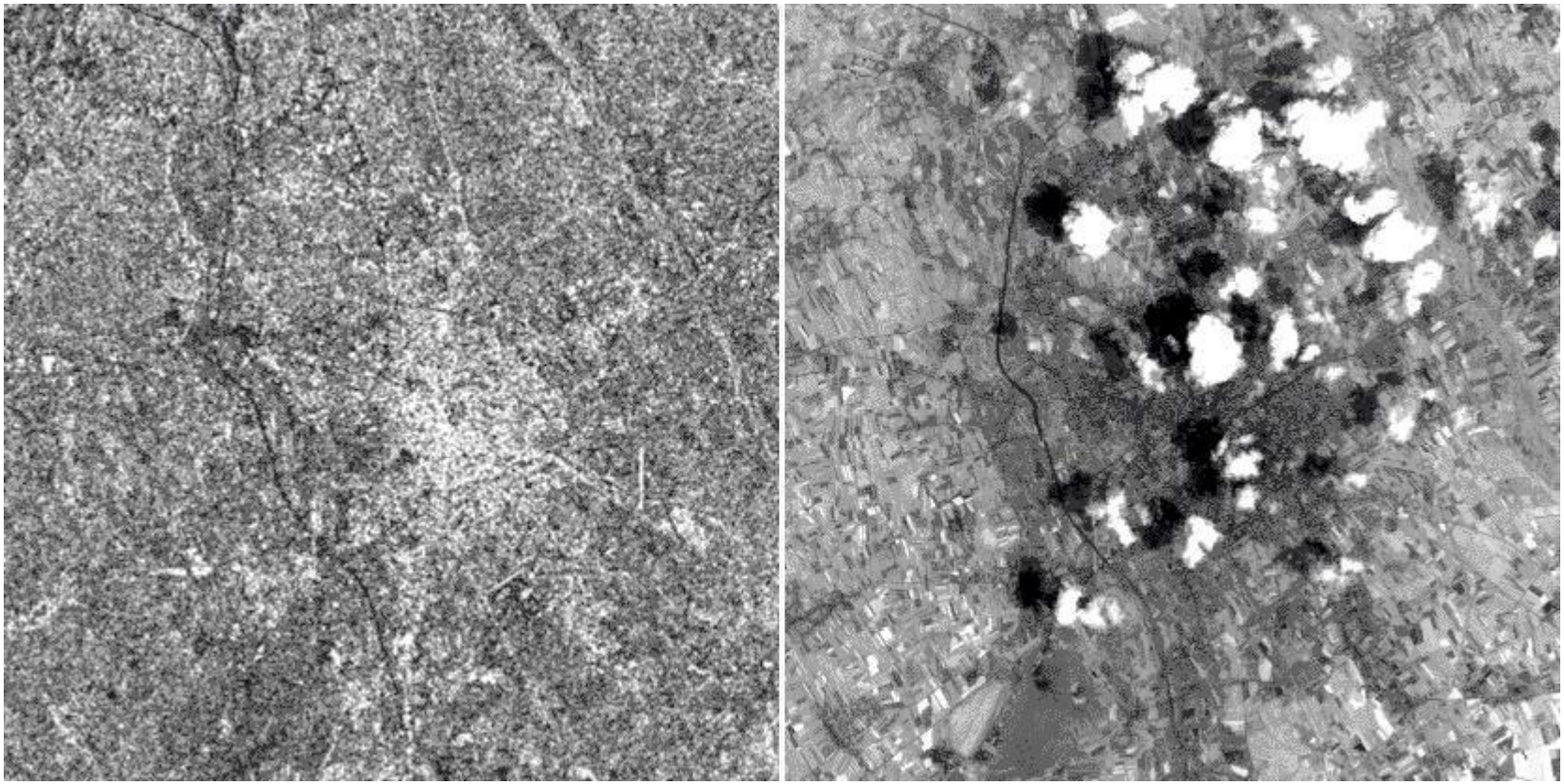
Applications of radar remote sensing systems

SAR's ability to pass relatively unaffected through clouds, illuminate the Earth's surface with its own signals, and precisely measure distances makes it especially useful for the following applications:

- Sea ice monitoring
- Cartography
- Surface deformation detection
- Glacier monitoring
- Crop production forecasting
- Forest cover mapping
- Ocean wave spectra
- Urban planning
- Coastal surveillance (erosion)
- Monitoring disasters such as forest fires, floods, volcanic eruptions, and oil spills
- Soil Moisture
- Water bodies
- Snow features
- …

Active Radar Remote Sensing

Advantages / Example all weather



These images were acquired over the city of Udine (I), by ERS-1 on the 4th of July 1993 at 9.59 a.m. (GMT) and Landsat-5 on the same date at 9.14 a.m. (GMT) respectively. The clouds that are clearly visible in the optical image, are not appearing in the SAR image.

SIR-C/XSAR OBSERVATIONS OF RAIN STORMS OVER BRAZIL

SITE NAME: SENA MADUREIRA, BRAZIL
DATA TAKE ID: 103.60
LAT/LONG: 9°/13°1' S; 68°15.5' W

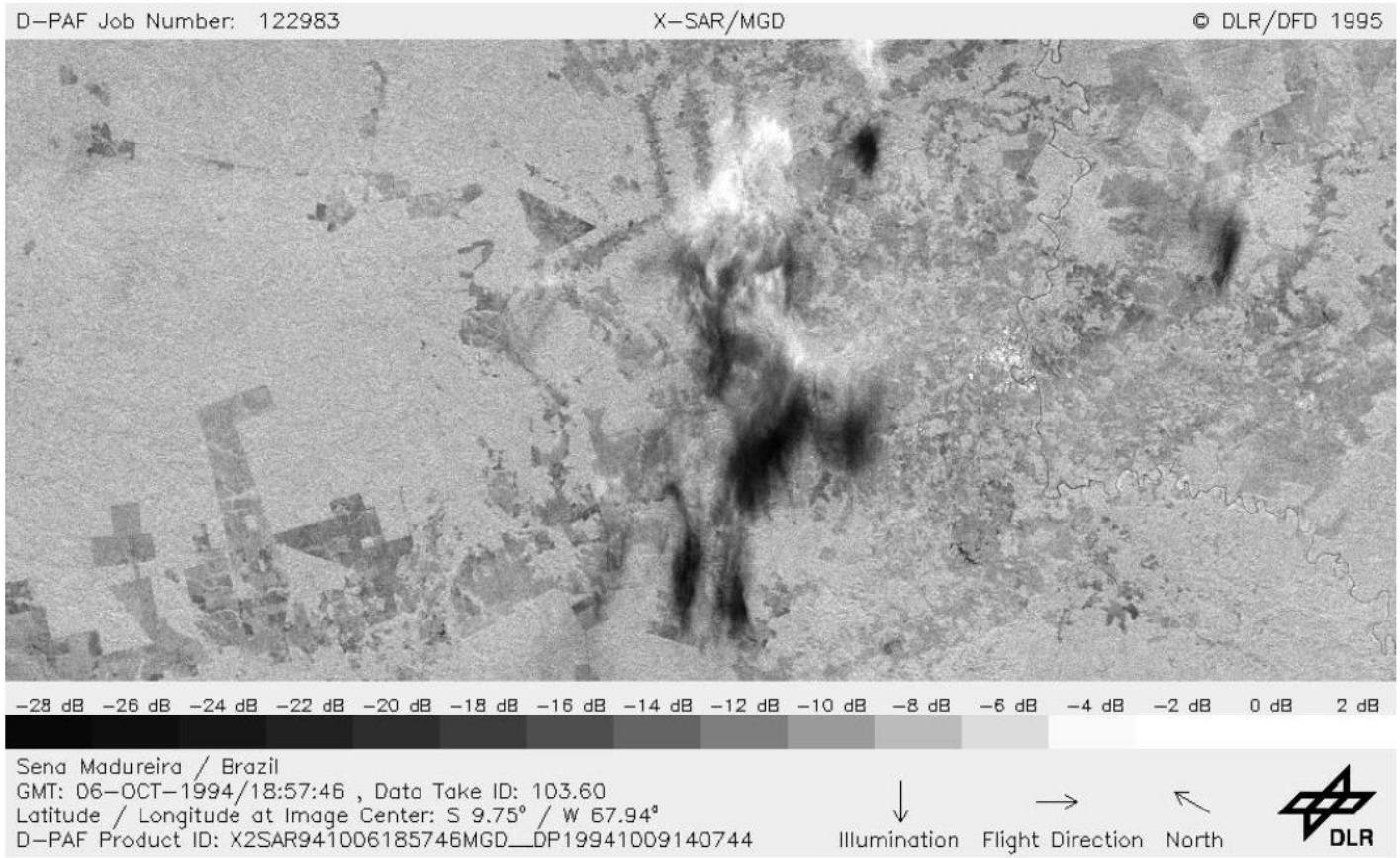
L-BAND C-BAND X-BAND

- UTILIZE PATH-INTEGRATED ABSORPTION AT MULTIPLE FREQUENCIES FOR RAIN-PARAMETER RETRIEVAL
- PATH-INTEGRATED ABSORPTION DEDUCED FROM COMPARISON OF σ_0 IN AND OUT OF STORM
- WILL ALSO INVESTIGATE ABSORPTION EFFECTS vs. POLARIZATION

ader DC
Anmelden
16 / 46
200%
Freigeben

Heavy Clouds and Rain Cells in X-Band SAR Images

→ Only visible at short wavelengths and extreme conditions



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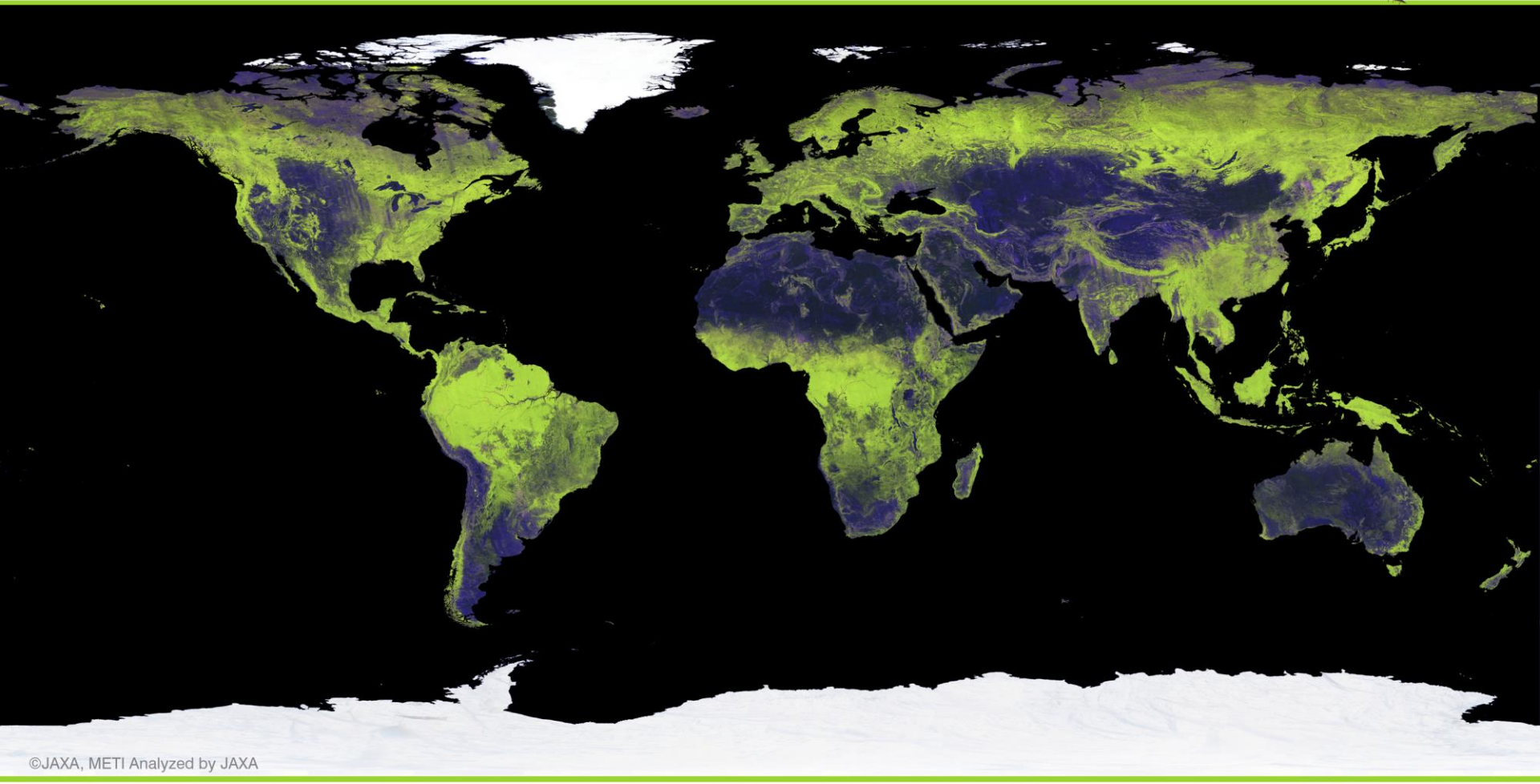
Japan Aerospace Exploration Agency

PALSAR 10m Global Mosaic 2009

ALOS

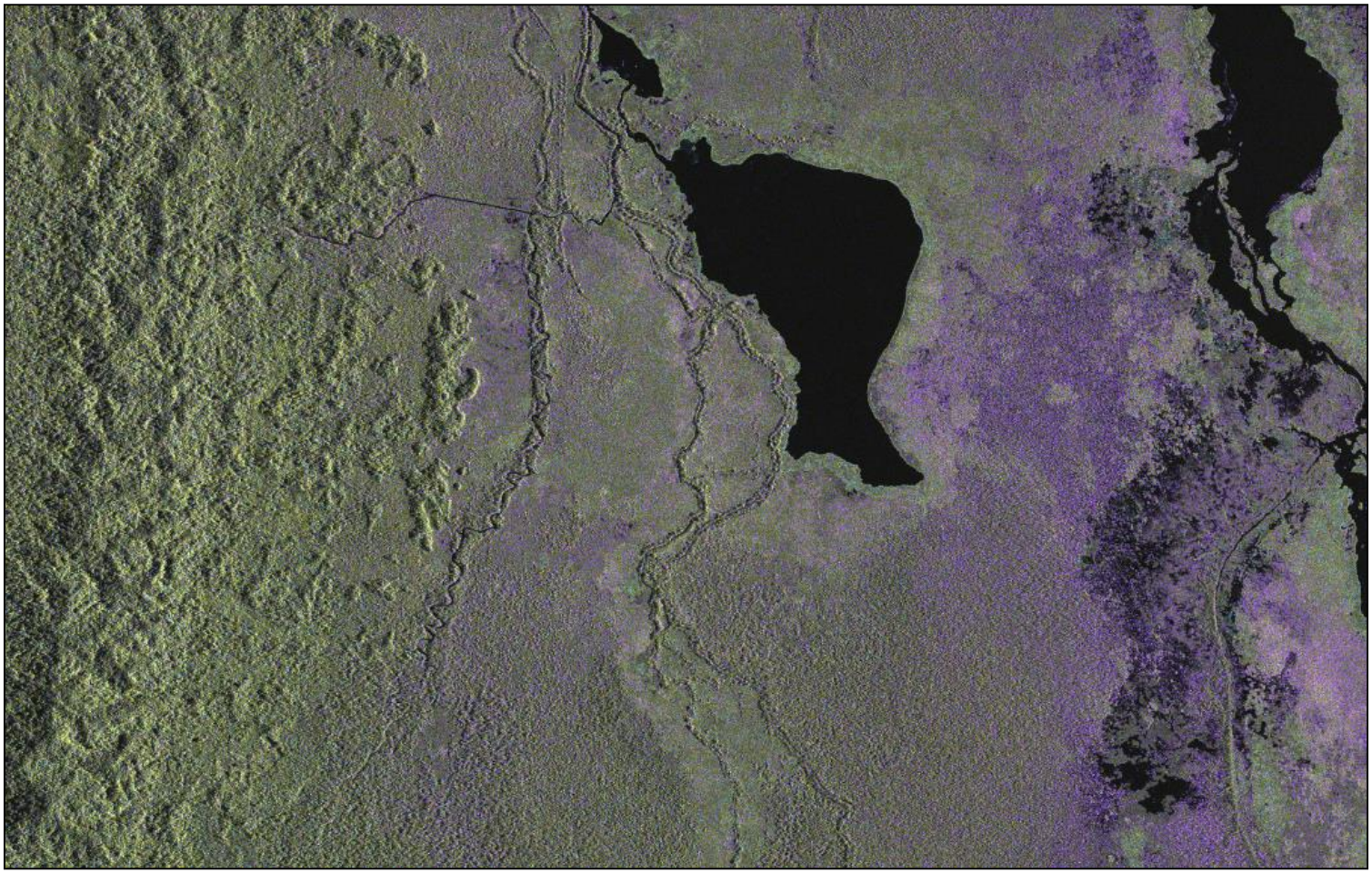


R:HH G:HV B:HH/HV

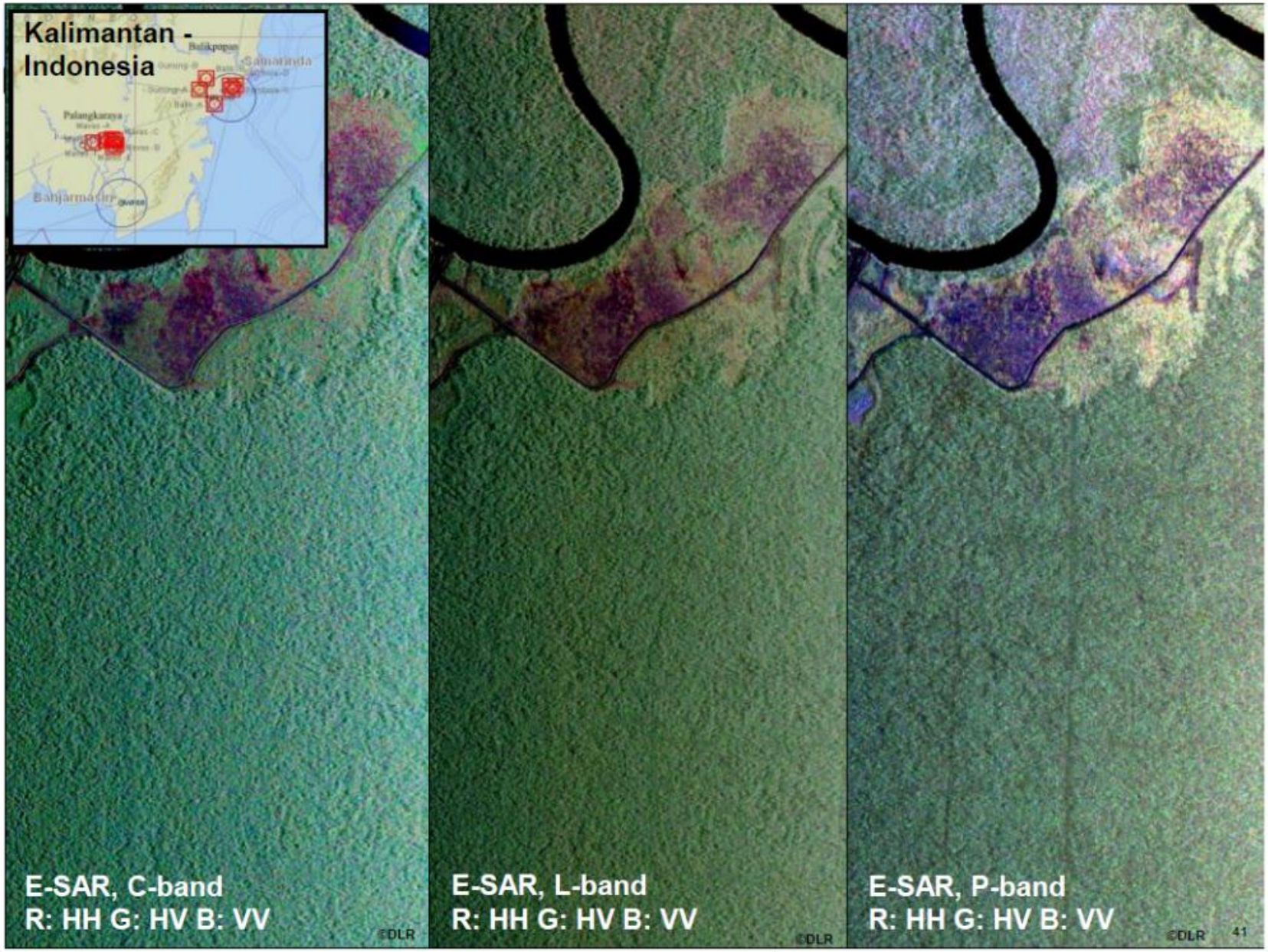
Remote Sensing Education Initiative

Active Radar Remote Sensing

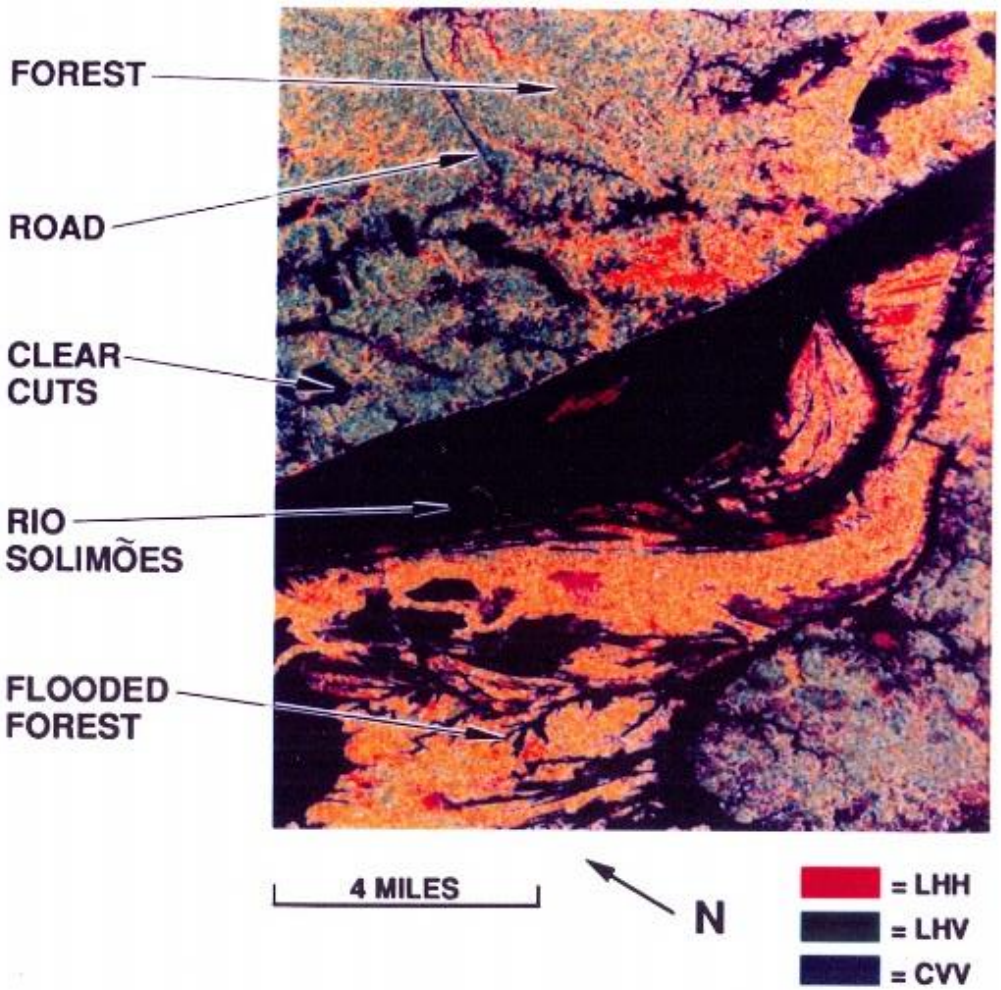
Advantages / Example all weather

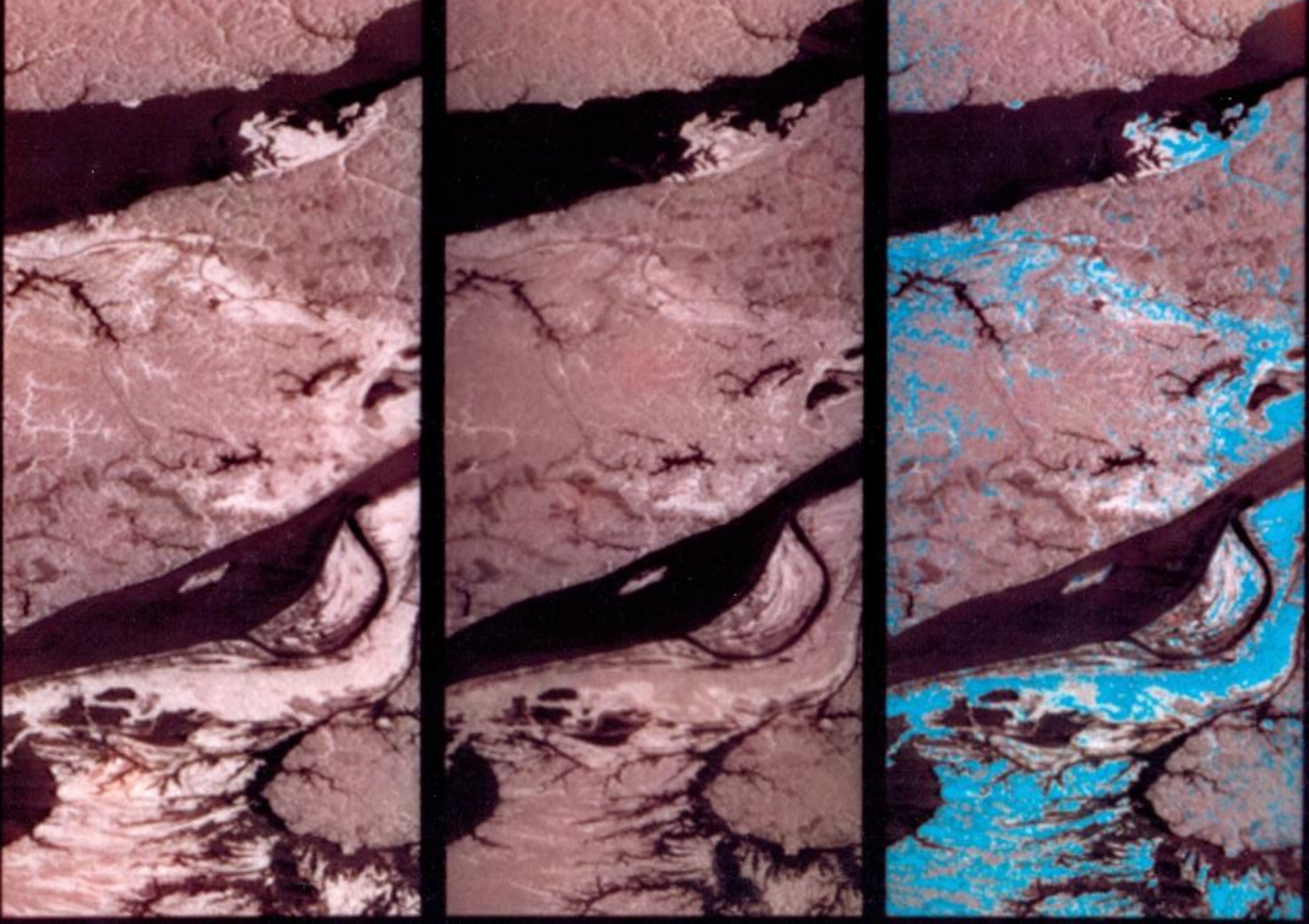


TS-X, Brazil


Kalimantan - Indonesia
Balikpapan
Samarinda
Palangkaraya
Banjarmasin
E-SAR, C-band
R: HH G: HV B: VV
©DLR
E-SAR, L-band
R: HH G: HV B: VV
©DLR
E-SAR, P-band
R: HH G: HV B: VV
©DLR
41

SIR-C/X-SAR
FOREST STUDY SITE – MANAUS, BRAZIL
APRIL 11, 1994 L-BAND FALSE COLOR COMPOSITE





SAR-EDU>Basics>SAR Remote Sensing>An Introduction

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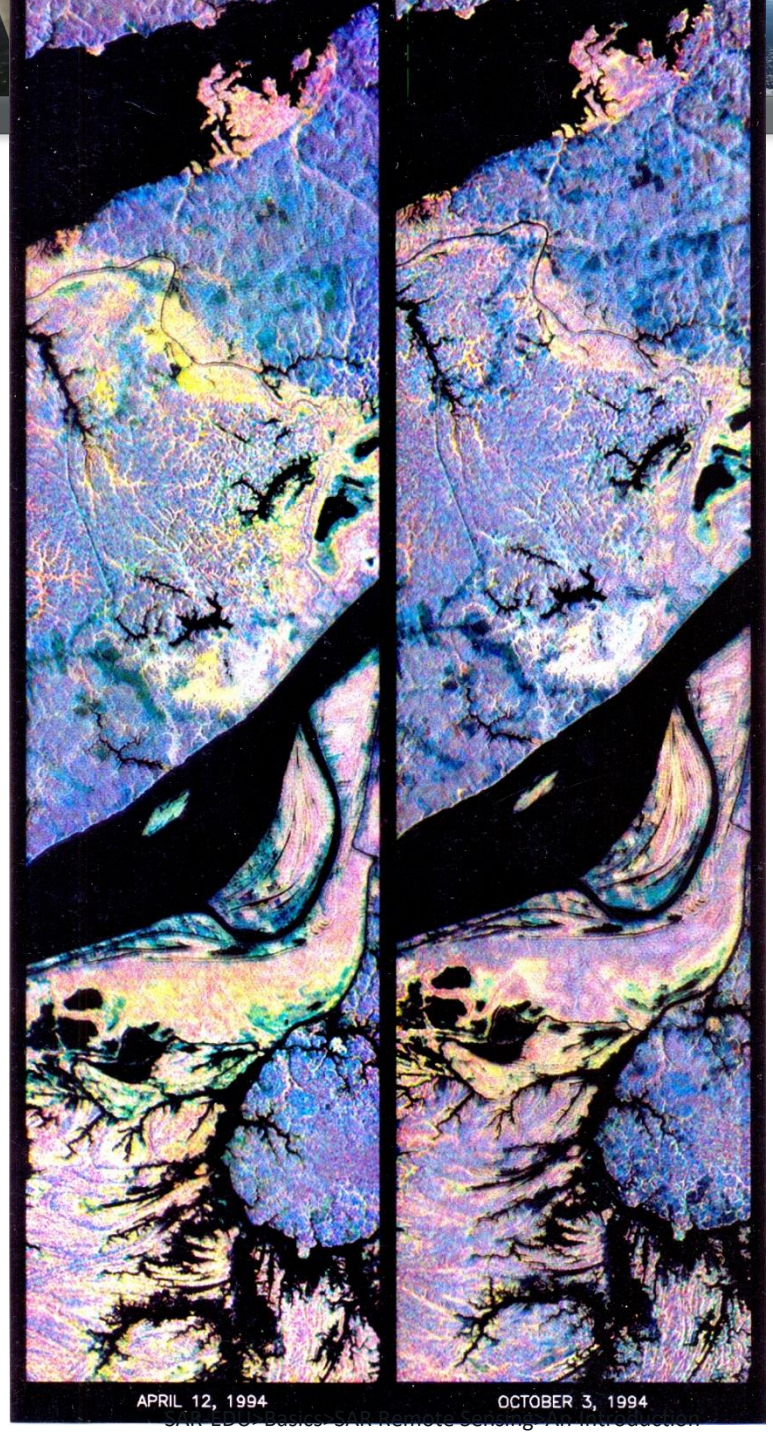


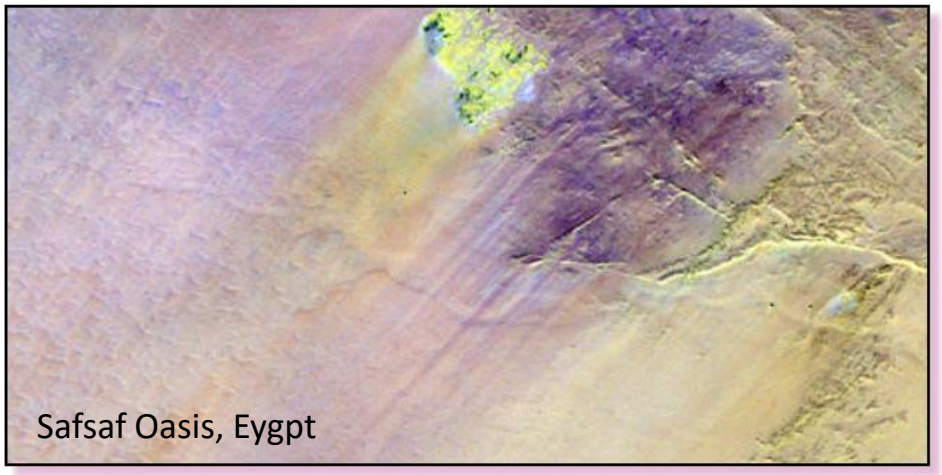
Active Radar Remote Sensing

Advantages / Example dielecric properties

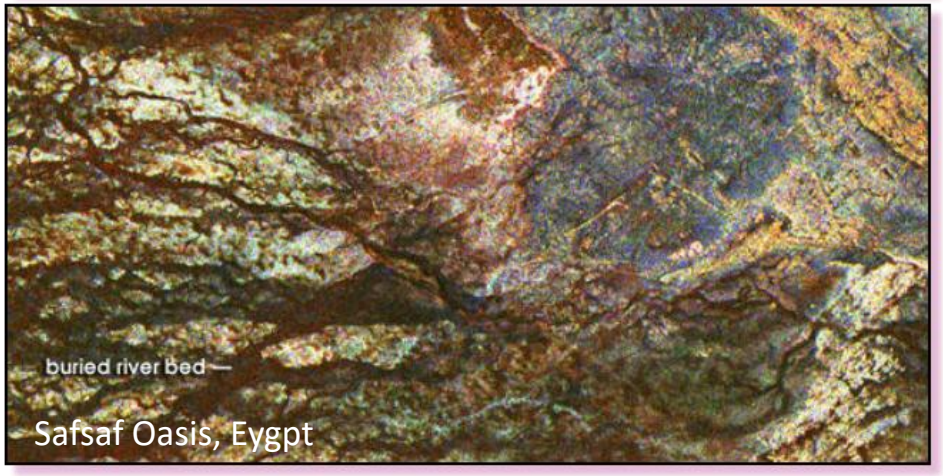
Irrgated fields:
Higher backscatter

Active Radar Remote Sensing

Advantages / Example subsurface penetration



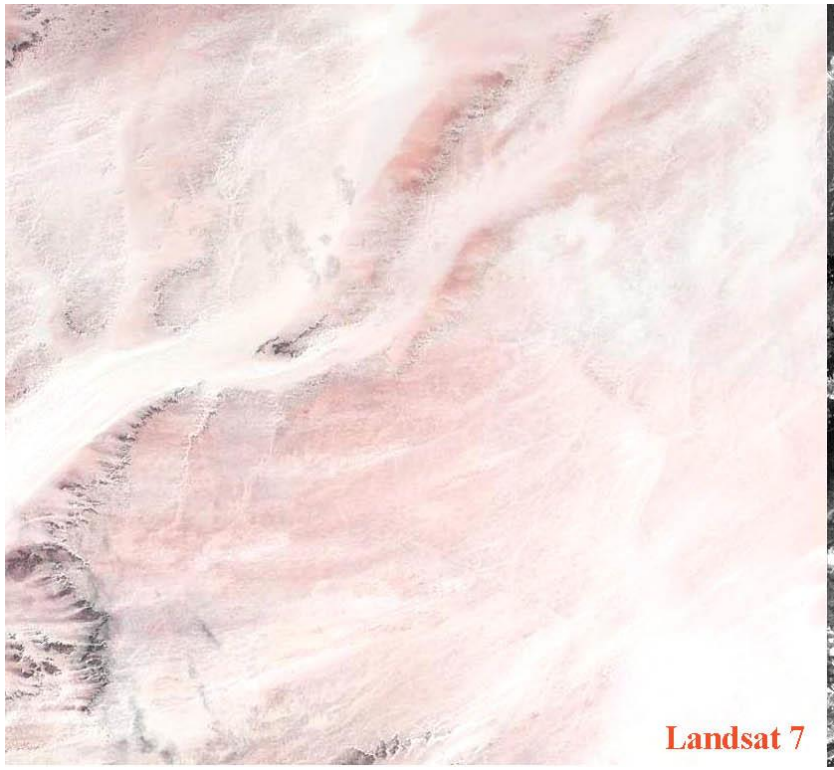
Landsat Thematic Mapper
shows the desert's surface

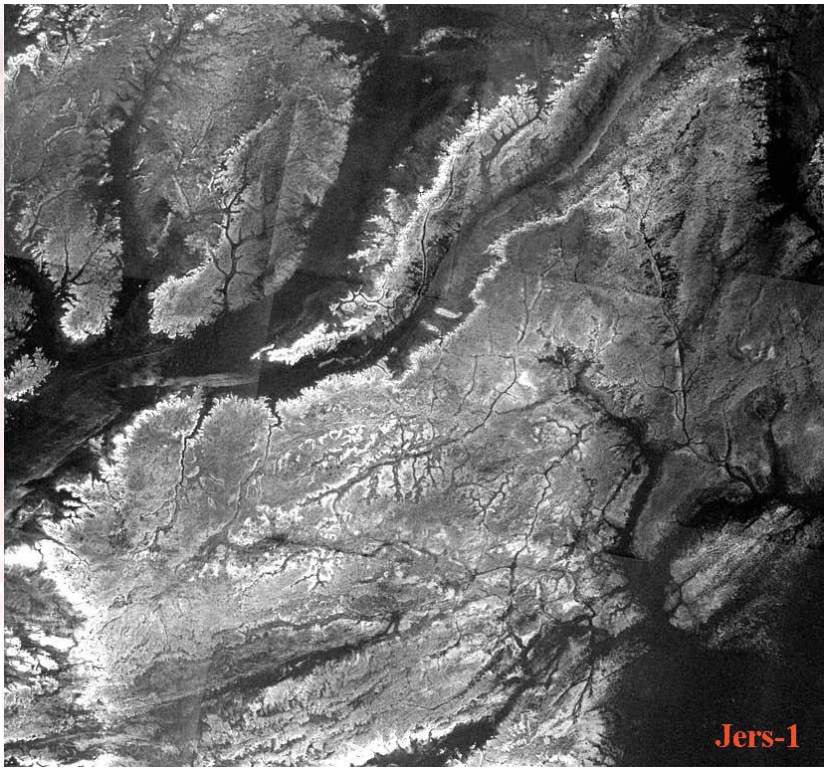


SIR-C/X-SAR
shows what the landscape might look like if stripped bare of sand

Active Radar Remote Sensing

Advantages / Example subsurface penetration





Summary

Classification of remote sensing systems

Recording Platform	Satellite/Shuttle		Aircraft/Balloon		Stationary	
Recording Mode	Passive (Electrooptical, Thermal Infrared, Thermal Microwave)			Active (Laser, Radar)		
Recording Medium	Analog (Camera, Video)			Digital (Whiskbroom, Line Array, 2D CCD)		
Spectral Coverage	Visible/Ultraviolet	Reflected Infrared		Thermal Infrared	Microwave	
Spectral Resolution	Panchromatic 1 Band	Multispectral 2 – 20 Bands		Hyperspectral 20 – 250 Bands	Ultraspectral > 250 Bands	
Radiometric Resolution	Very High (> 12 bit)	High (8-12 bit)		Medium (6 – 8 bit)	Low (< 6 bit)	
Spatial Ground Resolution	Ultra High < 1m	Very High 1 – 4 m	High 4 – 10 m	Medium 10 – 50 m	Low 50 – 250 m	Very Low > 250 m

(Ehlers 2002:11)

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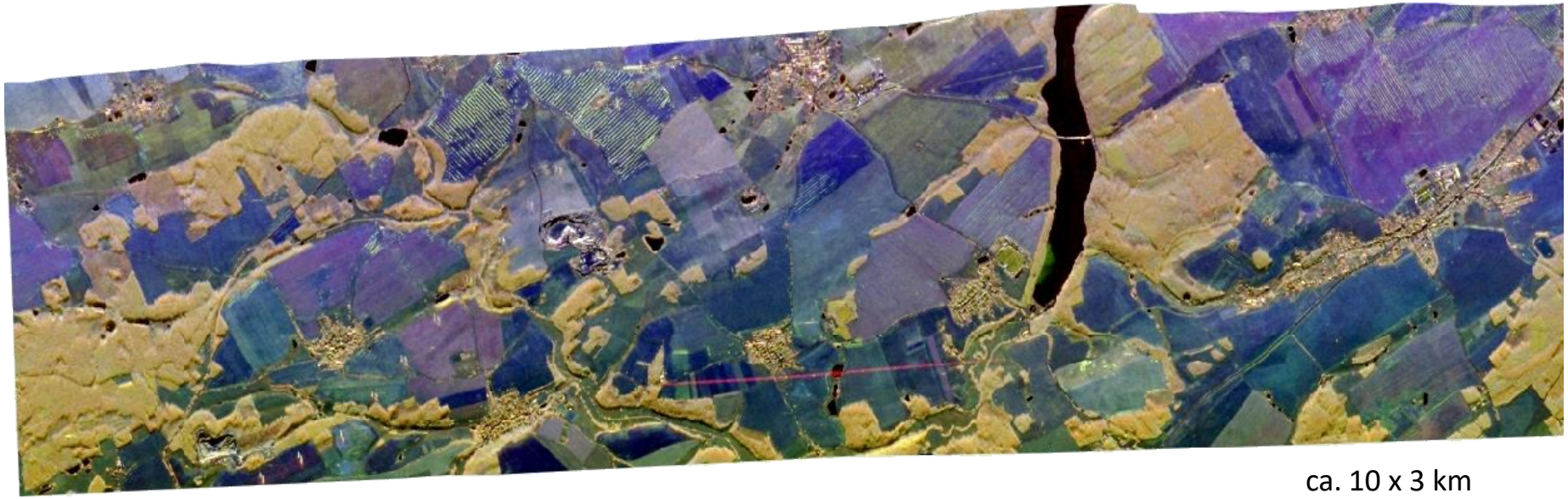
Applications



ca. 10 x 3 km

E-SAR (L-HH, L-HV, X-VV), Zeulenroda, Germany

SAREDU Remote Sensing Education Initiative

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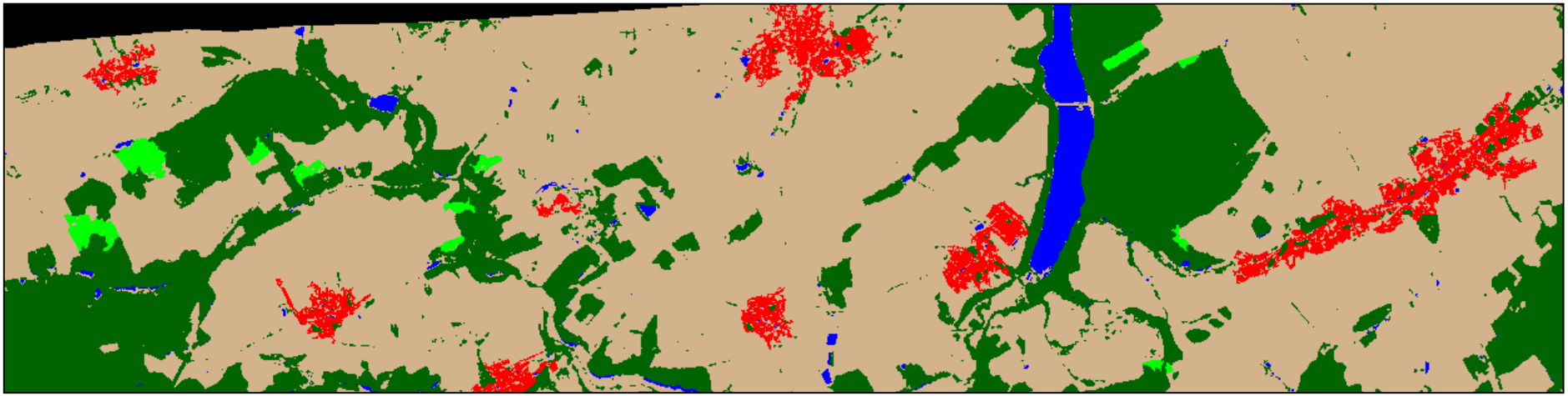
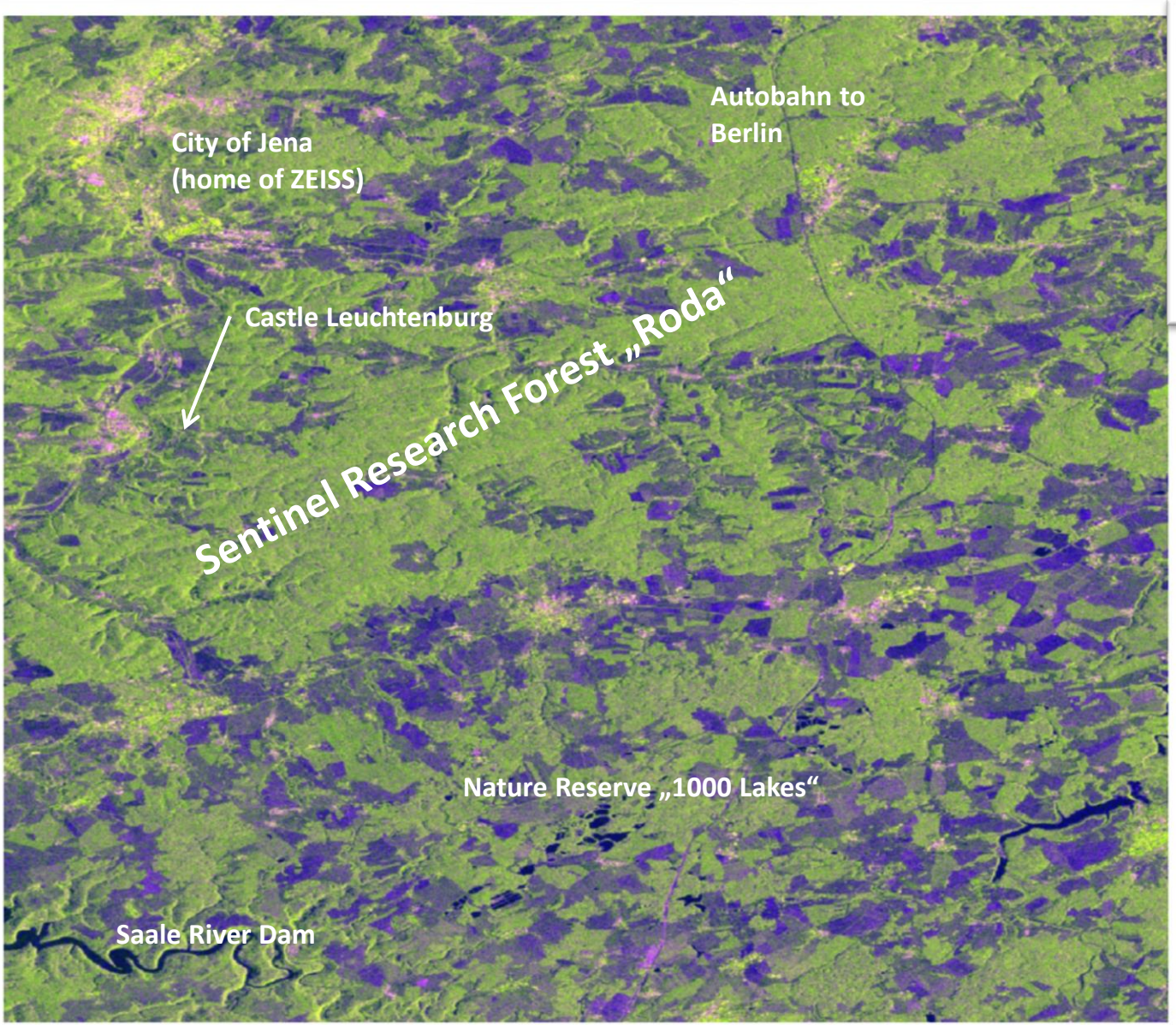
Applications



Classification of Land Cover

FIRST DEMONSTRATION OF LAND APPLICATIONS



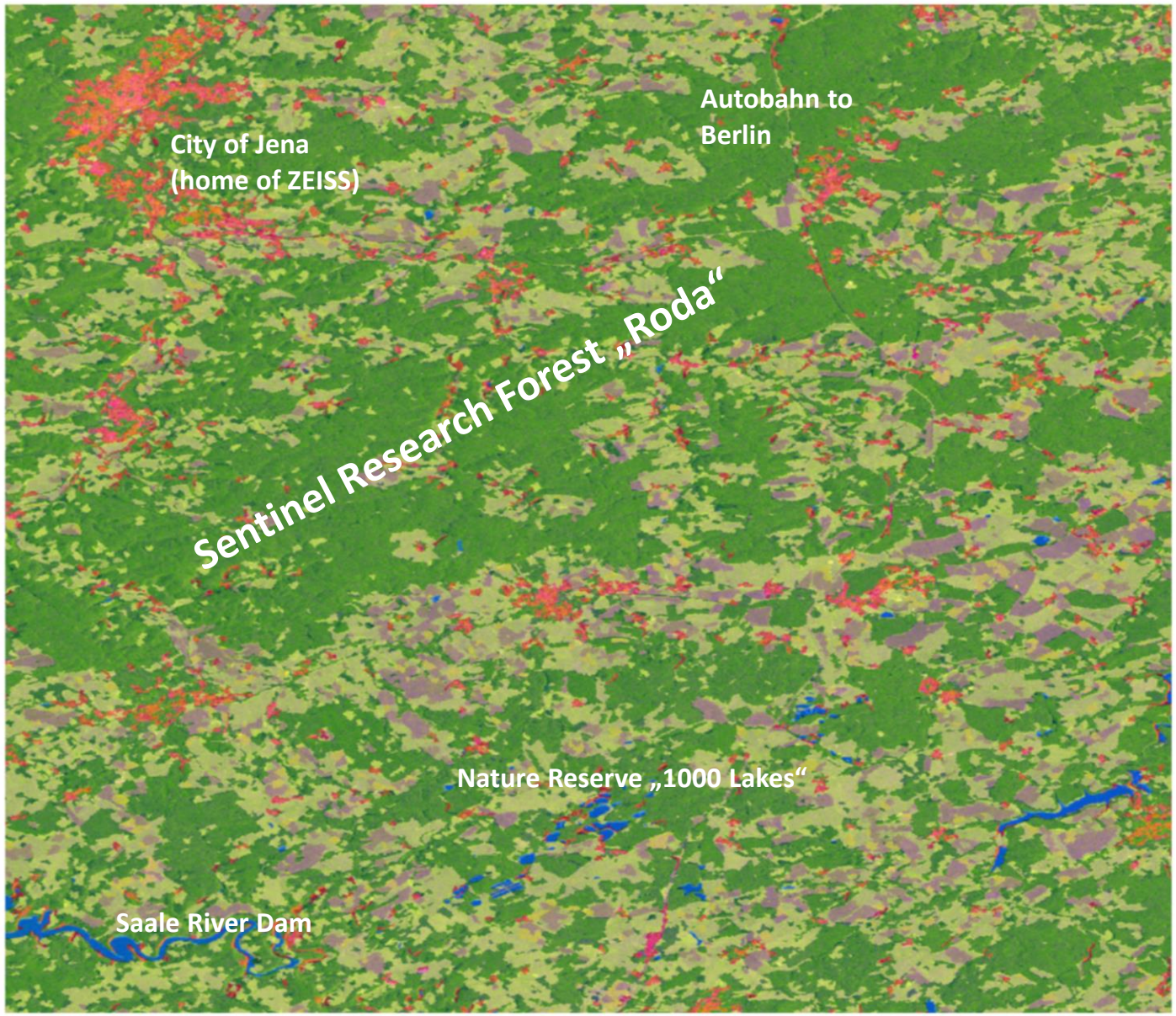
Castle Leuchtenburg
(http://burgerbe.files.wordpress.com/)

Location: Thuringia, Central Germany

Colour Composite
HH – HV – HH/HV

Acquisition Date: 26-April-2014

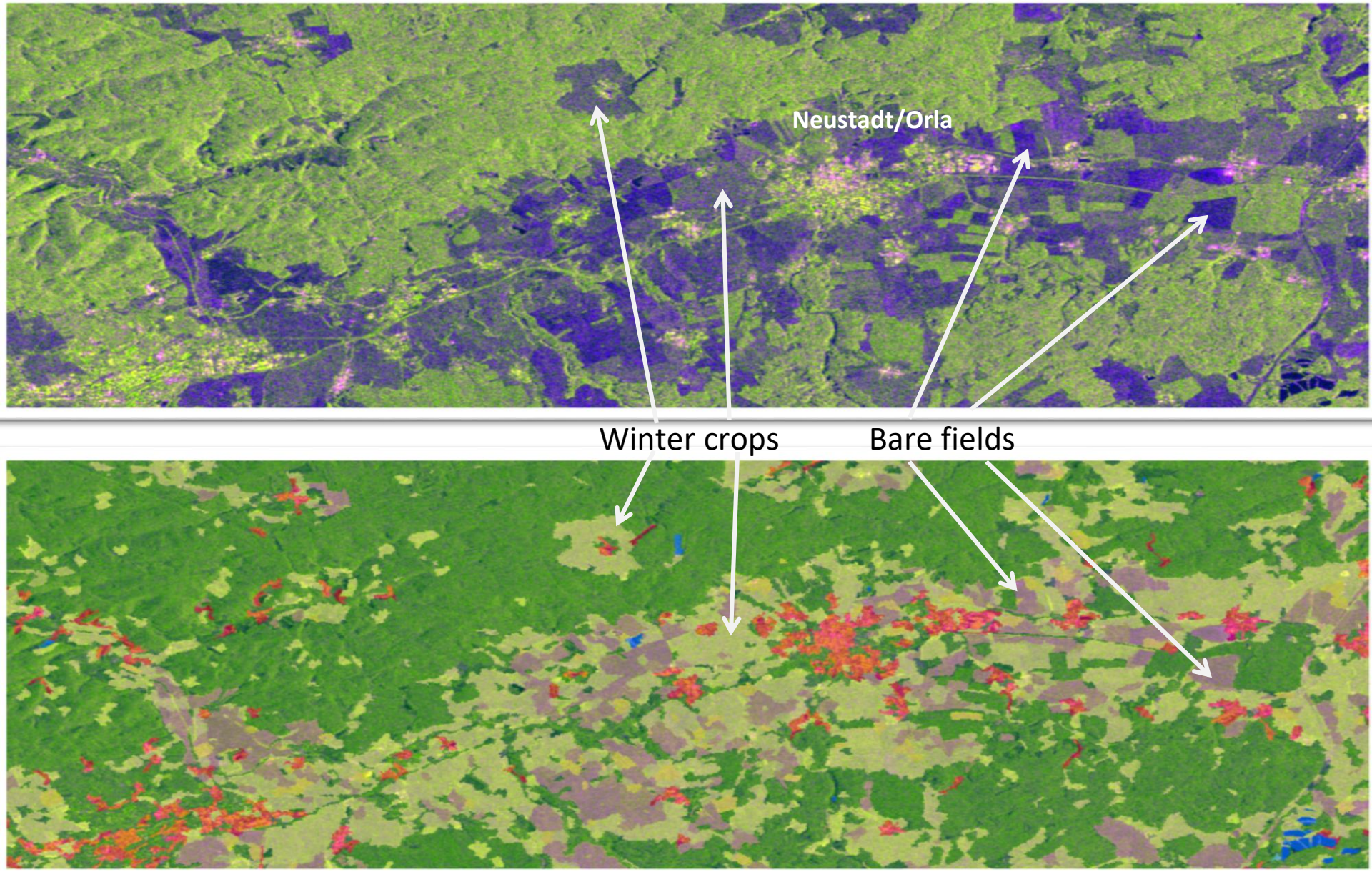
FIRST DEMONSTRATION OF LAND APPLICATIONS



Class. Method:
Random Forest

Classes:
Forest
Water
Urban
Winter crops
Bare fields

FIRST DEMONSTRATION OF LAND APPLICATIONS



CONTINUATION OF UNIQUE TIME SERIES SINCE 1991 with **HIGHER SPATIAL AND TEMPORAL RESOLUTION** and **INTERFEROMETRIC CAPABILITIES (S1A + S1B!)** for

- **land surface structural components:**
  - land cover as functional vegetation types
  - crop status from phenology
  - forest structural monitoring

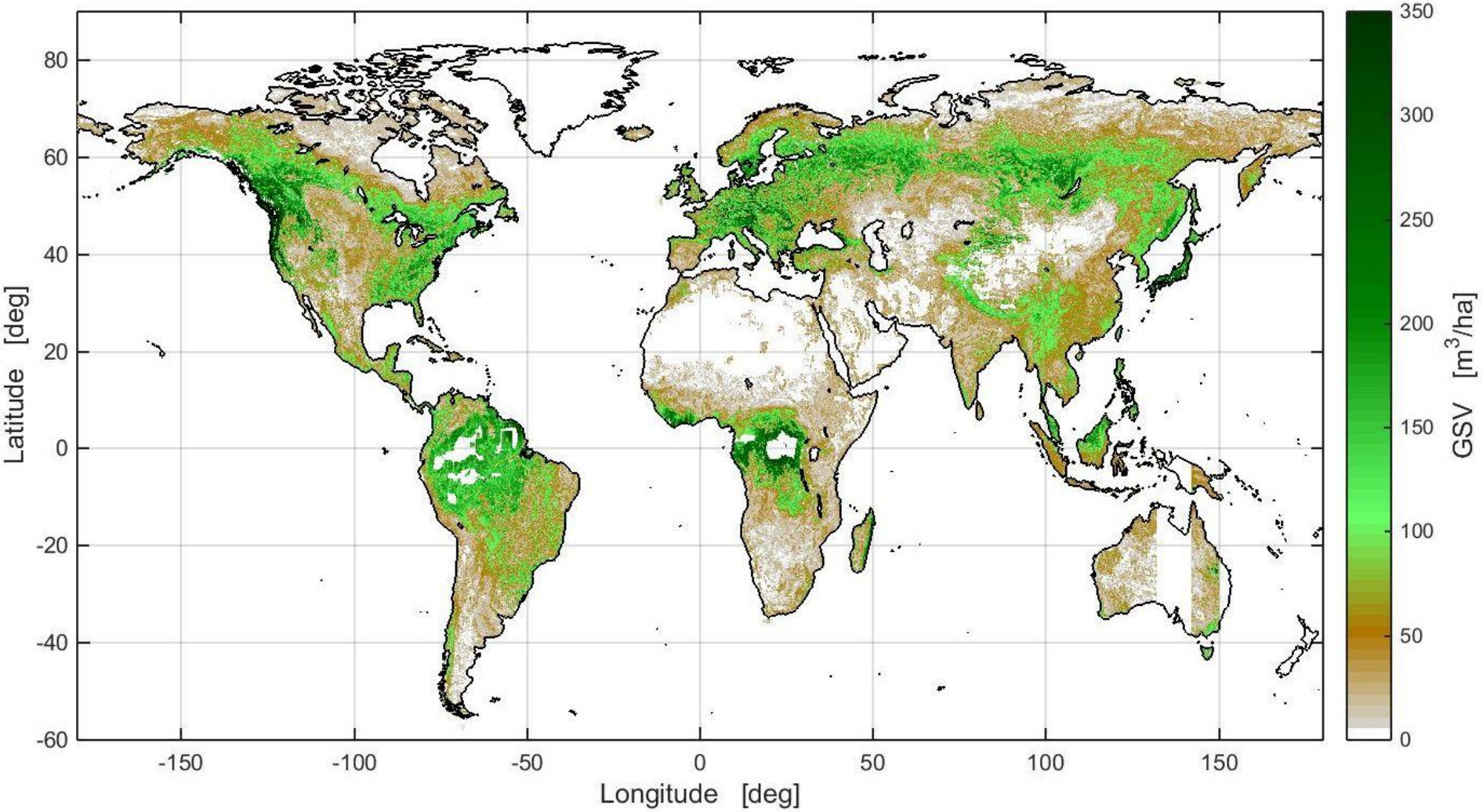
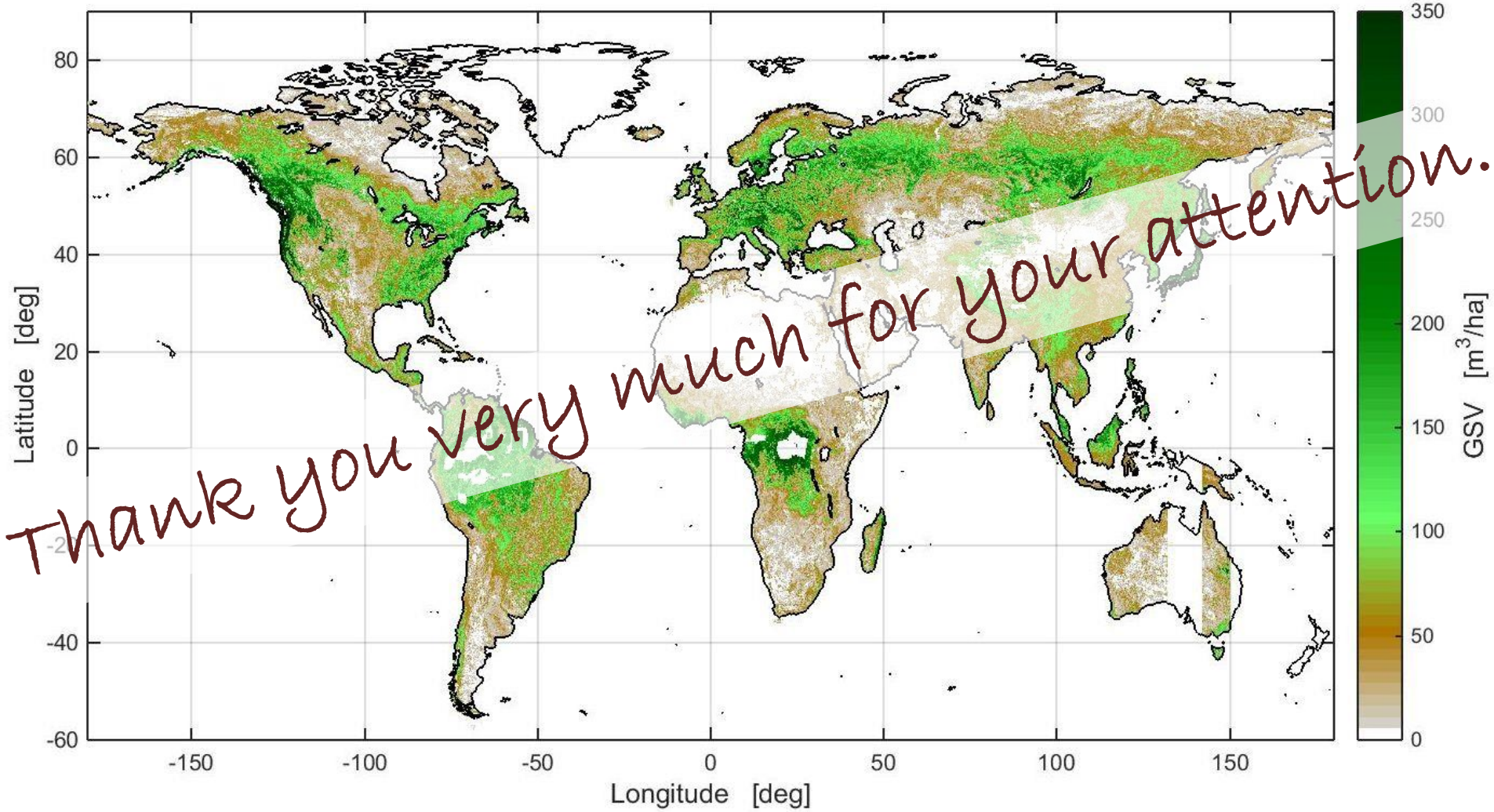
and from these ***above ground carbon storage***
plus ***anthropogenic impacts (urban, infrastructure)***

and for

- **the Earth's hydrological parameters:**
  - snow characteristics
  - surface soil moisture
  - freeze/thaw status
  - water bodies

All above are essential components in Global Change Research.

A global GSV-map for the year 2010



ENJOY SAR-EDU!