Remote Sensing for detecting plastics

UNIVERSITY OF LISBON
INTERDISCIPLINARY STUDIES
ON SUSTAINABLE ENVIRONMENT AND SEAS

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Overview

- Fundamentals
- Sensors
- Platforms
- Data characteristics
- Applications

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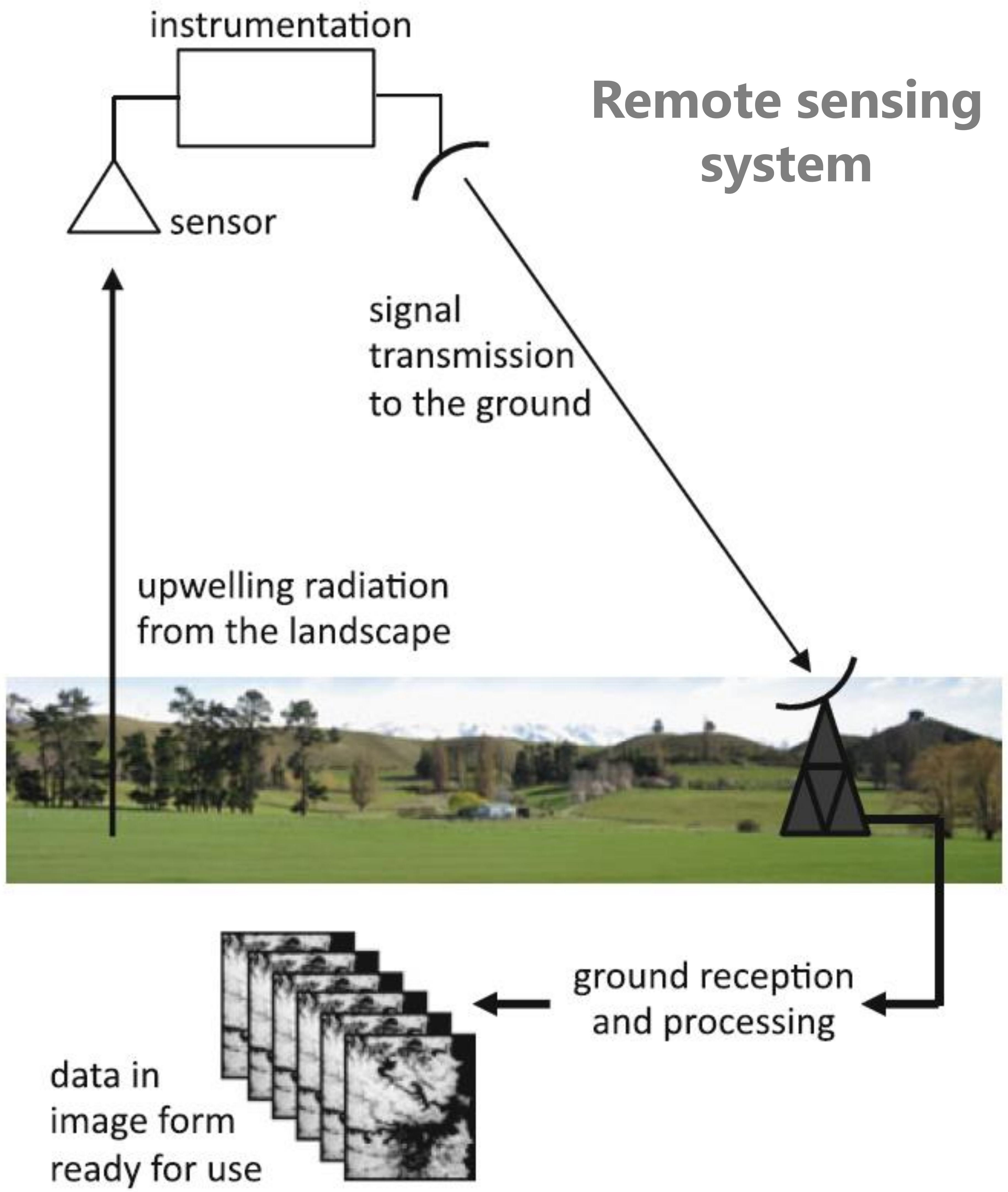
What is remote sensing?

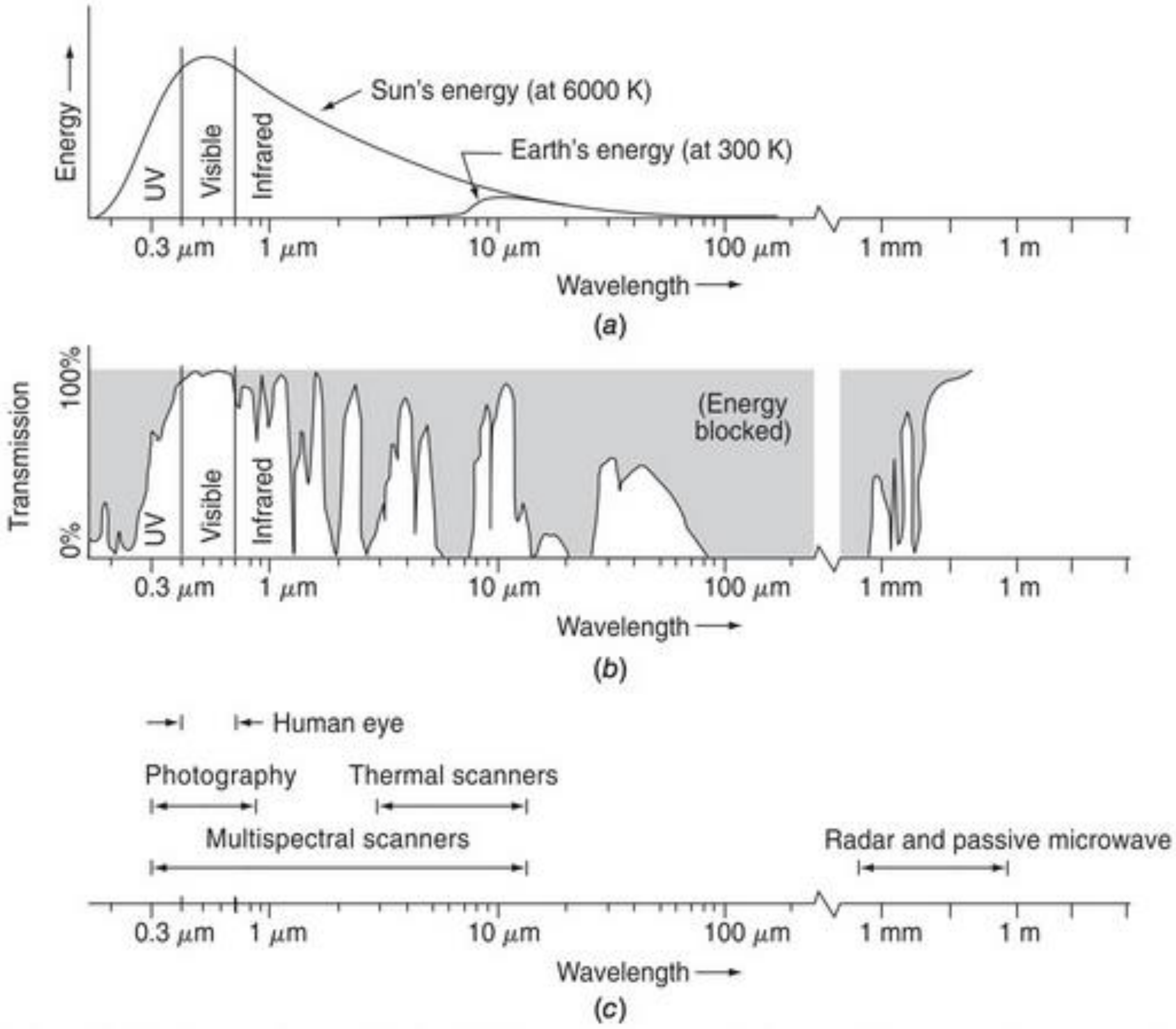
Remote sensing is the science that allows describing an object, surface or phenomena through the analysis of data acquired with a sensor without any physical contact between them.

Remote sensing system



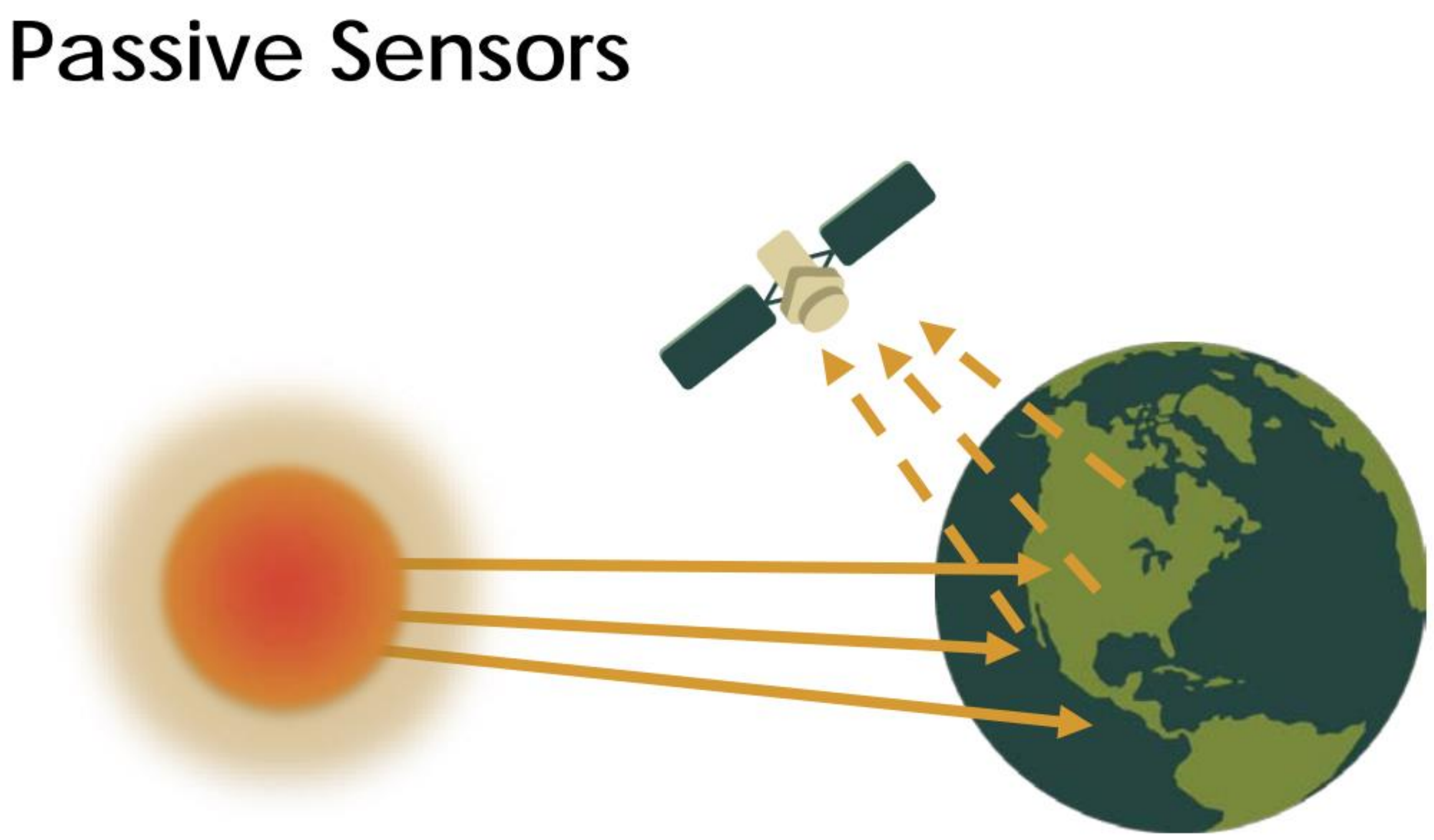
Richards, 2013

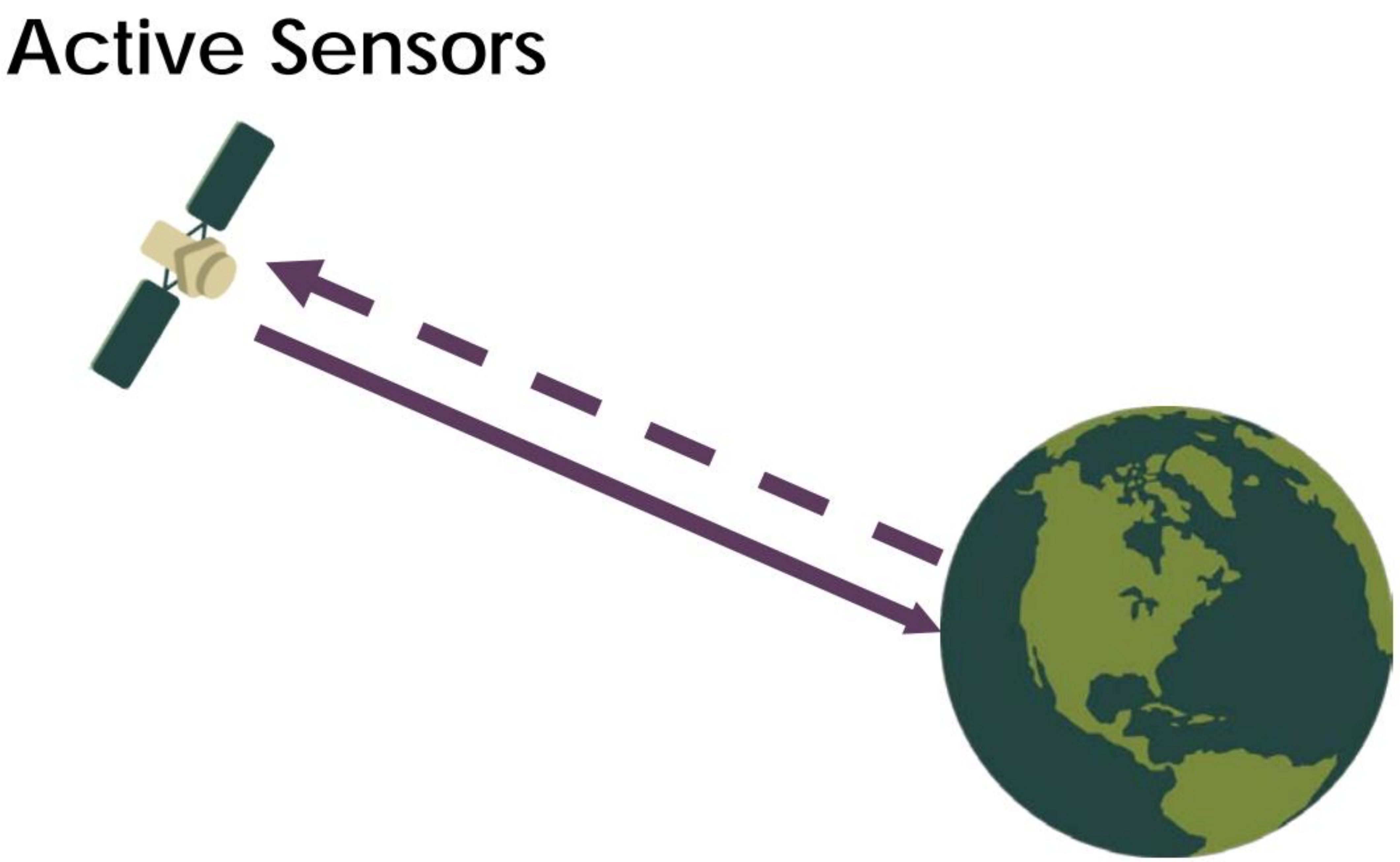
Energy and atmospheric transmission



Lillesand et al, 2015

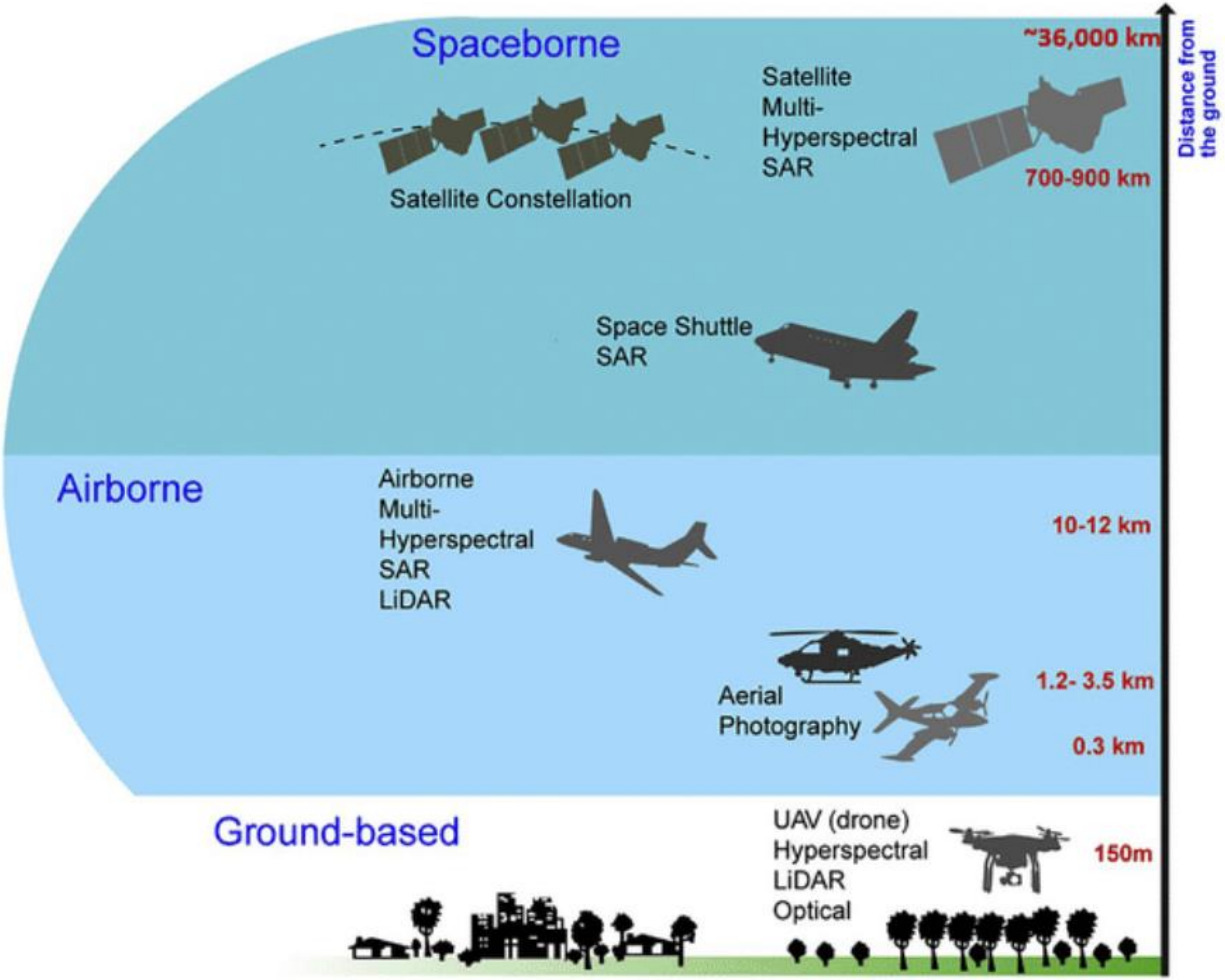
passive sensor versus active sensor





NASA Applied Remote Sensing Training Program
https://earthdata.nasa.gov/learn/backgrounders/remote-sensing

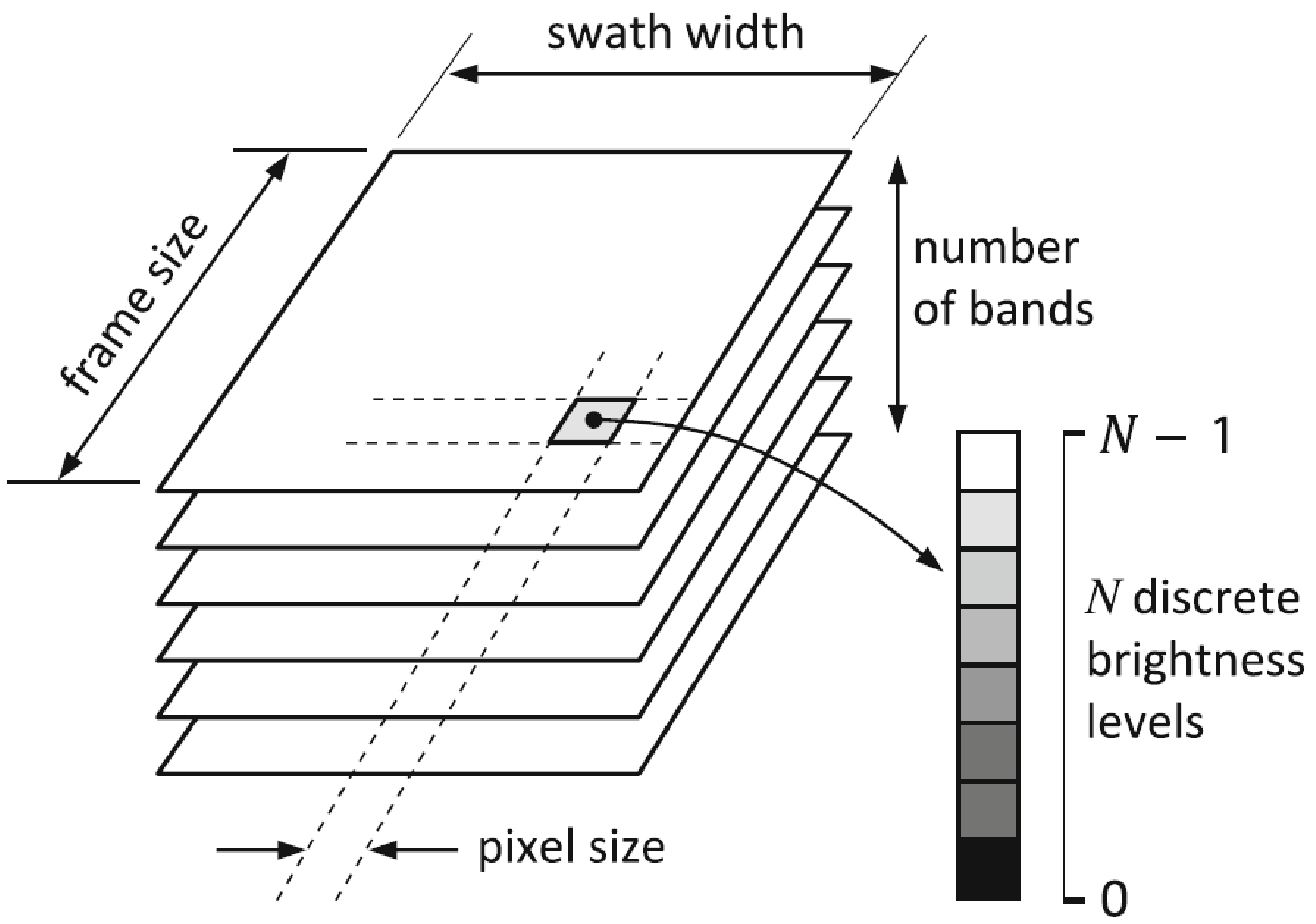
Platforms



Spaceborne
~36,000 km
Satellite
Multi-
Hyperspectral
SAR
700-900 km
Satellite Constellation
Space Shuttle
SAR
Distance from the ground
Airborne
Airborne
Multi-
Hyperspectral
SAR
LiDAR
10-12 km
Aerial
Photography
1.2- 3.5 km
0.3 km
Ground-based
UAV (drone)
Hyperspectral
LiDAR
Optical
150m

Primary data charcateristics

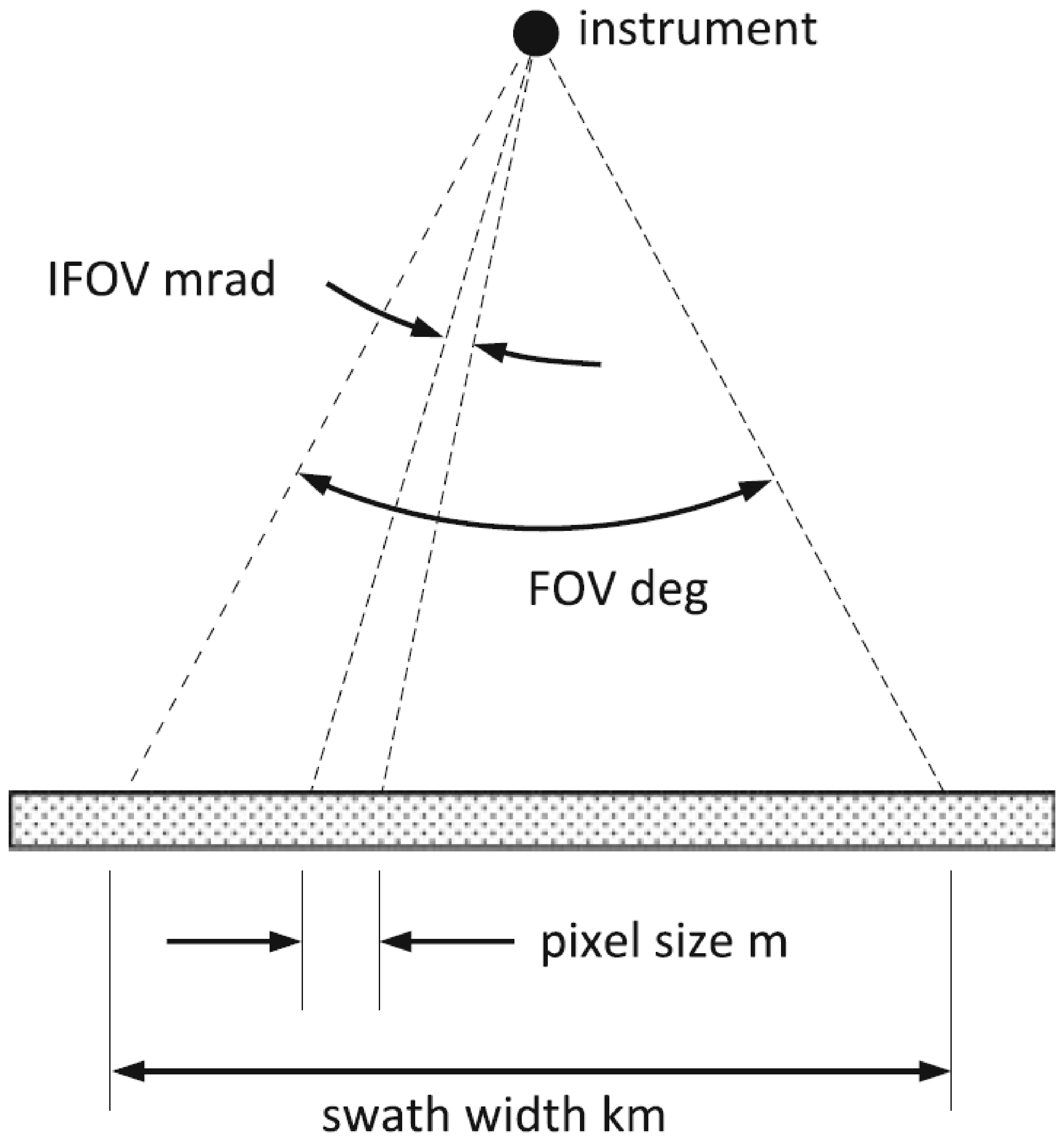
Technical characteristics of digital image data



$N = 2^m$

m	N
8	256
10	1024
12	4096
16	65536

Definition of image spatial properties

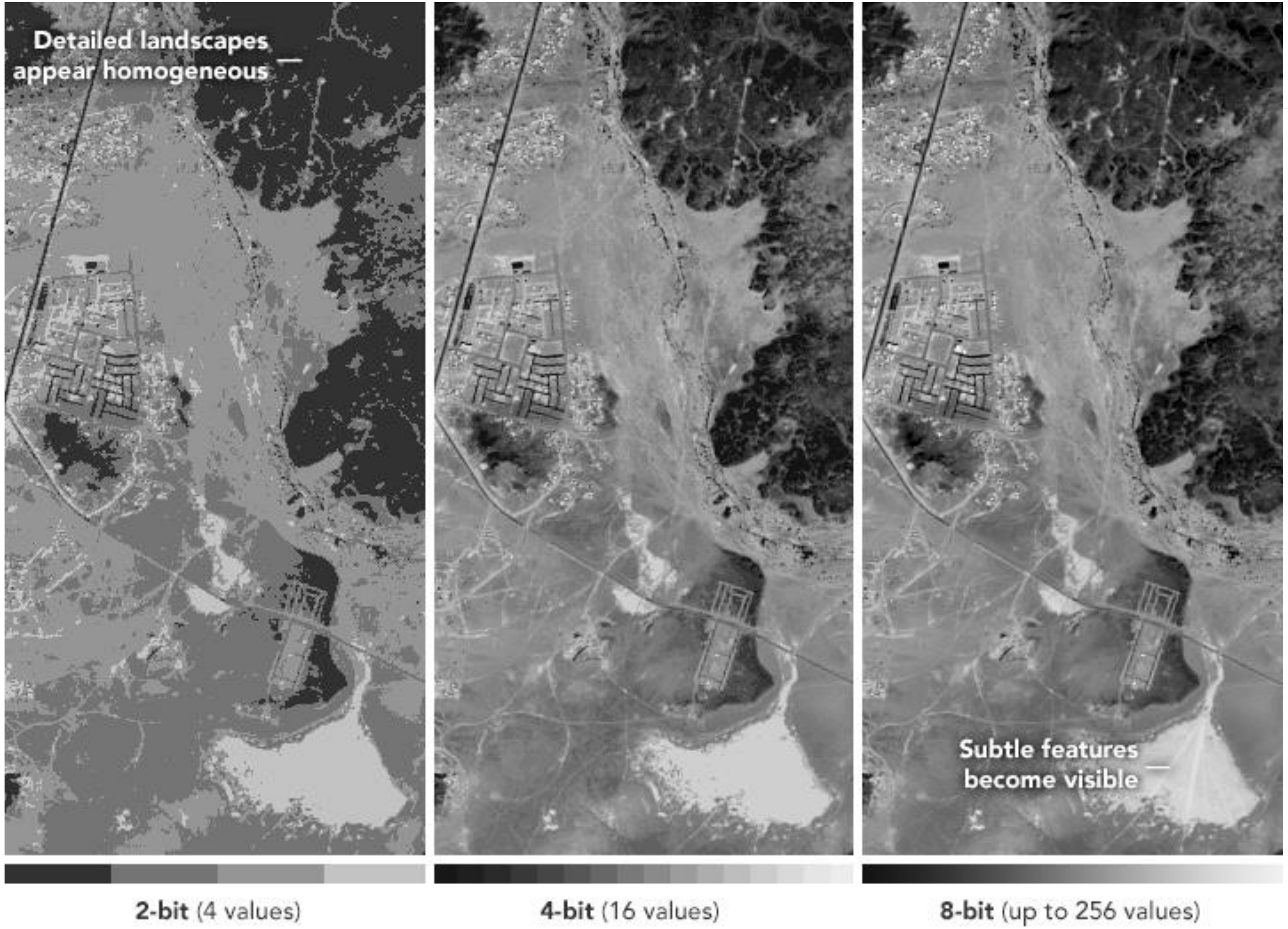


Richards, 2013

Radiometric resolution

How sensitive an instrument is to small differences in electromagnetic energy.

Sensors with high radiometric resolution can distinguish greater detail and variation in light. (NASA Earth Observatory images by Joshua Stevens, using Landsat data from the U.S. Geological Survey)



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Spatial resolution

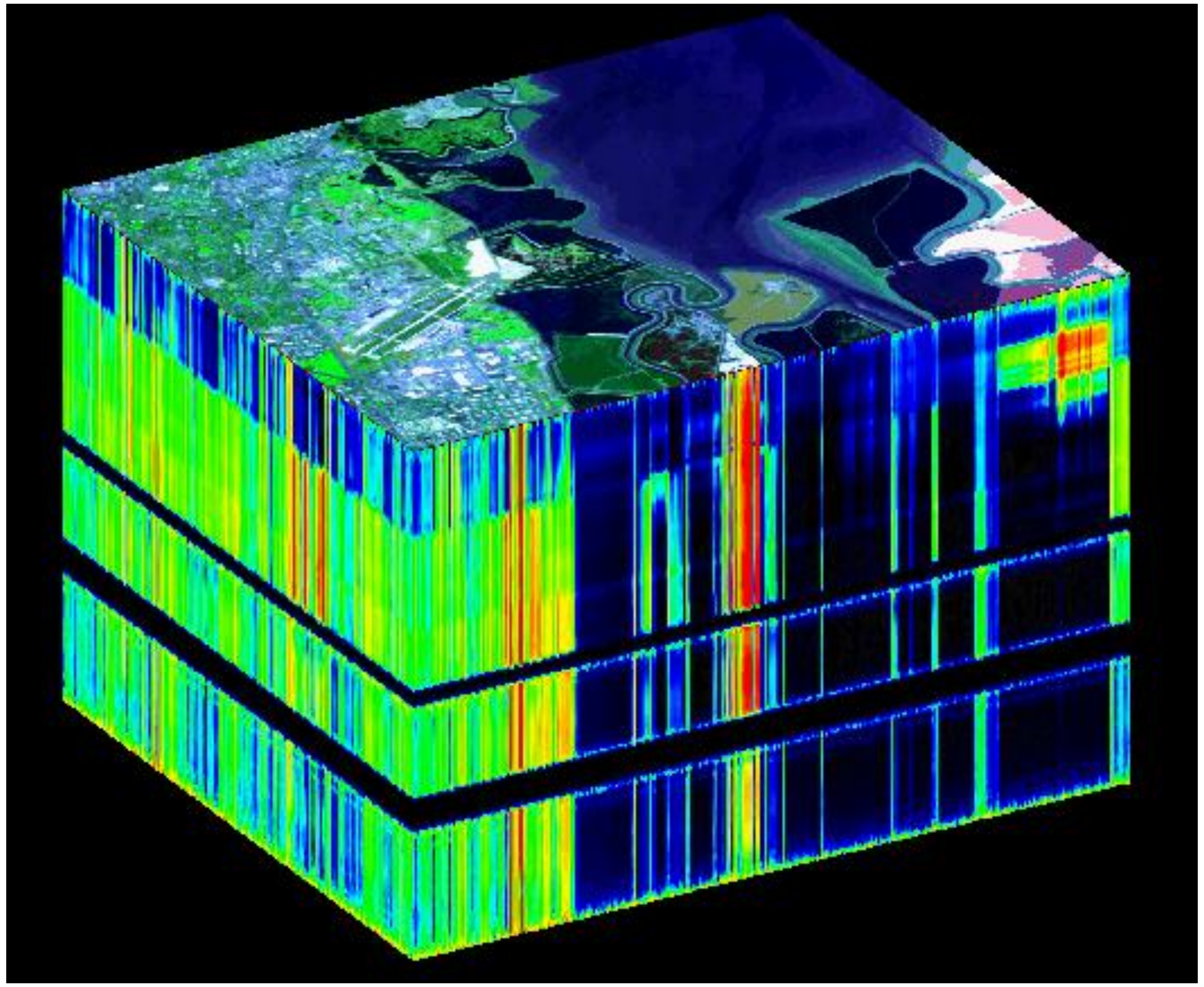
Landsat 8 data from July 7, 2019 over Reykjavík, Iceland.
NASA Earth Observatory.

https://earthdata.nasa.gov/learn/backgrounders/remote-sensing

Spectral resolution

***Spectral resolution* is the ability of a sensor to discern finer wavelengths, that is, having more and narrower bands.**

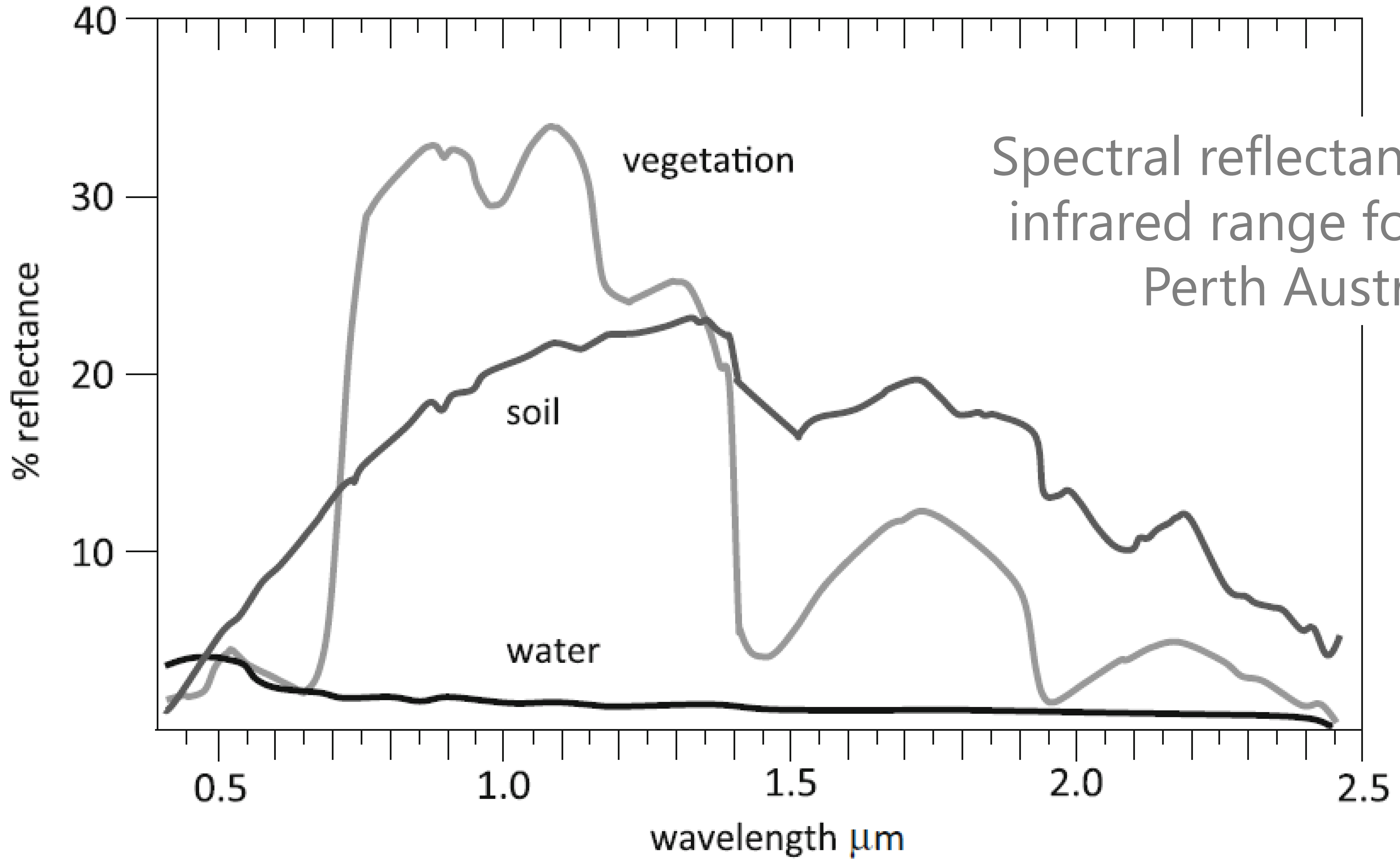
- Multispectral: 3-10 bands
- Hyperspectral: hundreds bands



The top of the cube is a false-color image made to accentuate the structure in the water and evaporation ponds on the right. The sides of the cube are slices showing the edges of the top in all 224 of the AVIRIS spectral channels. The tops of the sides are in the visible part of the spectrum (wavelength of 400 nanometers), and the bottoms are in the infrared (2,500 nanometers).

https://earthdata.nasa.gov/learn/backgrounders/remote-sensing

Sensing in the visible and reflected infrared ranges



Spectral reflectance characteristics in the visible and reflective infrared range for three common cover types, recorded over Perth Australia using the HyVista HyMap scanner

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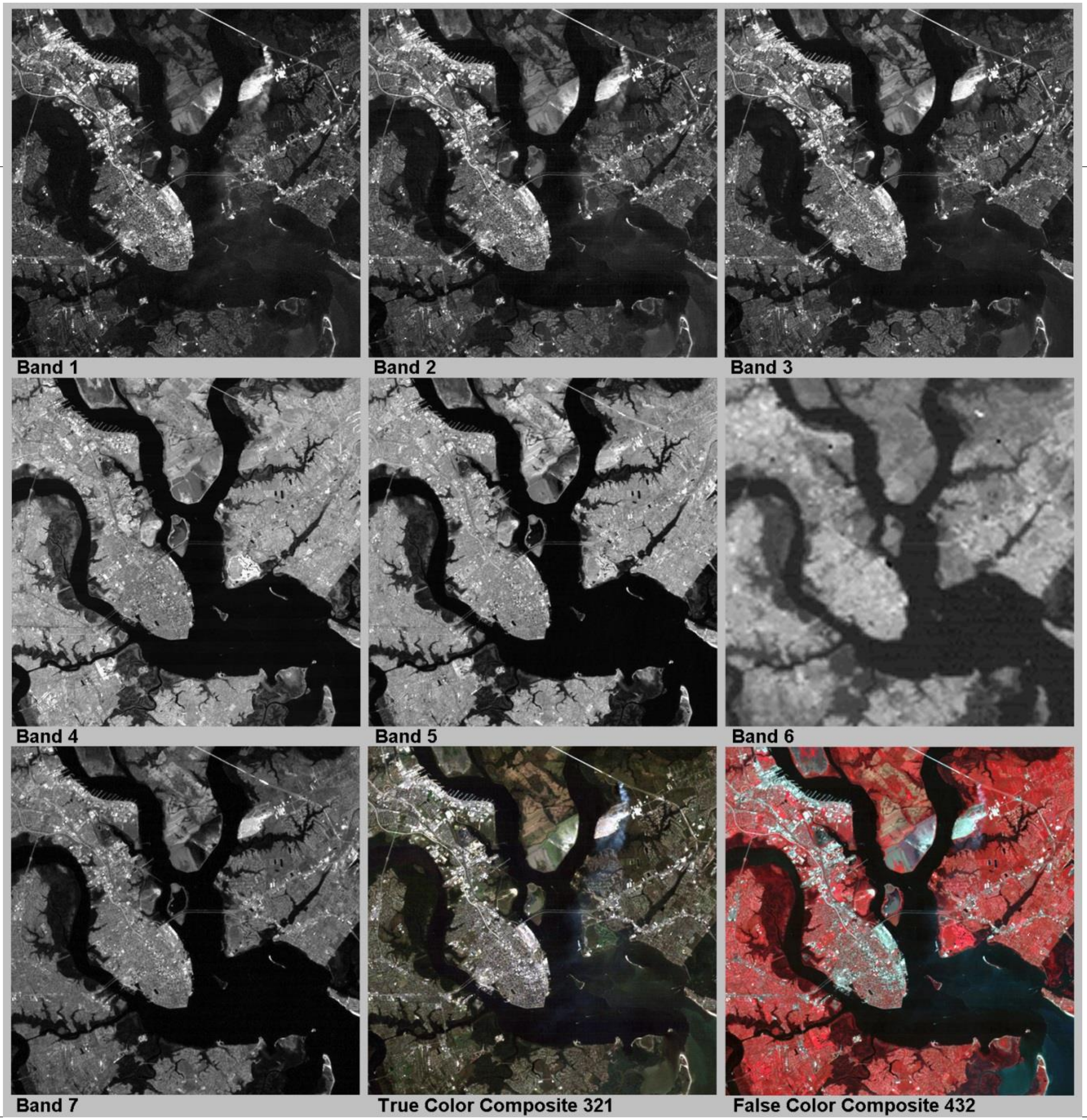
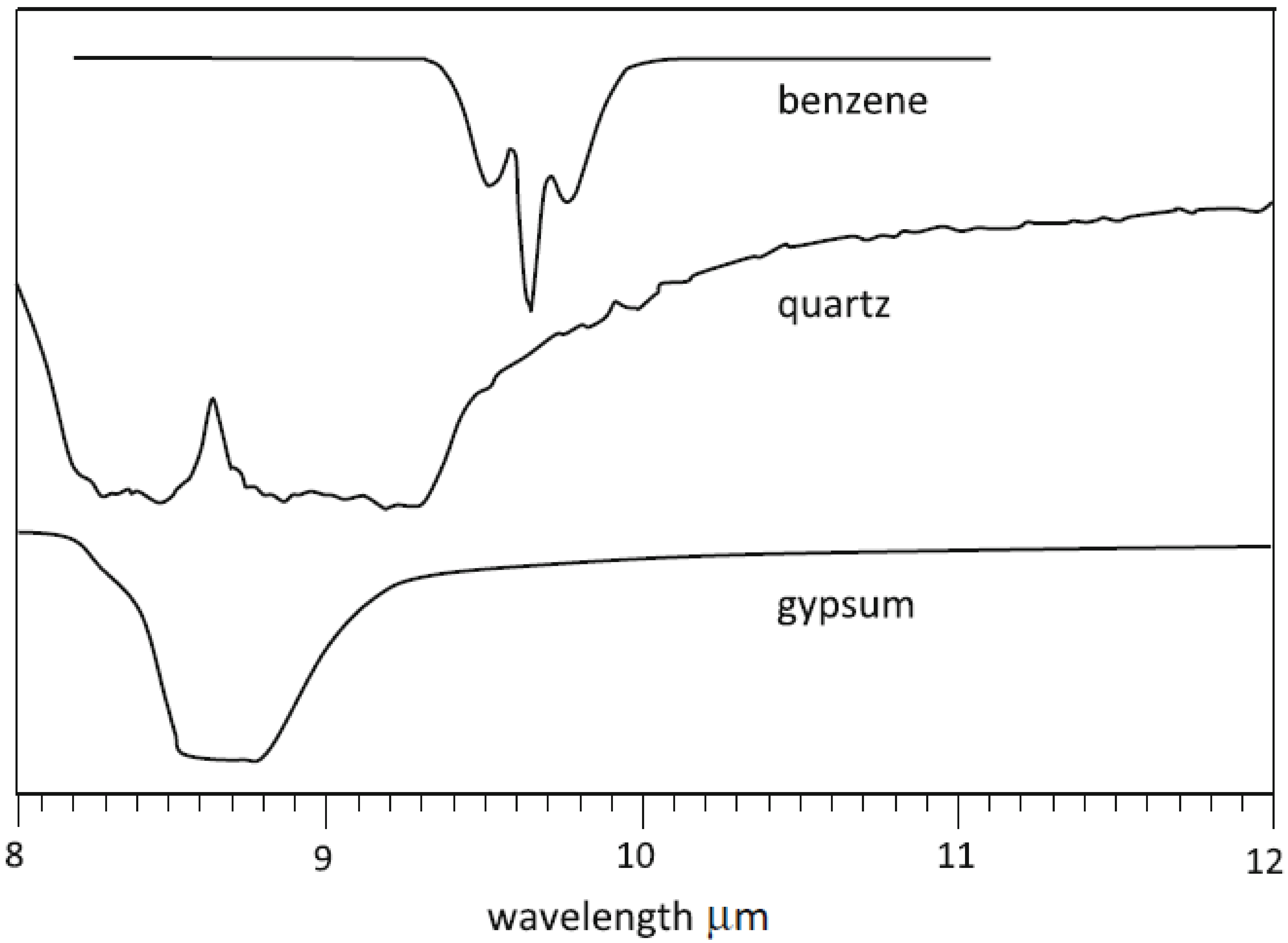
Sensing in the visible and reflected infrared ranges – Optical remote sensing

Set of images of the same geographic region acquired simultaneously by Landsat 5 TM satellite in different wavelengths (atmospheric windows):

Band 1: 0.45-0.52 (B)
Band 2: 0.52-0.60 (G)
Band 3: 0.63-0.69 (R)
Band 4: 0.76-0.90 (NIR)
Band 5: 1.55-1.75 (SWIR1)
Band 6: 10.40-12.50 (Thermal)
Band 7: 2.08-2.35 (SWIR2)



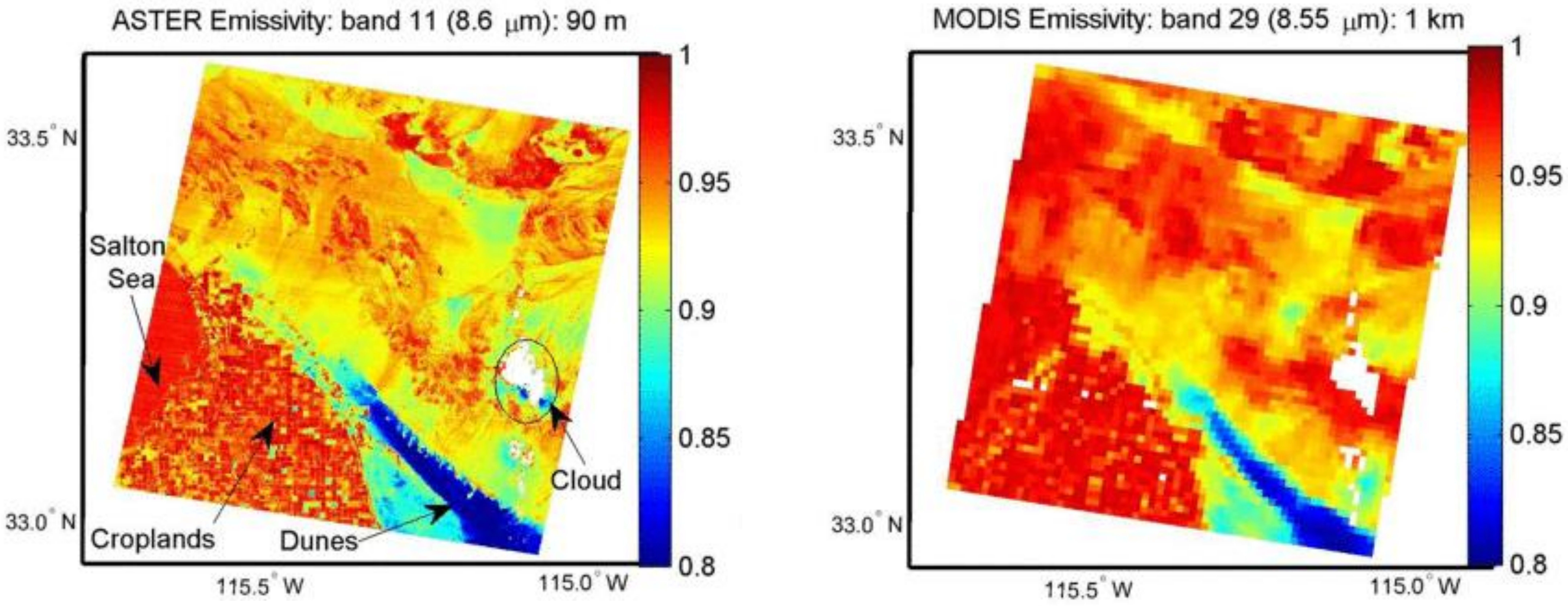
Sensing in the thermal infrared range



Some emissivity spectra in the thermal infrared range

G.C. Hulley and S.J. Hook, 2011
T. Schmugge, et al., 2001, pp. 715–717

Sensing in the thermal infrared range

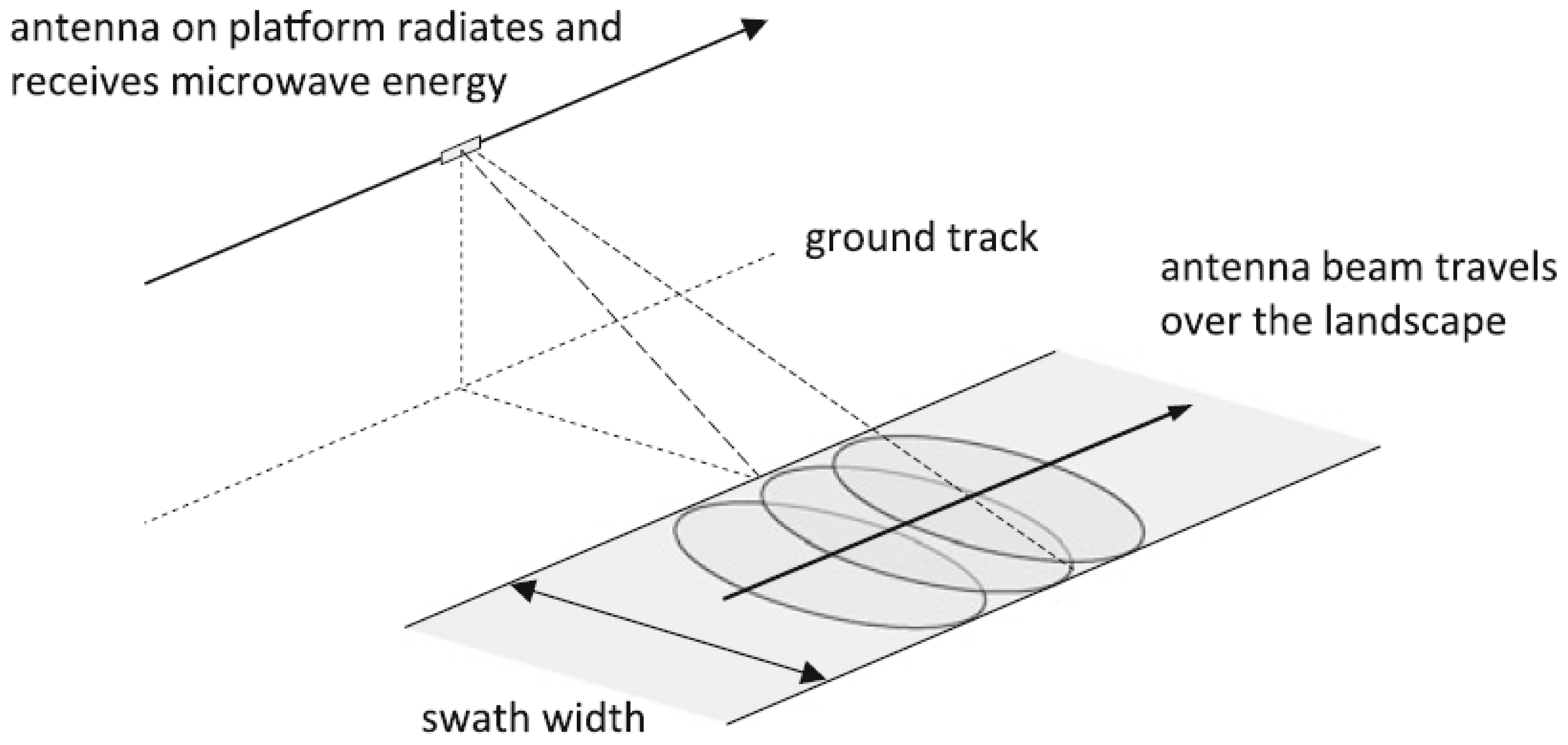


G.C. Hulley and S.J. Hook, Generating consistent land surface temperature and emissivity products between ASTER and MODIS data for earth science research, IEEE Transactions on Geoscience and Remote Sensing, vol. 49, no. 4, April 2011, pp. 1304–1315

Active Sensors

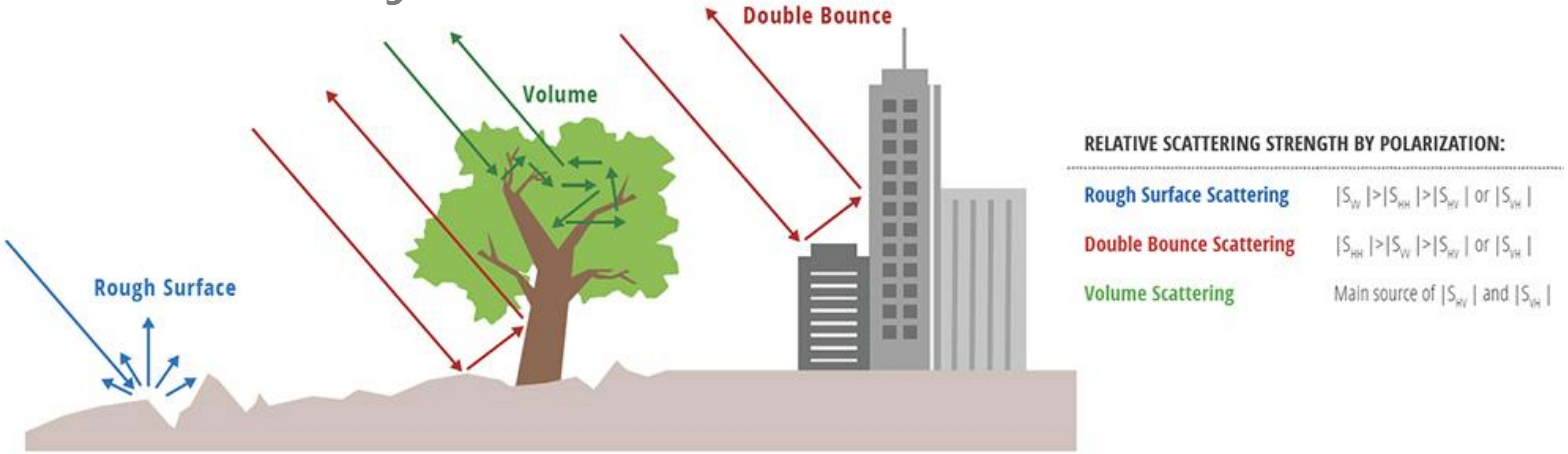
microwave ranges

Synthetic aperture radar (SAR) imaging



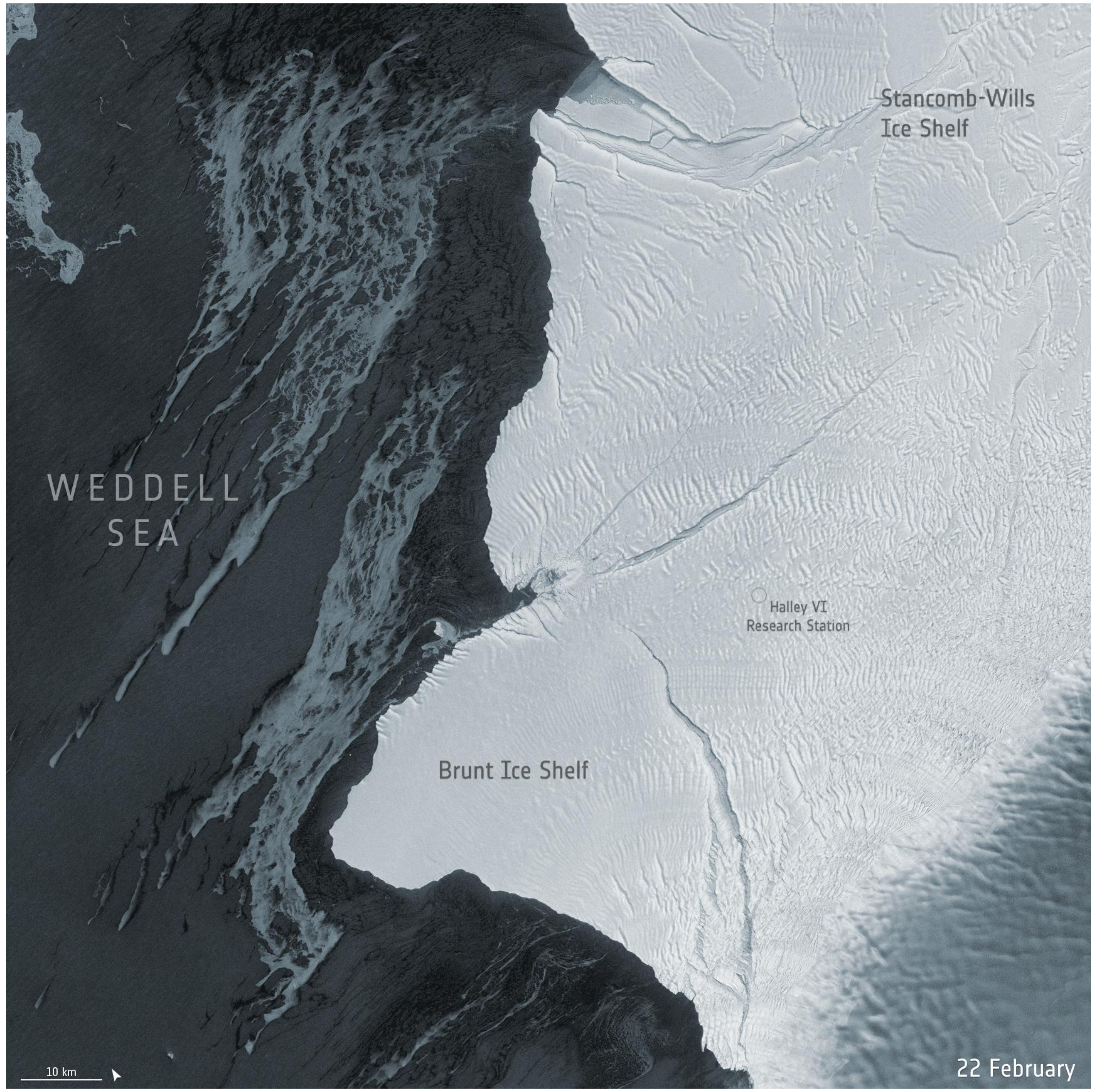
Richards, 2013

Polarization and Scattering Mechanisms



Strong scattering in HH indicates a predominance of double-bounce scattering (e.g., stemmy vegetation, manmade structures), while strong VV relates to rough surface scattering (e.g., bare ground, water), and spatial variations in dual polarization indicate the distribution of volume scatterers (e.g., vegetation and high-penetration soil types such as sand or other dry porous soils). Credit: NASA SAR Handbook.

SAR images



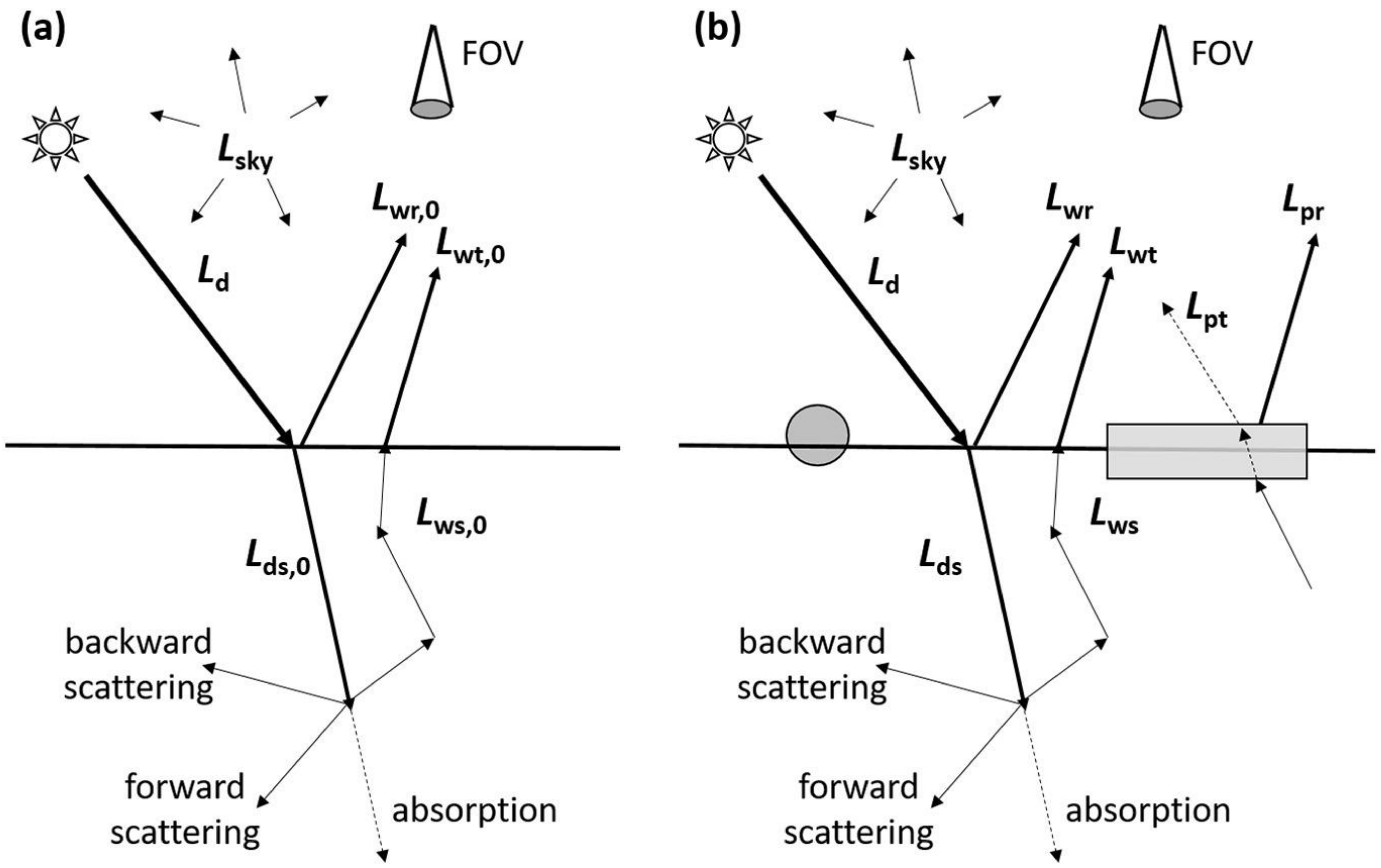
A giant iceberg, approximately 1.5 times the size of Greater Paris, broke off from the northern section of Antarctica's Brunt Ice Shelf on Friday 26th February.

New radar images, captured by the Copernicus Sentinel-1 mission, show the 1270 sq km iceberg breaking free and moving away rapidly from the floating ice shelf.

Can we use remote sensing to detect plastic debris on open waters?

Detecting macroplastics

Light reflectance controls the remote sensing signal of marine plastic litter



Schematic of sunlight hitting (a) an open water body, and (b) the same water body but with floating plastic. With Ld total downwelling sunlight (solar beam + diffuse sky light), Lds subsurface downwelling light, Lws subsurface upwelling light, Lwr light reflected directly off the water surface, Lwt subsurface upwelling light transmitted through the water-air interface, Lpr light reflected off the plastic and Lpt subsurface upwelling light transmitted through the plastic. Lw is total water leaving light, Lwr + Lwt, and Lp is total plastic leaving light, Lpt + Lpr; subscript '0' indicates the variables in the absence of plastic and FOV is field of view.

Goddijn-Murphy et al, 2018
https://doi.org/10.1016/j.marpolbul.2017.11.011

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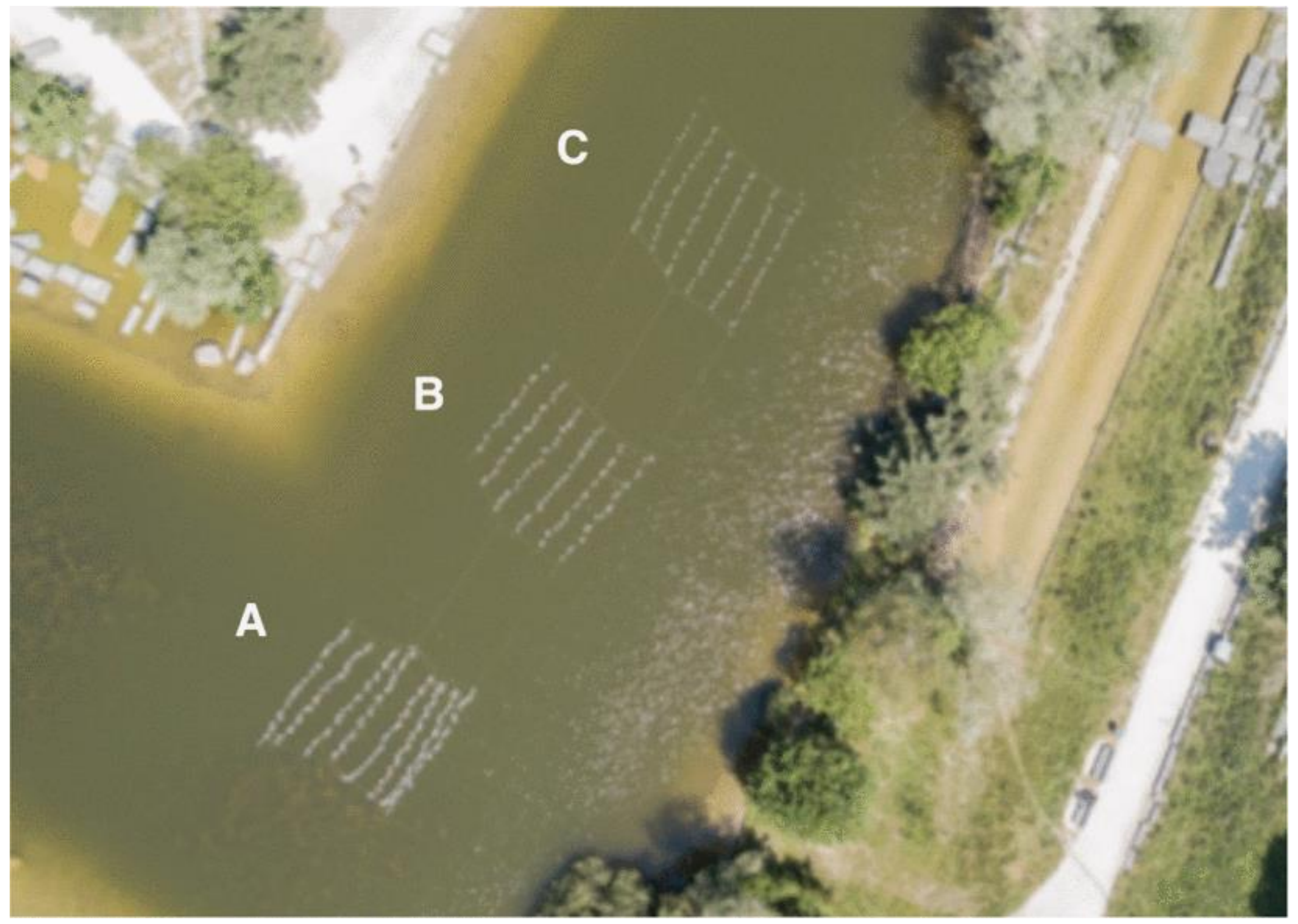
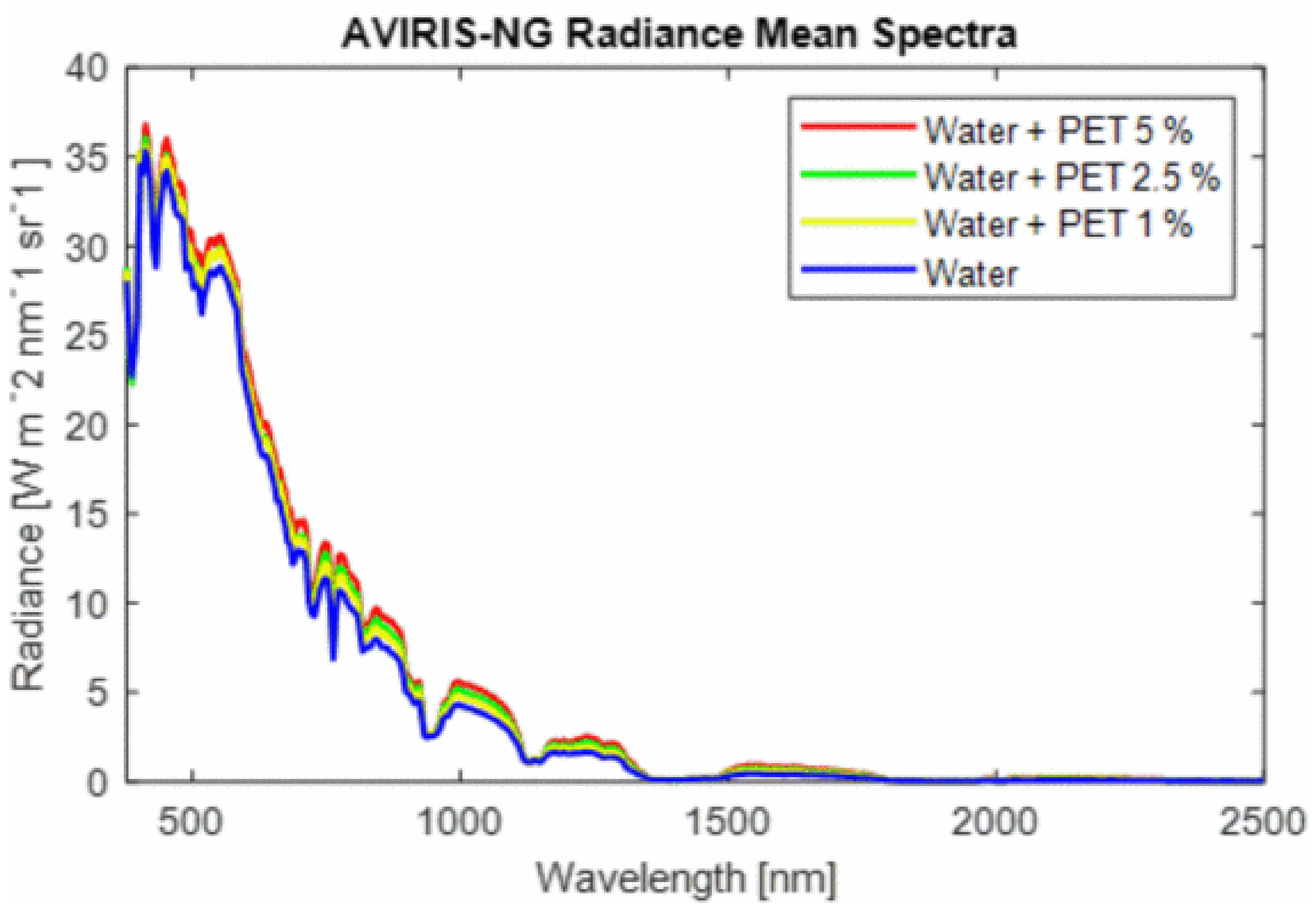
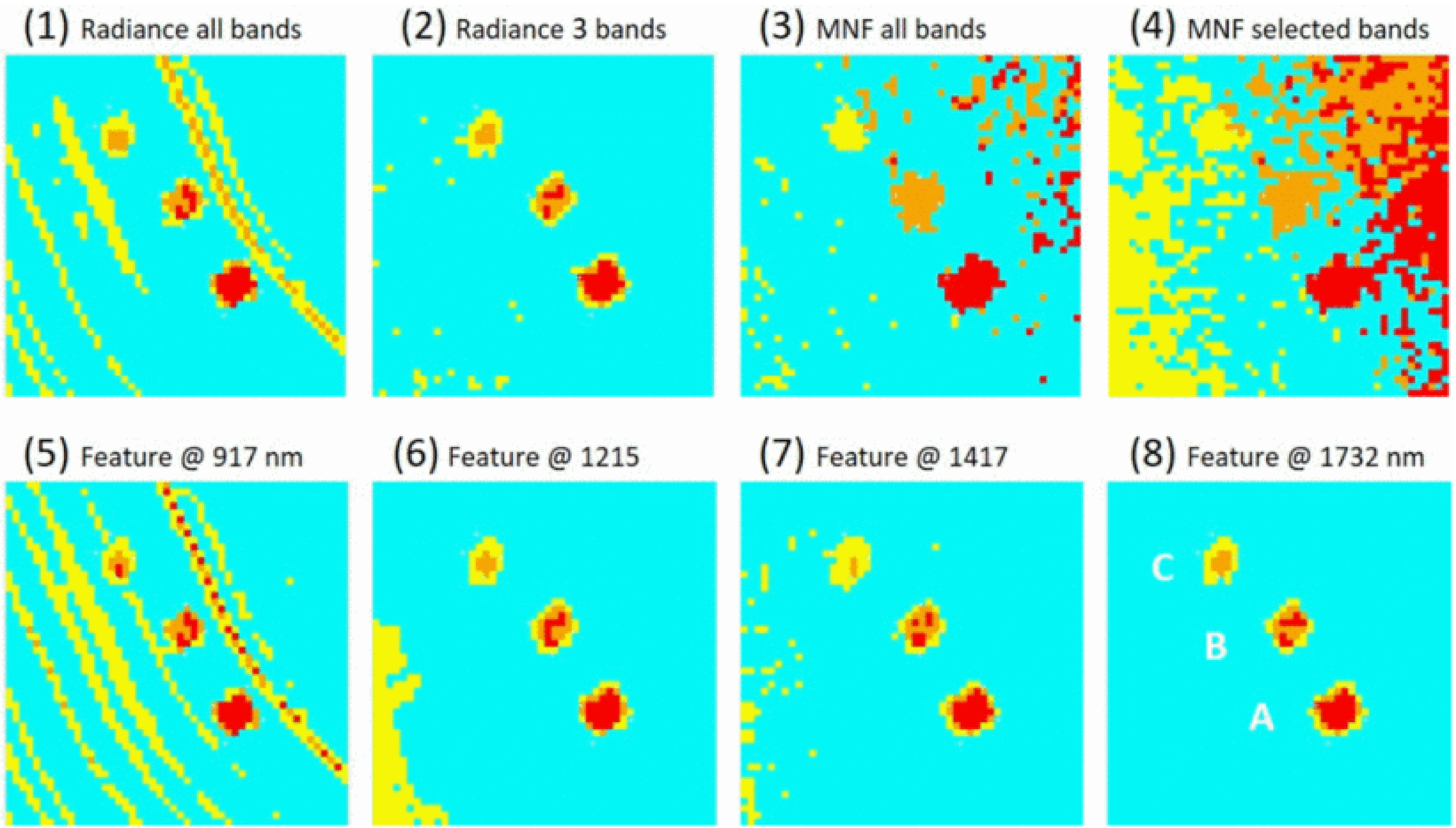
Detecting macroplastics

Classification of remote sensing in the visible and reflected infrared ranges



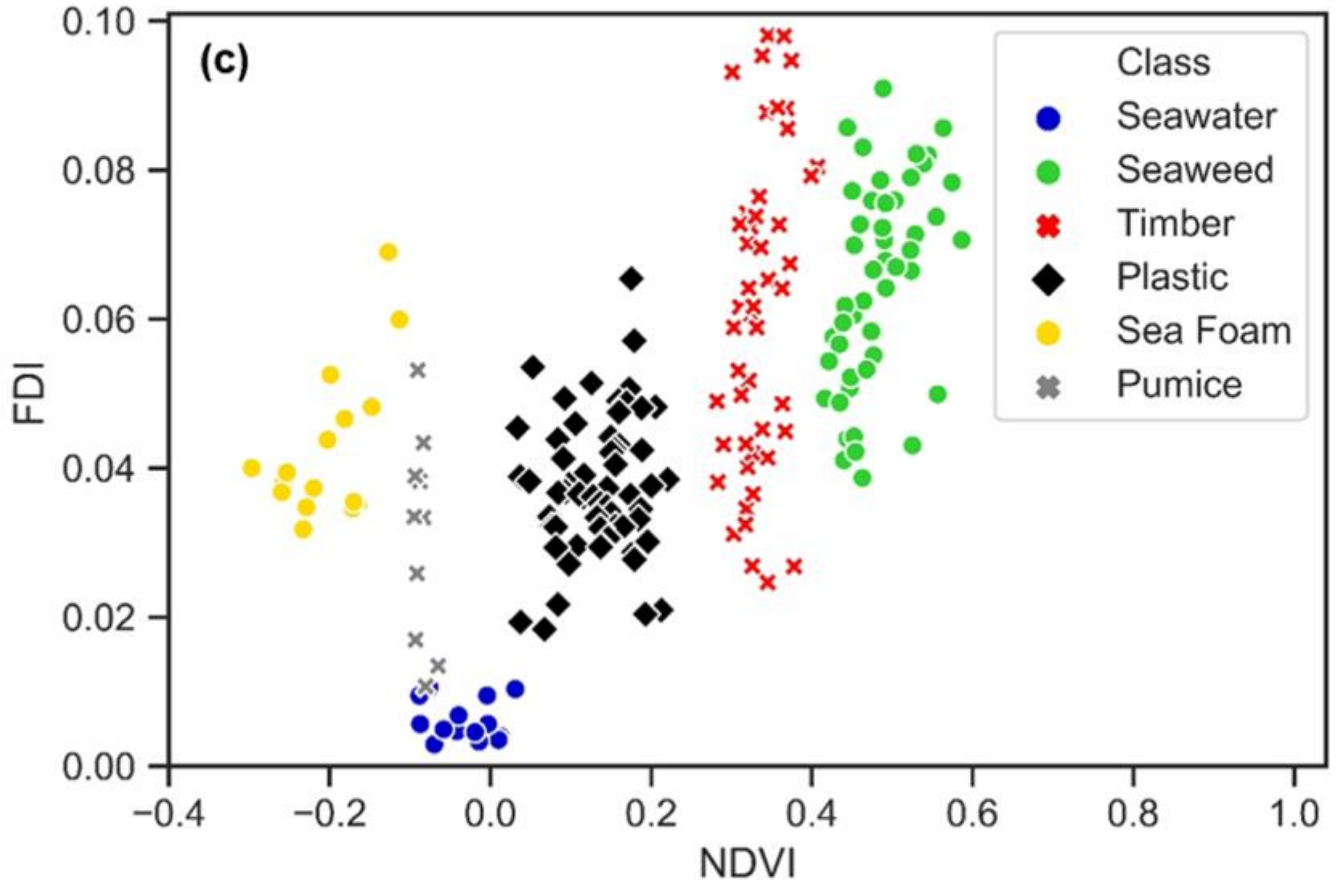




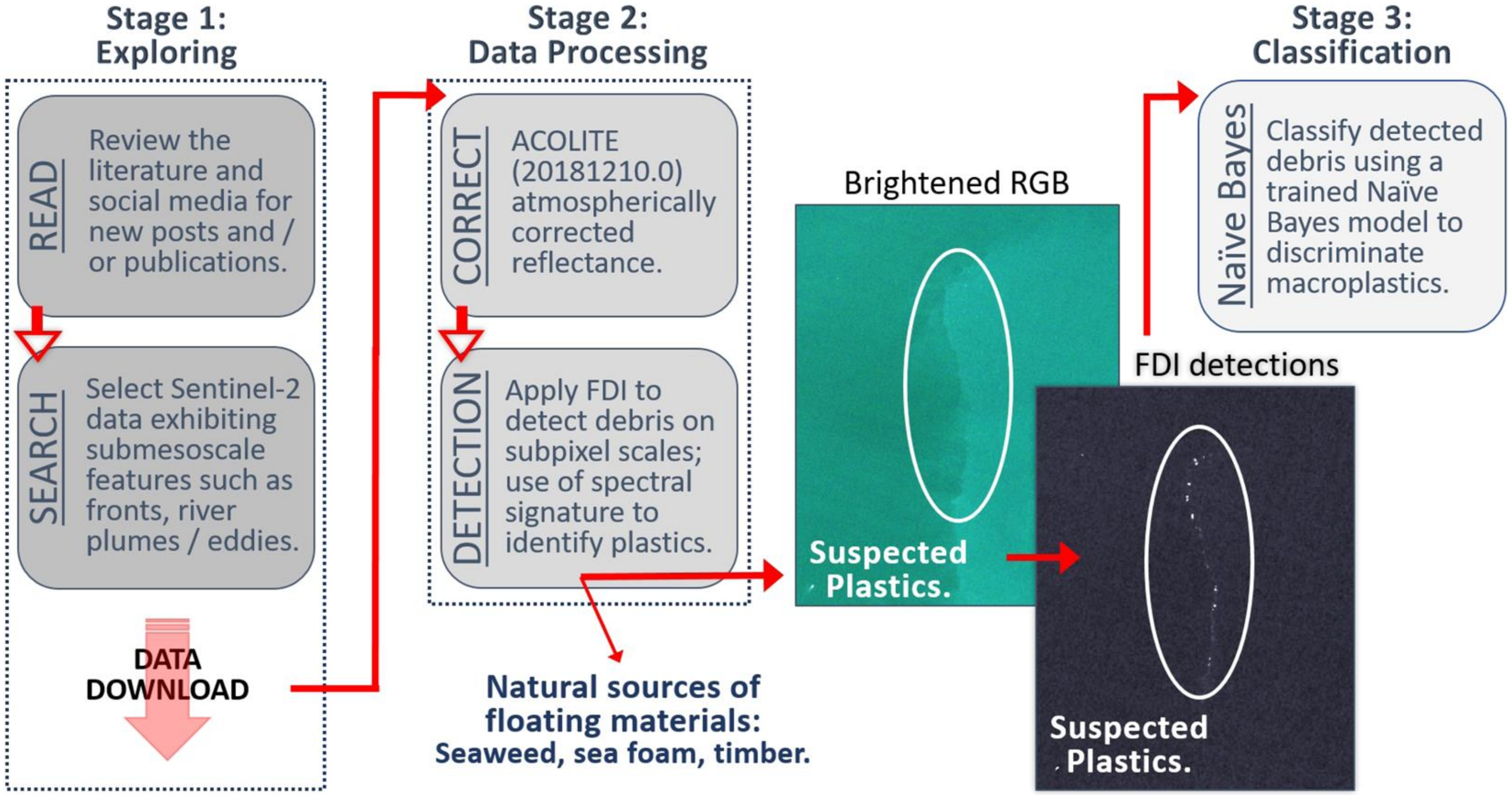
Hueni and S. Bertschi, 2020

Detecting macroplastics

Spectral indexes



Normalised Difference Vegetation Index (NDVI) vs Floating Debris Index (FDI)

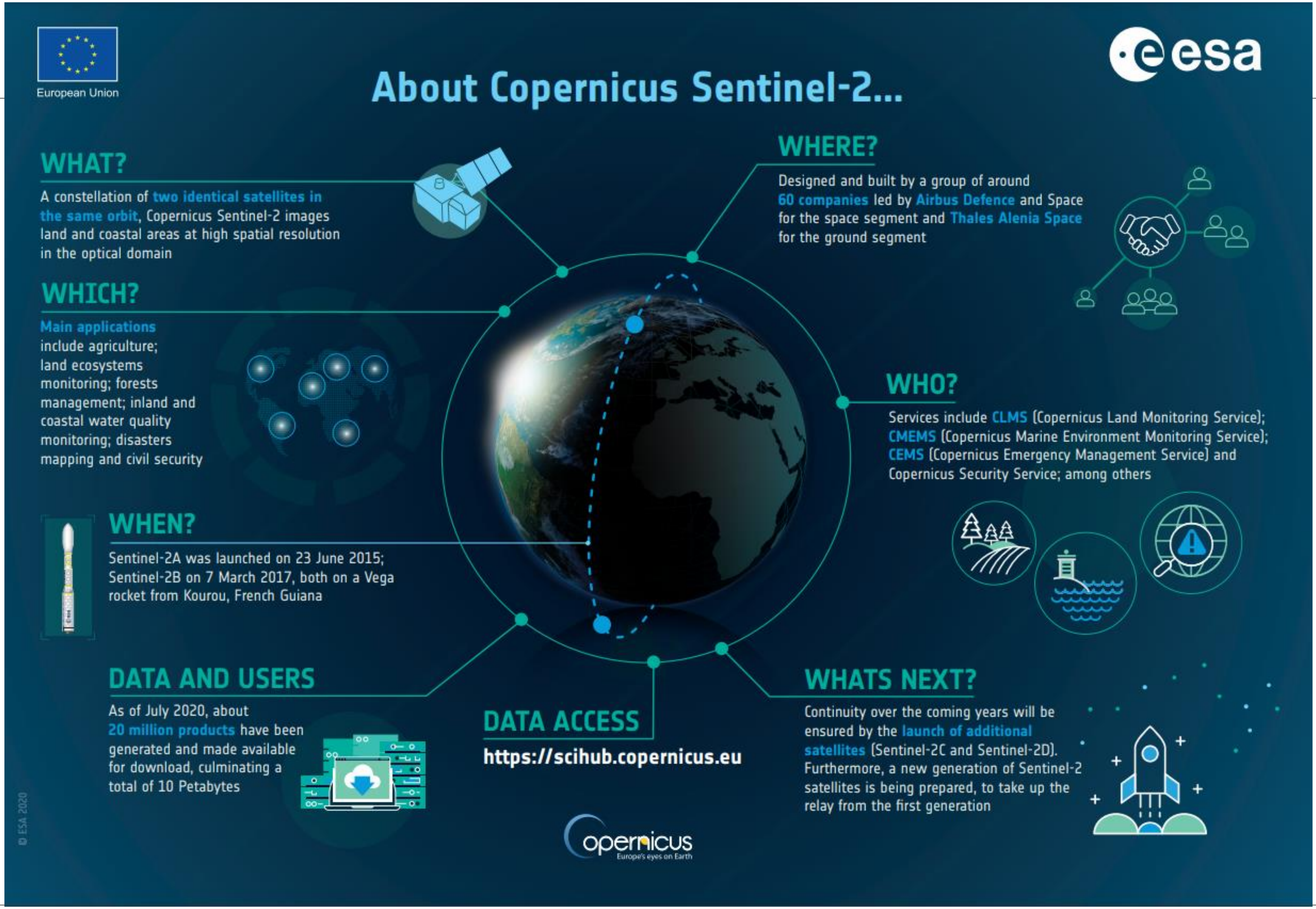


Biermann et al., 2020

Detecting macroplastics

https://sentinel.esa.int/web/sentinel/home

https://www.esa.int/Applications/Observing_the_Earth/Copernicus



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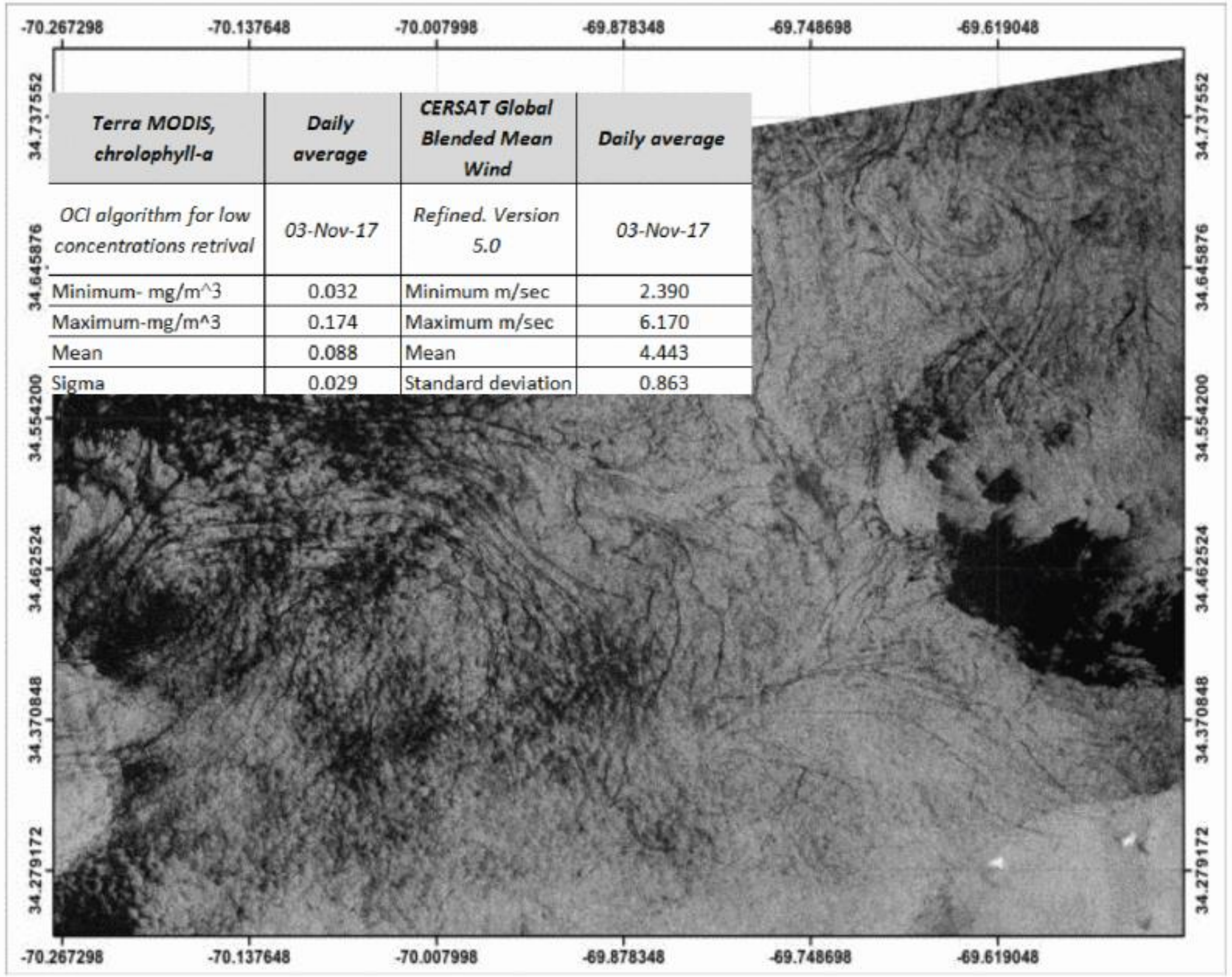
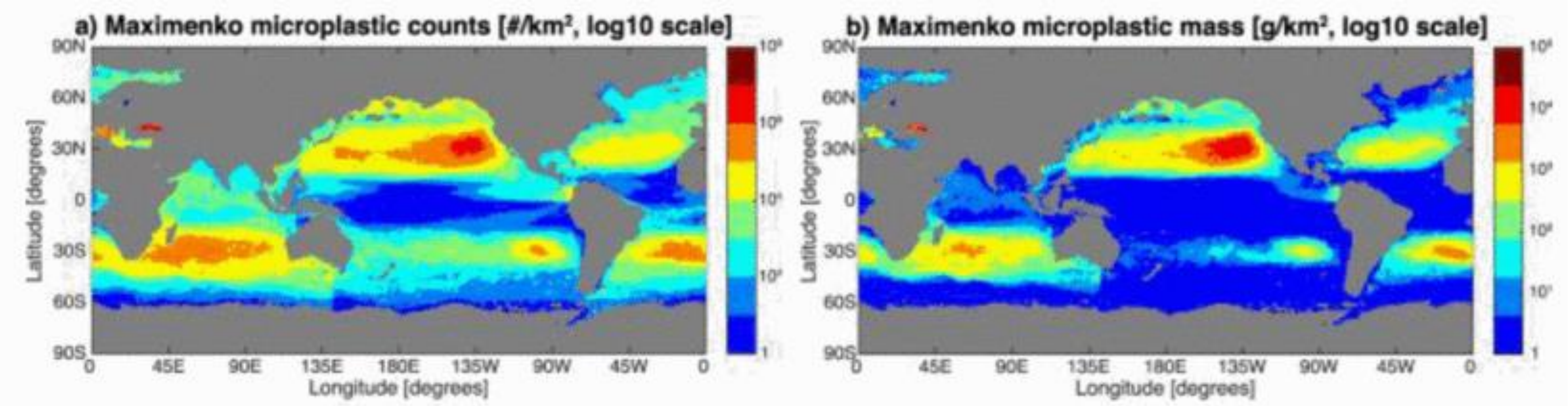
Detecting microplastics

Sentinel-1A sar with presumed surfactants and sea-slicks.
Date of acquisition-03/11/17, 22:00 pm



Terra MODIS, chrolophyll-a	Daily average	CERSAT Global Blended Mean Wind	Daily average
OCI algorithm for low concentrations retrival	03-Nov-17	Refined. Version 5.0	03-Nov-17
Minimum- mg/m^3	0.032	Minimum m/sec	2.390
Maximum-mg/m^3	0.174	Maximum m/sec	6.170
Mean	0.088	Mean	4.443
Sigma	0.029	Standard deviation	0.863

Solutions of microplastics count



Identify sites polluted by microplastics using SAR sensors by detecting the surfactants, sea-slicks and bio-films at the ocean surface (the dark patches in grayscale intensity SAR images), otherwise not visible in optical images

Davaasuren et al., 2018

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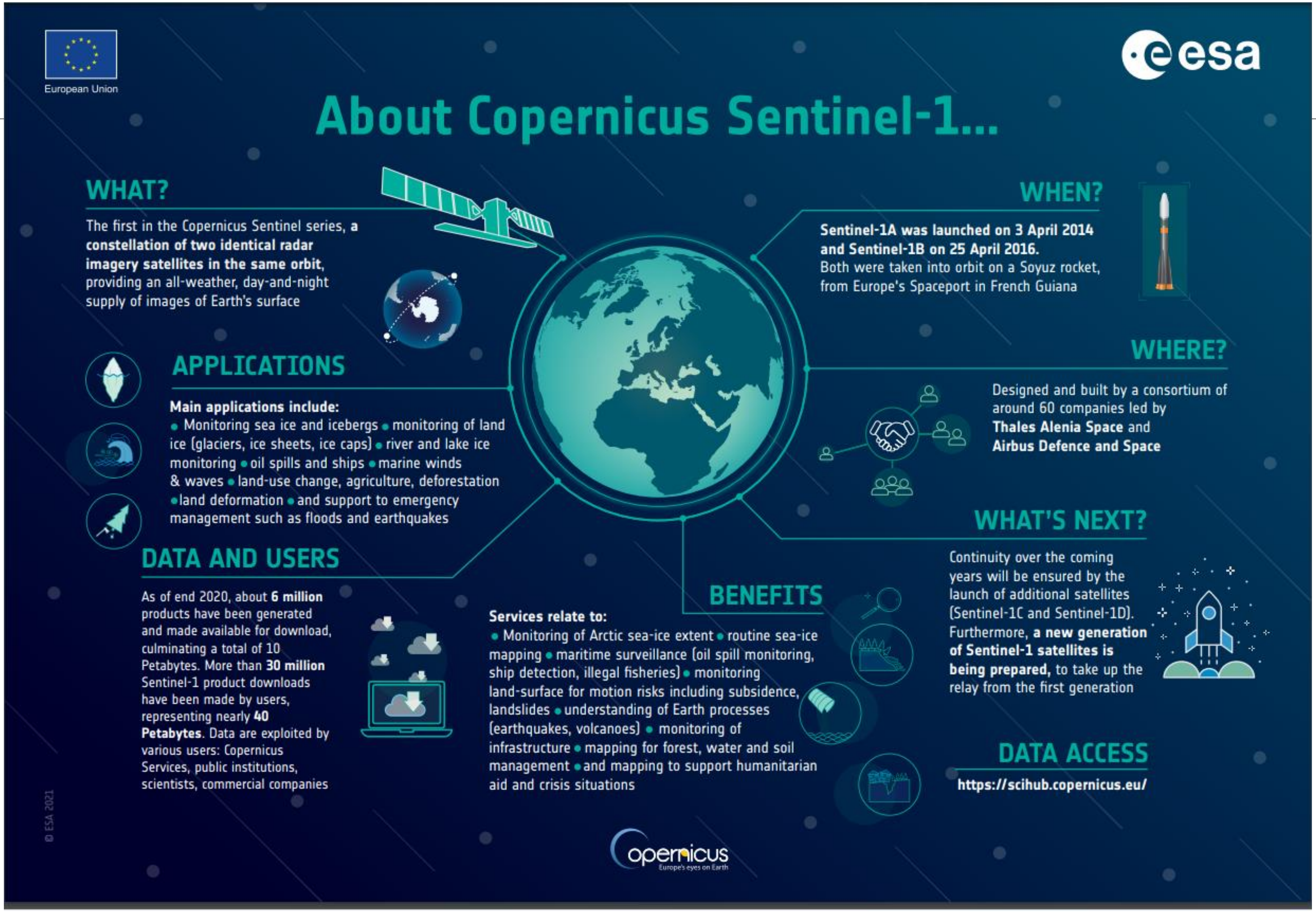
Detecting microplastics



https://sentinel.esa.int/web/sentinel/home

Drones

WORLD ECONOMIC FORUM

Use drone-mounted cameras to take thousands of aerial photos.

These photos are then used to train an AI algorithm to recognize images of plastic trash and distinguish between shells, jellyfish or plastic bags or bottle tops

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There is still much to be explored regarding the use of remote sensing to detect plastic debris in open waters.

Henderson Island lies in the South Pacific, about halfway between New Zealand and Chile. As one of the best examples of a coral atoll, Henderson Island is a UN World Heritage site and one of the world's biggest marine reserves. However, while this remote, uninhabited, tiny landmass may look idyllic and untouched by humans, it's one of the most plastic-polluted places on Earth.

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