

# 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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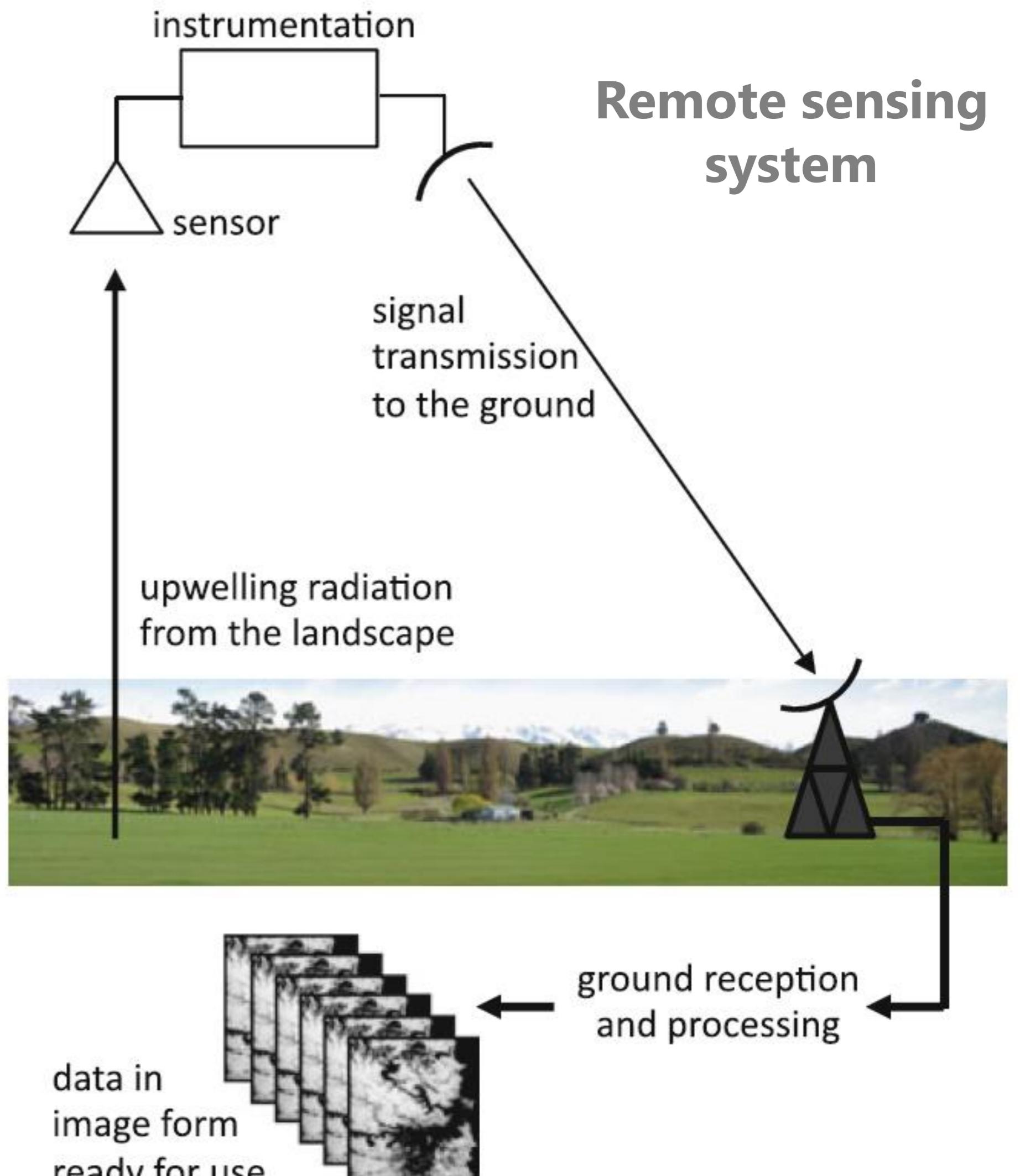
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# What is remote sensing?

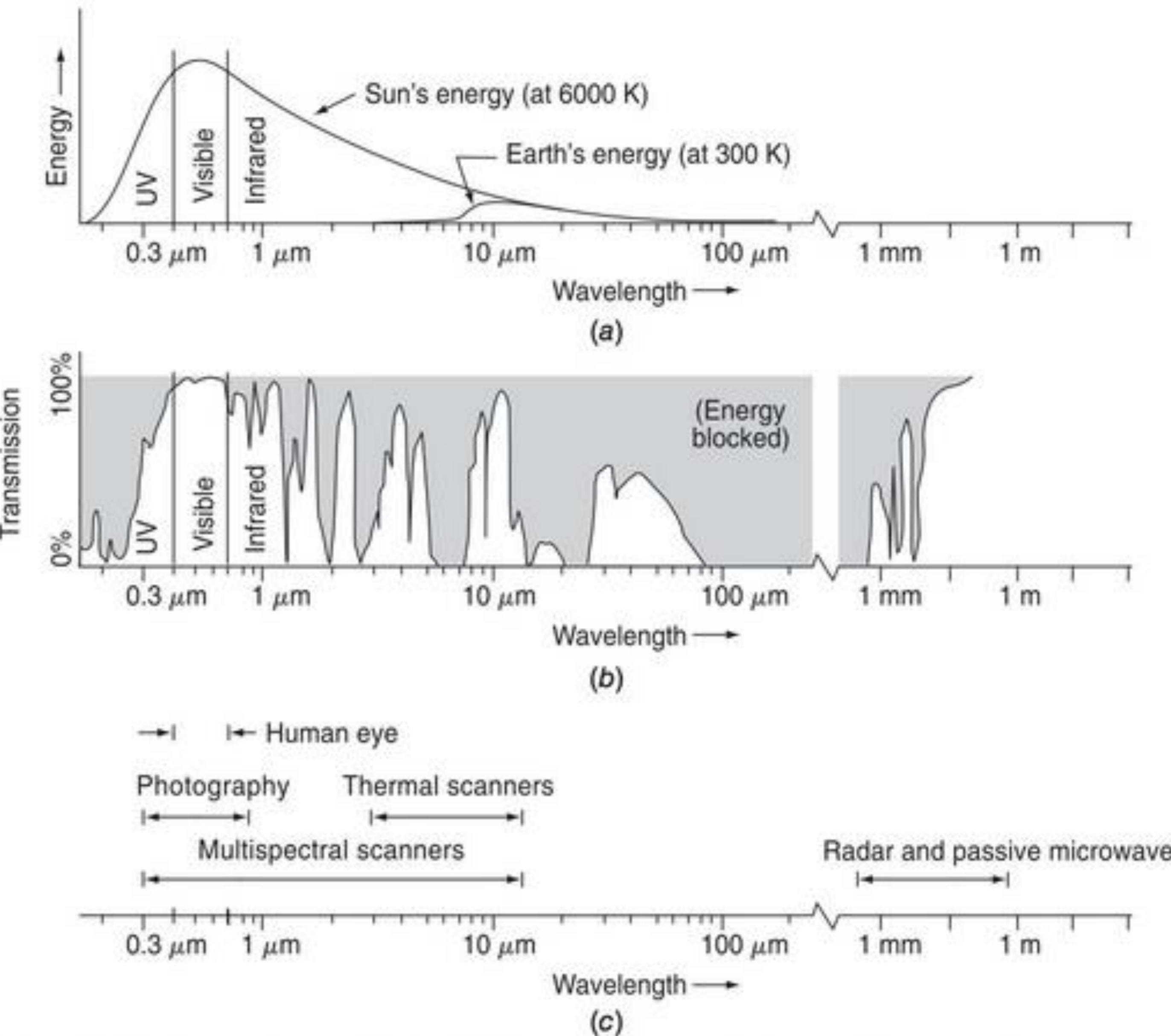
Remote sensing is the science that allows describing an object, surface or phenomena through the analysis of data acquired with a sensor without any physical contact between them.

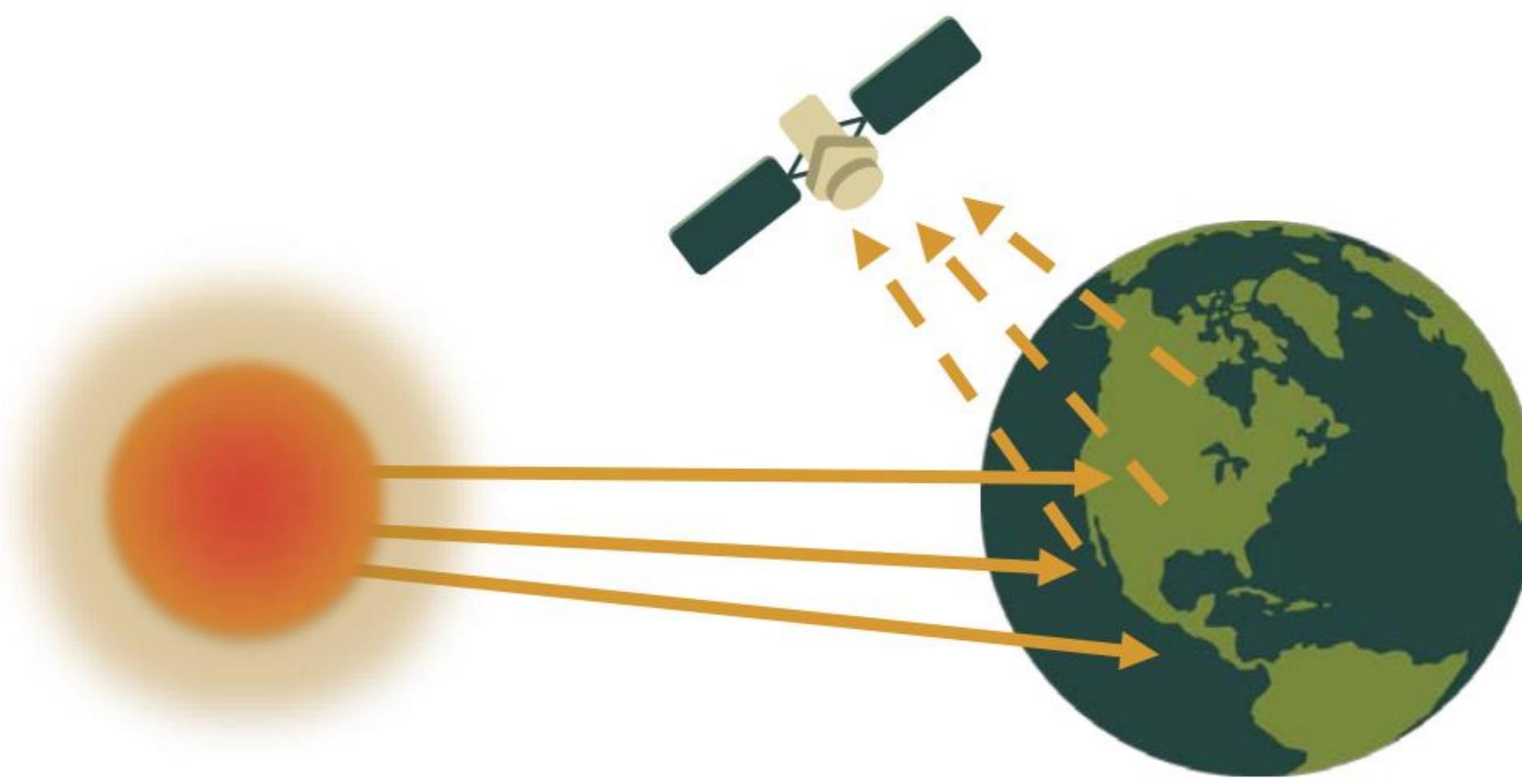
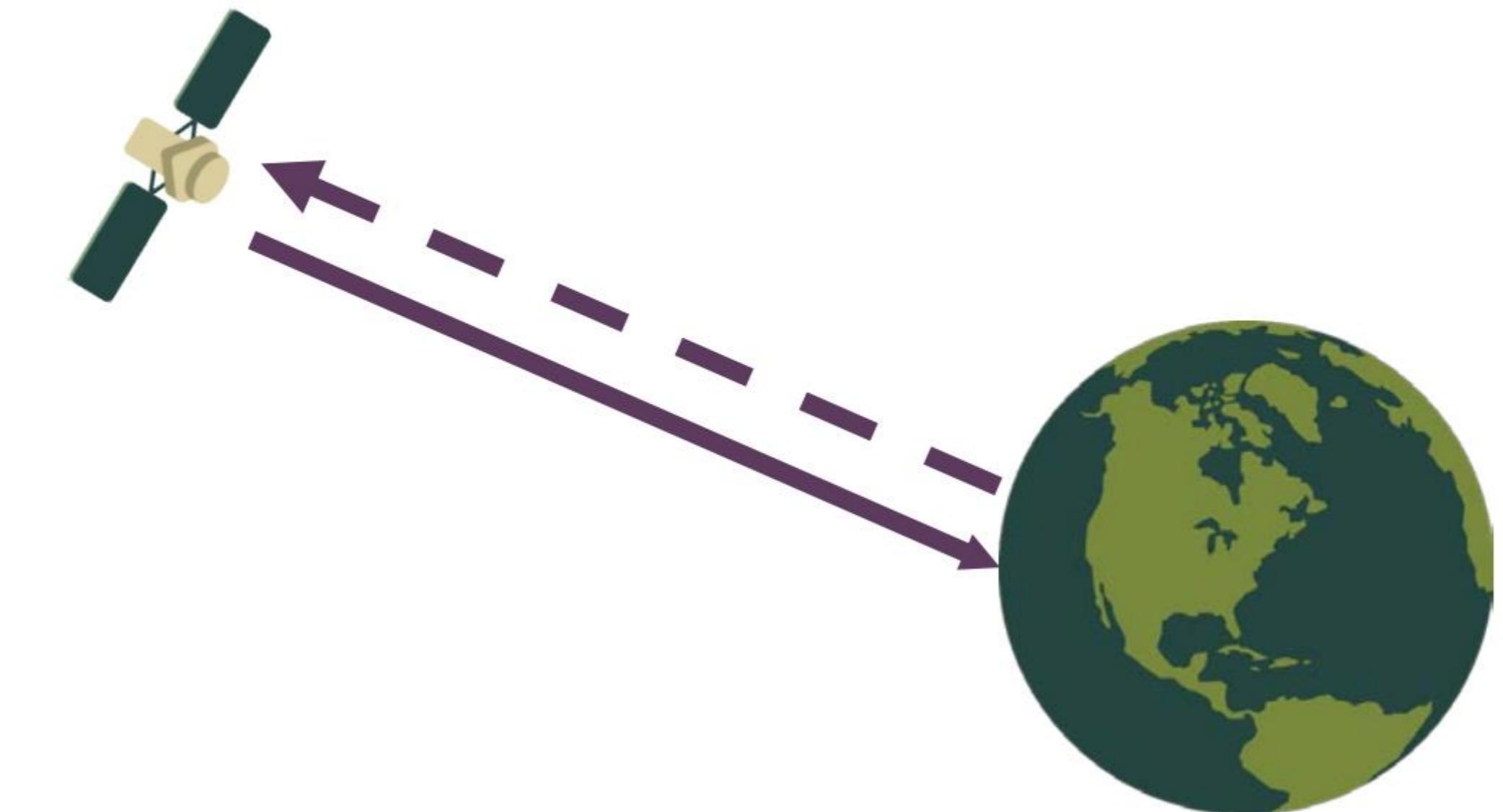


Richards, 2013



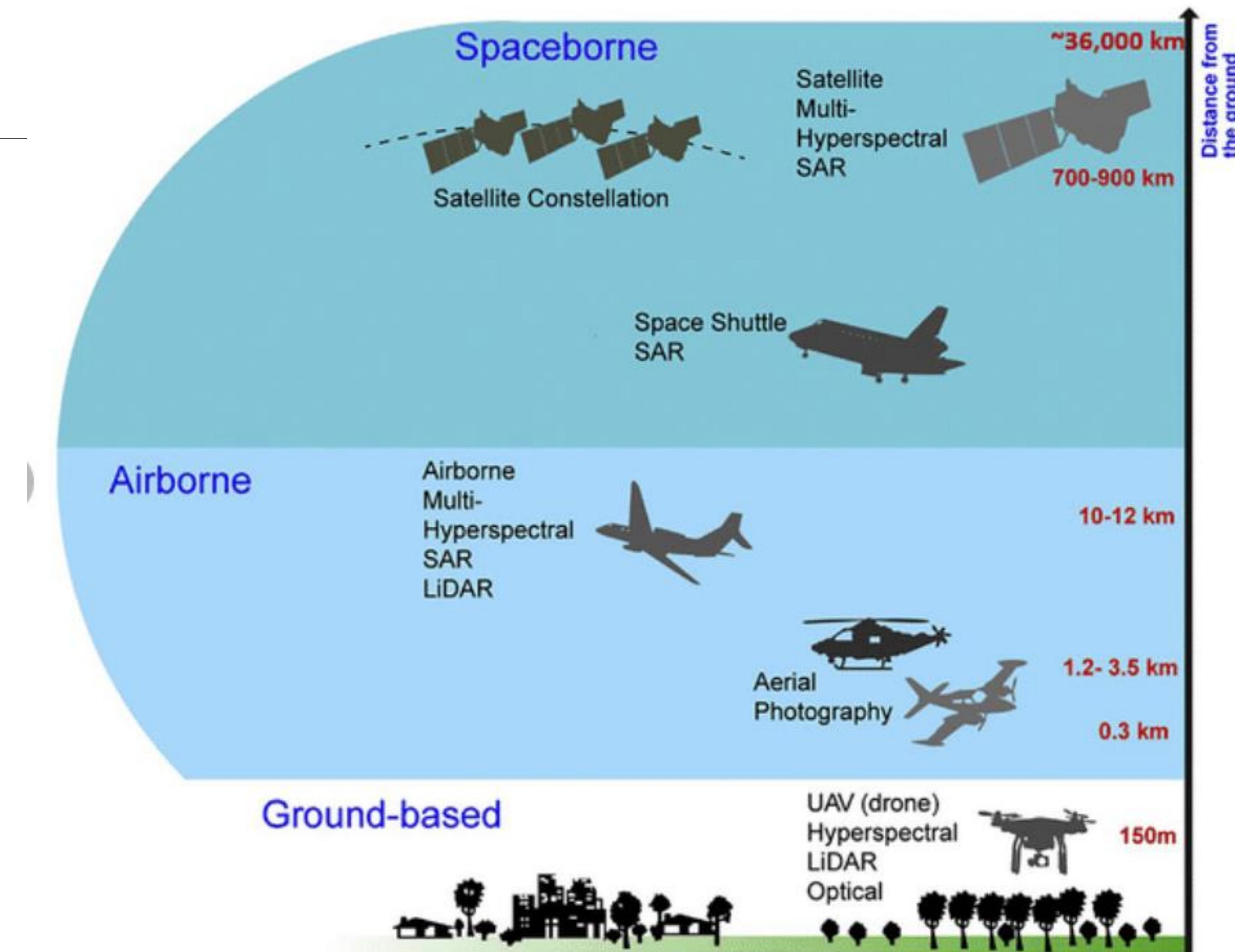
# Energy and atmospheric transmission



**Passive Sensors****Active Sensors**

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

## Platforms



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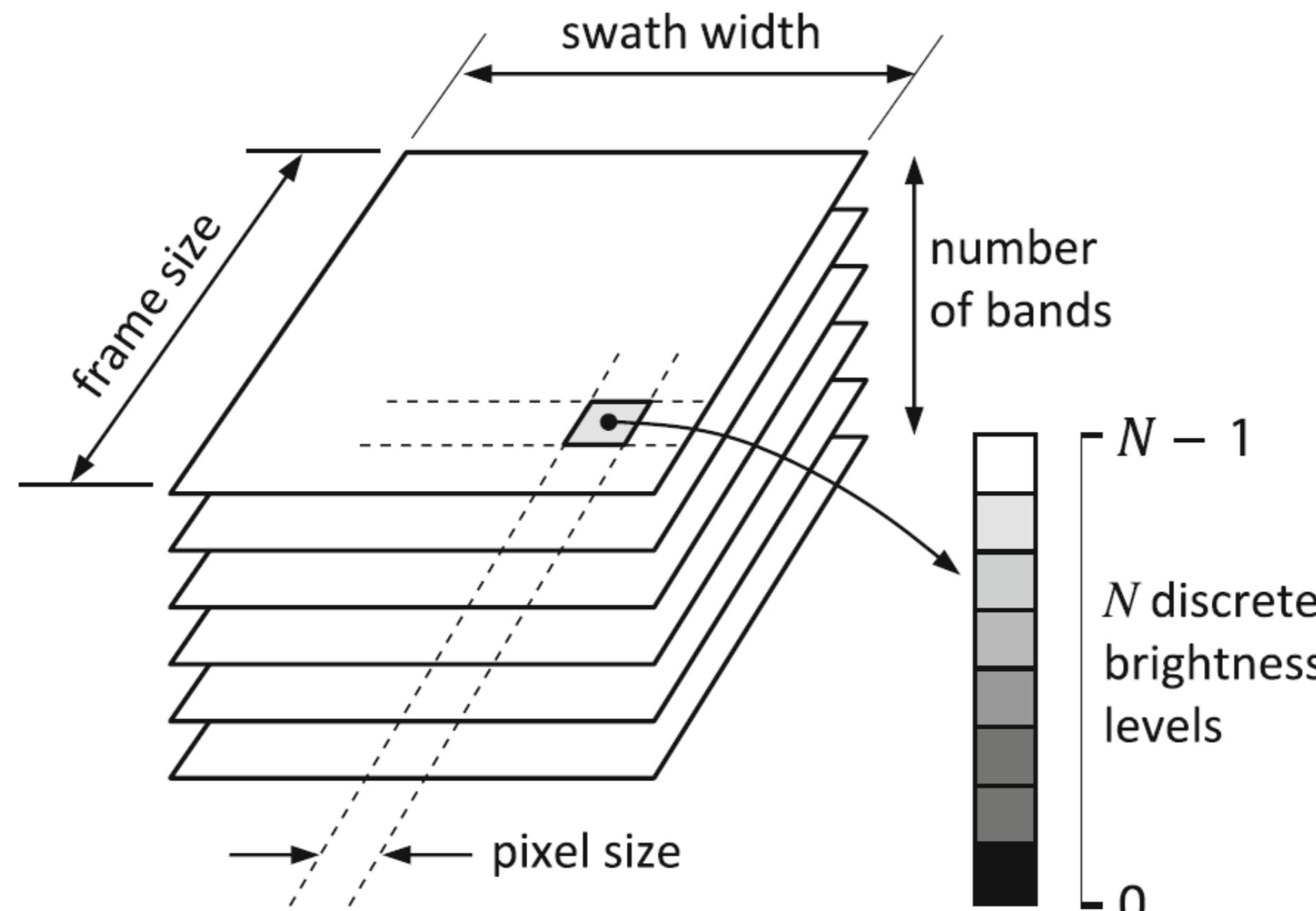
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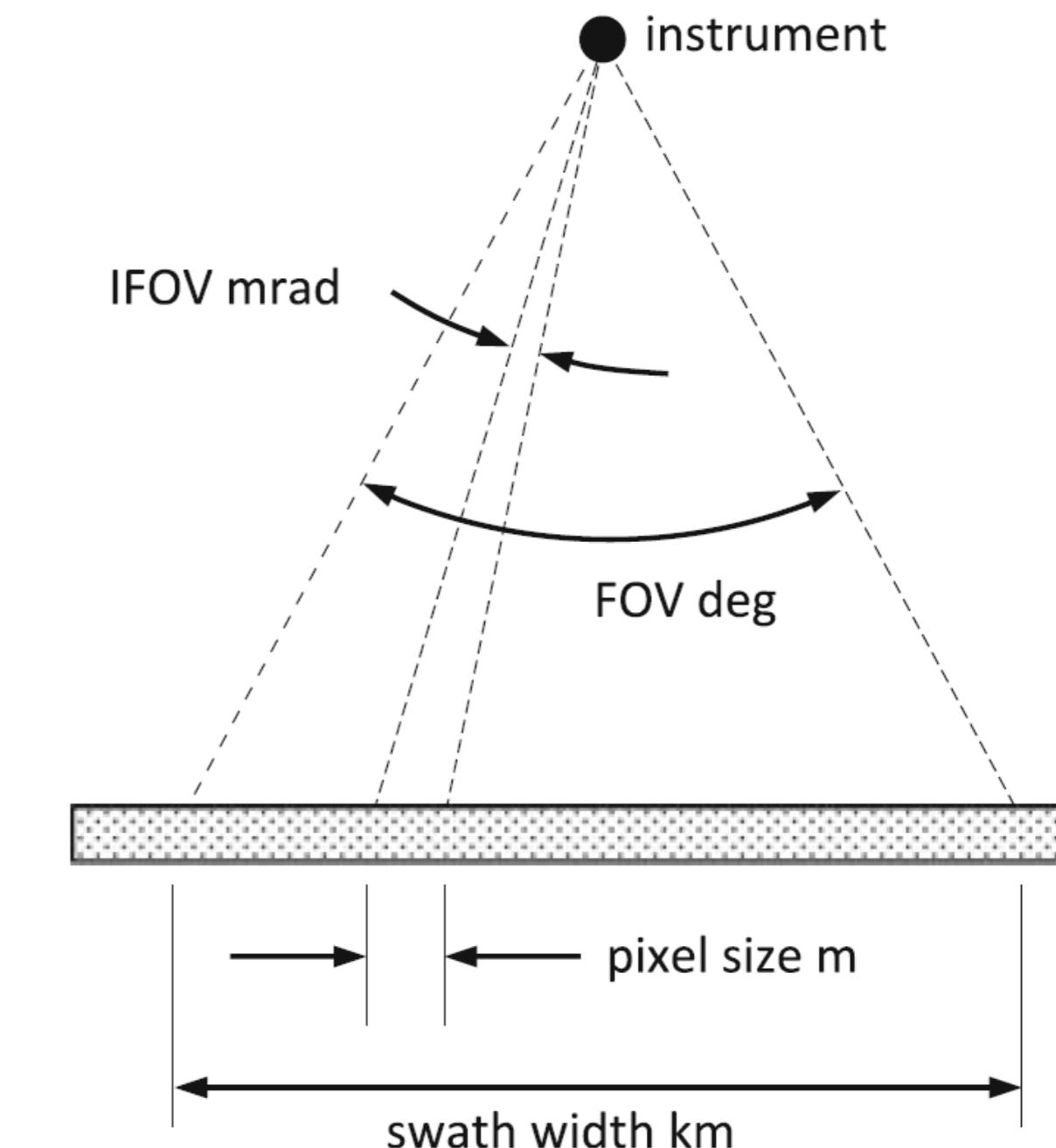


## Technical characteristics of digital image data



$N = 2^m$	
$m$	$N$
8	256
10	1024
12	4096
16	65536

## Definition of image spatial properties

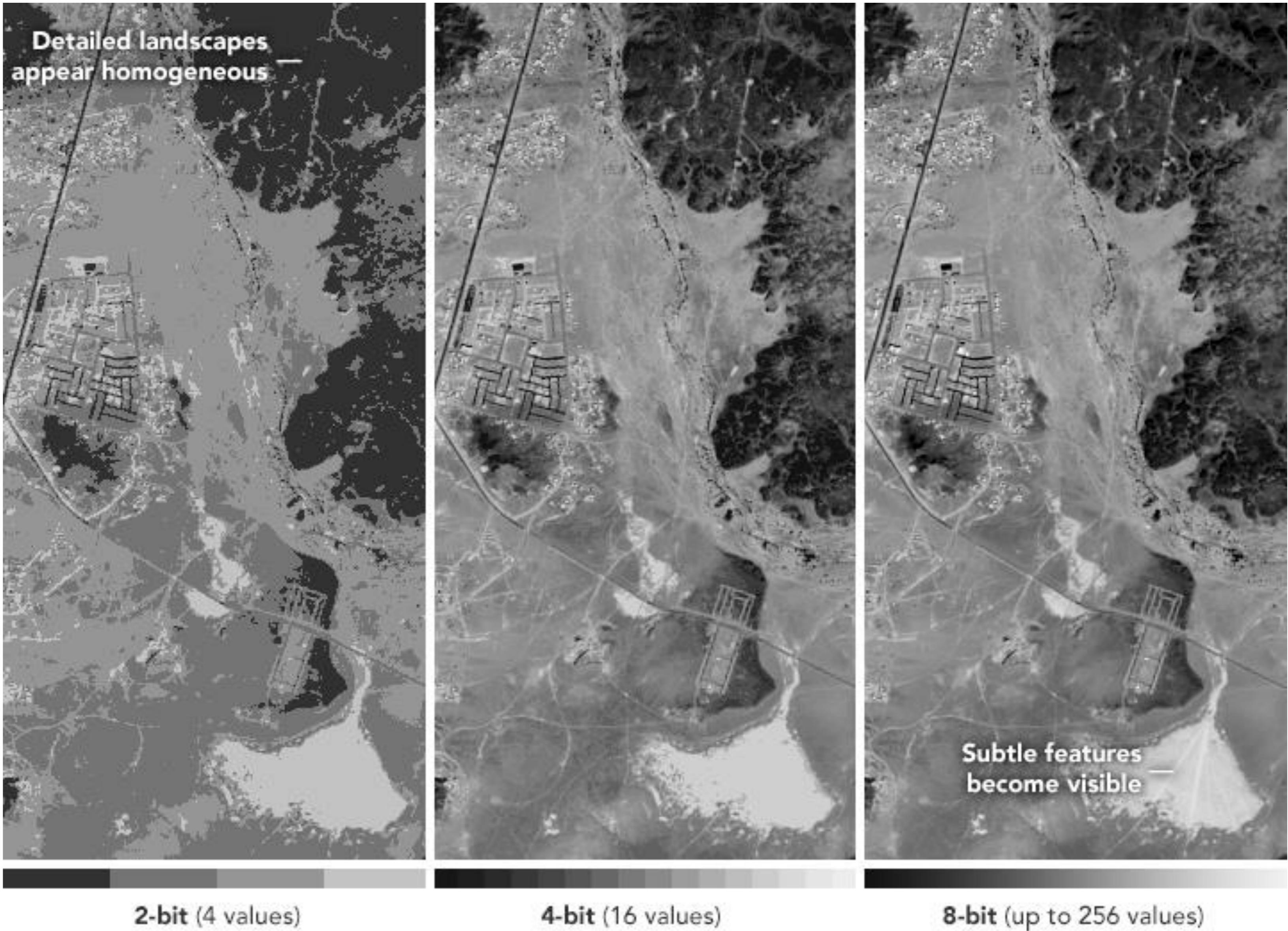


Richards, 2013

## 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>



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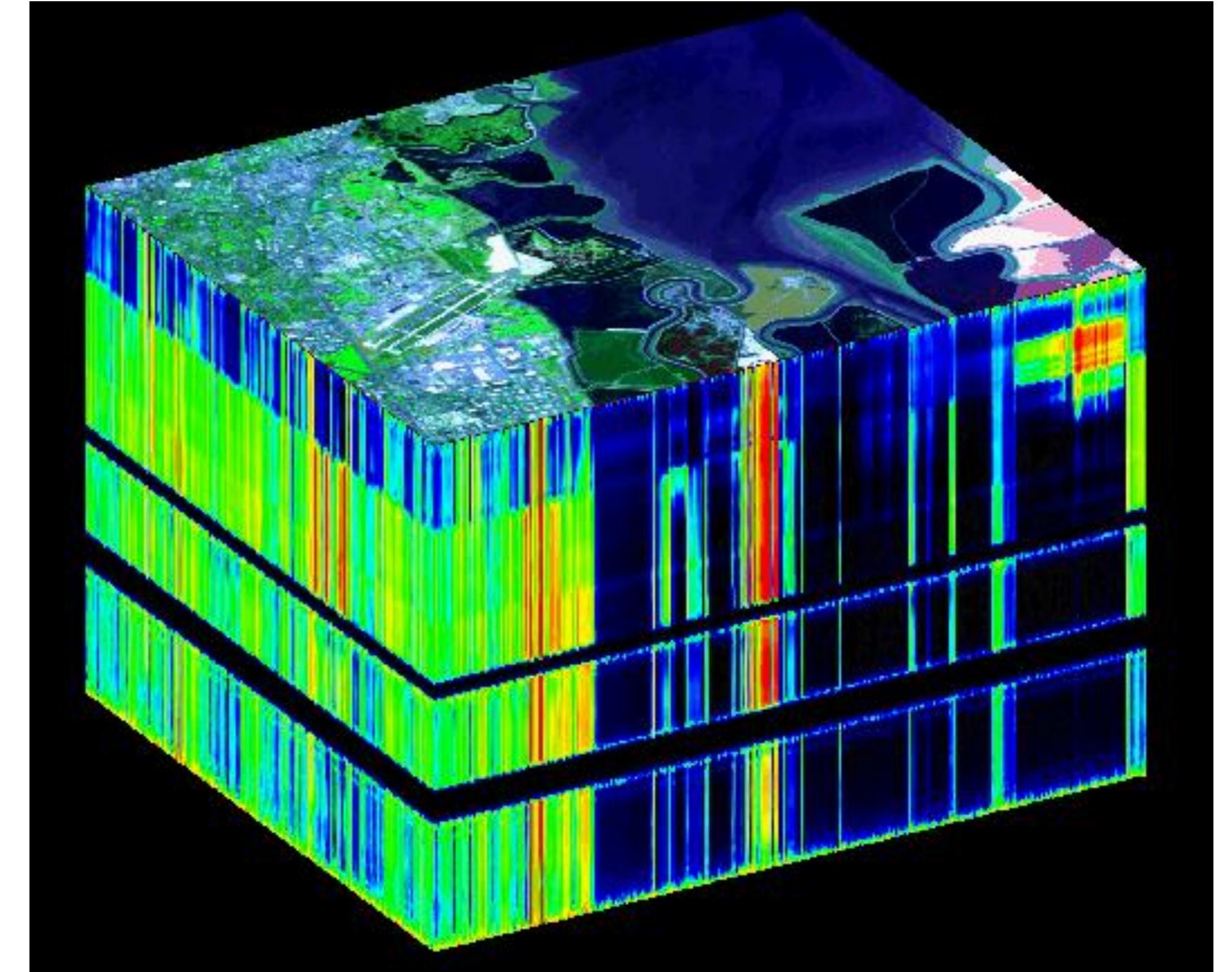


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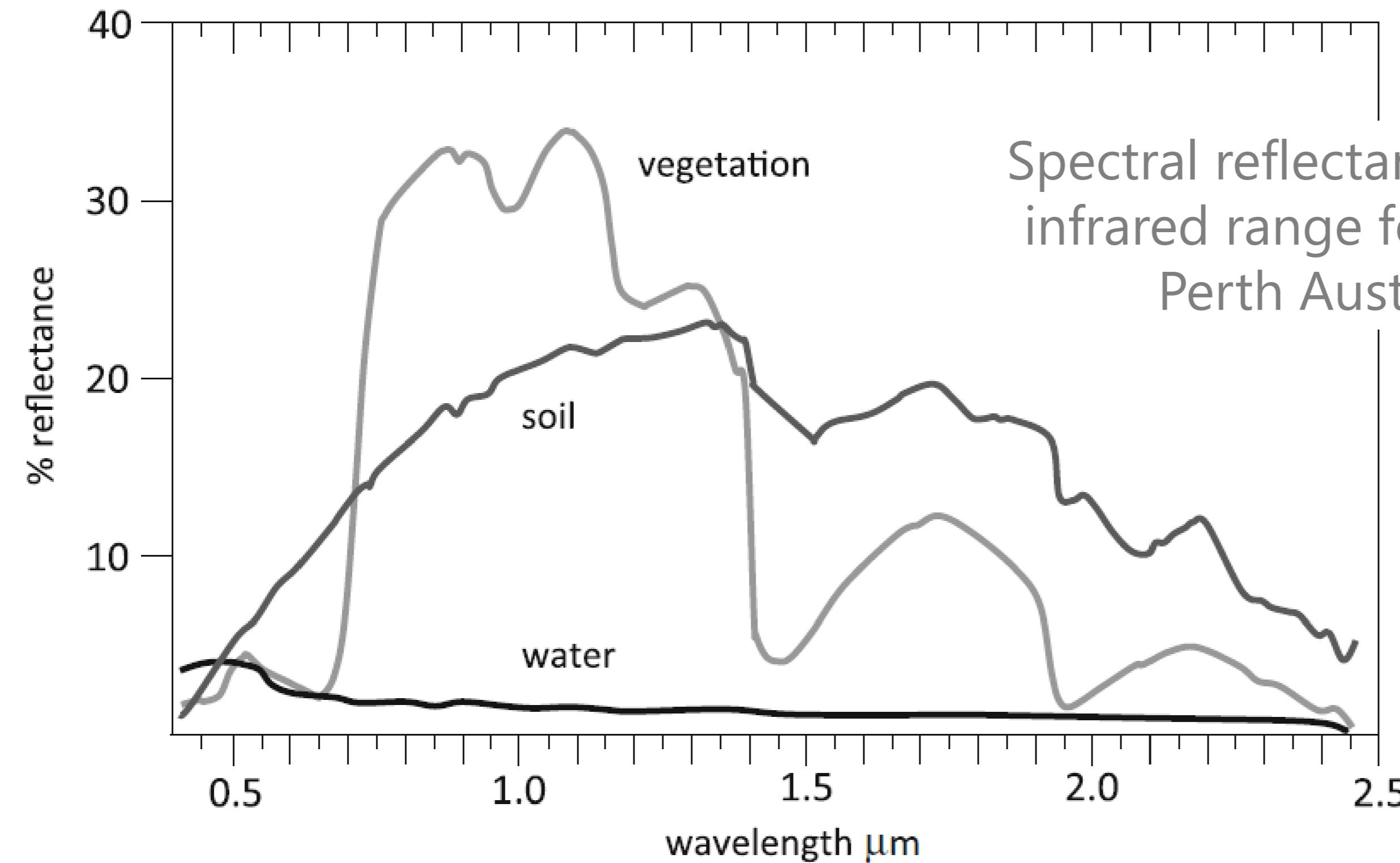


***Spectral resolution is the ability of a sensor to discern finer wavelengths, that is, having more and narrower bands.***

- 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).

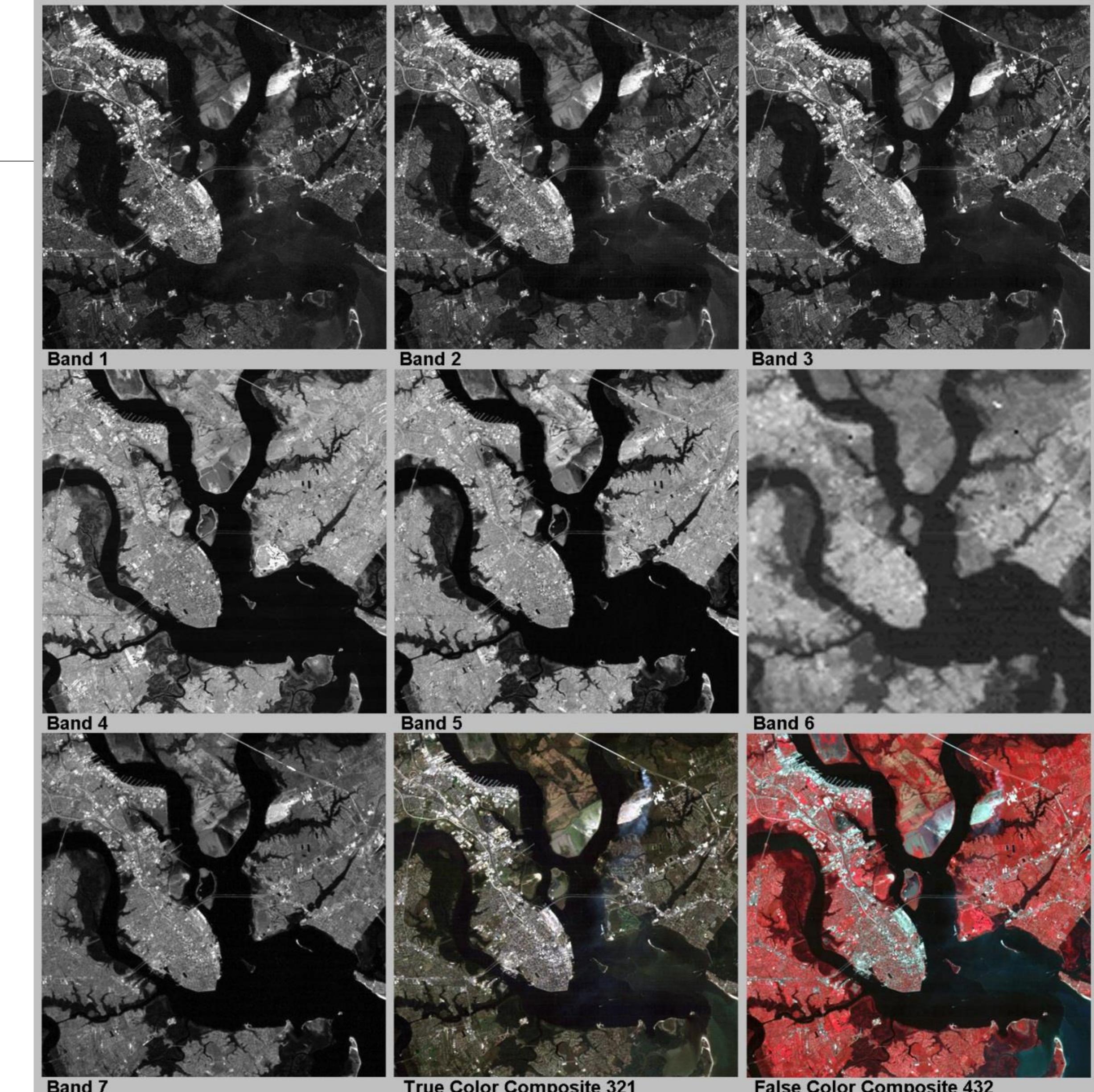


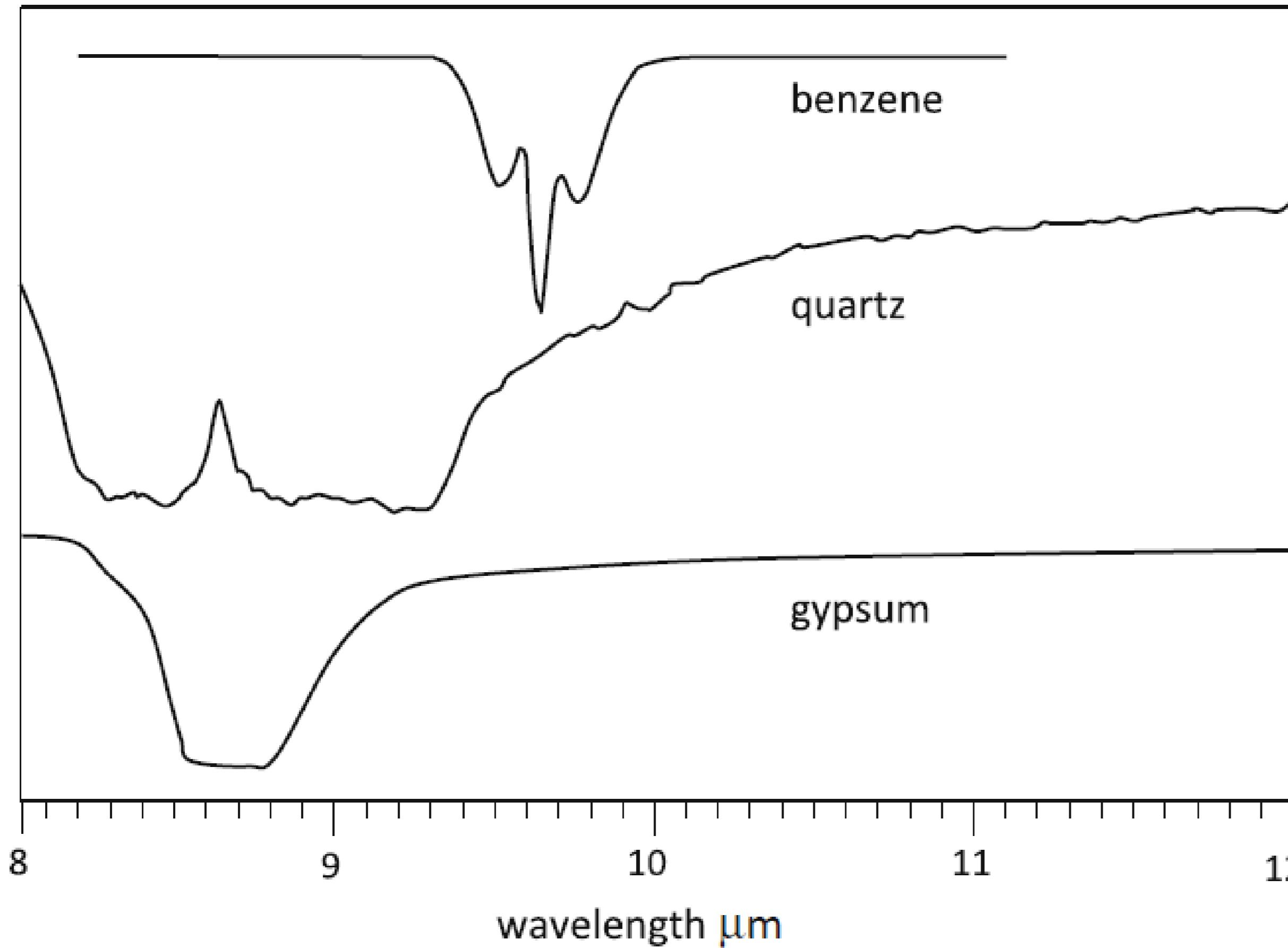
Spectral reflectance characteristics in the visible and reflective infrared range for three common cover types, recorded over Perth Australia using the HyVista HyMap scanner

# 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)

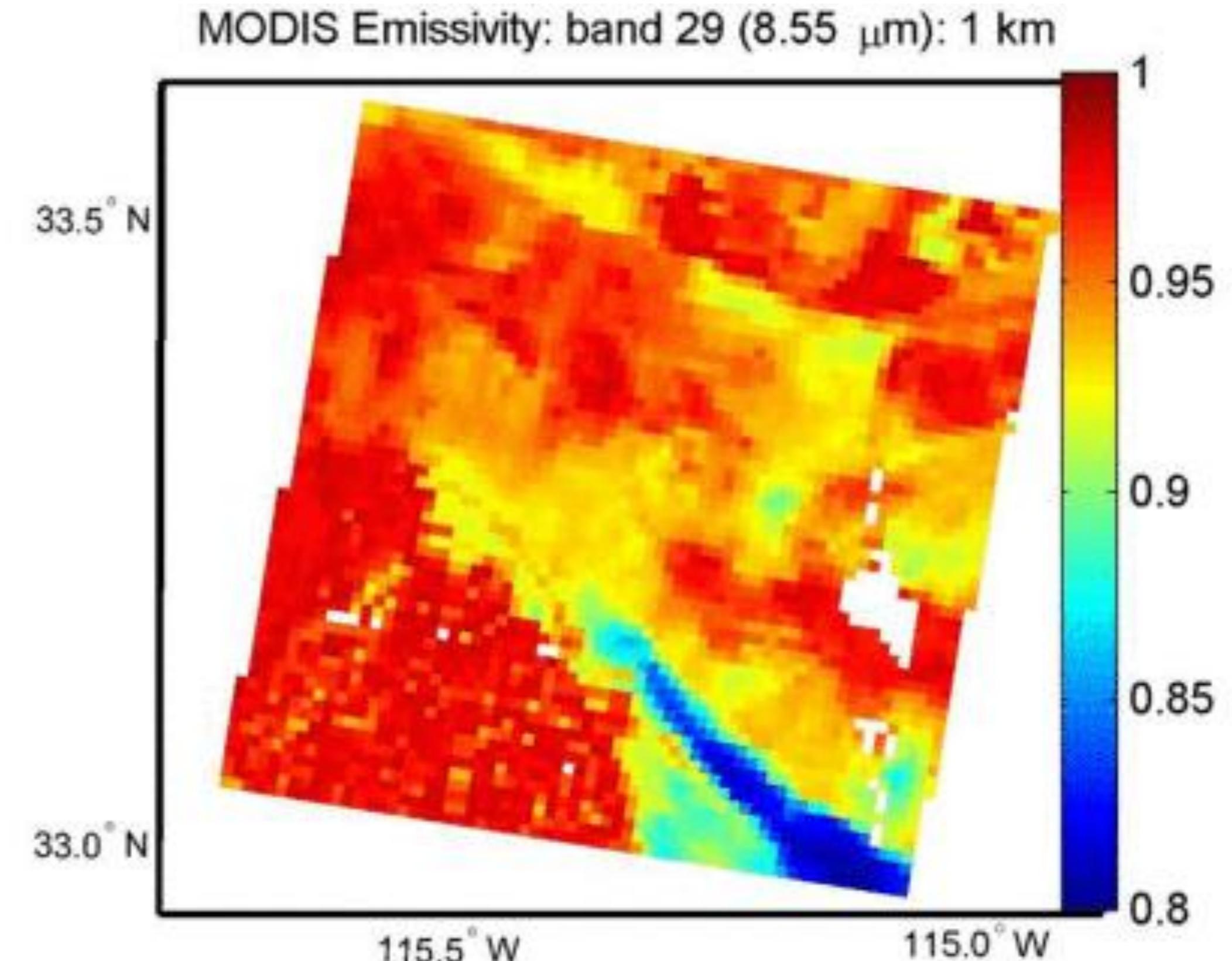
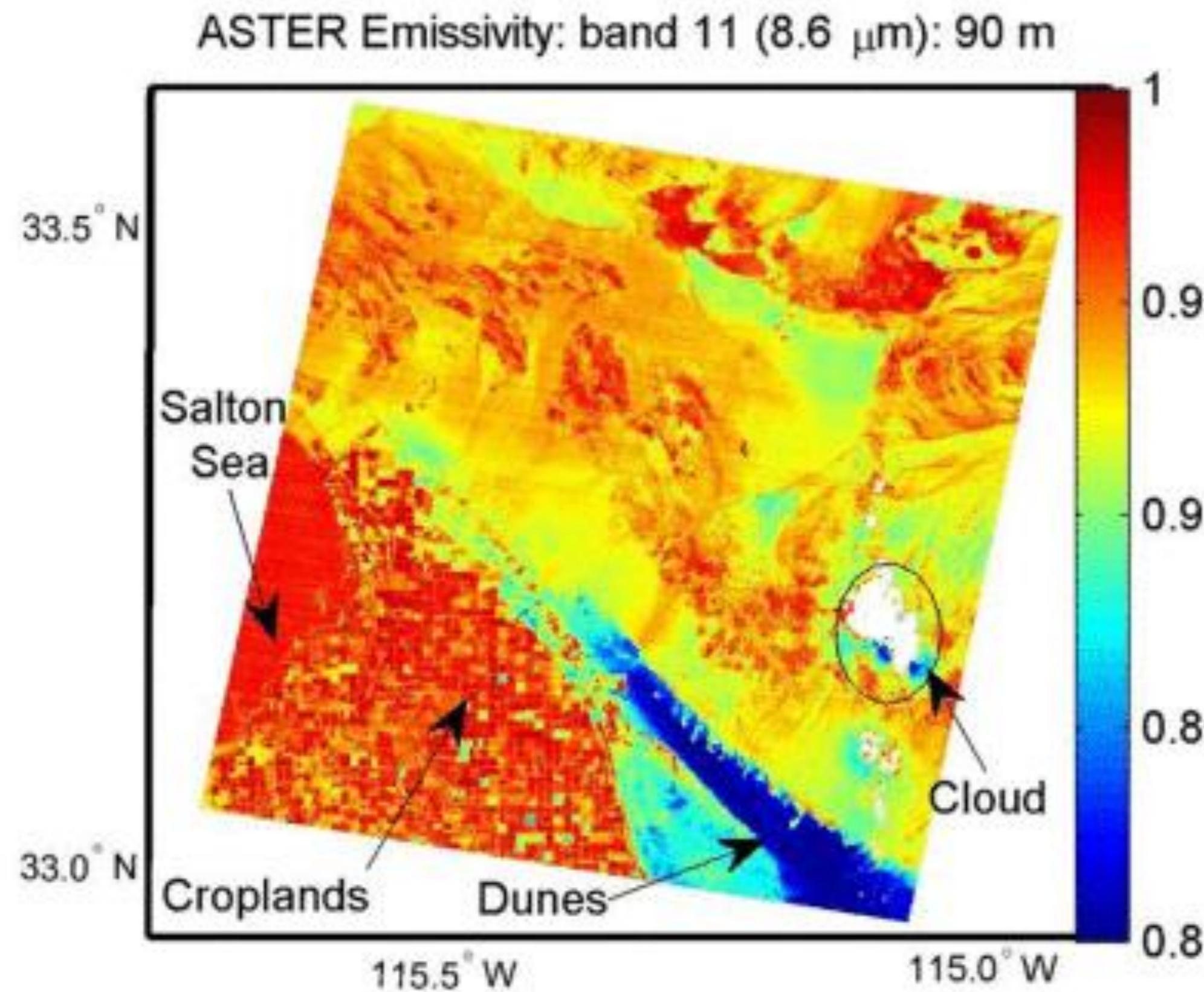




Some emissivity spectra in the thermal infrared range

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





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



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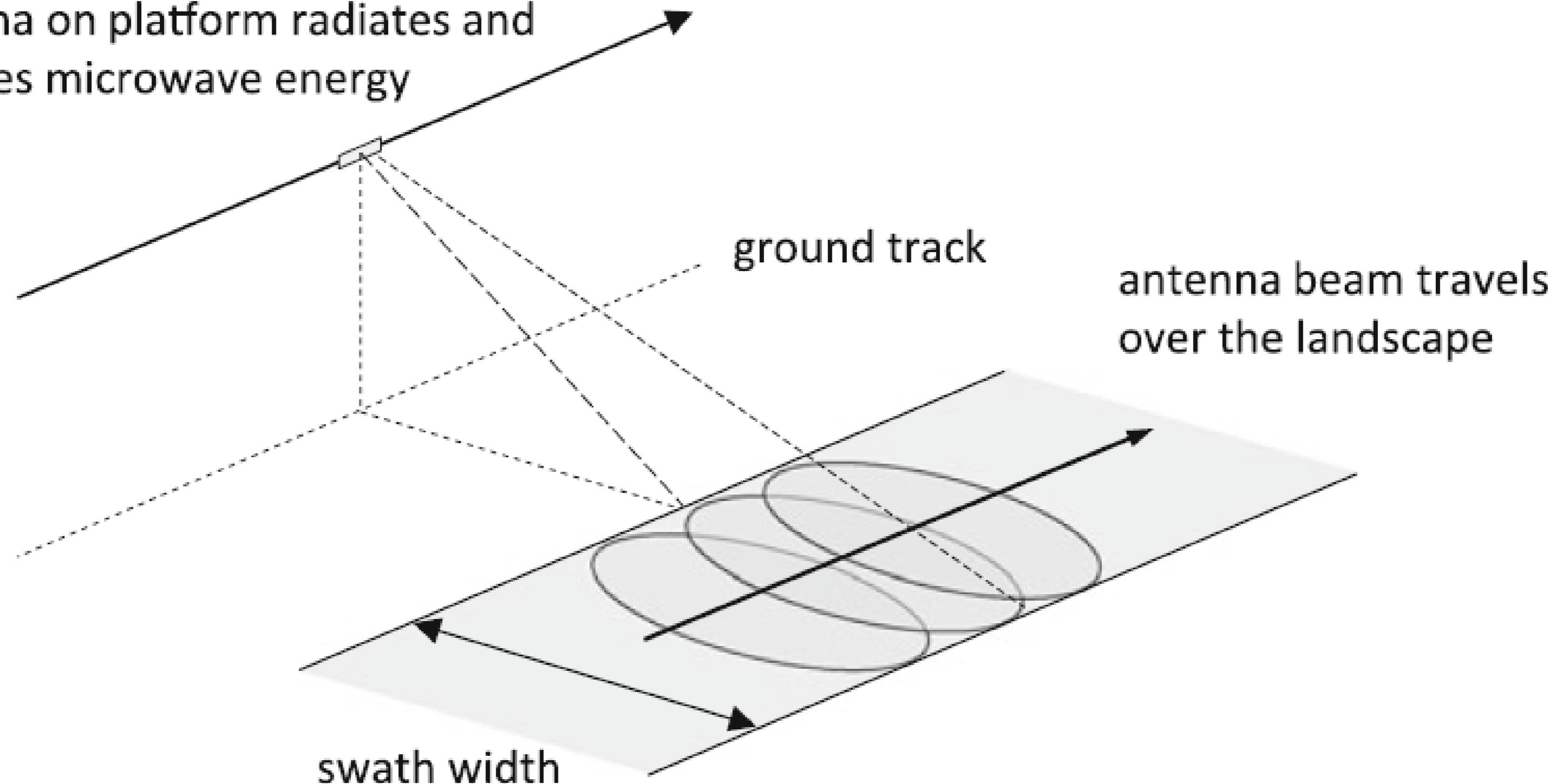


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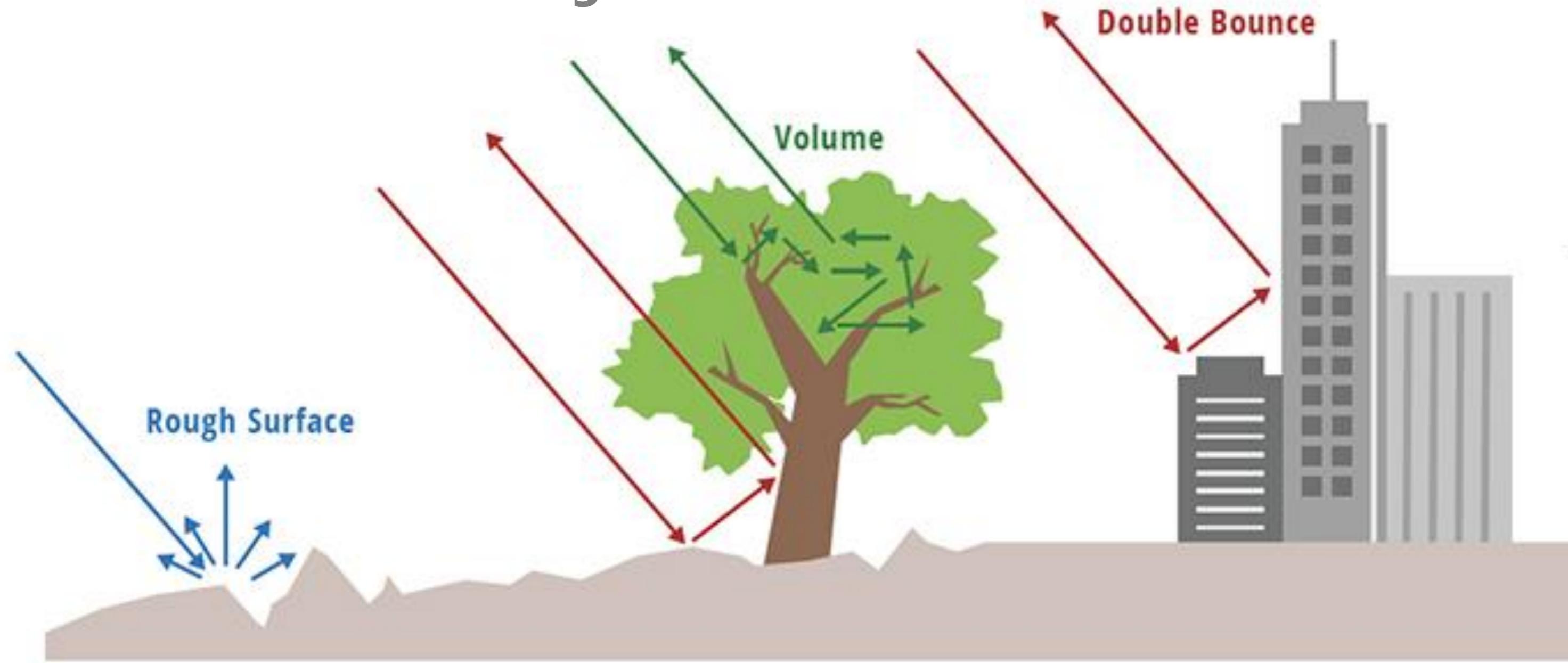
**microwave ranges**

antenna on platform radiates and receives microwave energy

**Synthetic aperture radar (SAR) imaging**

Richards, 2013

## Polarization and Scattering Mechanisms

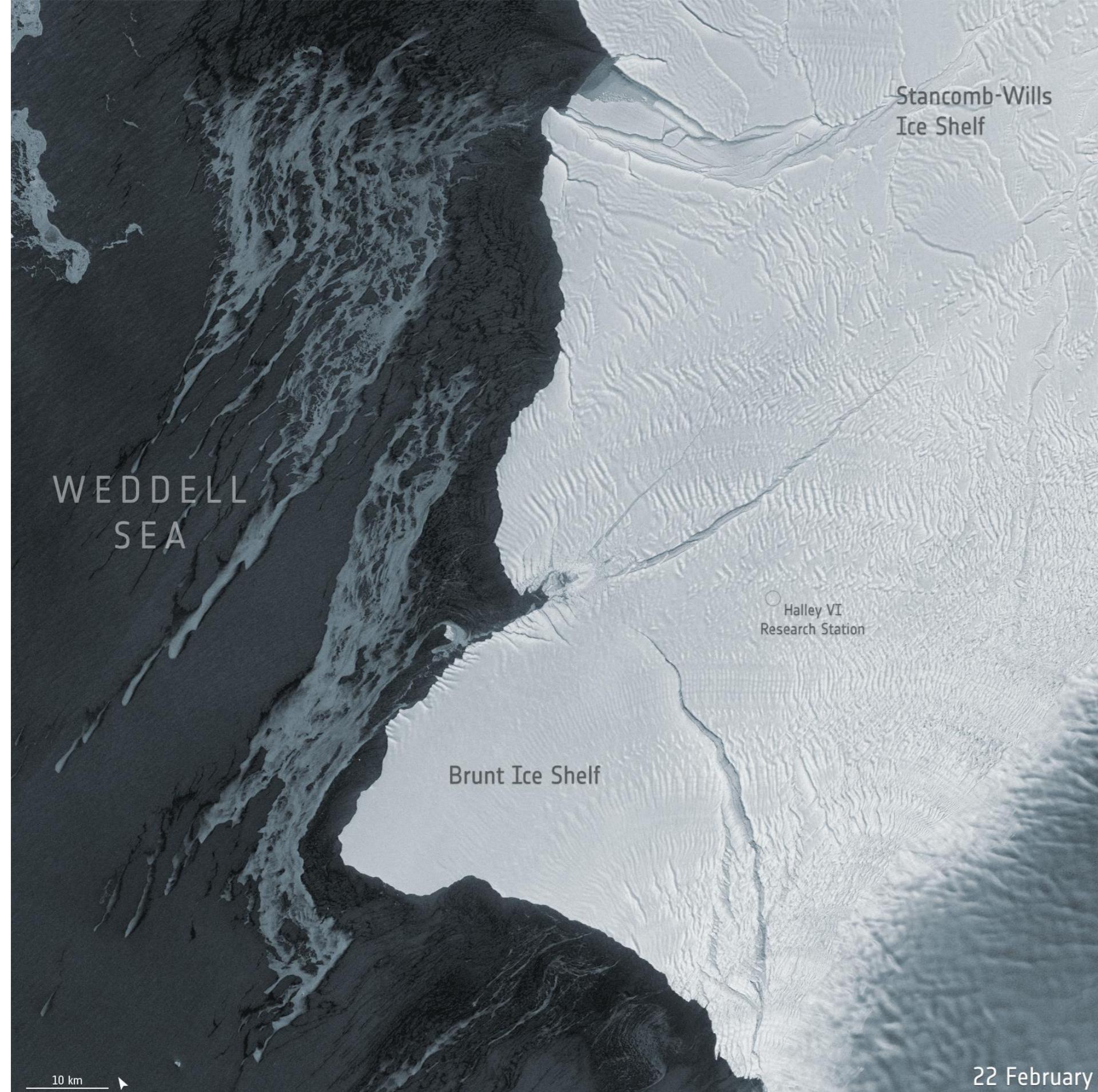


### RELATIVE SCATTERING STRENGTH BY POLARIZATION:

<b>Rough Surface Scattering</b>	$ S_W  >  S_{HH}  >  S_{HV} $ or $ S_{VH} $
<b>Double Bounce Scattering</b>	$ S_{HH}  >  S_W  >  S_{HV} $ or $ S_{VH} $
<b>Volume Scattering</b>	Main source of $ S_{HV} $ and $ S_{VH} $

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.





**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.**

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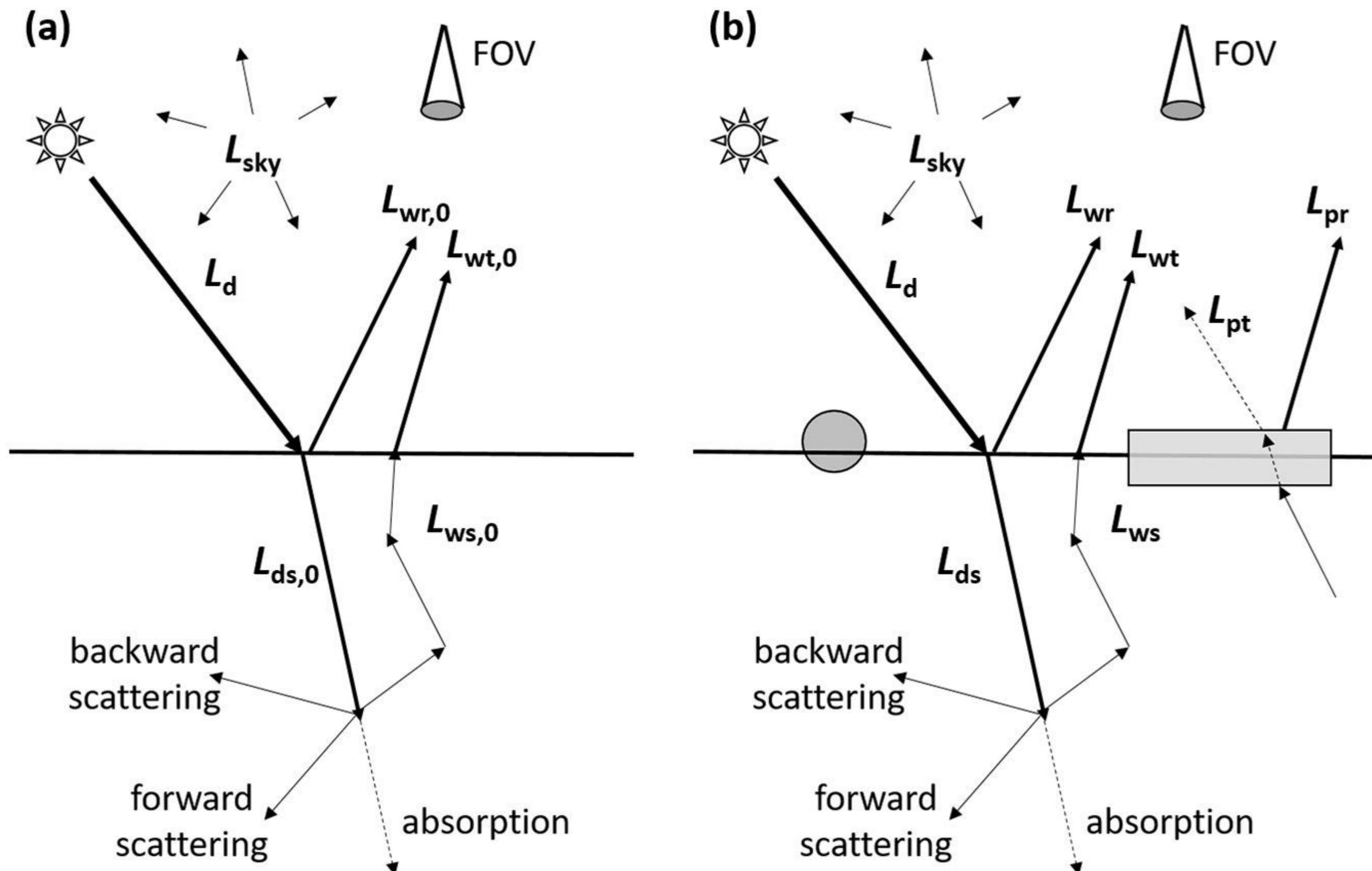
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## Can we use remote sensing to detect plastic debris on open waters?



## 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  $L_d$  total downwelling sunlight (solar beam + diffuse sky light),  $L_{ds}$  subsurface downwelling light,  $L_{ws}$  subsurface upwelling light,  $L_{wr}$  light reflected directly off the water surface,  $L_{wt}$  subsurface upwelling light transmitted through the water-air interface,  $L_{pr}$  light reflected off the plastic and  $L_{pt}$  subsurface upwelling light transmitted through the plastic.  $L_w$  is total water leaving light,  $L_{wr} + L_{wt}$ , and  $L_p$  is total plastic leaving light,  $L_{pt} + L_{pr}$ ; 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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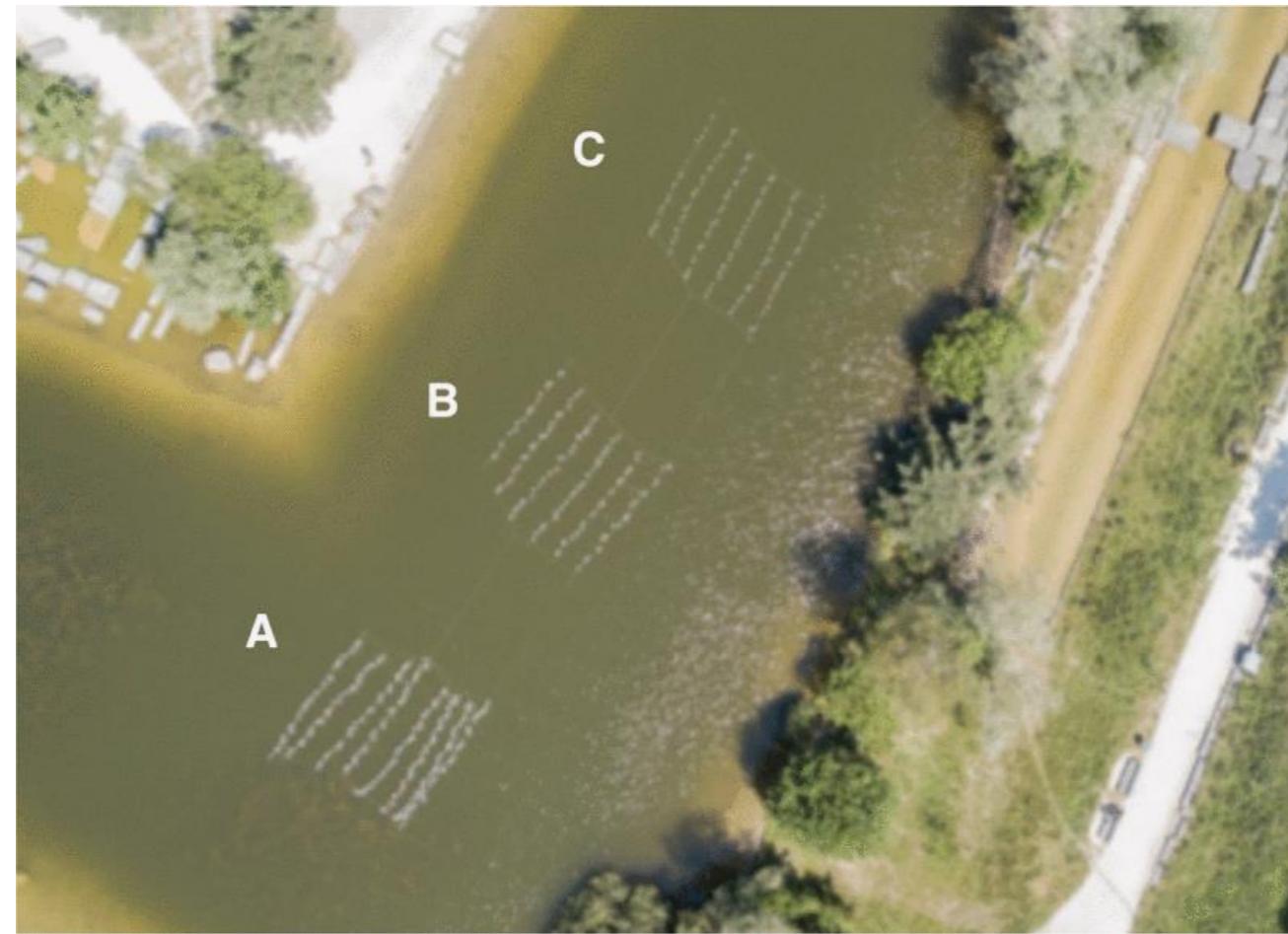
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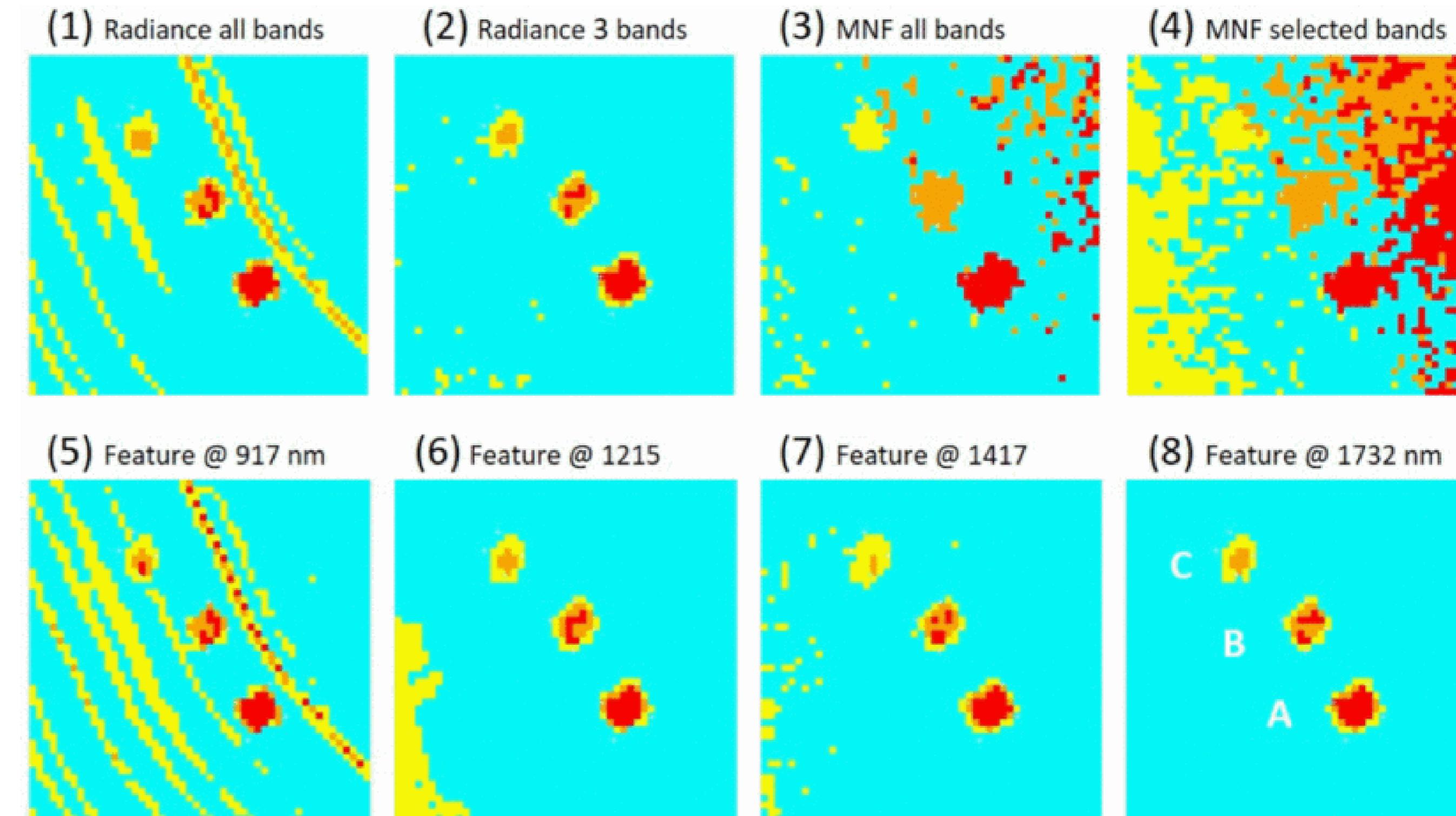
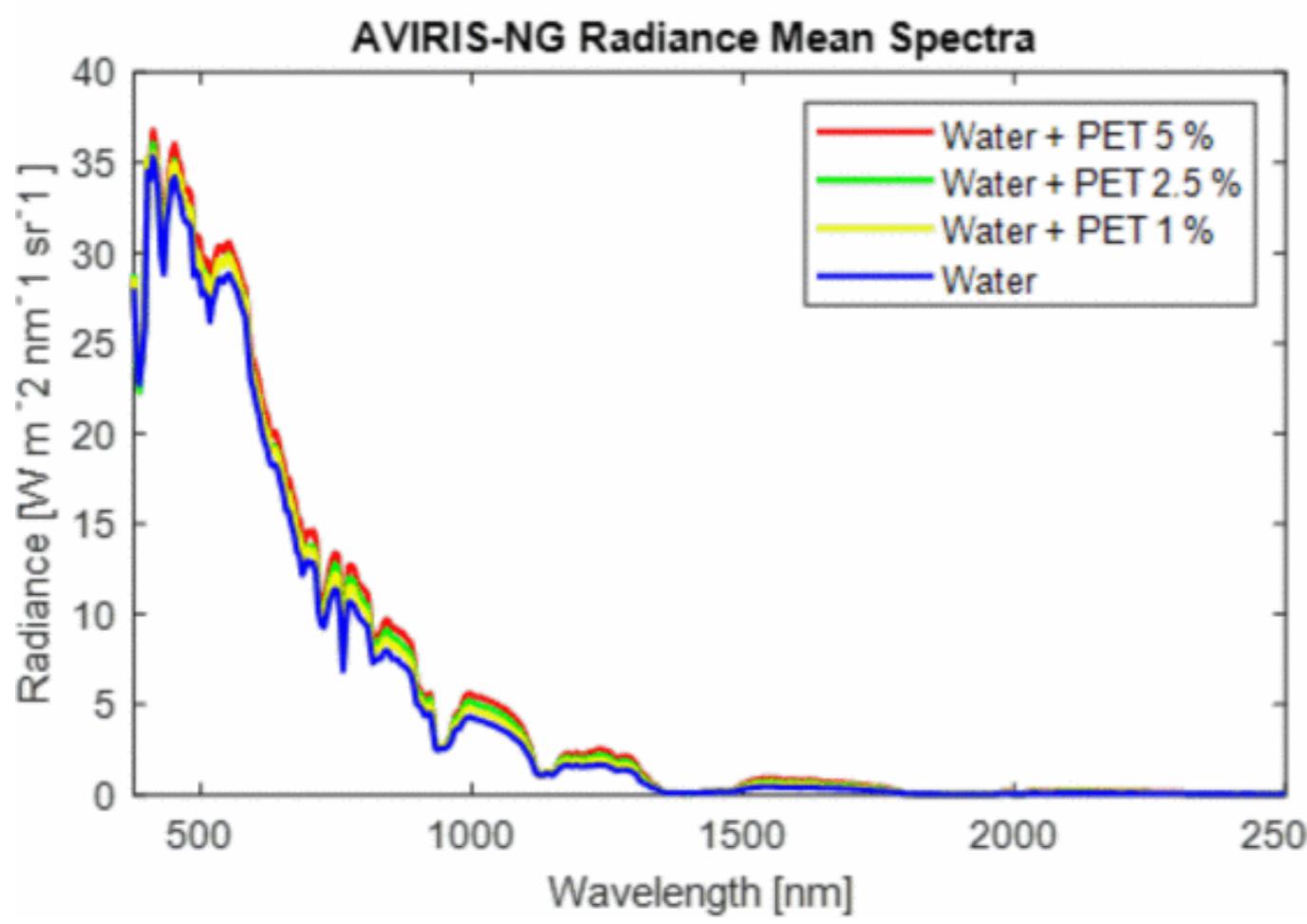


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## Classification of remote sensing in the visible and reflected infrared ranges



Hueni and S. Bertschi, 2020



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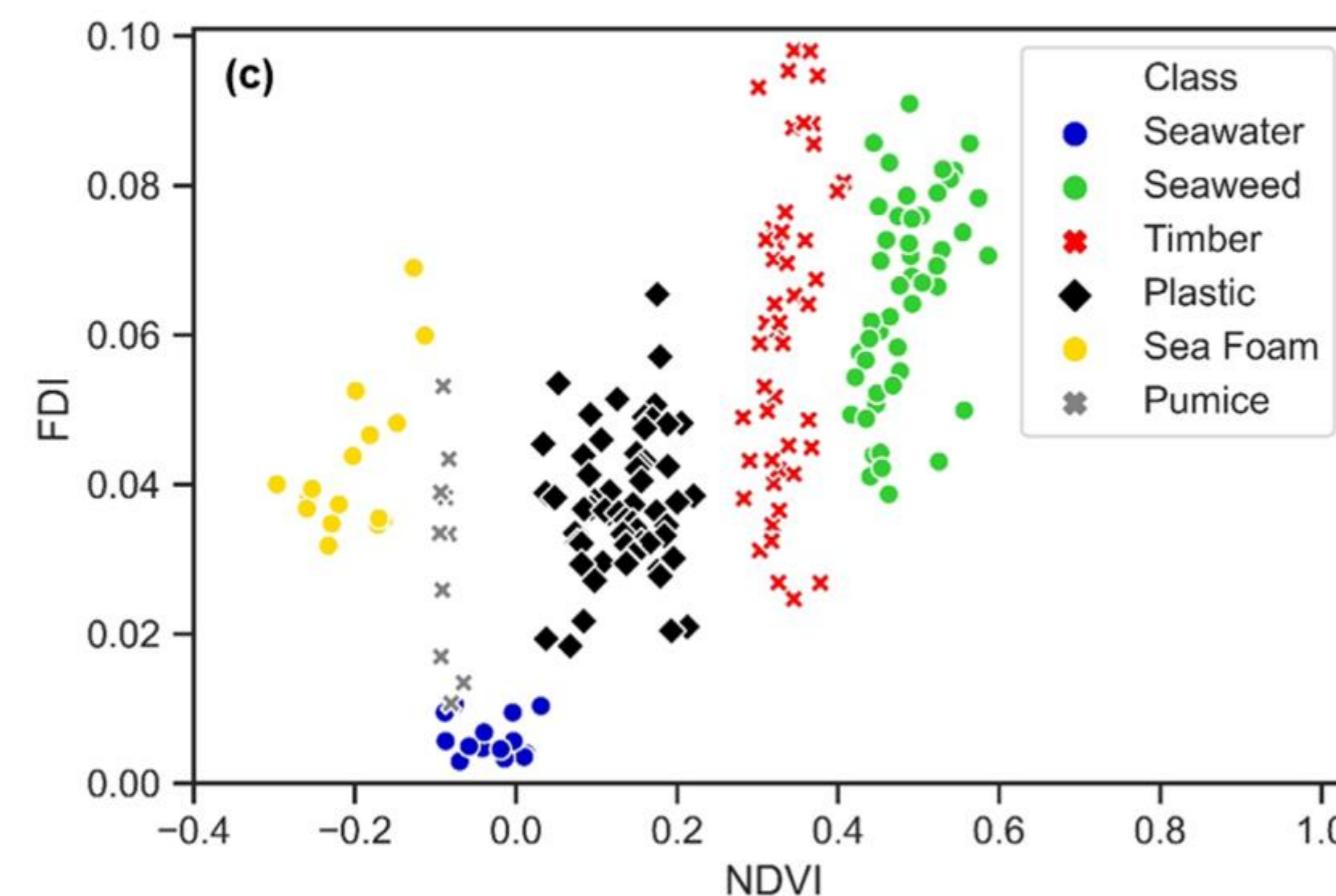
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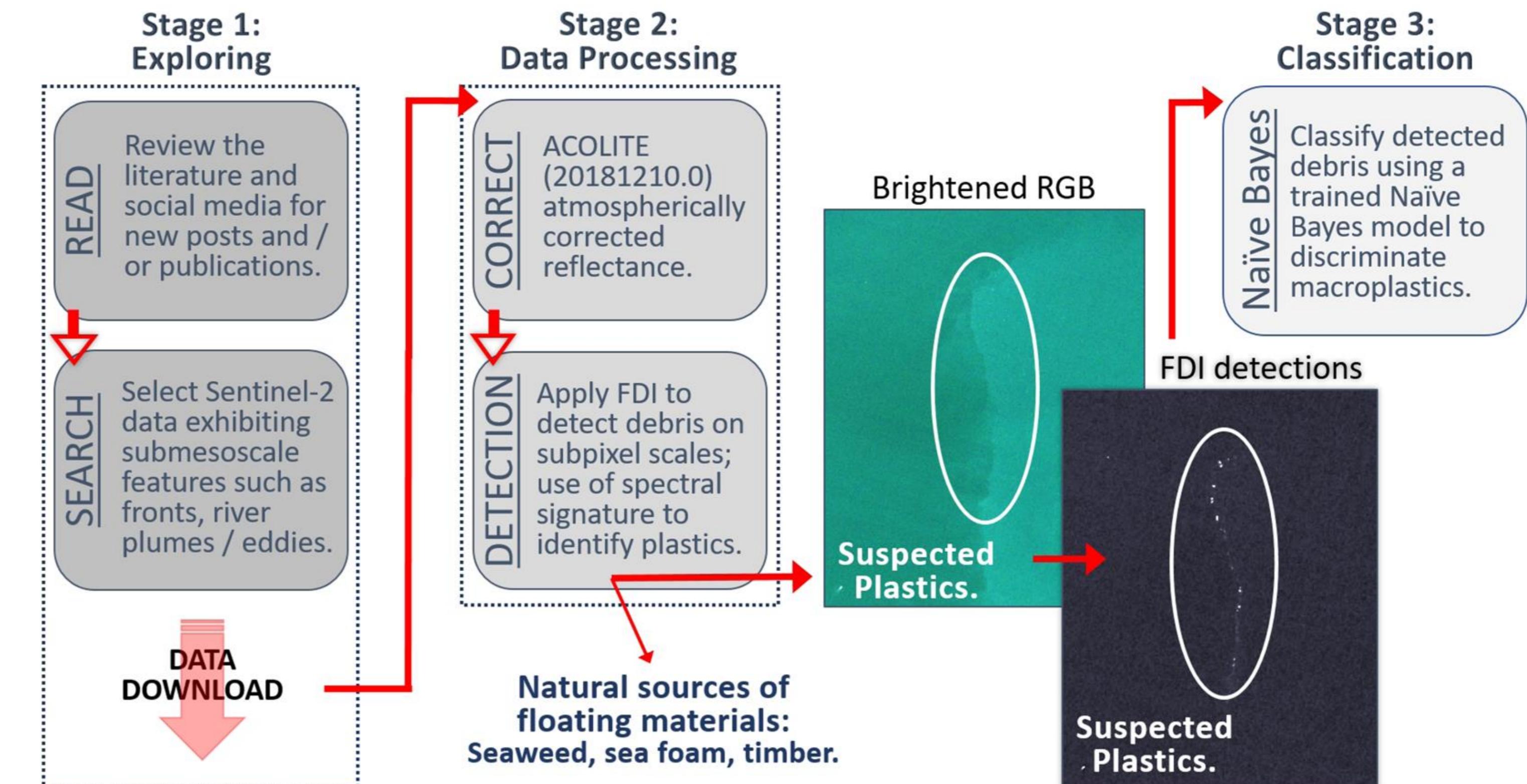
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## Spectral indexes



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



Biermann et al., 2020

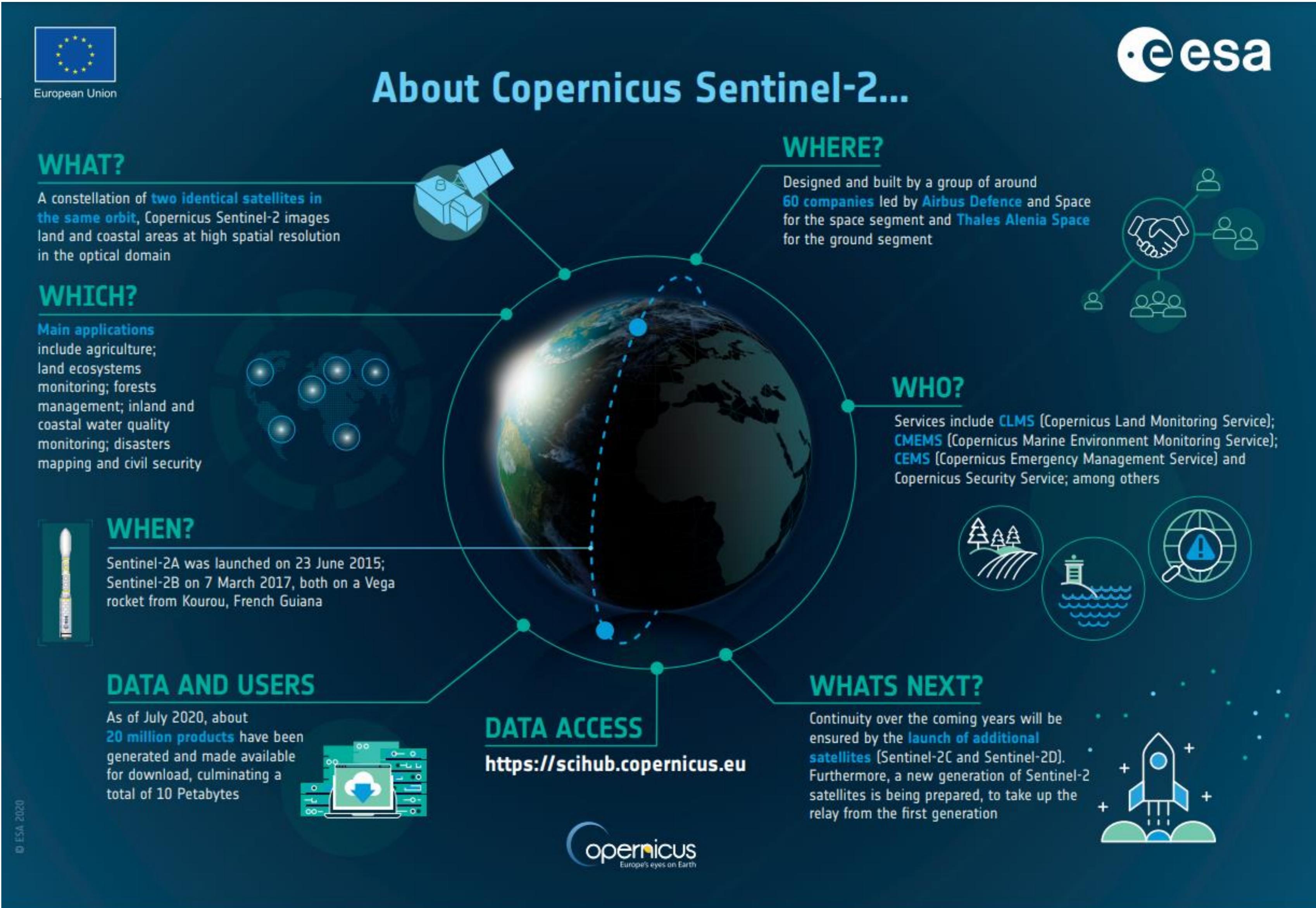
## Detecting macroplastics

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

[https://www.esa.int/Applications/Observing\\_the\\_Earth/Copernicus](https://www.esa.int/Applications/Observing_the_Earth/Copernicus)

European Union

## About Copernicus Sentinel-2...



**WHAT?**  
A constellation of **two identical satellites in the same orbit**, Copernicus Sentinel-2 images land and coastal areas at high spatial resolution in the optical domain

**WHICH?**  
Main applications include agriculture; land ecosystems monitoring; forests management; inland and coastal water quality monitoring; disasters mapping and civil security

**WHEN?**  
Sentinel-2A was launched on 23 June 2015; Sentinel-2B on 7 March 2017, both on a Vega rocket from Kourou, French Guiana

**WHERE?**  
Designed and built by a group of around **60 companies** led by **Airbus Defence and Space** for the space segment and **Thales Alenia Space** for the ground segment

**WHO?**  
Services include **CLMS** (Copernicus Land Monitoring Service); **CMEMS** (Copernicus Marine Environment Monitoring Service); **CEMS** (Copernicus Emergency Management Service) and Copernicus Security Service; among others

**DATA AND USERS**  
As of July 2020, about **20 million products** have been generated and made available for download, culminating a total of 10 Petabytes

**DATA ACCESS**  
<https://scihub.copernicus.eu>

**WHAT'S NEXT?**  
Continuity over the coming years will be ensured by the **launch of additional satellites** (Sentinel-2C and Sentinel-2D). Furthermore, a new generation of Sentinel-2 satellites is being prepared, to take up the relay from the first generation

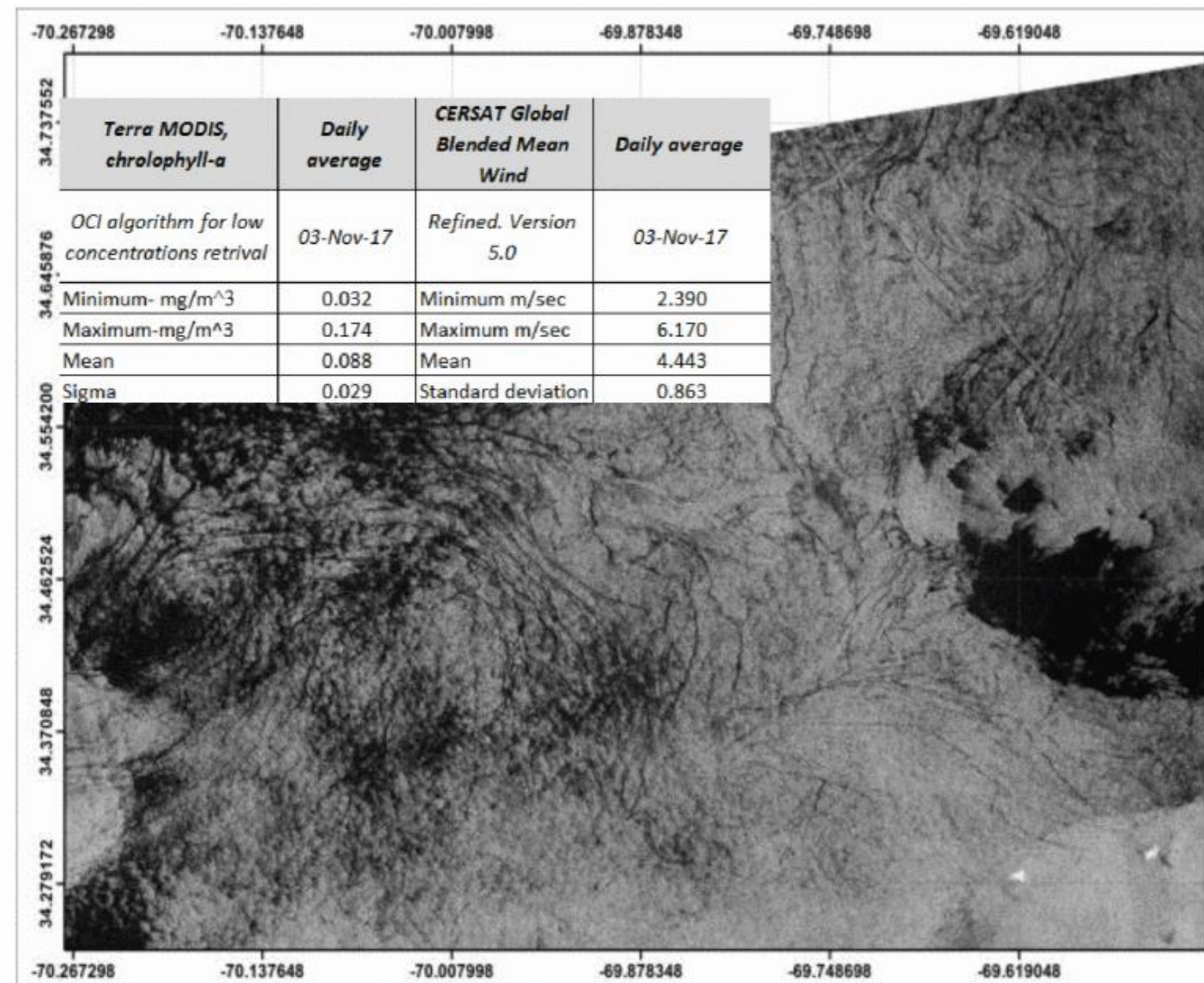
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Europe's eyes on Earth

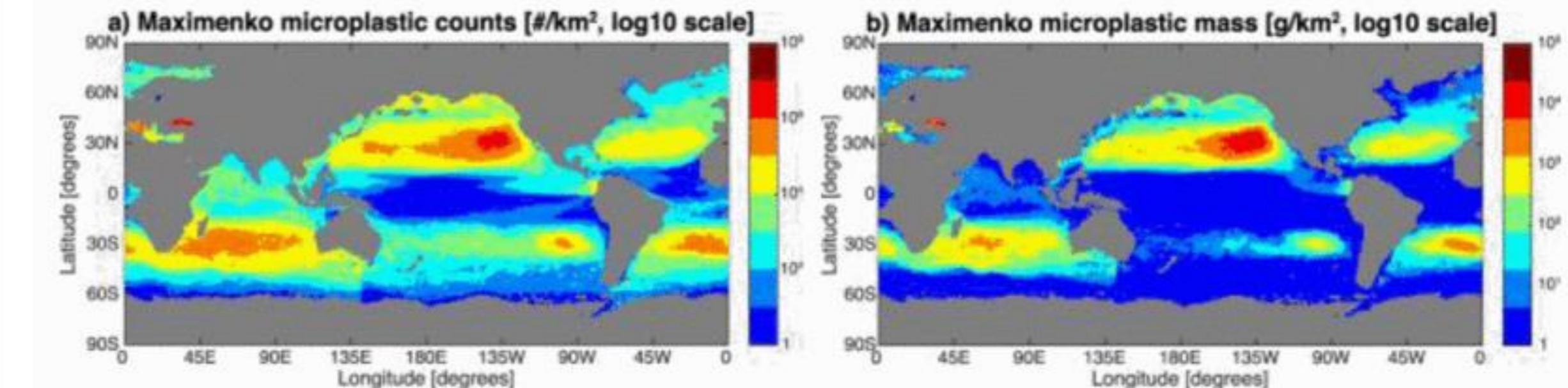


# Detecting microplastics

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



## Solutions of microplastics count



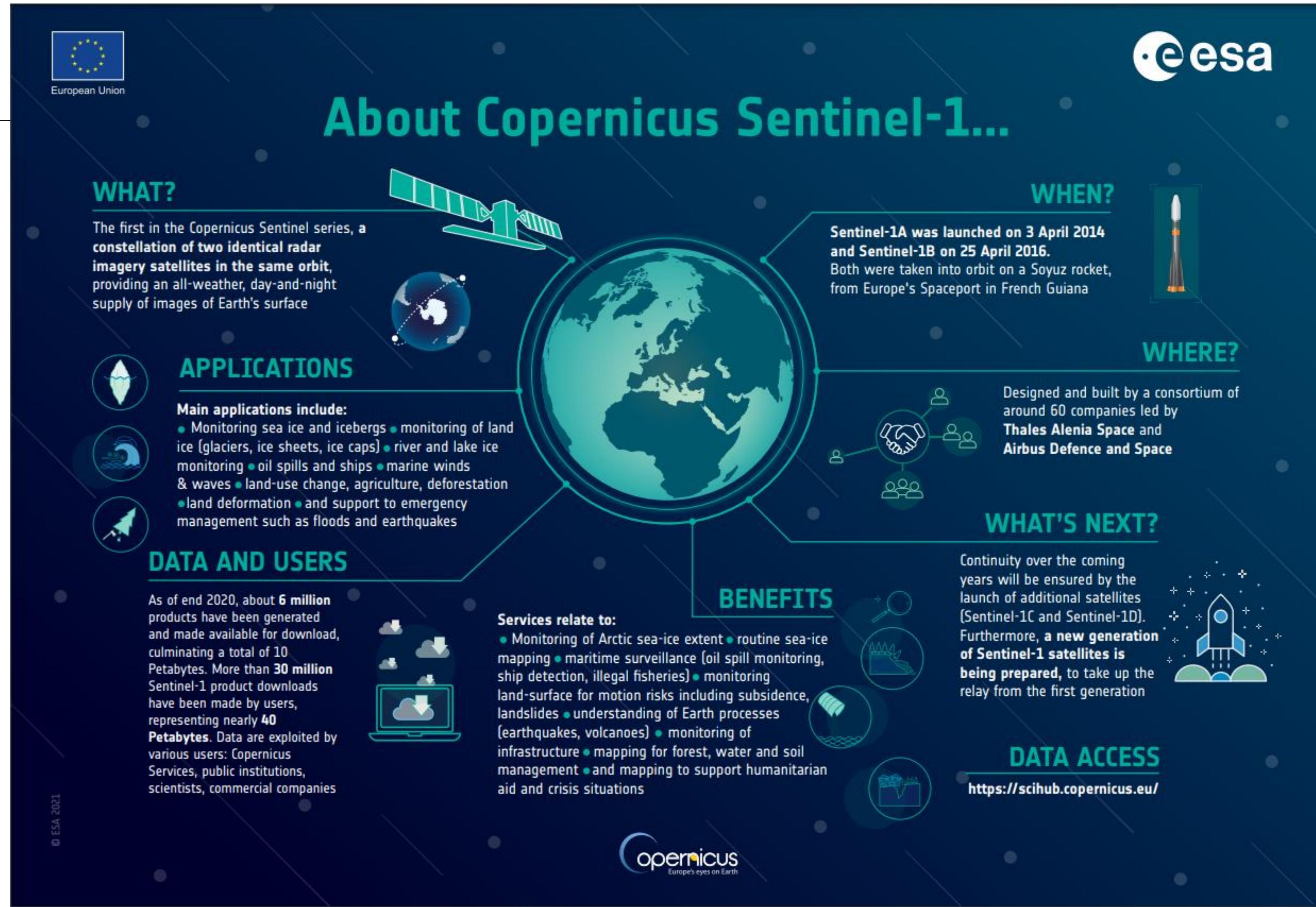
Identify sites polluted by microplastics using SAR sensors by detecting the surfactants, sea-slicks and bio-films at the ocean surface (the dark patches in grayscale intensity SAR images), otherwise not visible in optical images

Davaasuren et al., 2018



# Detecting microplastics

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



The infographic is titled "About Copernicus Sentinel-1..." and is presented in a circular format with a central Earth icon. It includes sections for "WHAT?", "APPLICATIONS", "DATA AND USERS", "BENEFITS", "WHEN?", "WHERE?", and "WHAT'S NEXT?".

**WHAT?**  
The first in the Copernicus Sentinel series, a **constellation of two identical radar imagery satellites in the same orbit**, providing an all-weather, day-and-night supply of images of Earth's surface.

**APPLICATIONS**  
Main applications include:  

- Monitoring sea ice and icebergs
- monitoring of land ice (glaciers, ice sheets, ice caps)
- river and lake ice monitoring
- oil spills and ships
- marine winds & waves
- land-use change, agriculture, deforestation
- land deformation
- and support to emergency management such as floods and earthquakes

**DATA AND USERS**  
As of end 2020, about **6 million** products have been generated and made available for download, culminating a total of **10 Petabytes**. More than **30 million** Sentinel-1 product downloads have been made by users, representing nearly **40 Petabytes**. Data are exploited by various users: Copernicus Services, public institutions, scientists, commercial companies.

**BENEFITS**  
Services relate to:  

- Monitoring of Arctic sea-ice extent
- routine sea-ice mapping
- maritime surveillance (oil spill monitoring, ship detection, illegal fisheries)
- monitoring land-surface for motion risks including subsidence, landslides
- understanding of Earth processes (earthquakes, volcanoes)
- monitoring of infrastructure
- mapping for forest, water and soil management
- and mapping to support humanitarian aid and crisis situations

**WHEN?**  
Sentinel-1A was launched on **3 April 2014** and Sentinel-1B on **25 April 2016**. Both were taken into orbit on a Soyuz rocket, from Europe's Spaceport in French Guiana.

**WHERE?**  
Designed and built by a consortium of around 60 companies led by **Thales Alenia Space** and **Airbus Defence and Space**.

**WHAT'S NEXT?**  
Continuity over the coming years will be ensured by the launch of additional satellites (Sentinel-1C and Sentinel-1D). Furthermore, a **new generation of Sentinel-1 satellites is being prepared**, to take up the relay from the first generation.

**DATA ACCESS**  
<https://scihub.copernicus.eu/>

**European Union** logo

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**Copernicus**  
Europe's eyes on Earth





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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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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Biermann, L., Clewley, D., Martinez-Vicente, V. et al. Finding Plastic Patches in Coastal Waters using Optical Satellite Data. *Sci Rep* 10, 5364 (2020). <https://doi.org/10.1038/s41598-020-62298-z>

N. Davaasuren et al., "Detecting Microplastics Pollution in World Oceans Using Sar Remote Sensing," *IGARSS 2018 - 2018 IEEE International Geoscience and Remote Sensing Symposium*, 2018, pp. 938-941, doi: 10.1109/IGARSS.2018.8517281.

Lonneke Goddijn-Murphy, Juvenal Dufaur, Proof of concept for a model of light reflectance of plastics floating on natural waters, *Marine Pollution Bulletin*, Volume 135, 2018, Pages 1145-1157, <https://doi.org/10.1016/j.marpolbul.2018.08.044>.

Lonneke Goddijn-Murphy, Steef Peters, Erik van Sebille, Neil A. James, Stuart Gibb, Concept for a hyperspectral remote sensing algorithm for floating marine macro plastics, *Marine Pollution Bulletin*, Volume 126, 2018, Pages 255-262, <https://doi.org/10.1016/j.marpolbul.2017.11.011>

Hueni and S. Bertschi, "DETECTION OF SUB-PIXEL PLASTIC ABUNDANCE ON WATER SURFACES USING AIRBORNE IMAGING SPECTROSCOPY," *IGARSS 2020 - 2020 IEEE International Geoscience and Remote Sensing Symposium*, 2020, pp. 6325-6328, doi: 10.1109/IGARSS39084.2020.9323556.

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

T. Schmugge, A. French, J. Ritchie, M. Chopping and A. Rango, ASTER observations of the spectral emissivity for arid lands, *Proc. Int. Geoscience and Remote Sensing Symposium*, vol. II, Sydney, Australia, 9–13 July 2001, pp. 715–717

The background of the image is an underwater scene. A large green sea turtle is swimming in the foreground, looking towards the camera. In the water above it, there is a significant amount of plastic waste, including a large plastic bag and several plastic bottles of various colors (blue, green, yellow). The water is a deep blue, and the surface is visible in the background where it meets a sky filled with clouds.

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