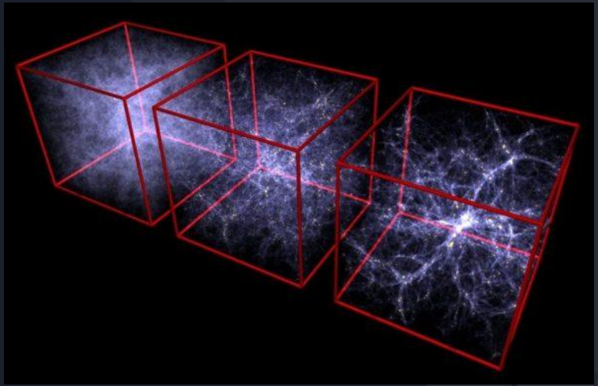
The Universe, The Earth and Uranus

(a personal journey through space, computers and music)

Edoardo Carlesi, PhD, Machine Learning Specialist, Bass player

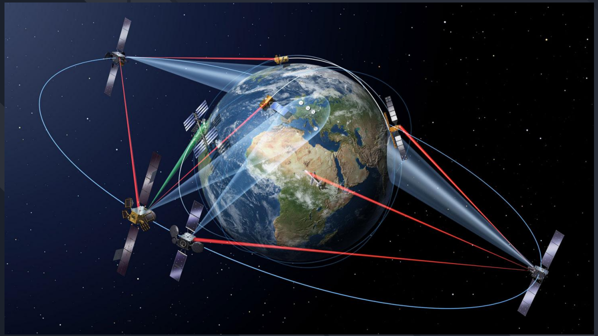
topnetwork

OUTLINE



The Universe:

Cosmological simulations



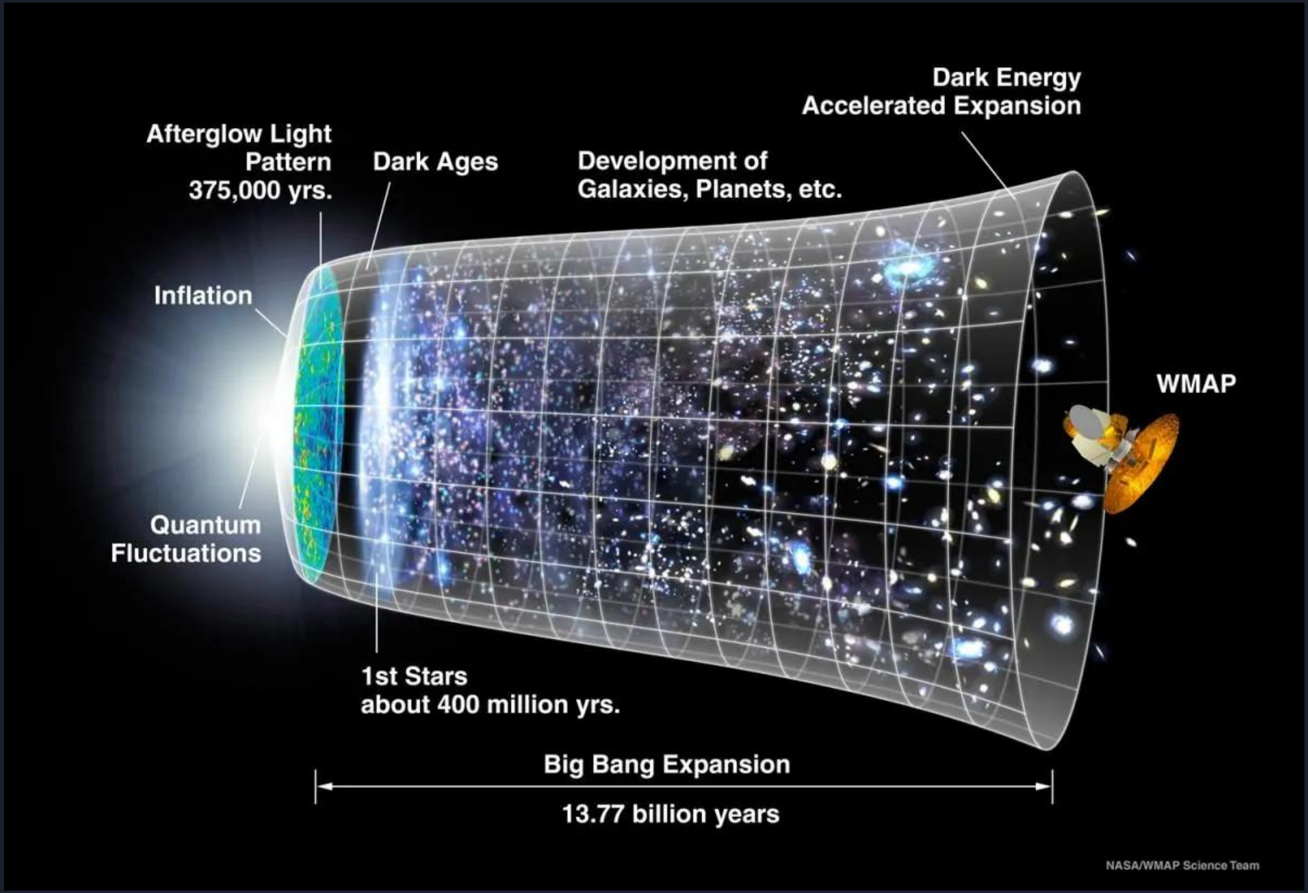
The Earth:

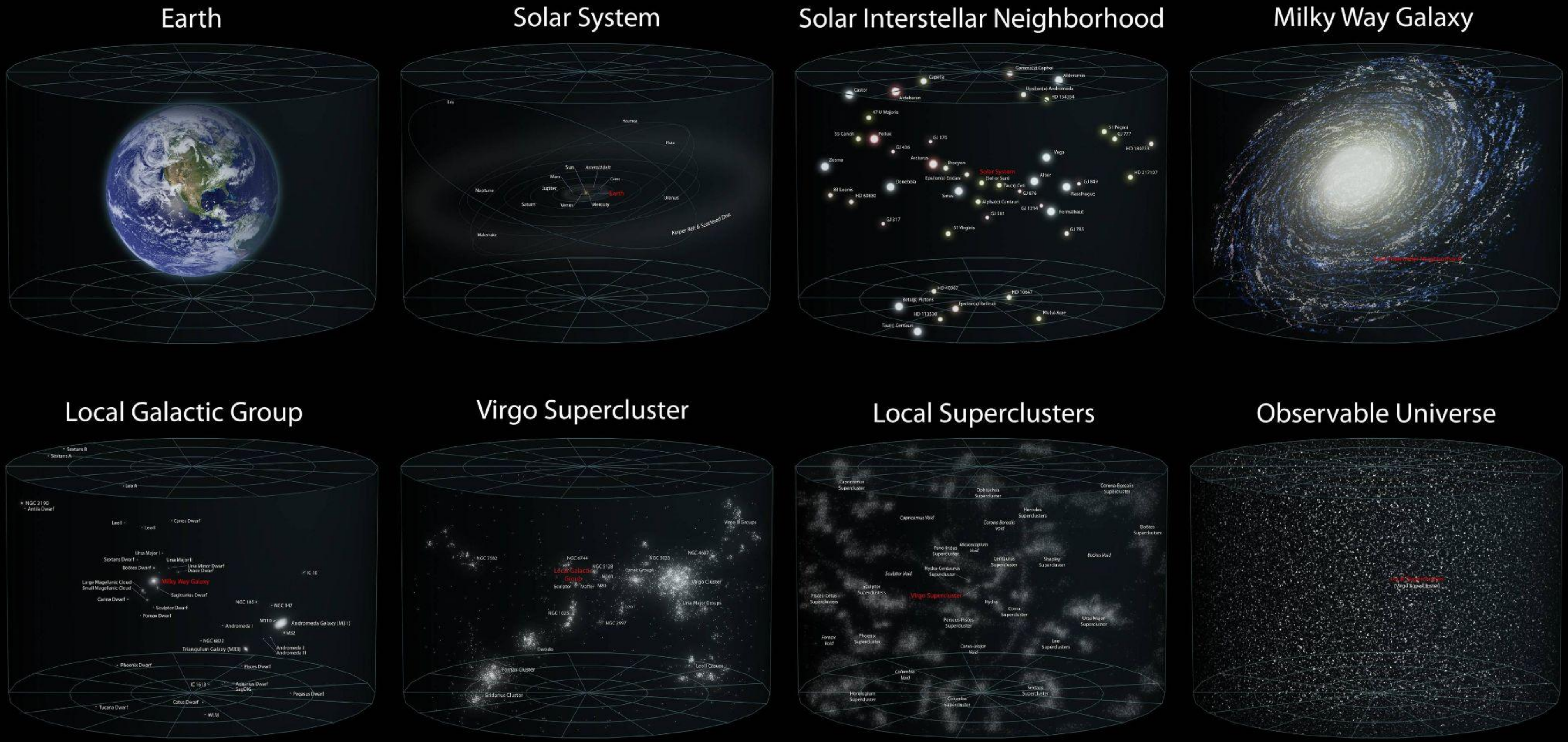
Satellite observations and machine learning

Uranus:

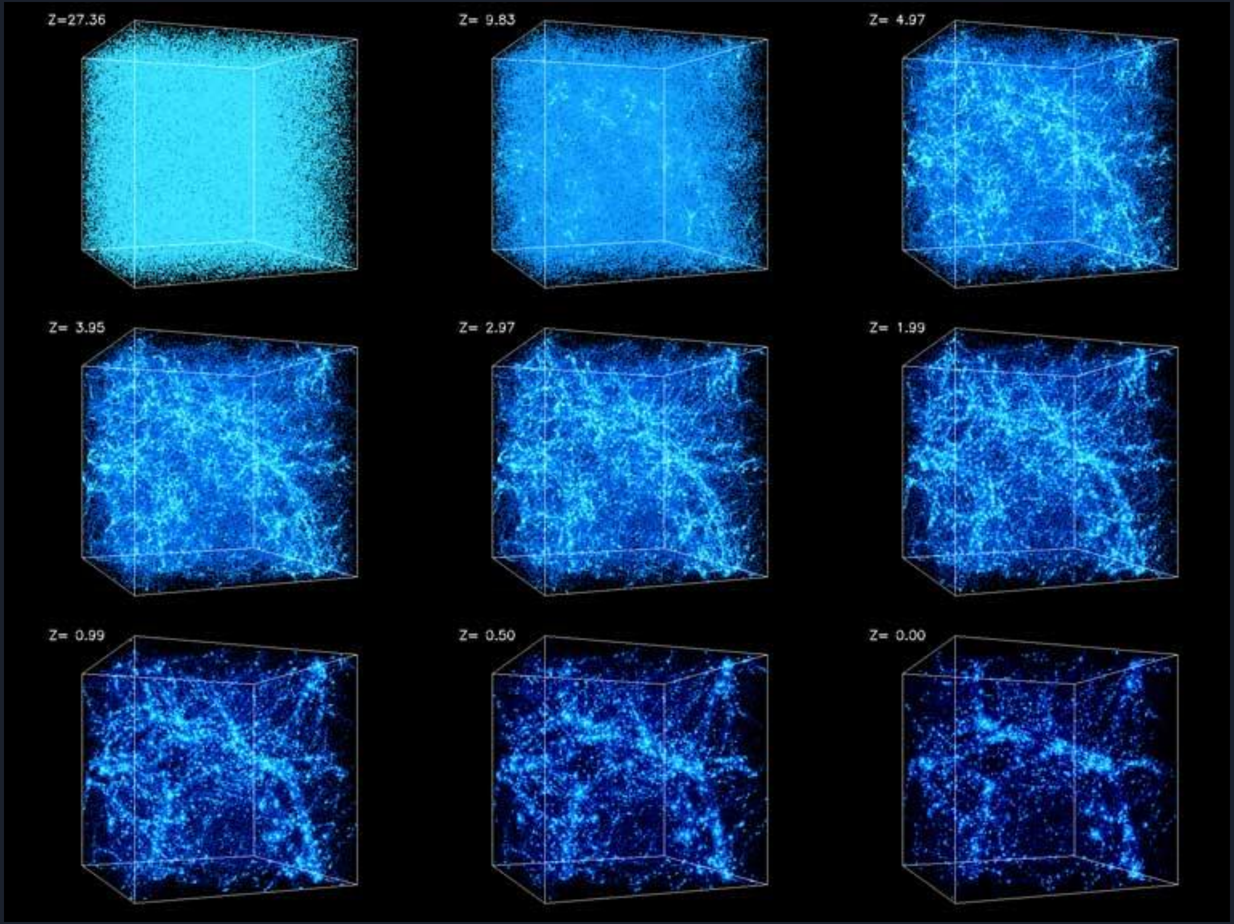
Music and parody

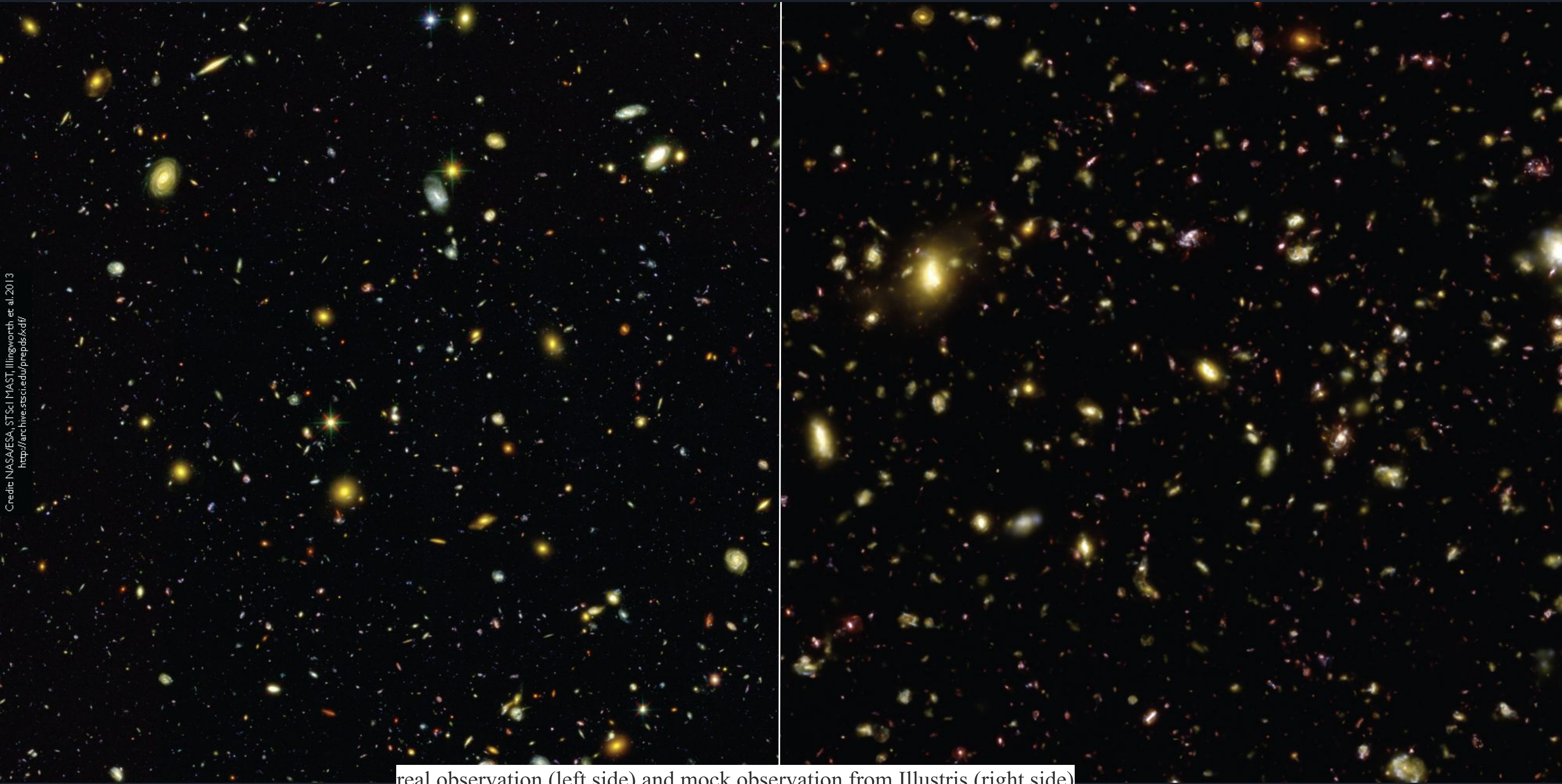
The Universe




Earth
Solar System
Solar Interstellar Neighborhood
Milky Way Galaxy
Local Galactic Group
Virgo Supercluster
Local Superclusters
Observable Universe

Simulating the Universe



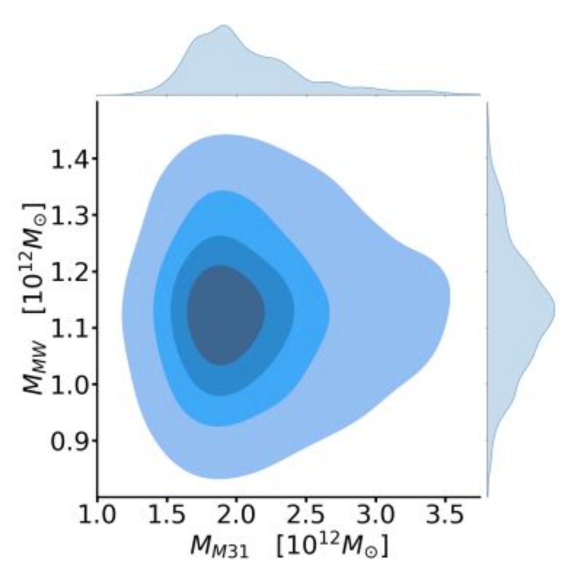


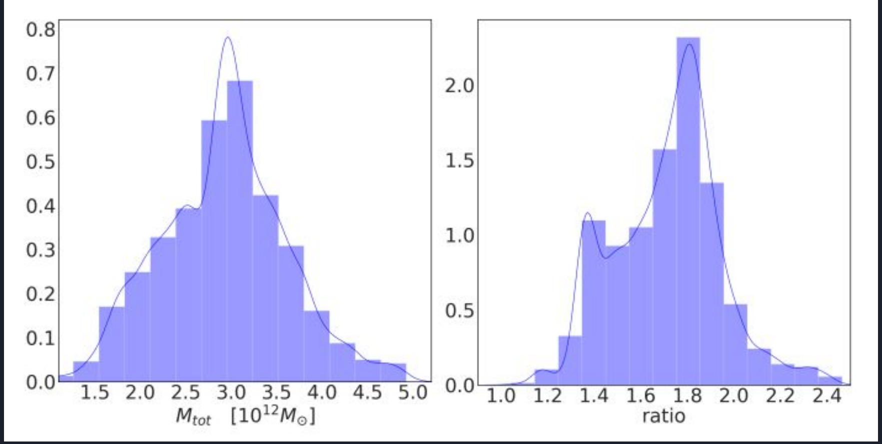
real observation (left side) and mock observation from Illustris (right side)

Cosmological simulations & Machine Learning

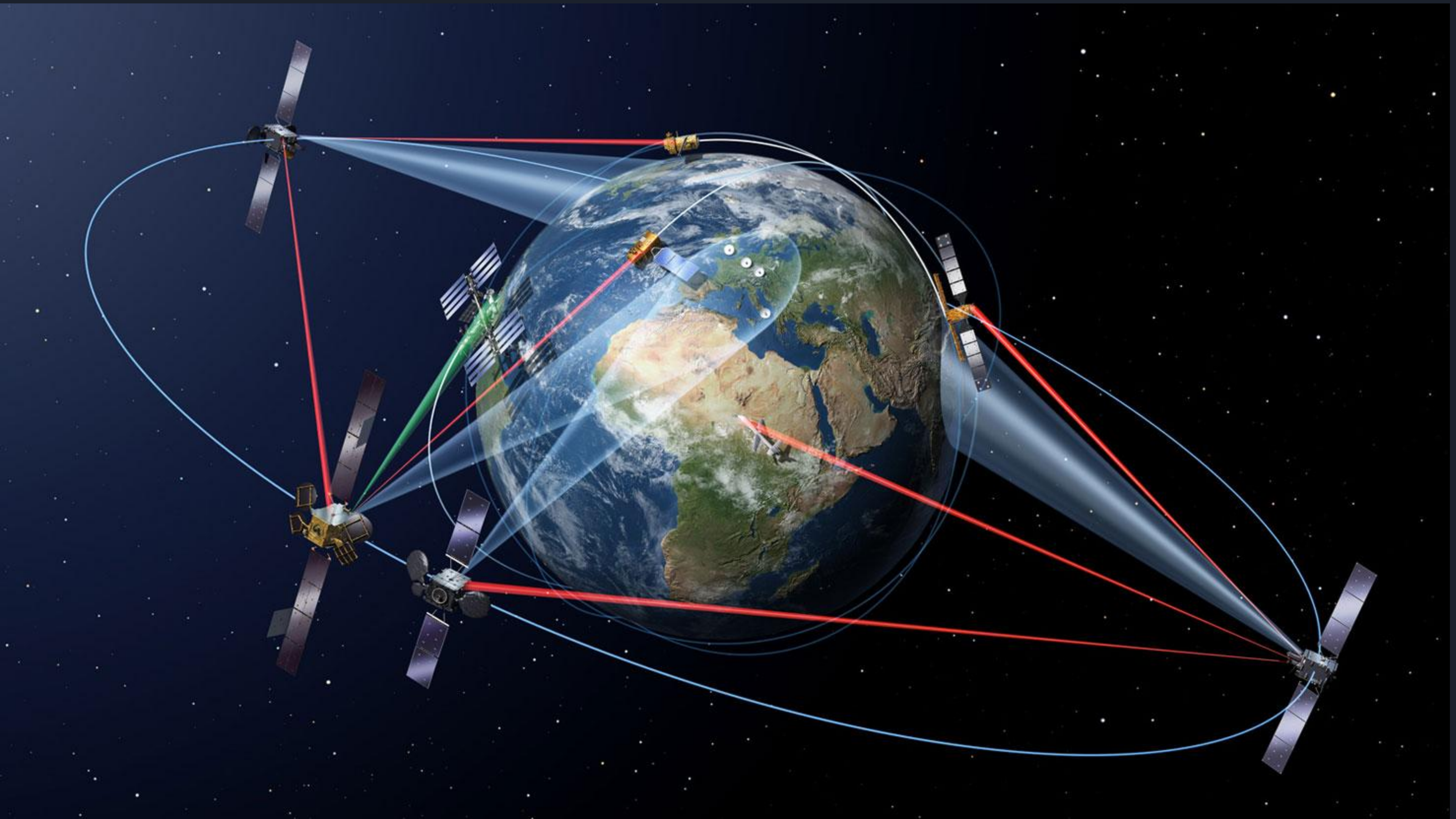
Estimation of the masses in the Local Group by Gradient Boosted Decision Trees

Edoardo Carlesi [1] ⋆, Yehuda Hoffman [1] †, Noam I Libeskind [2,3]
[1] Racah Institute of Physics, Hebrew University, Jerusalem, Israel
[2] Leibniz Institüt für Astrophysik Potsdam (AIP), An der Sternwarte, Potsdam, Germany
[3] University of Lyon, UCB Lyon 1, CNRS/IN2P3, IUF, IP2I Lyon, France





… what happens if you point the satellite-borne telescopes in the “wrong” direction?



Multi Spectral Image (MSI) DATA

Pro:

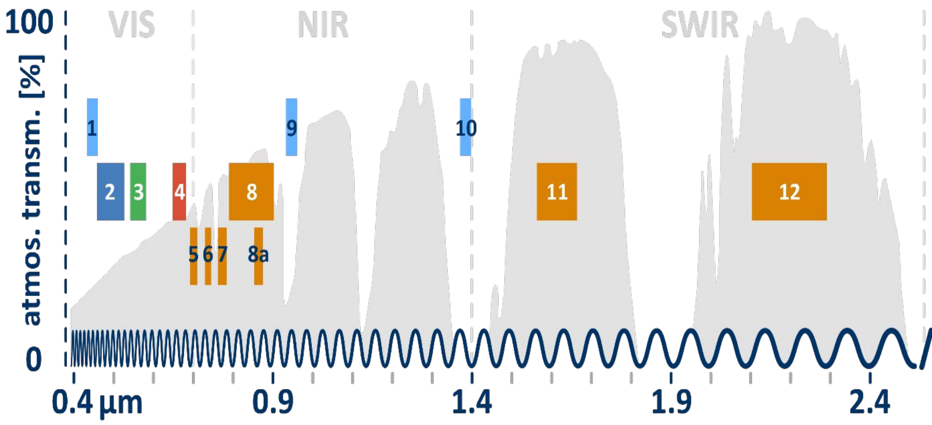
Directly understandable (**RGB**)

Many different wavelengths (Visible, Near Infra Red, Short Wave Infra Red)

Contra:

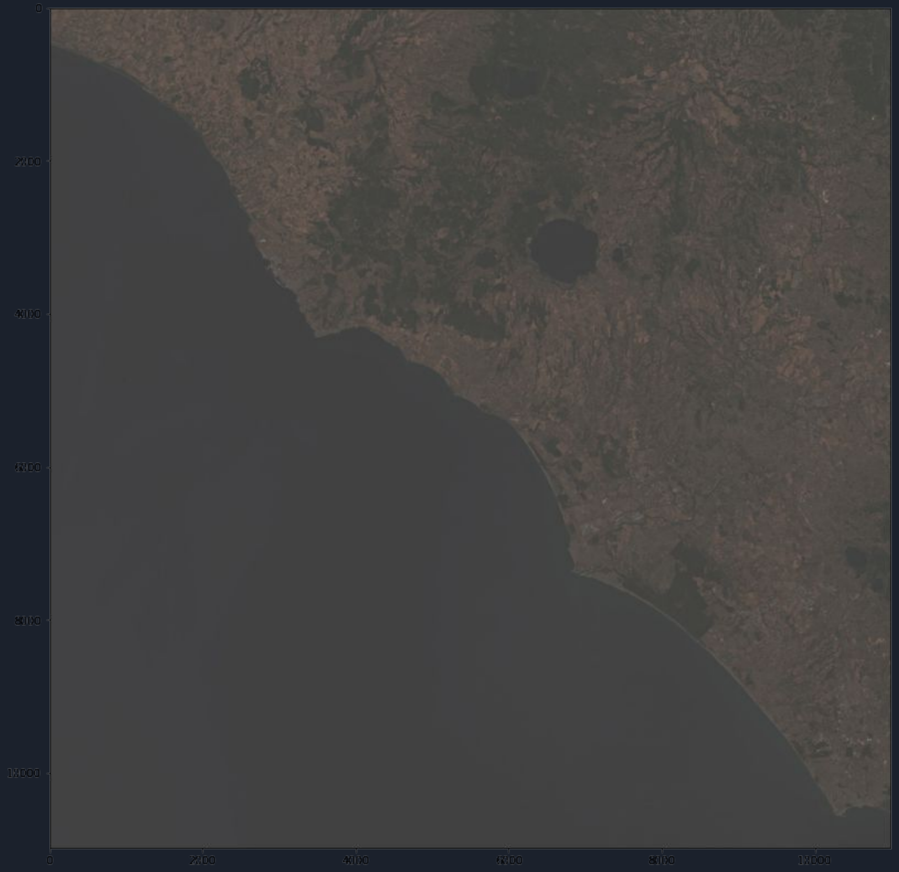
Atmospheric corrections

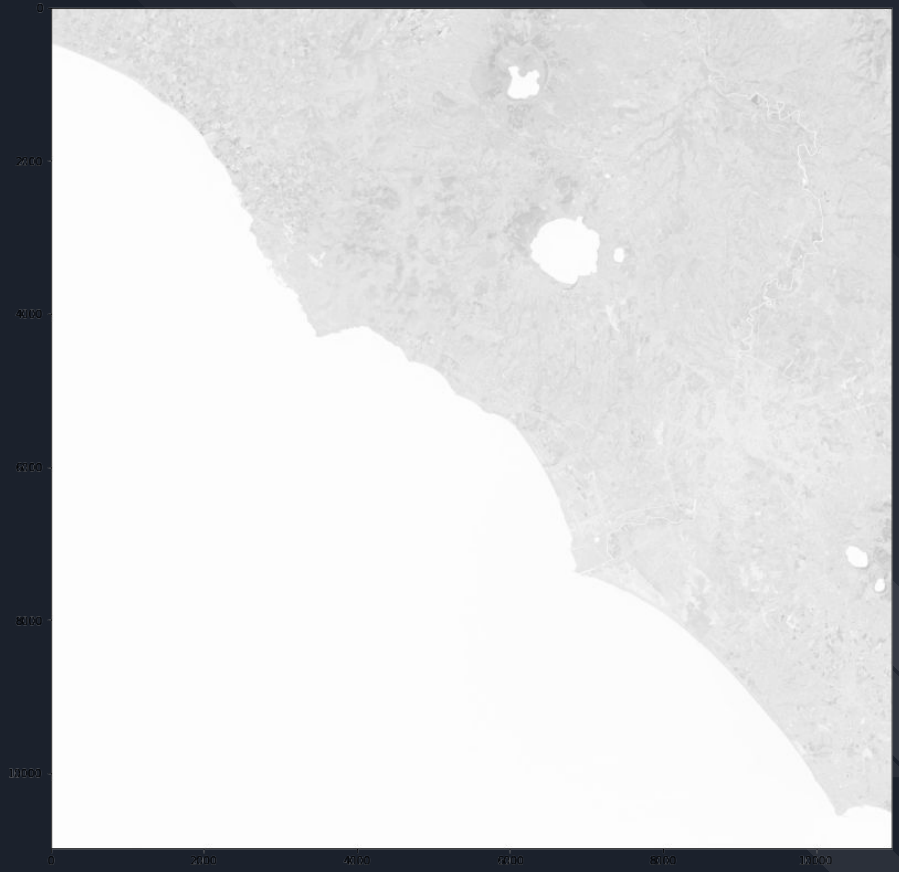
Clouds



BAND	SPECTRAL	WAVELEN. [µm]	GEOM. [m]	SENSOR
1	aerosols	0.429 – 0.457	60	MSI
2	blue	0.451 – 0.539	10	MSI
3	green	0.538 – 0.585	10	MSI
4	red	0.641 – 0.689	10	MSI
5	red edge	0.695 – 0.715	20	MSI
6	red edge	0.731 – 0.749	20	MSI
7	red edge	0.769 – 0.797	20	MSI
8	NIR	0.784 – 0.900	10	MSI
8a	narrow NIR	0.855 – 0.875	20	MSI
9	water vapour	0.935 – 0.955	60	MSI
10	SWIR cirrus	1.365 – 1.385	60	MSI
11	SWIR	1.565 – 1.655	20	MSI
12	SWIR	2.100 – 2.280	20	MSI

MSI IMAGES: RGB & NIR OF ROME AREA





DIRECT APPLICATION: SPECTRAL INDICES

Using a direct algebraic combination of the bands we can highlight some properties of the terrain:

NDVI: Normalized Difference Vegetation Index

NDVI = (NIR - RED) / (RED + NIR)

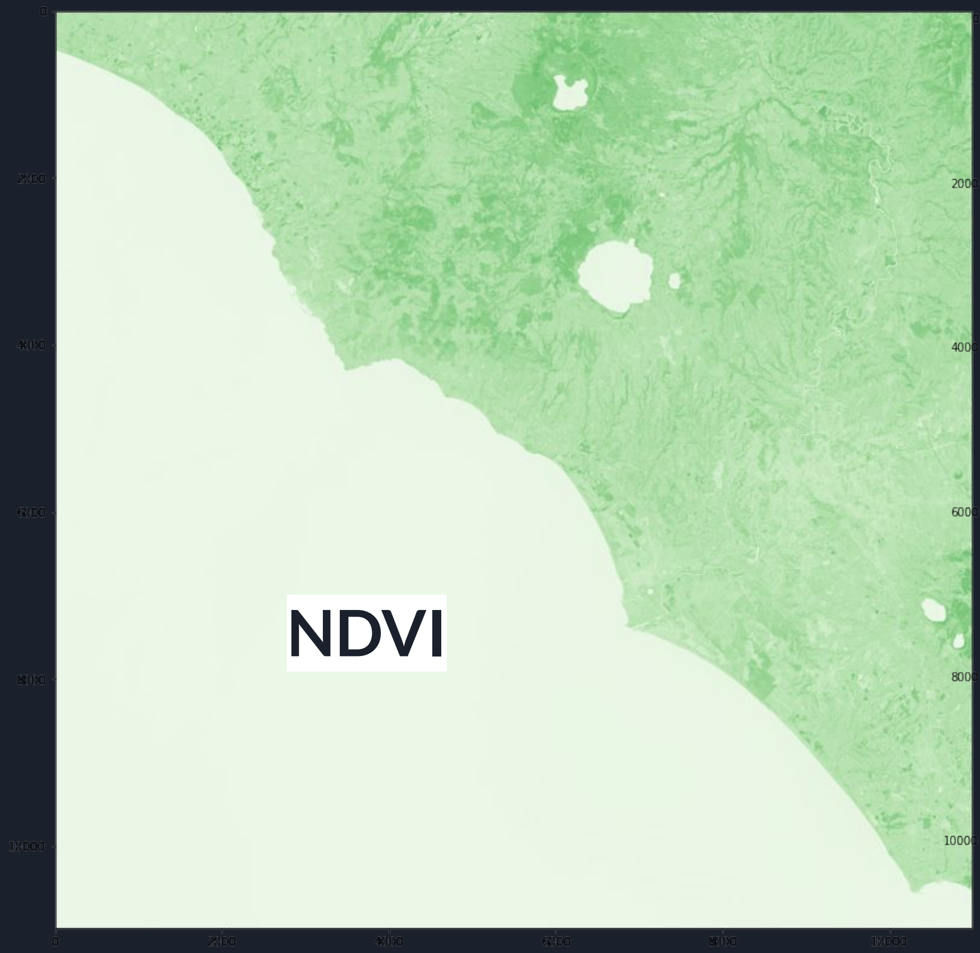
NDWI: Normalized Difference Water Index

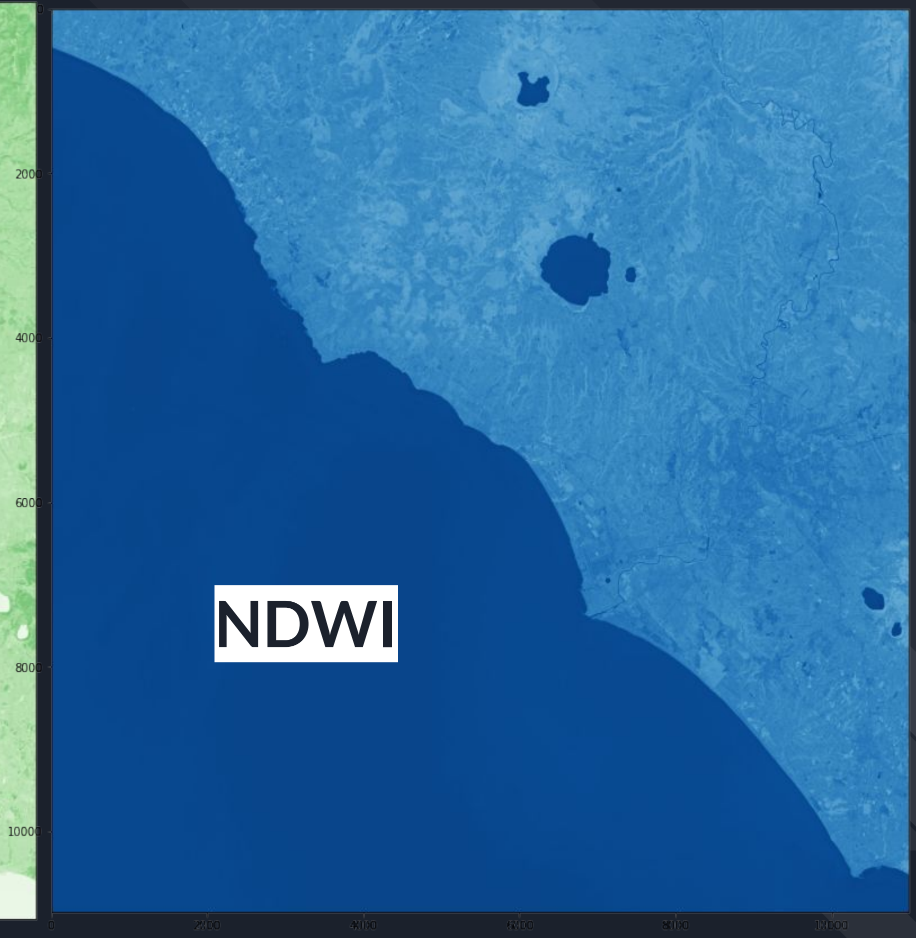
NDWI = (GREEN - NIR) / (GREEN + NIR)

NBR: Normalized Burned Ratio

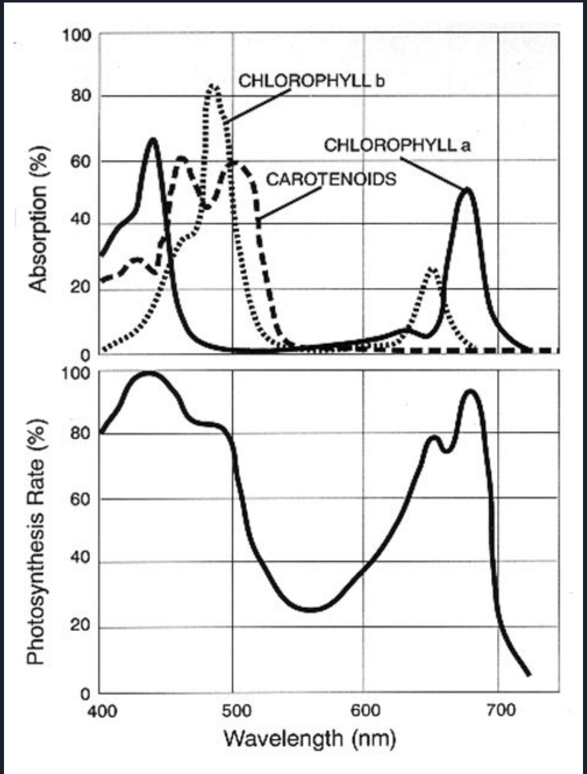
NBR: (NIR - SWIR) / (SWIR + NIR)

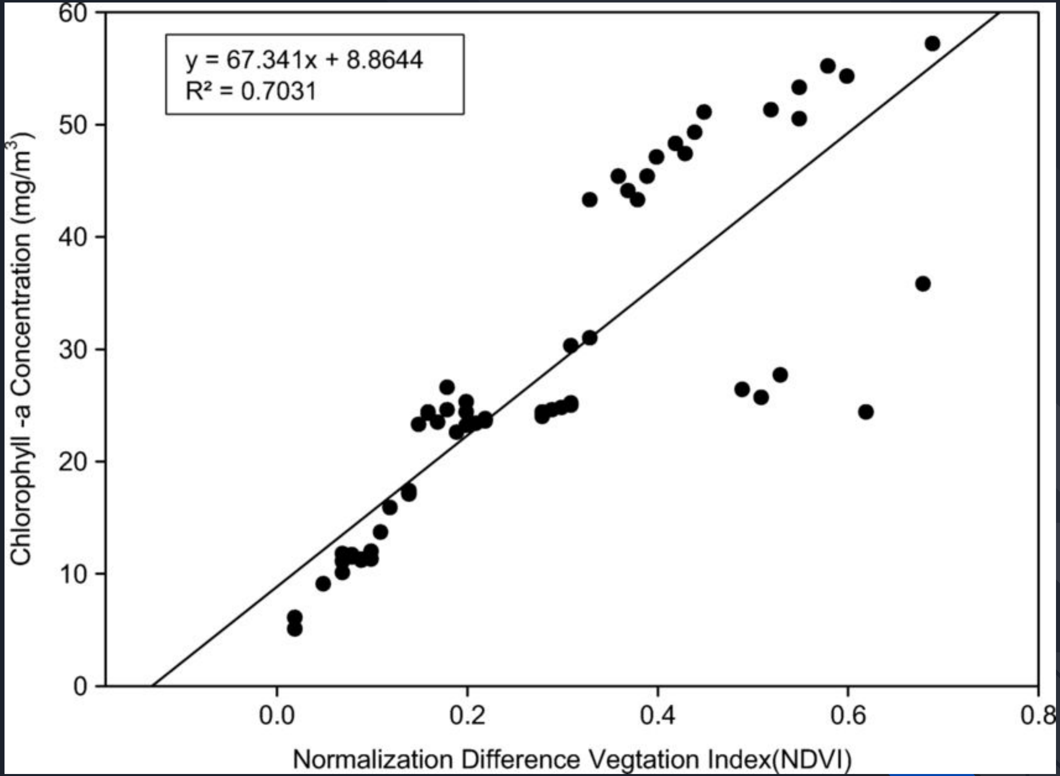
More custom indices: https://custom-scripts.sentinel-hub.com/custom-scripts/sentinel/


NDVI


NDWI

NDVI IS A GOOD PROXY FOR CHLOROPHYLL

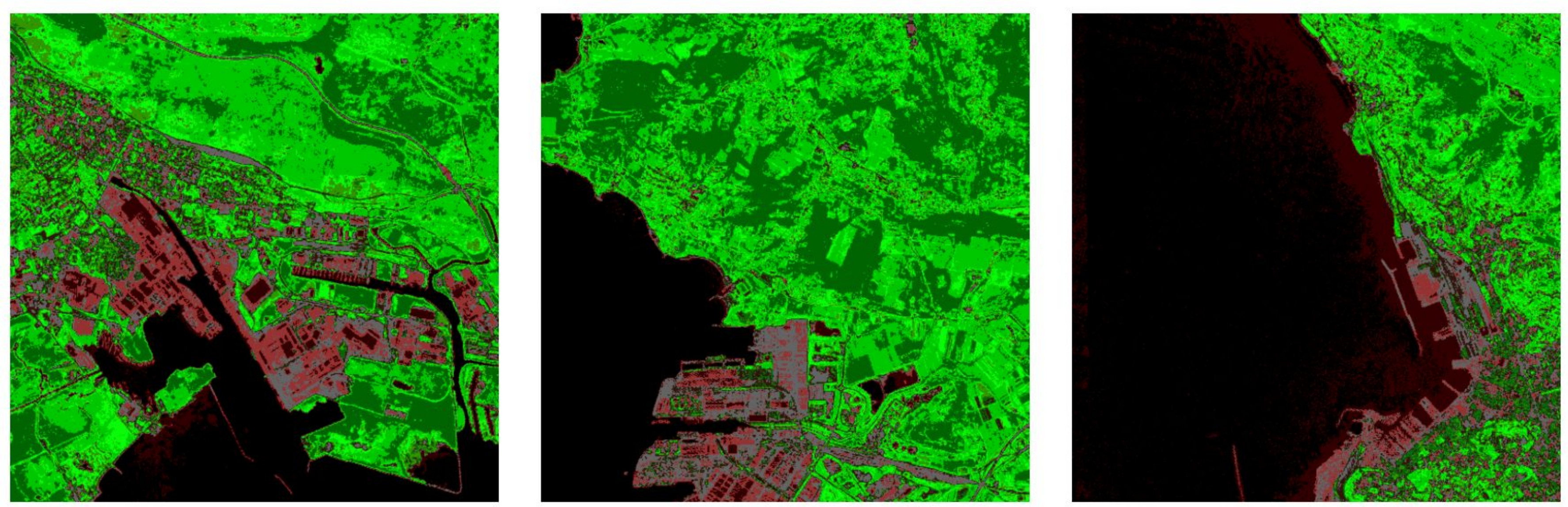




Choon et. al (2018) https://www.x-mol.net/paper/article/1213013456713879559

MULTISPECTRAL INDICES & BUILT AREAS

NDVI Range	Feature
-1 – 0	Water, snow, cloud
0 – 0.2	Barren land / built up /rock
0.2 – 1	Vegetation



NDVI TIME SERIES

Municipality of Comitini (Agrigento), Sicily

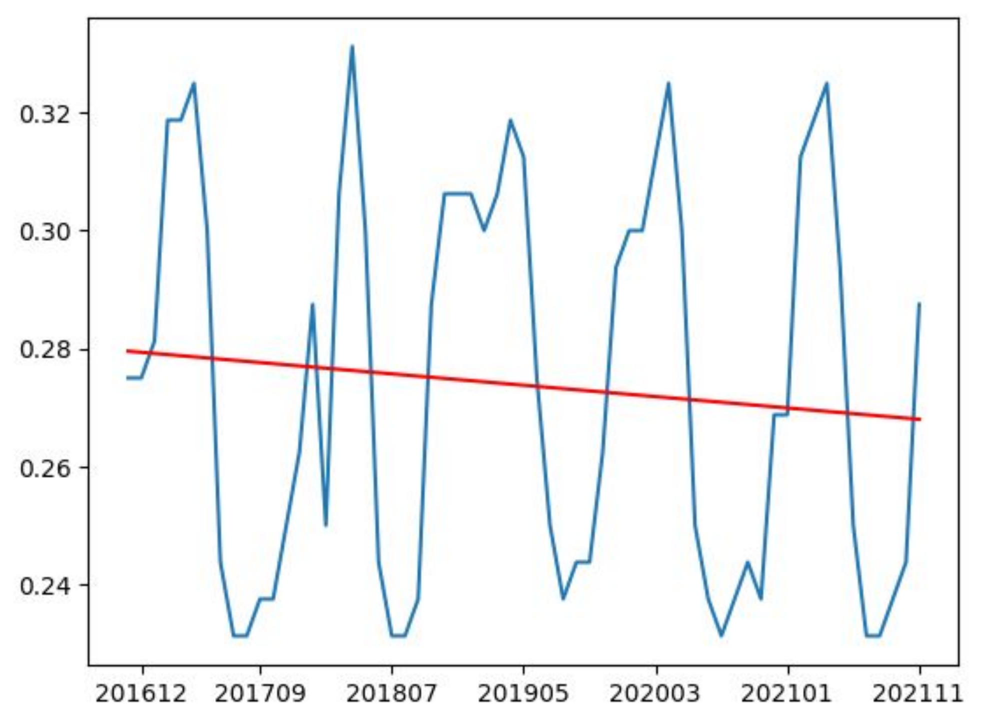


IMAGE SEGMENTATION: U-NET ARCHITECTURE

Base Architecture: UNet/CloudNet with bridge 1024/2048

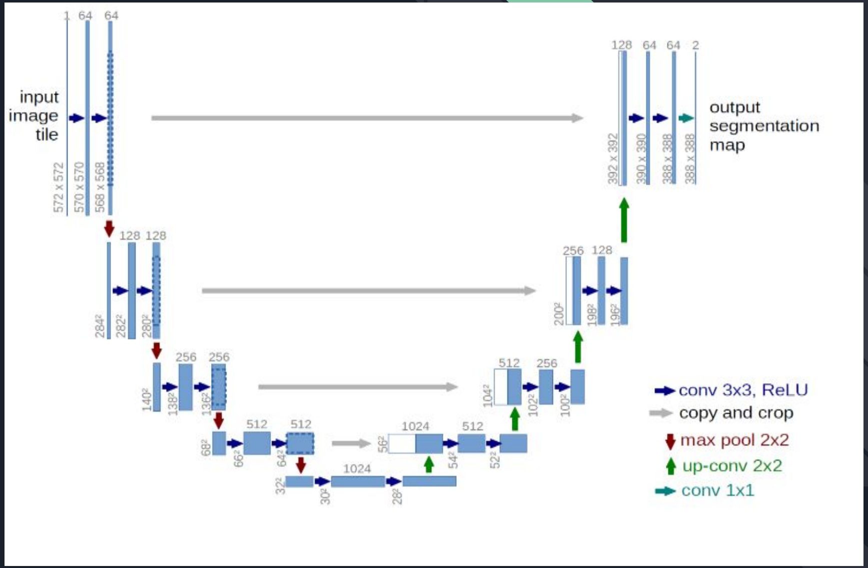
Multiclass: Water, Terrain, Trees, Buildings (ESRI classification, works better under different geo & weather conditions)

Input channels: R, G, B, NIR, NDVI, NDWI

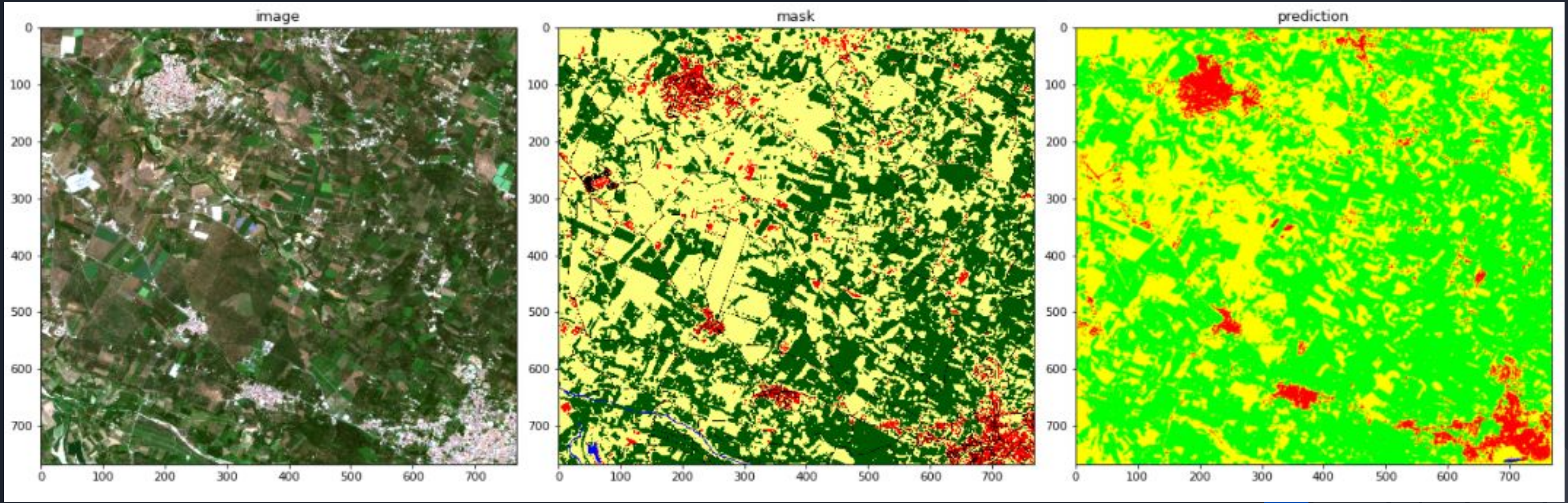
Tensor shape = (Nchannels, Xpatch, Ypatch)

Nchannels = 4, 5, 6

X/Ypatch = 64, 96, 128, 256, 384



TERRAIN SEGMENTATION AND LAND USE



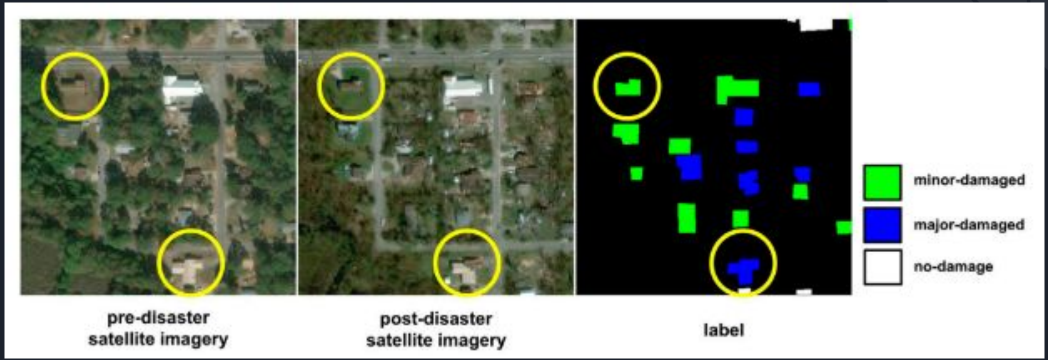
NATURAL HAZARDS: FIRE AND FLOOD

MONITORING

- Continuous and inexpensive
- Identify mostly impacted areas in remote locations
- Direct and orient rescue operations

PREVENTION

- Forecast (real time data)
- Identify risk areas (on historical datasets)



DAILY FIRE HAZARD INDEX

Fire hazard can be monitored and forecasted using local meteo data (real time) and satellite data (near real time)

Satellite data provide estimates of live / dry / susceptible vegetation

The final expression used to determine the DFHI is the following [55] :

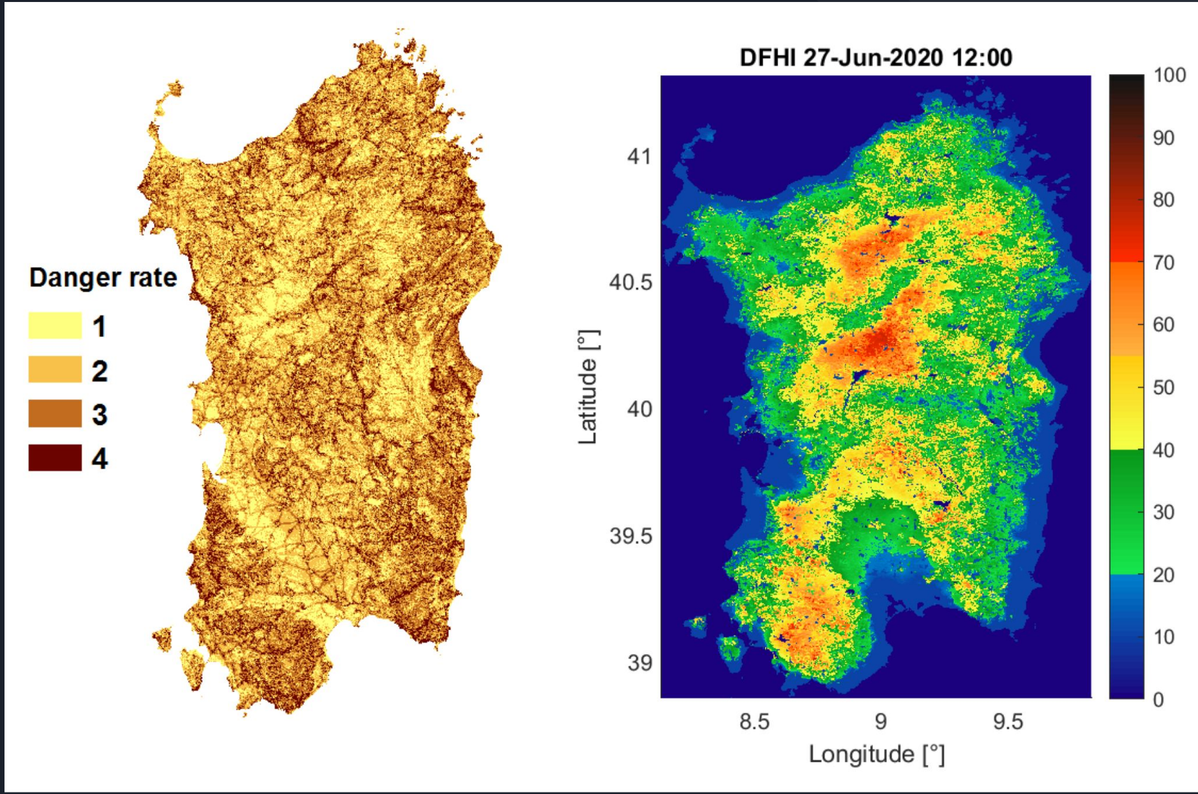
$$DFHI = (1 - L_f)(1 - TN_f) \cdot 100$$

where:

- L_f fraction of live vegetation (dimensionless);
- TN_f fraction of ten-hours timelag fuel moisture (dimensionless).

G. Laneve et al., Remote Sensing (2020)

FIRE RISK INDEX



G. Laneve et al., Remote Sensing (2020)

… and what about Uranus?

NANOWAR OF STEEL - Uranus feat. Michael Starr (Steel Panther)

SOME STATS

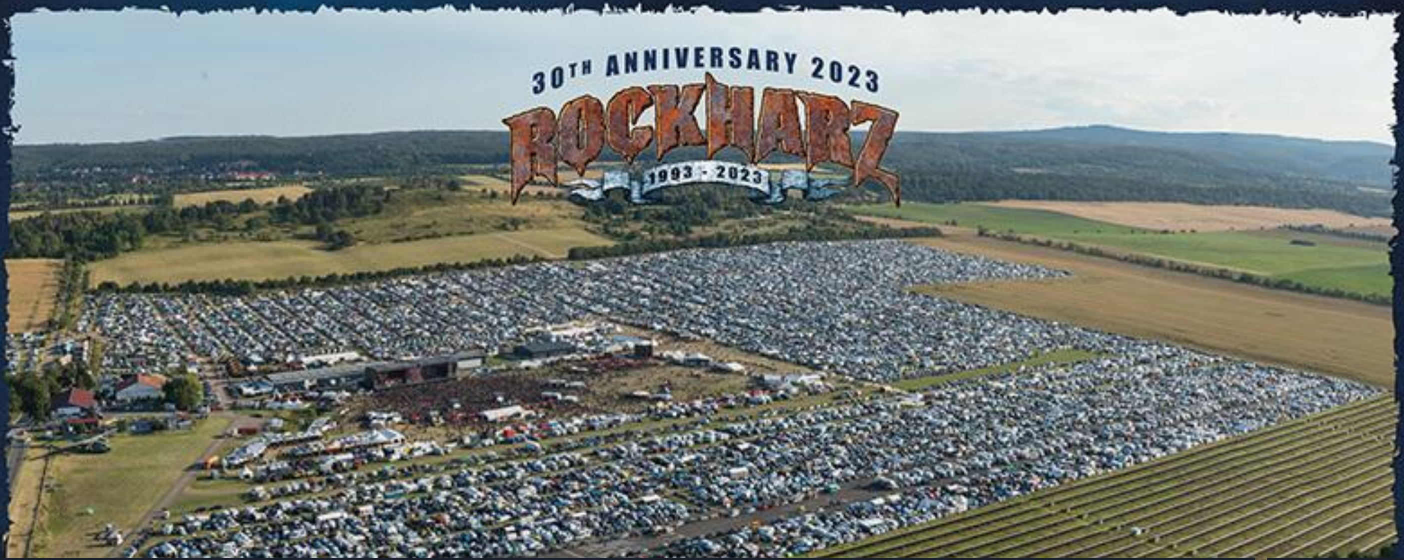
70+M views on YouTube
170k Monthly on Spotify

70+ shows in EU, UK, USA and Canada in 2023
40+ shows in EU, UK so far in 2024

Sold out shows in Italy, Denmark, Germany, Hungary, Austria, Spain, France, Poland, Bulgaria, Switzerland

Tens of thousands of albums and T-Shirts sold

CELEBRATING 20 YEARS OF NANOWAR OF STEEL IN MILAN (21.10.2023)



THAT’S IT! NOW I HAVE TO LEAVE TO PLAY A SHOW HERE TONIGHT…

EXTRA SLIDES

REMOTE SENSING THROUGH SATELLITES

TYPES OF SATELLITE DATA

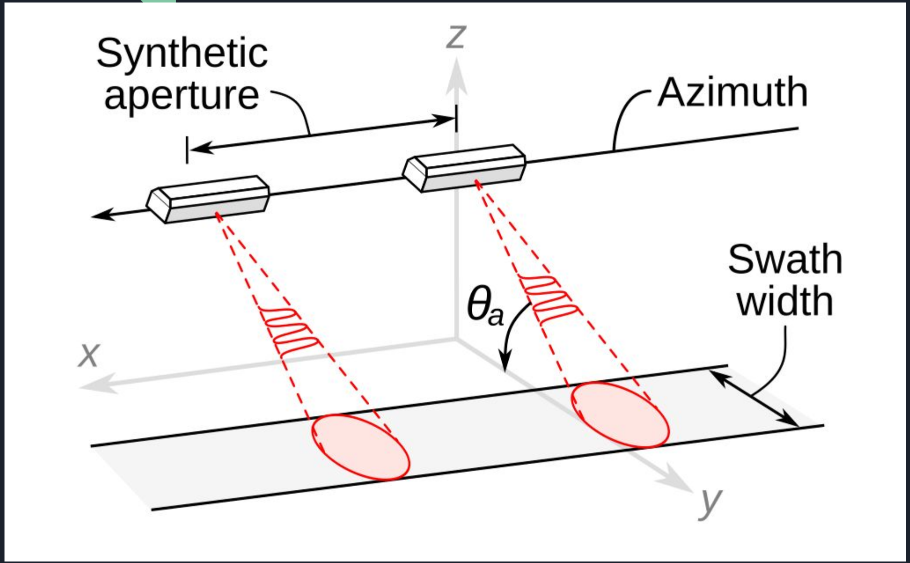
MULTI SPECTRAL IMAGES (MSI):
Passive sensors

(E.g. ESA Sentinel 2 & 3, NASA Landsat 7 & 8)

SYNTHETIC APERTURE RADAR (SAR):
Active sensors

(E.g. ESA Sentinel 1)

SYNTHETIC APERTURE RADAR (SAR)



Radio beams launched to the Earth

The movement of the satellite "simulates" a large antenna

Image quality / resolution depends on wavelength / polarization

Distortions induced by surface irregularities, different reflecting angles etc.

SAR DATA

Pro:

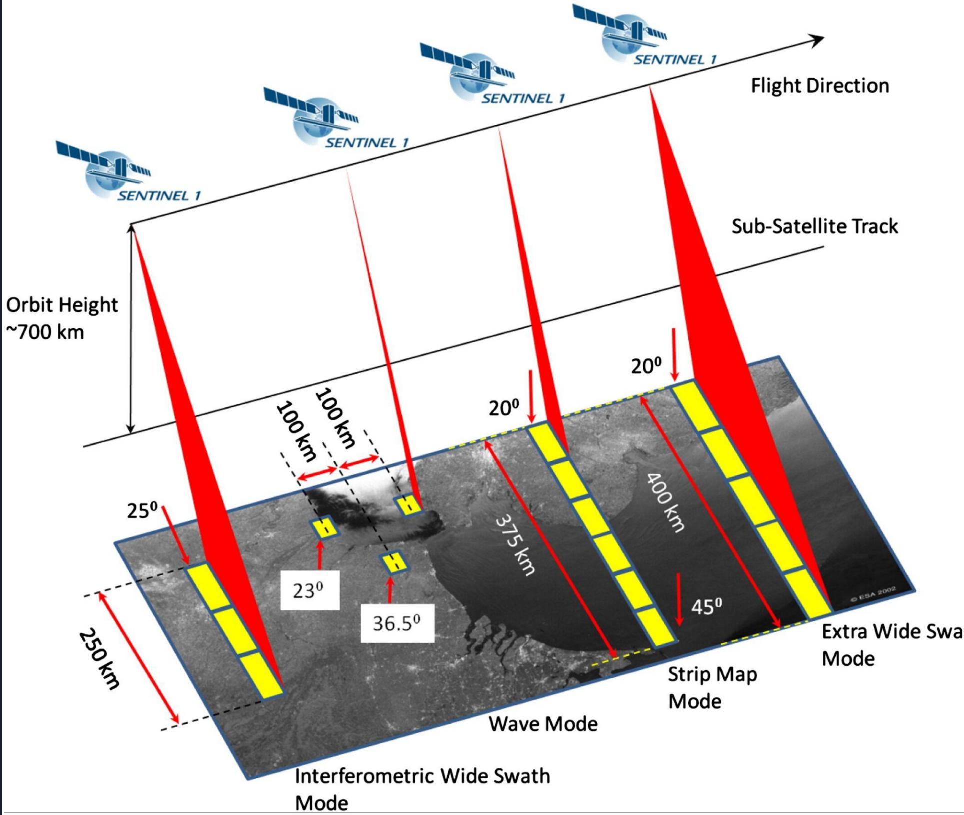
Weather-free measurements

Signal processing through time allows to detect mm-scale variations

Contra:

No true color information (false color with polarization)

Post processing is complex



SAR IMAGES

Vertical (V) and Horizontal (H) polarizations in transmission and reception

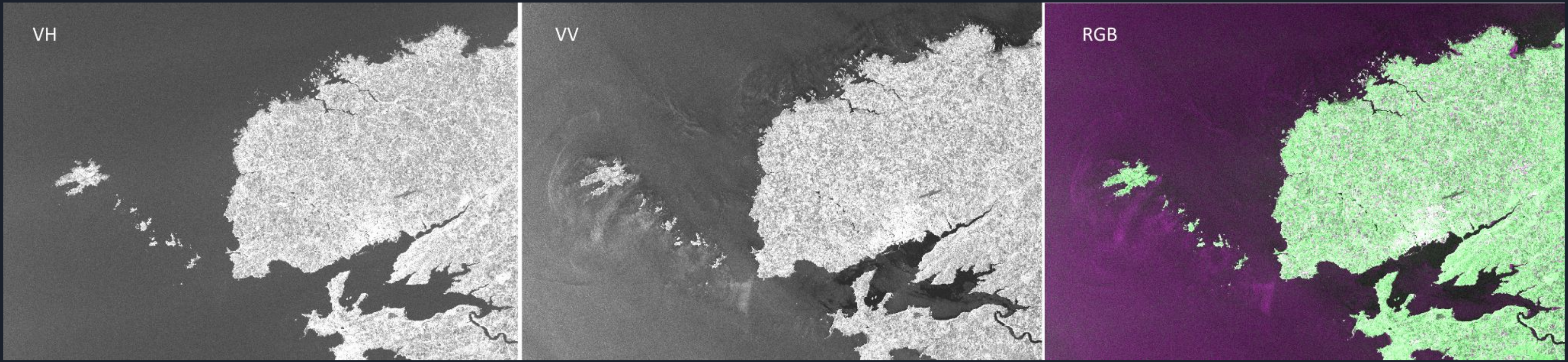


Image: Sentinel-1A over Brittany region, France
VV intensity image, VH intensity image, and RGB color composite

Composite RGB: VV channel for red, VH channel for green, |VV| / |VH| for blue

SAR APPLICATION: SUBSIDENCE

Subsidence is the vertical movement / sinking of the ground (for natural or human induced reasons e.g. groundwater extraction and depletion)

Differential Interferometric SAR data can detect subsidence trends up to a **few mm/year**

Friksten J. et al, Remote Sensing (2019)