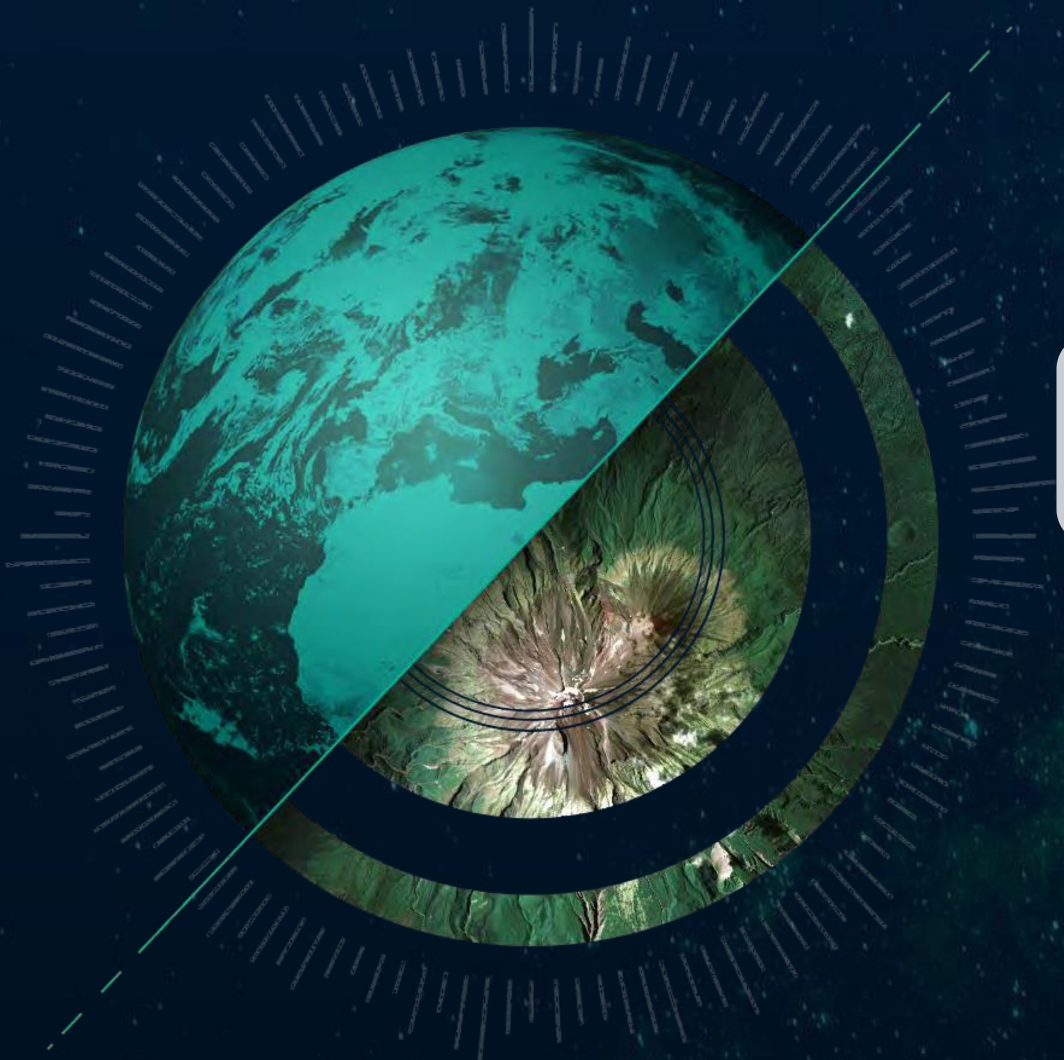
esa space solutions | Copernicus Academy | ÚSTAV GEOGRAFIE Prírodovedecká fakulta UPJŠ v Košiciach

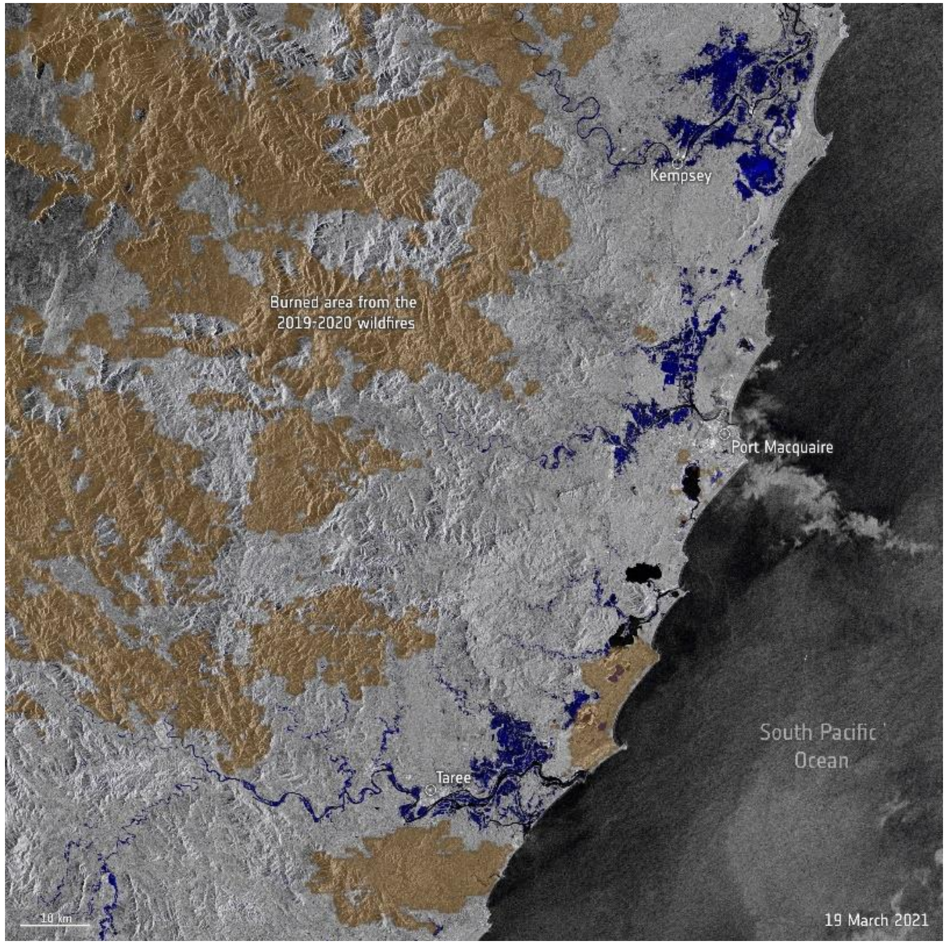


10. SAR and optical remote sensing for mapping floods

Why do we need to monitor flood events?

- Near 200 millions of affected people each year (more than half of affected people by a natural hazards)

- Timely detection and warnings allow communities to prepare and minimize damage, thus saving lives
- Flood monitoring aids in assessing flood risks, identifying vulnerable areas, and developing strategies to mitigate impacts on nature, human settlements, etc.
- Environmental monitoring helps evaluate the impacts and implement measures for conservation and restoration
- Flood monitoring data informs the design and management of infrastructure like dams, enhancing their resilience against flooding

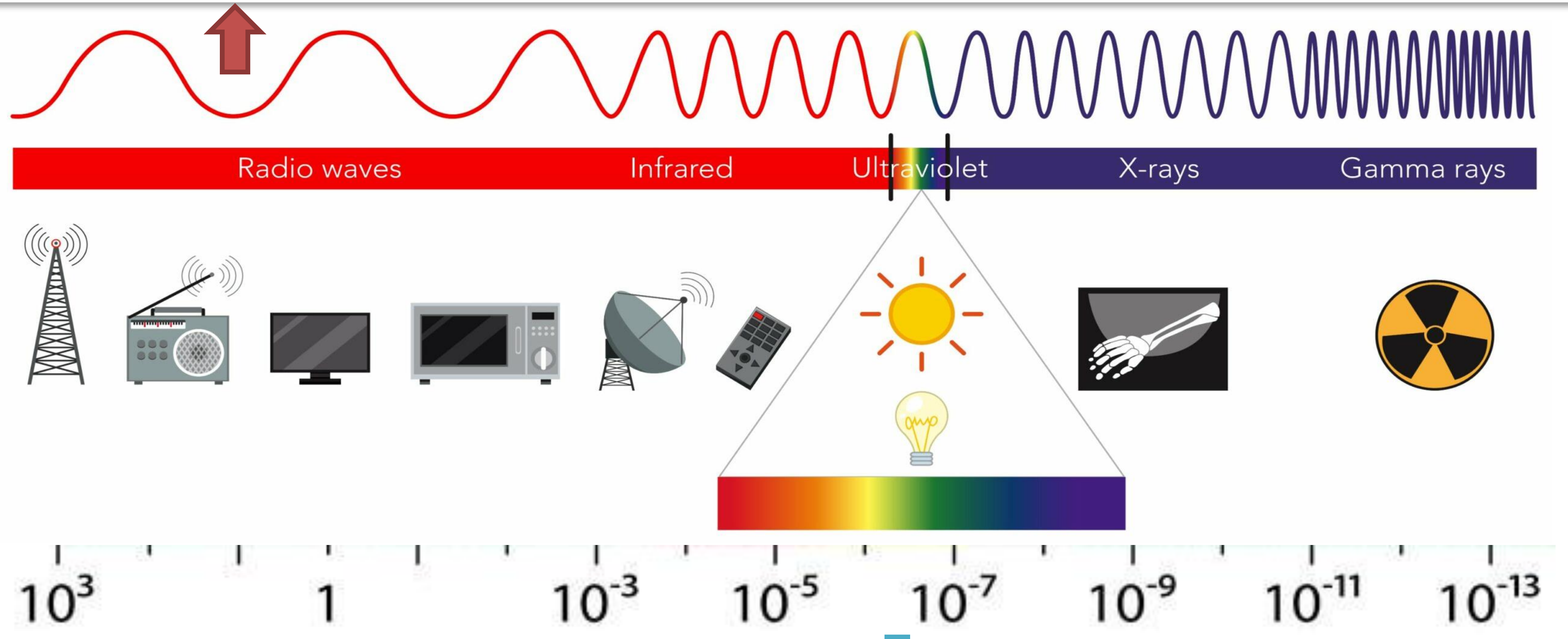


Credit: Contains modified Copernicus Sentinel data (2021), processed by ESA/NASA MODIS

SAR and optical for surface water mapping

RADAR SATELLITES
Weather & illumination independence
Penetration through cloud cover

Use: Detection of water surfaces
Changes in water levels



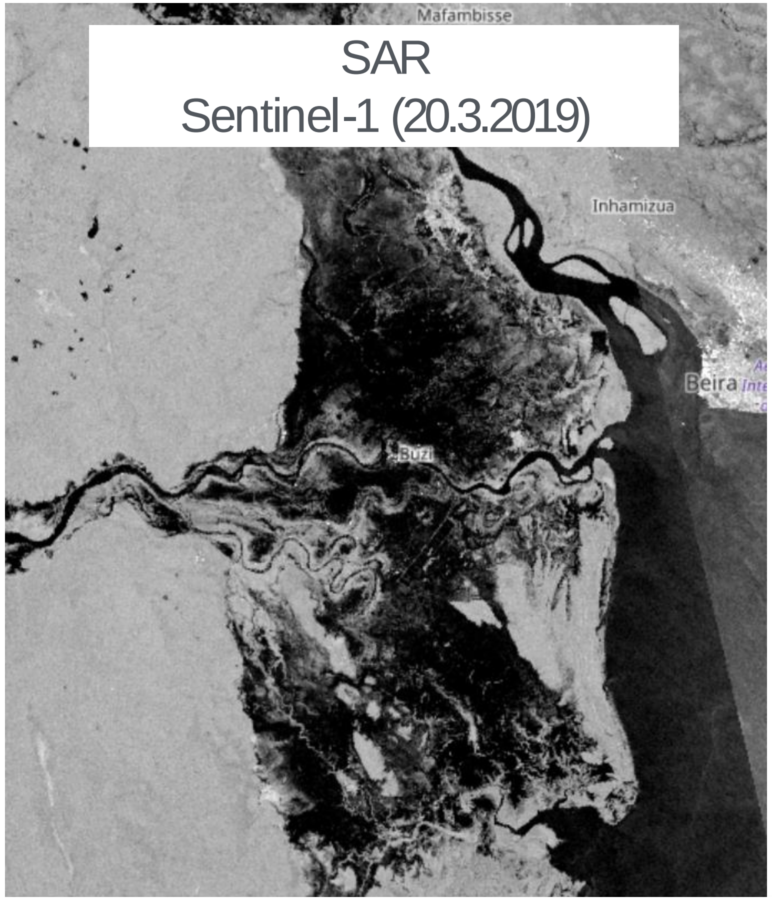
OPTICAL SATELLITES
Weather & illumination dependence
No penetration through cloud cover

Use: Flood extent, flood patterns, flood impacts
Analyzing changes before and after flooding events

Source:https://cthrumetals.com/emi-shielding/

SAR and optical for surface water mapping

Radar satellites, unlike optical ones, utilize microwave radar technology to capture data, enabling them to penetrate through clouds and atmospheric barriers. This distinct capability allows radar satellites to acquire flood mapping data even in adverse weather conditions.



SAR
Sentinel-1 (20.3.2019)

OPTICAL
Sentinel-2 (17.3.2019)

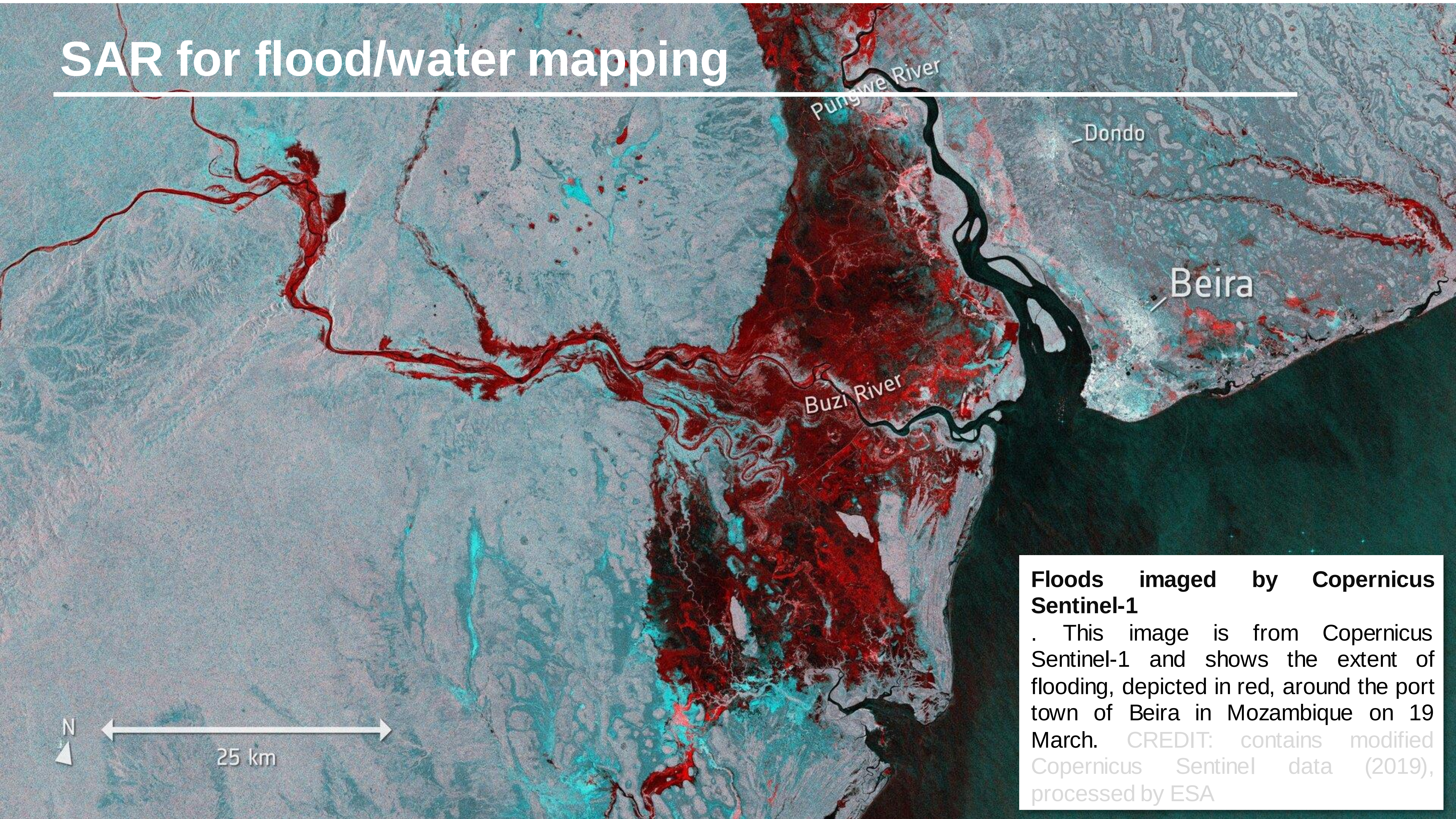
Floods in Beira, Mozambique

For more information, see the tutorials:

10. Flood Monitoring with Sentinel-1 & Sentinel-2 using the SNAP software

11. Flood Monitoring with Sentinel-1, Sentinel-2 data using the SNAP software

SAR for flood/water mapping

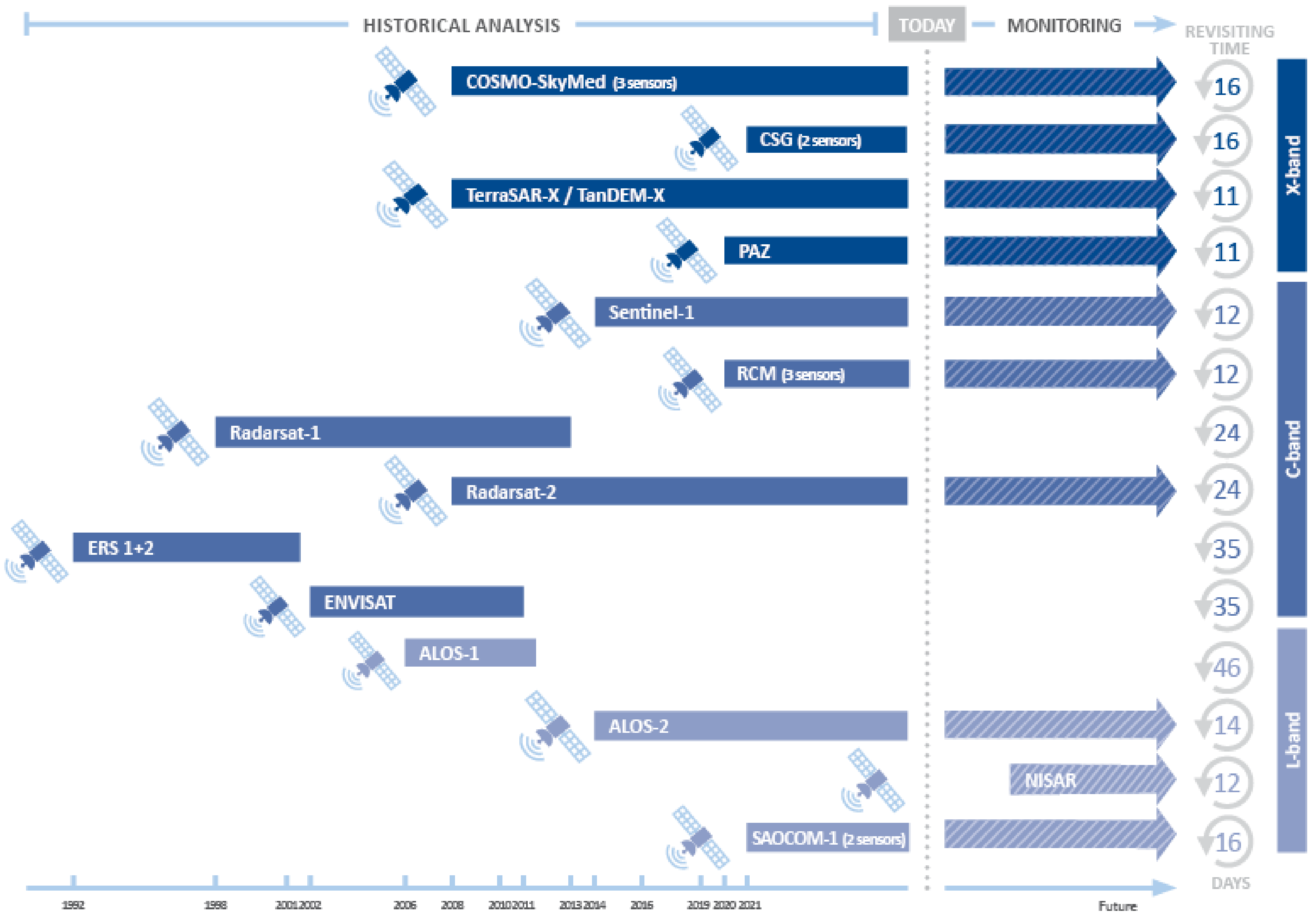


Floods imaged by Copernicus Sentinel-1
. This image is from Copernicus Sentinel-1 and shows the extent of flooding, depicted in red, around the port town of Beira in Mozambique on 19 March. CREDIT: contains modified Copernicus Sentinel data (2019), processed by ESA

The Microwave Spectrum

Band	Frequency f_0	Wavelength $\lambda = c/f_0$	Typical Application
Ka	27 – 40 GHz	1.1 – 0.8 cm	Rarely used for SAR
K	18 – 27 GHz	1.7 – 1.1 cm	
Ku	12 – 18 GHz	2.4 – 1.7 cm	
X	8 – 12 GHz	3.8 – 2.4 cm	**High-Resolution SAR** (urban monitoring; little penetration into vegetation cover □ can't see water under vegetation)
C	4 – 8 GHz	7.5 – 3.8 cm	**SAR Workhorse** (Sentinel-1; global mapping; improved vegetation penetration)
S	2 – 4 GHz	15 – 7.5 cm	**Increasing Use for SAR-Based Earth Observation**; NISAR will carry S-band
L	1 – 2 GHz	30 – 15 cm	**Medium-Resolution SAR** (NISAR; Geophysical monitoring; biomass and vegetation mapping; high penetration □ can see water under vegetation)
P	0.3 – 1 GHz	100 – 30 cm	**Biomass Estimation.** ESA Biomass will be first P-band spaceborne SAR

Former missions



https://site.tre-altamira.com/insar/

Ongoing missions

2007 : June: launches constellation Cosmo Skymed constellation , Terra SAR X
December: Radarsat 2

2012 : launch of RISAT (ISRO) , operational mode in 2015

2014 : Launch ALOS 2, band L

2014-2016: Launches of Sentinel 1A and 1B (Constellation Copernicus)

2016 : Gaofeng 3, C band (Quad Pol)

Recent advancements in InSAR

Sentinel-1, NISAR, TanDEM-L

Sentinel-1

- Launch Date: 2015, 2016
- Provides free and open data
- Globally available, acquired regularly irrespective of weather conditions
- Constellation of two C-band SAR sensors
- Wavelength: 5.6cm
- Polarization dual (VV/VH over land; HH/HV over ice)
- Image size: 250km swath with a resolution of 5mx20m
- Temporal coverage: every 6 days over Europe and every 12 days elsewhere

https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-1/Ride_into_orbit_secured_for_Sentinel-1C

Recent advancements in InSAR

Sentinel-1, NISAR, TanDEM-L

NISAR

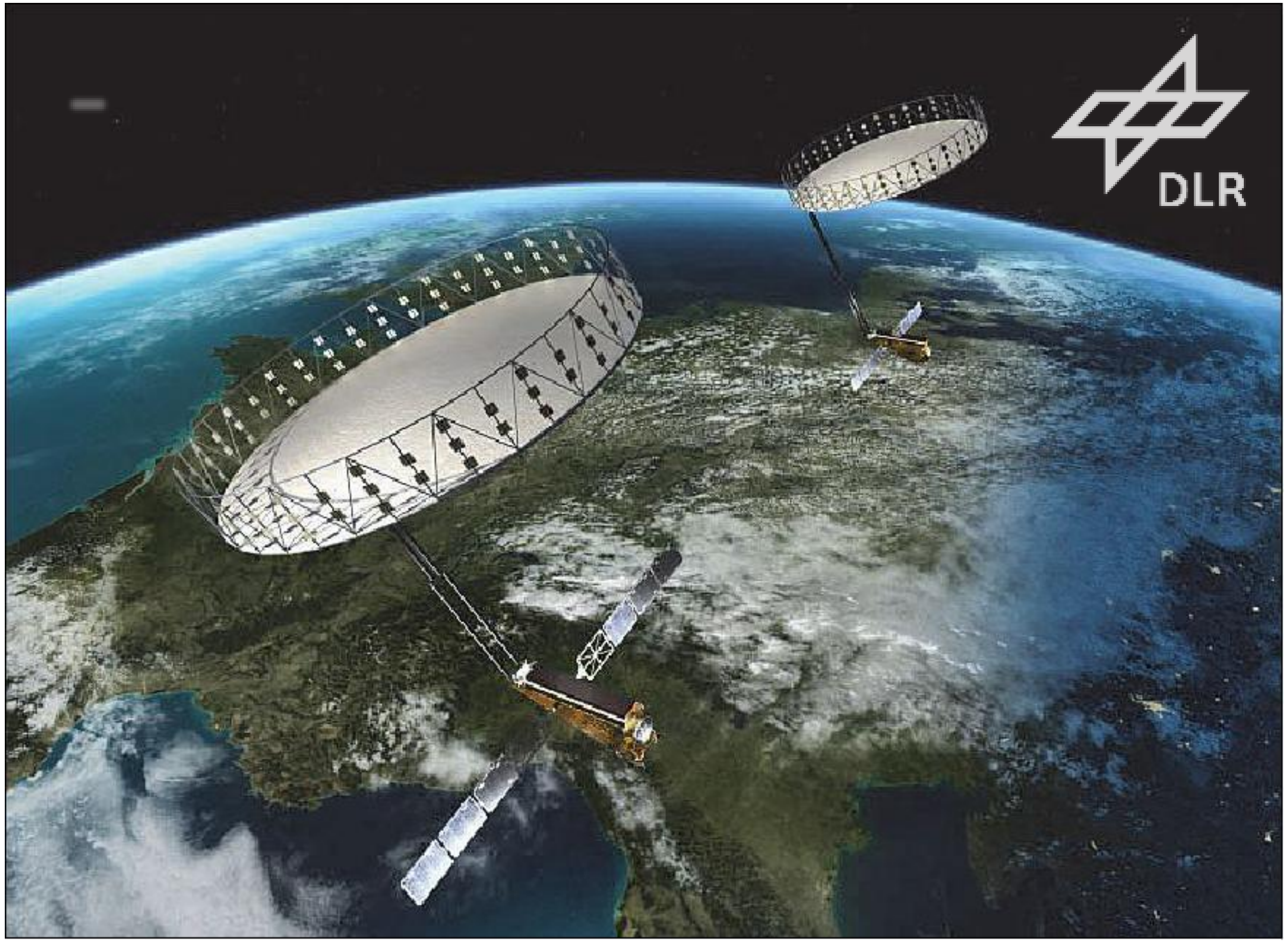
- Launch Date: 2023
- Provides free and open data
- First spaceborne L- and S- band SAR
- Temporal coverage: full global coverage in 12 days

https://www.jpl.nasa.gov/missions/nasa-isr

Recent advancements in InSAR

Sentinel-1, NISAR, TanDEM-L

TanDEM-L



- Launch Date: 2023
- Provides free and open data
- First spaceborne L- and S-band SAR
- Temporal coverage: full global coverage in 12 days

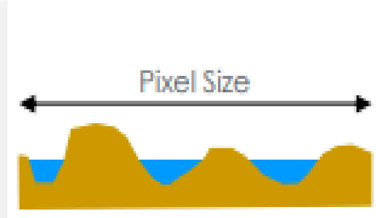
https://www.jpl.nasa.gov/missions/nasa-isr

Limitations of SAR for flood mapping

Wind Roughness on Water

Problem: Increases radar brightness and may prevent water detection

Mitigation: Use VH in addition to VV for water detection



Partially Inundated Pixels

Problem: Pixels are not dark enough for detection

Mitigation: Higher-resolution radar or combine with change detection approach

Water Under Dense Vegetation

Problem: Radar may not be able to penetrate vegetation

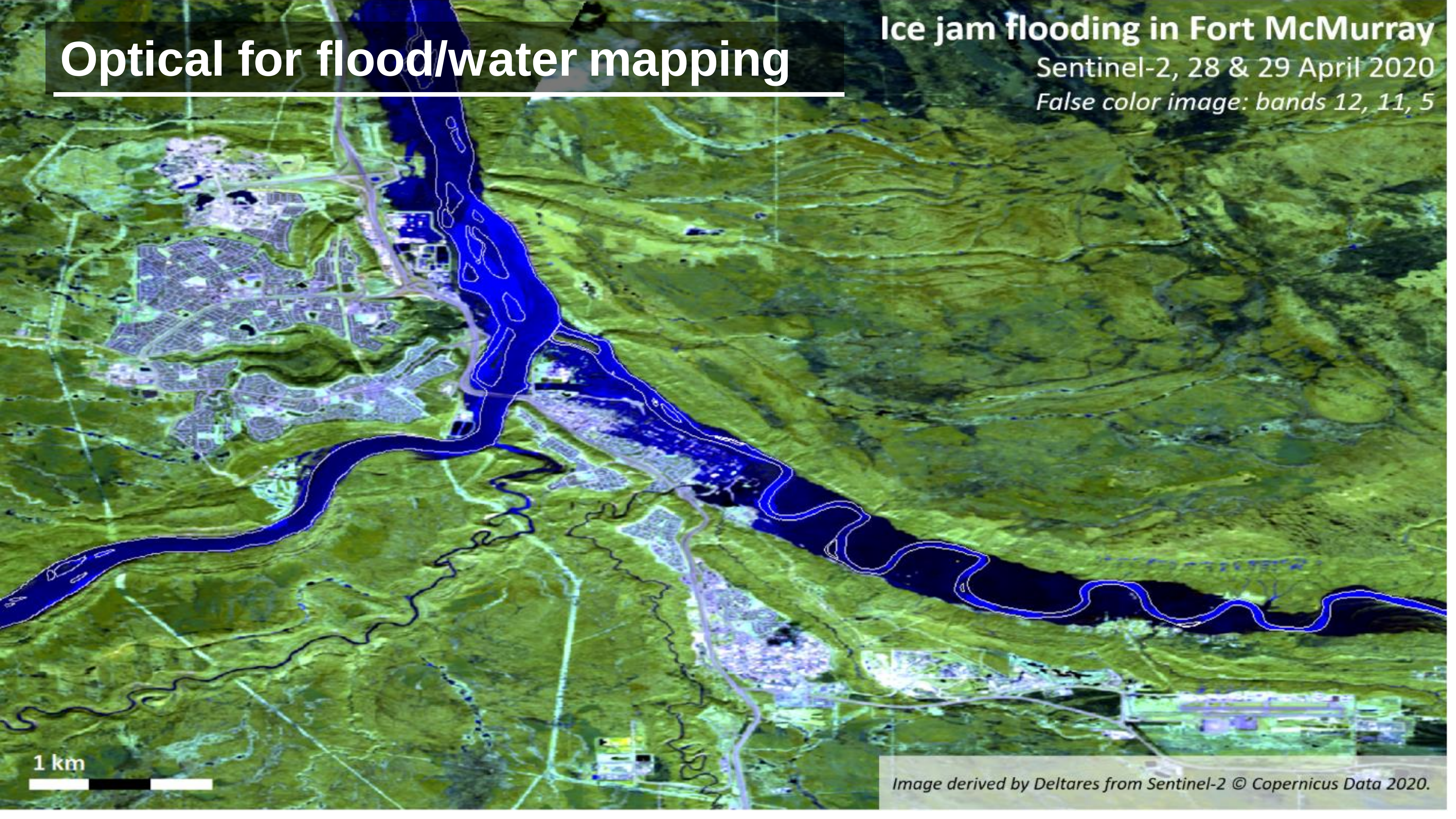
Mitigation: Use longer wavelenght (e.g. NISAR)

Water in Urban Environment

Problem: Due to side-looking geometry, buildings obstruct surface water from view

Mitigation: Use multiple viewing geometries – use optical data

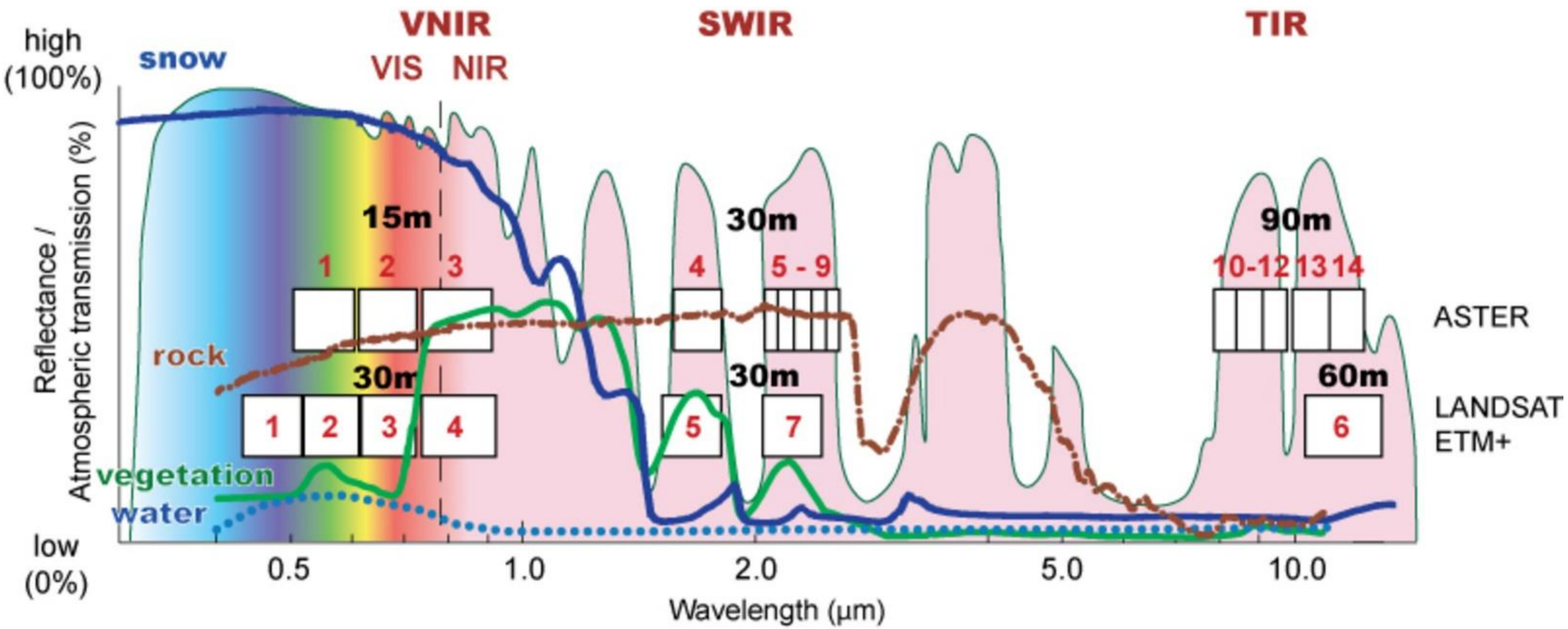
Optical for flood/water mapping



Optical Parameters to Consider for a Flood Mapping

Physical basis for Water bodies mapping

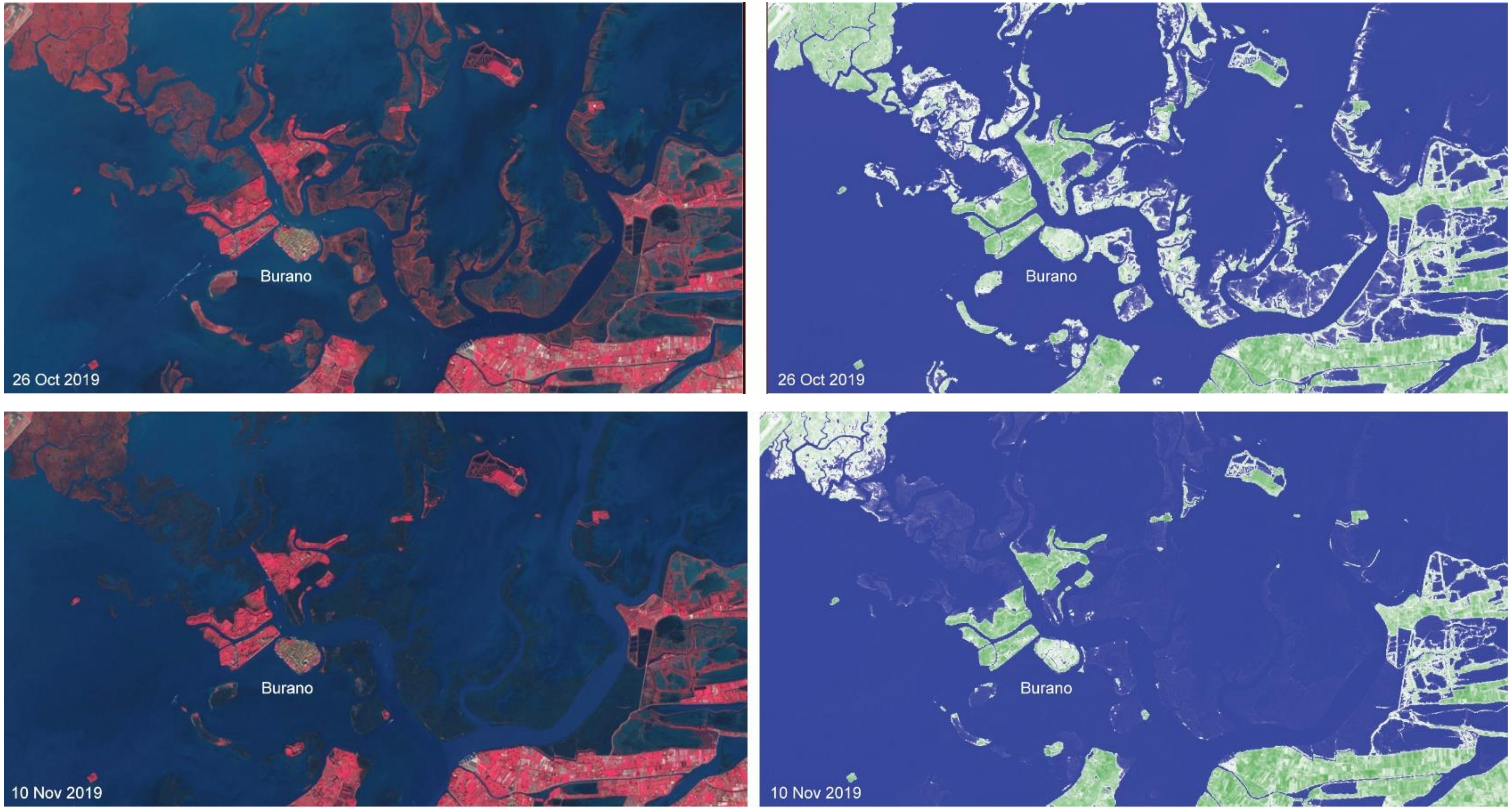
- Water absorbs the longer wavelengths of visible and NIR and SWIR domains
- Reflects the shorter wavelengths of the visible domain (blue, green)
- Water color depends on: depth, materials in suspension, vegetation



https:/www.esa.int/ESA_Multimedia/Images/2011/11/Reflectance_curves_of_snow_vegetation_water_and_rock

Optical Parameters to Consider for a Flood Mapping

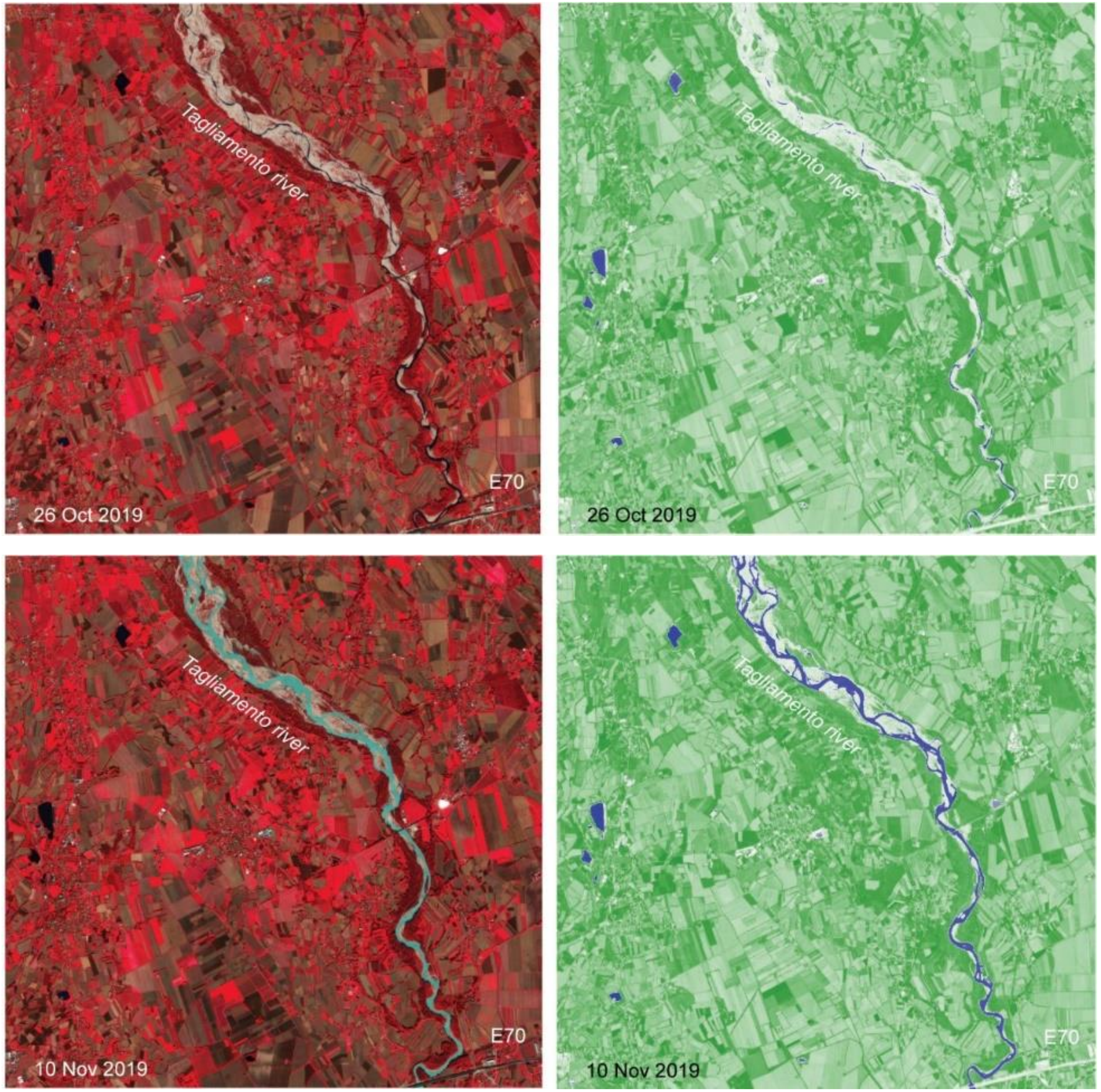
High variability of spectral answer and contrast



https://sentinel.esa.int/web/success-stories/-/copernicus-sentinel-2-captures-flooding-of-wetlands-in-the-laguna-of-venice

Optical Parameters to Consider for a Flood Mapping

High variability of spectral answer and contrast

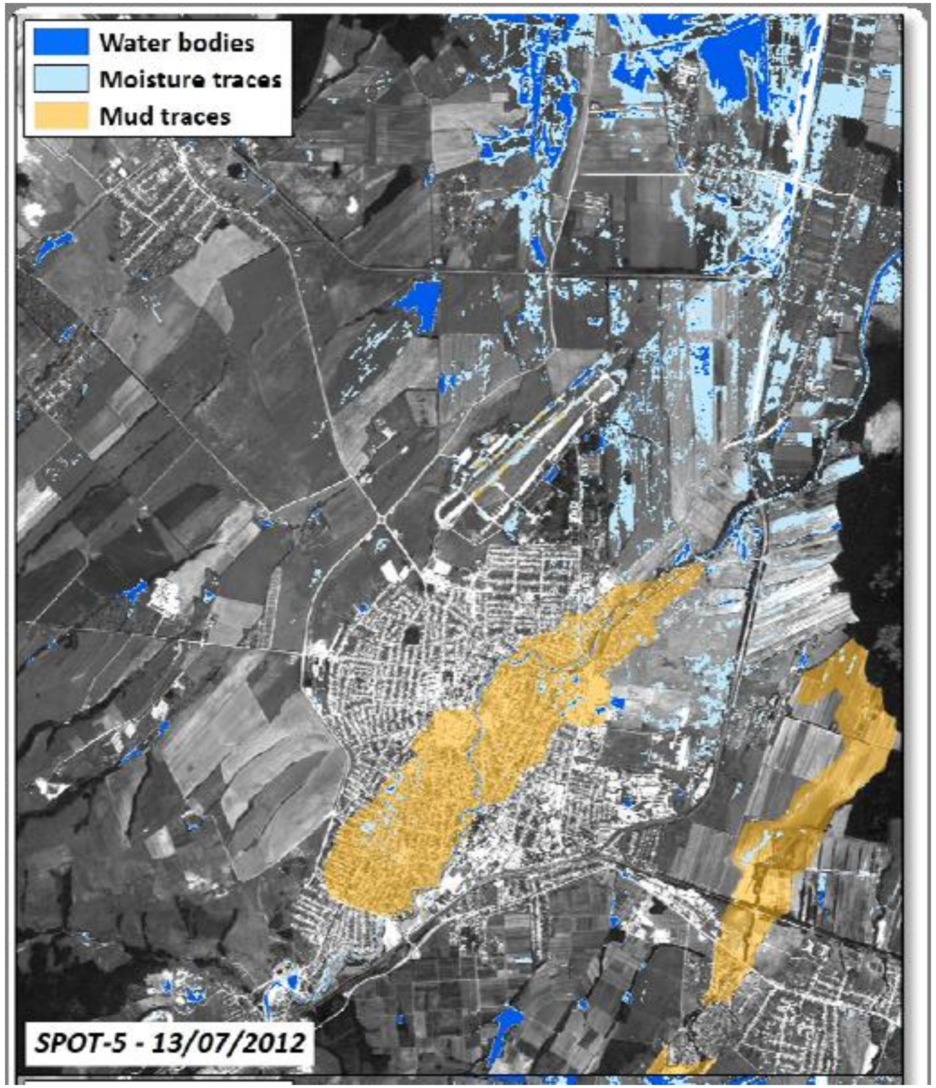


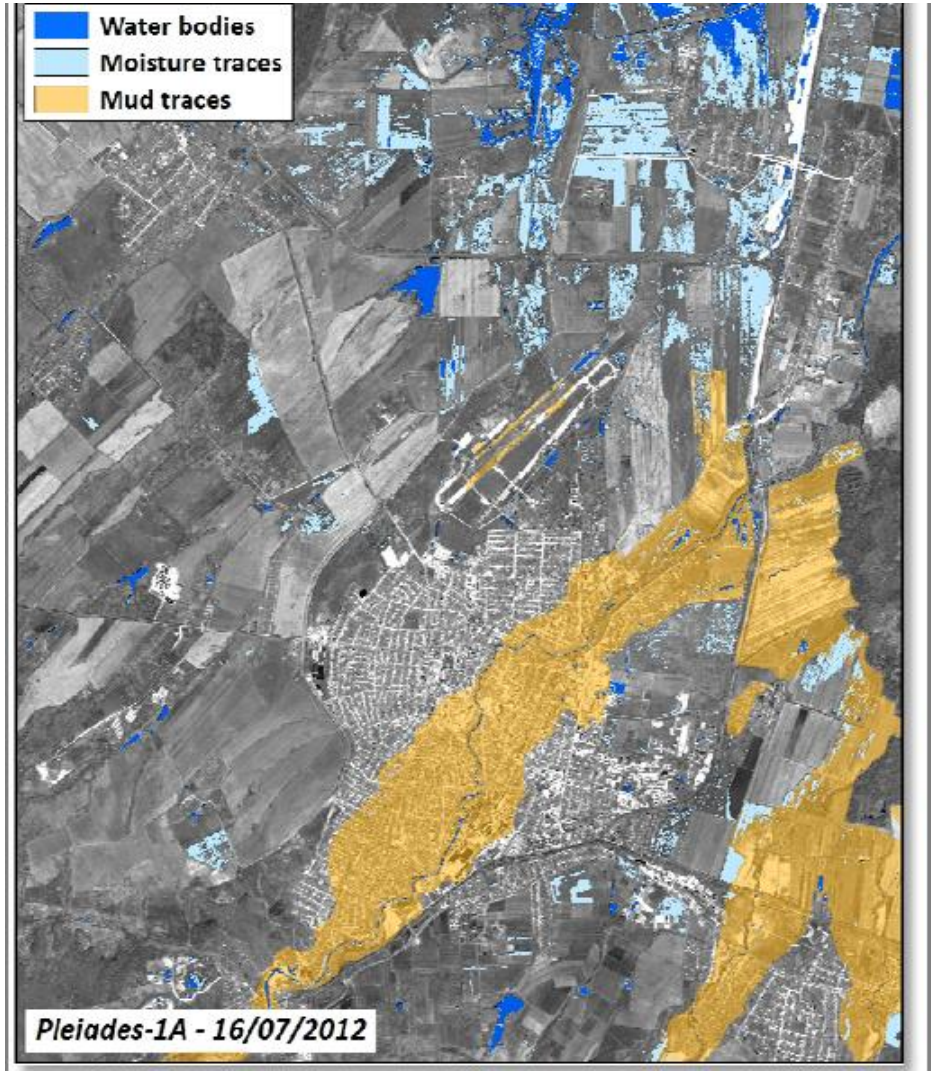
Copernicus Sentinel-2 captures rising river flow in the Tagliamento River
https://sentinel.esa.int/web/success-stories/-/copernicus-sentinel-2-captures-rising-river-flow-in-the-tagliamento-river

Common color compositions use visible, near infrared and shortwave infrared bands

Optical Parameters to Consider for a Flood Mapping

High variability of spectral answer and contrast





Flood traces classifications derived from SPOT 5 SWIR and VHR Pleiades data over Krymsk
https://ieeexplore.ieee.org/document/6723845/

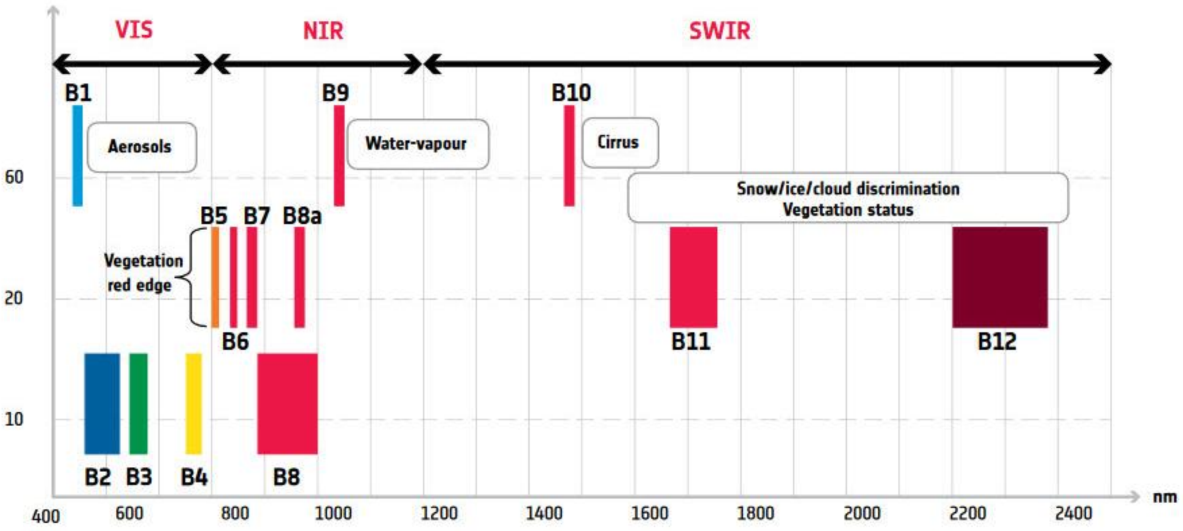
Optical Sensors for a Flood/Water Mapping

Sentinel-2

- Multi-Spectral imaging mission
- Sun-synchronous orbit 786 km,
- 290 km swath with 13 spectral bands (VIS, NIR & SWIR), at 10, 20 and 60 m spatial resolution
- 5 day revisit at Equator with 2 satellites

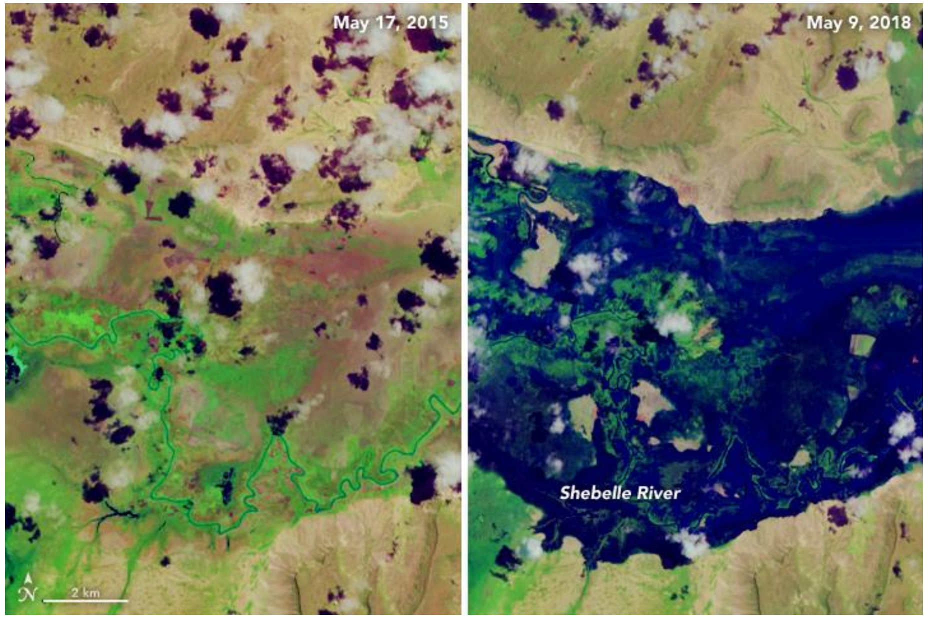
Landsat family

- Multi-Spectral imaging mission
- Systematic acquisition
- 8 days revisit (Landsat-8 and Landsat-9)
- Huge archive
- Since Landsat 4-5 . SWIR band
- 30 m



13 MSI bands are optimized for accurate atmospheric correction and vegetation monitoring

Source: http://esamultimedia.esa.int/docs/EarthObservation/Sentinel-2_ESA_Bulletin161.pdf



Source: https://landsat.visibleearth.nasa.gov/view.php?id=92130

Optical Sensors for a Flood/Water Mapping

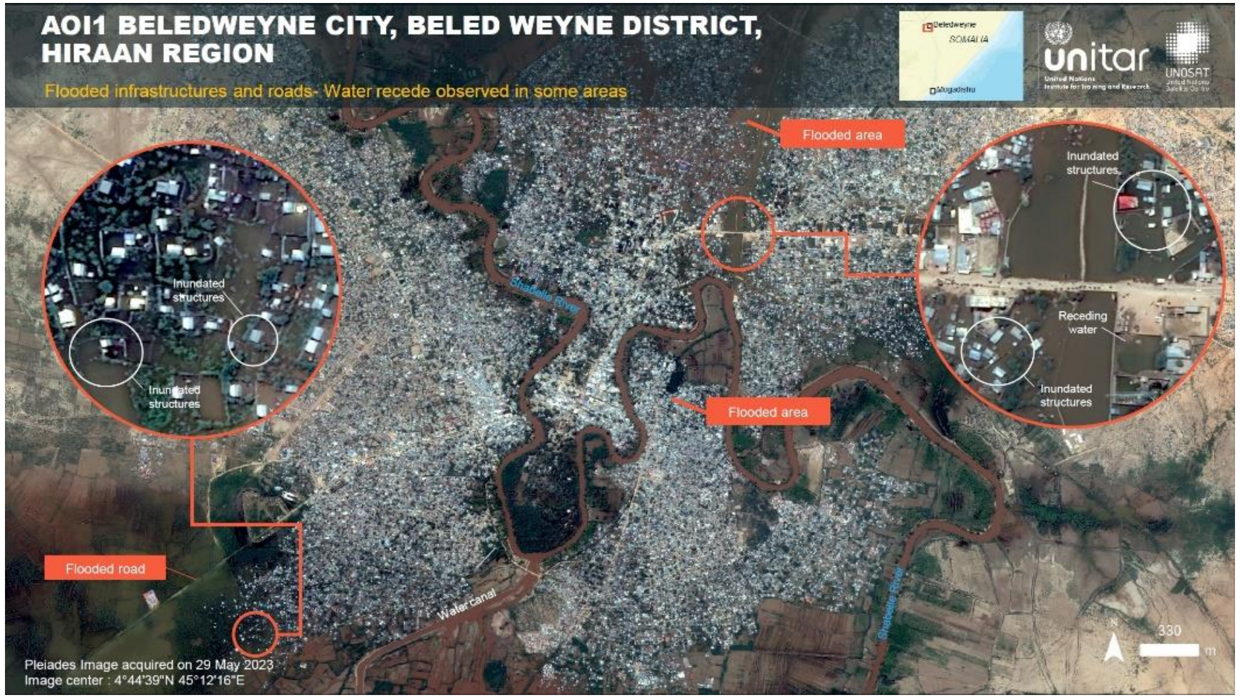
Spot family

- Very rich archive
- Visible, NIR, PAN bands
- Daily coverage capacity
- Spatial resolution 1,5-6m at nadir
- 2 satellites in constellation with Pleaides

Pleiades family

- 2 satellites in constellation
- Launch December 2011 and 2012
- 0,70 cm in PAN
- Visible, NIR, PAN bands

WorldView, etc.



Flash floods in Somalia are now affecting over 460,000 people according to the United Nations Office for the Coordination of Humanitarian Affairs (OCHA). Source:https://disasterscharter.org/es/web/guest/activations/-/article/flood-large-in-somalia-activation-821-

Thank you for the attention