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
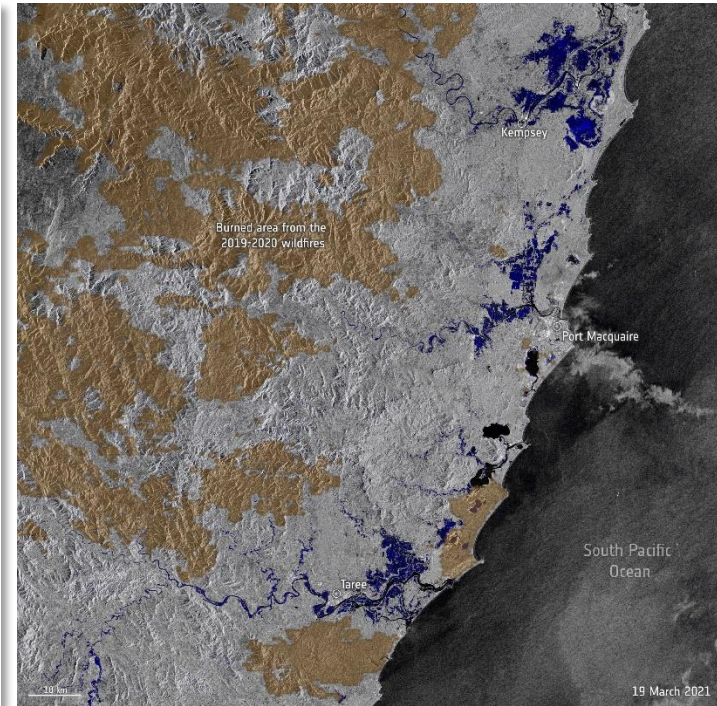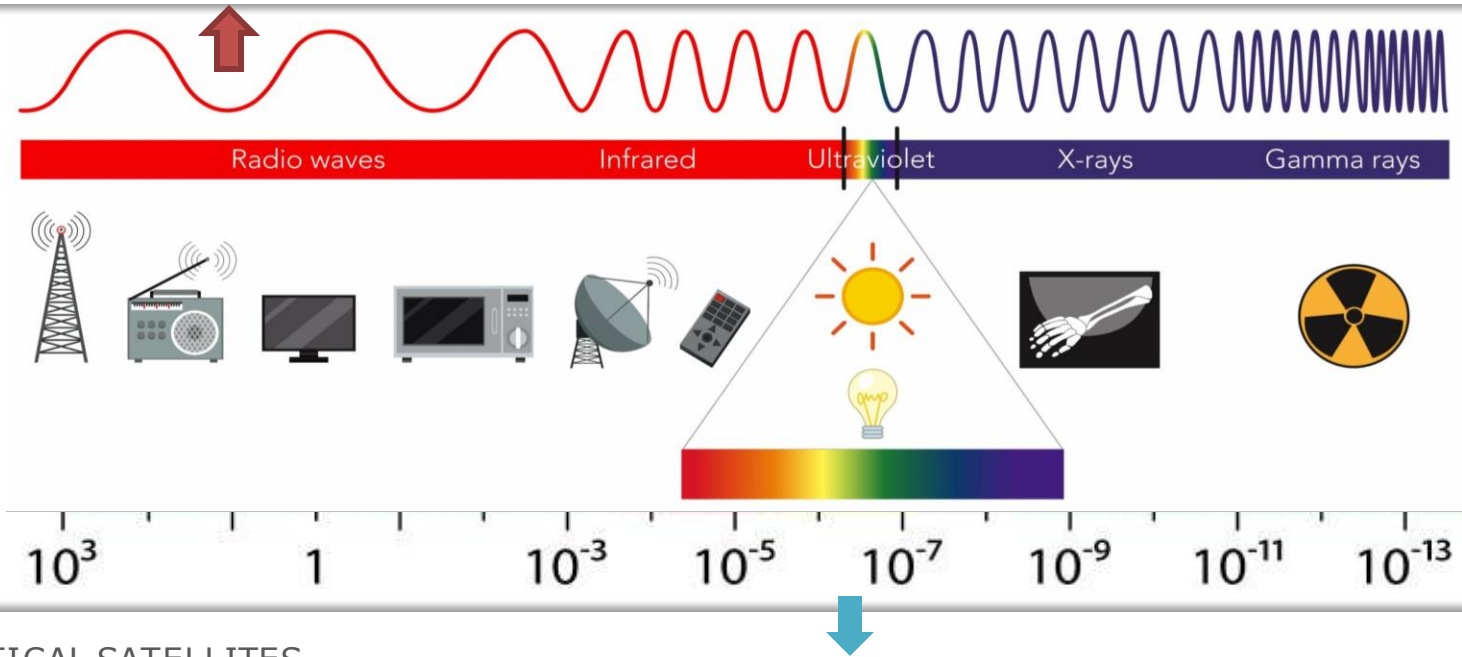

Credit: Contains modified Copernicus Sentinel data (2021), processed by ESA/NASA MODIS

SAR and optical for surface water mapping

RADAR SATELLITES

Weather & illumination independence   Use: Detection of water surfaces

Penetration through cloud cover   Changes in water levels

Radio waves   Infrared   Ultraviolet   X-rays   Gamma rays

10^3 1 10^{-3} 10^{-5} 10^{-7} 10^{-9} 10^{-11} 10^{-13}

OPTICAL SATELLITES

Weather & illumination dependence   Use: Flood extent, flood patterns, flood impacts

No penetration through cloud cover   Analyzing changes before and after flooding events

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)
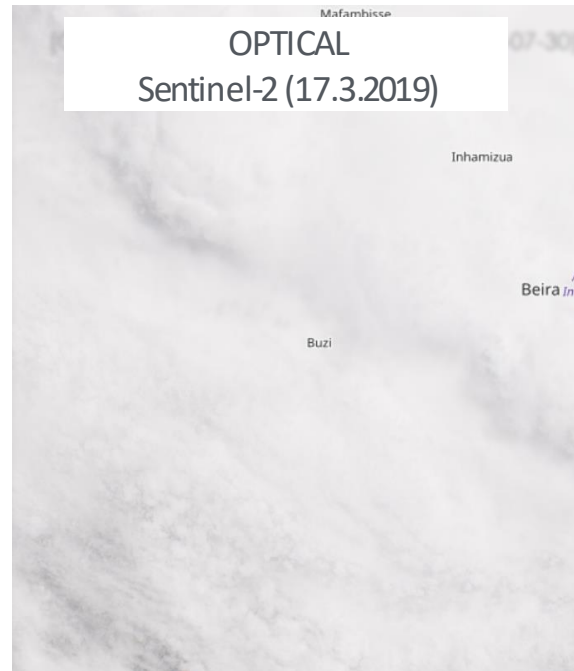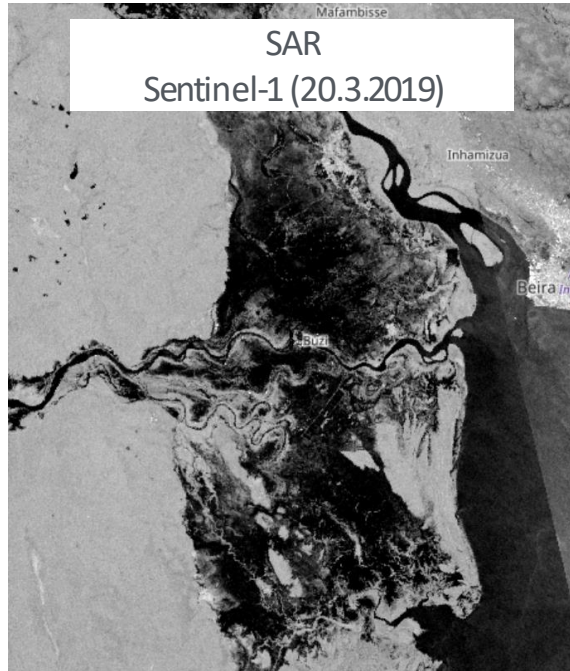
Floods in Beira, Mozambique

SAR for flood/water mapping
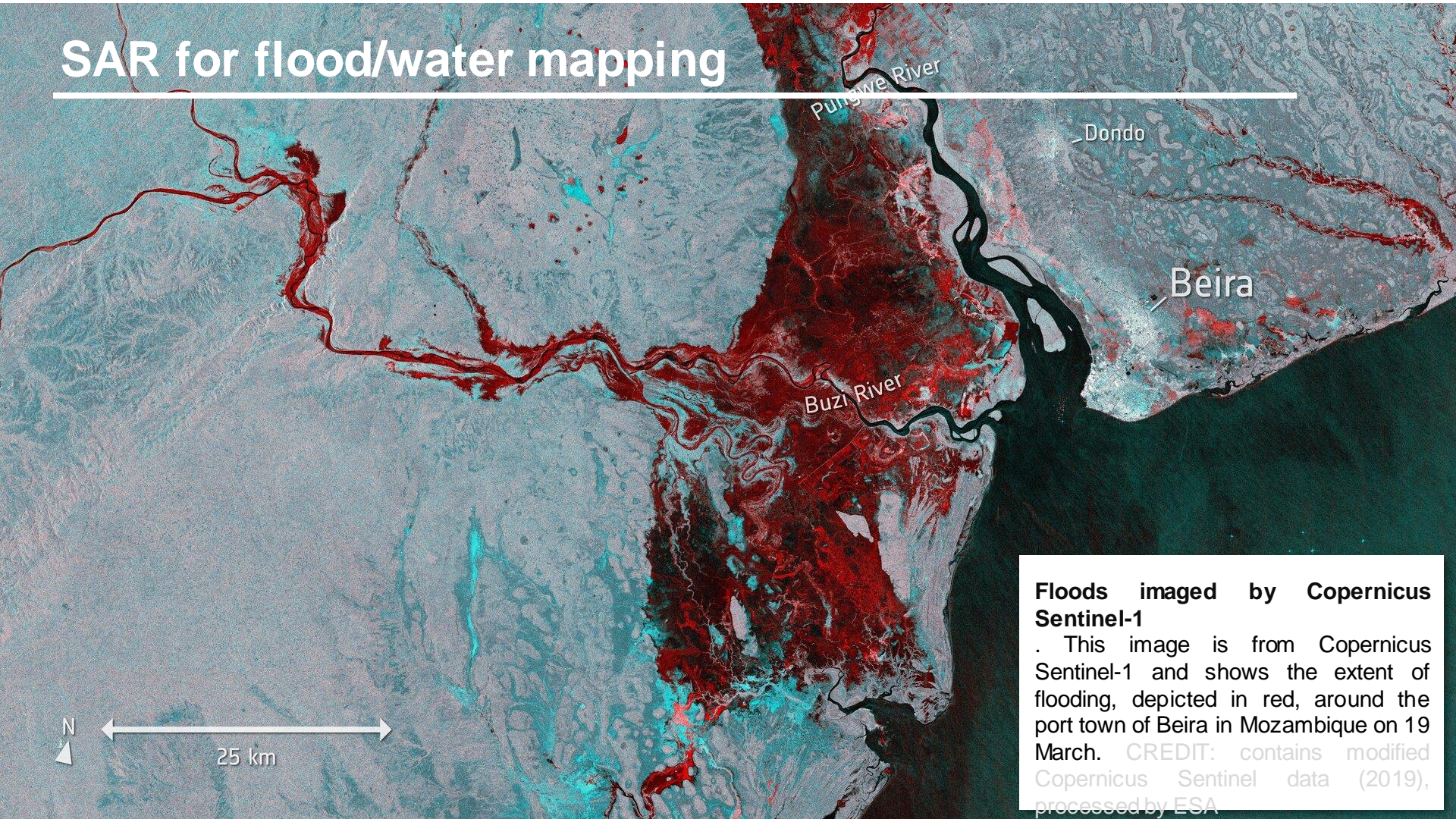
Pungwe River

Dondo

Beira

Buzi River

N

25 km

**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
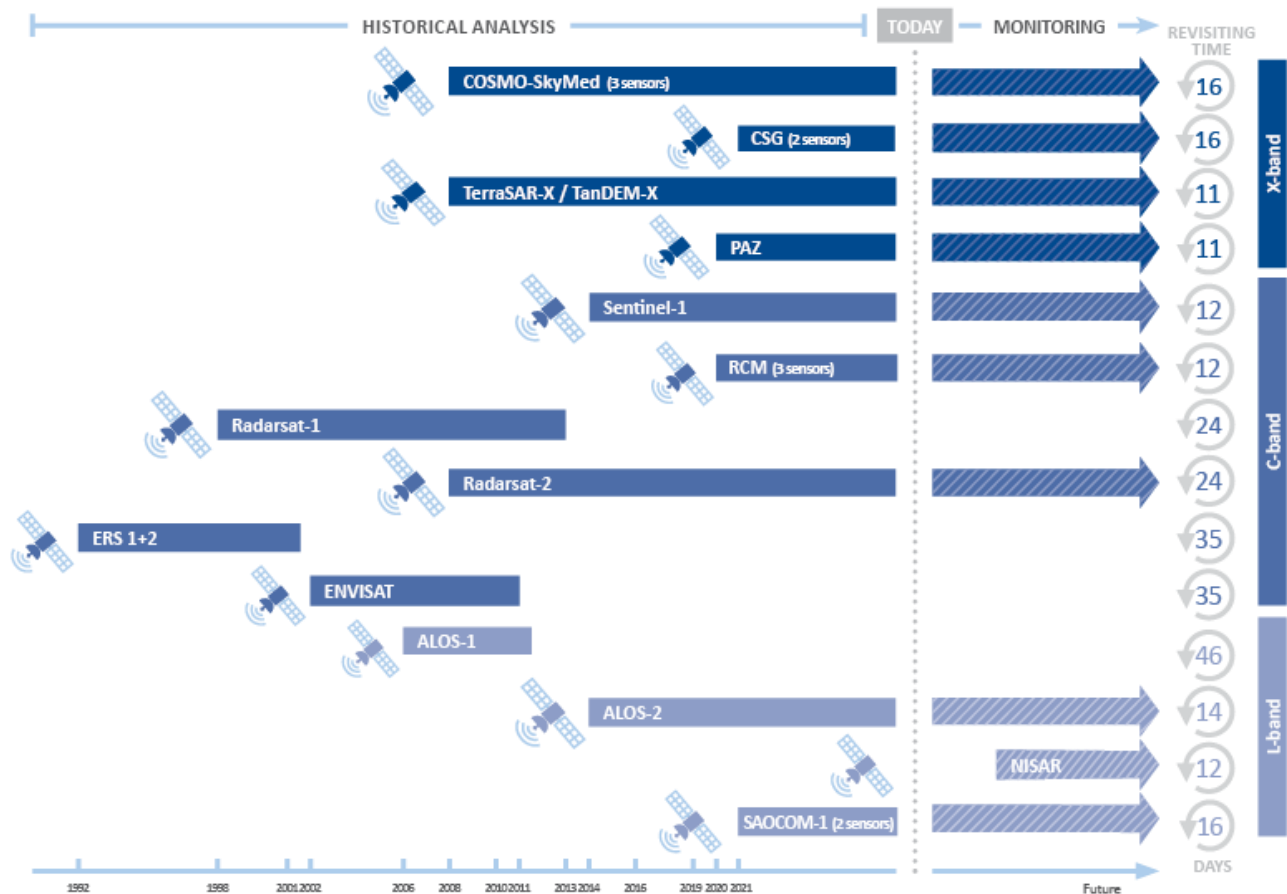
Ongoing missions

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
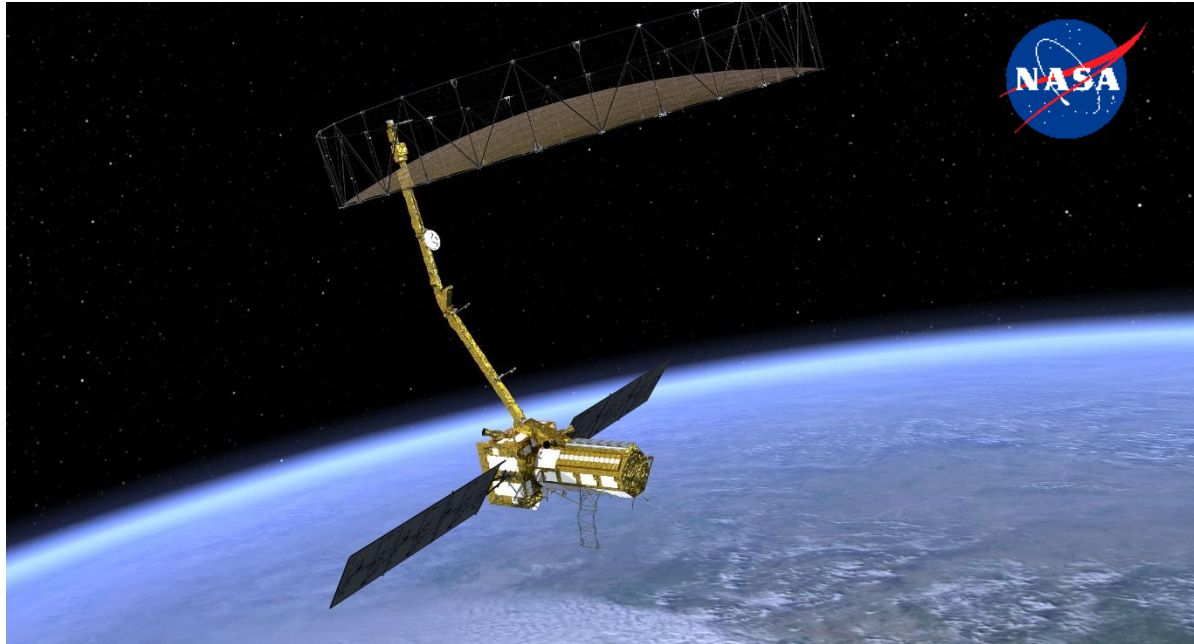
Sentinel-1, NISAR, TanDEM-L

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

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

Recent advancements in InSAR

Sentinel-1, NISAR, TanDEM-L

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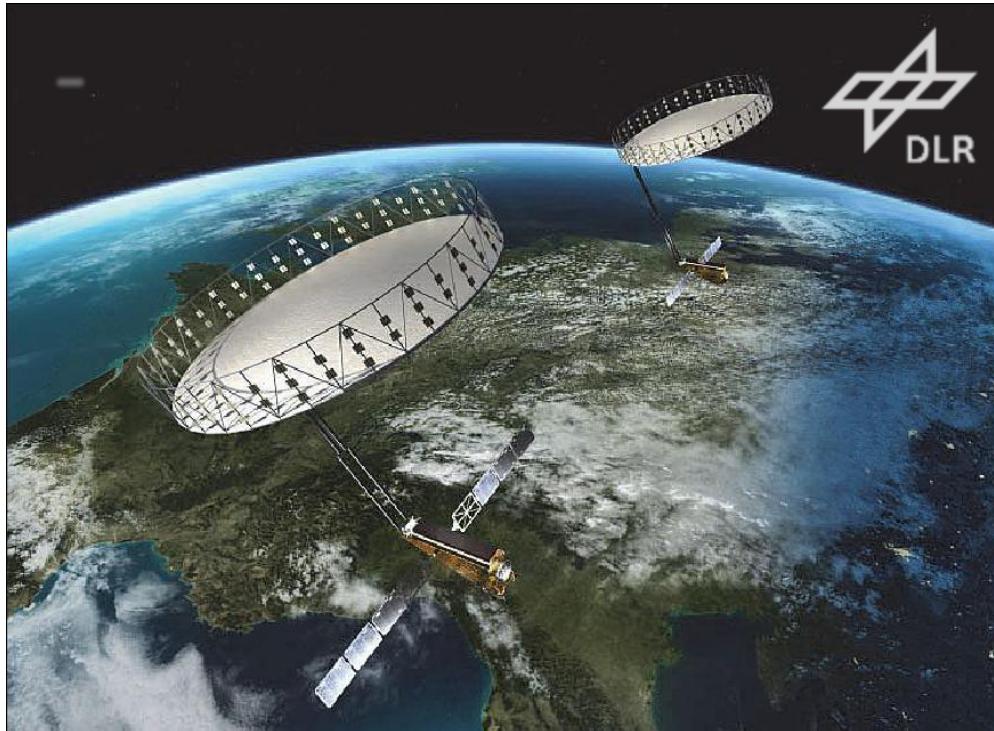
- Launch Date: 2023
- Provides free and open data
- First spaceborne L- and S- band SAR
- Temporal coverage: full global coverage in 12 days

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

Ice jam flooding in Fort McMurray
Sentinel-2, 28 & 29 April 2020
*False color image: bands 12, 11, 5*
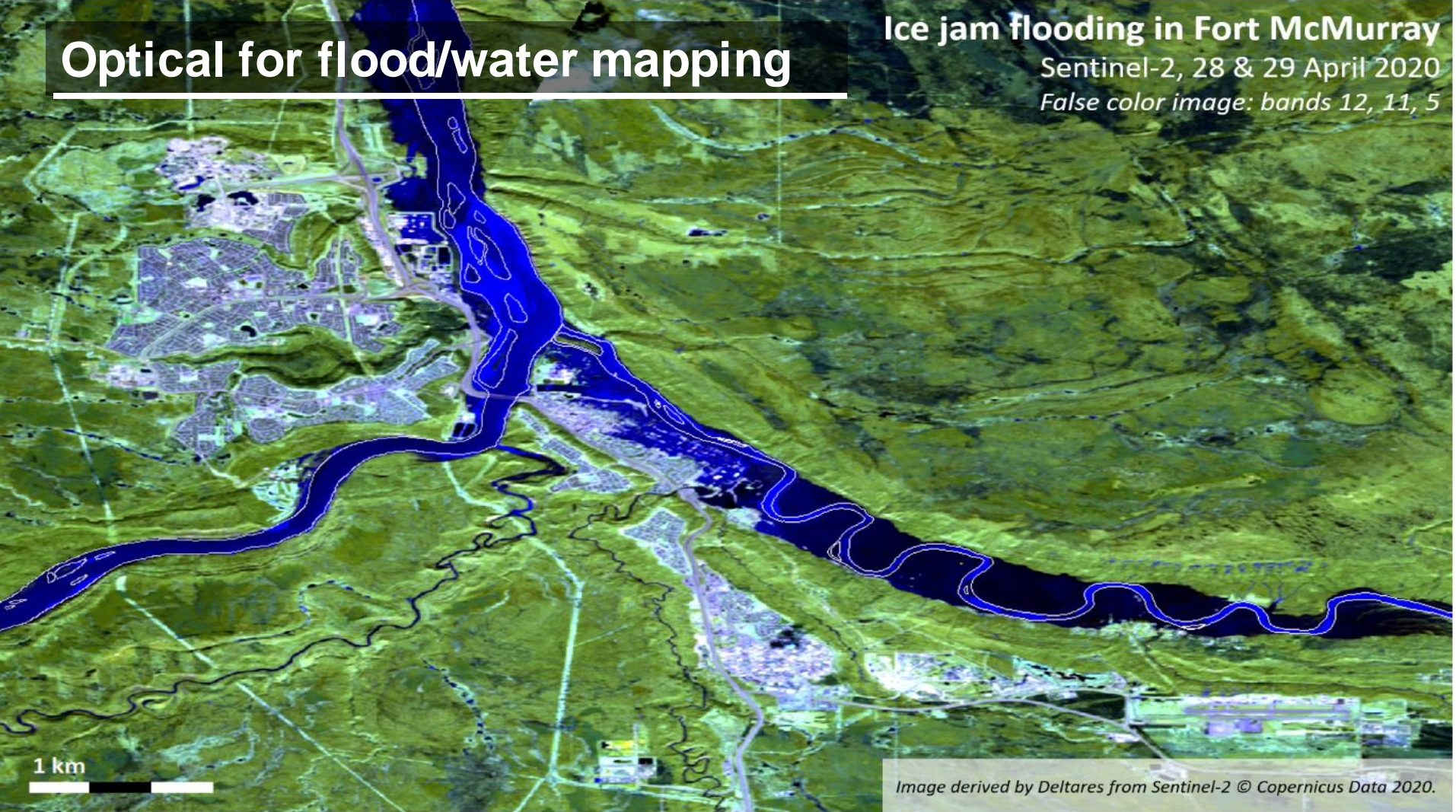
1 km

Image derived by Deltares from Sentinel-2 © Copernicus Data 2020.

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)
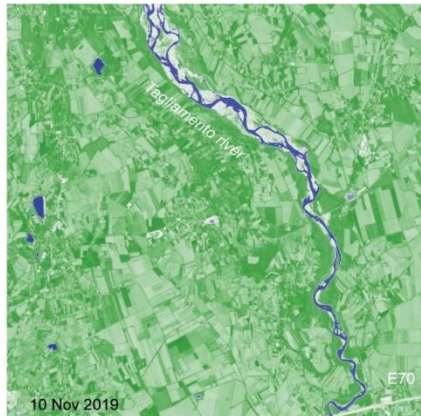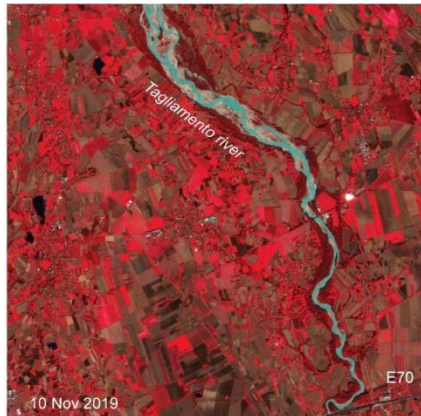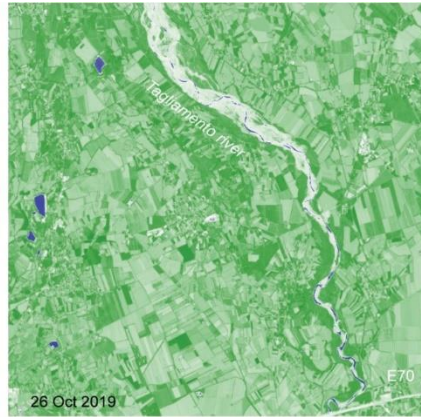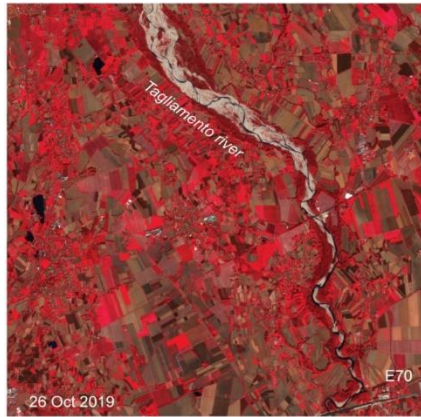- Water color depends on: depth, materials in suspension, vegetation
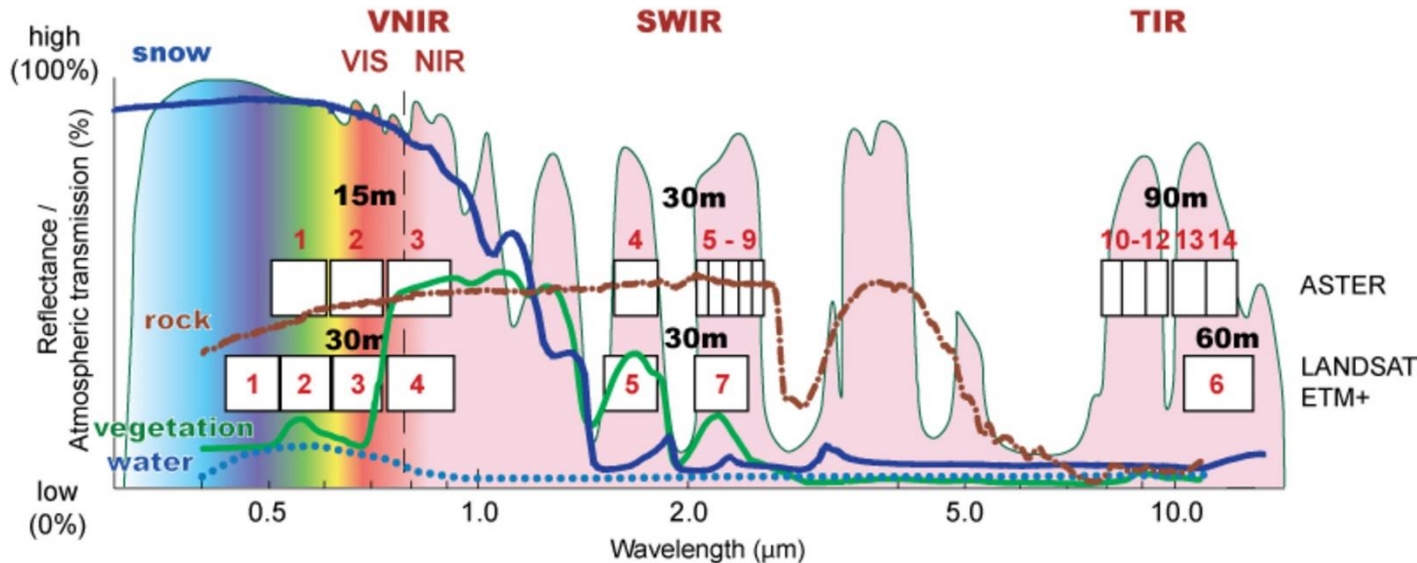
Optical Parameters to Consider for a Flood Mapping

High variability of spectral answer and contrast
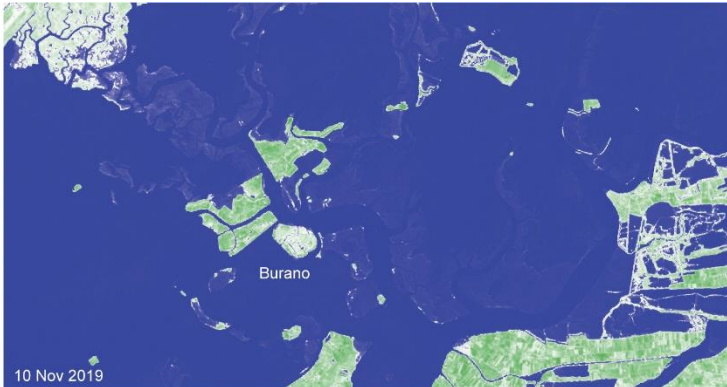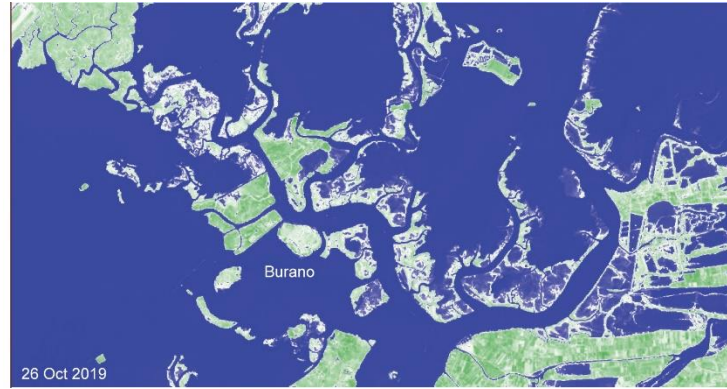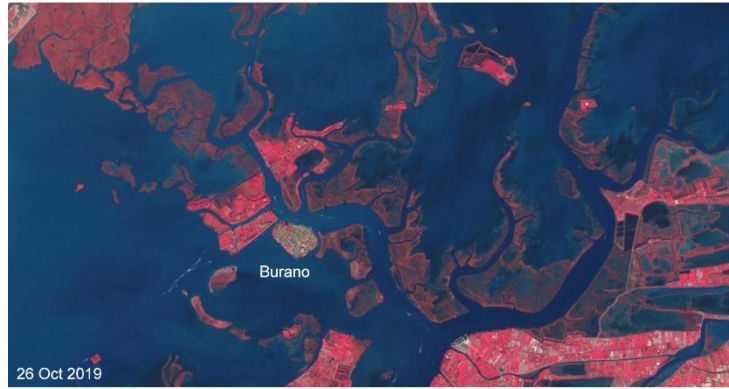
Optical Parameters to Consider for a Flood Mapping

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
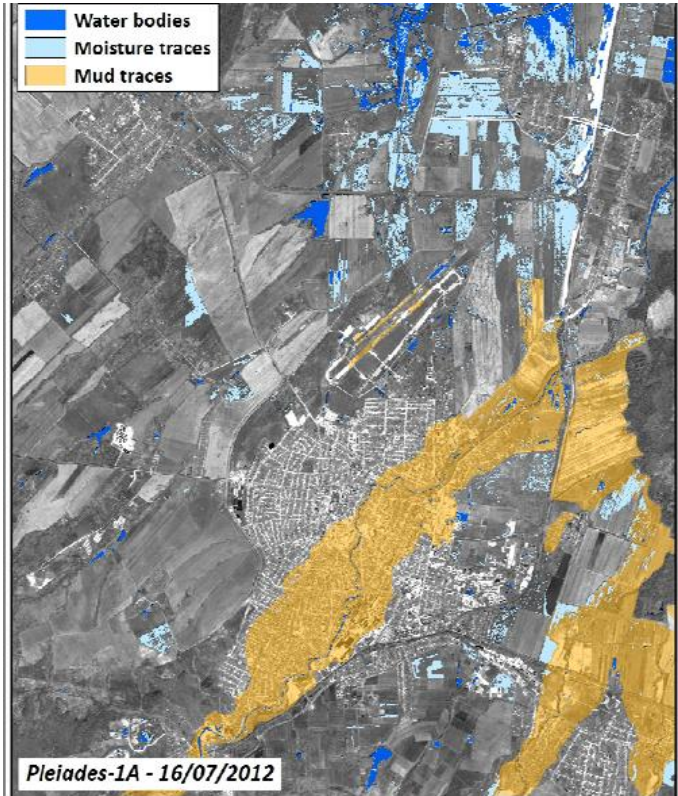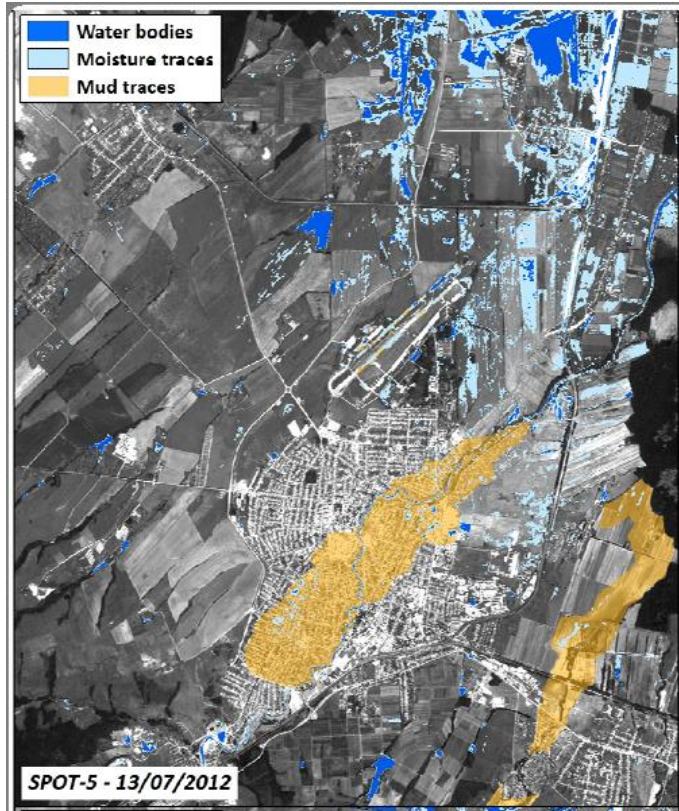
Flood traces classifications derived from SPOT 5 SWIR and VHR Pleiades data over Krymsk

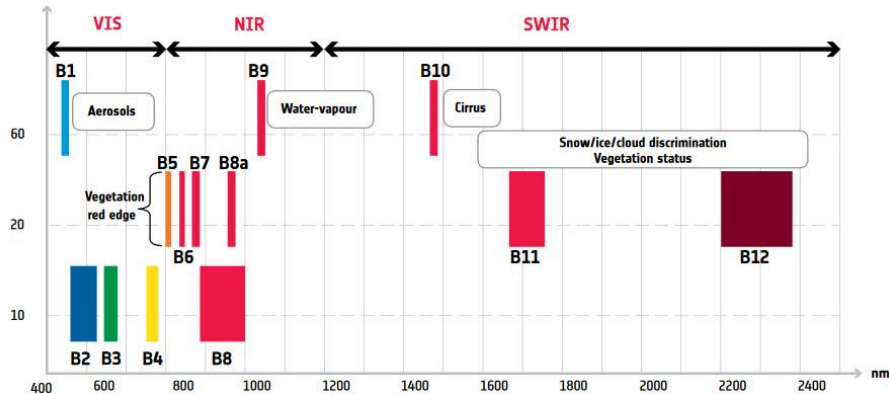https://ieeexplore.ieee.org/document/6723845/

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
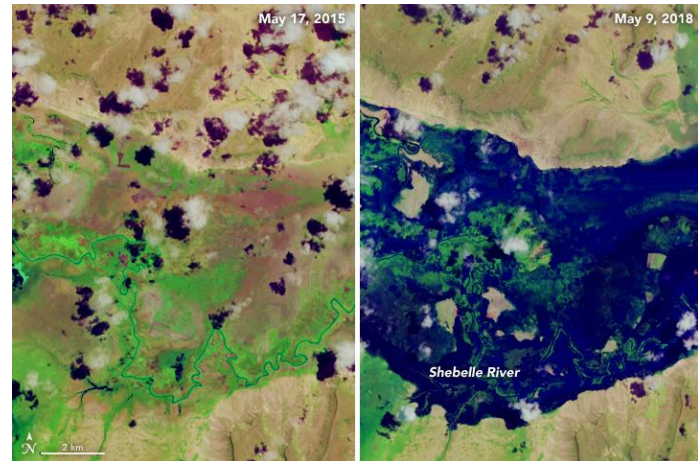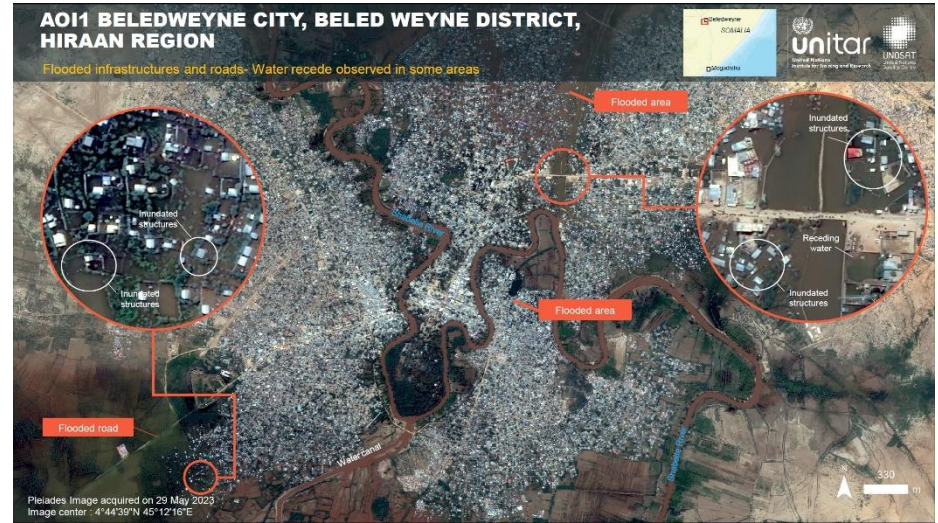
Optical Sensors for a Flood/Water Mapping

Spot family

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

Pleiades family

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

WorldView, etc.

AOI1 BELEDWEYNE CITY, BELED WEYNE DISTRICT, HIRAAN REGION
Flooded infrastructures and roads- Water recede observed in some areas

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

European Space Agency