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Copernicus Academy

ÚSTAV GEOGRAFIE
Prírodovedecká fakulta UPJŠ v Košiciach

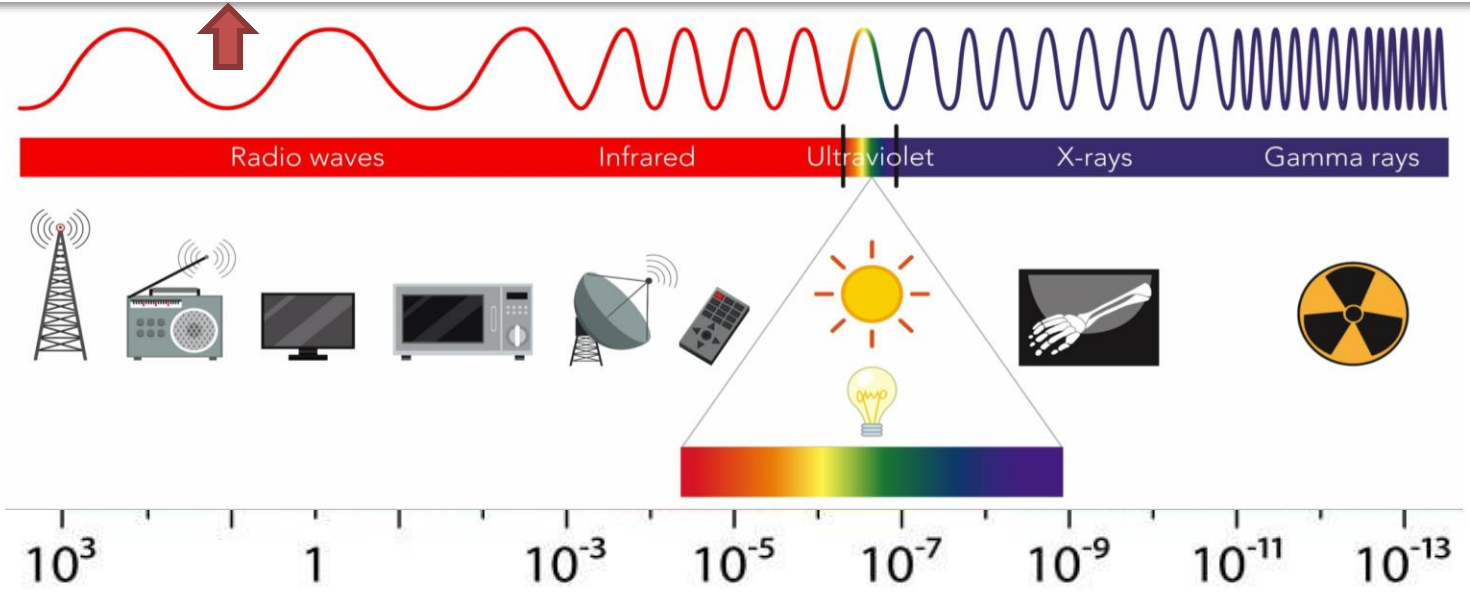
# 11. SAR and optical remote sensing for post-flood assessment and recovery

# SAR and optical for flood/postflood mapping

RADAR SATELLITES

Weather & illumination independence
Penetration through cloud cover

Use: Detection of water surfaces
Changes in water levels




OPTICAL SATELLITES

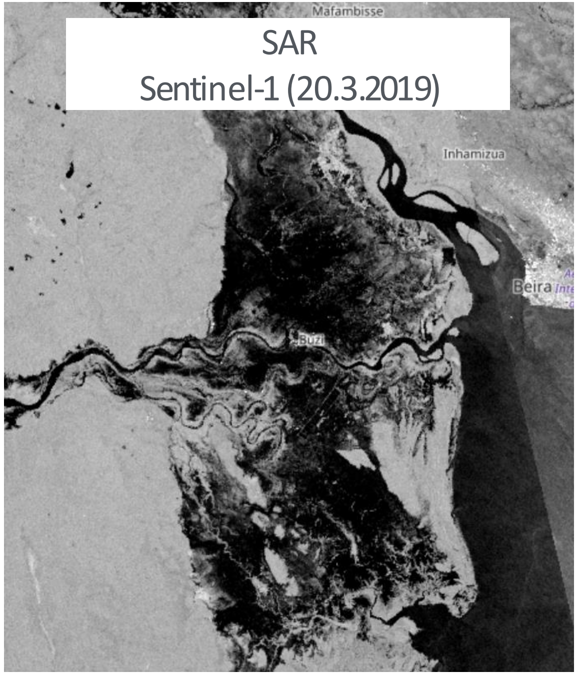
Weather & illumination dependence
No penetration through cloud cover

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

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

# SAR and optical for flood/postflood 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.



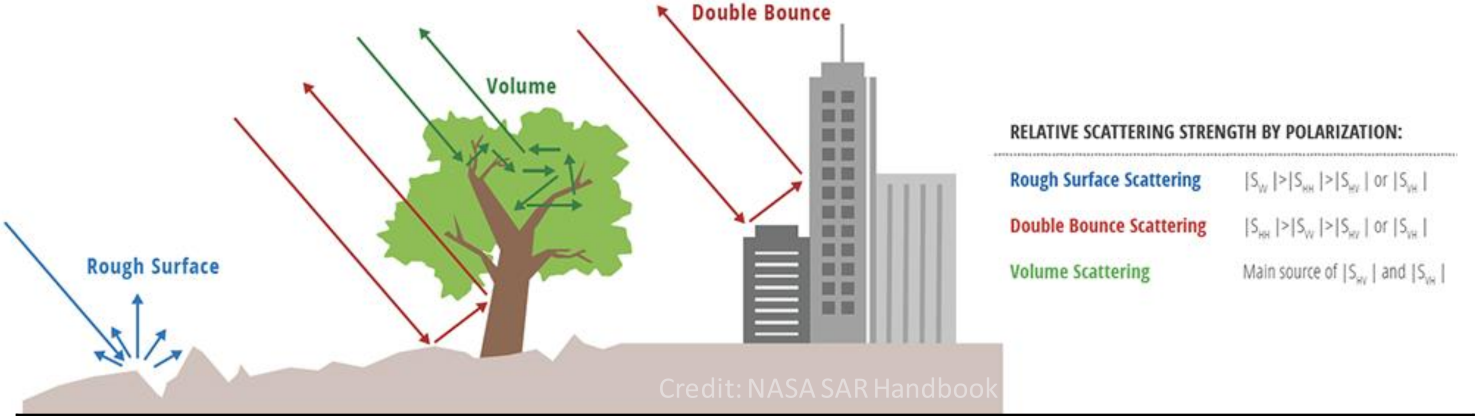


Floods in Beira, Mozambique

# Radar Parameters to Consider for a Flood Mapping

## Signal interacton

Analyzing the signal intensity from these various polarizations provides insights into the composition of the observed surface, as it relates to the following types of scattering:

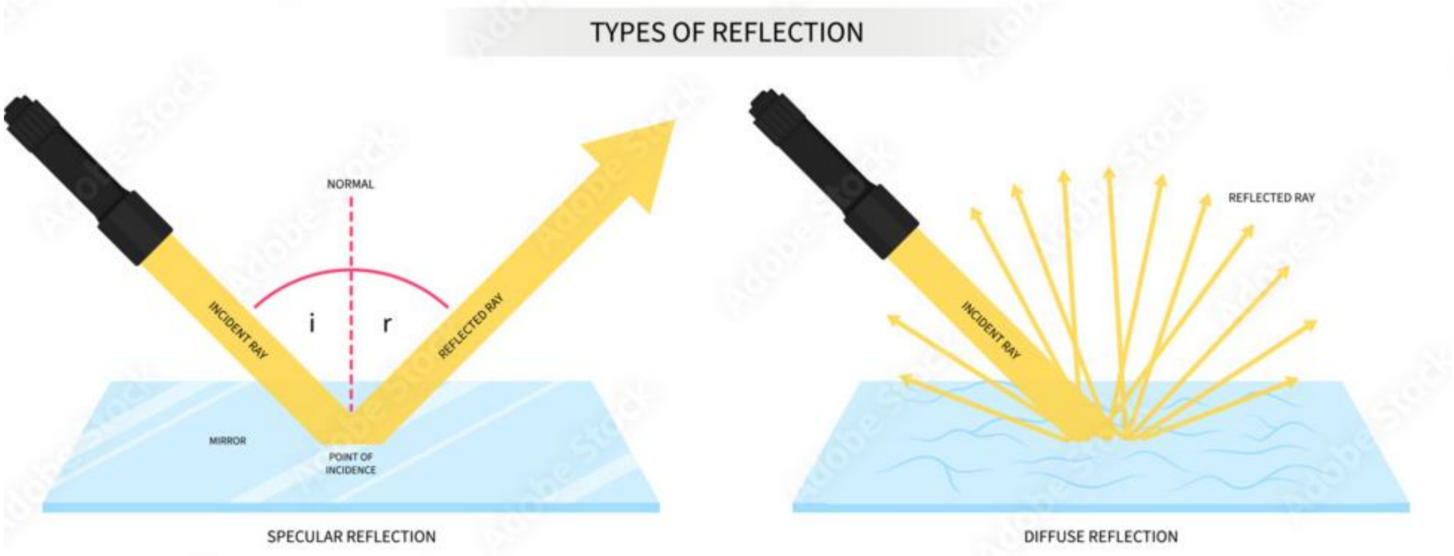



| | |
|---|---|
| Rough surface scattering | • most sensitive to VV scattering<br>• caused f.e. by bare soil or water |
| Volume scattering | • most sensitive to cross-polarized data like VH or HV<br>• scattering by the leaves and branches |
| Double bounce | • most sensitive to an HH polarized signal<br>• caused by buildings, tree trunks, or inundated vegetation |

# Radar Parameters to Consider for a Flood Mapping

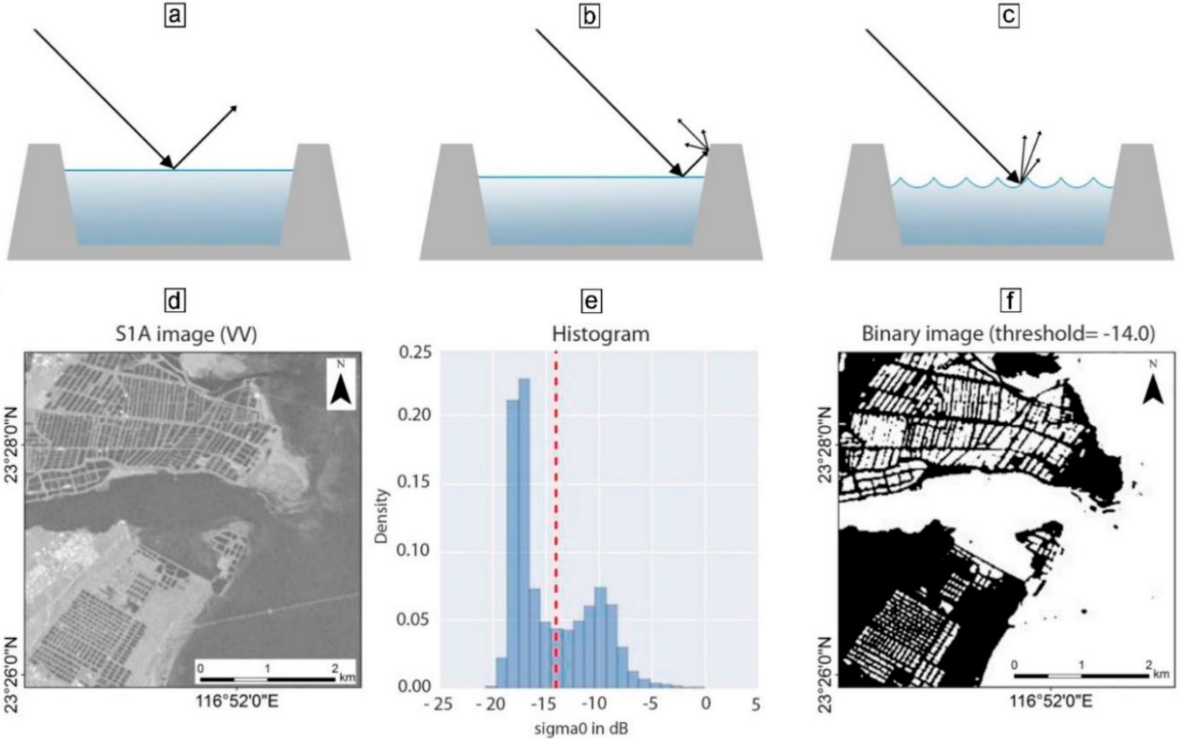
**Signal interacton**

- Calm water surfaces appear smooth, resulting in specular reflection and low backscatter in radar images
- In contrast, the surrounding land surface appears rougher, causing higher backscatter due to the scattering of radar waves by surface irregularities
- This difference in radar signatures allows for the mapping of water and other land surfaces



# Radar Parameters to Consider for a Flood Mapping

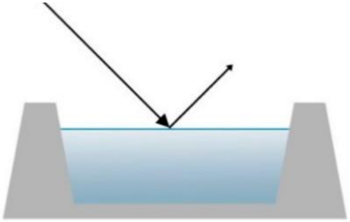
**Signal interacton**



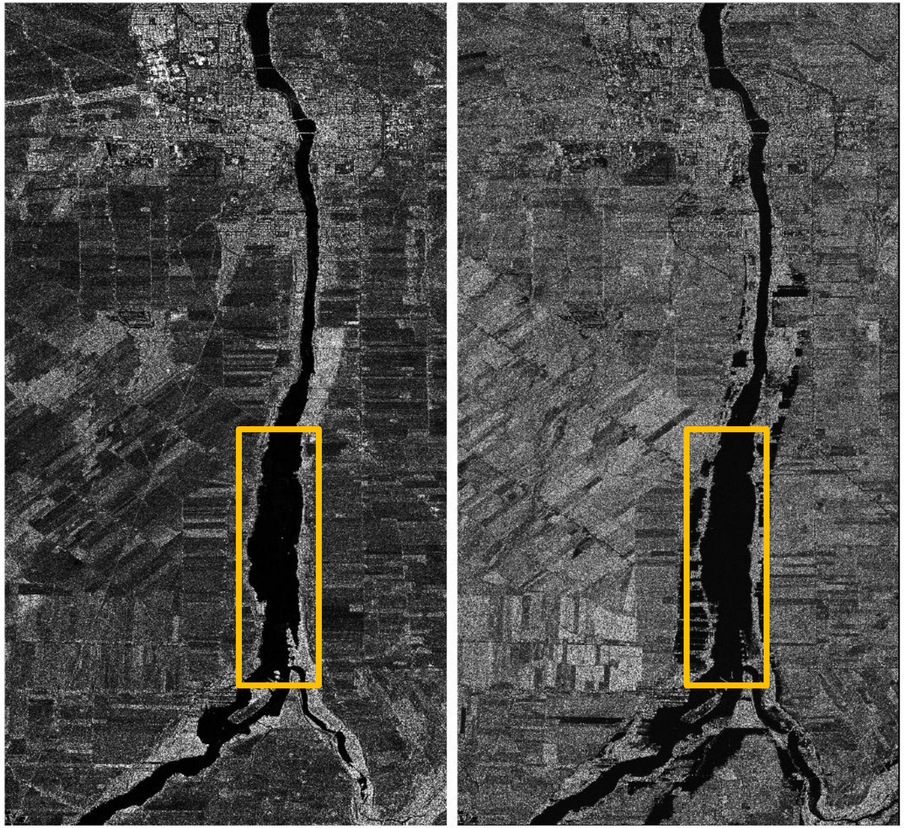

Examples of radar interaction with aquaculture ponds: (a) specular reflection (smooth water surface); (b) corner/embankment; and (c) diffuse reflection (rough water surface). (Bottom) S1A image (d); related histogram and classification threshold (e); and binary image of water and non-water after application of threshold (f). (Modified from Ottinger et al.

Source:https://www.mdpi.com/2072-4292/11/17/1985

# Radar Parameters to Consider for a Flood Mapping



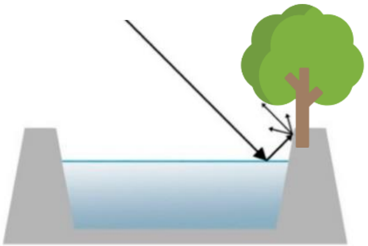
**Smooth, Level Surface**
(Open Water, Road)



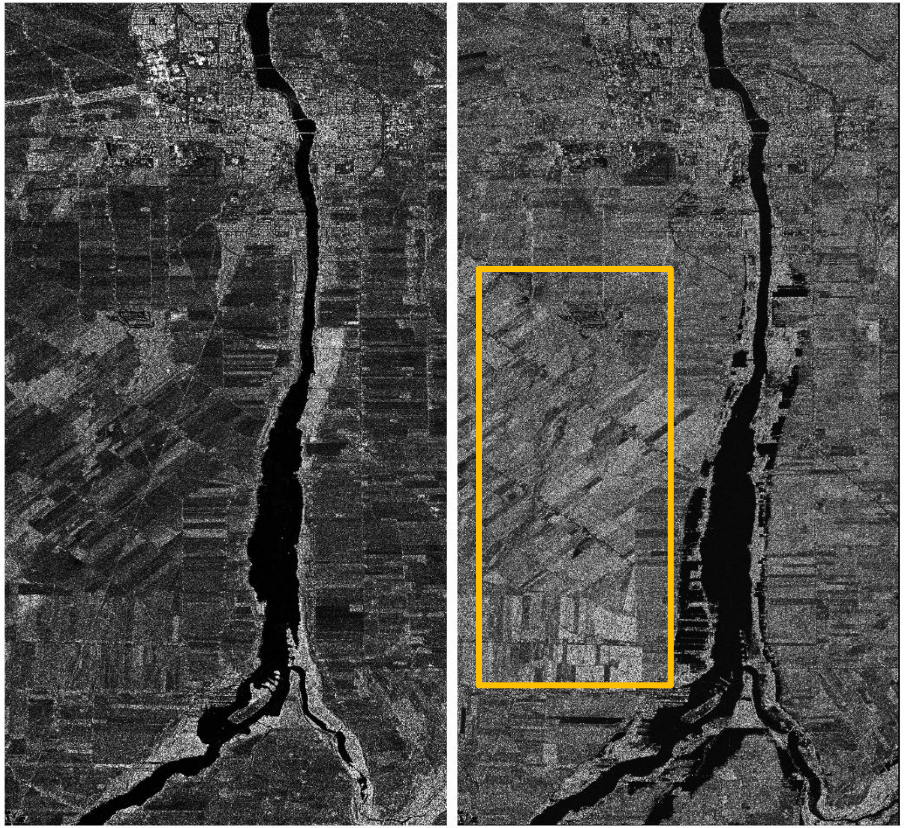
(a) (b)

https://www.mdpi.com/2072-4292/10/2/237

# Radar Parameters to Consider for a Flood Mapping



Inundated Vegetation



(a) (b)

https://www.mdpi.com/2072-4292/10/2/237

# Radar Parameters to Consider for a Flood Mapping

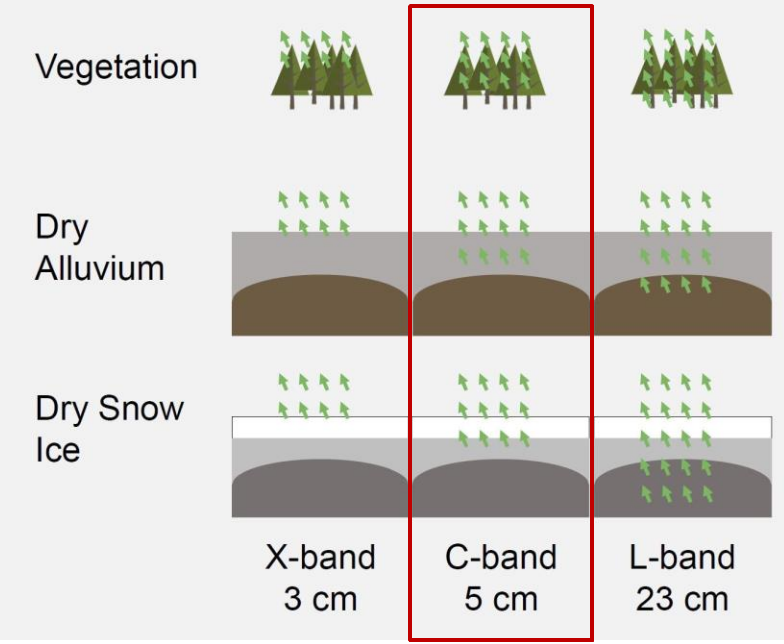
**Penetration through land covers as a Function of Wavelength and dielectric characteristics**

- The penetration depth is depending on **wavelength** and **dielectric characteristics** of objects
- Penetration - predominant consideration when selecting a wavelength
- Typically, longer wavelengths result in greater penetration into the target

**Flood Monitoring:**

- X-band mostly scatters at the tops of trees
- C- and L-band signals penetrate increasingly

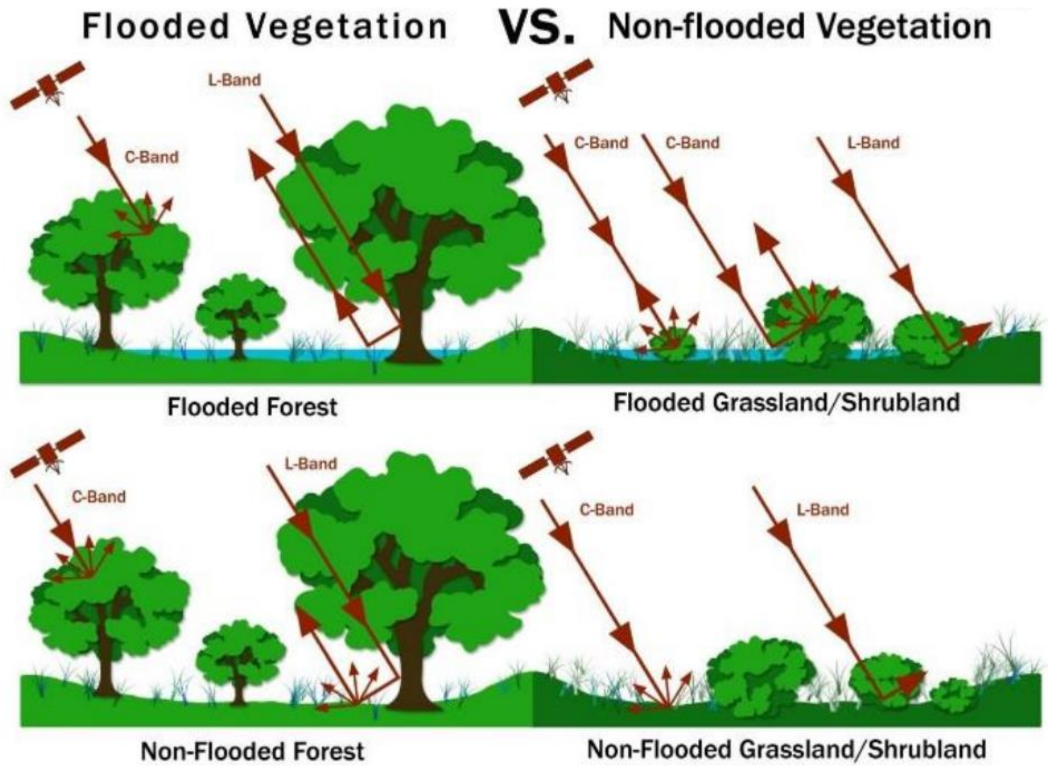
- Longer wavelength - better mapping of inundation under forest canopies




Source:https://medium.com/@preet.balaji20/decoding-synthetic-aperture-radar-sar-remote-sensing-sar-series-part-1-getting-started-d3409eb3b2e3

# Radar Parameters to Consider for a Flood Mapping

## Flooding under Vegetation Canopies




**C-band:**

~6cm, 4-8GHz

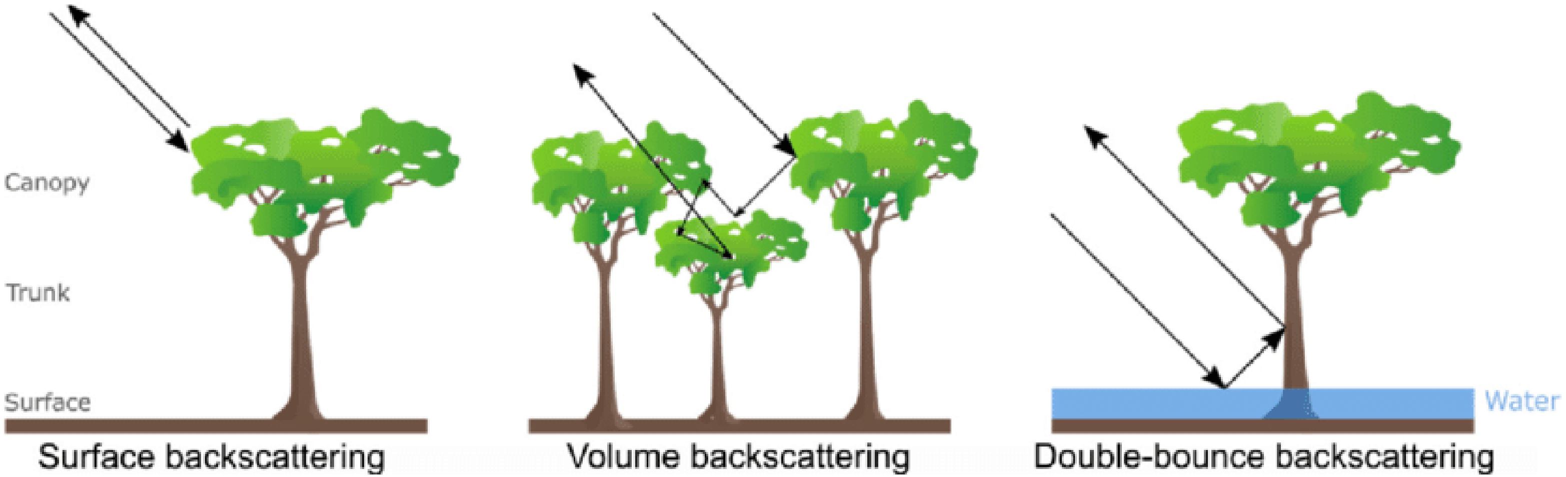
**L-band:**

~23cm, 1-2GHz

Enhanced return if tree cover underlain by water (double bounce effect – smooth water surface – vertical vegetation structures

# Radar Parameters to Consider for a Flood Mapping

## Flooding under Vegetation Canopies




**Nonflooded condition**

- Signal scattering in the crown and on the ground

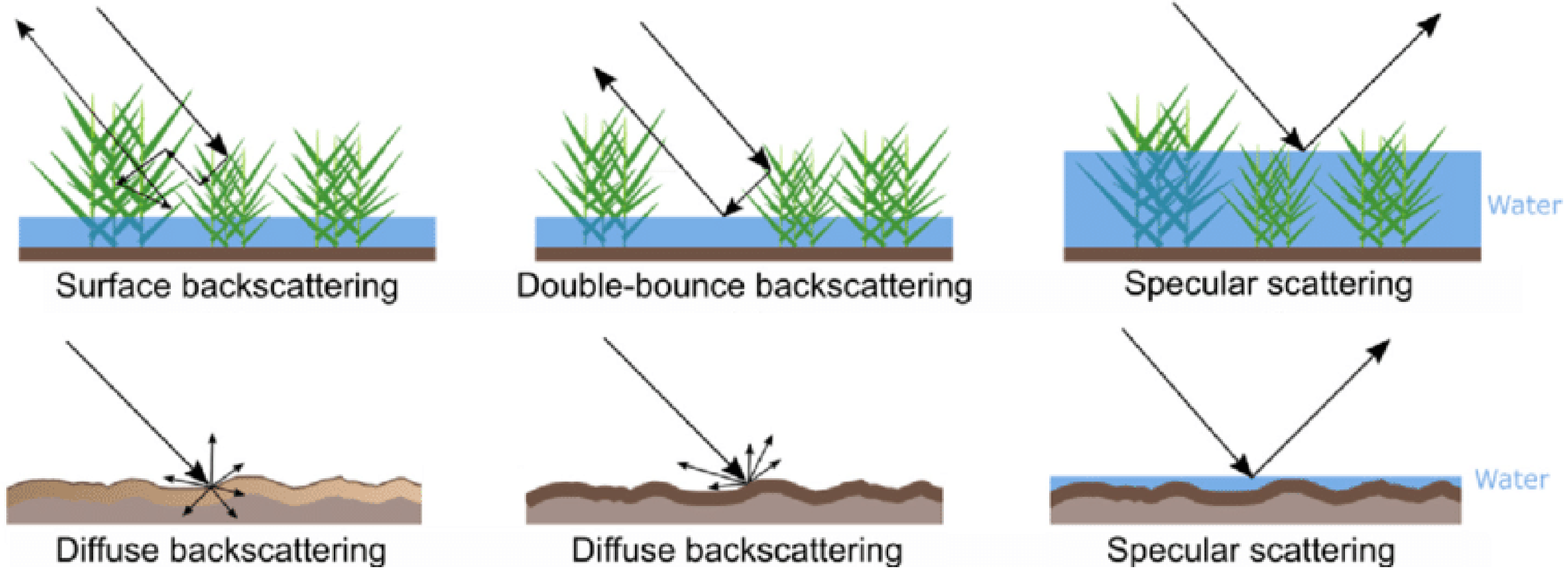
**Flooded condition**

- Submerged wetland/open water
- Strong double-bounce reflection between the tree trunks and the water surface

https://www.mdpi.com/2072-4292/12/14/2228

# Radar Parameters to Consider for a Flood Mapping

**Innundation in Crops and Meadows**



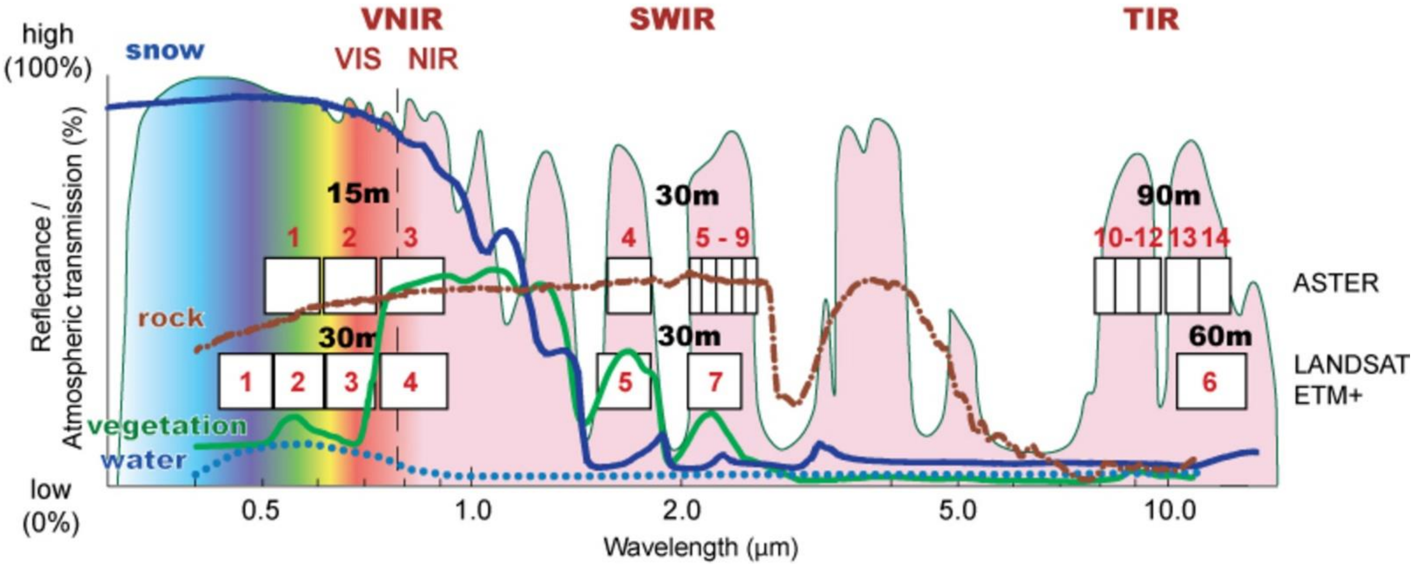

- Backscatter increases with soil moisture
- With increasing water level, backscatter becomes weaker with more specular reflection (scattering away from the sensor)

https://www.mdpi.com/2072-4292/12/14/2228

# Optical Parameters to Consider for a Postfloods/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 Postfloods/Flood Mapping

## Inidices for floods/postfloods mapping

| Index | Equation | Remark |
|---|---|---|
| Normalized Difference Water Index | NDWI = (Green − NIR)/(Green + NIR) | Water has positive value |
| Normalized Difference Moisture Index | NDMI = (NIR − MIR)/(NIR + MIR) | Water has positive value |
| Modified Normalized Difference Water Index | MNDWI = (Green − MIR)/(Green + MIR) | Water has positive value |
| Water Ratio Index | WRI = (Green + Red)/(NIR + MIR) | Value of water body is greater than 1 |
| Normalized Difference Vegetation Index | NDVI = (NIR − Red)/(NIR + Red) | Water has negative value |
| Automated Water Extraction Index | AWEI = 4 × (Green-MIR) − (0.25 × NIR + 2.75 × SWIR) | Water has positive value |

# Earth Observation Applications for Post-Flood Recovery

- Satellite imagery and data products have played a crucial role in addressing the floods along, facilitating effective response efforts
- The varied spatial, temporal, and spectral resolution of Earth observation (EO) data enables numerous applications for flood recovery
- Key areas where EO can aid in flood recovery efforts:

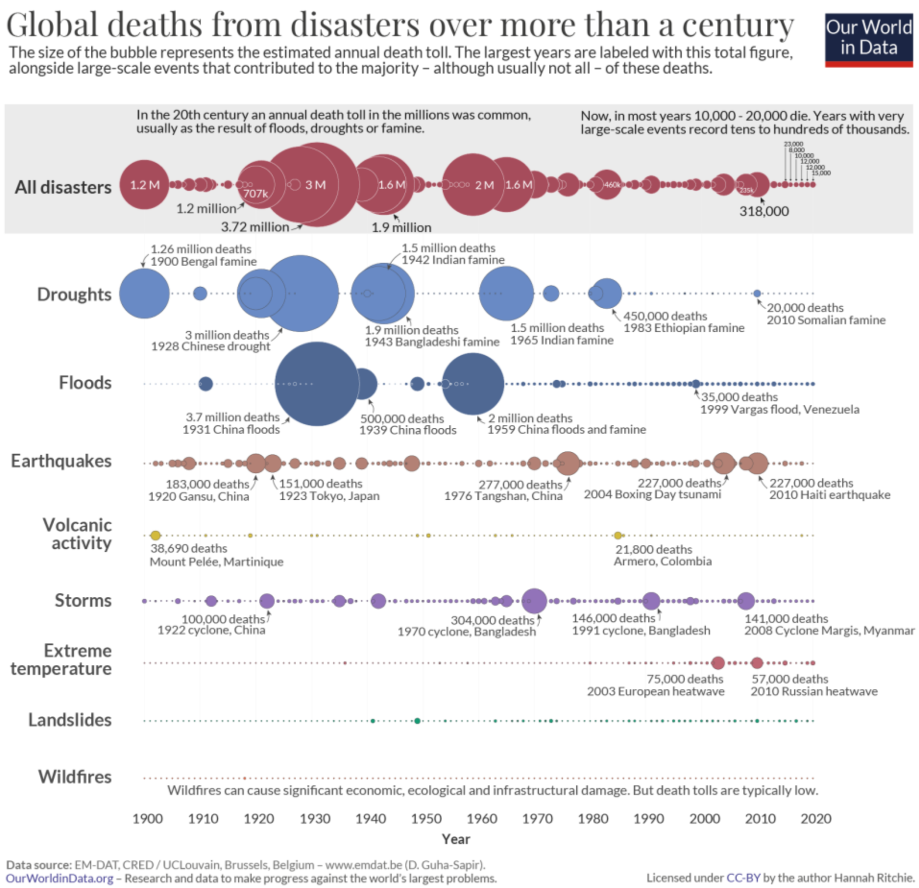
  - mapping flood extent

  - monitoring impacts

  - reducing flood risk

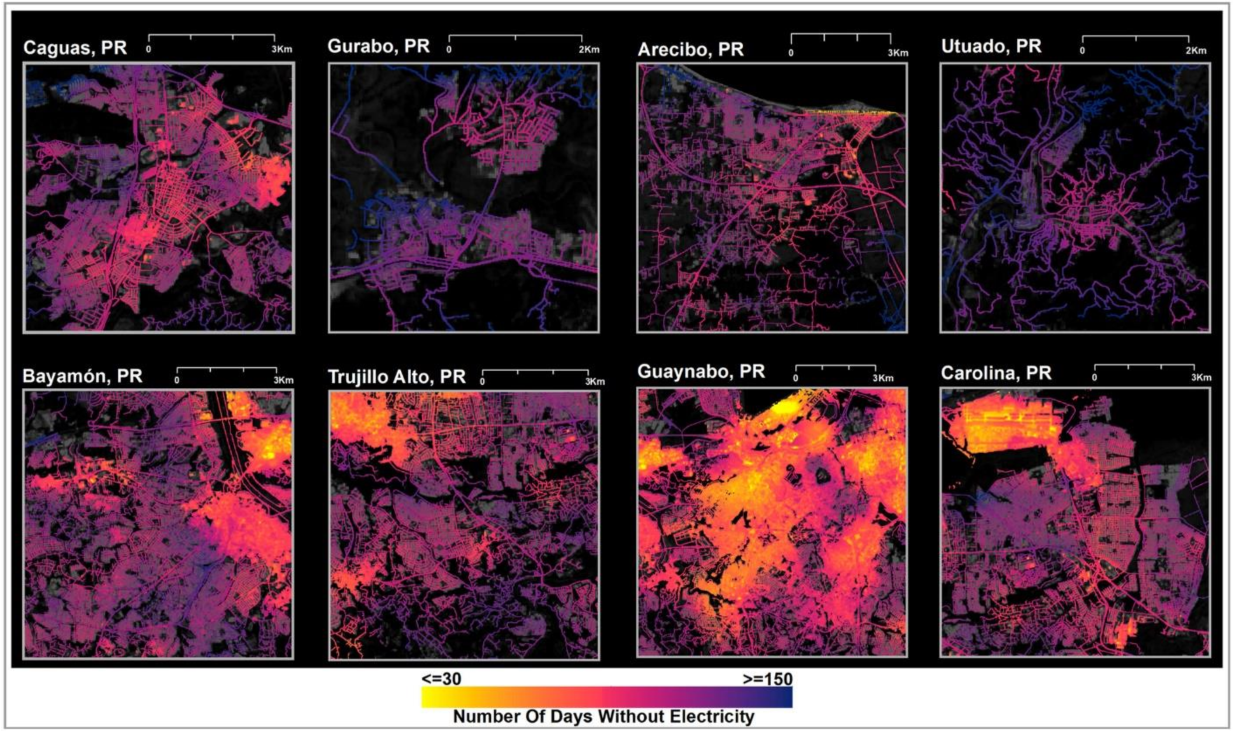
  - evaluating flood-related adaptation programs

Source:https://ourworldindata.org/natural-disasters#extreme-precipitation-and-flooding



# Earth Observation Applications for Post-Flood Recovery

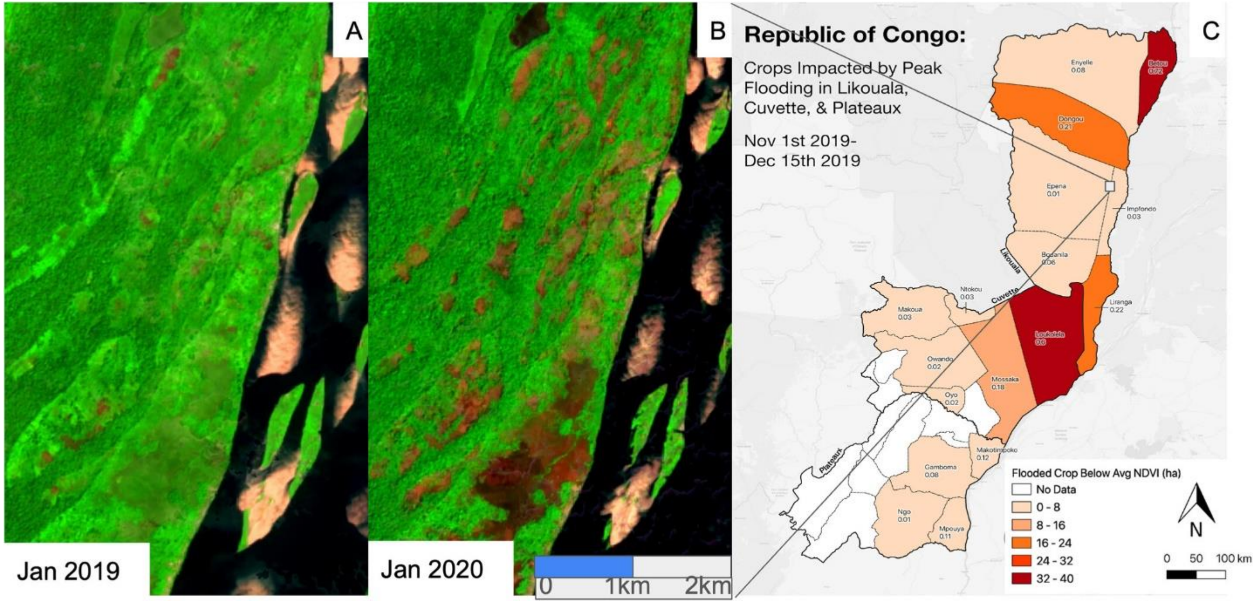
## Monitoring impacts




- Variation in electricity outages for different locations in Puerto Rico following Hurricane Maria based on time series of NASA Black Marble nighttime light imagery. Image from Román et al. (2019).
- https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2023EF003606

# Earth Observation Applications for Post-Flood Recovery

## Flood Risk Reduction




- An example of Earth Observation to provide flood recovery decision support. Series of Sentinel-2 imagery in a flood-affected area before the December 2019 flood in January 2019 (a) and after in January 2020 (b) in the Republic of Congo

https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2023EF003606

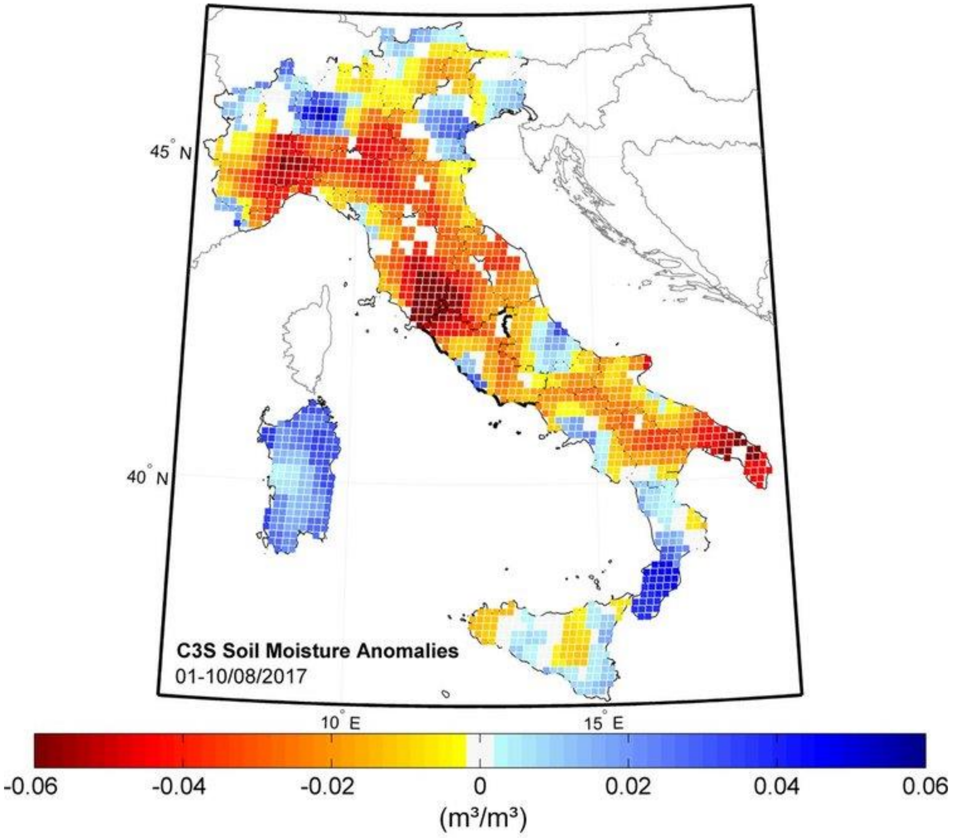
# Improving flood forecasting with Earth observation data

## Hydrological models to improve flood forecasting

- River discharge is a variable that is not typically easy to measure from satellites. However, new models using a combination of optical data from MODIS, to estimate river velocity, and radar altimetry measurements, to assess river levels rising – the same way scientists monitor sea levels rising

- Developing new models and leveraging cutting-edge sensor technology is crucial, especially with the deployment of new satellite constellations

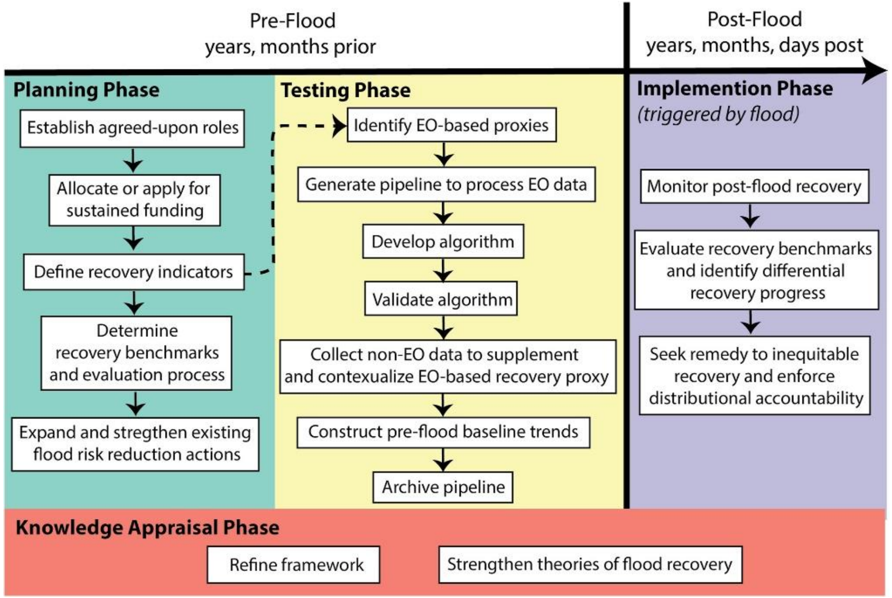
https://skywatch.com/improving-flood-forecasting-with-earth-observation-data/



# Improving flood forecasting with Earth observation data

## A Framework to Guide EO Monitoring of Flood Recovery

- Framework to guide Earth Observation monitoring flood recovery and redress inequitable post-flood recovery outcomes

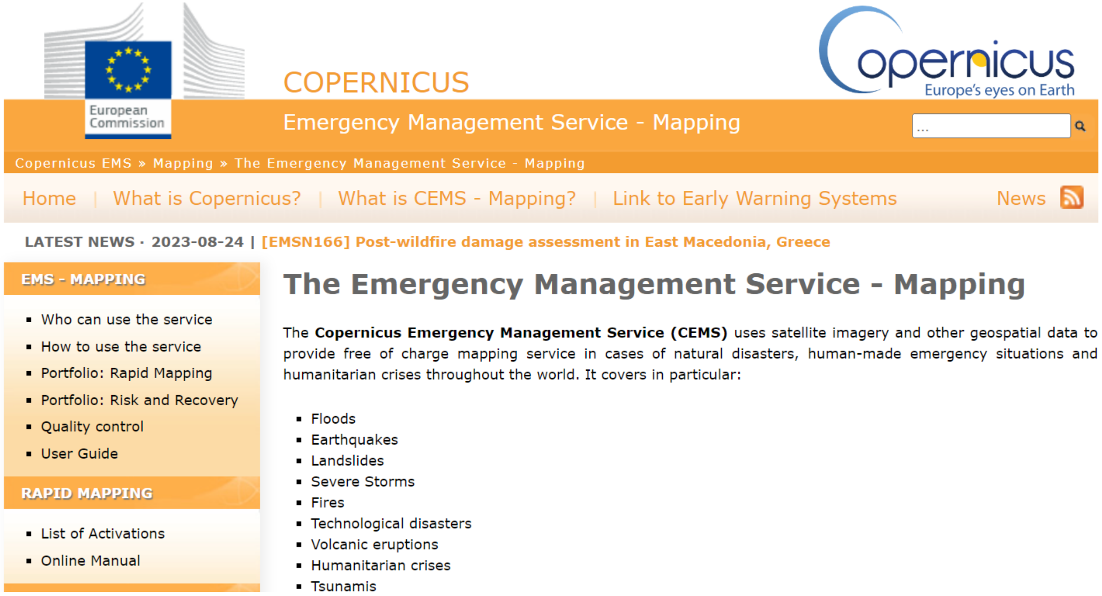



https://skywatch.com/improving-flood-forecasting-with-earth-observation-data/

# Improving flood forecasting with Earth observation data

## Operational Entities Monitoring Post-Flood Recovery

- EO can bolster effective disaster risk management, as demonstrated by established protocols that integrate EO into disaster response and recovery
- Notably, initiatives like the Committee on Earth Observations Satellites (CEOS) Recovery Observatory and Copernicus Emergency Management Service (CEMS) Risk and Recovery Mapping offer recovery mapping services.

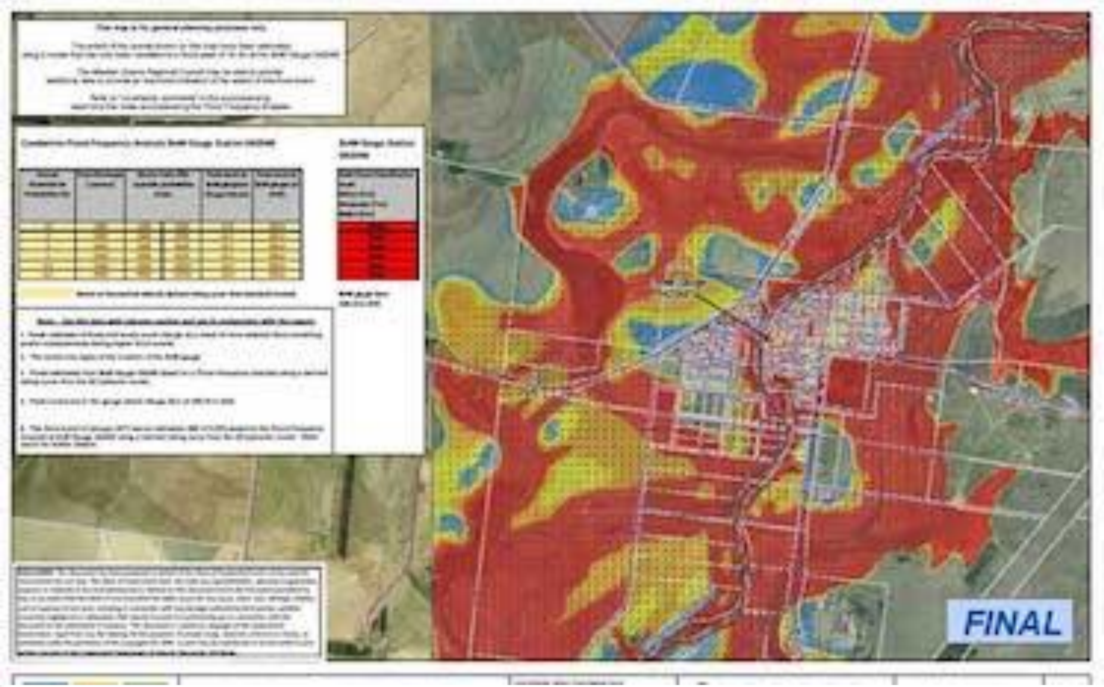



https://emergency.copernicus.eu/

# Improving flood forecasting with Earth observation data

## Improve understanding of disaster risks and costs to society

- Access to reliable and openly accessible data regarding disaster risks, expenses, impacts, and public investments in recovery and resilience is crucial for enhancing awareness and planning
- While there have been notable advancements in data quality for certain hazards, such as state-wide flood mapping, limitations persist in terms of data availability, consistency, and usability across various natural disaster risks

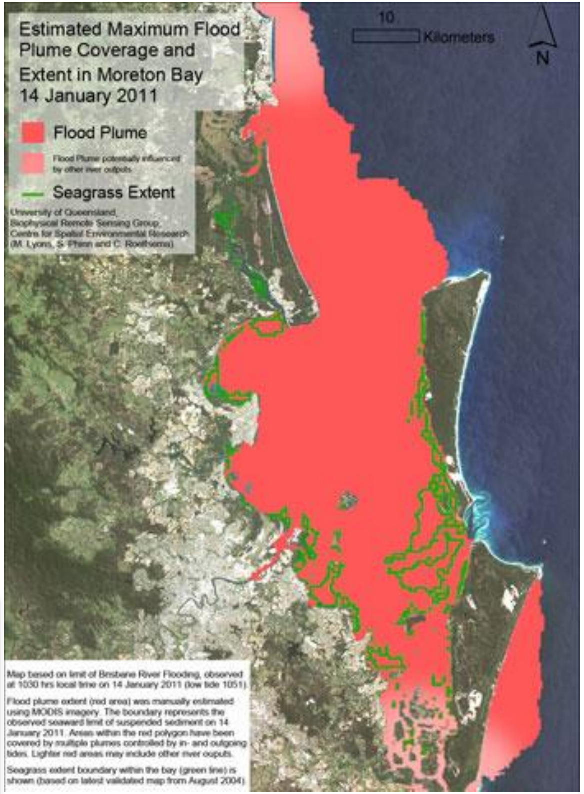



https://www.watertech.com.au/projects/flood-risk-mapping-queensland/

# Improving flood forecasting with Earth observation data

## Improve understanding of disaster risks and costs to society


FloodCheck is an online tool developed by Geoscience Australia, providing access to flood mapping and related information for Australia. It offers interactive maps and datasets to help users understand flood risks, monitor flood events, and support decision-making related to flood preparedness and response. FloodCheck integrates various data sources, including satellite imagery, rainfall data, and topographic information, to provide comprehensive flood information to the public, emergency responders, and policymakers.




A visualisation of the flood plume in Moreton Bay. Courtesy Mitchell Lyons

https://floodcheck.information.qld.gov.au/, https://www.uq.edu.au/news/article/2011/01/uq-experts-map-moreton-bay esa space solutions

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# Thank you for the attention