HAZARD: FLOOD - Exercises

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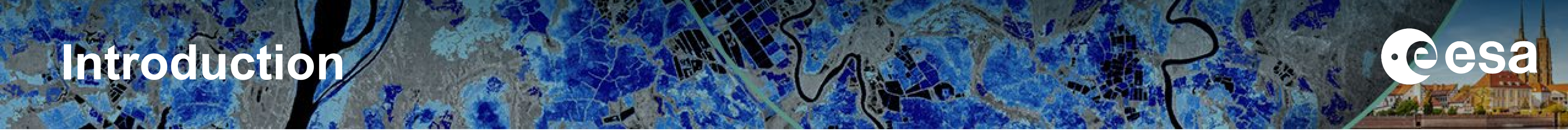
Algorithm 1

Floodwater mapping over bare soil



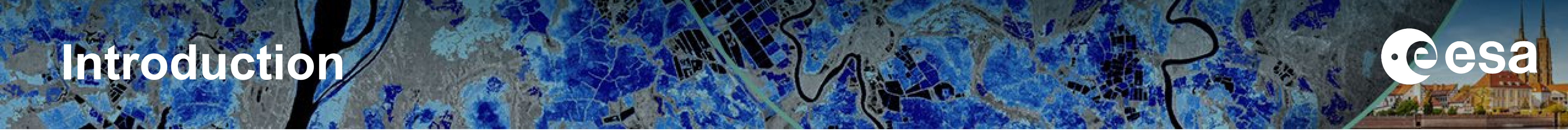
Introduction

Statistical–based algorithms typically parameterize a distribution functions to assign pixels to 2 semantic classes of interest: ‘water’ & ‘non-water’.

Flooded areas often represent only a small fraction of an entire SAR scene: difficulty in parameterizing such a distribution function.

Thus, the distribution of a SAR scene’s backscatter values is often not clearly bimodal.

A sufficiently high percentage of flooded pixels is typically required to estimate a reliable and robust distribution function that can be used for accurate delineation of all water bodies.



Introduction

The capability to detect flood cannot only rely on spectral signatures but also on the amount of changed pixels w.r.t. the image size.

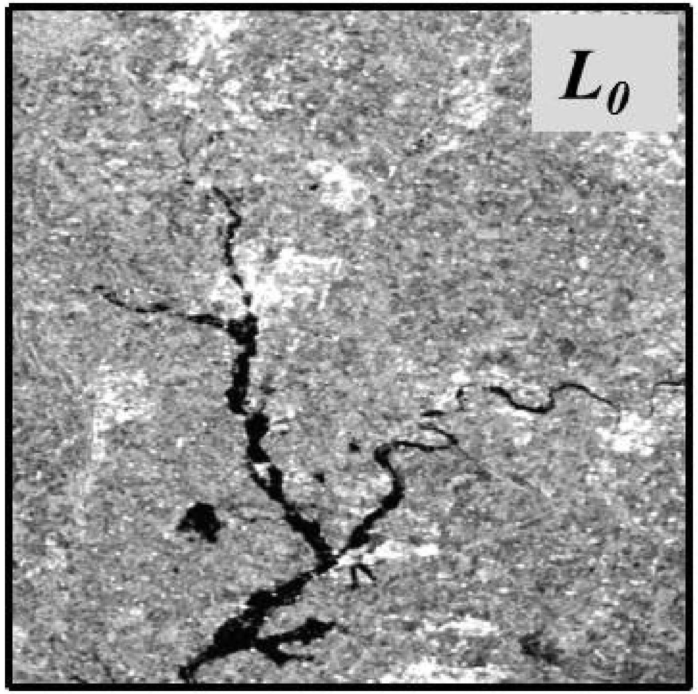
Split-based approach (SBA) has already been successfully applied to overcome this drawback, tiling images in sub-images of fixed size based on user expertise and image characteristics.

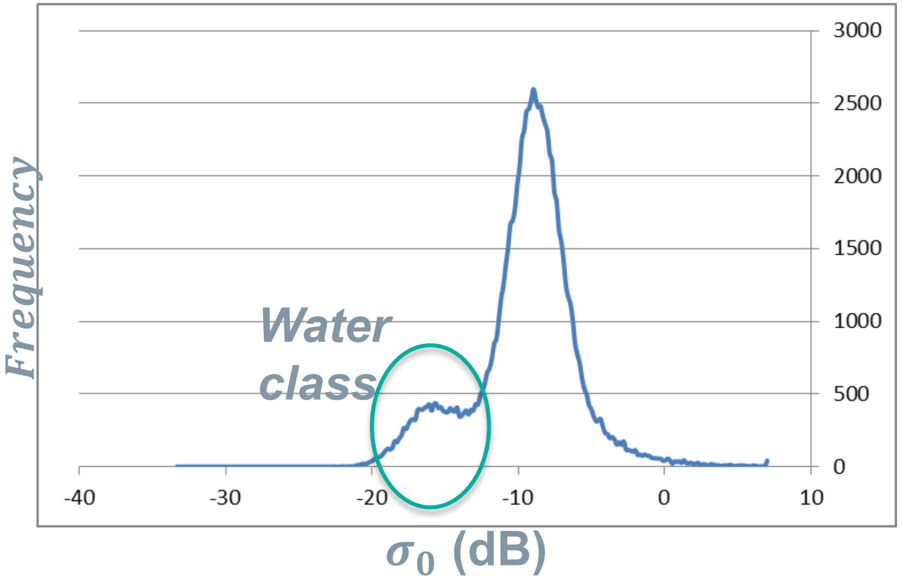
Nowadays, the availability of many different satellite missions with different characteristics highlight this aspect.

In the Hierarchical Split-Based Approach (HSBA) the size of tiles is not fixed a priori but it depends on the bimodality of the backscattering histogram of a tile.

Introduction

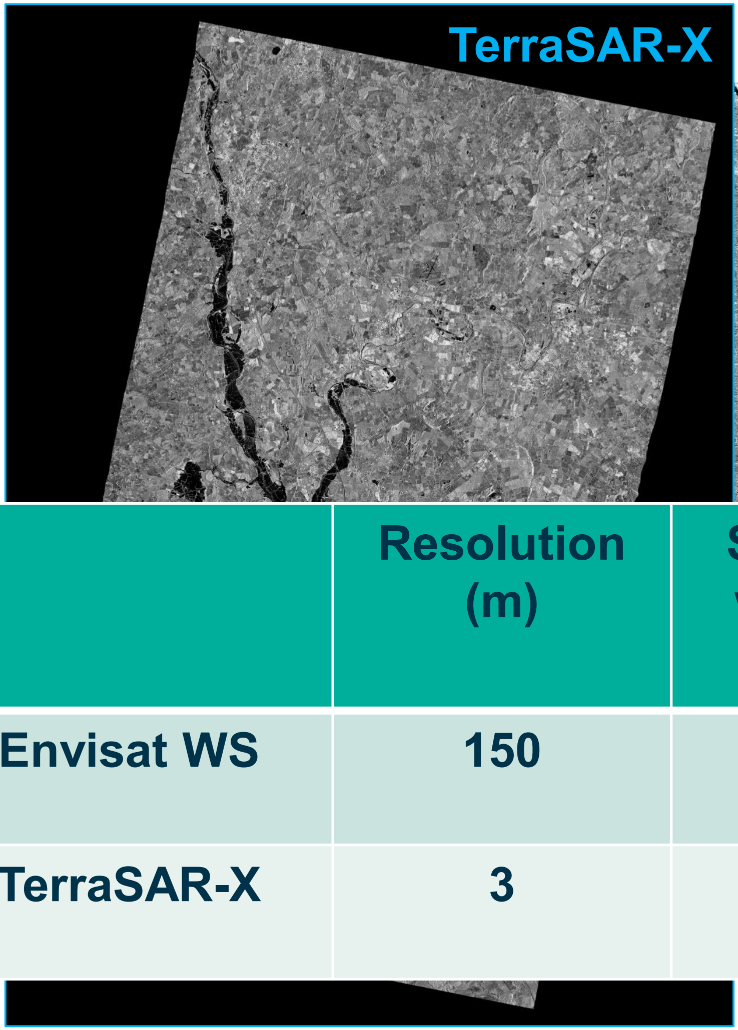
SAR flood image

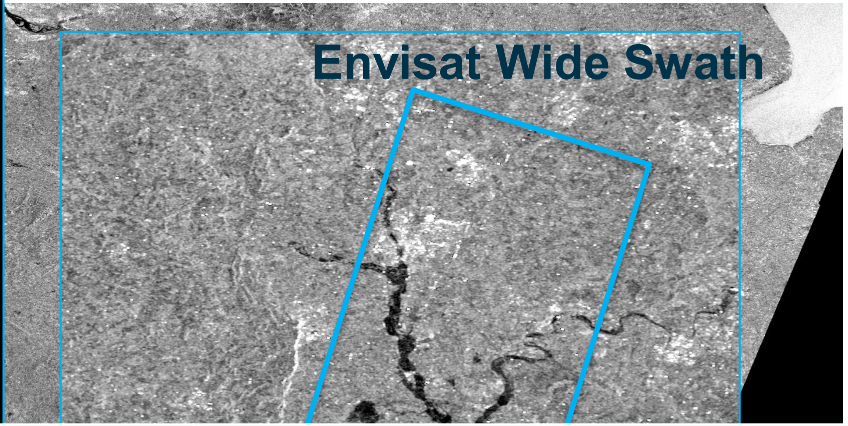




$$f_{flood\ IM}(\sigma_0) = f_{water}(\sigma_0) + f_{no\ water}(\sigma_0) = A_w e^{\frac{-(\sigma_0-\mu_w)^2}{2\sigma_w^2}} + A_{nw} e^{\frac{-(\sigma_0-\mu_{nw})^2}{2\sigma_{nw}^2}}$$

Introduction


TerraSAR-X


Envisat Wide Swath

	Resolution (m)	Swath width (Km)	Wavelength (cm)	Flooded pixels
Envisat WS	150	400	5.6	0.05 % (5100x2850)
TerraSAR-X	3	30	3	2% (15135x21294)

Methodology

Pre-processing of inputs (Flood & Reference images)

Hierarchical Split-Based Approach (HSBA) to select bimodal areas

Based on the statistics of the selected bimodal areas, we use a hybrid methodology, which combines region growing and change detection, for the automatic extraction of the flood extent in the entire scene.

Methodology – Pre-processing

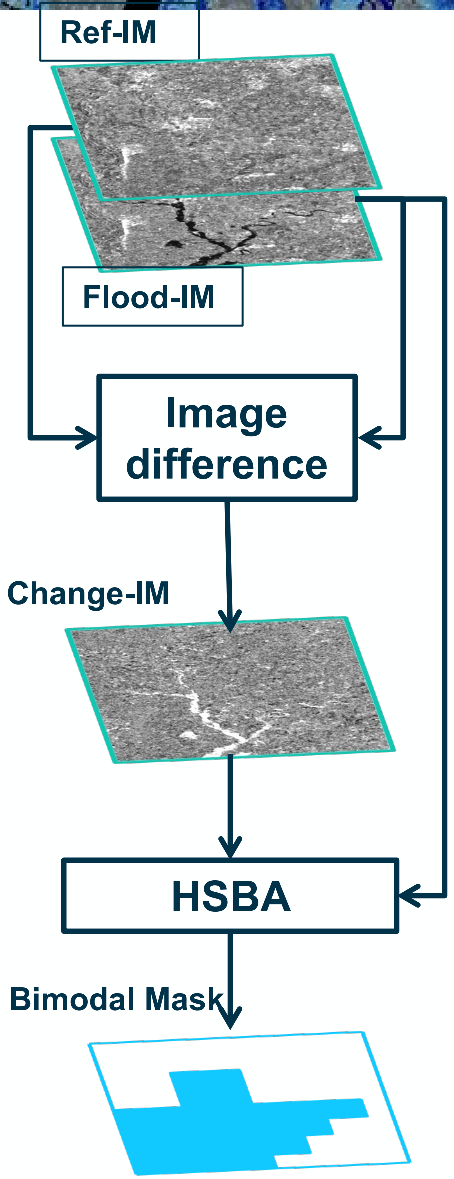
Reference and flood images are:

- Co-registered on SAR geometry
- Calibrated
- Geocoded on a common cartographic system using a DEM
- De-speckled in order to attenuate the speckle component and increase the equivalent number of looks (ENL)

Logarithmic operator is applied:

- to increase the dynamic of low intensity values
- to obtain a more symmetrical classes distributions
- with the increased ENL, the PDF of the speckle approaches the Gaussian one faster with log-transformed

Methodology - HSBA



Ref-IM

Flood-IM

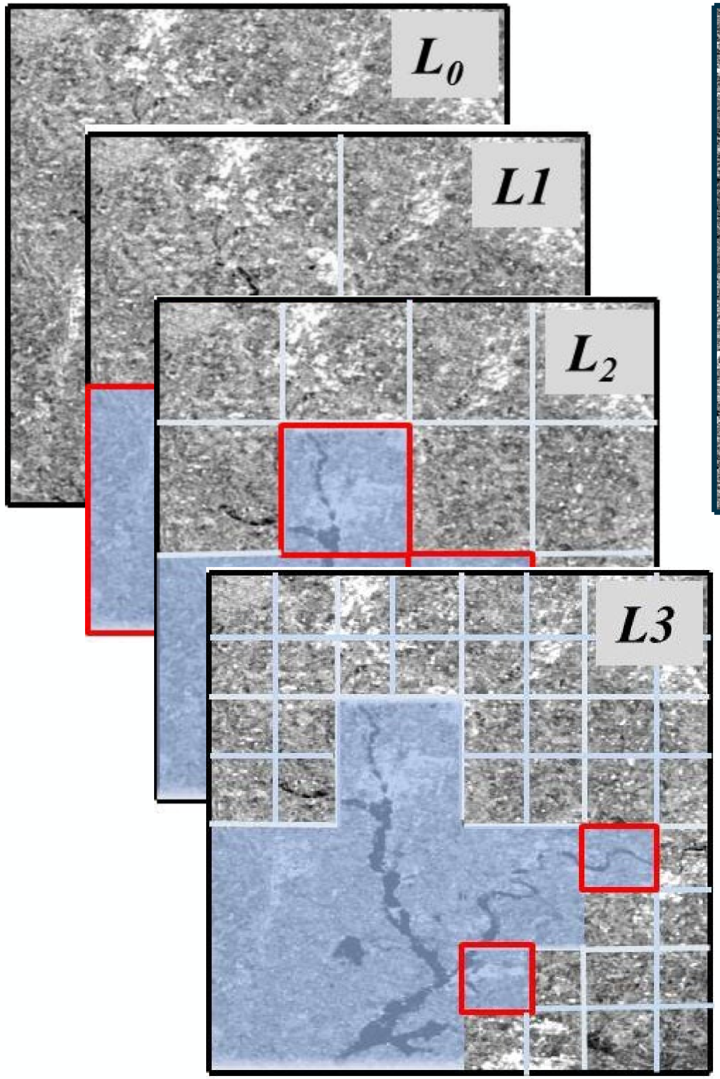
Image difference

Change-IM

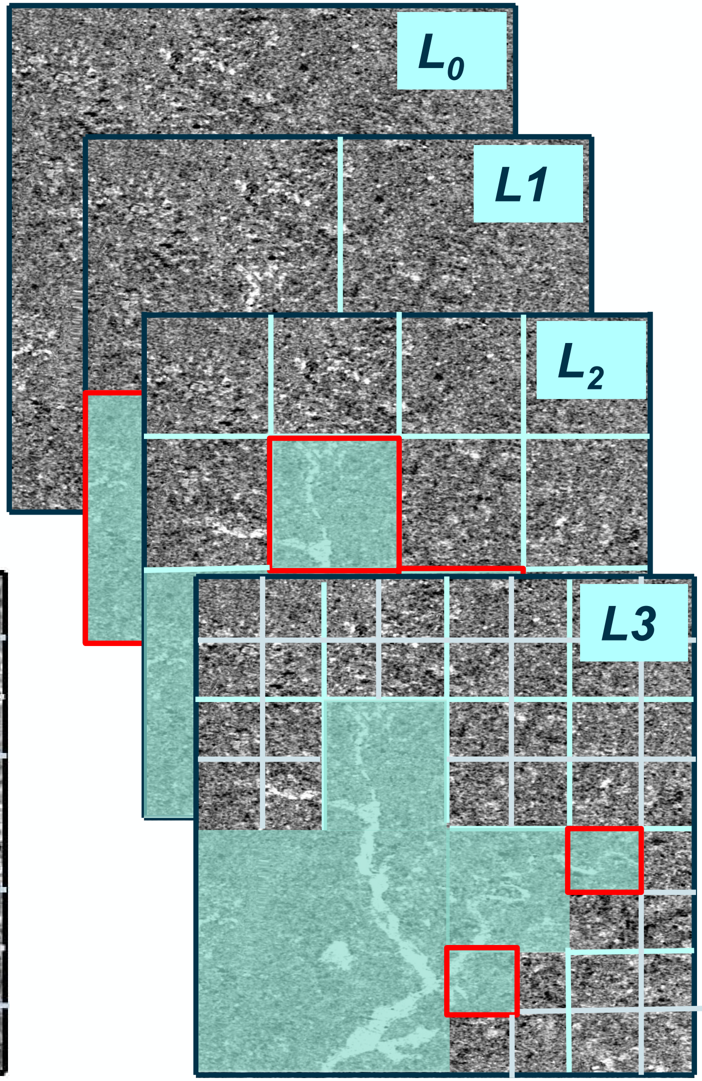
HSBA

Bimodal Mask

Flood-IM



Change-IM



Methodology - HSBA

Distributions of Food-IM and Change-IM are assumed Gaussian:

$$f_{flood\,IM}(\sigma_0) = f_{water}(\sigma_0) + f_{no\,water}(\sigma_0) = A_w e^{\frac{-(\sigma_0-\mu_w)^2}{2\sigma_w^2}} + A_{nw} e^{\frac{-(\sigma_0-\mu_{nw})^2}{2\sigma_{nw}^2}}$$

$$f_{change\,IM}(\Delta\sigma_0) = f_{no\,change}(\Delta\sigma_0) + f_{change}(\Delta\sigma_0) = A_{nc} e^{\frac{-(\Delta\sigma_0-\mu_{nc})^2}{2\sigma_{nc}^2}} + A_c e^{\frac{-(\Delta\sigma_0-\mu_c)^2}{2\sigma_c^2}}$$

To ,fit the distributions the Levenberg-Marquardt algorithm is used.

Rules to select tiles:

Flood-IM and Change-IM Histograms bimodal, Ashman D > 2

$$AD_{flood\,IM} = \sqrt{2}\frac{|\mu_w - \mu_{nw}|}{\sqrt{(\sigma_w^2 + \sigma_{nw}^2)}} > 2 \qquad AD_{change\,IM} = \sqrt{2}\frac{|\mu_{nc} - \mu_c|}{\sqrt{(\sigma_{nc}^2 + \sigma_c^2)}} > 2$$

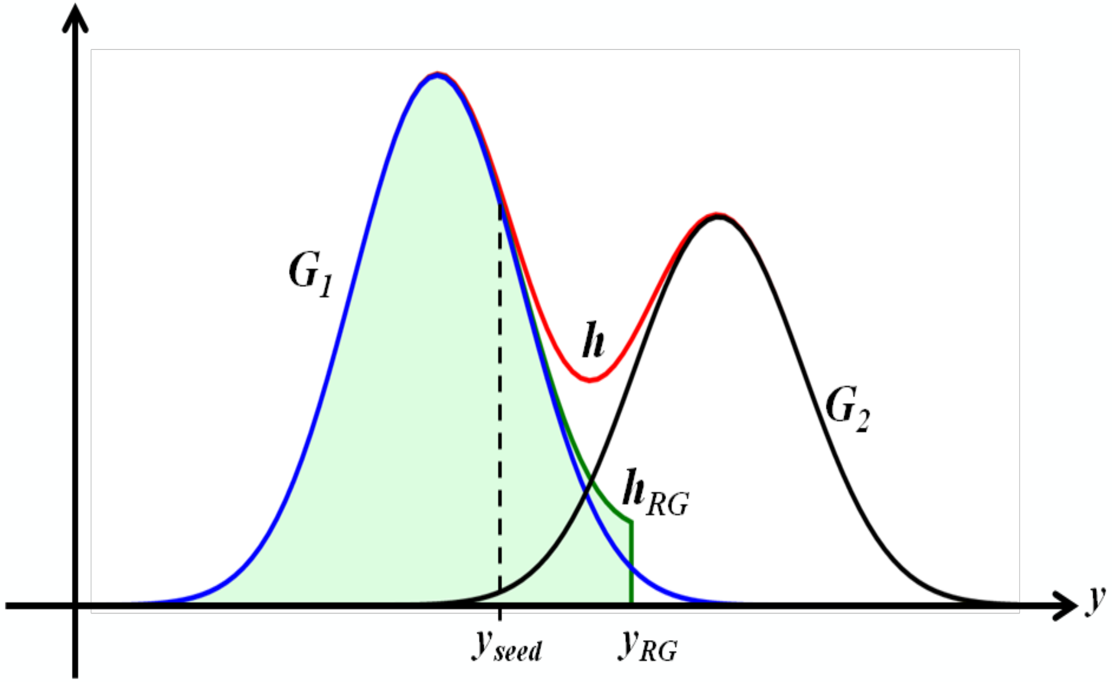
Smallest class: 10% of the tile.

Class of changes must have a positive mean value.

Methodology – Region growing

The selection of the threshold can benefit from the combination of the contextual information of the image with its intensity information.

Here, we use a region growing approach that assumes that pixels constituting the target class are clustered rather than randomly spread out over the entire image.



Test case: Severn river 2007

Flood event: July 22, 2007.

Dataset:

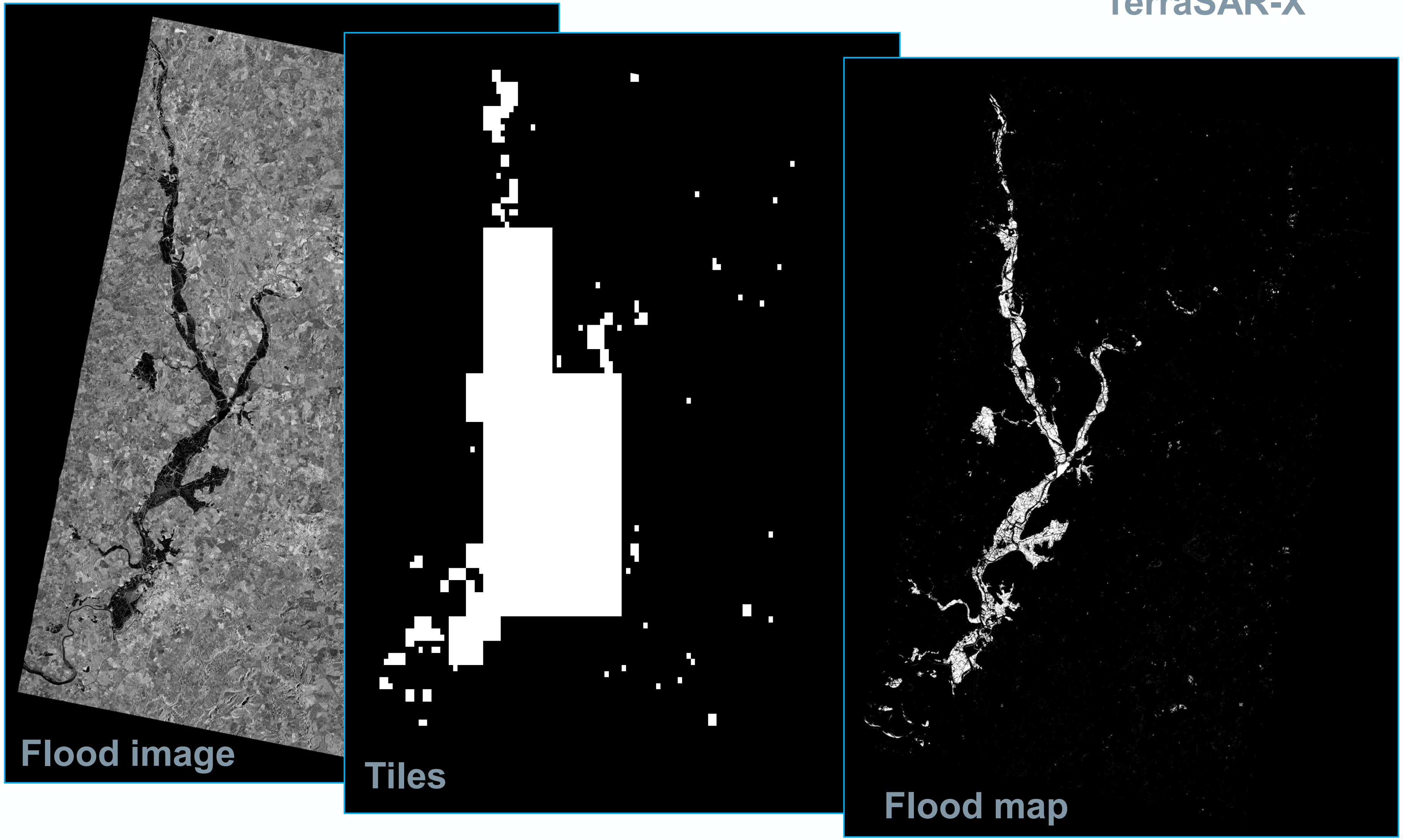
- TerraSAR-X (3m):
  - July 25, 2007 (Flood).
  - July 22, 2008 (Reference)
- Envisat WS (150m):
  - July 27, 2007 (Flood).
  - August 16, 2010 (Reference).

Validation Dataset:

- Aerial photographs: July 24, 2007 (0.2 m)

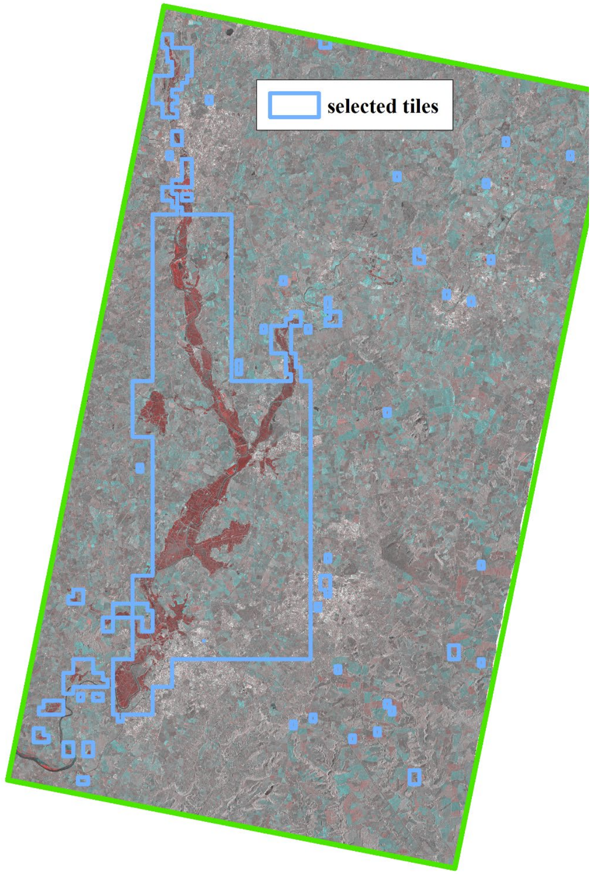
Test case: Severn river 2007

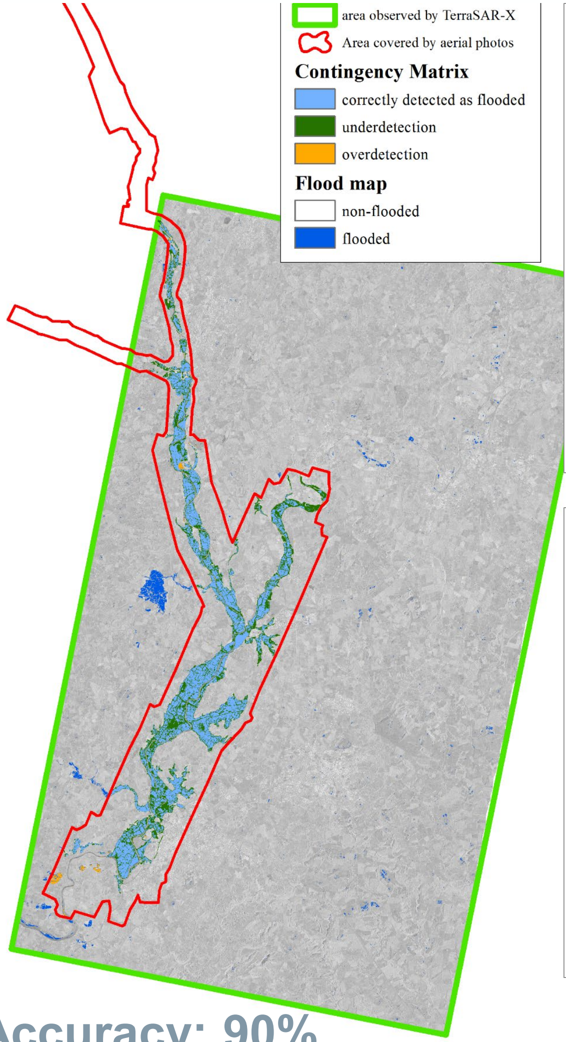
TerraSAR-X

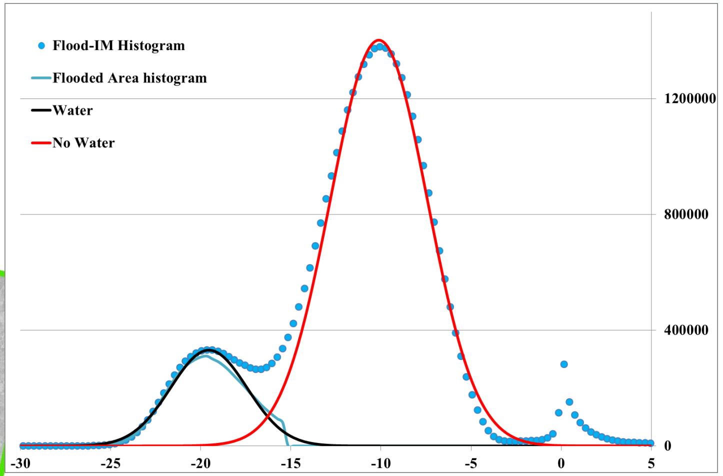


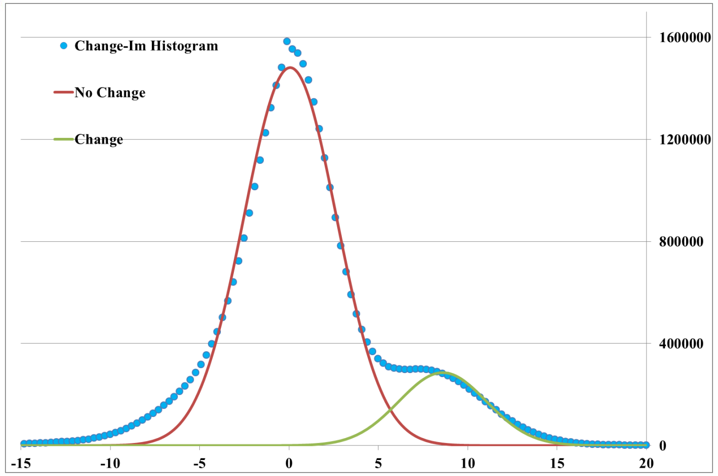
Test case: Severn river 2007

TerraSAR-X





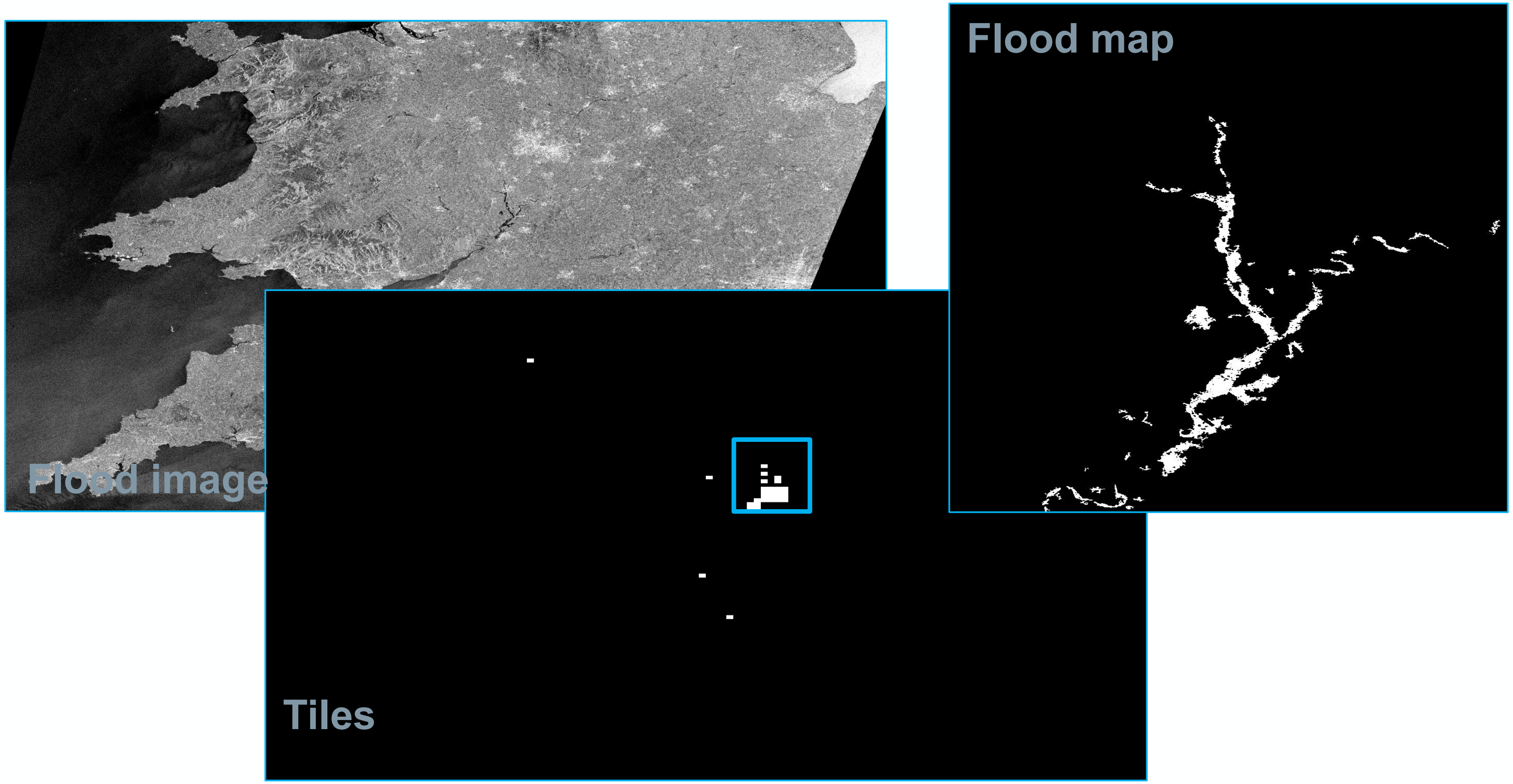




Accuracy: 90%

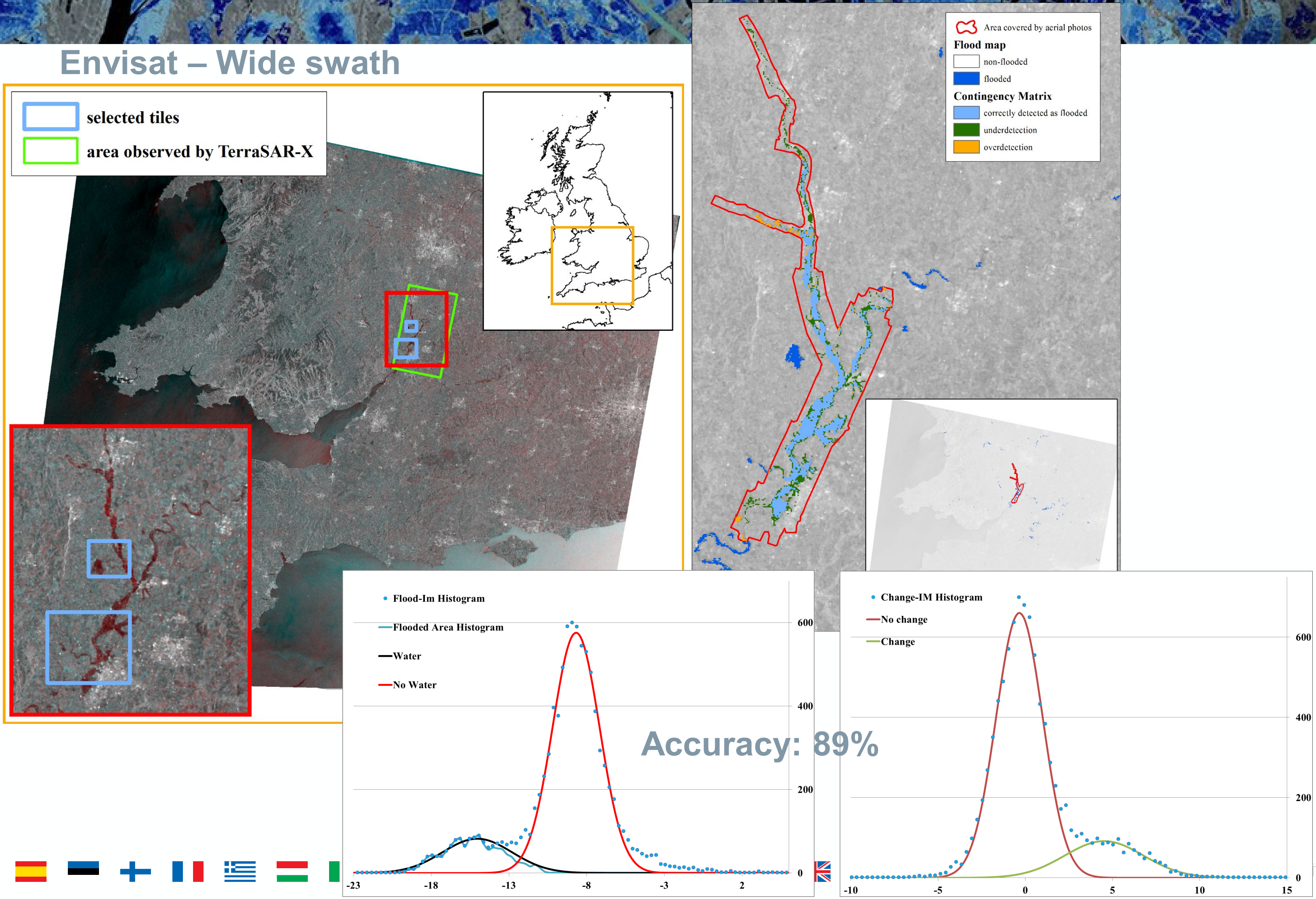
Test case: Severn river 2007

Envisat – Wide swath



Test case: Severn river 2007

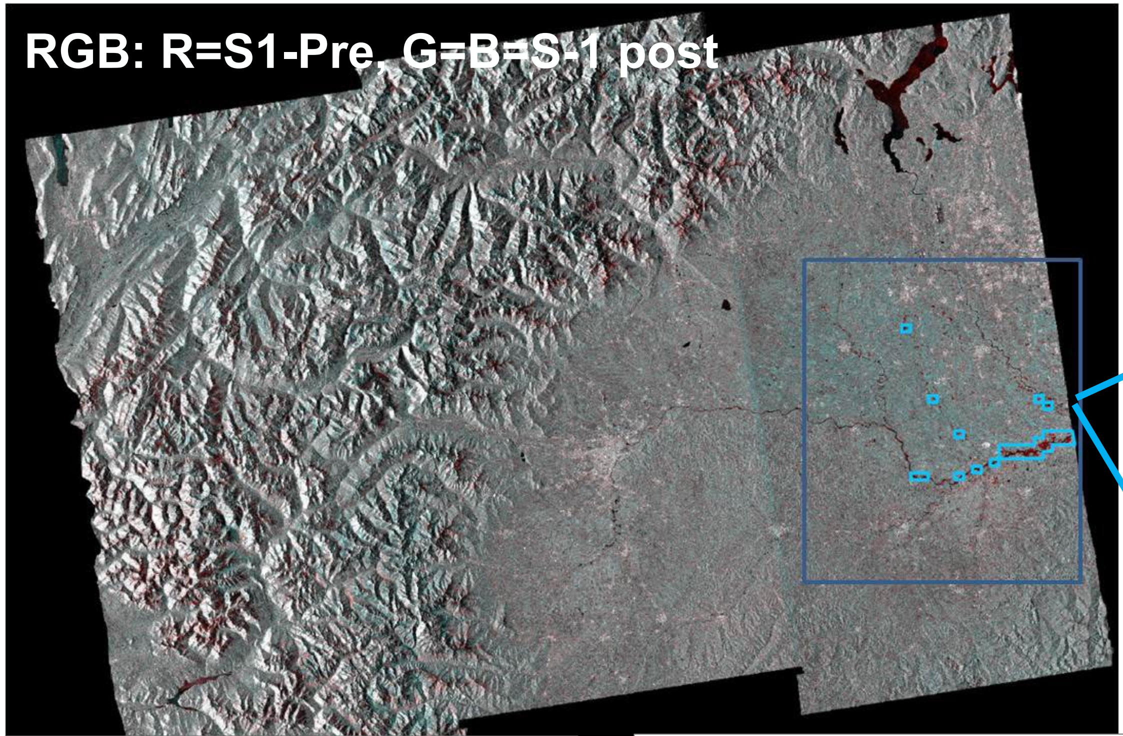
Envisat – Wide swath

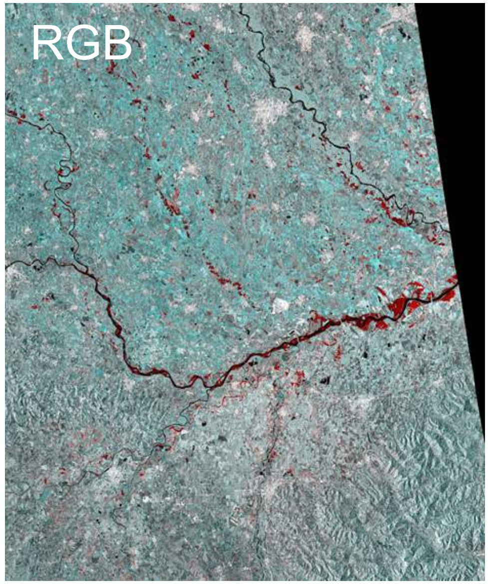


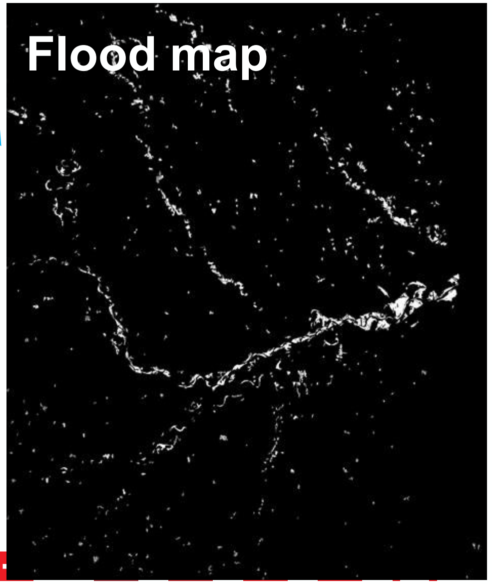
Accuracy: 89%

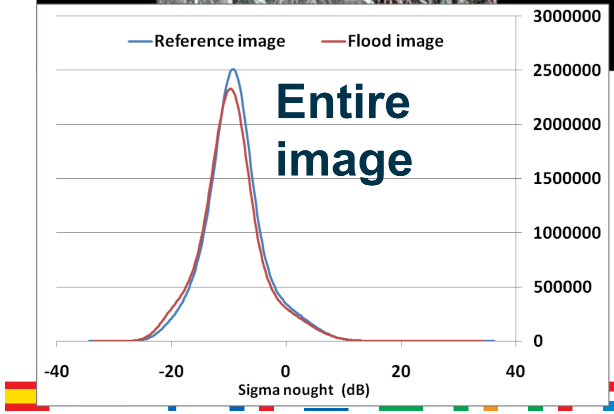
Po river (Italy). October 2014.

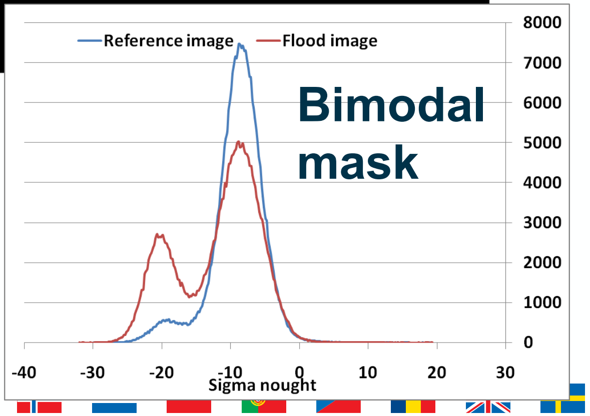
Sentinel-1, Spatial Resolution: 20m





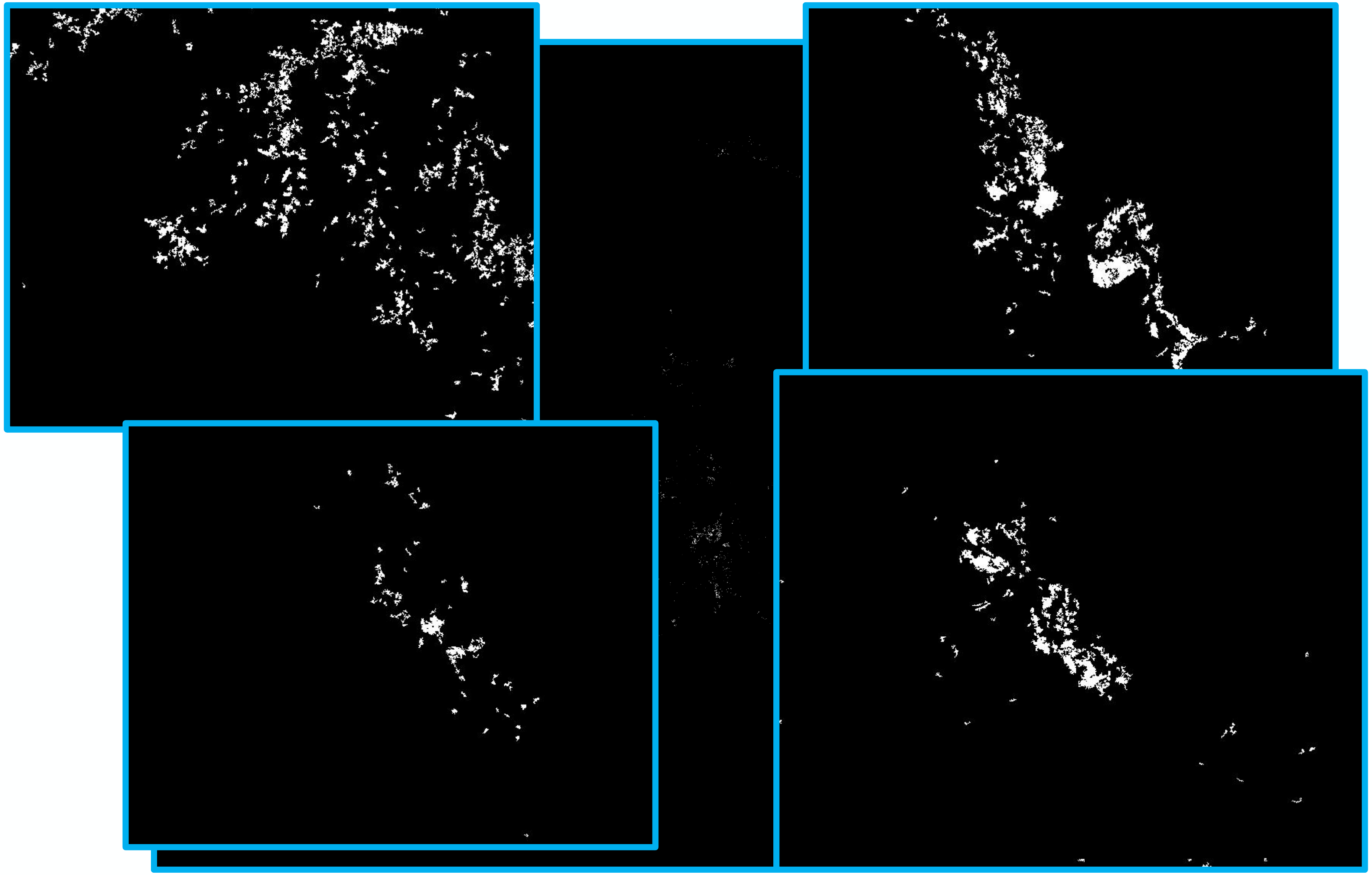






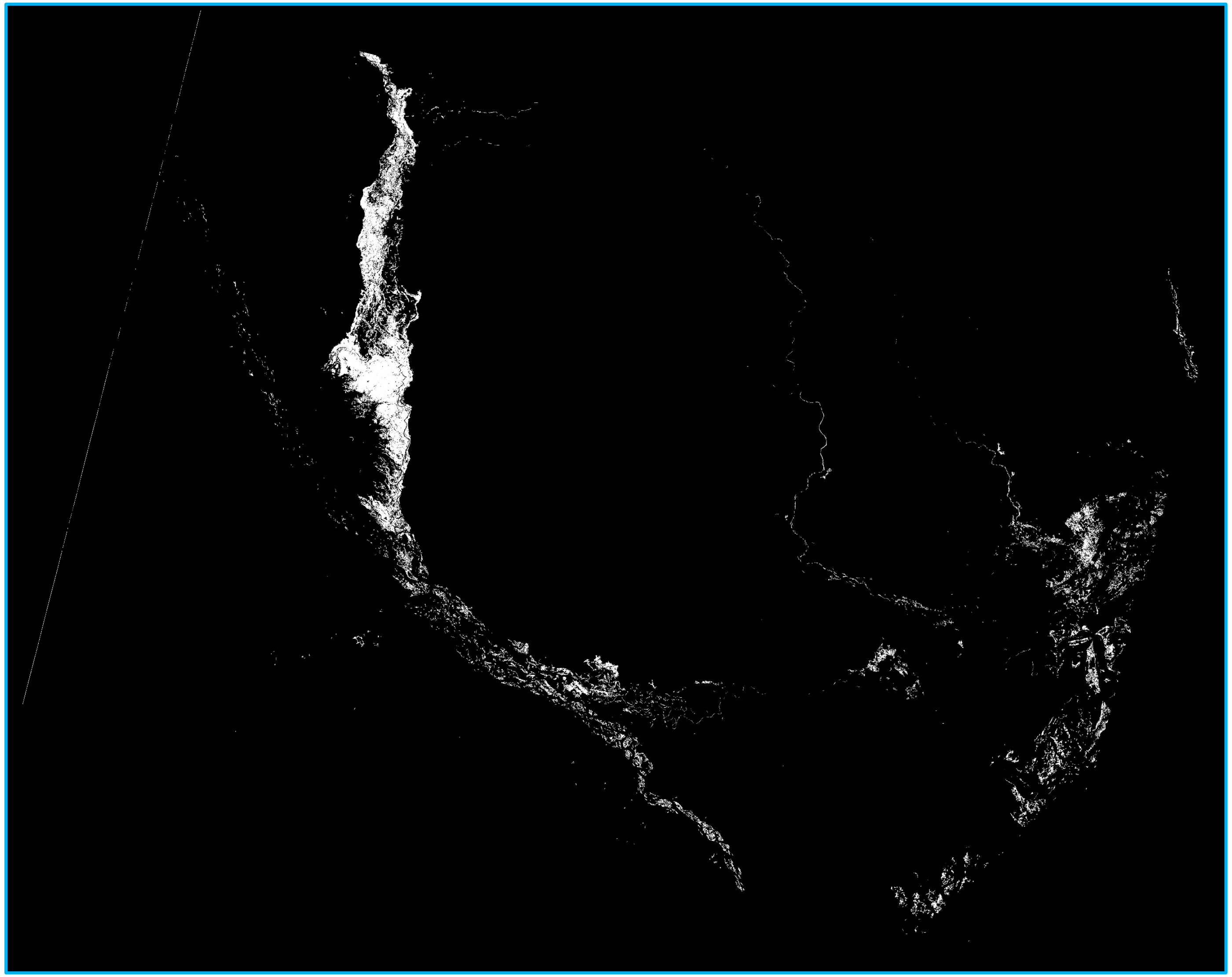
Philippine. December 2014

Sentinel-1, Spatial Resolution: 20m



Zambezi. January 2015

Sentinel-1, Spatial Resolution: 20m



Algorithm 2

Floodwater mapping in urban areas

Introduction

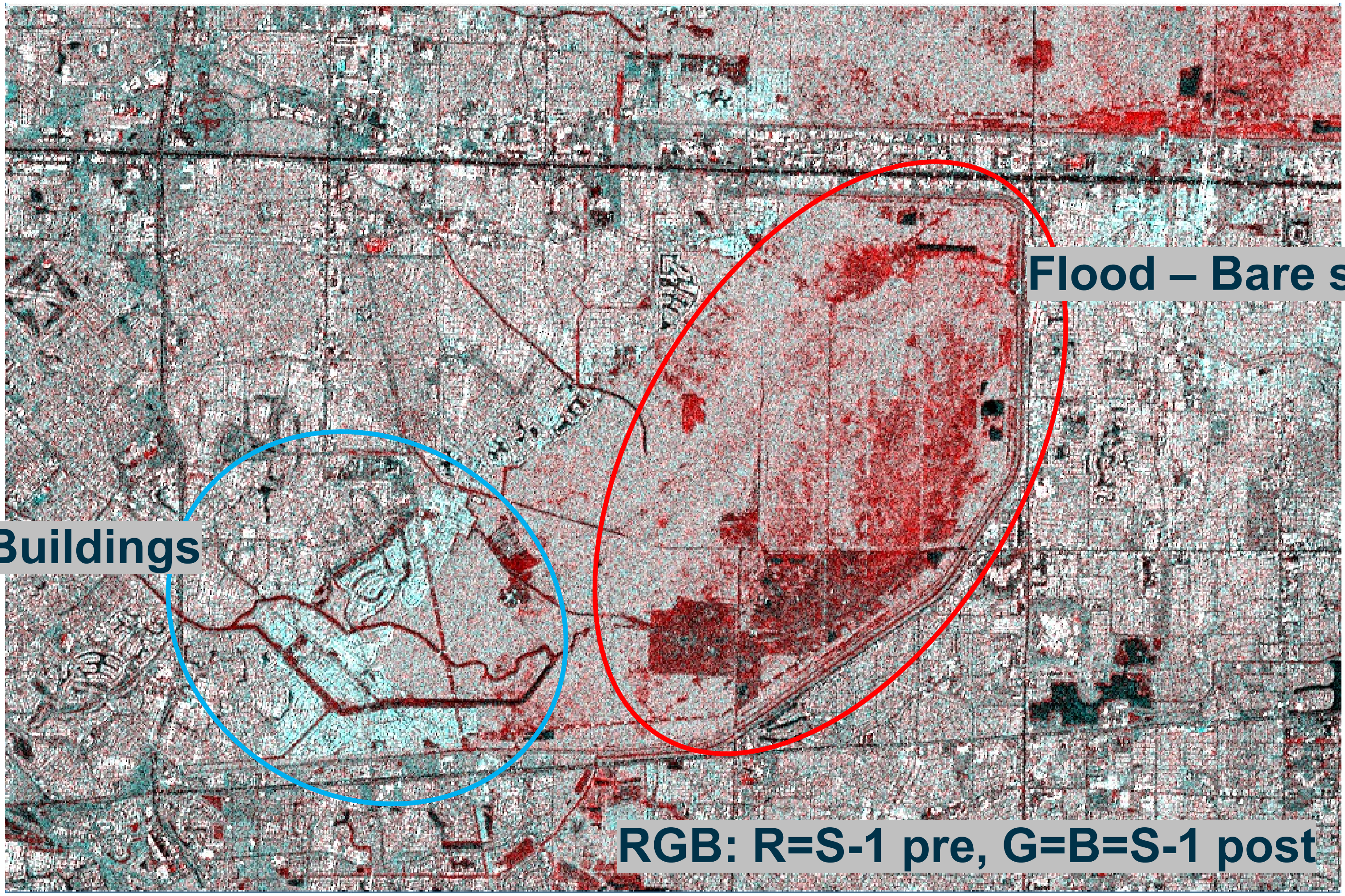
The presence of water in urban areas, e.g., on a road in front of a building, can be detected thanks to a significant enhancement of the double-bounce scattering mechanism, as the smooth and high permittivity water increases the surface reflectivity.

The double-bounce increase, due to the presence of floodwater, may not be high enough if the building facades are not parallel to the SAR flight direction.

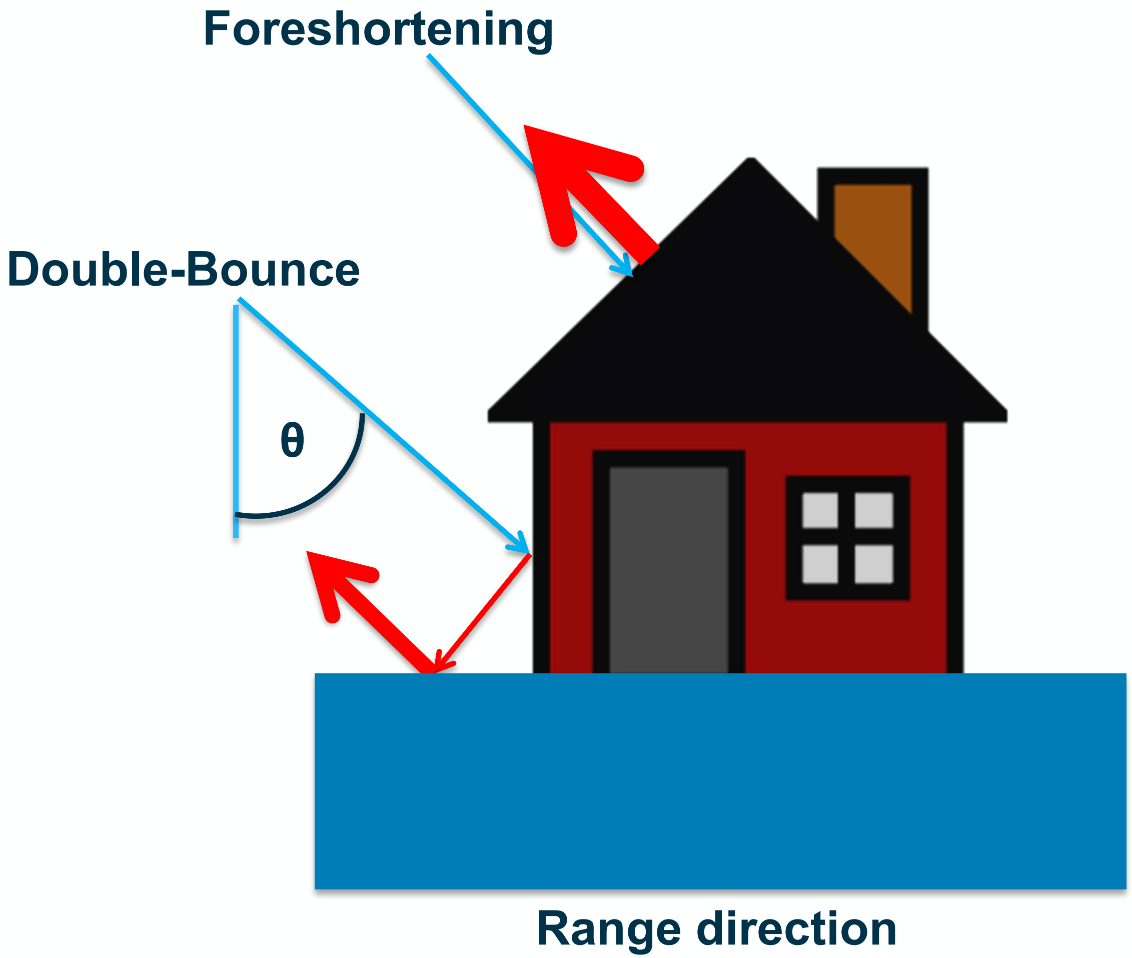
The Interferometric SAR (InSAR) coherence, ρ, can be used to reduce under detection in urban areas.

Introduction

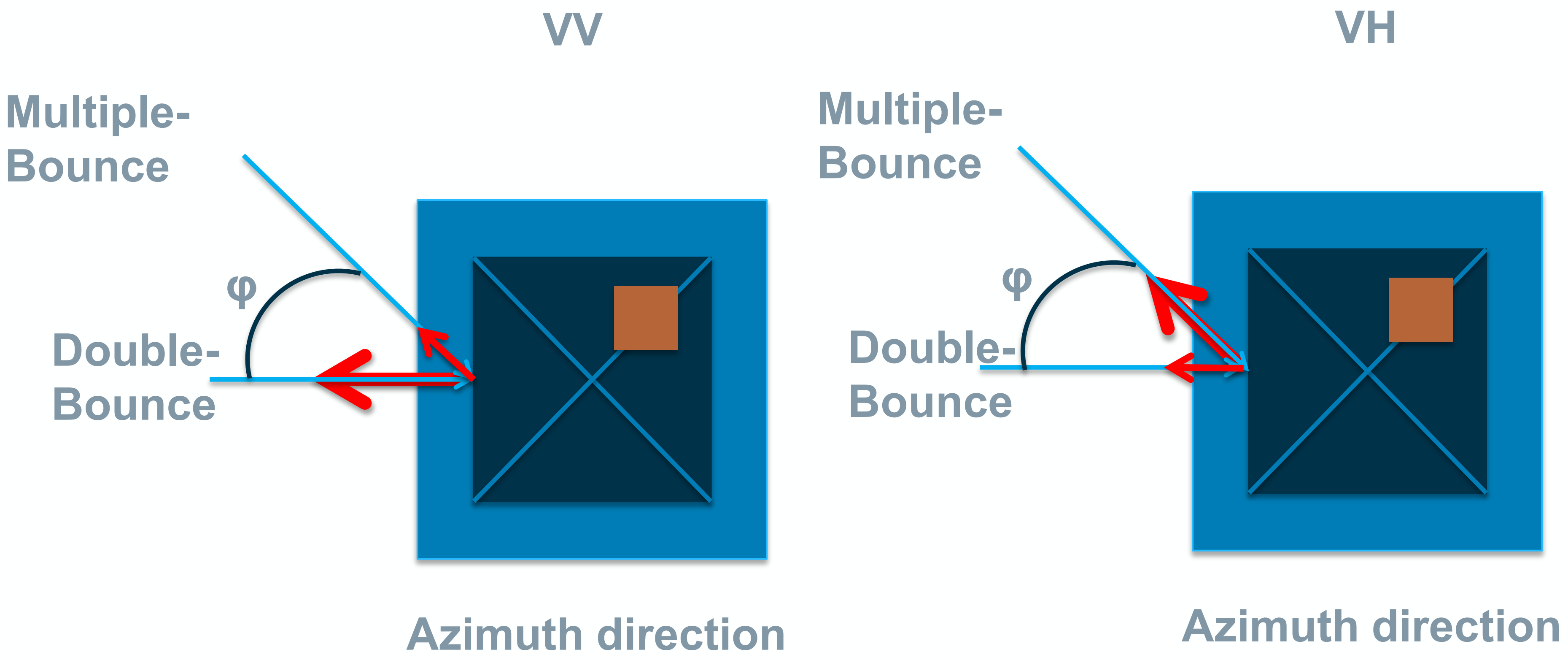
Sentinel-1



Introduction



Introduction



VV

Multiple-Bounce

φ

Double-Bounce

Azimuth direction

VH

Multiple-Bounce

φ

Double-Bounce

Azimuth direction

Multitemporal InSAR coherence

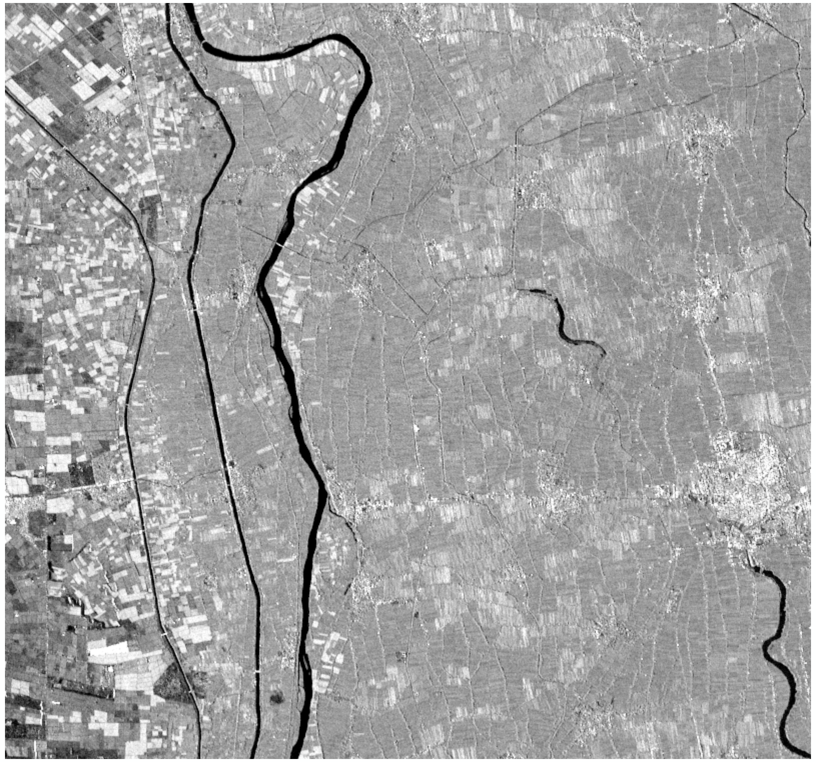
The degree of correlation, or coherence, between the two constituent images of an interferometric acquisitions is measured as the magnitude of the complex cross correlation between the images.

$$\gamma = \frac{\left| < e_1 e_2^* > \right|}{\sqrt{< \left| e_1 \right|^2 >< \left| e_2^* \right|^2 >}}$$

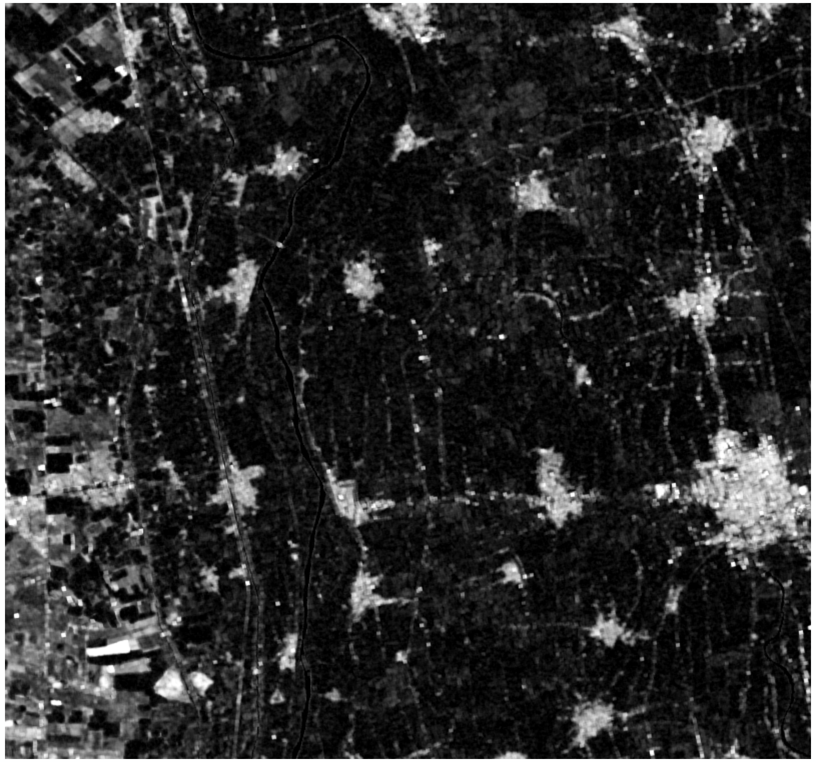
Urban areas

I. Building backscattering presents high values.

II. InSAR coherence in urban areas presents high values.



SAR Intensity



InSAR coherence

Multitemporal InSARcoherence

The high sensitivity of the Interferometric SAR (InSAR) coherence to small changes in the scene has been also exploited to map floods in urban areas using very high- resolution SAR sensors, such as COSMO-SkyMed.

The enhanced and systematic observational capabilities of Sentinel-1, i.e. high revisit time and small orbital tube, could be effectively used for a more accurate detection of floodwater in urban areas.

Multitemporal InSAR coherence

Double-bounce is a key features to identify the presence of water.

In the areas where double-bounce occurs:

- σ_0 stable in time and high (when no flood);
- σ_0 increases in the presence of water;
- The co-event InSAR coherence (CC) decreases with respect to the pre-event one.

InSAR coherence:

- The InSAR coherence is the normalized cross correlation between images and it is related to the change in the spatial arrangement in time of the scatterers within a SAR image pixel.
- A coherence image can be built using either two images taken before the event (pre-event coherence) or with one before and one during the flood event (co-event coherence).

InSAR coherence limitations

The InSAR coherence is generally affected by temporal decorrelation, which means that it als odecreases for reasons other than catastrophic events.

→ It is mandatory to focus the analysis only on the Double-Bounce objects.

The InSAR coherence is generally affected by spatial decorrelation, so that it decreases with the increase of perpendicular baseline.

→ Sentinel-1 is a perfect candidate given that the relatively narrow orbit tube (i.e. small perpendicular baseline of interferometric acquisitions)

Algorithm

Identification of double-bounce objects, i.e. buildings.

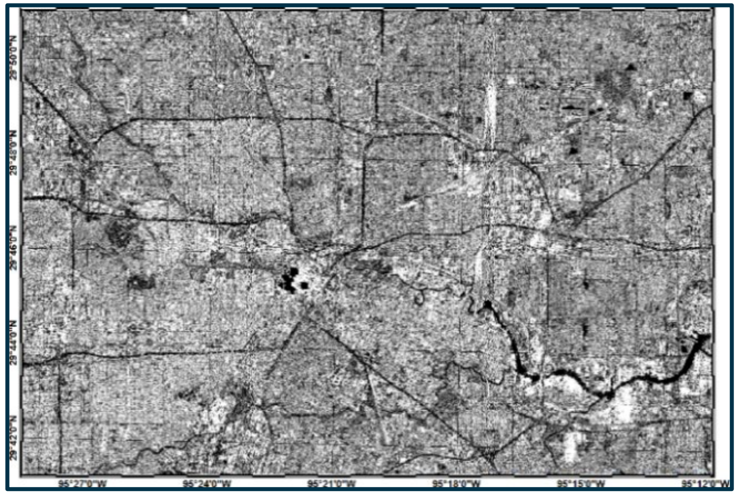
Extraction of pre-event and co-event coherence maps by a sliding window.

Calculate the coherence difference map only in the double-bounce objects.

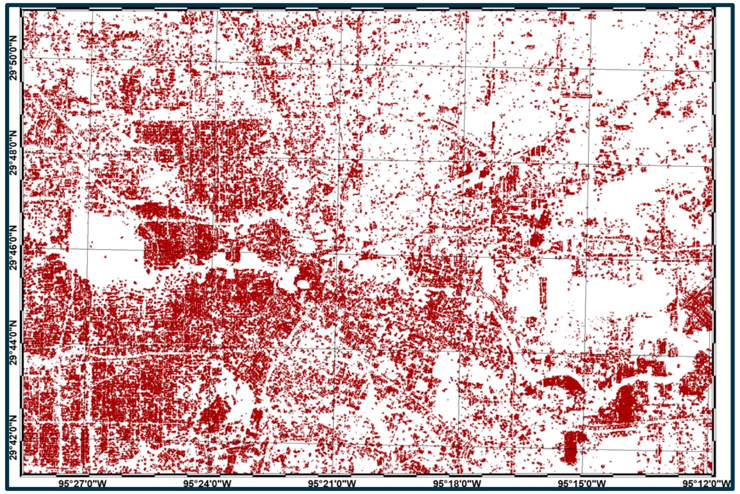
Threshold the image difference.

Example of Buildings map from Sentinel-1

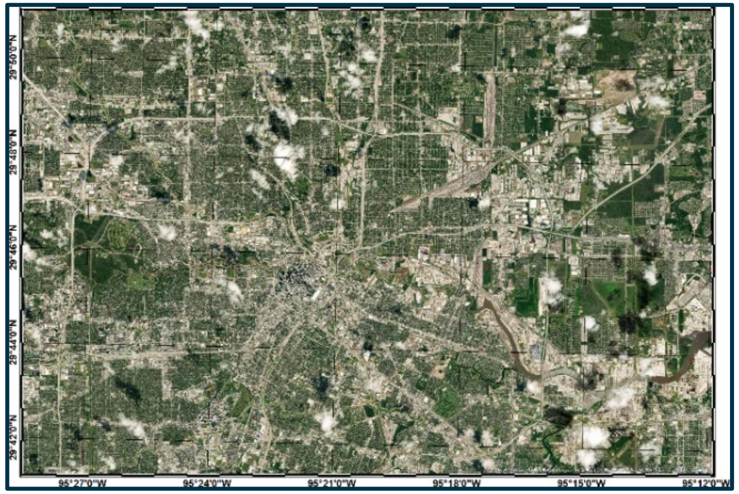
Sentinel-1



Building map

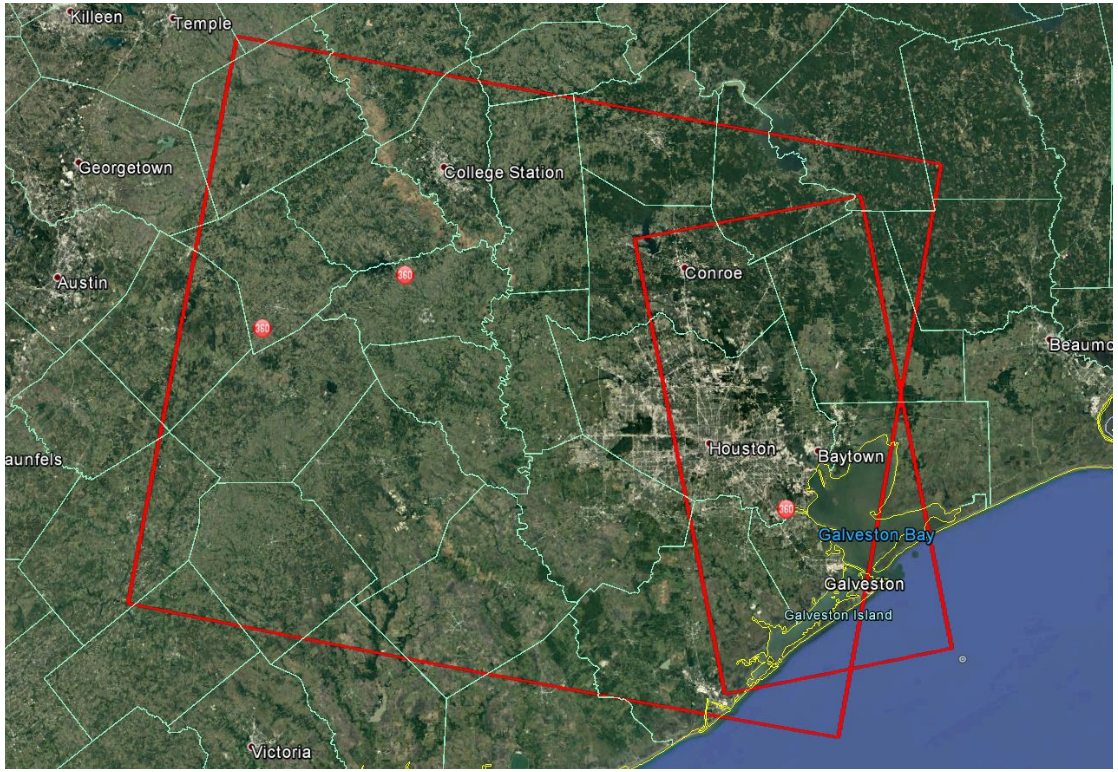


Optical image

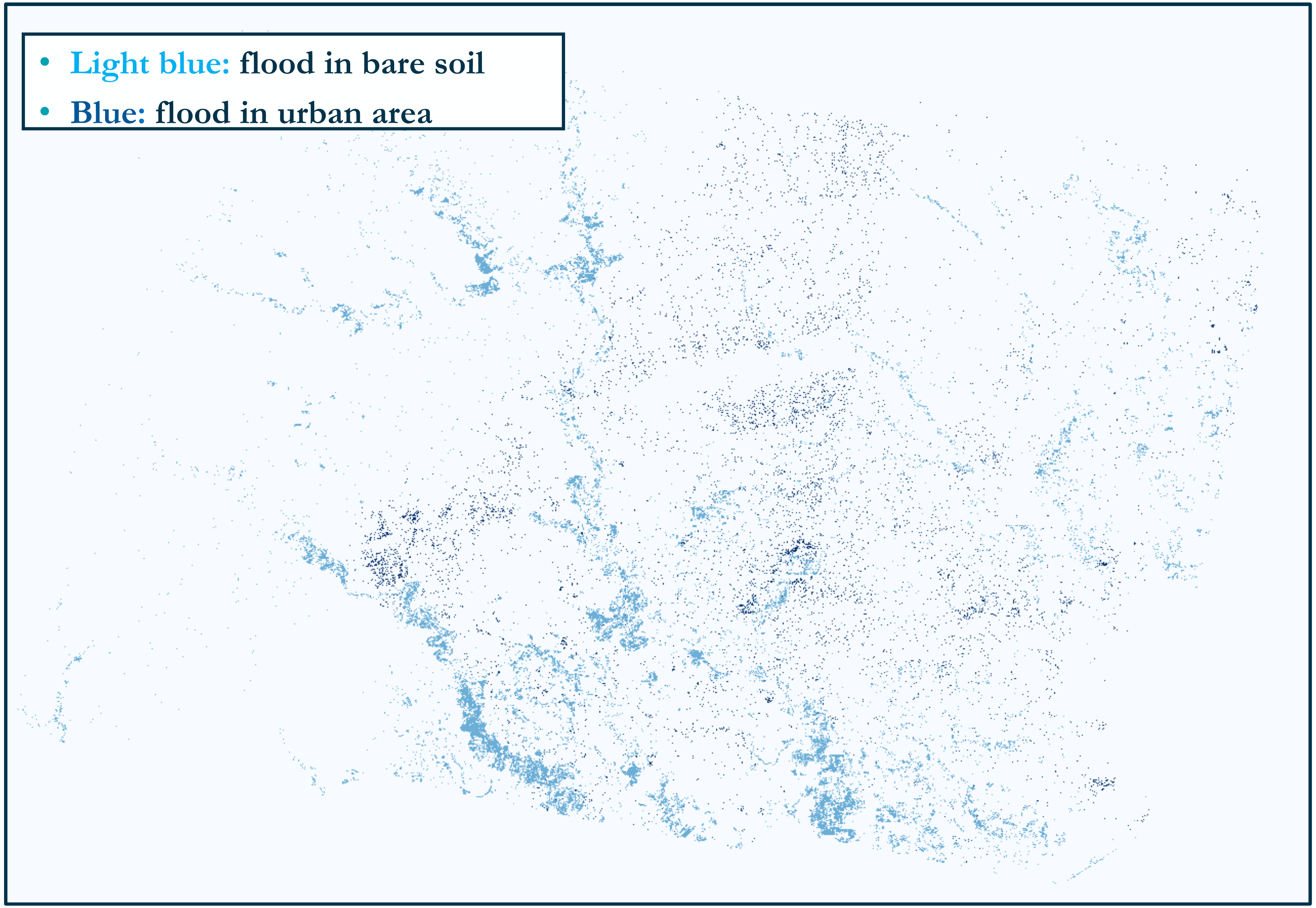


Test case 1: Houston 2017

Satellite	Date	Pol
S1-A IW	18/08/2017 12:22	VV
S1-B IW	24/08/2017 12:22	VV
S1-A IW	30/08/2017 12:22	VV

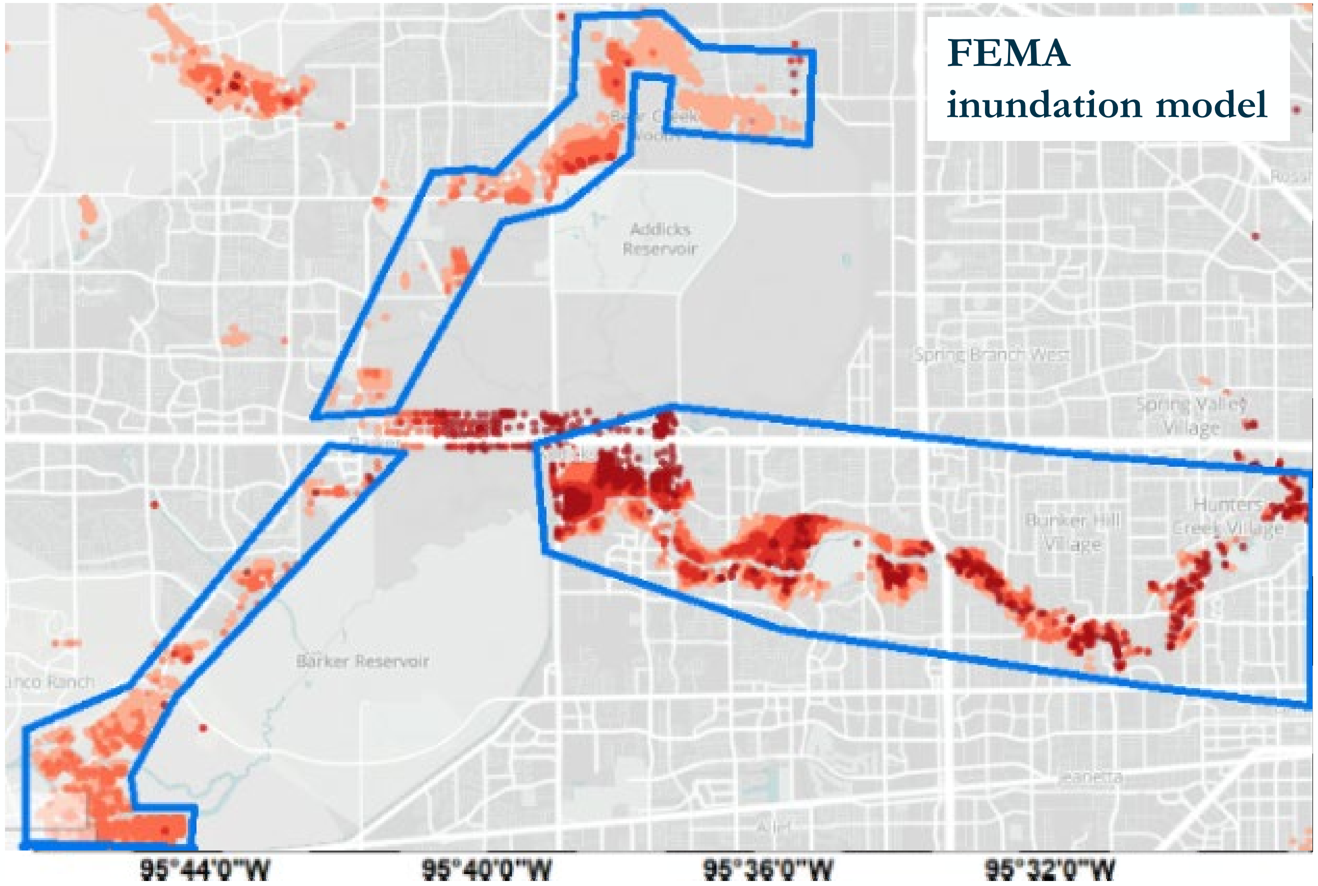


Test case 1: Houston 2017



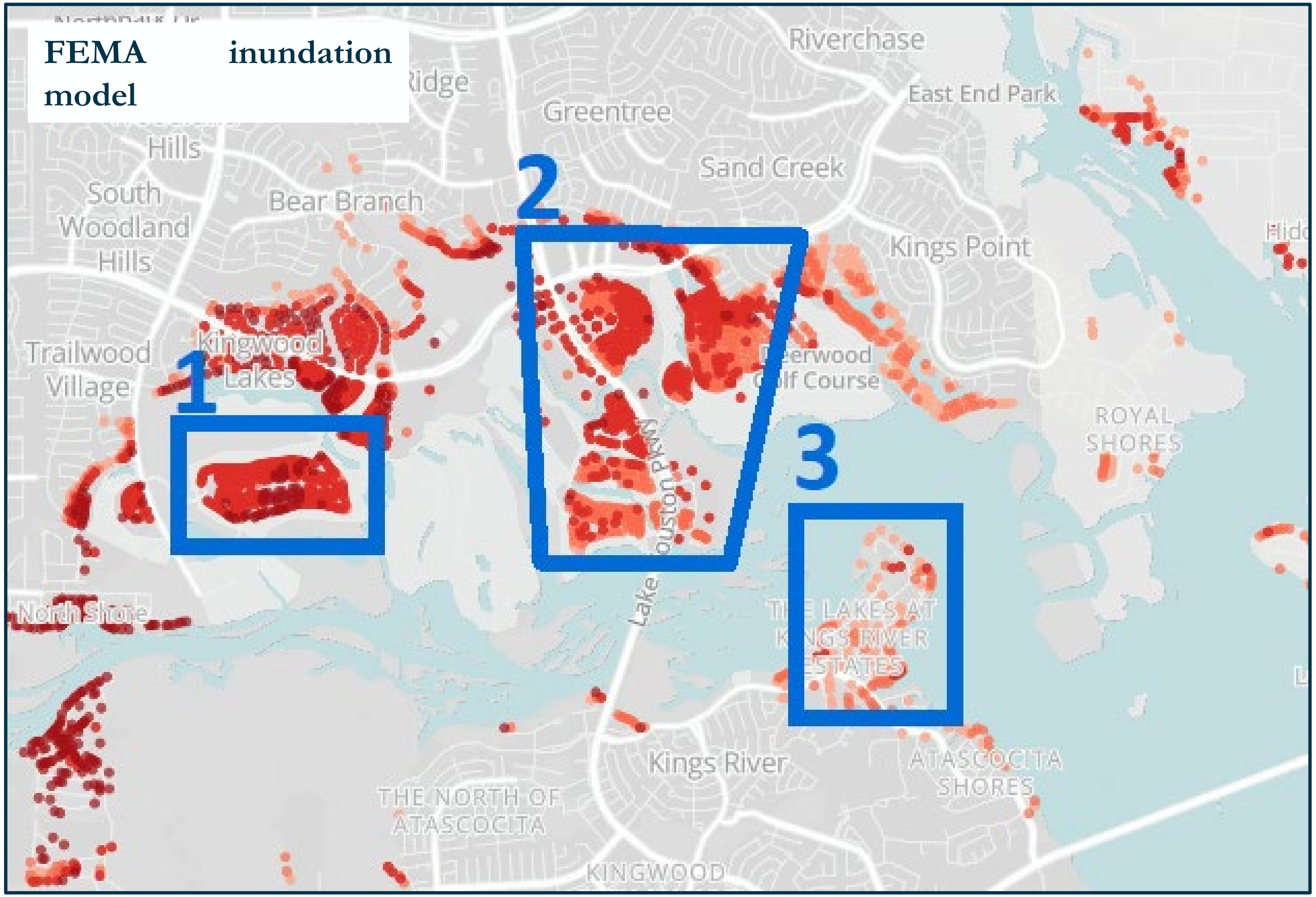
- Light blue: flood in bare soil
- Blue: flood in urban area

Test case 1: Houston 2017



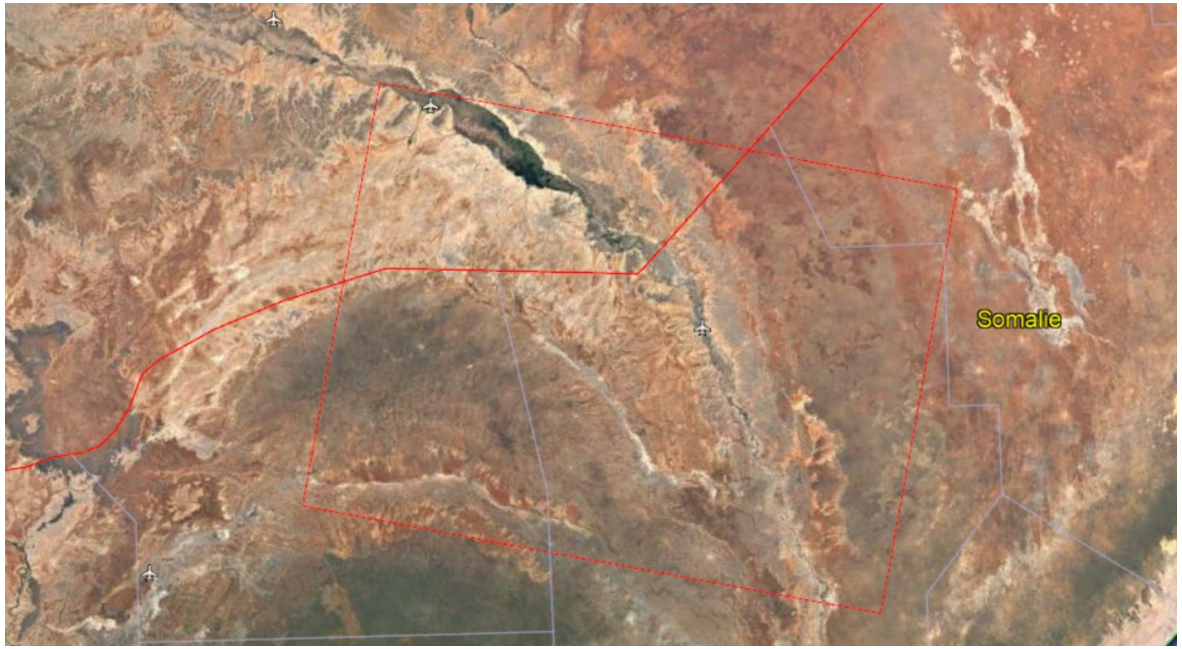
FEMA inundation model

Test case 1: Houston 2017


FEMA inundation model

Test case 2: Somalia 2018

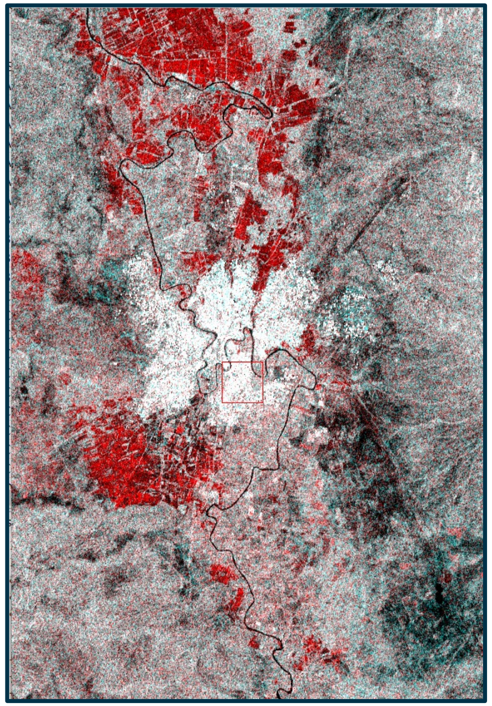
Satellite	Date	Pol
S1-A IW	02/04/2018	VV
S1-A IW	14/04/2018	VV
S1-A IW	26/04/2018	VV
S1-A IW	08/05/2018	VV
S1-B IW	14/05/2018	VV



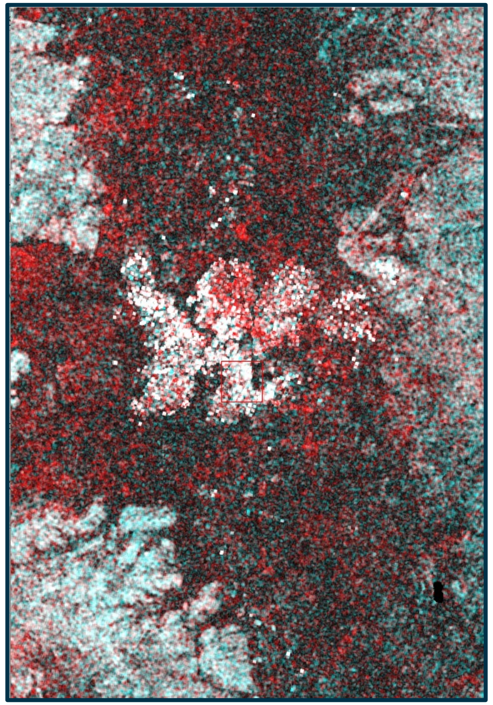
Test case 2: Somalia 2018

26/04/2018

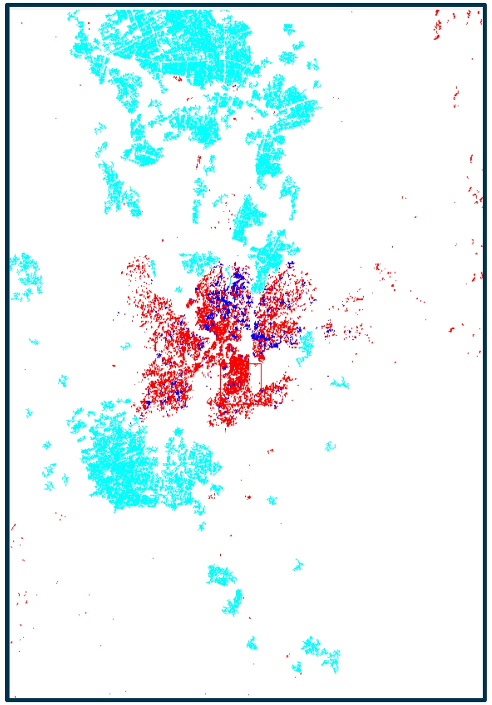
RGB Intensity



RGB coherence



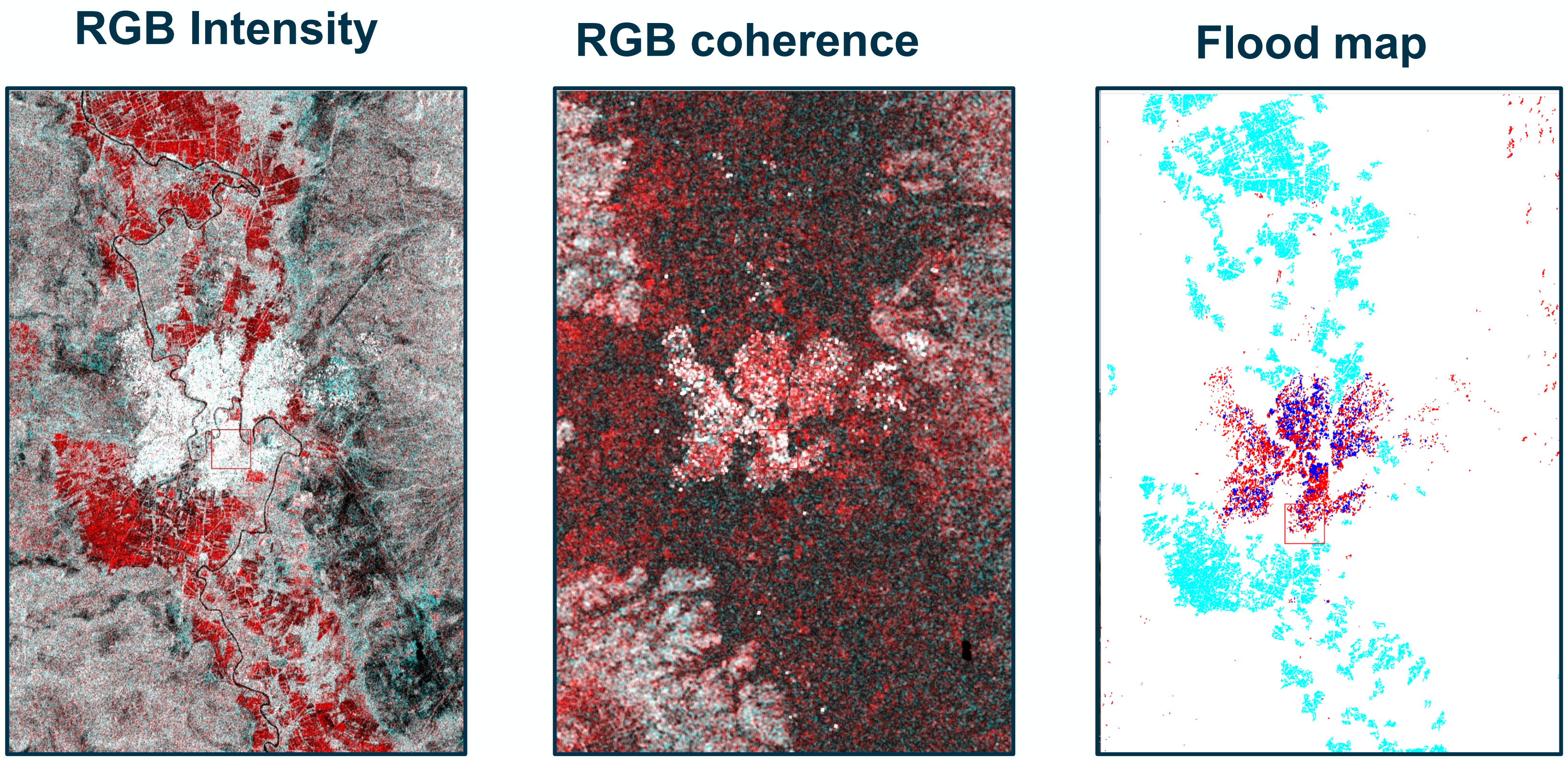
Flood map



- **Light blue:** flood in bare soil
- **Blue:** flood in urban area
- **Red:** unflooded buildings

Test case 2: Somalia 2018

8/5/2018



RGB Intensity

RGB coherence

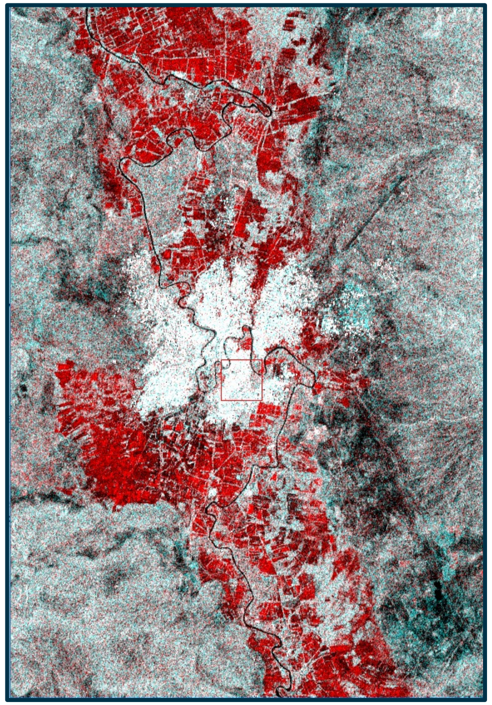
Flood map

- Light blue: flood in bare soil
- Blue: flood in urban area
- Red: unflooded buildings

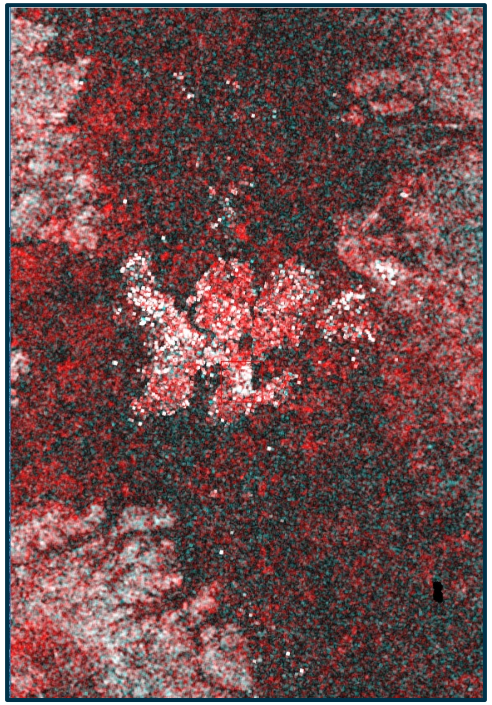
Test case 2: Somalia 2018

14/05/2018

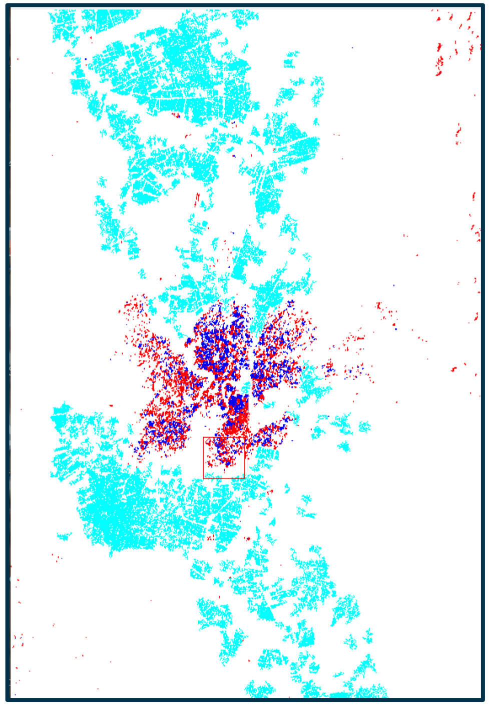
RGB Intensity



RGB coherence



Flood map



- **Light blue:** flood in bare soil
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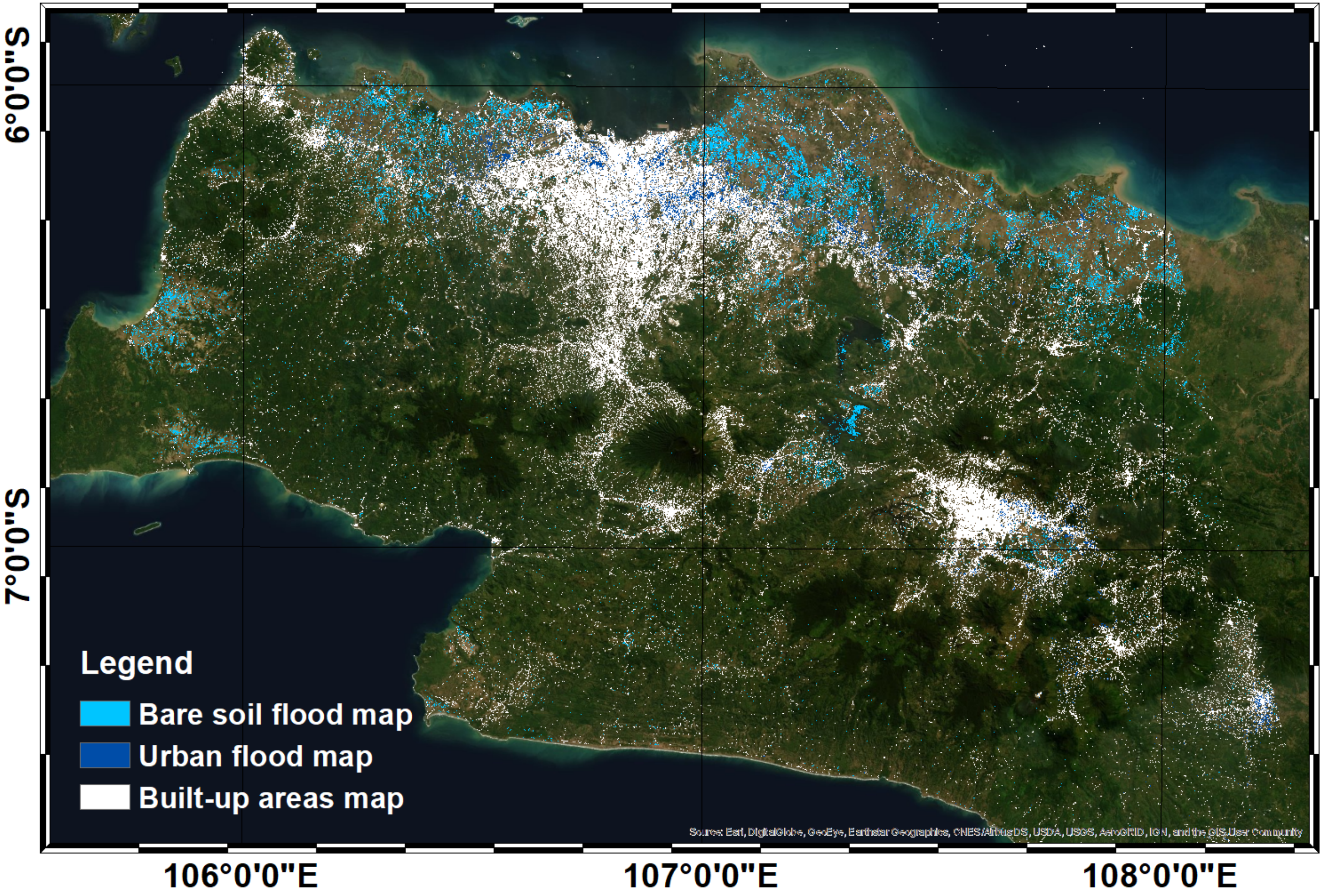
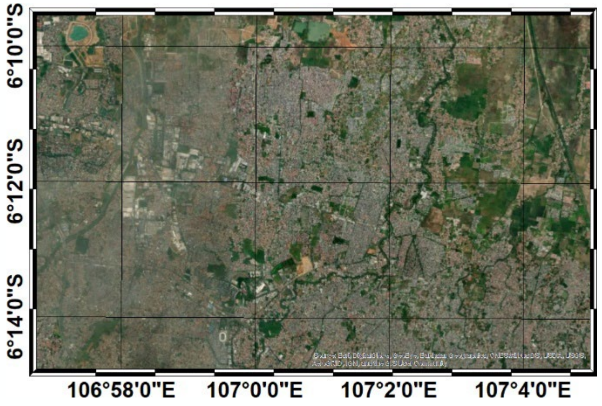
Test case 3: Jakarta 2020



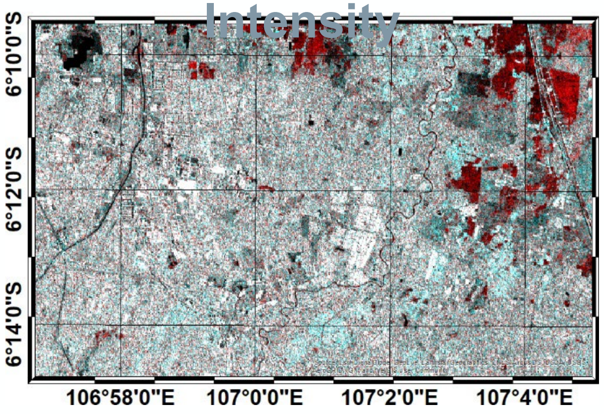
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

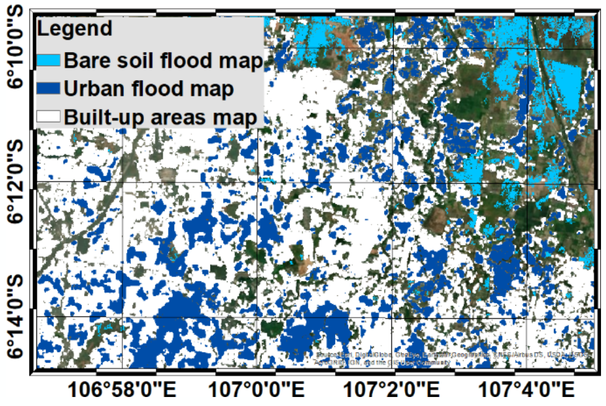
Test case 3: Jakarta 2020

Optical image

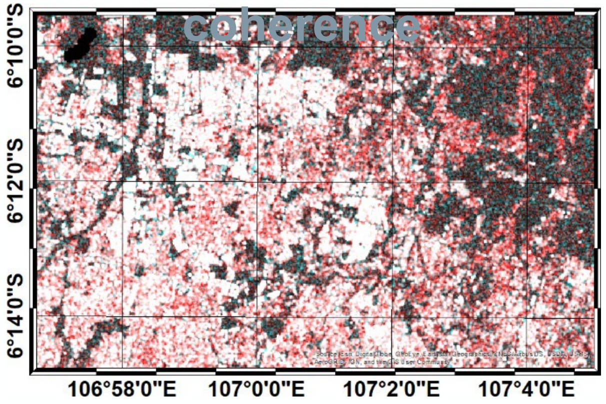


RGB SAR VV Intensity

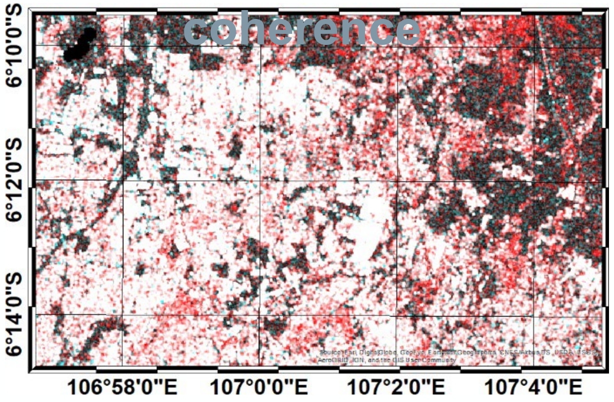


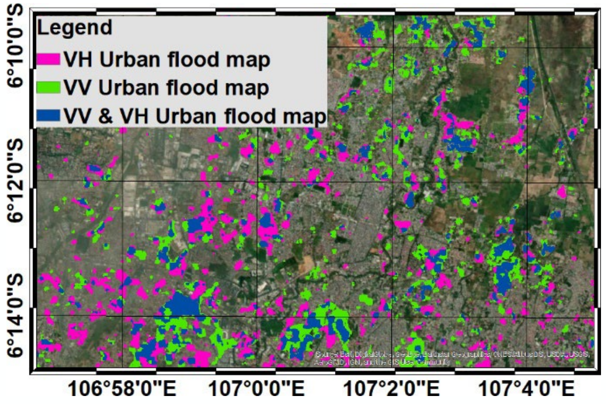


RGB SAR VH coherence



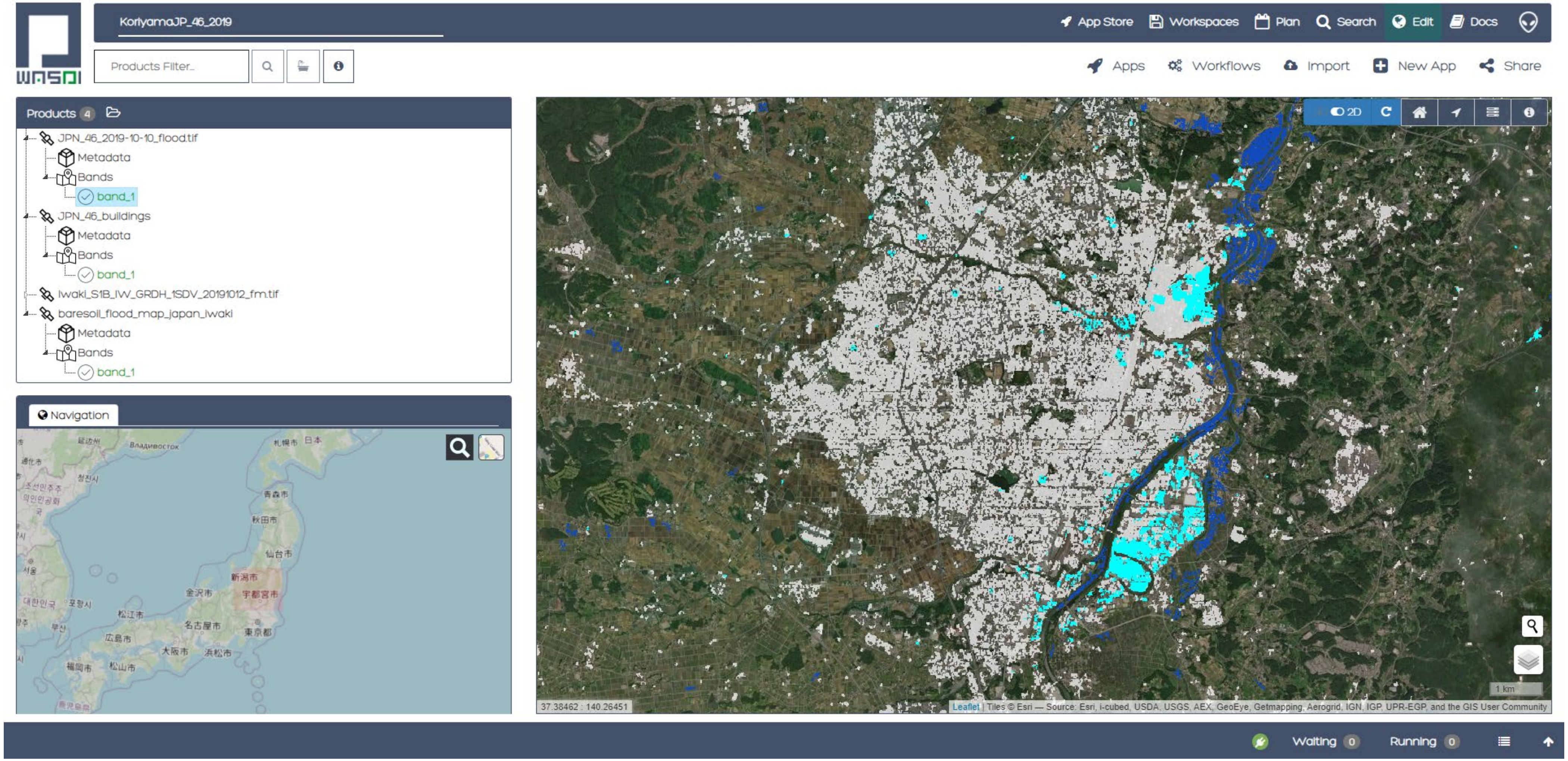
RGB SAR VV coherence





Test case 4: WASDI platform – Japan 2019

Open flood 🟦 Urban areas ⬜ Urban flood ■



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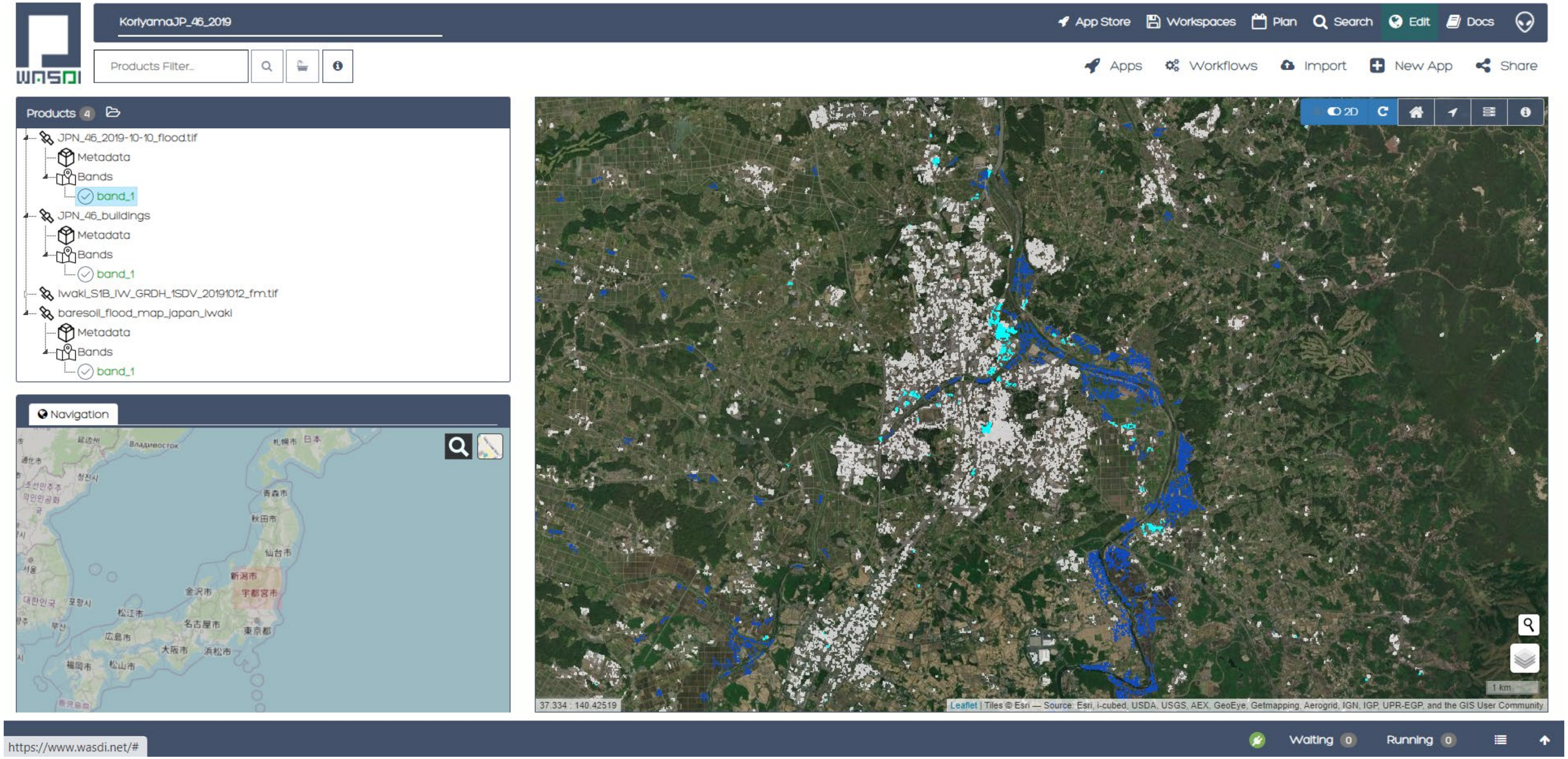
  - Metadata
  - Bands
    - band_1
- JPN_46_buildings
  - Metadata
  - Bands
    - band_1
- Iwaki_S1B_IW_GRDH_1SDV_20191012_fm.tif
- baresoil_flood_map_japan_iwaki
  - Metadata
  - Bands
    - band_1

37.38462 : 140.26451

Test case 4: WASDI platform – Japan 2019

Open flood 🟦 Urban areas ☐ Urban flood 🟦



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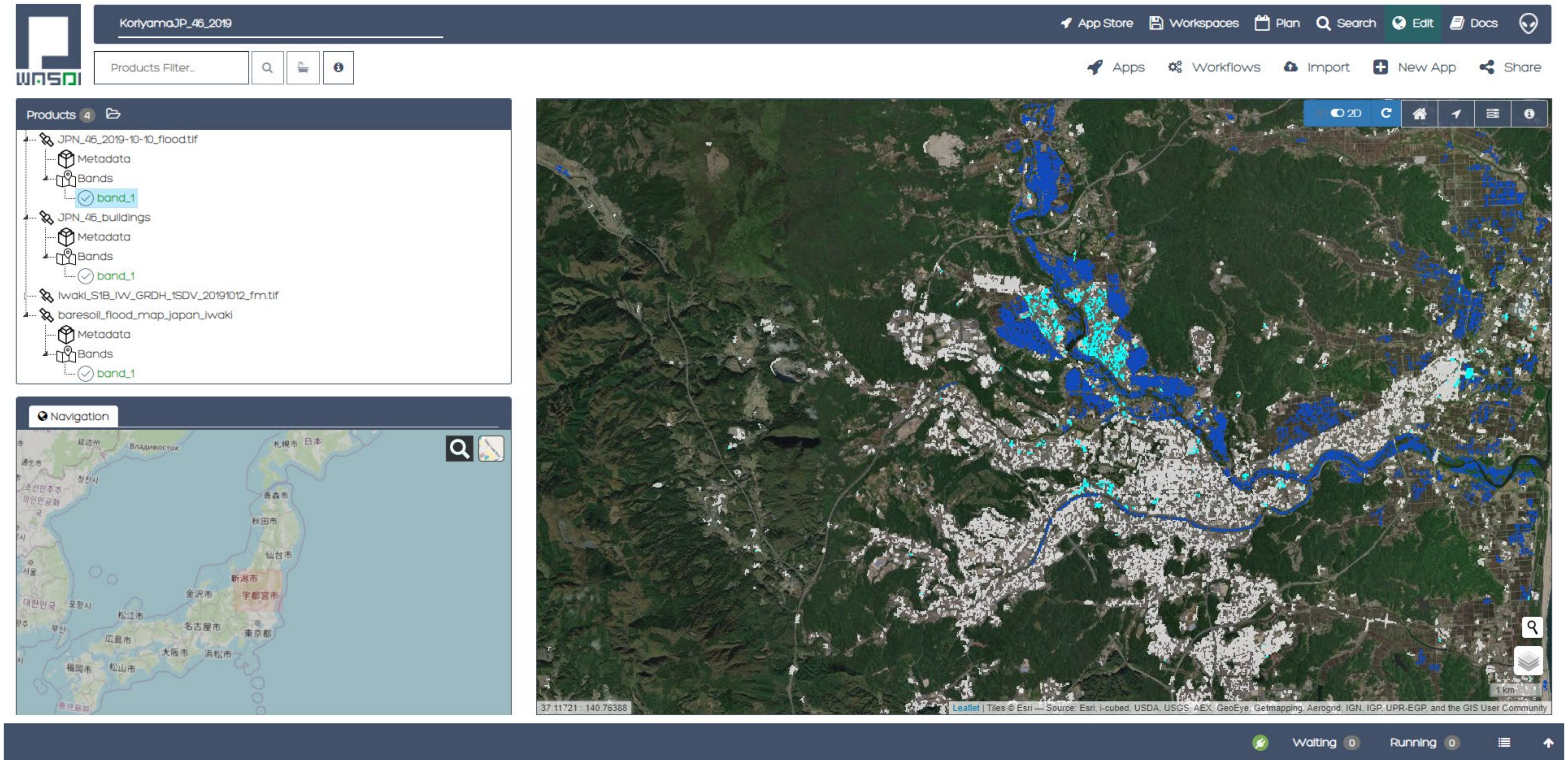
  - Metadata
  - Bands
    - band_1
- Iwaki_S1B_IW_GRDH_1SDV_20191012_fm.tif
- baresoil_flood_map_japan_iwaki
  - Metadata
  - Bands
    - band_1

Test case 4: WASDI platform – Japan 2019

Open flood 🟦 Urban areas ⬜ Urban flood 🟦



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- Iwaki_S1B_IW_GRDH_1SDV_20191012_fm.tif
- baresoil_flood_map_japan_iwaki
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  - Bands
    - band_1