

# AI4Copernicus 2023

Accurate and automatic flood maps based on SAR and optical data

WNSI

# EO Flood Maps - SAR On Demand

SAR have been used since the late 1980s, early 1990s to map floods.

## 11 March 2011



IEEE GEOSCIENCE AND REMOTE SENSING LETTERS, VOL. 9, NO. 3, MAY 2012

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## Analysis and Interpretation of the COSMO-SkyMed Observations of the 2011 Japan Tsunami

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**Abstract**—The major outcomes of the analysis of the COSMO-SkyMed (CSK) synthetic aperture radar (SAR) observations of the area hit by the 2011 Japan tsunami are presented. The height of the tsunami waves was such as to cause a widespread inundation of the coastal area. The SAR acquisitions have been performed on March 12 (i.e., one day after the tsunami occurred) and March 13, 2011 in interferometric mode, so that not only the information on the intensity of the radar signals, but also the complex coherence has been used. The interpretation of the available data has allowed us to detect the flooded areas, as well as the receding of the floodwater from March 12 to March 13, 2011 and the presence of the debris floating above the water surface. Moreover, thanks to the high spatial resolution of the CSK images, the presence of floodwater in some urban areas in the Sendai harbor has been revealed by exploiting the information on the coherence. Our interpretations have been confirmed by a couple of optical images used as benchmarks.

**Index Terms**—Change detection, COSMO-SkyMed, flood, synthetic aperture radar (SAR), 2011 Japan tsunami.

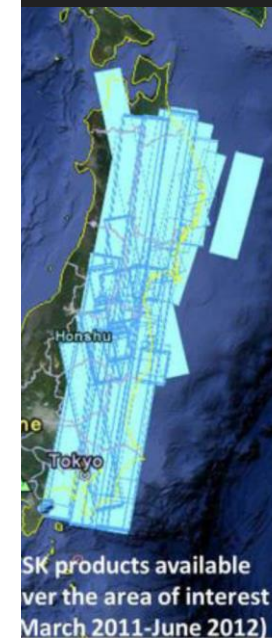
### I. INTRODUCTION

THE SEISM that occurred in Japan on March 11, 2011, which struck the northeast coast of the Honshu Island, represents one of the largest earthquakes ever recorded in the history. However, the cause of the huge number of casualties, of most of the widespread damages and of the crisis at the Fukushima-Daiichi nuclear plant, was not the earthquake, but the destructive tsunami, originated by the earthquake, that hit the coastline several minutes after the seism. Indeed, because of the tremendous energy that was given off, the tsunami waves exceeded 10 m in height, and, once reached the shore, they quickly inundated the coastal region, destroying entire villages. Reportedly, the Miyagi Prefecture was the most damaged area, with the Sendai plain that was largely flooded.

Moreover, radiation emitted from the damaged nuclear reactors made *in situ* campaigns very dangerous. Indeed, satellite remote sensing represented not only the most effective, but also the safest, and, to some extent, the unique way to assess the Japan tsunami-affected areas [1].

Among remote sensing sensors, synthetic aperture radar (SAR) systems have key features, such as the capability to work even in cloudy conditions and both during daytime and nighttime, which make them the most powerful tool to monitor natural disasters [2]. Moreover, the recent launch of a new generation of SAR instruments, such as TerraSAR-X (TSX) and COSMO-SkyMed (CSK), allows emergency managers to use damage maps at very high spatial resolution. The improvement of the spatial resolution of radar images, which can reach 1 m in the spotlight operation mode, is fundamental when dealing with scenes including not only rural, but also urban and suburban areas, as for the Japan tsunami case. For instance, a method to detect floodwater in urban areas using TSX, which takes also advantage of ancillary high-resolution Light Detection And Ranging (LiDAR) digital terrain models, was proposed in [3], whereas before the deployment of the new generation of SARs, extraction of flooded areas within urban settlements was considered an unfeasible task [4], [5].

In addition to the very high spatial resolution, CSK gives the possibility of performing frequent observations of regions hit by natural disaster, thanks to the four-satellite constellation that offers a revisit time that can reach 12 h in the worst case [6]. While most of the automatic change detection methods available in the literature single out the changes induced by a specific event by using a pre-event image and a postevent one (e.g., [7] and [8]), CSK offers to the users a better opportunity to monitor the various stages of the temporal evolution of a natural disaster, for example, high-resolution flood evolution maps.



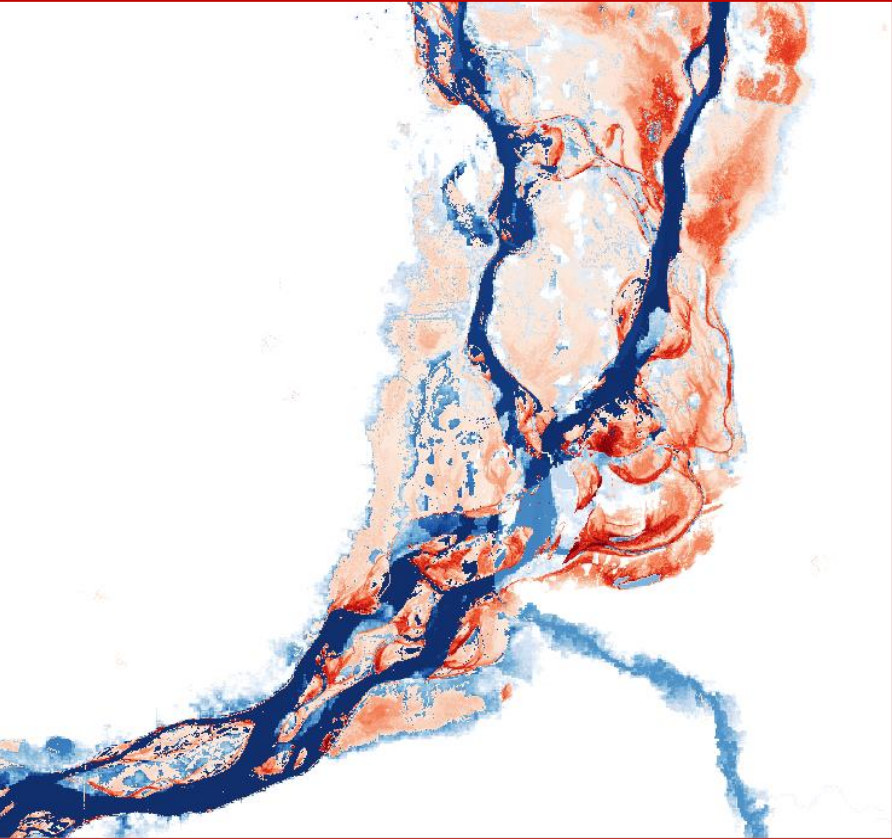
# EO Flood Maps – SAR Automation

*Sentinel Missions enabled the automation of the Flood Delineation maps production on vast AOIs (continuously updated) and full flood Archives production.*

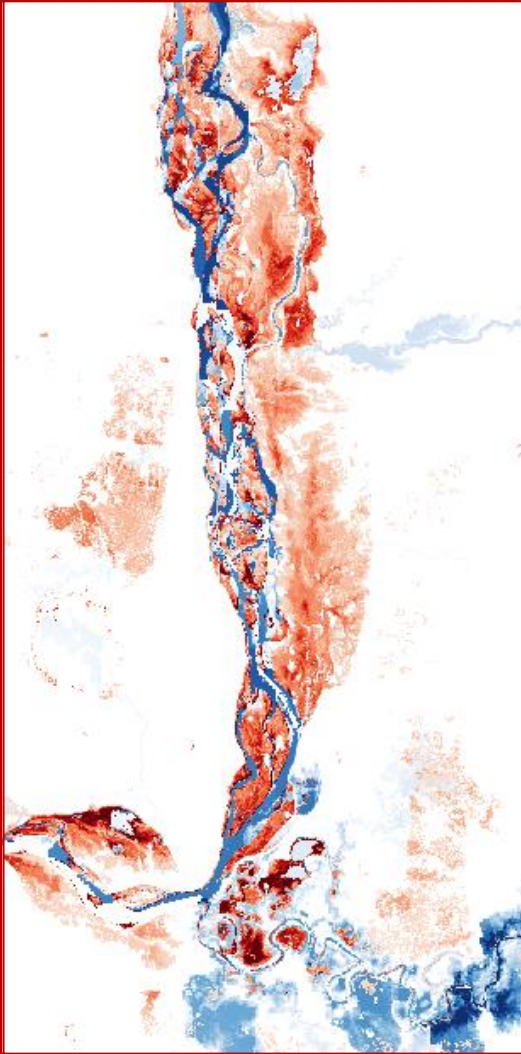
The screenshot displays the WASDI web interface for a project titled "MYANMAR-FREQUENCY-MAP". The interface includes a search bar with the text "flood", a navigation menu with options like "Workflow", "Import", "WASDI Apps", "Processor", "Optical", "Radar", and "Share", and a "Products" list on the left. The product list contains numerous entries with IDs such as "MY\_flood\_2017-12-31\_2017-12-31\_count\_365\_N200W970S150E1000". Below the product list is a "Navigation" panel showing a map of Myanmar with various regions labeled. The main area of the interface is a large satellite-style map showing a complex network of blue flood channels over a green and brown landscape. The bottom of the interface shows a status bar with "Waiting" and "Running" indicators.

# EO Flood Maps – Observations and Models

*Validation of the flood Models.*



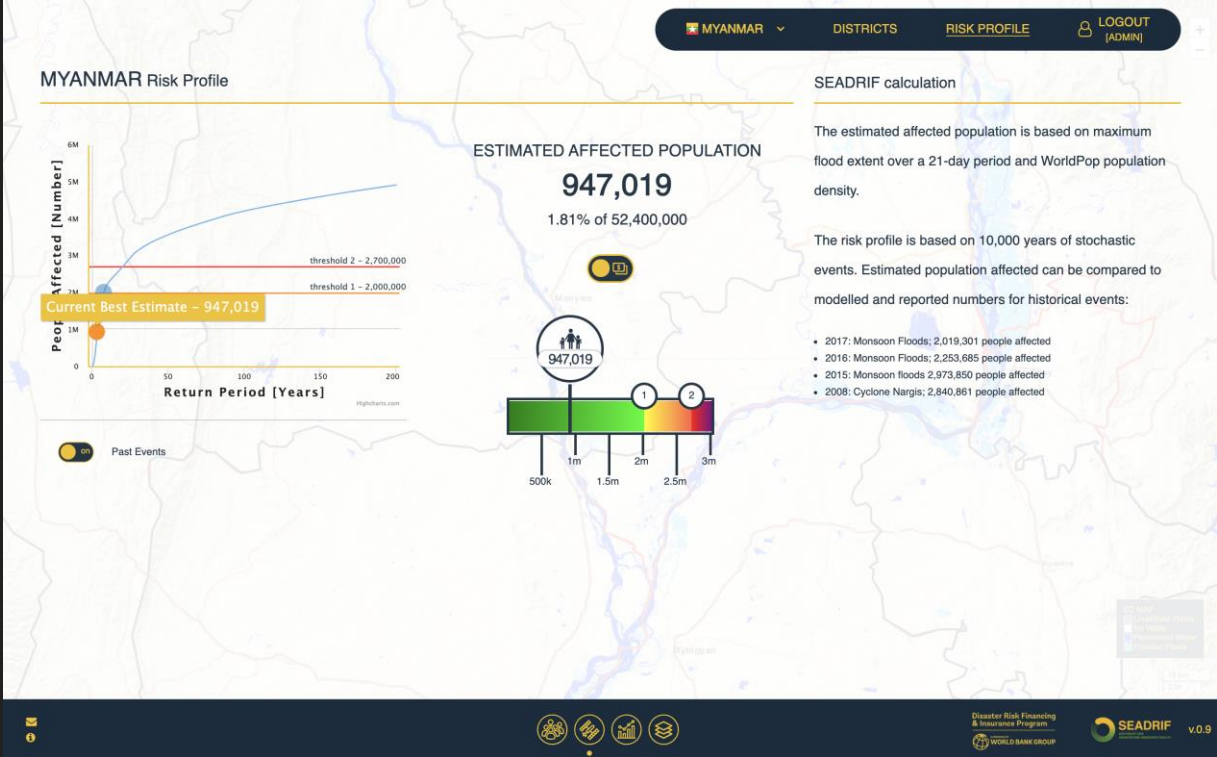
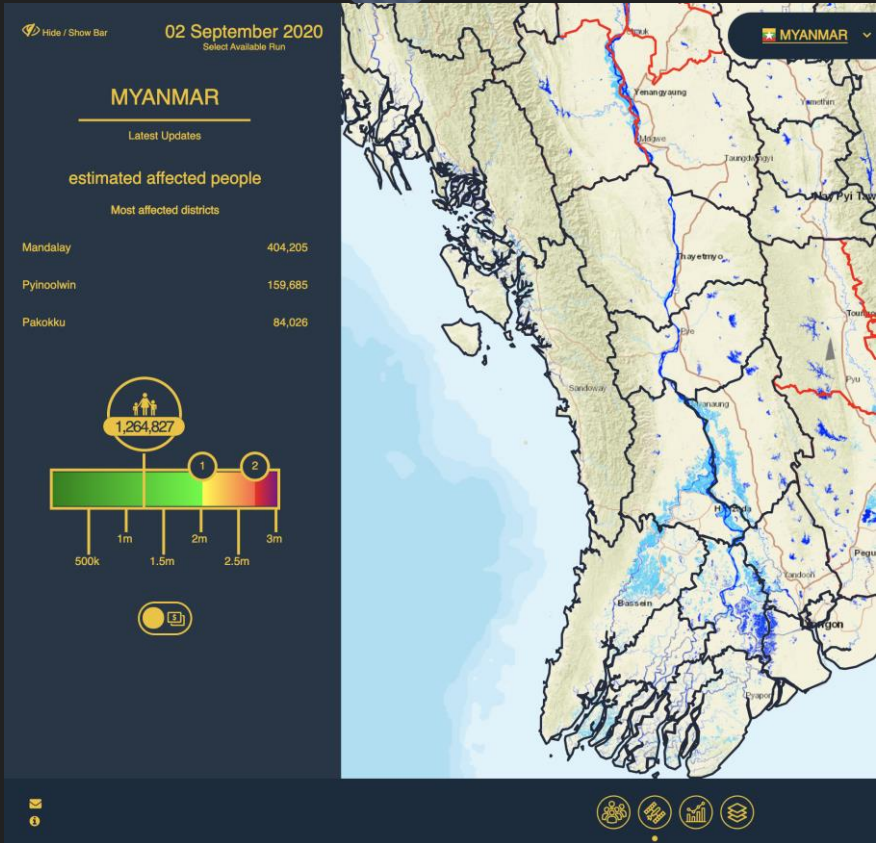
0 5 10 [m] --> Modeled Hazard Map



0 26 50 --> S1 Flood Frequency Map

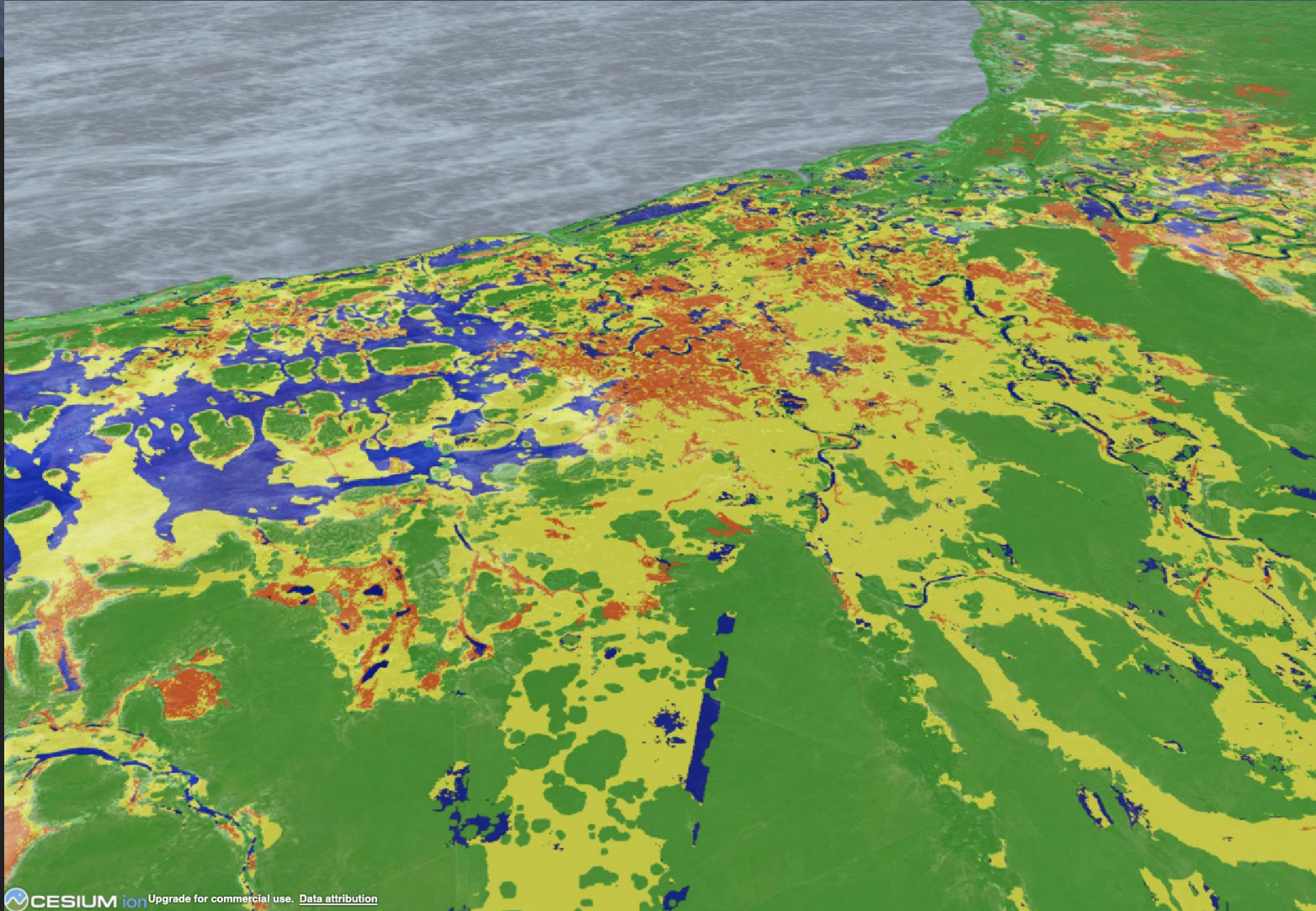
# EO Flood Maps – Climate Change Challenges

*Disaster Risk Financing offers a lean way to unlock resources for a fast and prompt reaction when a disaster occurs. This is particularly important when sovereign risk is considered in countries where the magnitude of flood events often overcomes the response capacity of the institutions.*



# EO Flood Maps – Optical Detection

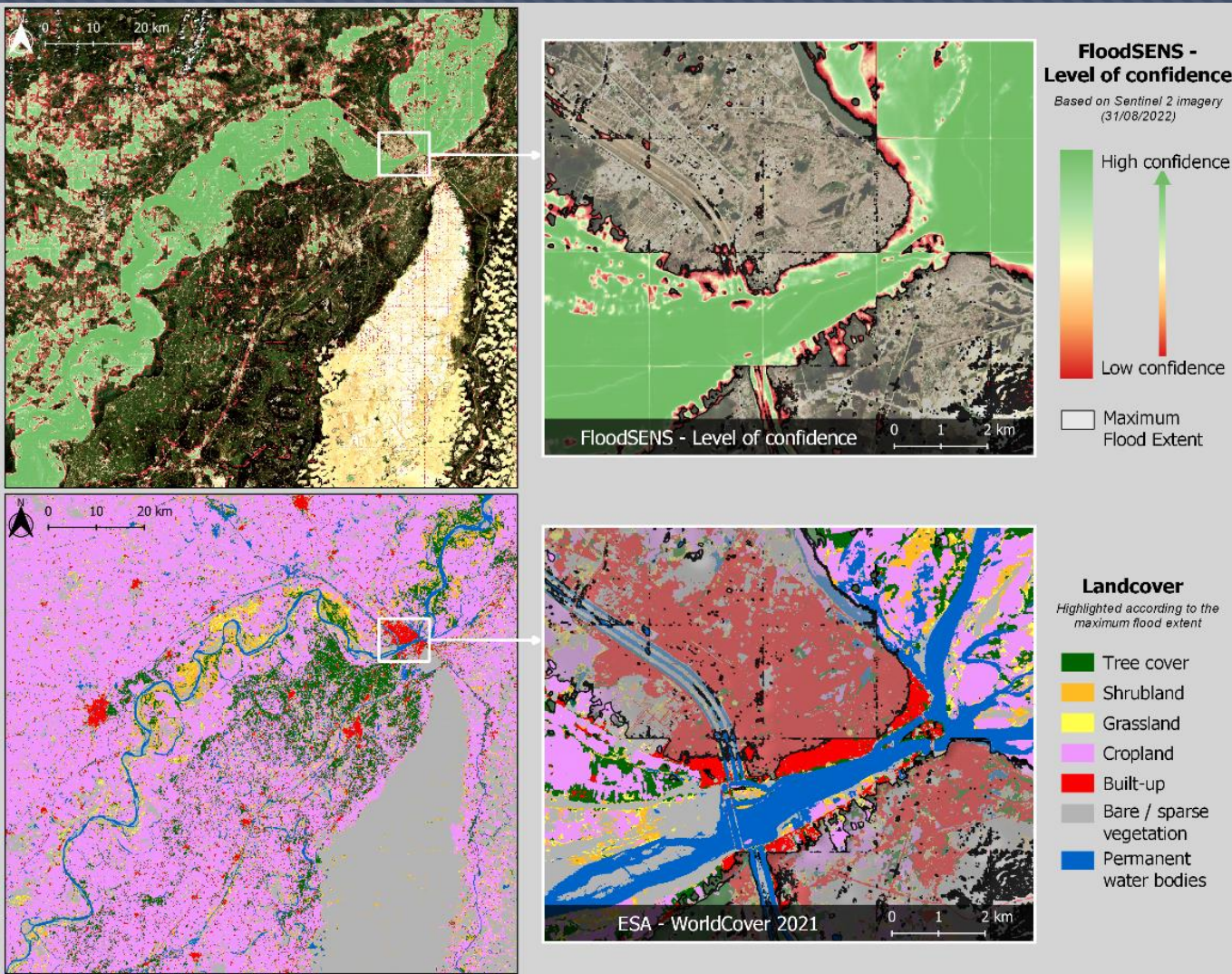
*Despite the abundance of sensors, the Acquisition frequency remains a challenge. Augmenting the number of satellites to be used automatically would improve detection skills.*



Blue – Permanent Water  
Red – flood detected by both  
Orange – detected by only one  
Yellow – detected by one/not detected by the other

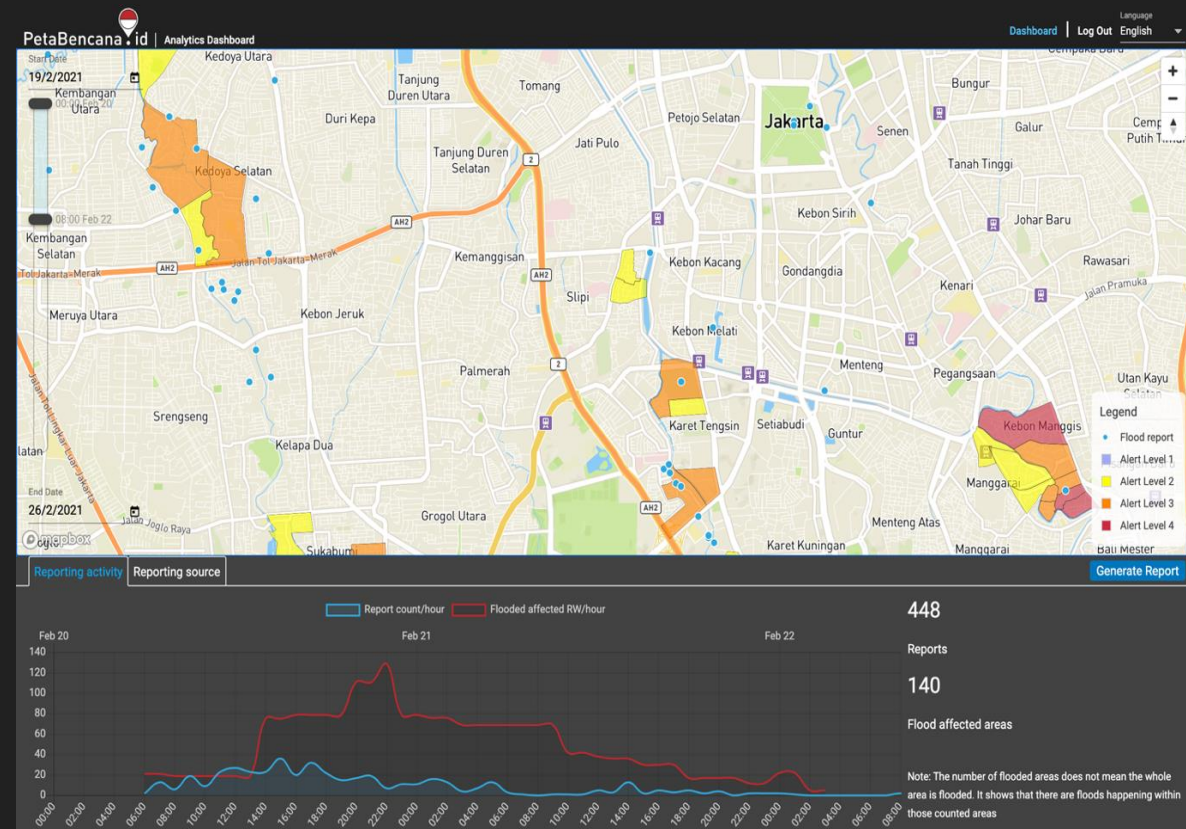
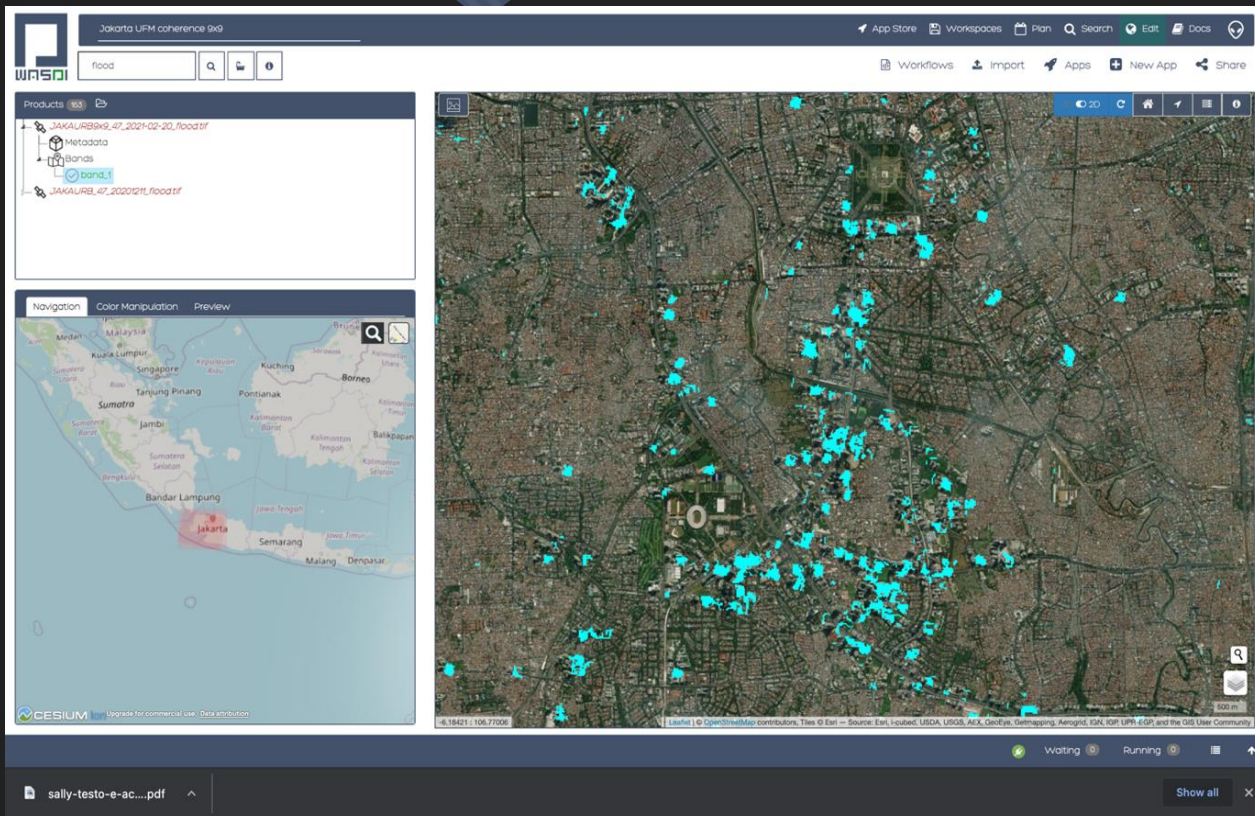
# EO Flood Maps – AI Under Clouds

*FloodSENS uses ML to infer flood impact areas from S-2 flood images, with no cloud, low cloud...*



# EO Flood Maps – Urban Floods

*The combination of coherence and intensity can help detecting floods in Urban Areas*

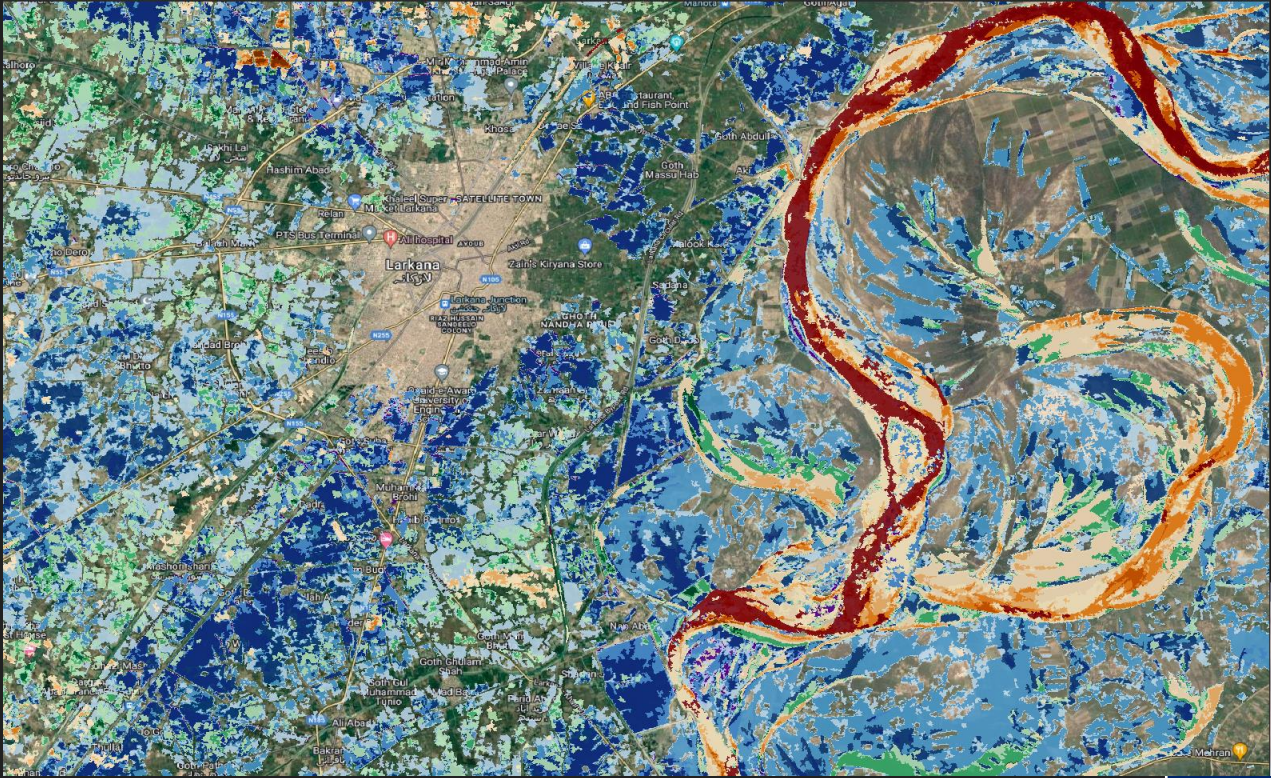
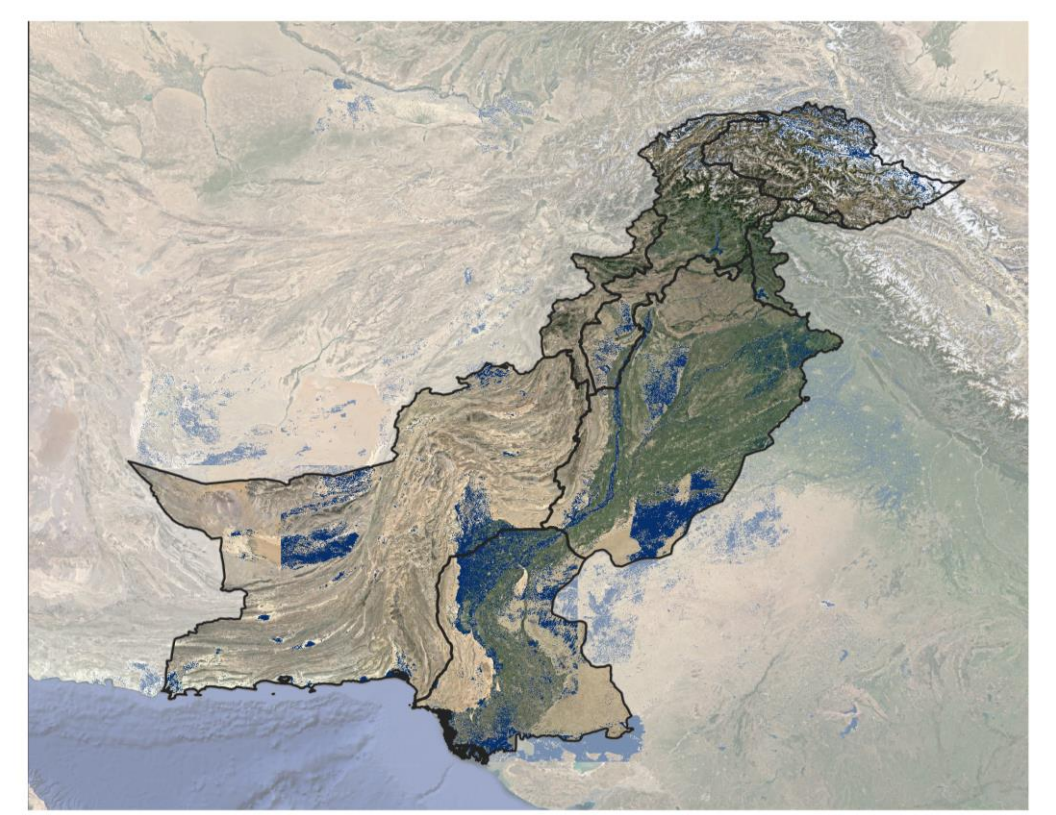




# EO Flood Maps – Flood Evolution

*Pakistan Activation 2022: Synoptic View and Flood Temporal Monitoring (LARKANA Detail)*

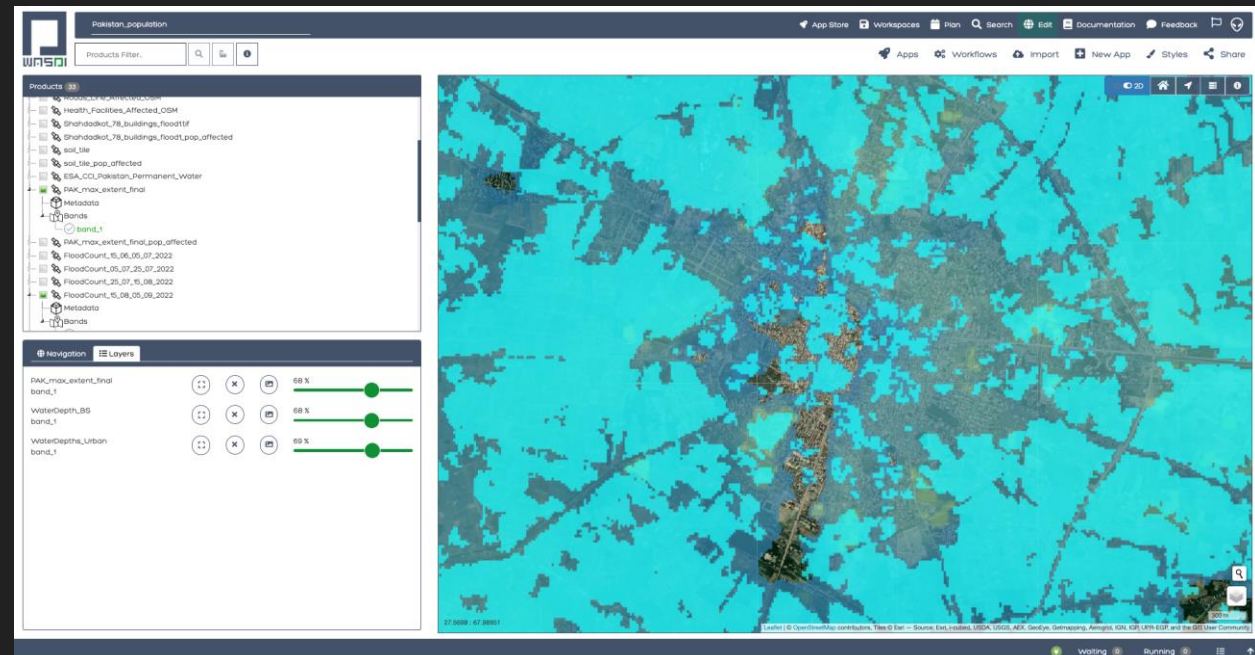
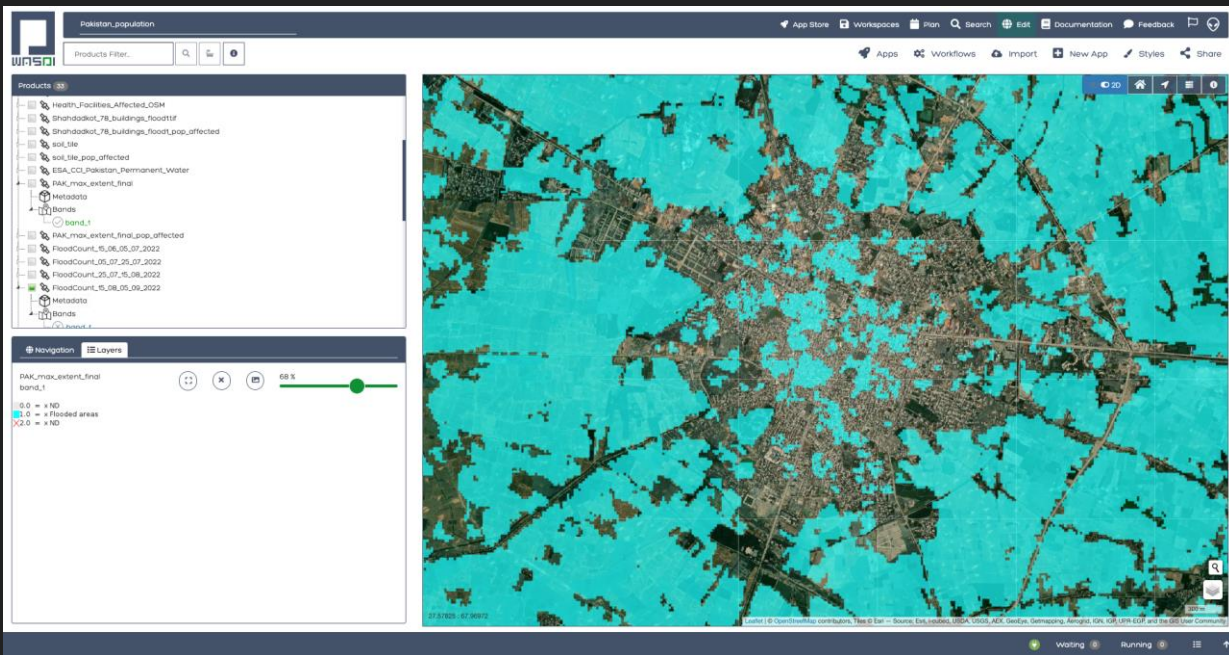
15/6 – 5/7 → 5/7 – 25/7 → 25/7 – 15/8 → 15/8 – 5/9 → 5/9 – 15/9



Pakistan 06-09/2022

# EO Flood Maps – Water Depths / Gap Filling

The combination of flood delineation maps with local DEM (and Artificial Intelligence?) can help to derive water depths and fill the gaps



Pakistan 06-09/2022

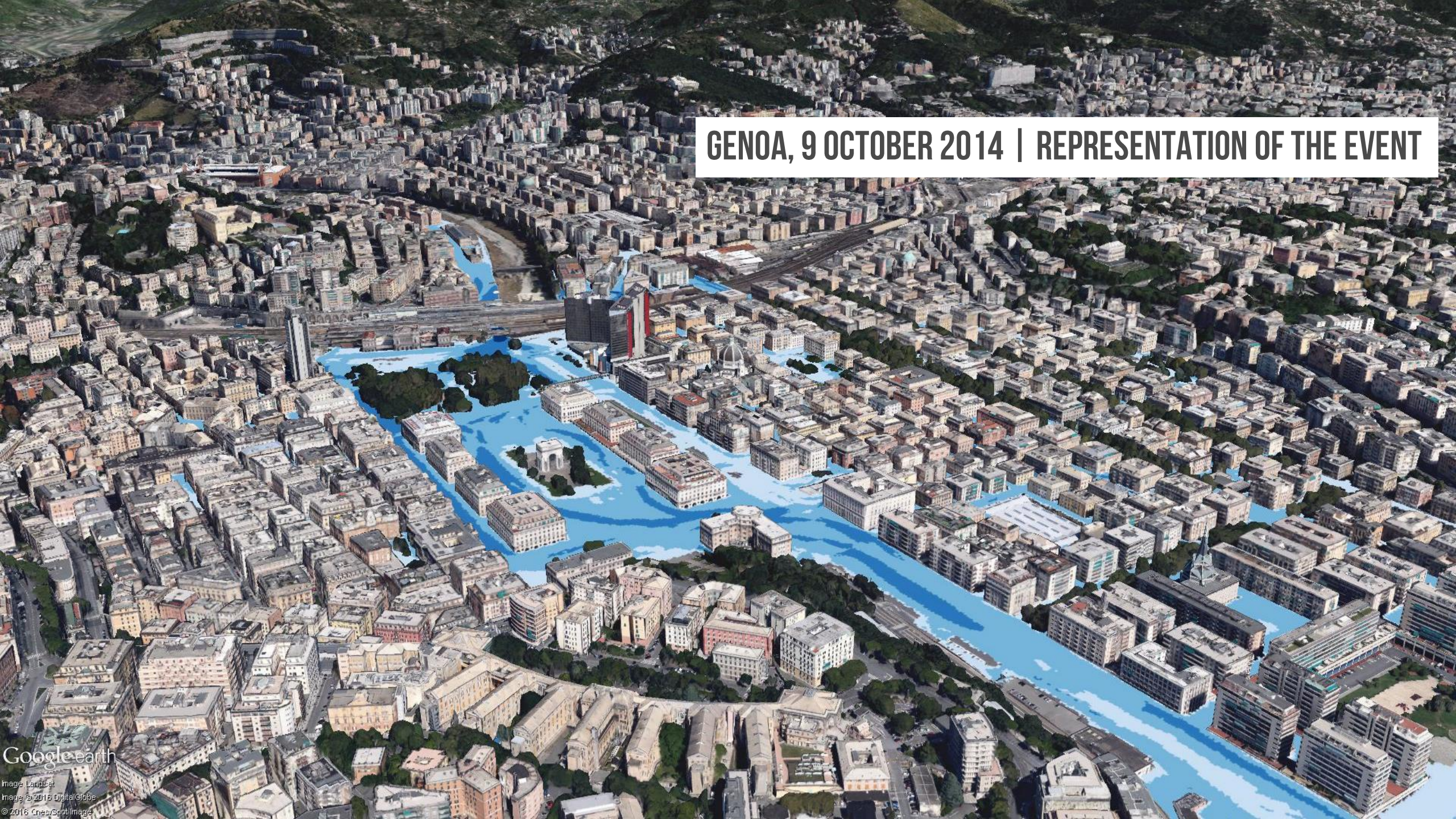


# EO Flood Maps – Population Affected

*Integration with worldwide available layers can help to derive useful information*

The screenshot displays a web-based GIS application interface. At the top, the title "Pakistan\_population" is visible. The interface includes a navigation menu with options like "App Store", "Workspaces", "Plan", "Search", "Edit", "Documentation", "Feedback", and "Share". A "Products Filter" search bar is present. On the left, a "Products" list shows various layers such as "Flood\_Count\_North", "Pop\_affected\_North", "Education\_Facilities\_Affected\_GSM", "Roads\_Line\_Affected\_GSM", and "Health\_Facilities\_Affected\_GSM". Below this is a "Layers" panel with a legend for "PAK\_max\_extent\_final\_pop\_affected band\_1", showing a color scale from 0.0 to 9.40009155273438. The main map area shows a 3D view of a city with flood zones in blue and population affected areas in green, yellow, and orange. The bottom status bar shows "Waiting" and "Running" indicators.

**GENOA, 9 OCTOBER 2014 | REPRESENTATION OF THE EVENT**



# EO Flood Maps – Impacts

RasorGenova

[Apps](#) [Workspaces](#) [Plan](#) [Search](#) [Edit](#) [Project: WASDI Trial](#) FREE

Products Filter...

[Apps](#) [New App](#) [Workflows](#) [Import](#) [Create Jupyter](#) [Styles](#) [Share](#)

**Products** 6

- Bands
- roads
- exposure\_markers
- Metadata
- Bands
- exposure\_markers
- exposures
- Metadata
- Bands
- exposures
- crops
- genova\_bisagno\_flo\_2014\_pop\_affected
- Metadata
- Bands

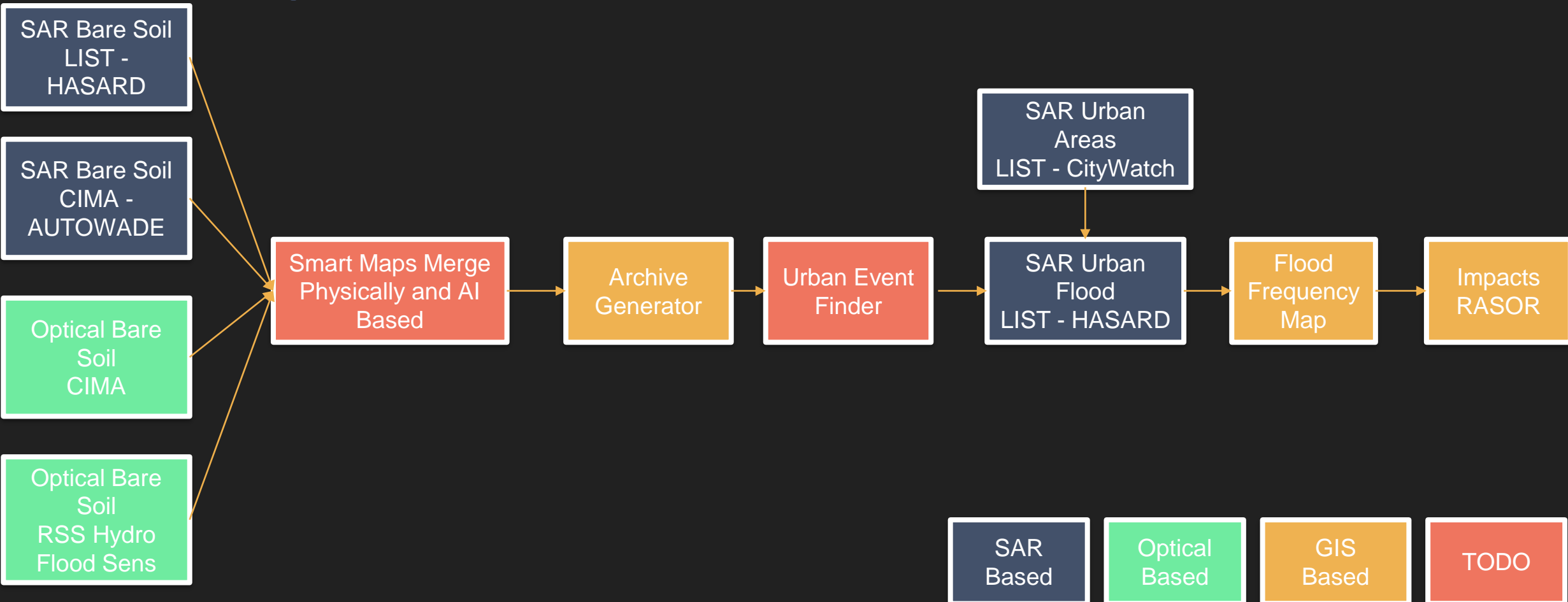
**Navigation** **Layers**

exposure_markers	<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	100 %	<div style="width: 100%; height: 10px; background-color: green; border: 1px solid black;"></div>
exposure_markers	<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	100 %	<div style="width: 100%; height: 10px; background-color: green; border: 1px solid black;"></div>
roads	<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	100 %	<div style="width: 100%; height: 10px; background-color: green; border: 1px solid black;"></div>
roads	<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	100 %	<div style="width: 100%; height: 10px; background-color: green; border: 1px solid black;"></div>
exposures	<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	100 %	<div style="width: 100%; height: 10px; background-color: green; border: 1px solid black;"></div>
exposures	<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	100 %	<div style="width: 100%; height: 10px; background-color: green; border: 1px solid black;"></div>
genova_bisagno_flo_2014_pop_affected	<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	100 %	<div style="width: 100%; height: 10px; background-color: green; border: 1px solid black;"></div>
band_1	<input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/>	100 %	<div style="width: 100%; height: 10px; background-color: green; border: 1px solid black;"></div>

The map displays the city of Genova, Italy, with several red star markers indicating specific impact locations. Yellow and orange shaded areas represent flood zones, primarily along the coast and in the central urban areas. Major roads like Corso Italia and Corso Aurelio Saffi are visible. The map includes a 300m scale bar and coordinates 44.40064 : 8.92806.

# EO Flood Maps – What's next?

*Putting all together in an automatic chain can leverage and speed up existing applications. Artificial Intelligence can help to merge different maps and to analyze the archives to trigger the automatic execution of detections in Urban Areas*





Always thanks to our beloved Partners:



Q&A



Thanks for your attention !

Any doubt?