WGISS-61
Sentinel-1: A Game Changer for Disaster Response

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6.3

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CEOS Committee on Earth Observation Satellites

Earth Observation

- ❖ Over the past few decades, Earth Observation (EO) satellites have emerged as a major data source for providing critical information during disasters.
- ❖ Many satellite constellations, originating from both the private sector and institutional organizations, are increasingly available and feature diverse characteristics.
- ❖ EO satellites have the capability of repetitively acquiring data globally.
- ❖ Optical data can provide detailed information with a high level of granularity.
- ❖ SARs are of special importance because due to their sensitivity to variations in land cover and their near all-weather, day-and-night imaging capability.
- ❖ Combining data from various satellite missions is essential for achieving a high revisit time.

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Disatser Managers Needs

- Regularly updated information at a global scale.
- Fast access to the information.
- Higher level of spatial details and large spatial coverage.
- Avoid downloading large amounts of data.
- Avoid the need for an IT expert to manage cloud computing infrastructures.

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Enabling technology

- Regularly updated Onboard processing capacity.
- High-performance and cloud computing infrastructures.
- Advanced deep-learning algorithms to derive value-added information from raw data.
- AI-based data-driven methods to leverage synergies in the data diversity.

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Sentinel-1

- Sentinel-1 satellite(s) enabling systematic, high-frequency radar observations at global scale.
- 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.
- InSAR coherence is generally affected by spatial decorrelation, so that 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)***

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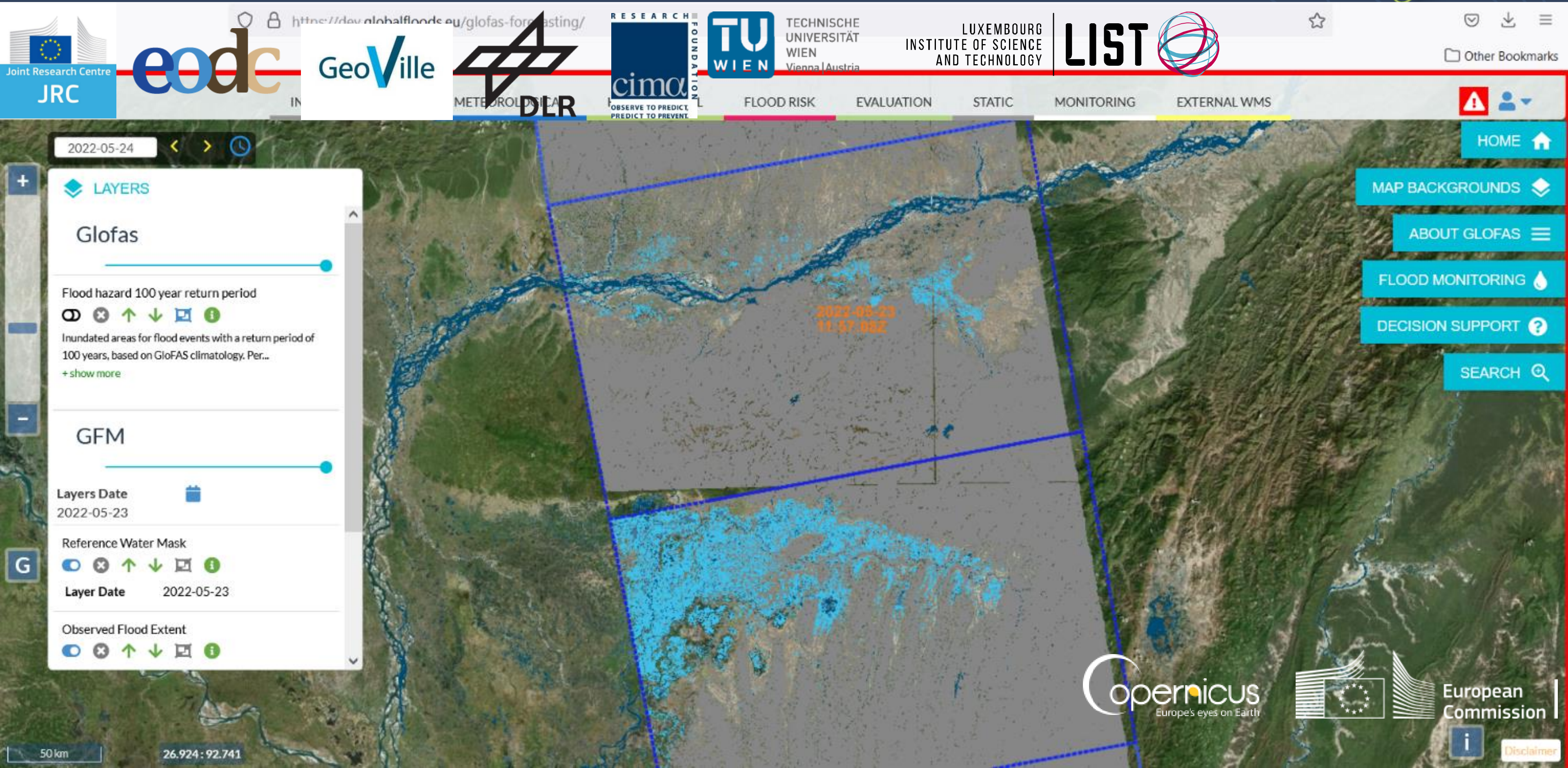
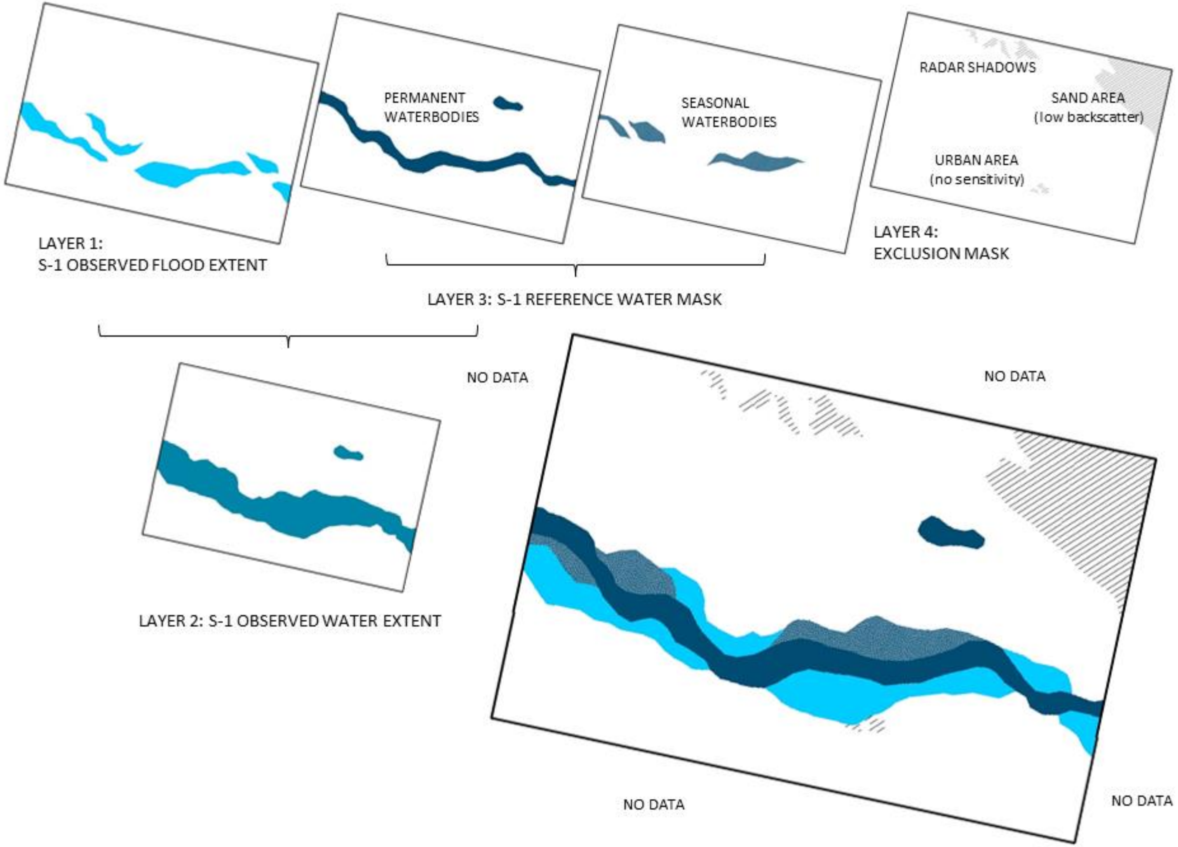
Global flood monitoring (GFM)



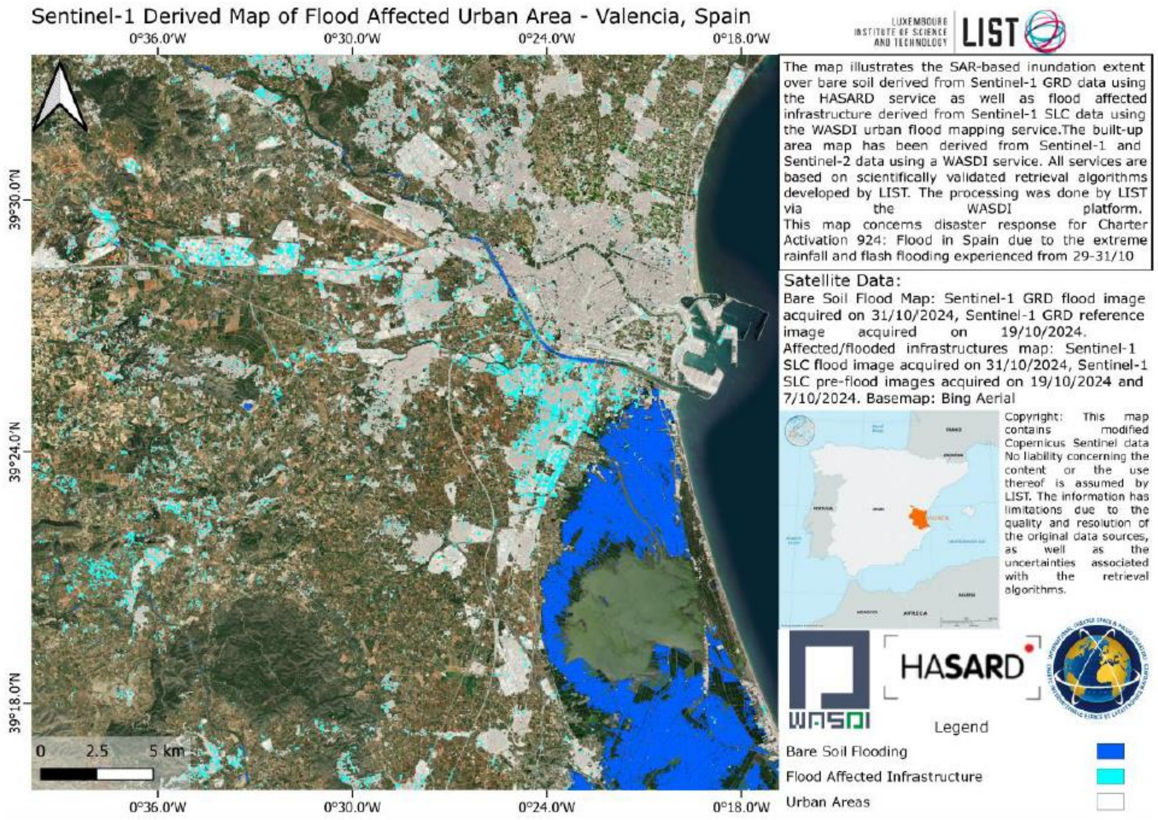
Global flood monitoring (GFM)



Floodwater products:

- ❖ Flood extent
- ❖ Permanent water
- ❖ Seasonal water

Floods in urban areas



We developed an urban-aware U-Net model that uses Sentinel-1 dual polarization multitemporal intensity and coherence data, along with a building probability map, to identify flooding in bare soil and urbanized areas.

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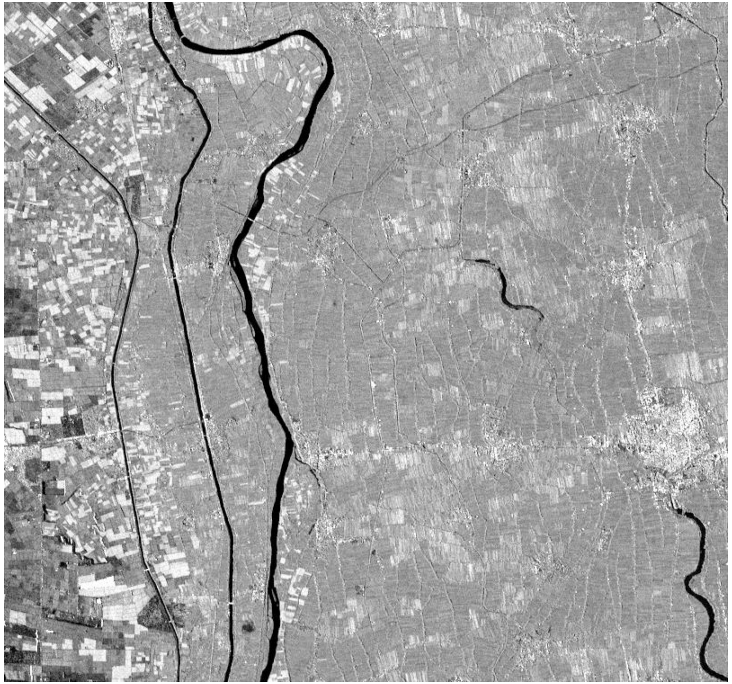
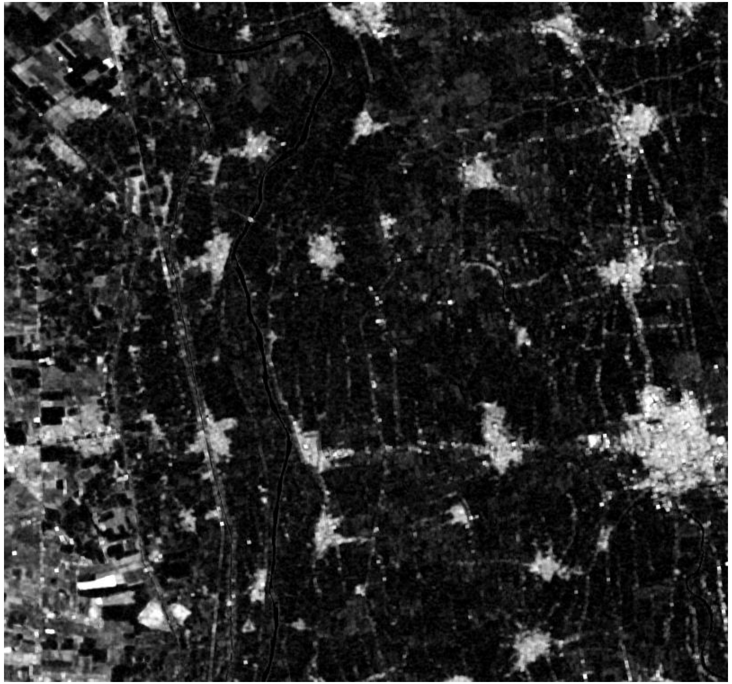
Floods in urban areas

SAR Intensity



InSAR coherence



Floods in urban areas

- The urban-aware module is applied to facilitate the learning process of the model by focusing on the more representative and robust features for different targets (i.e., different flood classes).
- The proposed urban-aware module uses a priori information, i.e., an SAR-derived probabilistic urban mask, and it consists of channel-wise attention and urban-aware normalization submodules to calibrate features and improve the final predictions.
- The channel attention and urban-aware normalization submodules are applied sequentially.

J. Zhao, Y. Li, P. Matgen R. Pelich, R. Hostache, W. Wagner, M. Chini, "Urban-Aware U-Net for Large-Scale Urban Flood Mapping Using Multitemporal Sentinel-1 Intensity and Interferometric Coherence", IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 60, 2022.

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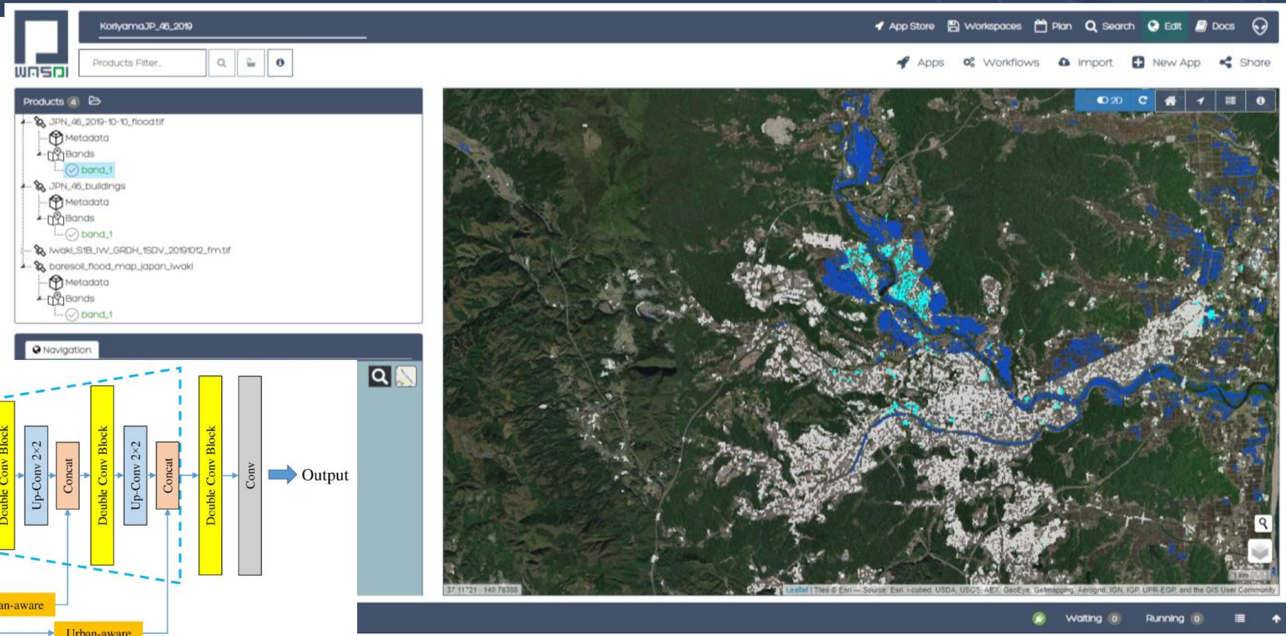
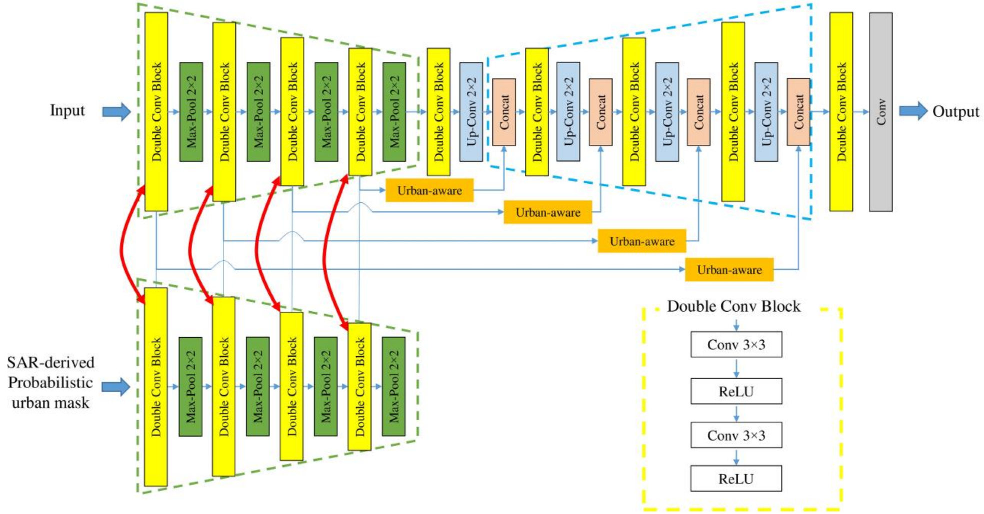
Floods in urban areas





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Urban area mapping

- Deep Learning (DL) methods are powerful for learning representations from complex and high-dimensional data.
  - Supervised DL models do not generalize well on test datasets that have a different distribution with respect to training data.
- Training data is expensive to collect and update.
  - Only sparse labelled training data are available at a large scale.
- *We develop an automatic built-up area mapping framework using Sentinel-1 and Sentinel-2 data that:*
  - Automatically generates labels for training data in a given area of interest.
  - Trains a cross-fusion neural network using synergies between Sentinel-1 SAR and Sententi-2 multi-spectral data.

Li, Y., Matgen, P. and Chini. M, "Extraction of built-up areas using Sentinel-1 and Sentinel-2 data with automated training data sampling and label noise robust cross-fusion neural networks," Int. J. Appl. Earth Observ. Geoinf., vol. 139, May 2025, Art. no. 104524 https://doi.org/10.1016/j.jag.2025.104524

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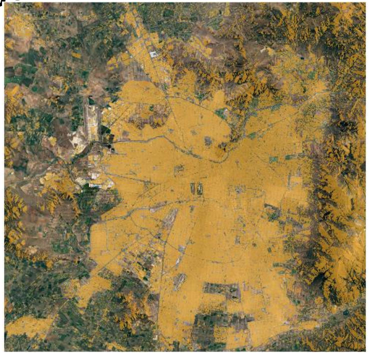
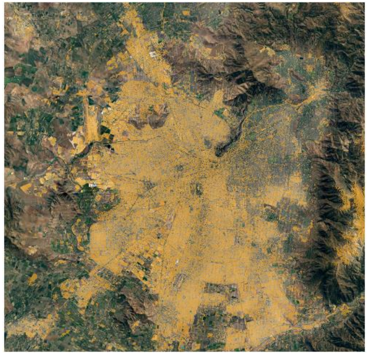
Automatic labels generation

Santiago

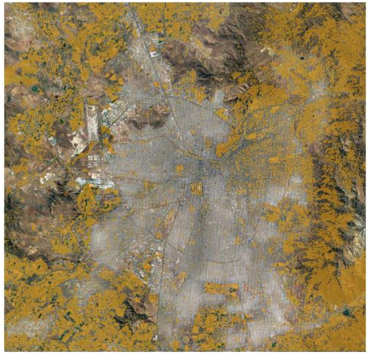


Sentinel-1 backscattering based built-up mask

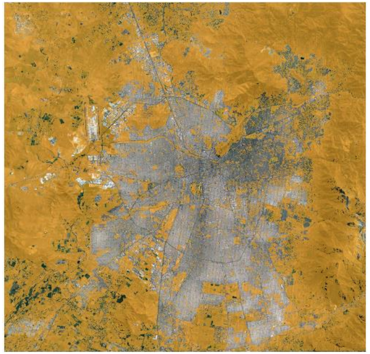
Sentinel-2 NDBI based built-up mask



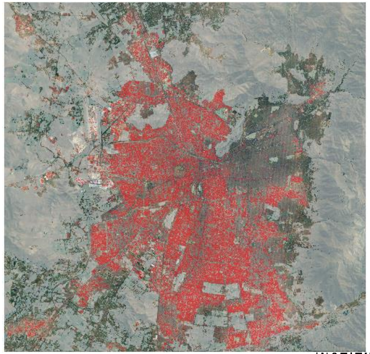
Sentinel-2 BUI based built-up mask



Sentinel-2 NDVI based vegetation mask



Sentinel-2 NDRB based bareness mask



Labels of training data

Built-up
Non-built-up

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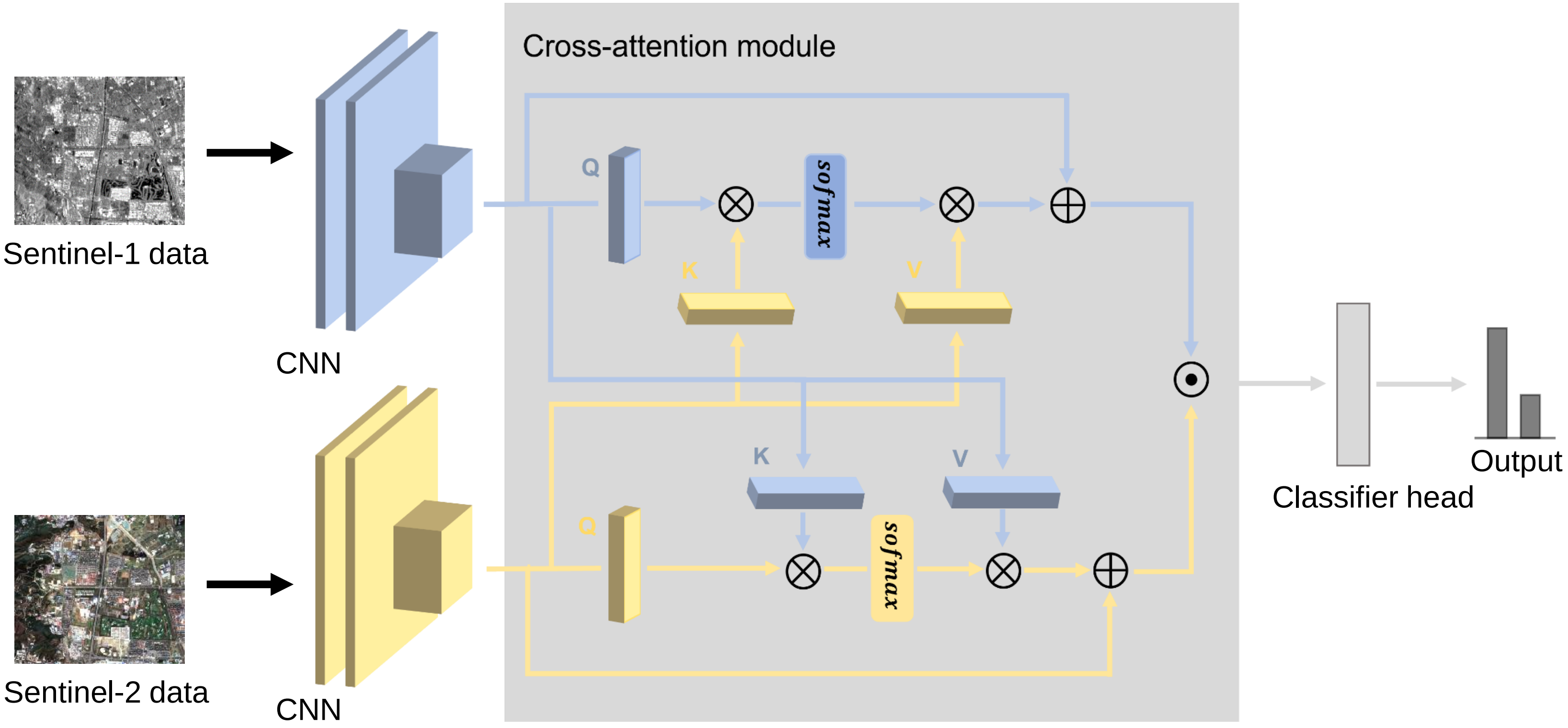
Cross-fusion Network



⊗ : Matrix Multiplication ⊕ : Add ⊙ : Concatenate

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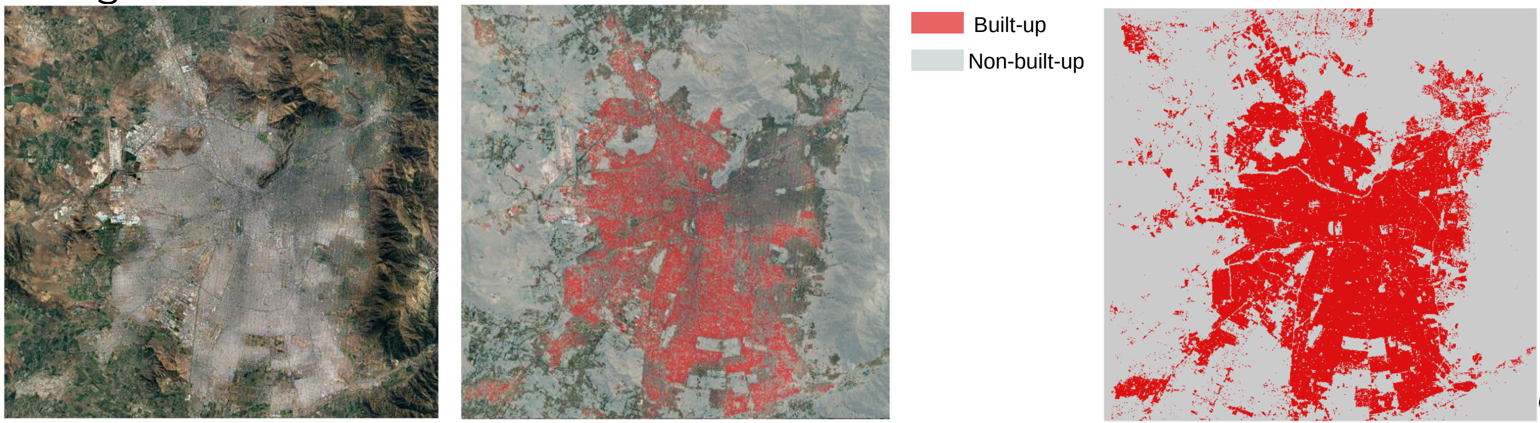
Cross-fusion Network

- The cross-fused features are concatenated for the final prediction.
- To make the model more resilient to label errors a virtual adversarial training (VAT) regularization is added.
- The total loss function is composed of a standard cross-entropy term and a VAT regularization term.

Santiago



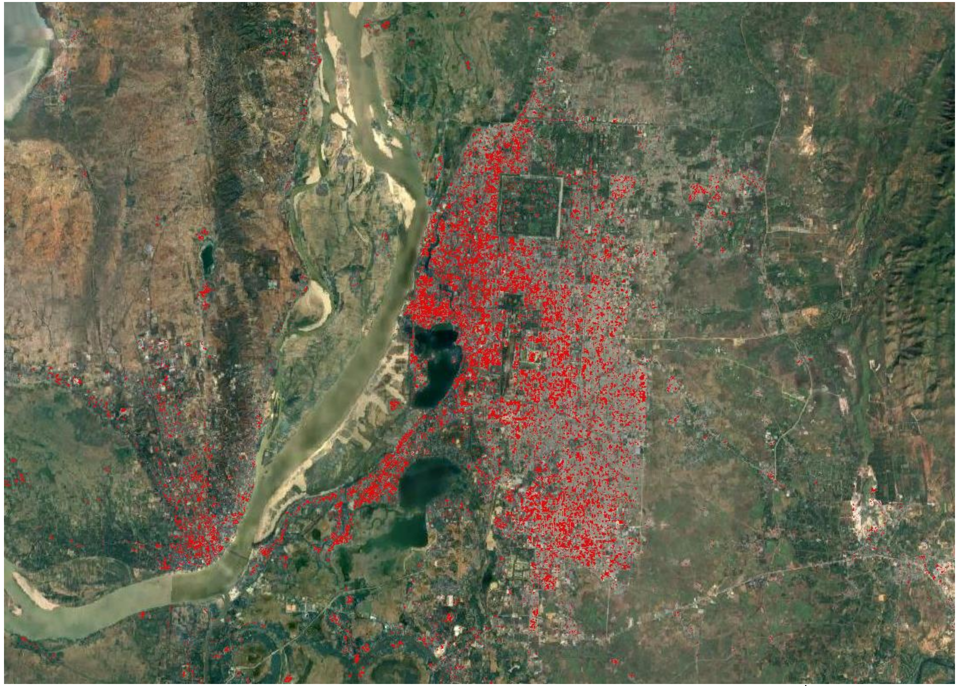
Labels of training data

Final building map

Building Damage Assessment

- ❖ All-Weather, Radar-based Near Real-Time Monitoring
- ❖ Rapid, Large-Scale Assessment
- ❖ Adaptable & Generalizable AI
- ❖ Efficient Self-Supervised Learning

2025 Myanmar earthquake



F1 – Score: 0.82

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Thanks!!!!!

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