# Change Detection Using Sentinel-1

## 1. Data Description

For this study, two Sentinel-1 Ground Range Detected (GRD) Interferometric Wide (IW) mode datasets were used to analyze urban changes in **Dehradun, India**.

| Acquisition Date | Product Name | Polarization | Orbit Direction |
|---|---|---|---|
| 6 February 2016 | S1A_IW_GRDH_1SSV_20160206 | VV | Ascending |
| 11 September 2025 | S1A_IW_GRDH_1SDV_20250911 | VV+VH | Descending |

The datasets were selected to provide a long temporal baseline (2016–2025) for detecting urban expansion and land surface changes.

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## 2. Data Preprocessing

Preprocessing was performed using **ESA SNAP (Sentinel Application Platform)** to prepare the SAR data for change detection. The following sequential steps were applied to each product:

### 2.1 Unzipping and Loading

The downloaded .zip Sentinel-1 GRD products were extracted and opened in SNAP to access metadata and sub-swath information.

### 2.2 Thermal Noise Removal

Thermal noise removal was applied to eliminate artificial signal variations caused by the sensor system, improving radiometric consistency across the image.

### 2.3 Radiometric Calibration

Calibration converted the raw backscatter intensity values into **sigma nought ($\sigma^0$)**, representing the radar reflectivity of the Earth's surface. This step ensures the data are physically meaningful and comparable between acquisition dates.

### 2.4 Multi-looking

Multi-looking was applied to reduce speckle and geometric distortion by averaging several looks. The number of looks was chosen to produce approximately square pixels while preserving spatial detail.

### 2.5 Speckle Filtering

A **Lee filter (3×3 window)** was applied to further suppress speckle noise while retaining edge and texture information, essential for accurate change analysis in urban environments.

### 2.6 Terrain Correction (Range-Doppler)

The **Range-Doppler Terrain Correction** algorithm was used to geocode the SAR images and correct geometric distortions caused by topography and radar side-looking geometry.

- **DEM Used:** SRTM 1 Arc-Second (≈30 m)
- **Projection:** Automatic UTM zone selection. This step produced orthorectified images in map coordinates with uniform pixel spacing.

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## 3. Image Stacking and Conversion

A **stack** was created to allow pixel-by-pixel comparison between temporal datasets.

- For the 2016 dataset: **VV polarization** was used.
- For the 2025 dataset: both **VV and VH** polarizations were included to capture surface roughness and volumetric scattering changes.

Before analysis, all backscatter bands were converted from **decibel (dB)** to **linear scale** using the transformation: This ensures proportional relationships between signal intensities during change computation.

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## 4. Threshold-Based Change Detection

Color manipulation and histogram analysis were used to identify suitable threshold values for urban and non-urban classes.

For each band:

- **2016 (VV):** Pixels with backscatter > −9.5 dB were classified as **built-up or urban** (assigned value 255).
- **2025 (VV and VH):** Similar thresholding was applied to isolate high-backscatter regions representing built-up expansion.

The binary layers (urban = 255, non-urban = 0) were color-coded for visualization and overlaid to assess spatial changes.

## 5. Result Analysis

The processed and classified Sentinel-1 images from **6 February 2016** and **11 September 2025** were visually and statistically compared to assess urban growth patterns in **Dehradun**.

#### 5.1 Interpretation of Backscatter Values

Radar backscatter intensity ($\sigma^0$) represents the amount of radar signal reflected back to the satellite.

For urban studies, the backscatter mainly depends on surface roughness, geometry, and moisture content.

Thus, **higher backscatter (−9 dB or above)** generally indicates **built-up or impervious surfaces**, while **lower backscatter (below −15 dB)** corresponds to **vegetation or water**.

In this study:

- For **2016 (VV)**, pixels with $\sigma^0 > -9.5$ dB were considered **urban or built-up**.
- For **2025 (VV and VH)**, similar thresholds were applied:
    - **VV > −9 dB** → strong double-bounce → **dense urban/built-up**
    - **VH > −14 dB** → moderate volume scattering → **mixed urban/vegetation areas**

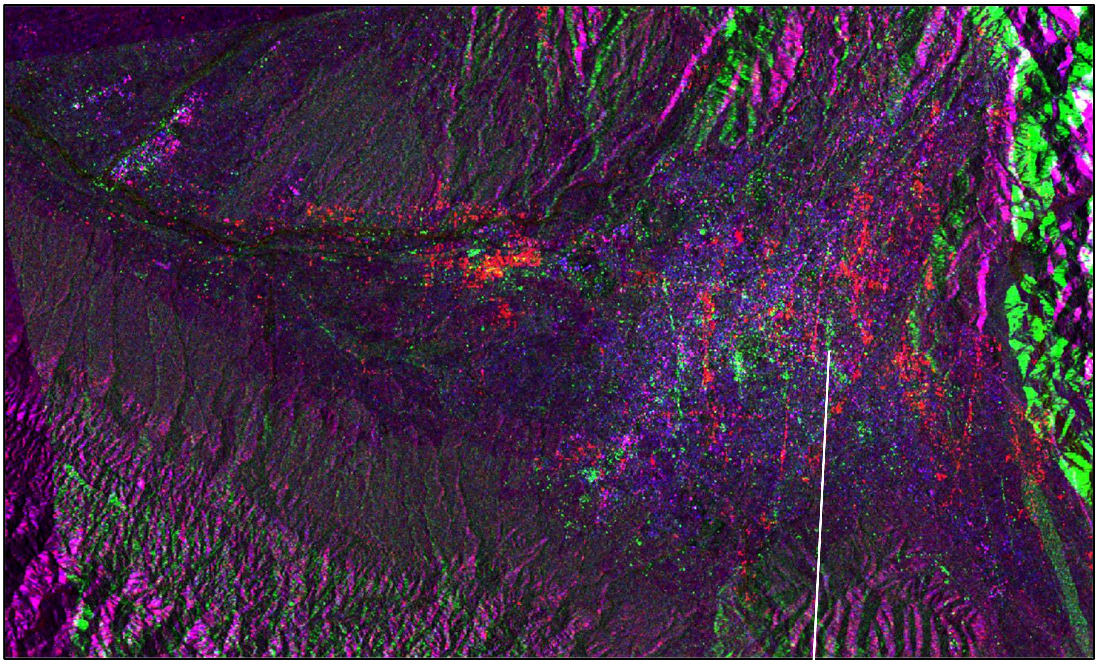
The combination of **VV (surface + double-bounce)** and **VH (cross-polarized volume scattering)** improved the discrimination between built-up and non-built-up regions in the 2025 dataset.

**5.2 Final Observation**

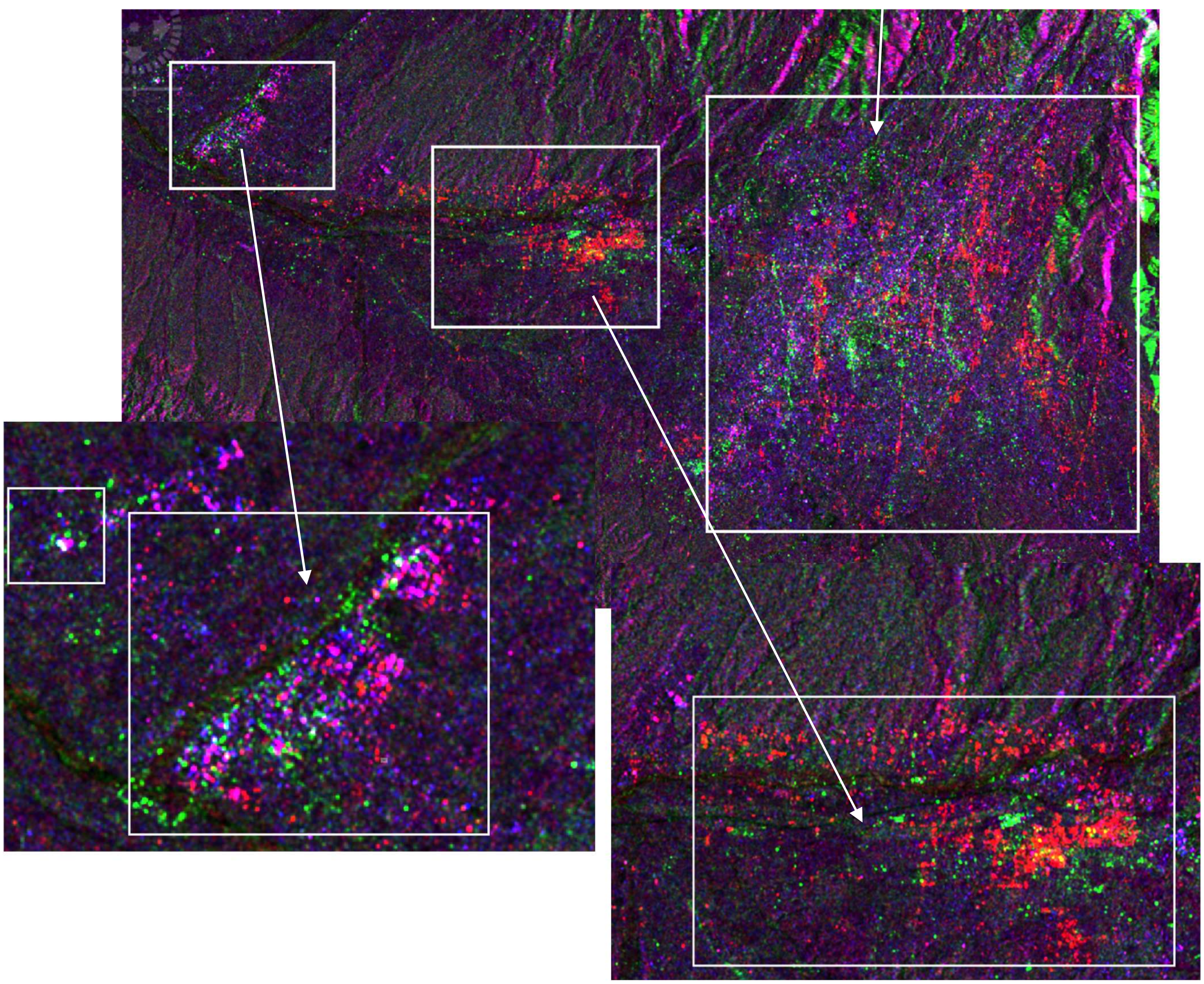
The overall analysis indicates substantial **urban growth in Dehradun between 2016 and 2025**, with an expansion trend primarily:

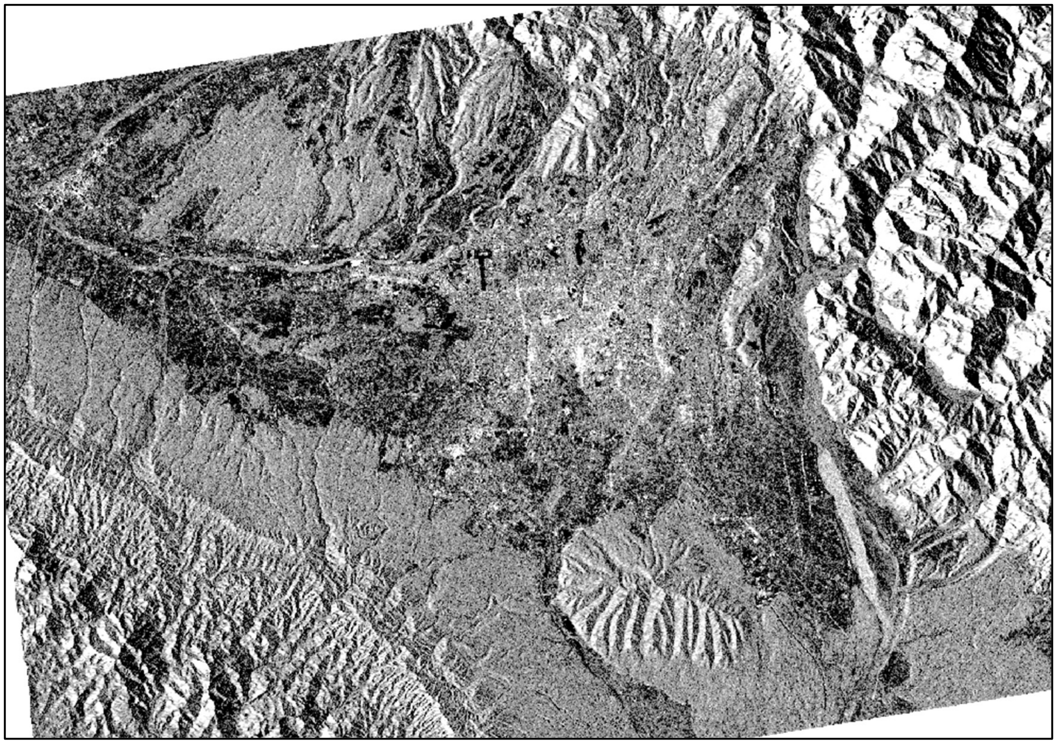
- Toward **south and southeast** of the city,
- Along **major transport corridors**,
- With **peripheral conversion of vegetated and agricultural areas into built-up zones**.

Backscatter analysis confirmed that urban areas exhibit **VV > −9 dB** and **VH > −14 dB**, while surrounding vegetation and open areas remain below these thresholds.
The combination of multi-temporal VV and VH backscatter provided a robust basis for **SAR-based urban change detection**.

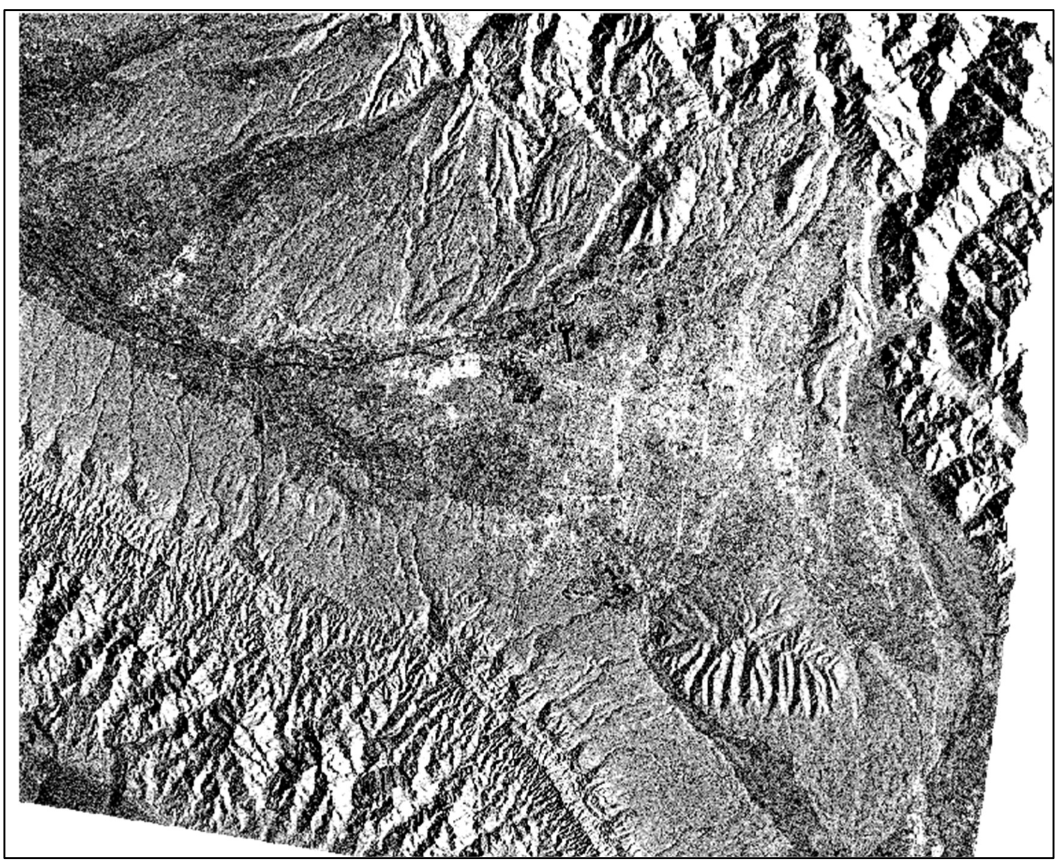


RGB-Stack Image: R-2025_VV, G-2016_VV, B-2025_VH

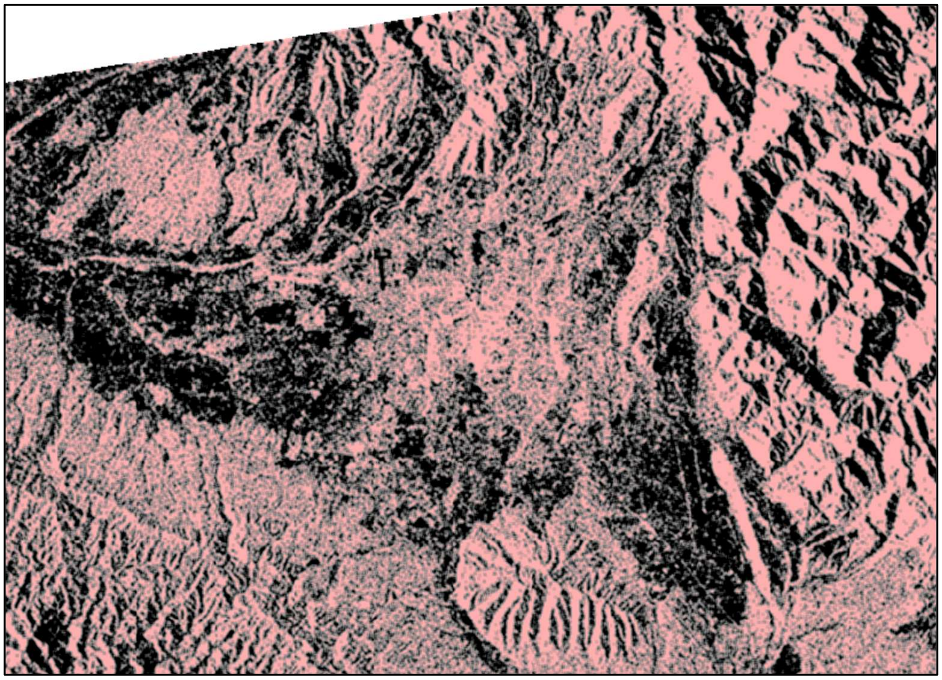




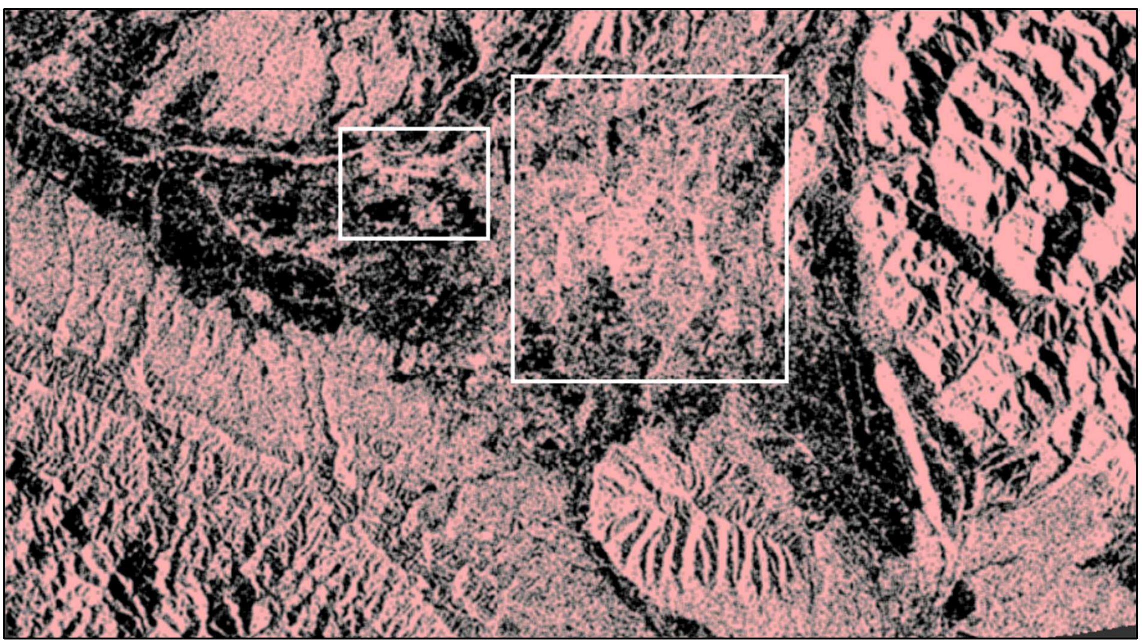
Sigma0_VV_mst_06Feb2016_db



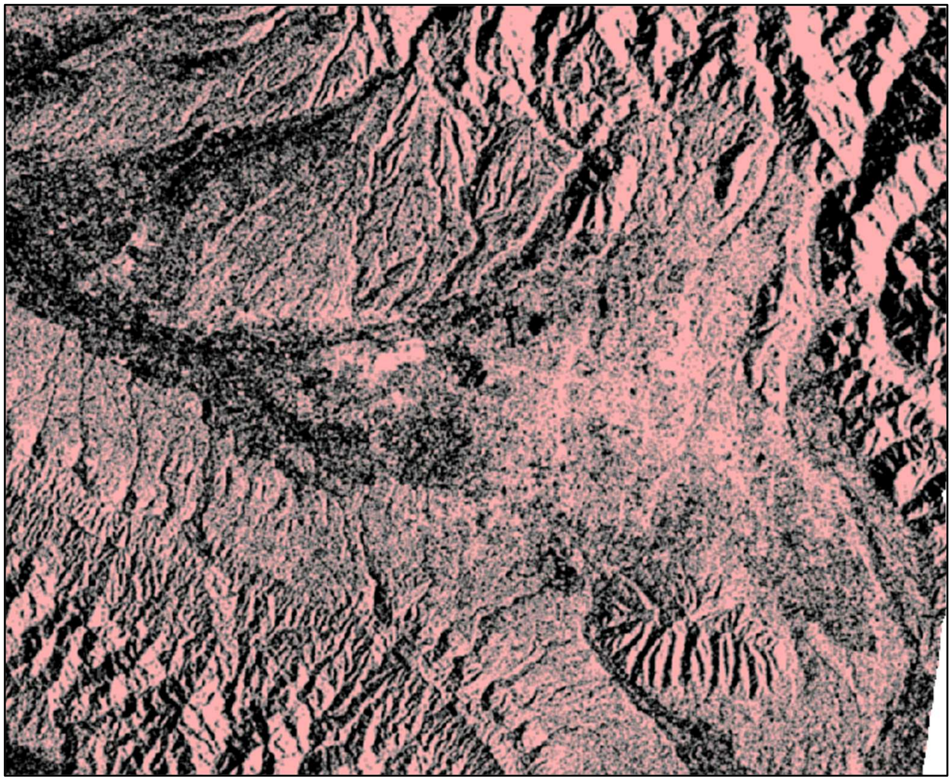
Sigma0_VV_slv2_11Sep2025_db



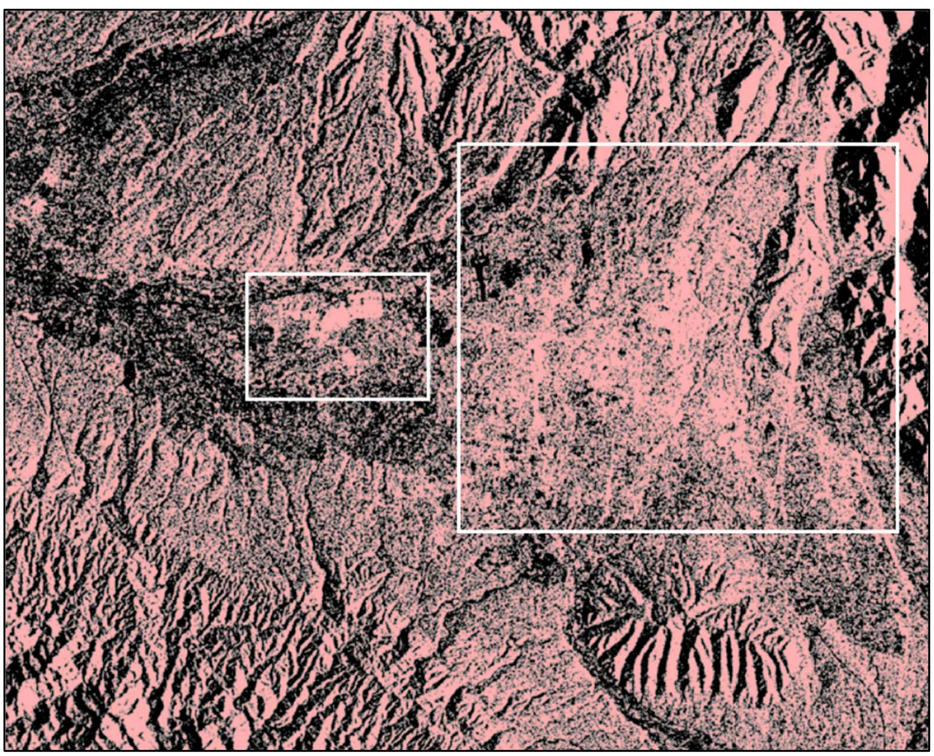
S1A_IW_GRDH_1SSV_20160206_mean3



Marked Urban Area



S1A_IW_GRDH_1SSV_20250911_mean3



Marked Urban Area