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Assessment of flooding risk in Lima, Peru, through change detection based on ERS-1/2 and Sentinel-1 time series

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Abstract:
Catastrophic floods, that happened in Lima in 1997–1998 and 2017–2018 (years selected for this study), caused hundreds of fatalities and significant economic loss. To test the hypothesis that information mined from satellite synthetic aperture radar (SAR) images can provide valuable inputs into the common workflow of flooding hazard assessment, the complete archives collected over the Rímac River basin by the European Space Agency's ERS-1/2 missions and the European Commission's Copernicus Sentinel-1 constellation were screened. SAR backscatter color composites and ratio maps were created to identify change patterns in the study years. A total of 197 changes (32.10 km^2) due to flooding-related backscatter variations and 212 (26.40 km^2) due to anthropogenic processes were highlighted. The areas inundated during the flooding events in the study years mostly concentrate along the riverbanks and plain, where gentle slope (≤5°), and the presence of alluvial deposits, also indicate greater susceptibility to flooding. Through geospatial integration with ancillary data (topography, geology, urban footprint, etc.), a risk classification map of Lima was produced. The map highlights the sectors of potential concern along the Rímac River, should flooding events of equal severity as those captured by SAR images occur in the future.

Keywords: flooding, synthetic aperture radar, change detection, risk classification, urban remote sensing

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Source: Andina/Difusión


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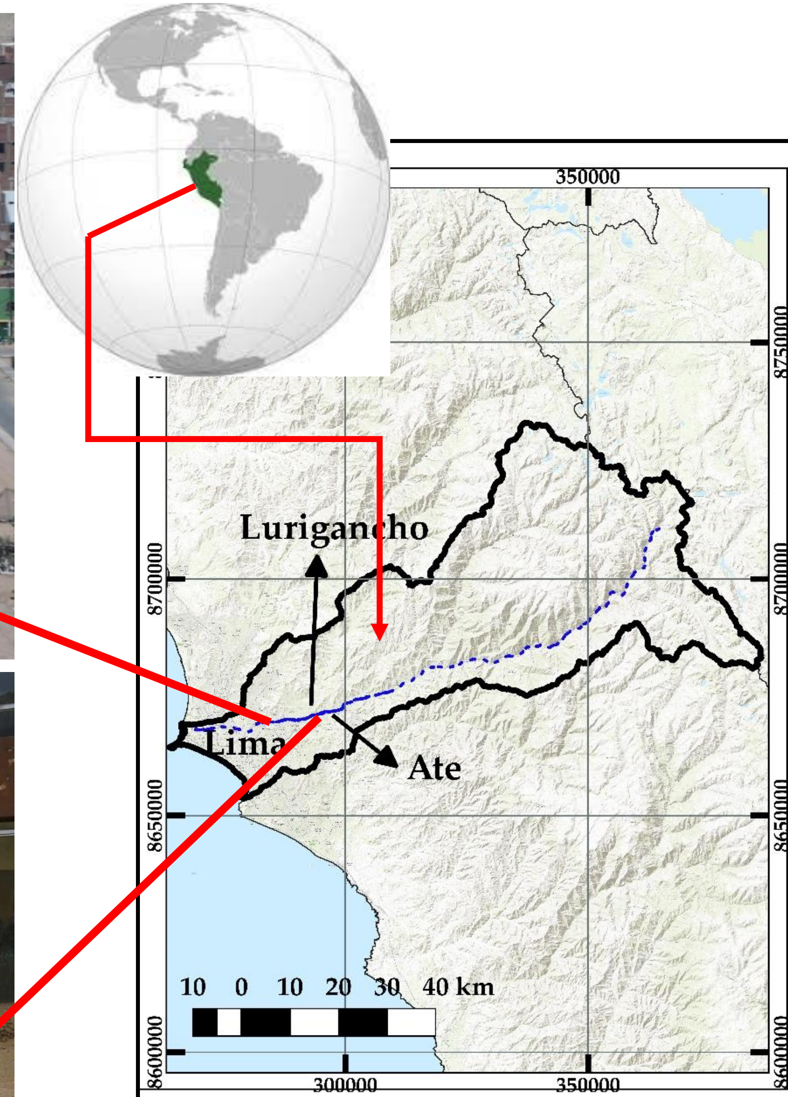
Source: Celso Roldan/Agence France-Press-Getty Images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Lima
Ate
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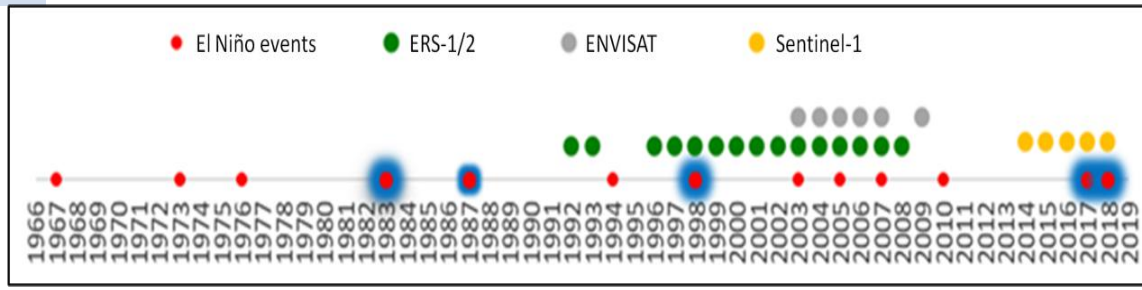
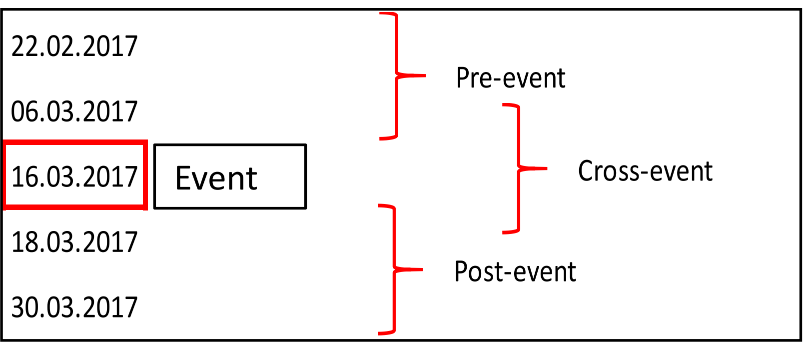
Extraordinary “El Niño” events and dates of major floods in the Rímac River basin

Extraordinary events	Number of flood events	Dates of flooding in urban areas
1982–1983	Data n.a.	December 1982 – June 1983
1997–1998	6	09/02/1998 23/02/1998
2017–2018	13	14/01/2017 31/01/2017 16/03/2017 14/02/2018 22/02/2018

Flood events and “El Niño” phenomenon vs. availability of C-band SAR satellite data from the ERS-1/2, ENVISAT and Sentinel-1 missions. The most intense events are indicated in blue

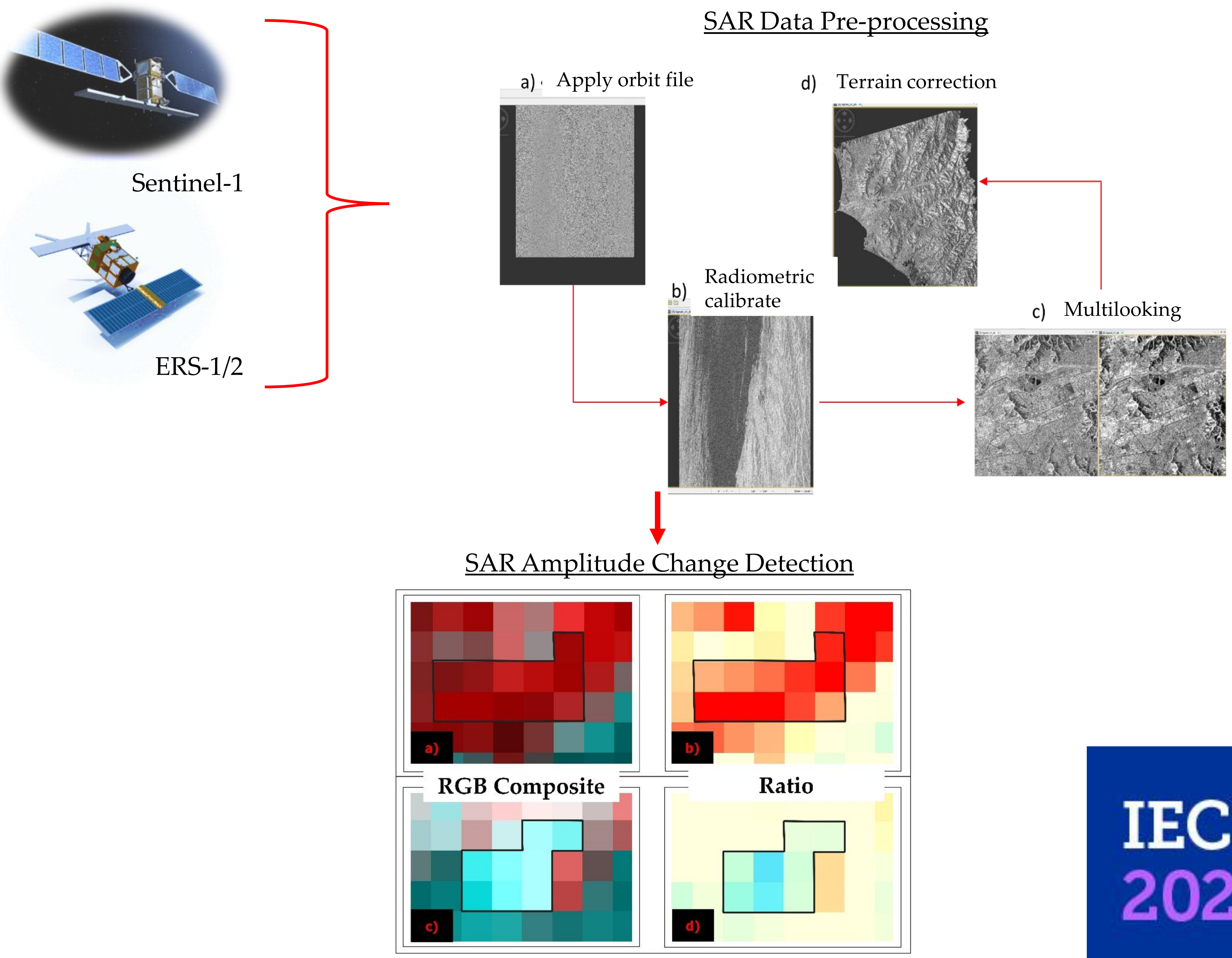


Example of Sentinel-1 image categorization for the flood event of March 16, 2017

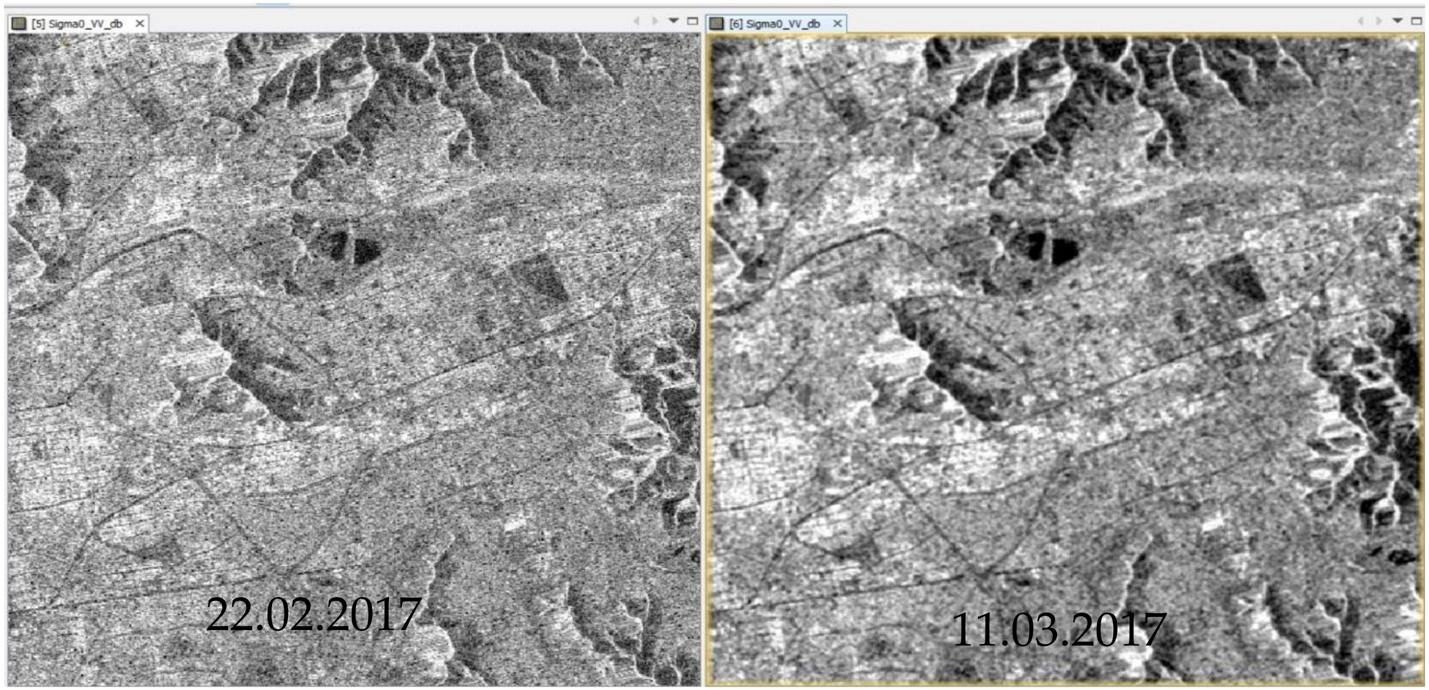


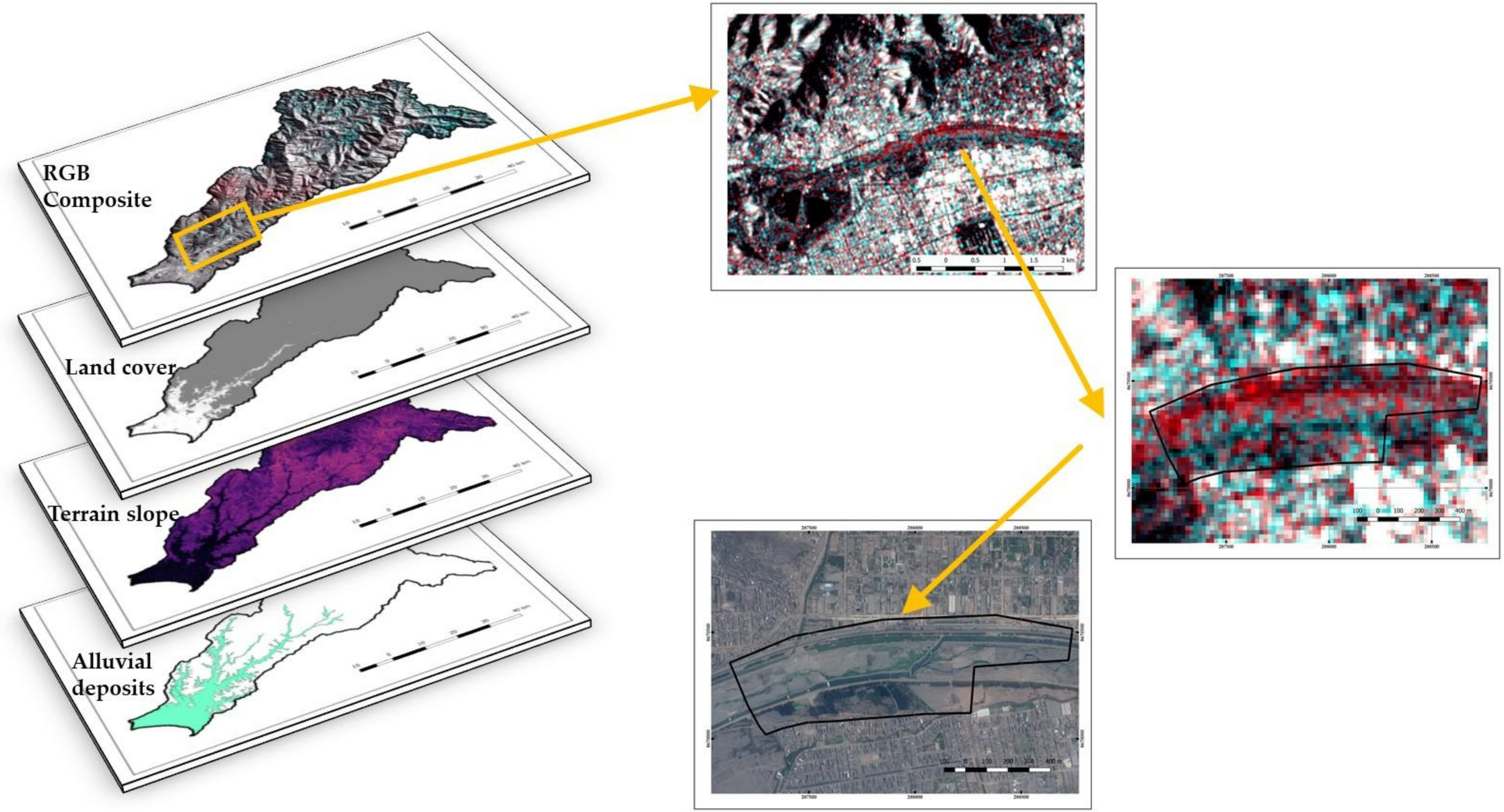
SAR image working pairs made of ERS-1/2 and Sentinel-1 scenes over Lima, Peru

SAR image working pairs	Pre-event	Cross-event	Post-event	Total number of SAR working pairs
1997–1998	1	4	4	9
2017–2018	10	10	10	30


SAR Data Pre-processing
Sentinel-1
ERS-1/2
a) Apply orbit file
b) Radiometric calibrate
c) Multilooking
d) Terrain correction
SAR Amplitude Change Detection
a)
b)
RGB Composite
Ratio
c)
d)

Example of change detection





GIS-based analysis workflow: datasets showing spatial distribution of hazard factors and elements at risk (i.e. alluvial deposits, slope and land cover) are integrated with the SAR-based RGB composites to detect and interpret the observed change patterns of radar backscatter as Flooding (F) and No-Flooding (NF) changes. Satellite optical imagery from Google Earth is exploited for validation

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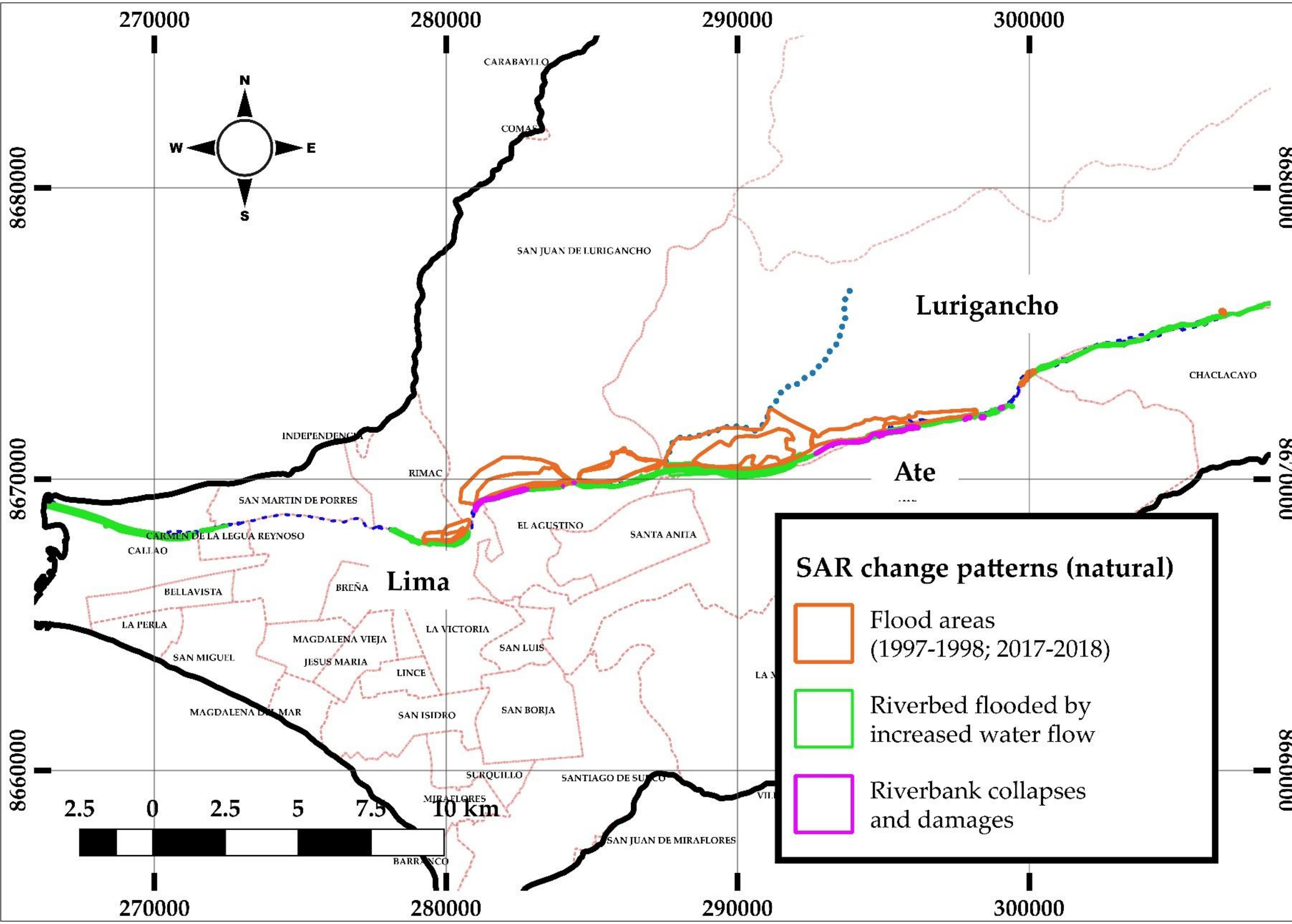
Results…

Distribution of the areas of the Rímac River basin where the 197 changes patterns in the radar backscatter that are likely related with flooding were observed and mapped. Where visible, dashed lines indicate sections of rivers where no change patterns have been found



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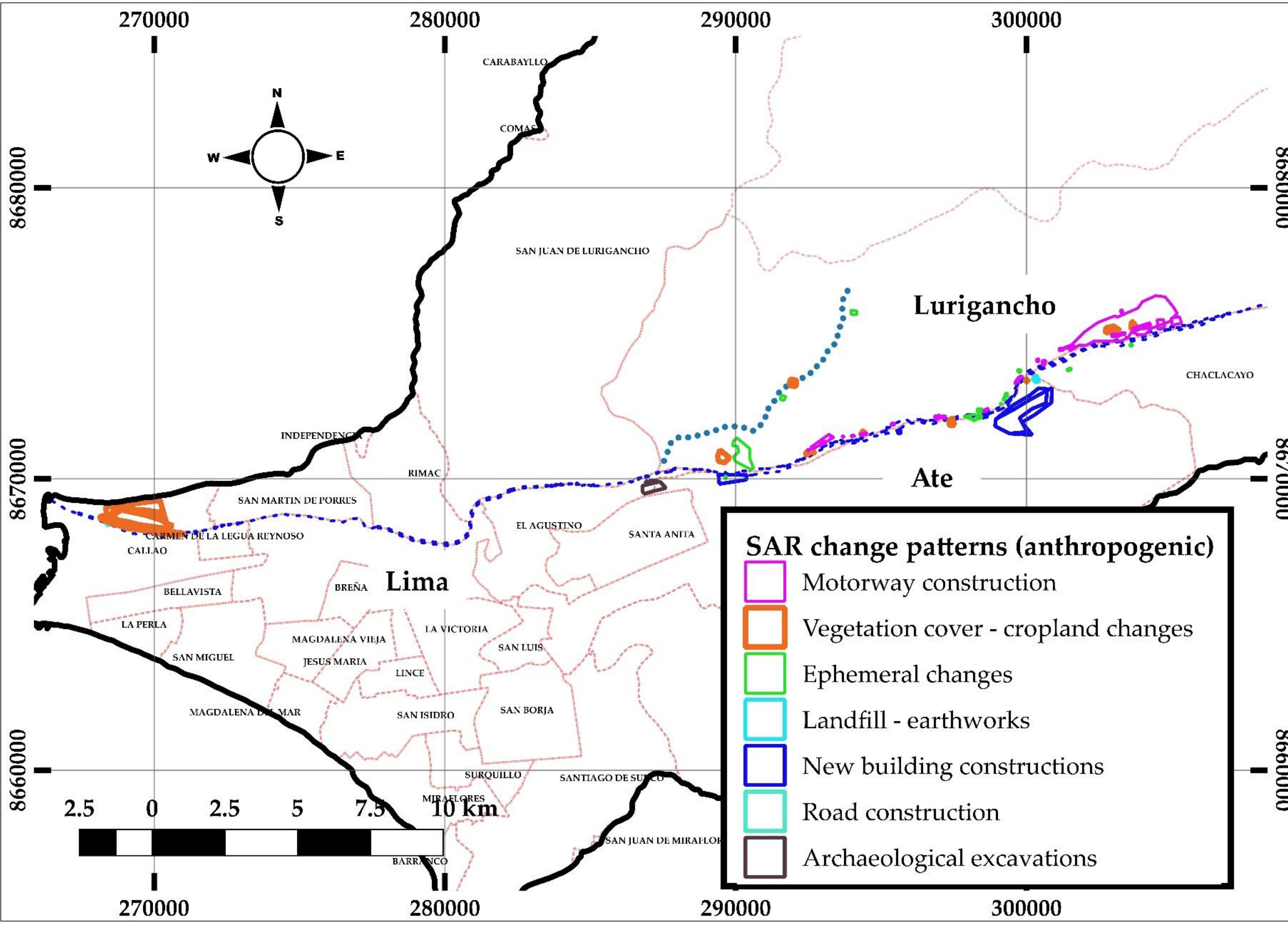
…Results…

Distribution of the 212 changes in the radar backscatter, likely due to human activities (anthropogenic), observed and mapped within the Rímac River basin



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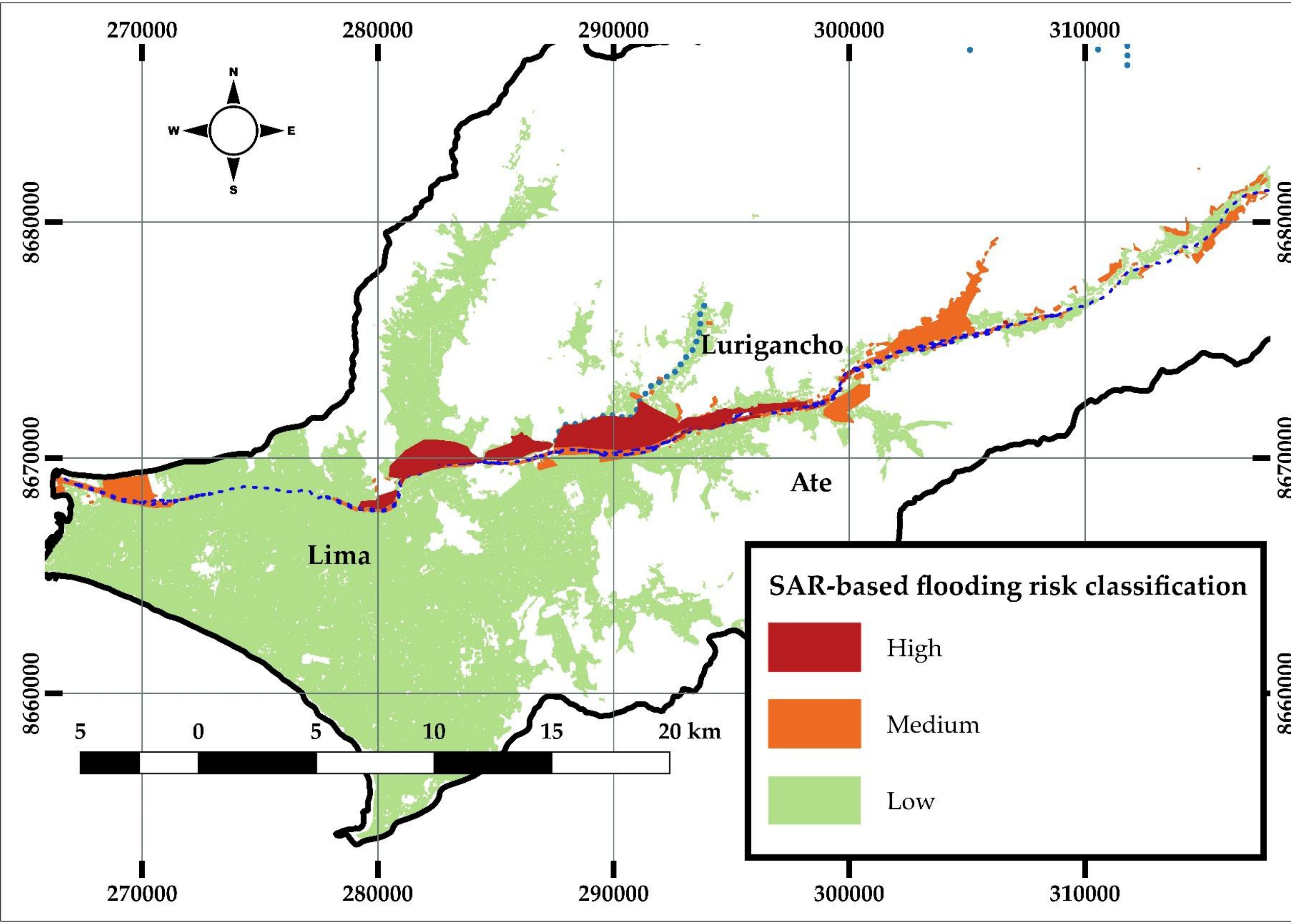
…Results

Map of flooding risk classification at basin scale over Lima, based on the combination of satellite SAR evidence, natural and anthropogenic factors of flooding hazard



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Discussion and Conclusions

For the generation of the Rímac River basin flood risk map, shown in the previous slide, three risk levels were defined: high, medium and low risk.

The factors determining the level category were, first of all, the terrain slope, the surface occupied with alluvial deposits, and/or the presence of urban or non-urban area. With this approach we found that all the radar backscatter changes with a given significance for flooding risk assessment are located onto alluvial deposits, their most common slope value is ≤ 10°, and they split among urban and non-urban areas.

The areas identified at a high risk of flooding are those that in the years 1997–1998 and 2017–2018 were directly affected by the flooding event, and where satellite data and/or ground evidence suggest that material loss occurred (e.g., collapse of riverbanks), slope was ≤ 5° or within 6°-10°, and urban fabric is onto alluvial deposits.

The medium risk was attributed to non-urban areas that could be affected by flooding events as a result of the combination between slope with values ≤10° and presence of alluvial deposits.

…Discussion and Conclusions

In the end, urban areas where neither previous evidence of flooding nor changes in the satellite data were found, and where it is very unlikely that they would be inundated due to their slope values within 15° and 20°, and/or local geology, were classified at low risk.

Because this map is the outcome of combining hazard and risk factors, and the changes (both due to flooding or not) found in the SAR data, it provides the zoning of the areas at risk with respect to flooding events of equal or greater magnitude than those occurred in 1997–1998 and 2017–2018, if no hazard and risk mitigation measures are undertaken. By comparison with hazard and susceptibility maps made solely based on geological factors (e.g. published by Villacorta et al., 2015), the present map has the advantage to embed flood event-based information as well as knowledge of the impacts of recent urbanization within the hazard assessment. Therefore, the information mined from SAR time series contribute to improve hazard mapping products.

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Full paper reference

Alvan Romero, N.; Cigna, F.; Tapete, D. ERS-1/2 and Sentinel-1 SAR Data Mining for Flood Hazard and Risk Assessment in Lima, Peru. *Appl. Sci.* **2020**, *10* (18), 6598. doi: 10.3390/app10186598

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