

Computational Conflict Research

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Conflict Research – Why?

- Armed (political) conflict responsible for 1000s of fatalities across the globe every month
 - Both intra- & intercountry conflicts
- Armed conflict...
 - ...leads to migration within countries and across borders
 - ...has disastrous economic consequences
 - ...undermines functioning of political systems
 - ...prevents countries from escaping poverty
 - ...hinders humanitarian assistance (where most needed)
- Research topics:
 - Understanding the determinants & mechanisms of conflict
 - Developing early-warning systems
 - Would potentially allow for prevention & mitigation
 - What are the consequences of armed conflict?

Overview over joint research projects

- Use of remote sensing data to improve forecasting of conflict
- Analysis of tweets in Ukraine
 - Switch from Russian to Ukrainian
- Designed a statistical model to capture the diffusion of conflict across space & time
- Nowcasting conflict events
 - Ongoing
- Detection of building destruction via publically available satellite images
 - Just finished, topic today 😊

Detection of Building Destruction in Armed Conflict from Publicly Available Satellite Imagery

Daniel Racek, Qi Zhang, Paul W. Thurner, Xiao Xiang Zhu, Göran Kauermann, 2025

Background & Motivation

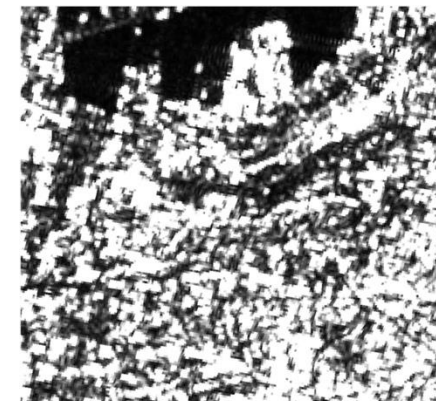
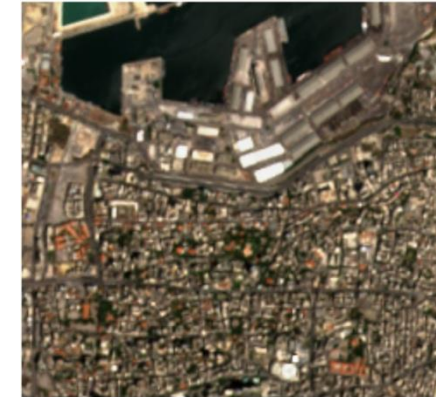
- Quality & resolution of satellite images has substantially improved in past decade
- Multitude of uses for conflict research:
 - Landcover classification & changes over time
 - Economic activity
 - Detection of destruction & damage
- However: High-resolution satellite images typically not freely available
 - And very expensive ☹️
- How far can we get with freely available satellite images?



<https://www.bizjournals.com/denver/news/2020/03/25/maxar-satellite-images-denver-coronavirus.html>

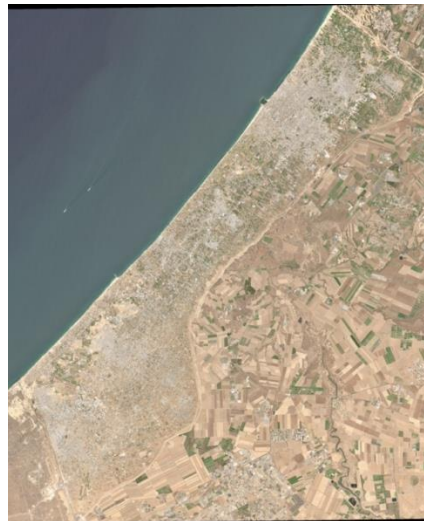
Research Question

- European Space Agency (ESA) launched multiple earth observation satellites in past decade
 - Images acquired are completely free of use (for public, scientific, or commercial purposes)
- Can we detect destruction during conflict/war using these images?
- Missions of interest:
 - Sentinel-2: Optical images
 - Multi-spectral data with 13 bands
 - Visible, near infrared & short wave infrared light frequencies
 - 10 m to 60 m resolution
 - „Low“ resolution of images makes buildings very pixelated
 - Issues with cloud coverage (sometimes entire image covered by clouds)
 - Basically impossible
 - Sentinel-1: Synthetic aperture radar (SAR) images
 - Form of radar
 - Allows for three-dimensional reconstructions of objects
 - (Matrix of complex numbers)
 - 20m resolution
 - Not affected by clouds
 - Use of 3D reconstruction helps even when images are of lower resolution
 - More promising 😊



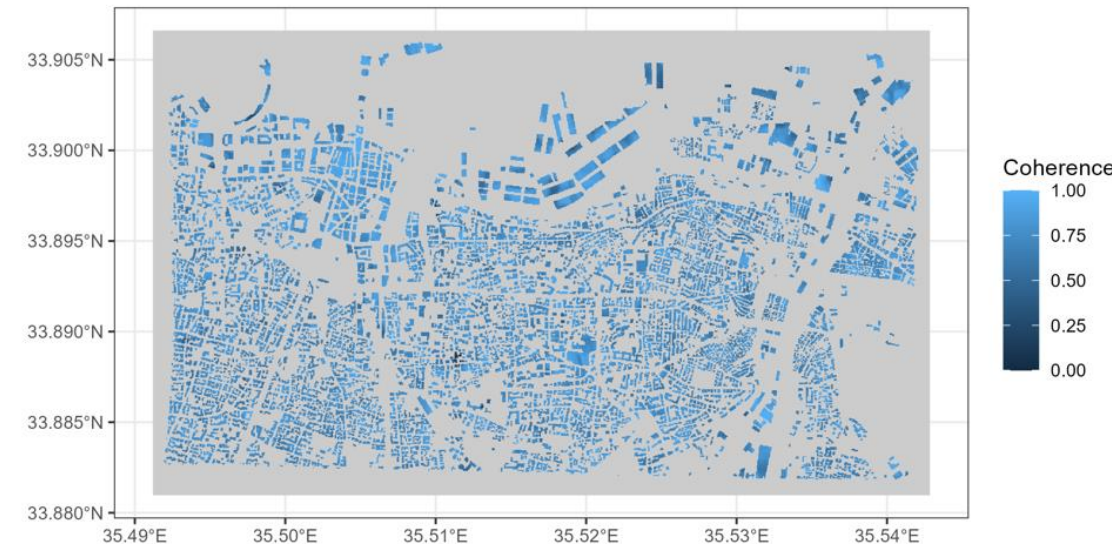
Research Study

- Evaluation across three case studies
- Beirut:
 - Harbor explosion
 - 4th August 2020
 - Single-day event
 - Ground truth available
- Mariupol
 - Russia-Ukraine war
 - Start of invasion: 24th February 2022
 - Destruction over multiple weeks
 - Some ground truth available
- Gaza:
 - Israel-Hamas war
 - 7th October 2023
 - Destruction over multiple months
 - No reliable ground truth available



Basic Methodology

- Unsupervised detection
 - No „training“ needed
- Images (of same location) are repeatedly taken in 12-day interval
- Construct „coherence“ of pixels between two images
 - How similar are backscattered signals?
 - If highly unsimilar: something must have changed (e.g. destruction of building)
 - Presence of elemental scatterers & geometry of satellite passes introduce noise → techniques to counteract this
 - Via interferometric SAR (InSAR) (Bamler and Hartl, 1998)
 - Final result: time series of coherence scores for each pixel
- Augment results by using known building footprints
 - From OpenStreetMaps



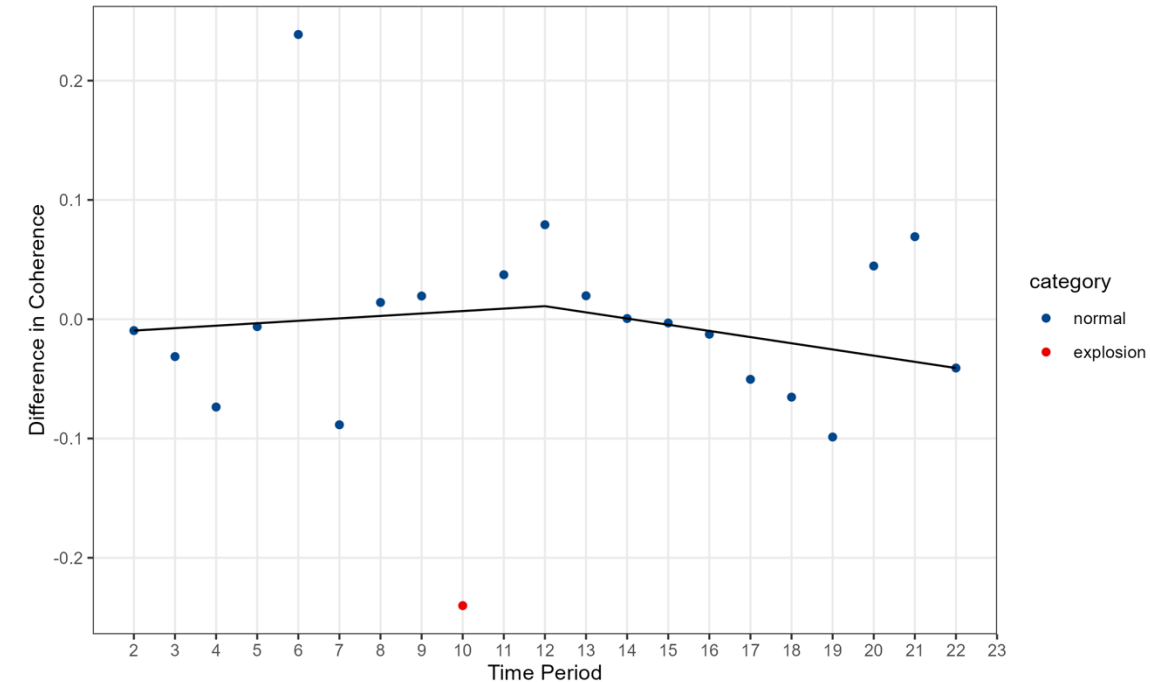
Basic Methodology

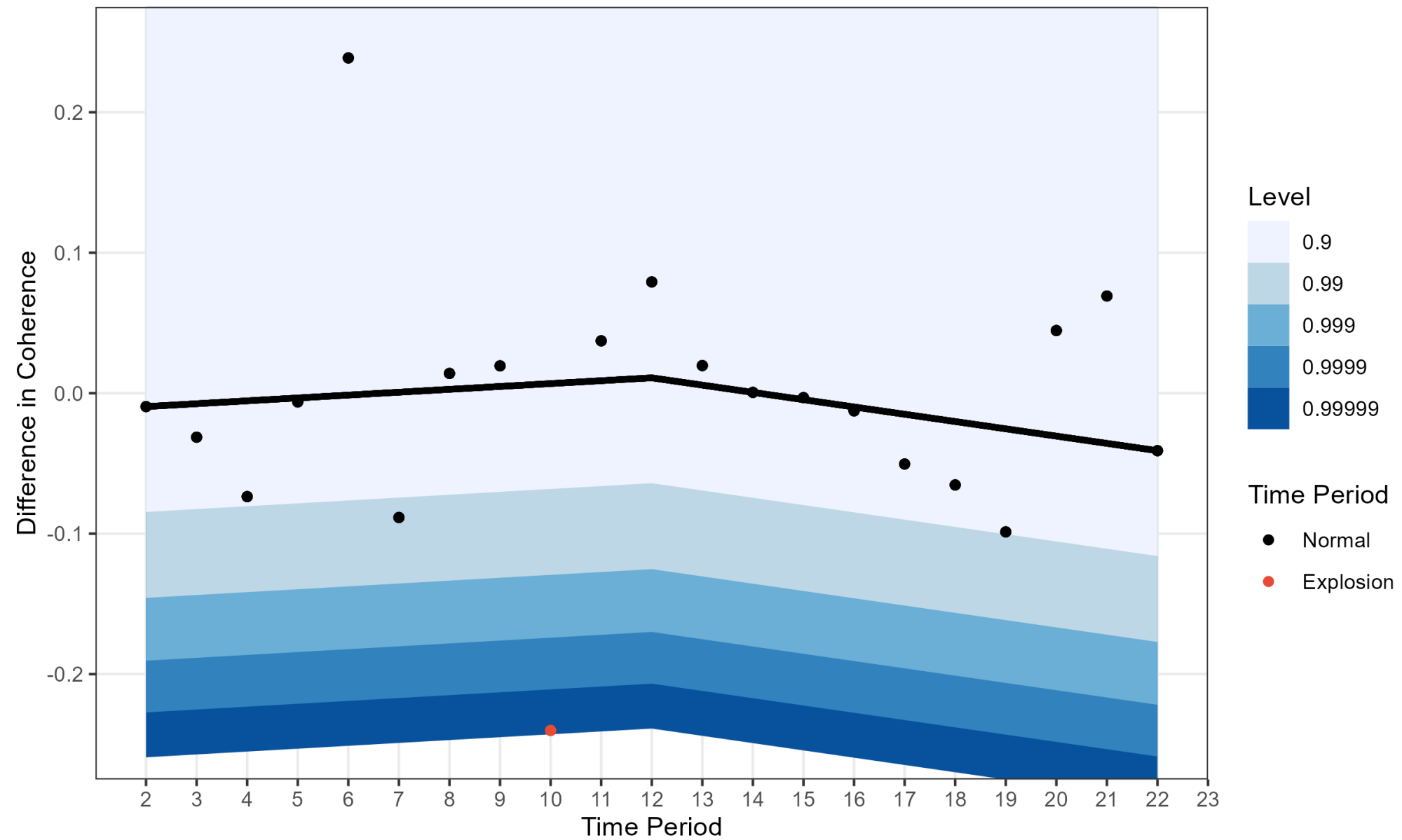
- Flexible median regression on each pixel
- Calculate residuals
 - Roughly normally distributed with larger tails
 - Residuals at tails do not follow same distribution
- Estimate SD of residuals with robust-scale estimator (Qn)
 - (Rousseeuw and Croux, 1993)
 - Minimally affected by these outliers
- Under hypothesis of normal distribution with standard deviation $\hat{\sigma}_i$, probability to observe each residual $r_{i,t}$ (or more extreme one)

$$p(r_{i,t}) = Pr(R_{i,t} \leq r_{i,t})$$

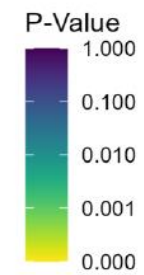
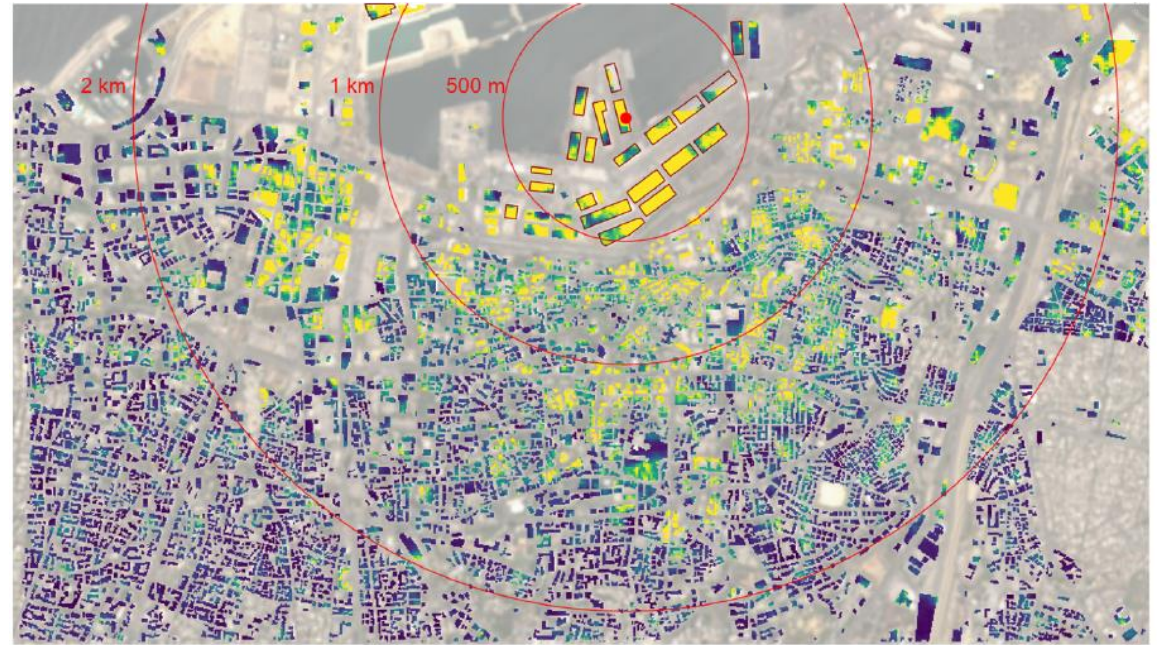
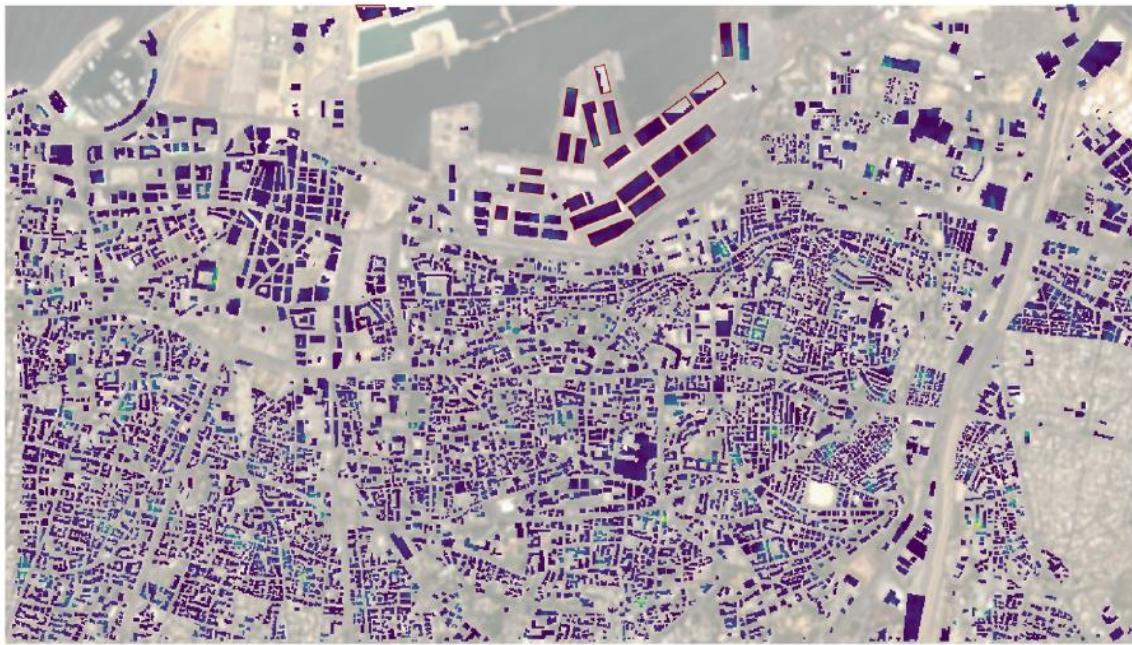
- With $R_{i,t} \sim \text{Normal}(0, \hat{\sigma}_i^2)$
- → one-sided p-value

- Evidence coherence score not just observed by chance, but instead due to structural changes of building
- Straightforward methodology to combine p-values for buildings consisting of multiple pixels (harmonic mean)
- Classification threshold possible





Beirut

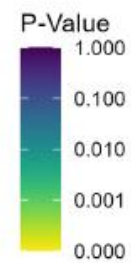
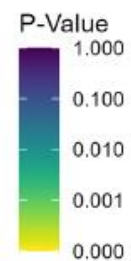
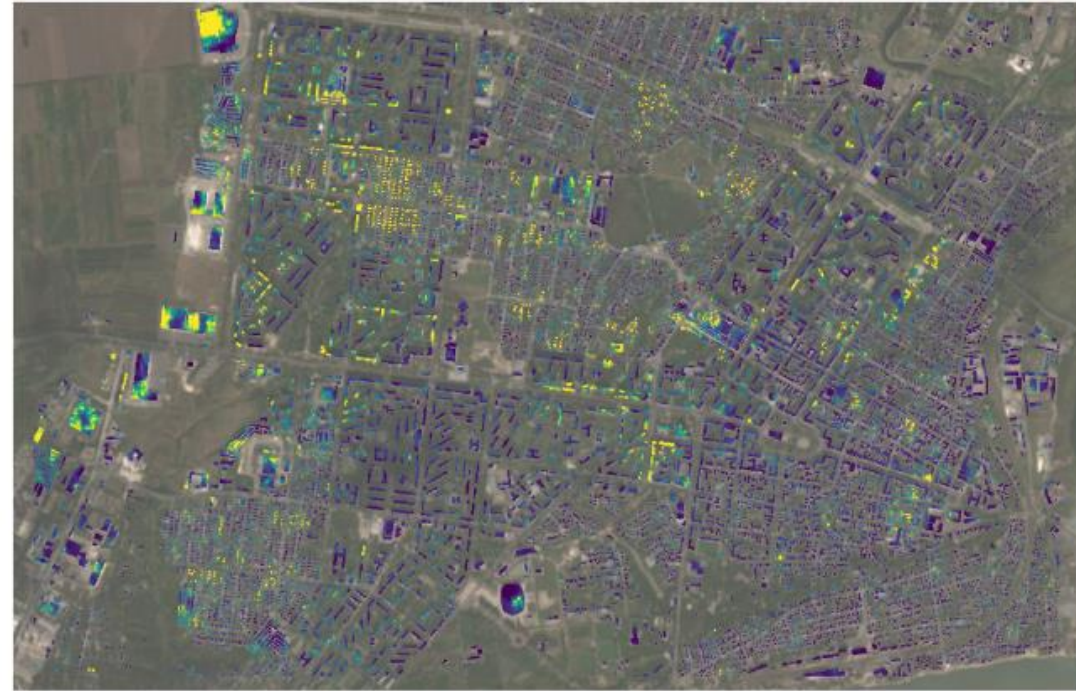




Detection

- No Destruction
- Destruction

Mariupol

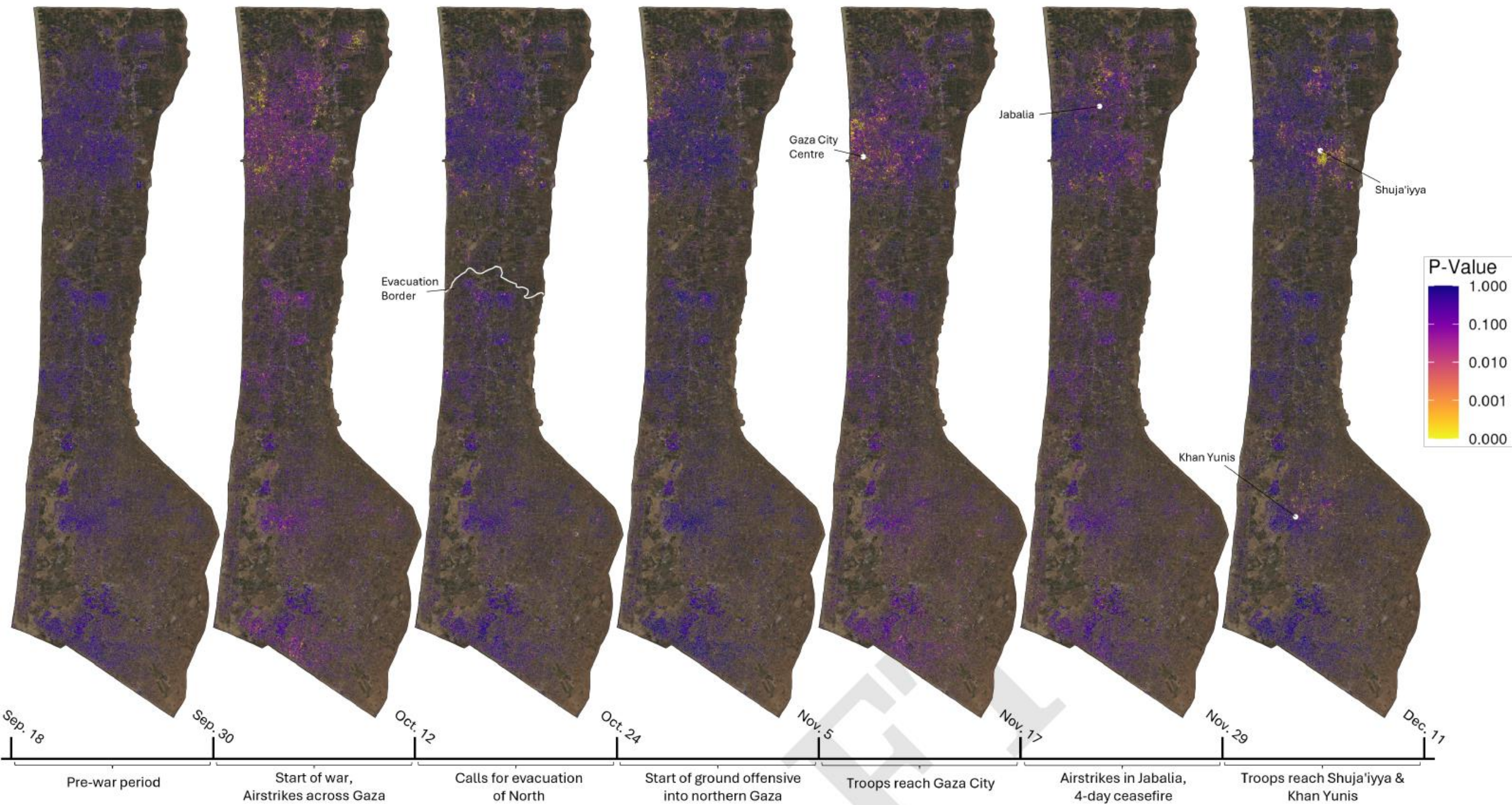




Detection

- No Destruction
- Destruction

Gaza



References

- Racek, D., Zhang, Q., Thurner, P., Zhu, X. X., & Kauermann, G. (2025). *Detection of Building Destruction in Armed Conflict from Publicly Available Satellite Imagery* (No. 86t3g_v1). Center for Open Science.
- Bamler, Richard, and Philipp Hartl. "Synthetic aperture radar interferometry." *Inverse problems* 14.4 (1998): R1.
- Rousseeuw, Peter J., and Christophe Croux. "Alternatives to the median absolute deviation." *Journal of the American Statistical association* 88.424 (1993): 1273-1283.

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