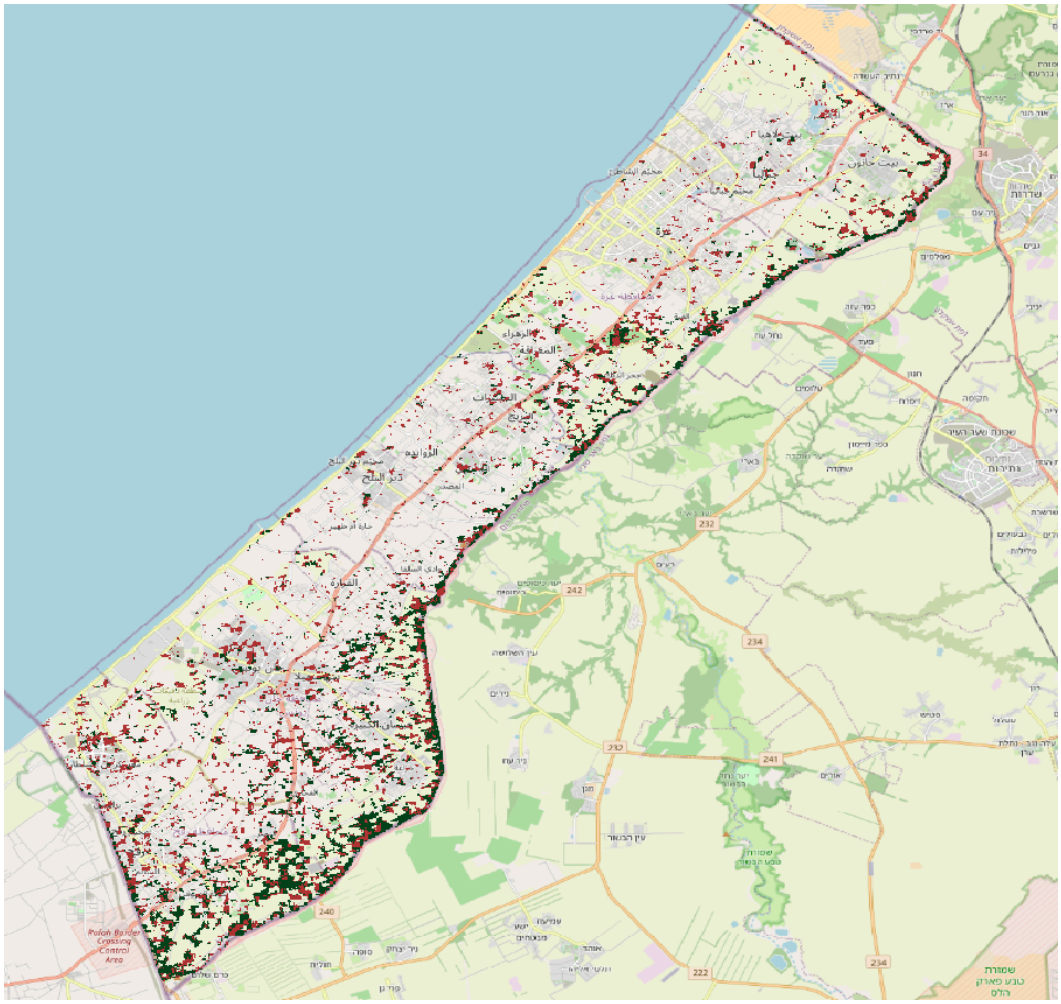
# GIS-1 Final Project Report

Monitoring Urban Damage with InSAR in Gaza




**Aakanksha Agrawal**

GIS-1 and Remote Sensing

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# INTRODUCTION

Widespread, repeated damage within cities is a hallmark of modern and increasingly urbanized warfare

Monitoring urban damage is important for protecting civilians, guiding humanitarian response and relief, and identifying affecting infrastructure throughout a conflict.
During times of armed conflict, many network changes occur, from partial censorship and media blackouts to total destruction of internet infrastructure. It becomes increasingly difficult for stakeholders(international aid organizations, family members, governments of the world) to get to the ground truth about the affected area. Remote sensing can offer a wealth of information about a humanitarian setting like a conflict zone or a refugee camp when data scarcity is usually normal.




In this project, I aim to use GIS tools to map structural damage in Gaza.

## State of Internet in Gaza

Gaza's only fiber optic cable that connects it to the global internet runs through Israel, making it infrastructurally dependent on Israel. Israeli authorities control

the electromagnetic sphere and restrict Palestinian operators' use of frequencies. They also maintain total control over importing essential equipment and technologies in the West Bank and Gaza. Due to the Israeli military blockade on Gaza since 2007, only material for civil use are allowed in, and any entry of equipment and construction materials must be approved by Israel's Ministry of Defence. As a result, some necessary equipment has been denied entry under the allegation of "dual use" issues, and ISPs operating in Gaza cannot upgrade their services. To date, people in Gaza are still using 2G mobile networks. In the West Bank, 3G mobile networks were allowed for Palestinian companies in 2018, after 12 years of negotiations with Israel.



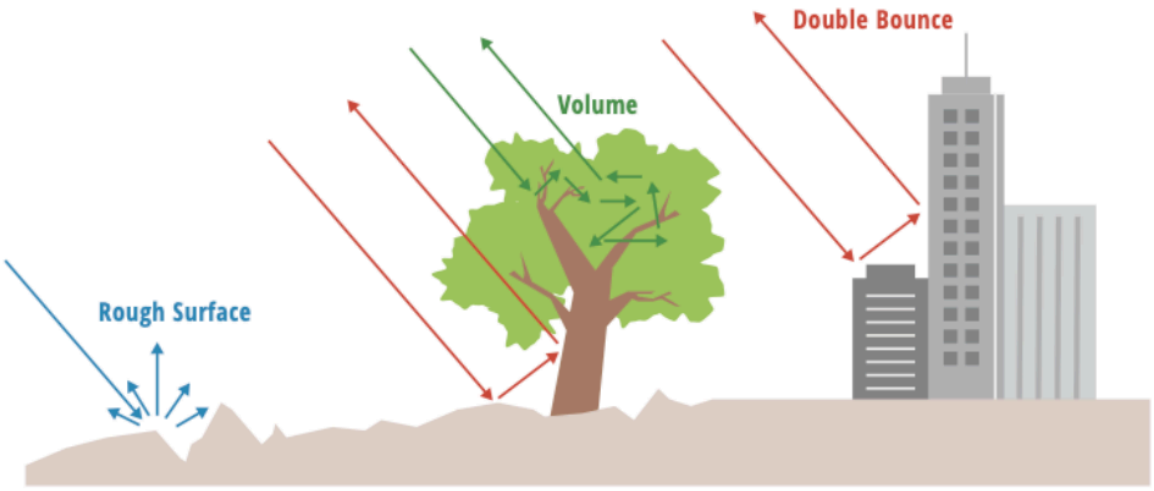

## METHODOLOGY

**Radar images tell us about the structure of a region.**

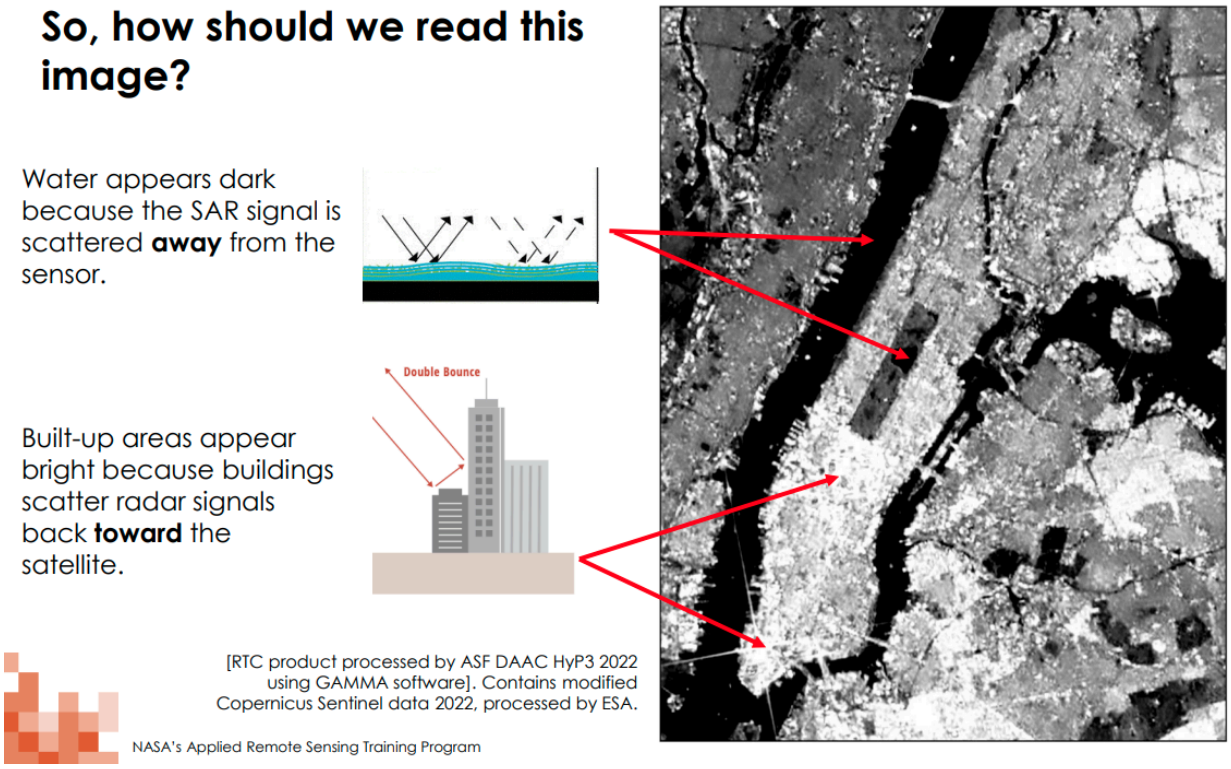
Synthetic Aperture Radar (SAR) is a remote sensing technique that illuminates a region with microwaves and records the echo of the microwave pulses that are reflected back to the satellite sensor. This SAR "intensity" image tells us about the strength of microwave reflection back to the sensor, which we refer to as scattering.

**SAR images tell us about the structure of an image region.**

Scattering mechanisms differ based on the structure of objects. This scattering affects how regions appear in different types of SAR imagery.



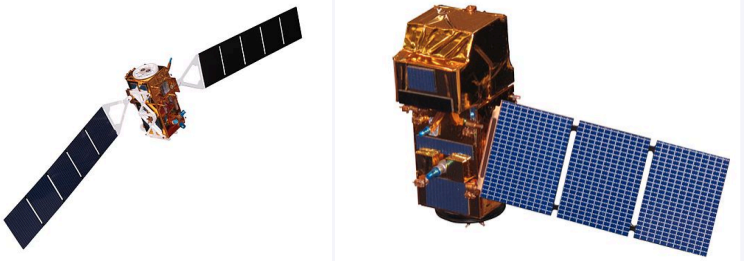

Source: The SAR Handbook




Interferometric synthetic aperture radar, abbreviated InSAR (or deprecated IfSAR), is a radar technique used in geodesy and remote sensing. This method uses two or more synthetic aperture radar (SAR) images to generate maps of surface

deformation or digital elevation, using differences in the phase of the waves returning to the satellite

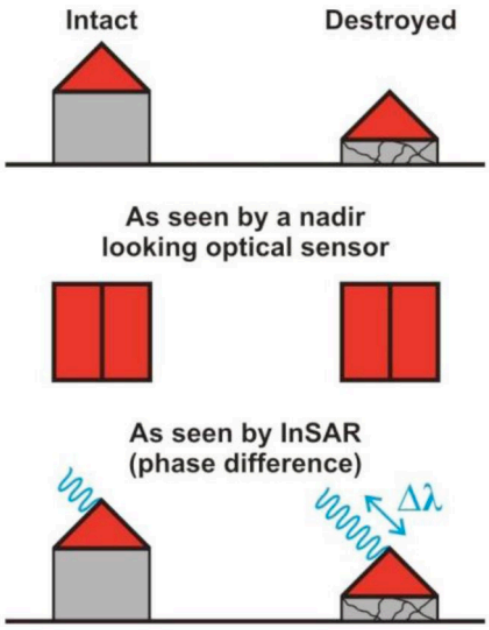
The ESA launched Sentinel-1A and Sentinel-1B, both C-band sensors, in 2014 and 2016, respectively. Together, they provide InSAR coverage on a global scale and on a 6-day repeat cycle.



Model of a Sentinel-2 satellite

**How can radar be used to map damage?**

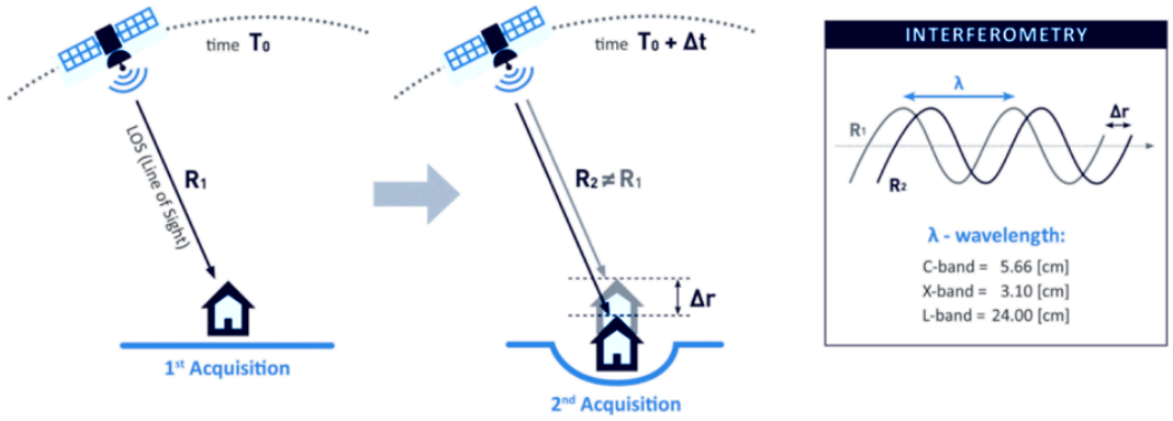
SAR's structural sensitivity enables damage mapping. Partial building collapse changes the position of the scatterer in an image region. But directly from above (i.e., nadir), an optical sensor wouldn't detect this change. Detection of structure changes is possible using phase information from the SAR image.




Source: Plank (2014)

**Interferometry measures the difference in two SAR phases**

Interferometric SAR (InSAR) is the difference in complex phase between two SAR acquisitions. It is used to map topography and changes in structure, like ground motion from an earthquake.

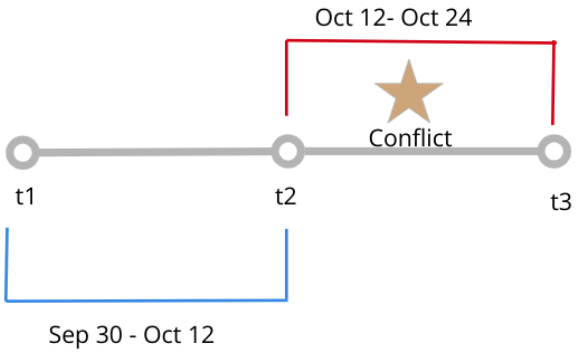



Source: TRE ALTAMIRA

Coherence is an **estimate** of the **scattering stability** of an image region. Coherence is measured from 0 to 1 . 0, which is low coherence, indicates that structural changes took place during that temporal period. 1, which is high coherence, on the other hand, indicates that not many structural changes took place in that period and that the area was structurally stable.

**We want to map coherent areas that de-correlate with conflict.**
This means that we want to look for coherent image regions that show reduced coherence during a conflict event. I compare 2 InSAR images and look for a decrease in coherence, i.e., areas(or pixels) that went from high to low.

My first InSAR image is based on the baseline pairs of Sep 30 and Oct 30, which I'll call "pre-event", and the second InSAR image is based on the baseline pairs of Oct 12 and Oct 24  which I'll call "event"




Change in coherence is calculated by doing raster band math on "..._cor.tif" files for the pre-event and event InSAR files

$$\Delta\gamma = \frac{\gamma_{event} - \gamma_{pre-event}}{\gamma_{pre-event}}$$

$\Delta\gamma$ is the change in coherence between the pre-event and event coherence images.

## GOALS

Detect locations of urban change during armed conflict

- Leverage InSAR time series data for long-term analysis

- Understand different strengths and limitations of radar data compared to perhaps more traditional data sources from optical or nighttime lights data for example

## HYPOTHESIS

Mapped structural damage using InSAR matches with media and civilian reports.

## MATERIALS

1. Alaska Satellite Facility
2. GIS-1

## PROCEDURE

1. **PREPROCESSING**

1.1 First, make a pre-event and event temporal timeline and look for SAR baseline pairs on the Alaska Satellite Facility

1.2 Give them for InSAR processing, download and load them in QGIS

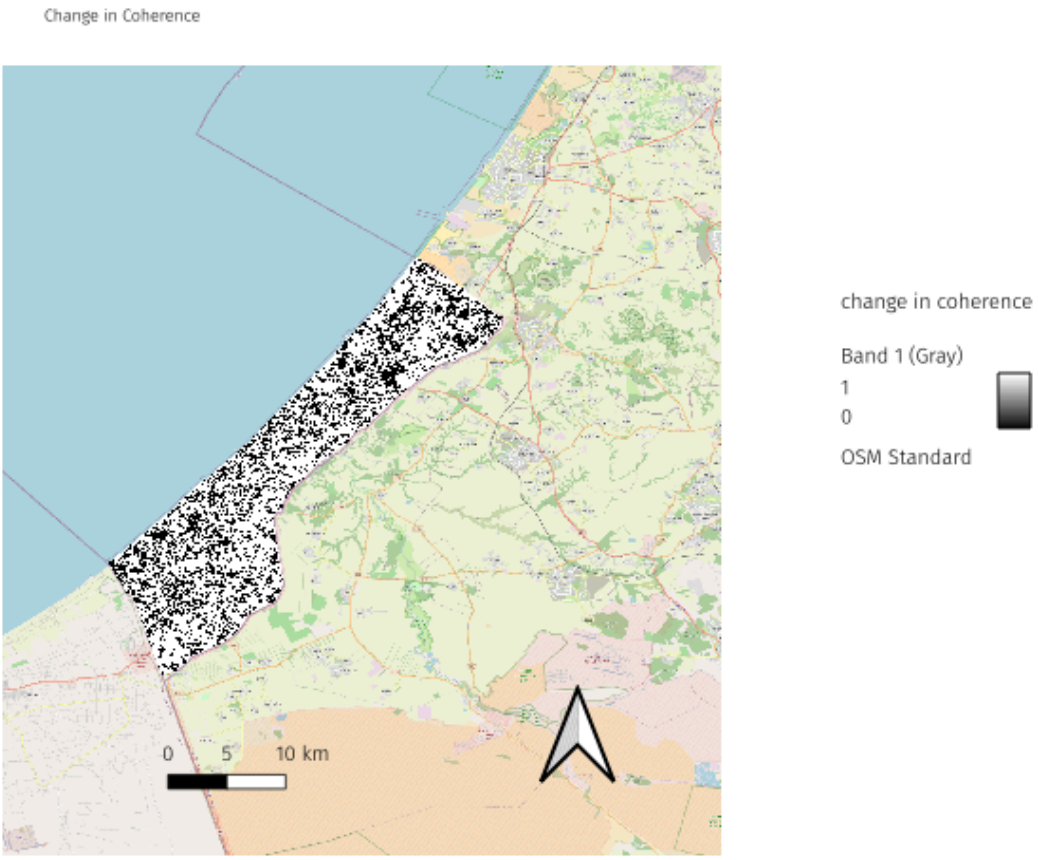
| | |
|---|---|
|  |  |
| Pre-event InSAR(Sep 30 - Oct 12) | Event InSAR(Oct 12 - Oct 24) |

2. **Change in coherence map**

**2.1 Raster calculator to calculate the change in coherence using the formula:**

$$\Delta\gamma = \frac{\gamma_{event} - \gamma_{pre-event}}{\gamma_{pre-event}}$$

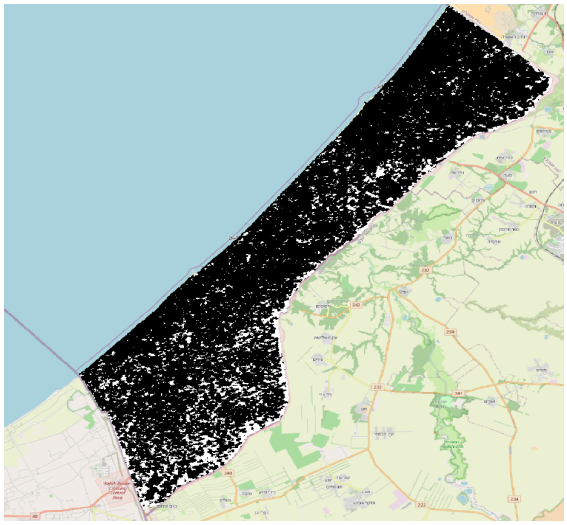
**2.2 "Reclassify by table" to mask out areas with coherence >0 (as they represent an increase in coherence, the signal we are trying to find is a decrease in coherence that corresponds to structural damage. Hence, areas that see an increase in coherence are not relevant to us).**




3. **Pre-event map masked**

**A strict threshold for pre-event coherence is important to deal with potential noise.Noise can be introduced due to various factors such as environmental**

**conditions, changes in vegetation, or minor alterations not related to structural damage. We make a mask using a fixed threshold of 0.9. By setting a threshold of 0.9, the analysis focuses on areas with very stable scattering properties between the two-time points, thereby reducing the likelihood of identifying false positives due to noise. A threshold close to 1 (where 1 indicates perfect coherence) ensures that only those changes that substantially impact the structural stability or composition of the area are considered.**



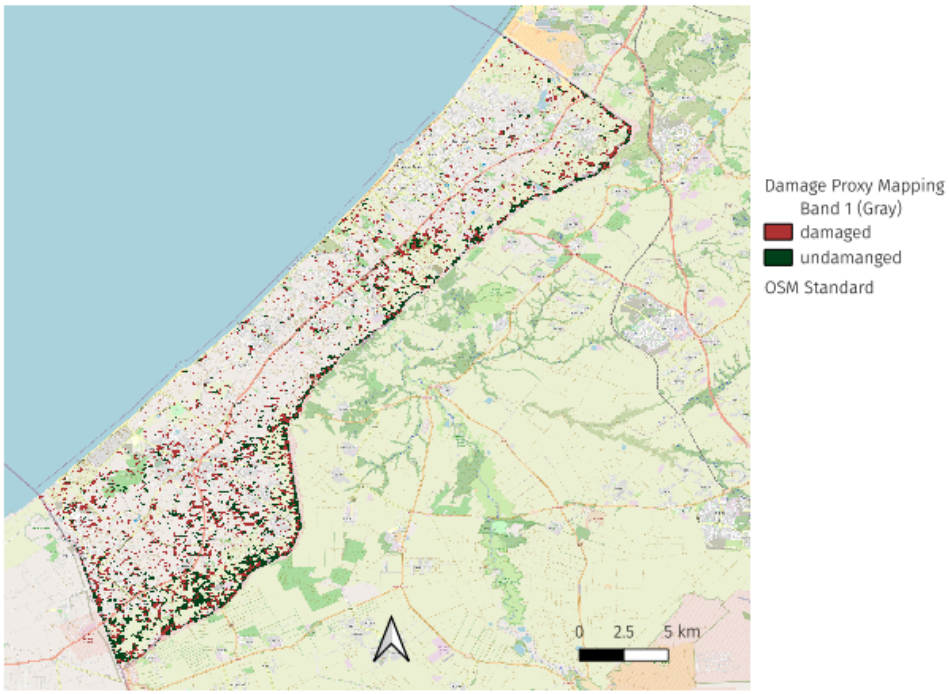
4. **Damage proxies overlaid onto an ESRI basemap in QGIS**

**4.1 Raster calculator to find out areas that had a decrease in coherence: Here we try to get pixels that were initially white i.t had a high coherence in "pre-event" image, and then subsequently became black i.e saw a decrease in coherence in the "event" image. This is what we hypothesize to be structural damage**

**4.2 Change symbology to single band-pseudocolor to interpret the results:**

**4.3 Overlay on basemap**

Damage Proxy map between Oct 12 and Oct 24 2023 in Gaza




## RESULTS

1. We see a decrease in coherence all along the 60 km long Israeli-controlled fence (Closed and restricted area) along the North and East of the Gaza Strip and in the buffer zone. This could be possible due to IDF entering Gaza for a ground invasion




What news sources say:

Source: [Satellite images reveal 400 vehicles in Israel near Northern Gaza]



Satellite images reveal 400 vehicles in Israel near northern Gaza

Ground invasion of besieged area could be imminent, analysis suggests

A satellite photo provided by Planet Labs shows many objects near the northern Gaza region that appear to be vehicles.

MASASHI IJICHI, YUKIKO UNE and HIROFUMI YAMAMOTO, Nikkei staff writers

October 16, 2023 18:18 JST

Oct 31: [A Detailed Satellite View of Israel's Invasion] by NY Times and Planet Labs




2. We see coherence decrease in both northern parts of the strip - Gaza City and southern parts - areas of Khan Younis. The Nothern parts could be structural damage due to airstrikes, and the southern parts could be due to the creation of large refugee camps and migration of citizens to the south as intimated by IDF

## 2.1 Gaza City - a closer look




Nov 12: Word Health Organization Director-General Tedros Adhanom Ghebreyesus said **Al Shifa Hospital(geo-referenced above)** – a stated target of the Israeli military, which

says the facility is the location of a significant Hamas command post – "is not functioning as a hospital anymore."

Oct. 20: Israeli military forces pound Gaza with heavy airstrikes, hit a **Greek Orthodox church building(geo-referenced above)** in Gaza City

**Al-Quds Hospital:** On Oct. 14, Israel told the hospital to evacuate by 4 p.m. the same day, but hospital officials said they cannot move delicate patients.

## LIMITATIONS AND PROBLEMS

1. Mapping damage through InSAR relies heavily on context as it's not optical imagery
2. Results need to be interpreted along with information from media sources, international organizations and many more
3. Proxy damage mapping means minimizing decorrelation related to processes that are not likely associated to sudden structural damage occurring during a conflict period. We can try to mitigate other types of decorrelation by:

    1. Masking out areas of low coherence in pre-event scenes better

    2. Minimizing difference in **temporal coherence** by choosing InSAR pairs with similar temporal baseline

    3. Minimize **geometric coherence** using small perpendicular baseline InSAR pairs

## REFERENCES

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the war in Ukraine

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7. War Related Building Damage Assessment in Kyiv, Ukraine, Using Sentinel-1 Radar and Sentinel-2 Optical Images
8. https://onlinelibrary.wiley.com/doi/10.1002/ldr.4249
9. https://edition.cnn.com/2023/10/10/world/map-israel-hamas-war-dg/index.html