Investigating the spatiotemporal relationship between thermal anomalies and surface deformation; The Arkalochori Earthquake sequence of September 2021, Crete, Greece.

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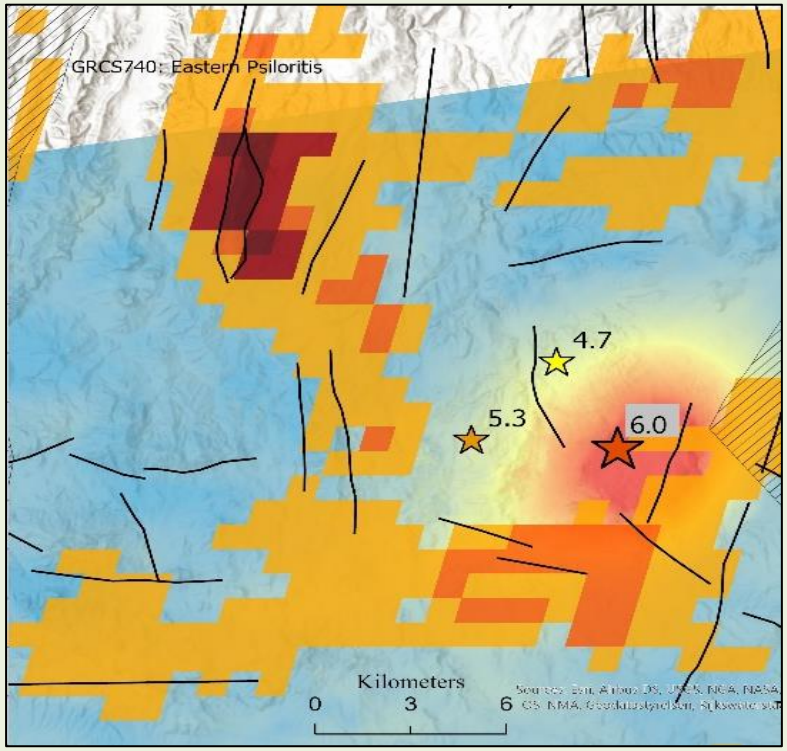


HELLENIC MEDITERRANEAN UNIVERSITY

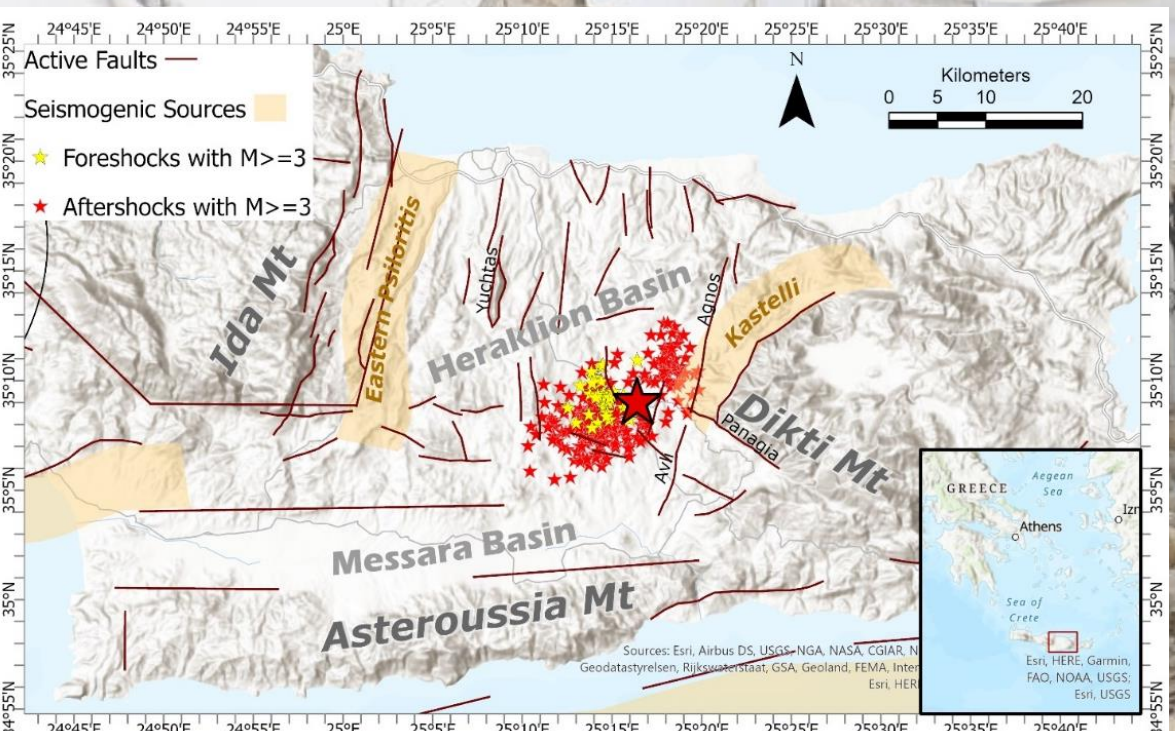
INSTITUTE OF PHYSICS OF THE EARTH'S INTERIOR & GEOHAZARDS

EGU – May 2022

The case of Arkalochori

A strong onshore earthquake of magnitude **M_w 6.0** occurred near the village of **Arkalochori** in central Crete on September 27, 2021, at 06:17:21 UTC.

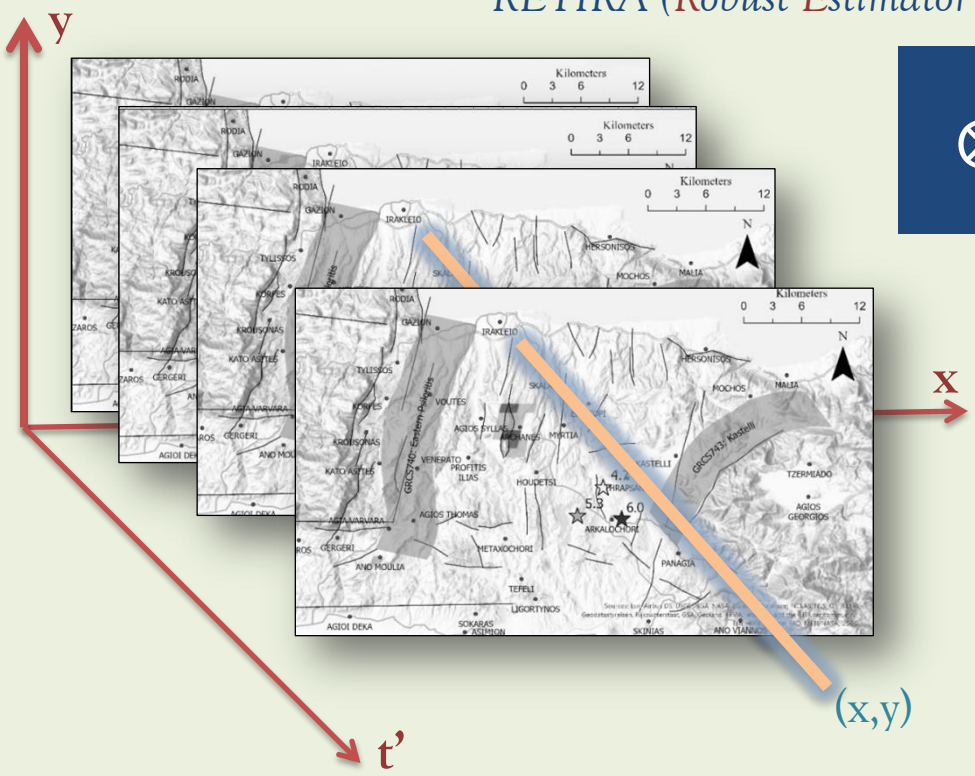
- ➢ Strong, rare and unexpected earthquake.
  - ○ The earthquake was triggered by the Kastelli Fault [Vassilakis et al., 2022], with RI up to 812yrs [Caputo et. al. 2010].
  - ○ Biggest onshore earthquake on Crete island.
- ➢ 01/06/21 - 24/07/21: 155 foreshocks, 4 with magnitude > M4.0.
- ➢ 24/07/21: Mw4.8 over 250 earthquakes with magnitude up to M3.8 until 27/09/21.
  - ○ 8 aftershocks ≥ M4.2 occurred on 27/09/2021.
- ➢ 1 death, 36 injuries & over 5.000 buildings were damaged.



Image's source: https://kede.gr/

The RETIRA-index

RETIRA (Robust Estimator of TIR Anomalies) INDEX [Tramutoli et. al. 2005]:



$$\otimes_{\Delta T}(r,t') = \frac{\Delta T(r,t') - \mu_{\Delta T}(r)}{\sigma_{\Delta T}(r)}$$

- $\Delta T(r,t')$ represents the difference $(T(r,t') - T(t'))$ of the observed TIR signal value T(x,y,t) with the spatial average T(t) of all the pixels of the satellite image. T(x,y,t) is measured for each pixel of the satellite image (r), while T(t) is calculated in place on the satellite image, without considering the cloudy pixels, all representing the same class of the study area (land or sea) according to where the r is located.
- $\mu_{\Delta T}(r)$ represents the time average and $\sigma_{\Delta T}(r)$ the standard deviation of $\Delta T(r,t')$ measured at site r, computed only on cloud-free pixels from satellite images of the ***homogenous datasets*** ($t' \in \tau$).

The **MODIS LST** Daily L3 Global 1km (MOD11_A1) product (i.e., the version 005 (V5)) was used.

The RETIRA-index

- Initial images (July – October | 2012 - 2021): 1.230
- Images remaining with a cloud coverage < 80%: 1.086
- Calculation of the $\Delta T(r,t')$ and the monthly reference fields $\mu_{\Delta T}(x,y)$ & $\sigma_{\Delta T}(x,y)$.
- RETIRA index was calculated for 105 images:
  - July: 31
  - August: 31
  - September: 28
  - October: 15

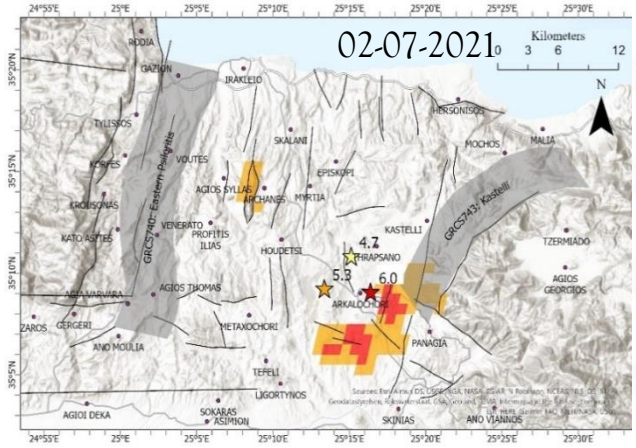
18 contained TA with RETIRA > 3.

- Performed an assessment of the results to distinguish TA due to seismicity.

9 quite intense and rare, *spatially extensive* and *time persistent*, TIR signal transients were identified (*8 pre-seismic & 1 co-seismic).*

- Investigation of the spatial relationship of the TA with other geologic features.

July & August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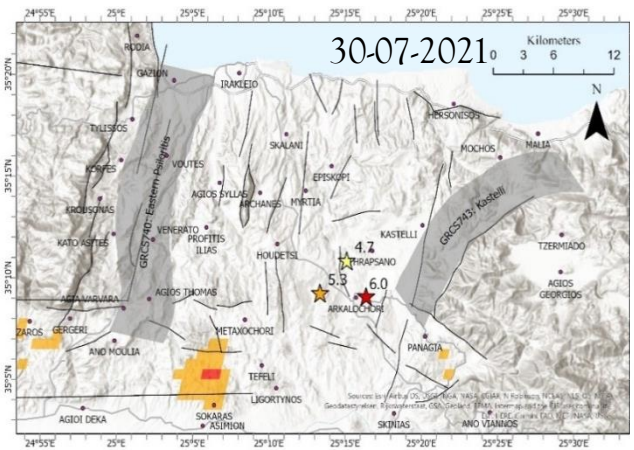
GRCS740: Eastern Pediaithis
GRCS743: Kastelli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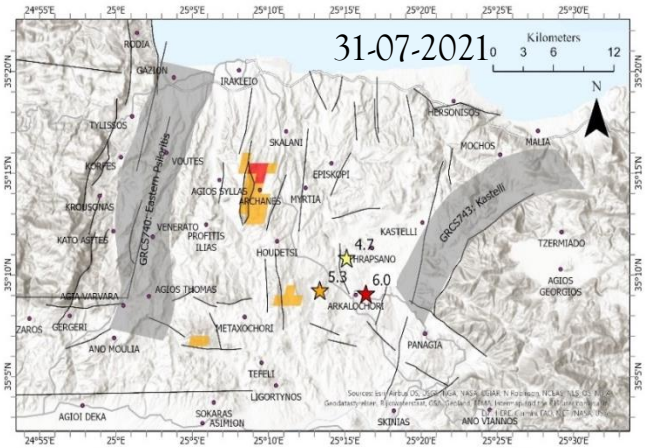
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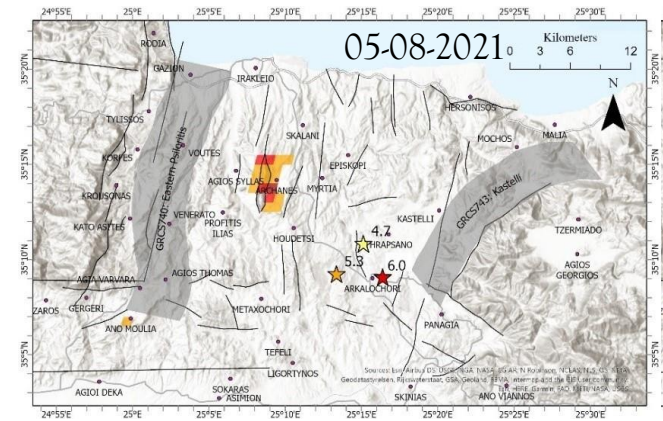
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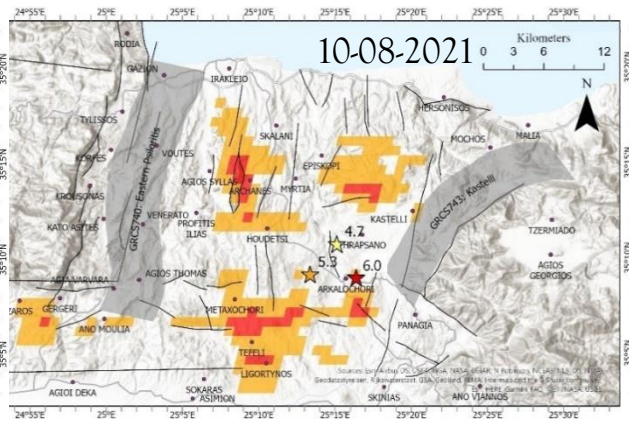
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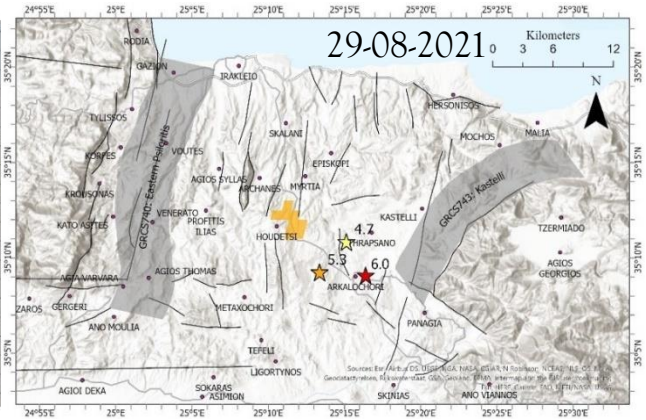
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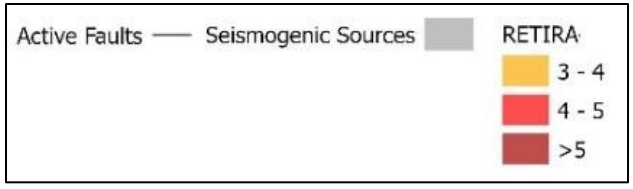
Active Faults
Seismogenic Sources
RETIRA
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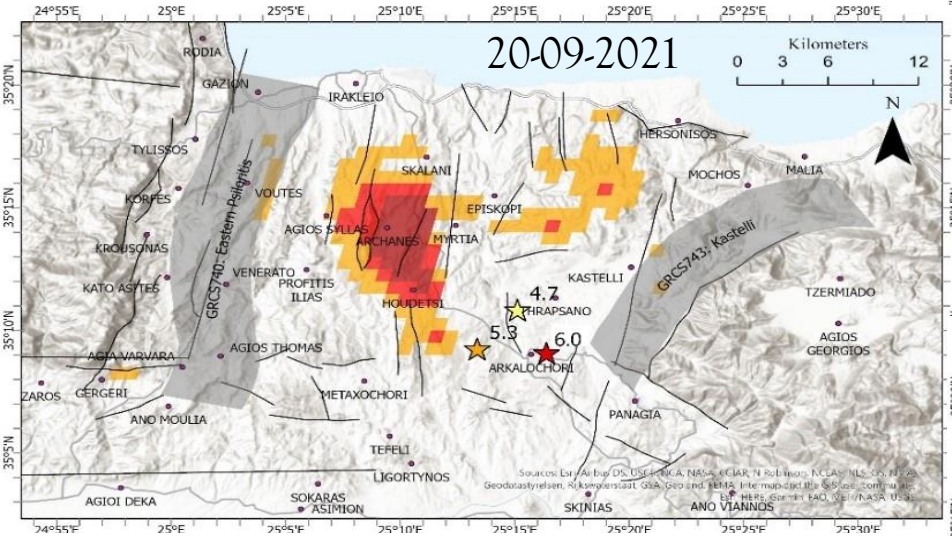
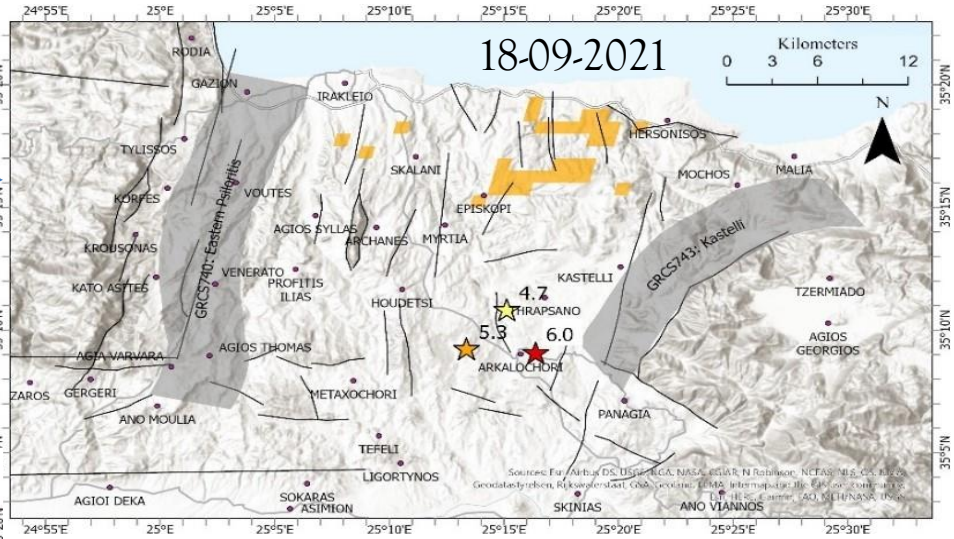
September

9 and 7 days before the main event on September 27 .





Active Faults — Seismogenic Sources

RETIRA

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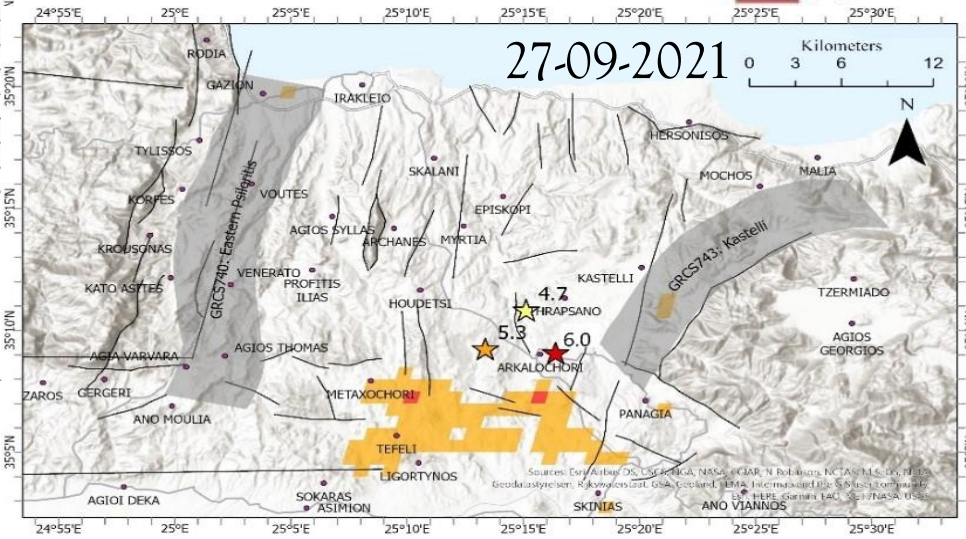


The last thermal anomaly was detected on the day of the main earthquake M6.0 **(co-seismic TA).**

Interferometric Synthetic Aperture Radar (InSAR)

1st pair (ascending): 23/09/2021 – 29/09/2021

Master images

M6.0

27/09/2021

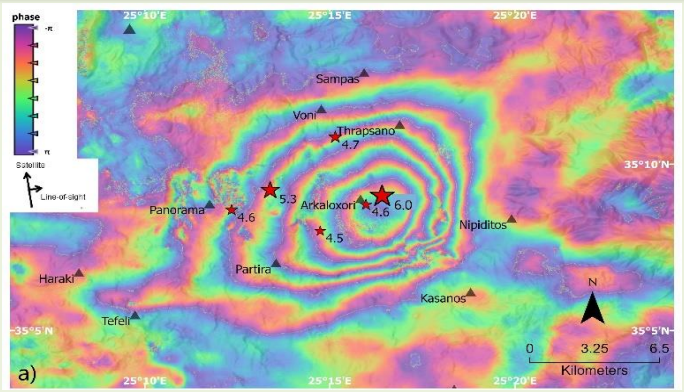
Slave images

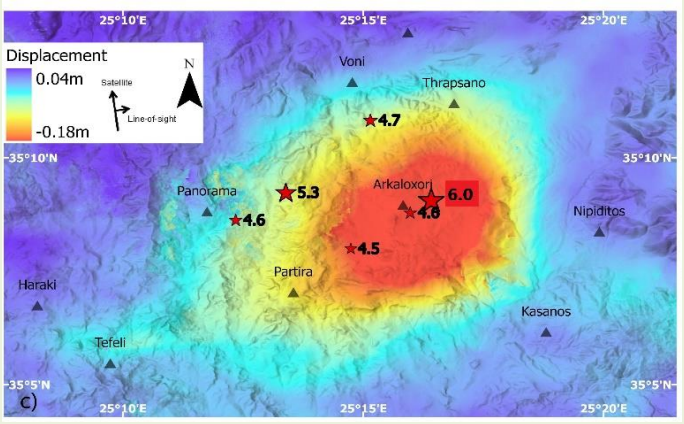
2nd pair (descending): 25/09/2021 – 01/10/2021

Images were downloaded by ESA's Sentinel-1A and Sentinel-1B satellites (https://scihub.copernicus.eu/).

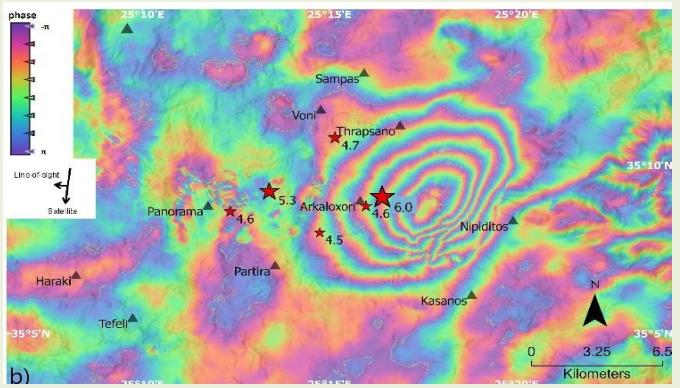
Interferometric processes carried out by the open ESA's SNAP software.

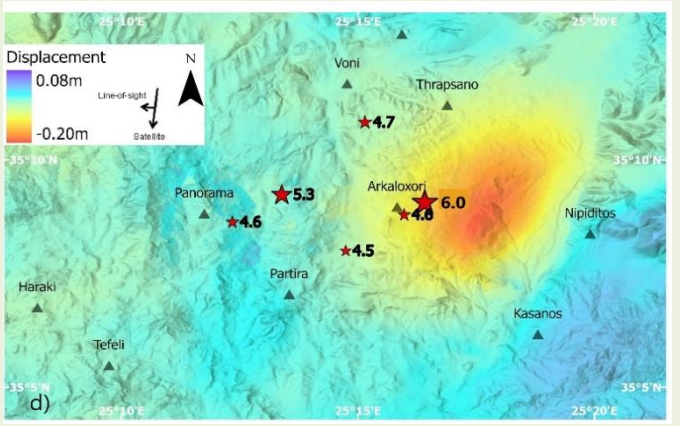
Ascending





Descending

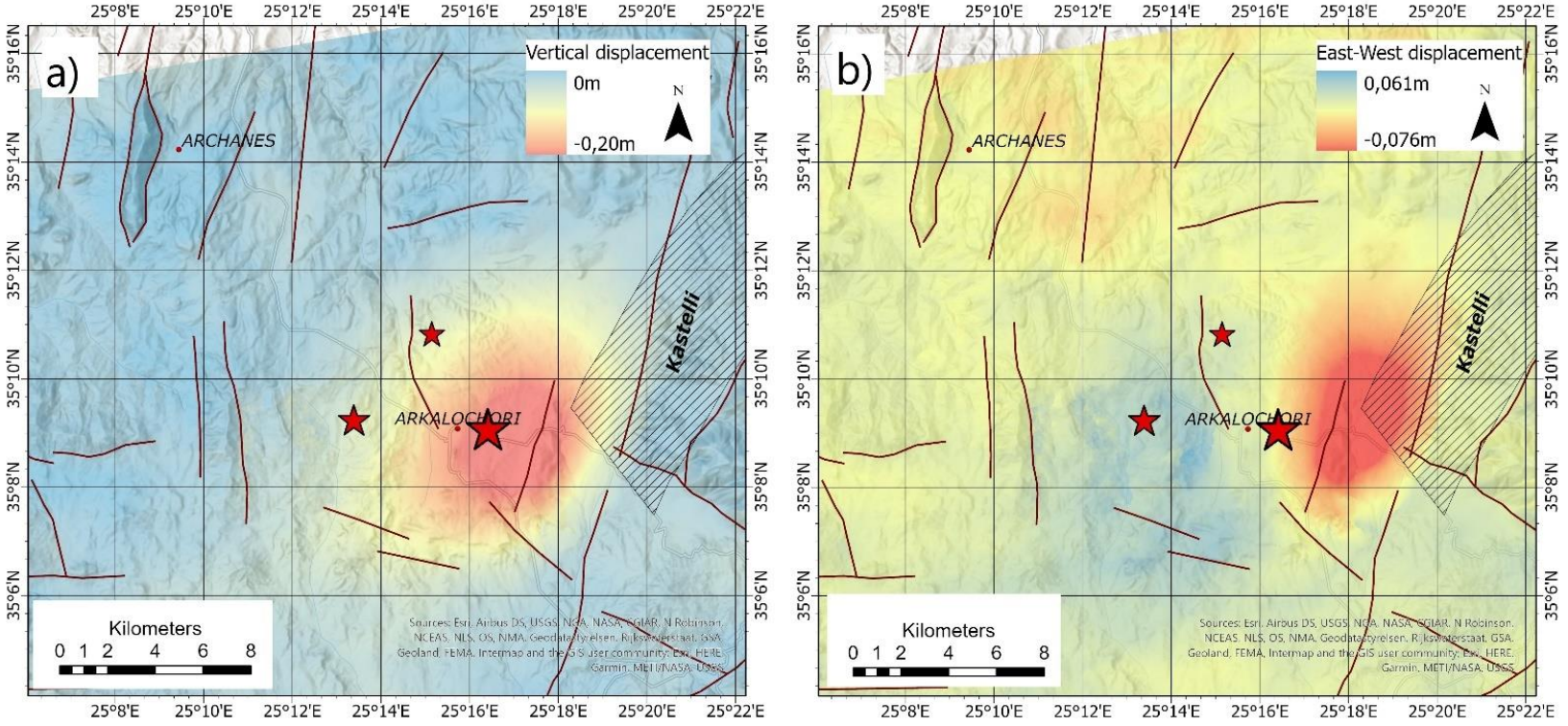




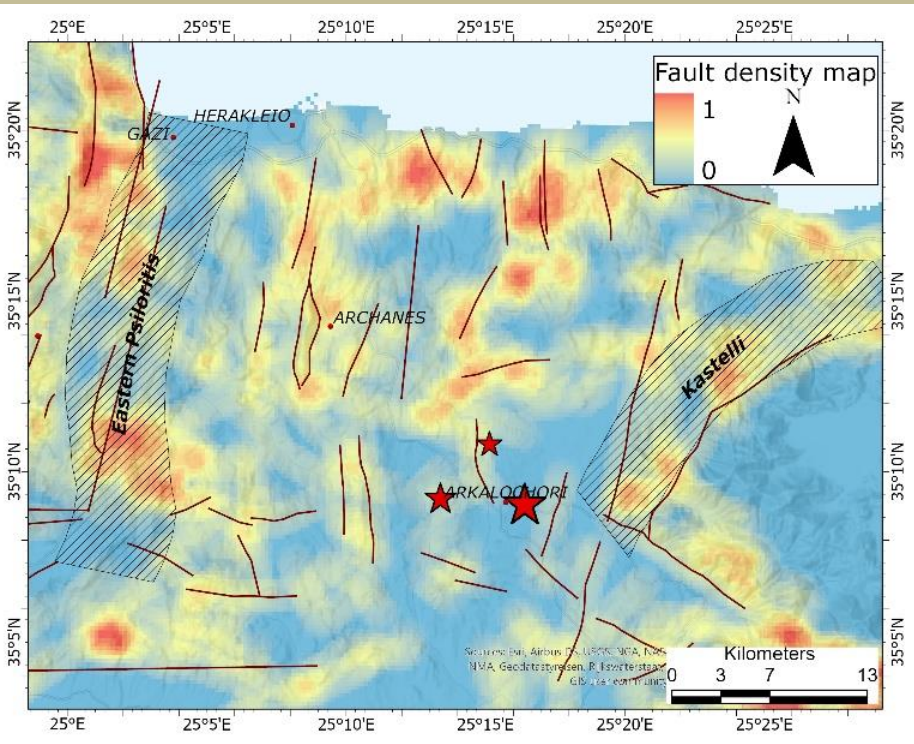
Displacement maps

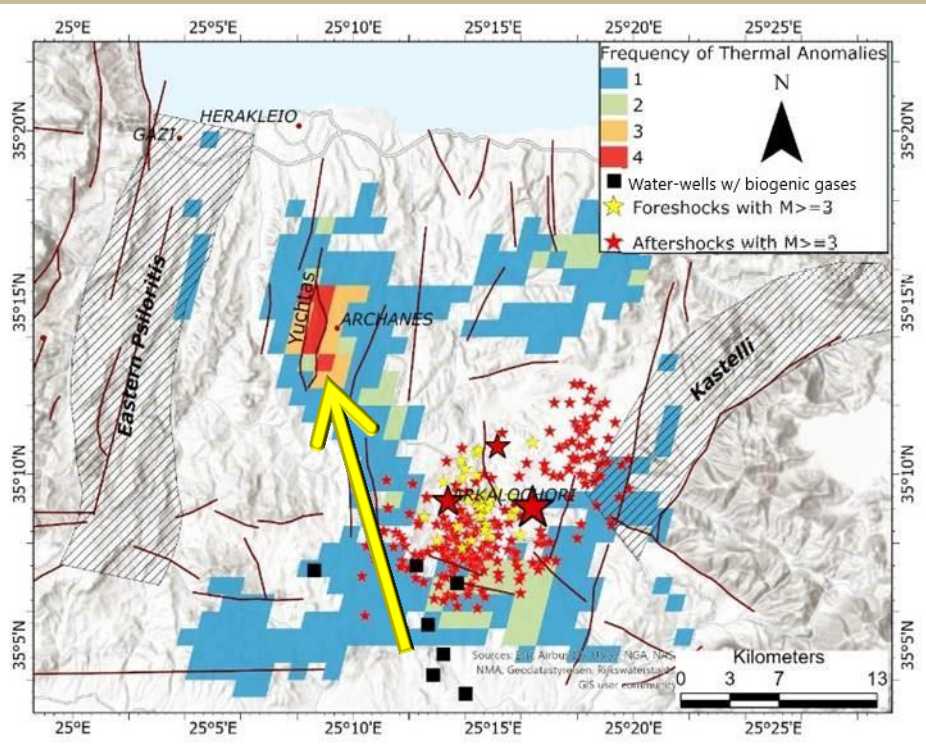
- Ground deformation in **vertical (up-down)** direction shows subsidence **up to 20 cm** while no uplift displacement was detected.

- The horizontal (east-west) displacement map reveals an eastward movement up to 6 cm and a westward movement up to 7.6 cm.



Preliminary results



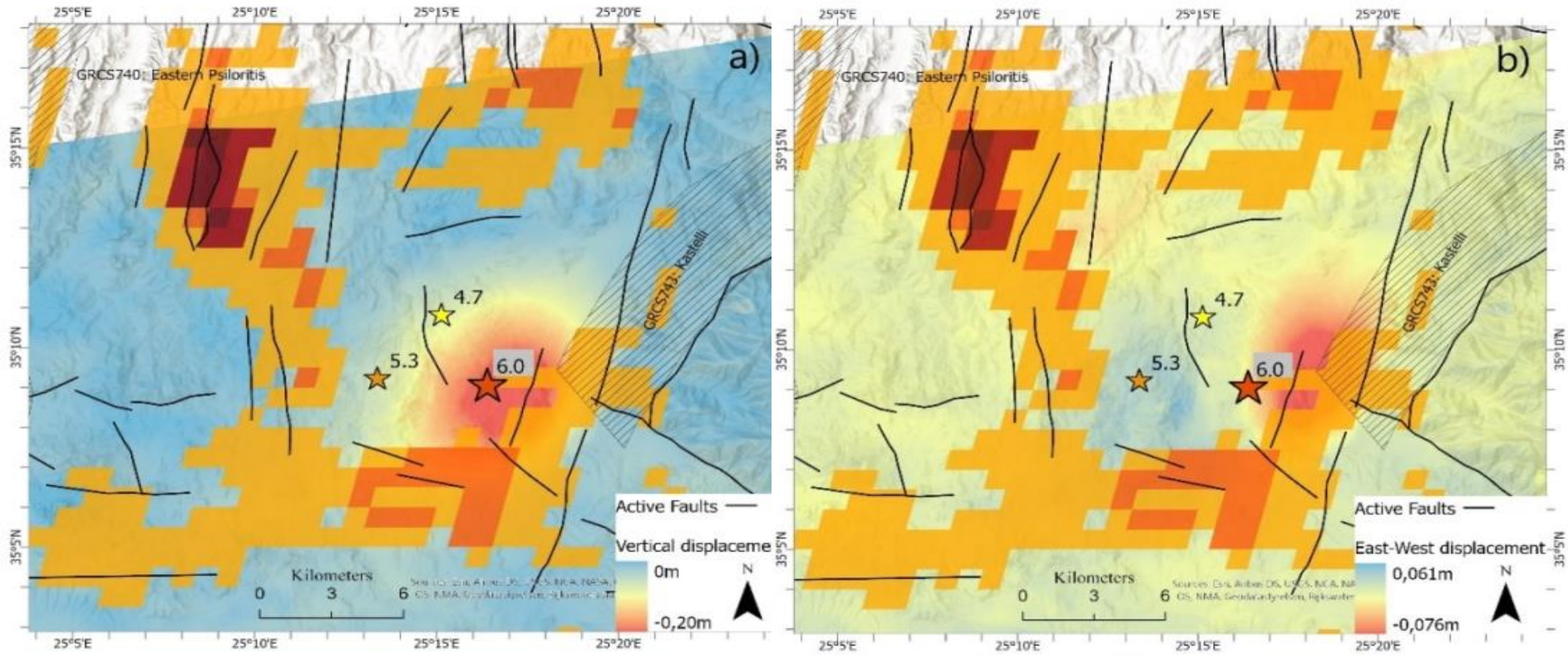


Preferential spatial distribution of TA over time seems to be controlled by the existence of the faults.

- Presence of biogenic gases on water-wells in the Messara basin [Panagopoulos et al., 2022].
- Uplifting of the gasses through the tectonic faults due to changes of the sub-surface physicochemical processes.
- Trapped gases release with the increase of stress [Pulinets & Ouzounov 2011].

The gases migrated to the NNW following the bed strata and the faults and were degassed near Mount Yuchtas due to the high fault density.

Preliminary results



The superimposition reveals the existence of overlapping area in the south of Arkalochori.

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Thank You!

Source: Eurokinissi & VectorStock