How to detect slow slip and long-term seafloor displacement? Lessons from two acoustic ranging campaigns on the submerged flank of Mt Etna

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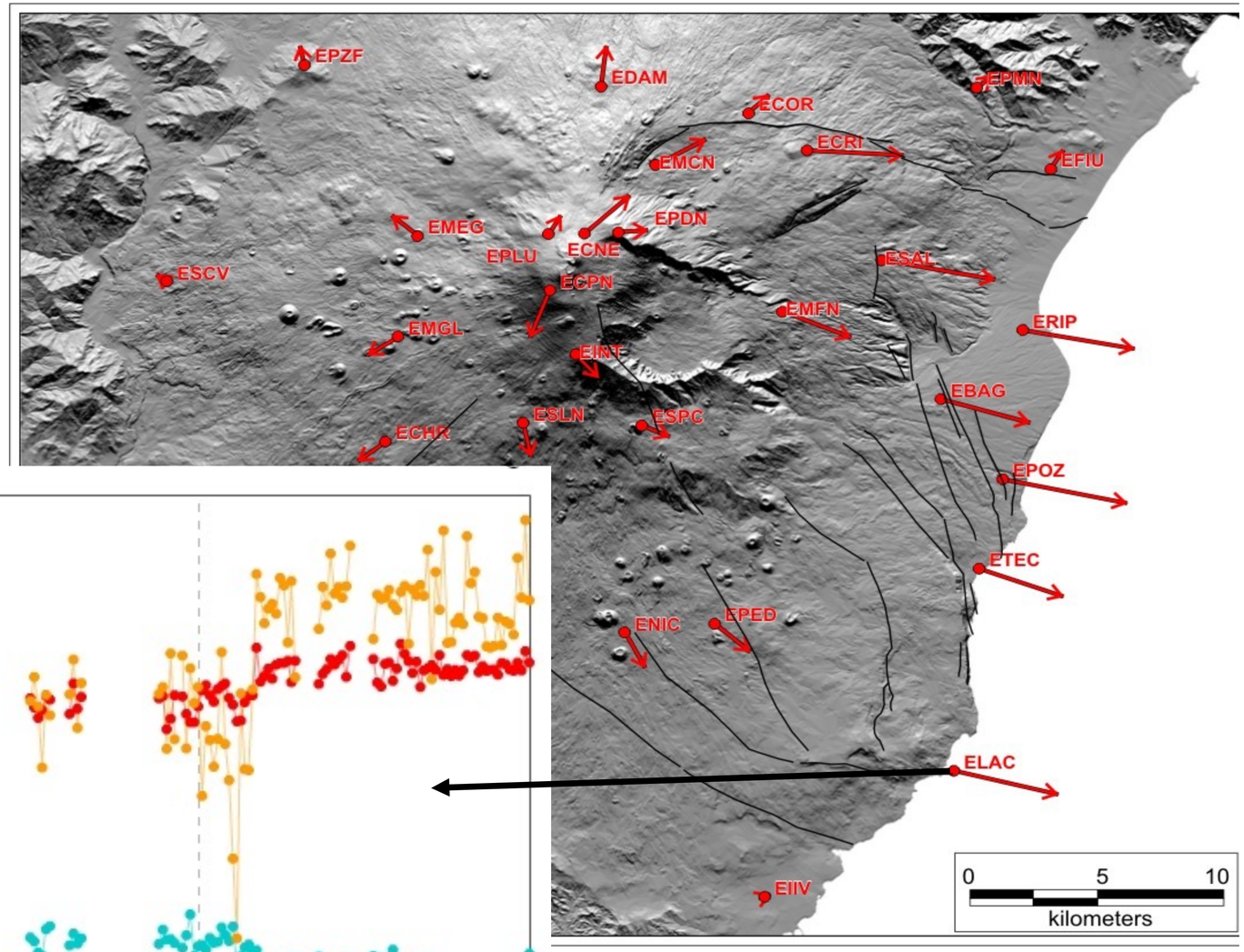
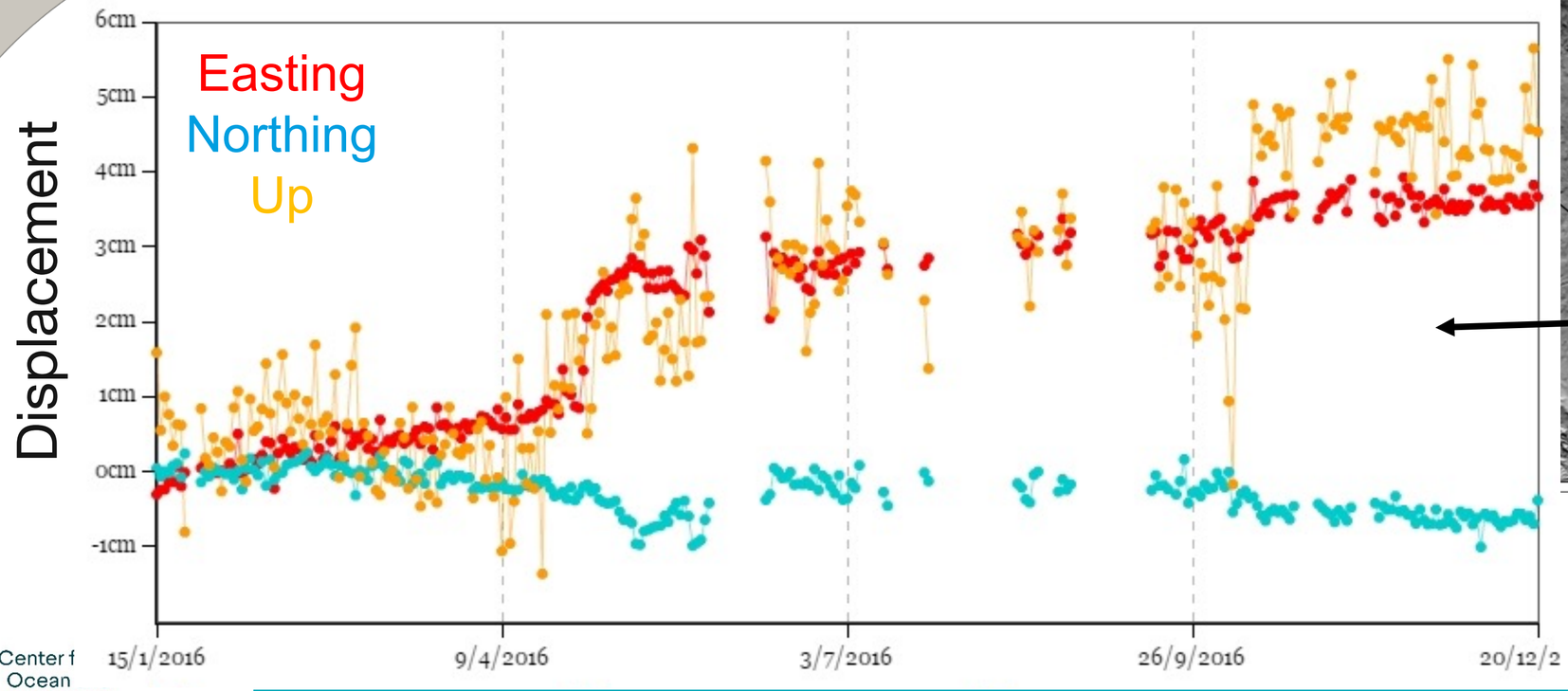
Flank instability:

- Flank extends under water.
- Highest displacement rates at the coast.
- No information on offshore displacement from satellite data.





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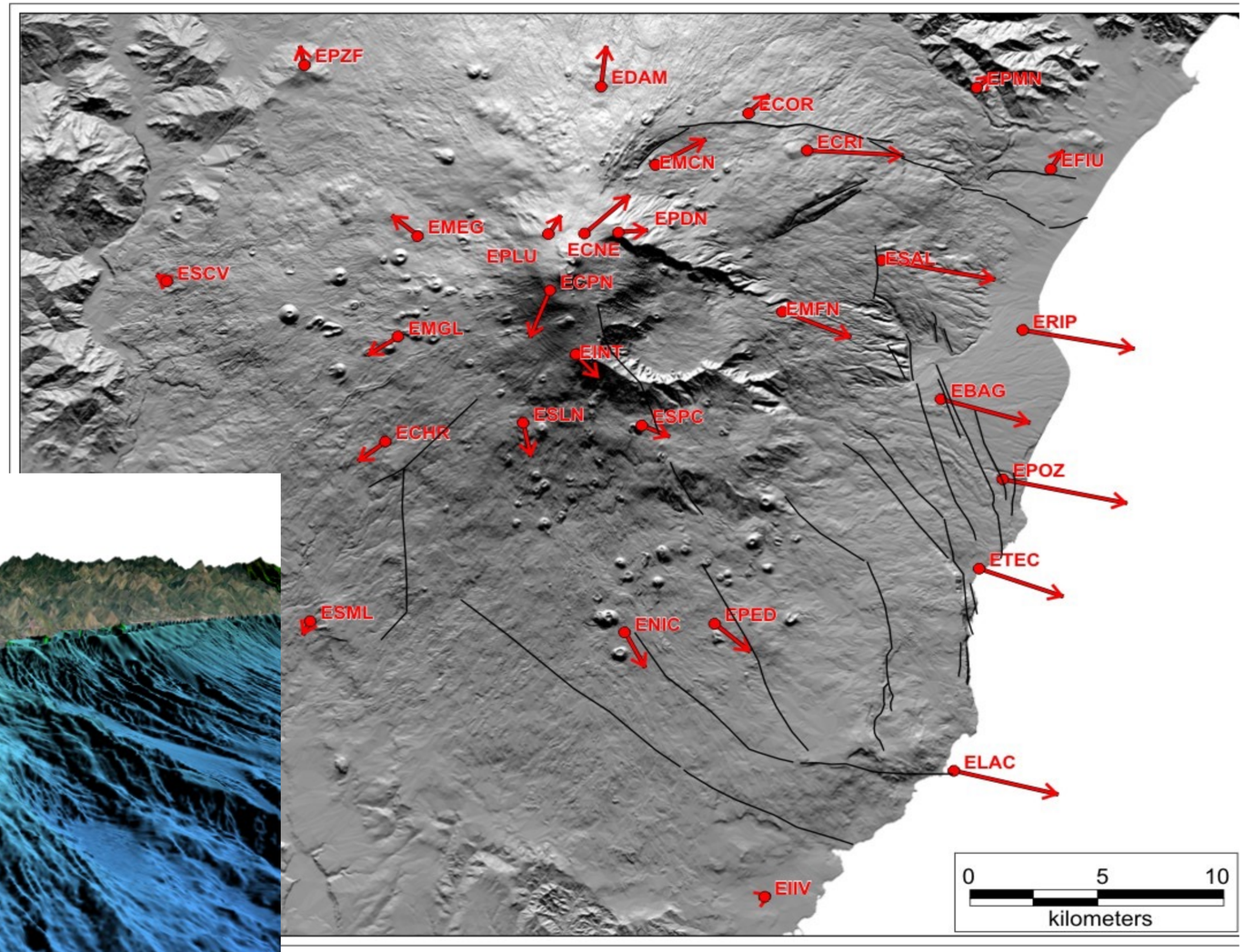
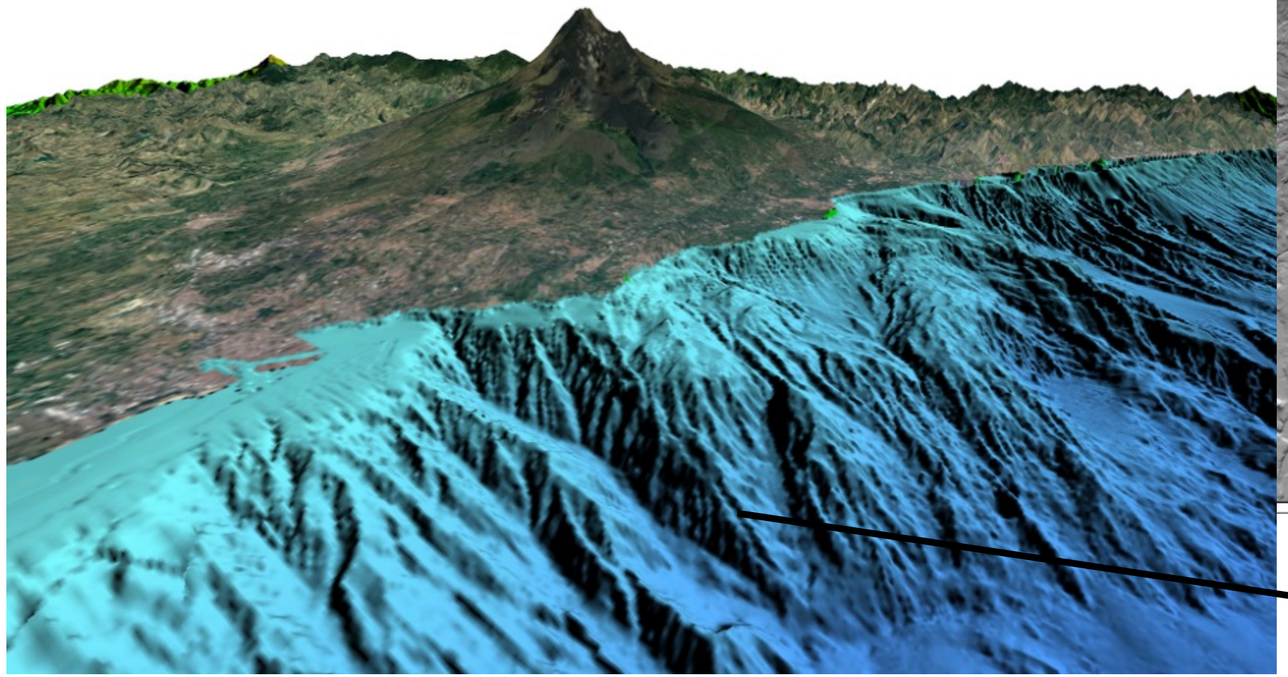
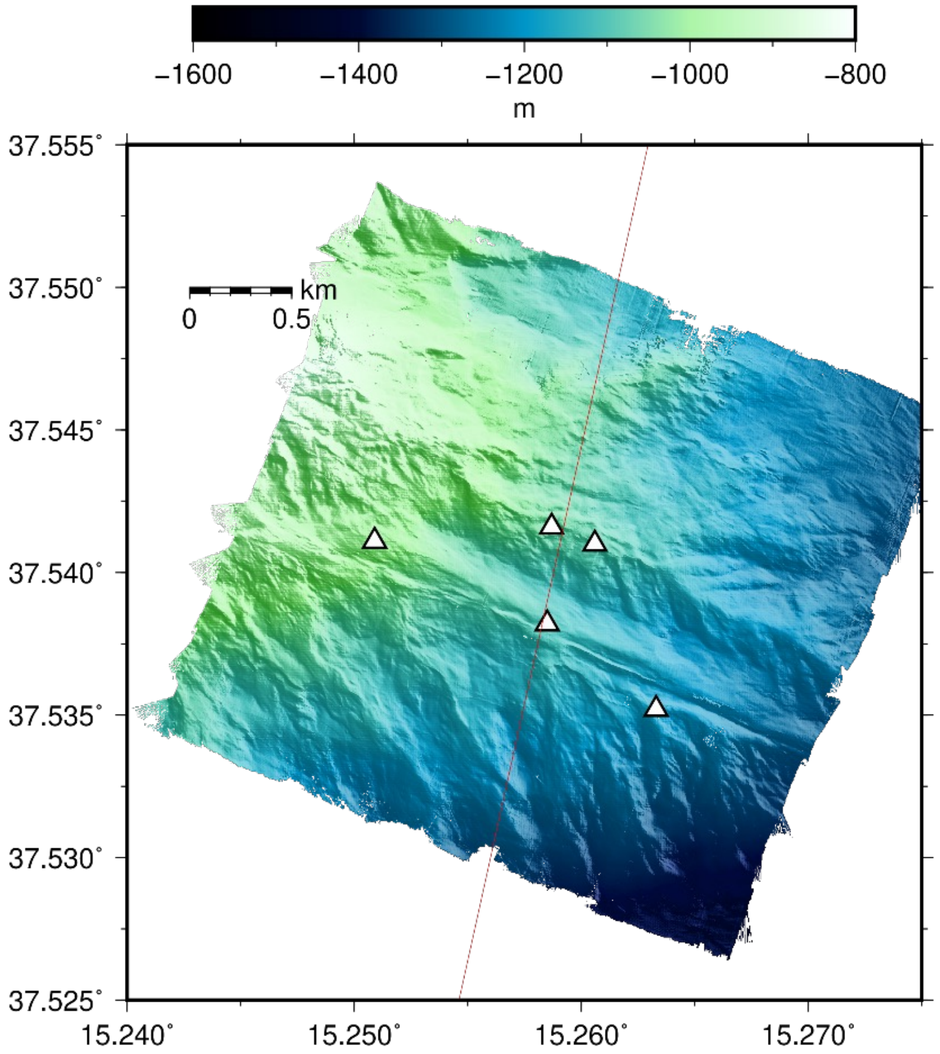
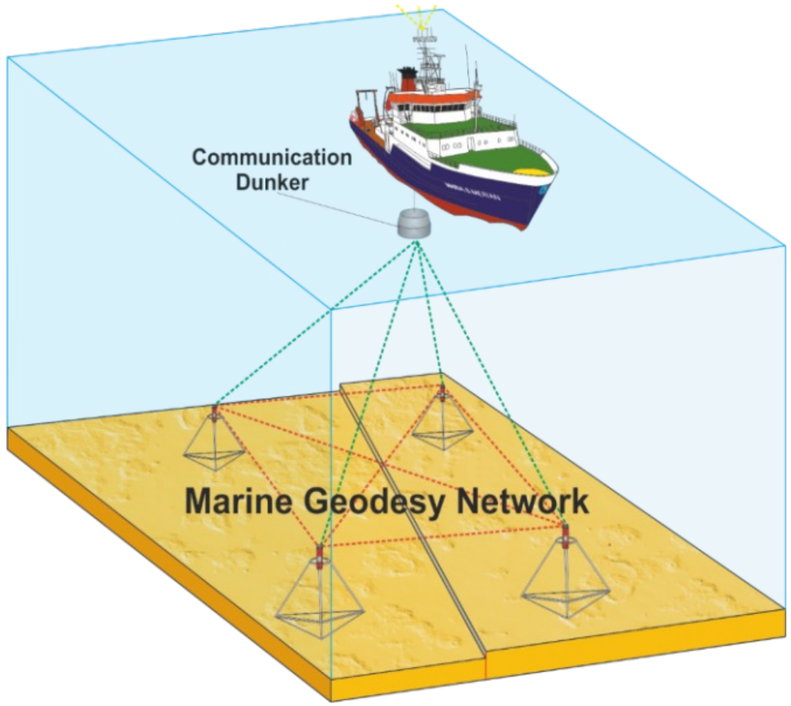




Location of direct-path ranging network

First Deployment in April 2016





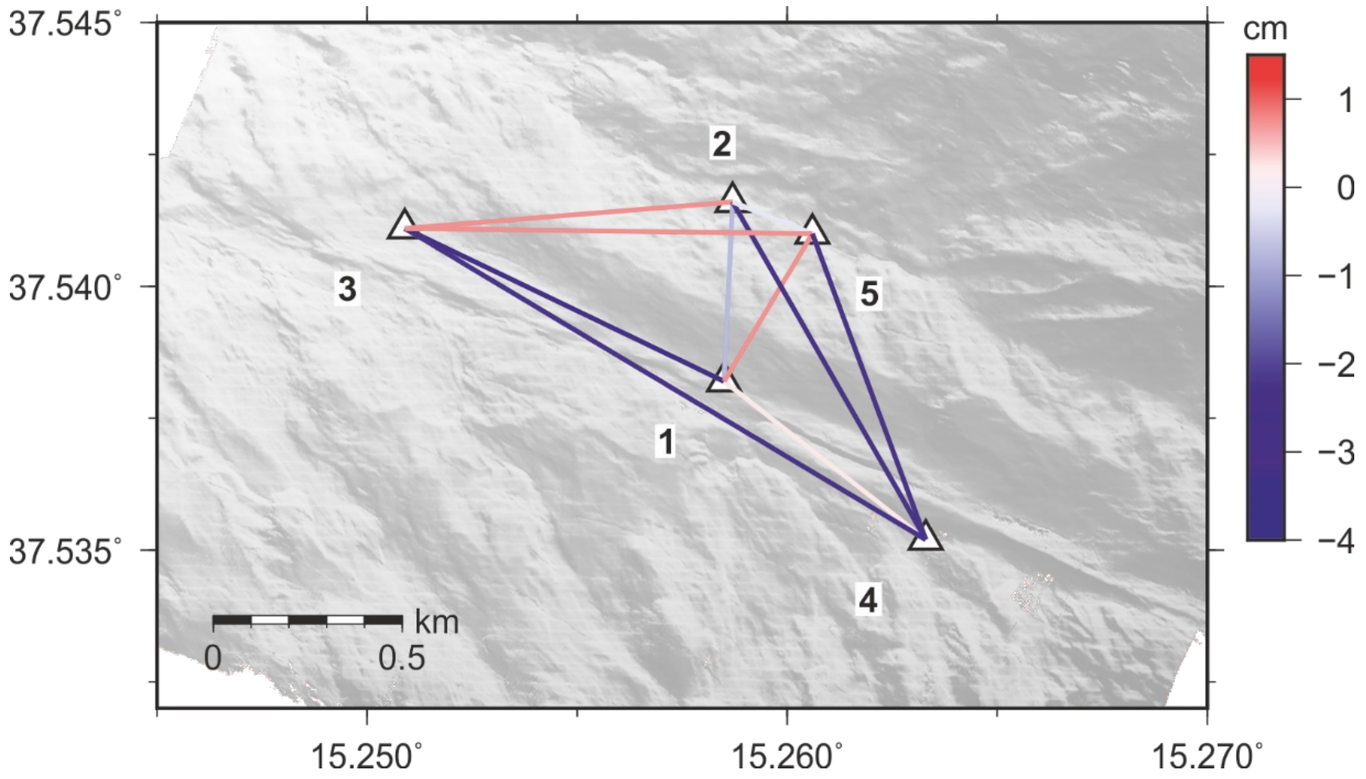
Acoustic direct-path ranging:

5 transponders = 10 baselines

Continuous data 04/2016 - 01/2018

Interrogation interval 75 min

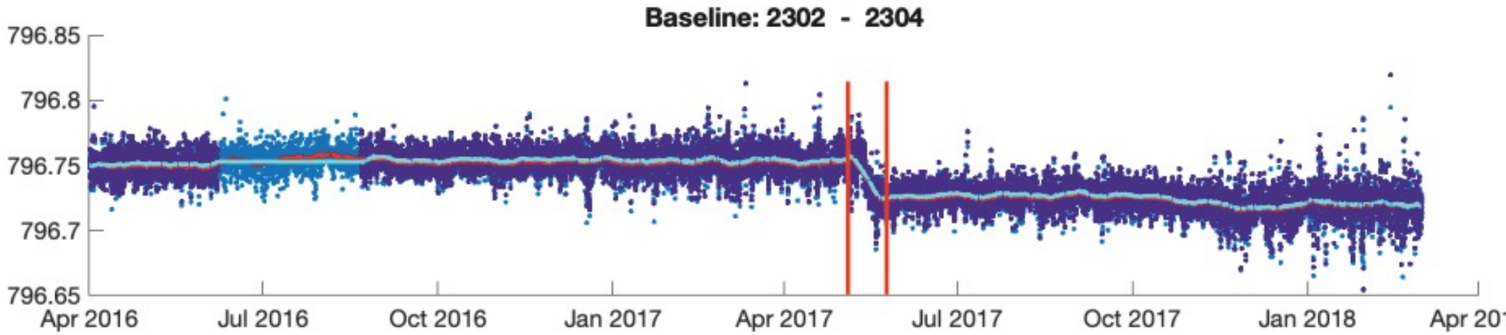
Deployment 2016 - 2018

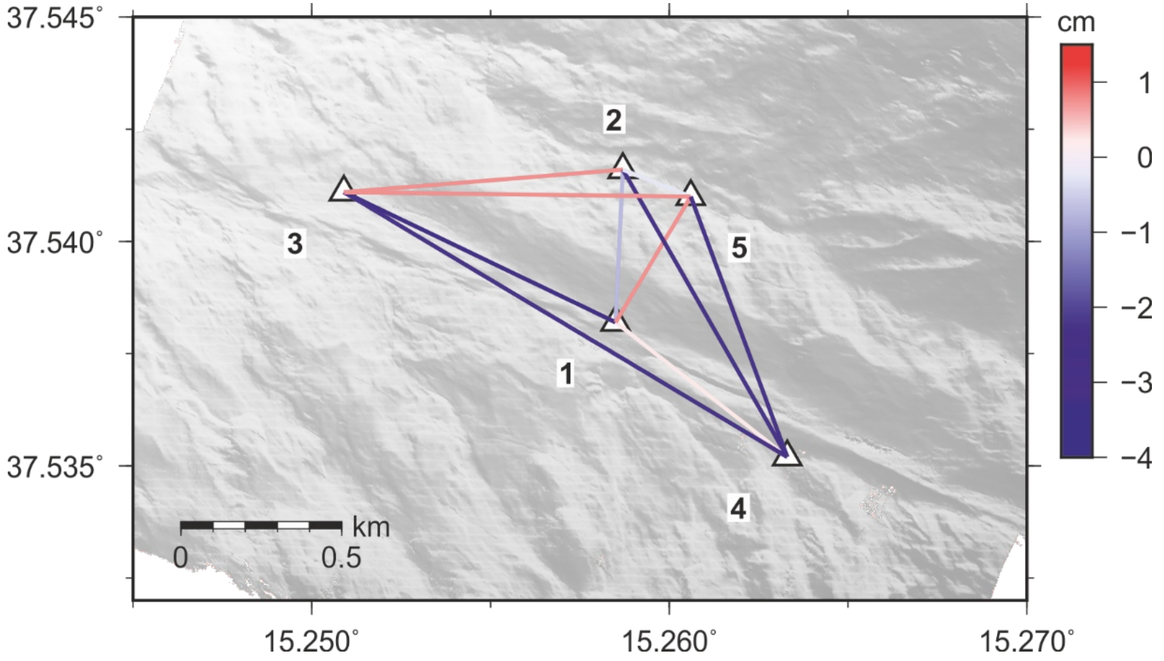


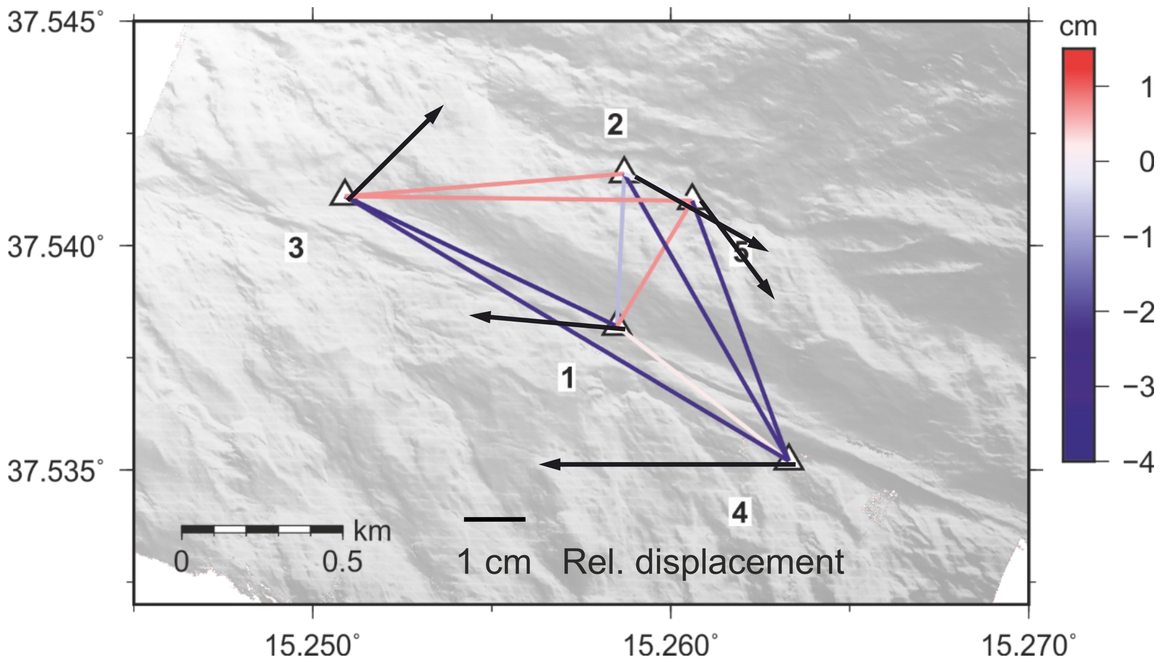
The May 2017 event

- Data consistent with dextral strike slip motion
- 4 cm in ~8 days → slow slip

Changes in acoustic distance between transponders at the seafloor

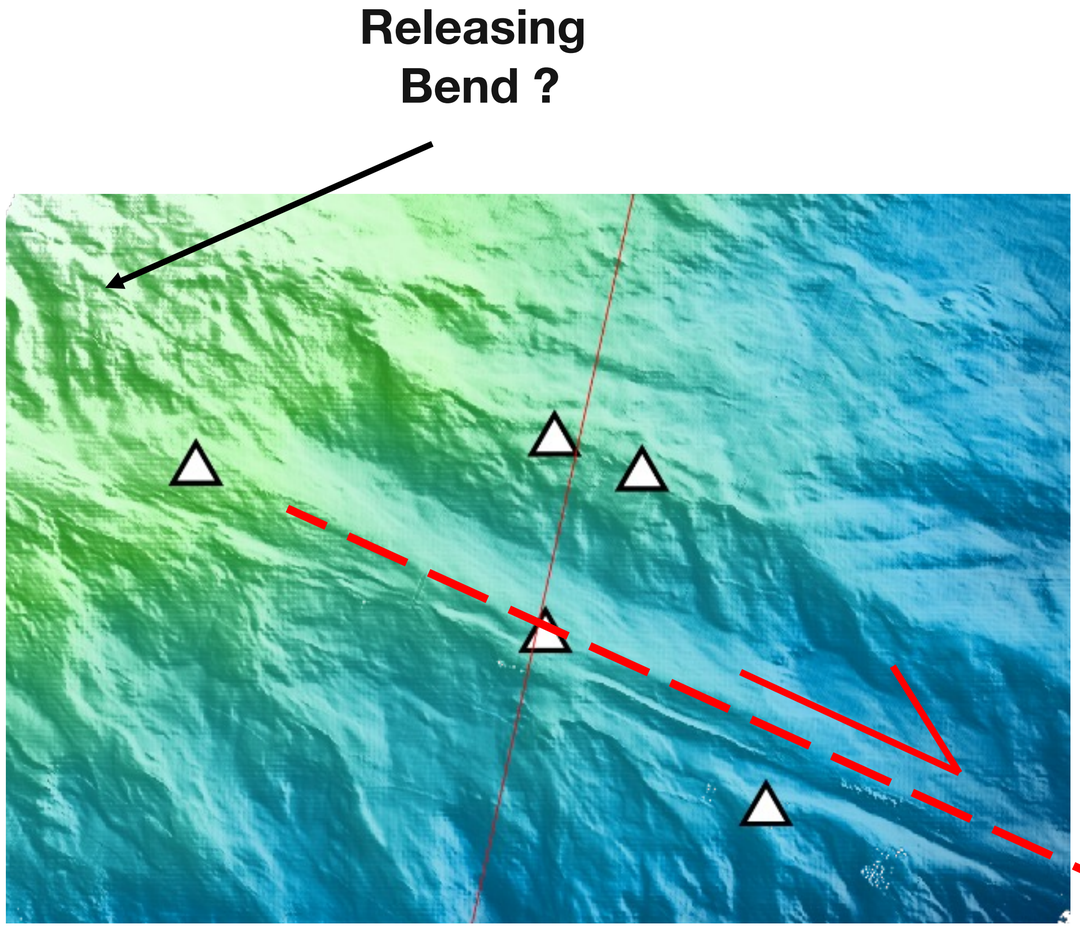




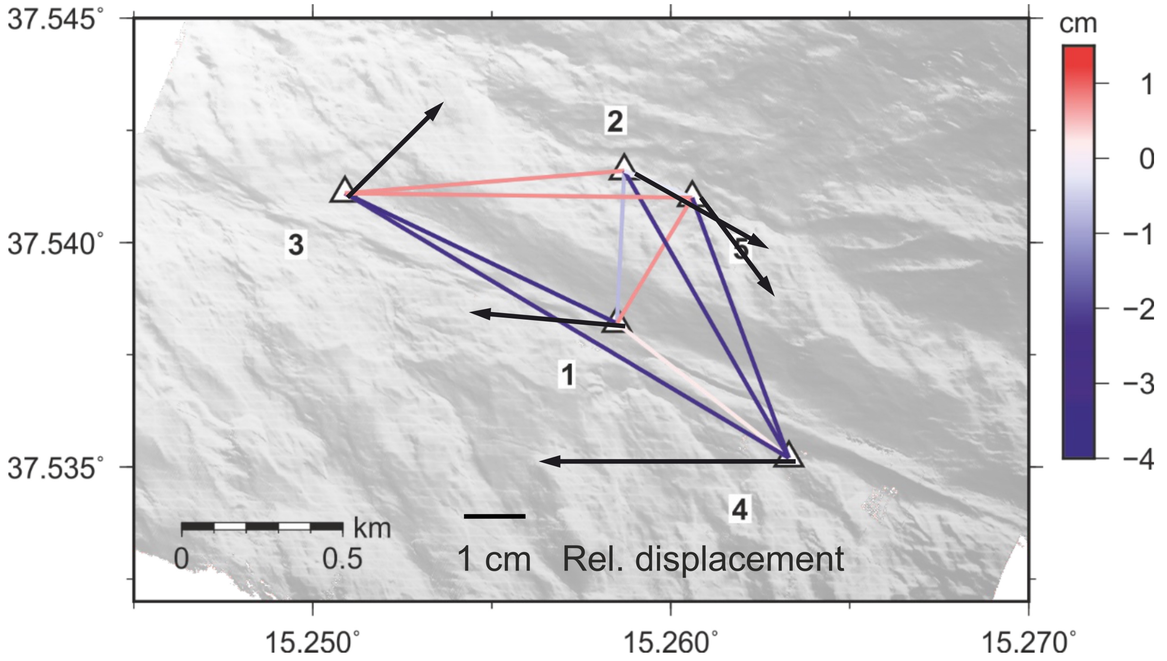


Acoustic distance changes → Relative station displacement

Using Free Network Adjustment
(internally constrained)

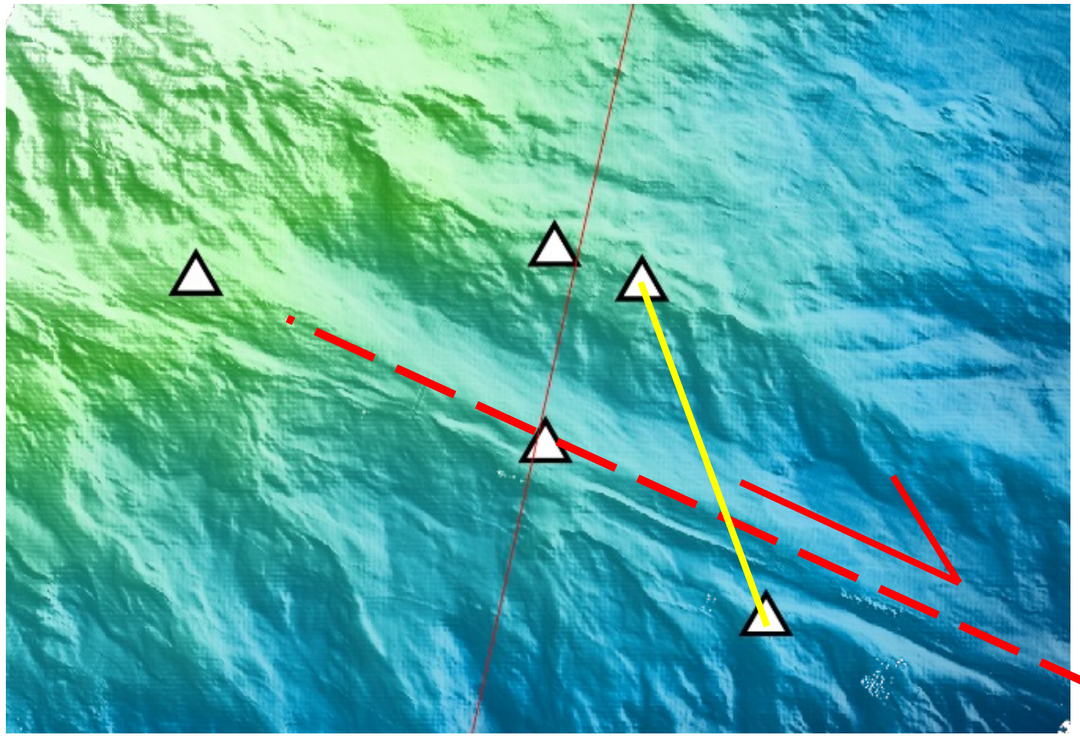


Relative station displacement



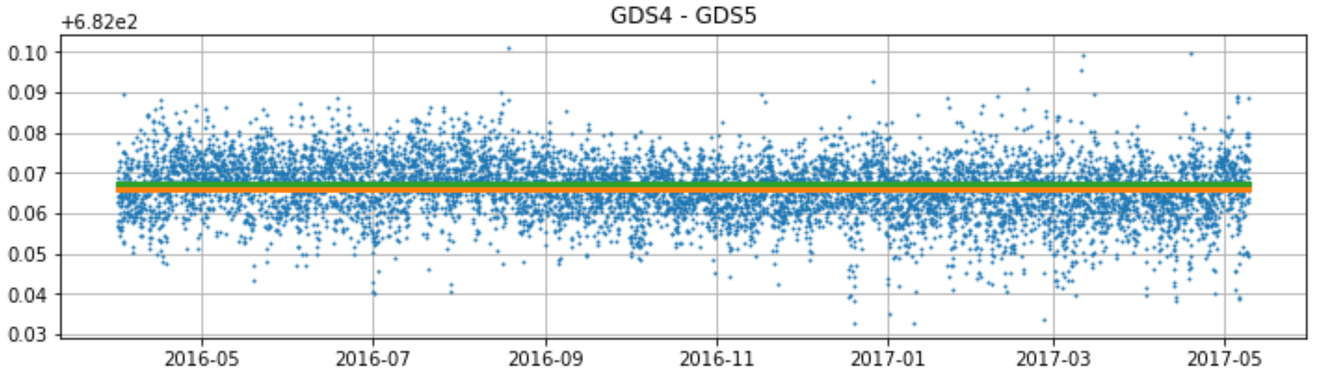
- Adjustment reveals right-lateral movement with up to 4 cm displacement.
- The westernmost station displaces in northeast direction.

Evidence for long-term displacement?

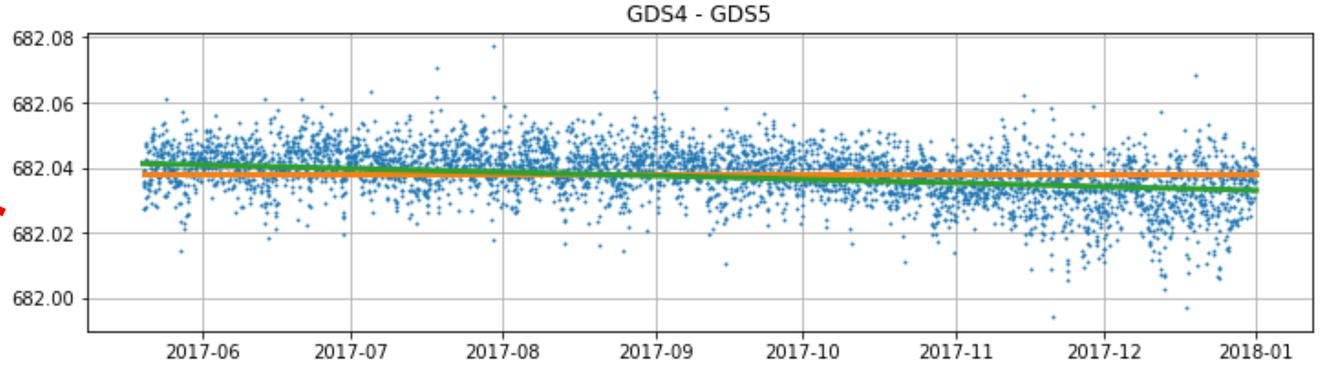


Before the 2017 slow slip event:

Mean over all
Mean of start vs. end



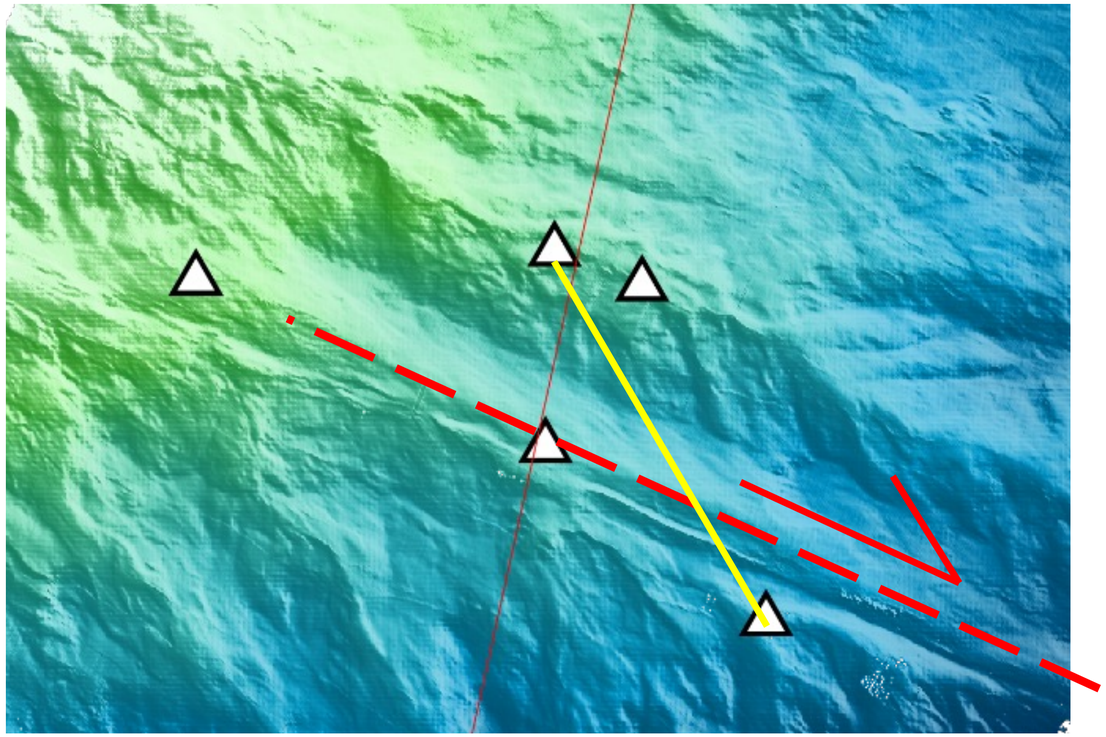
- No significant change in acoustic distance on fault-crossing baselines before the may 2017 event.



After the 2017 slow slip event:

- < 1 cm change in acoustic distance starting late 2017 (shortening).

Evidence for long-term displacement?



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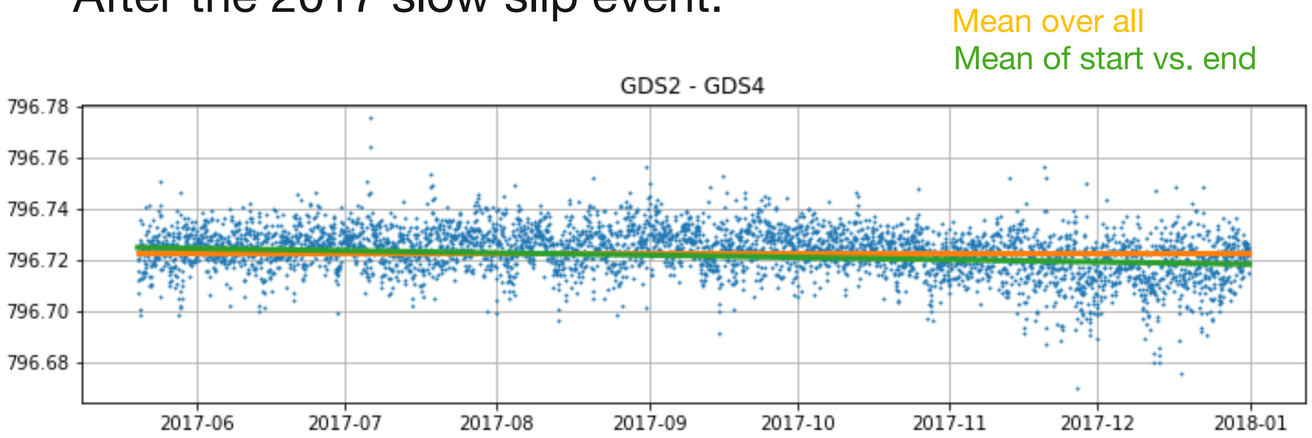
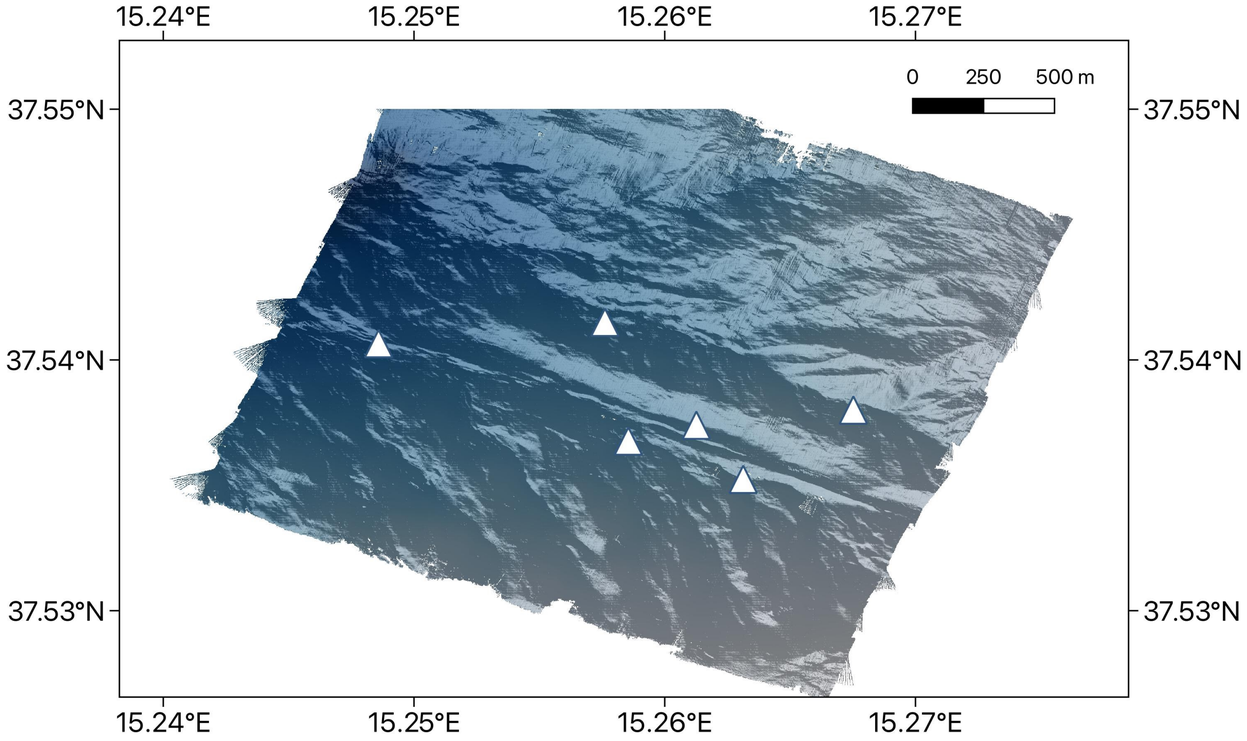
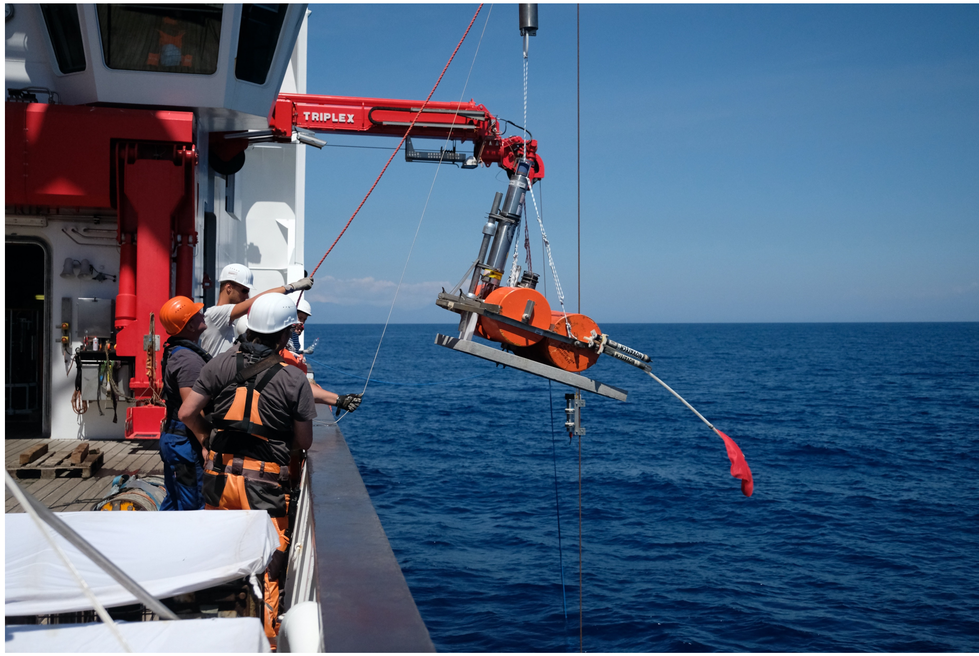


- < 1 cm change in acoustic distance, starting late 2017 (shortening of transponder distance).
- Baseline change equals 8 – 10 micro strain.

Deployment in August 2020

- 6 transponders with 3 stations close to the fault





Installation of the second seafloor geodesy network in 2020.

3 transponders located on each side of the mapped fault which showed evidence of recent strike-slip deformation.

Deployment in August 2020

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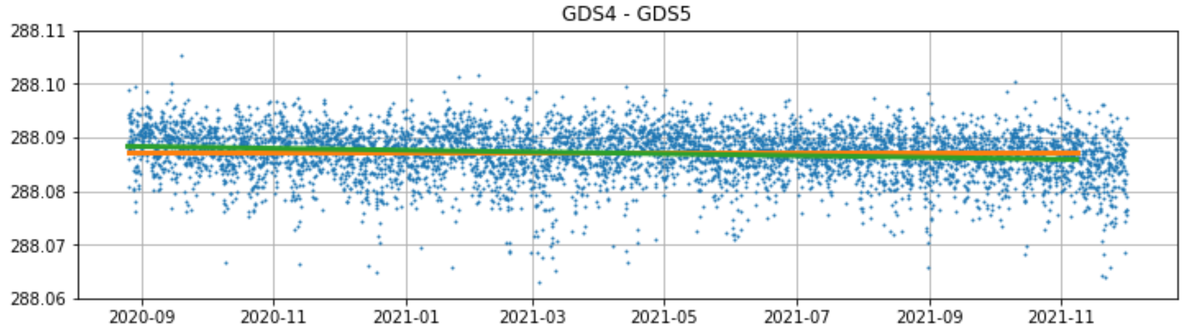
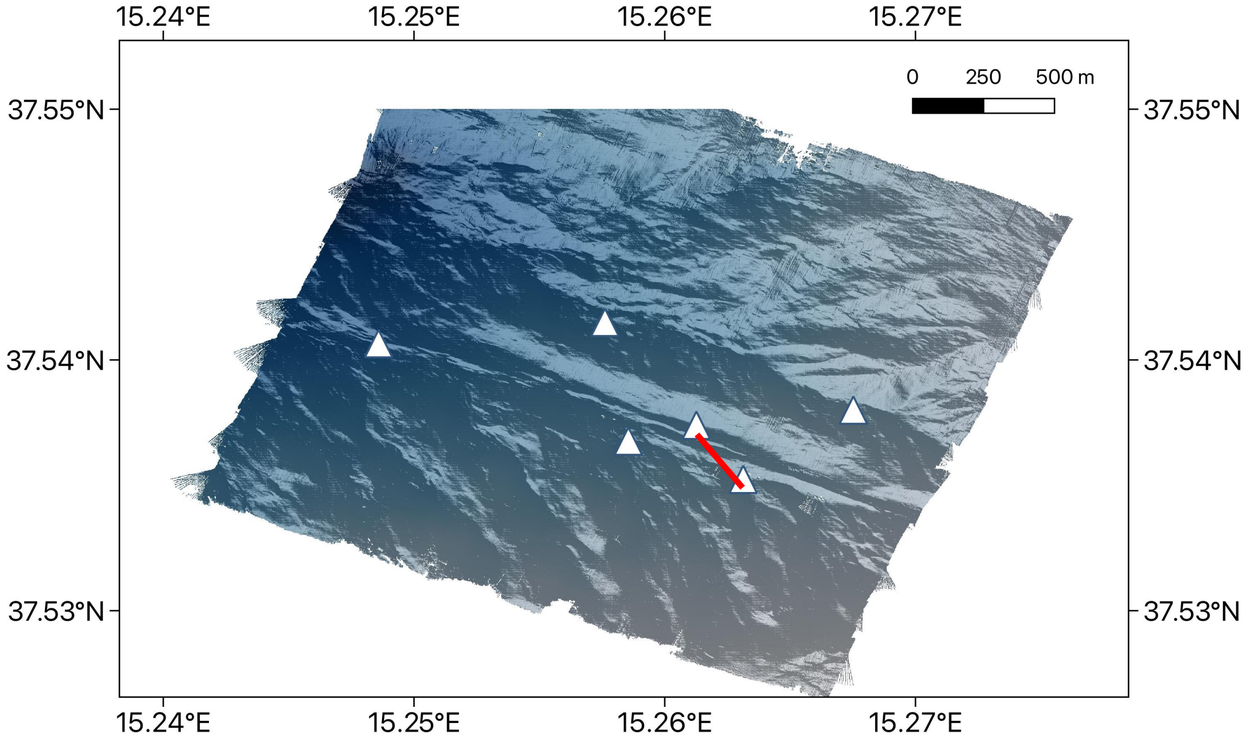


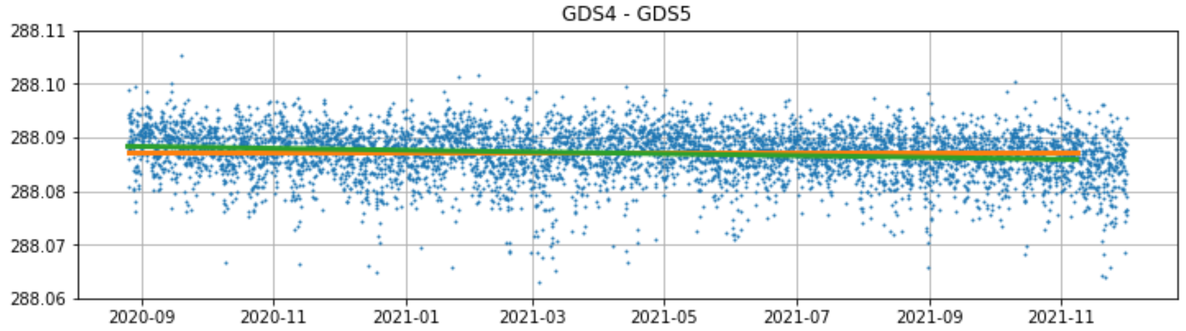


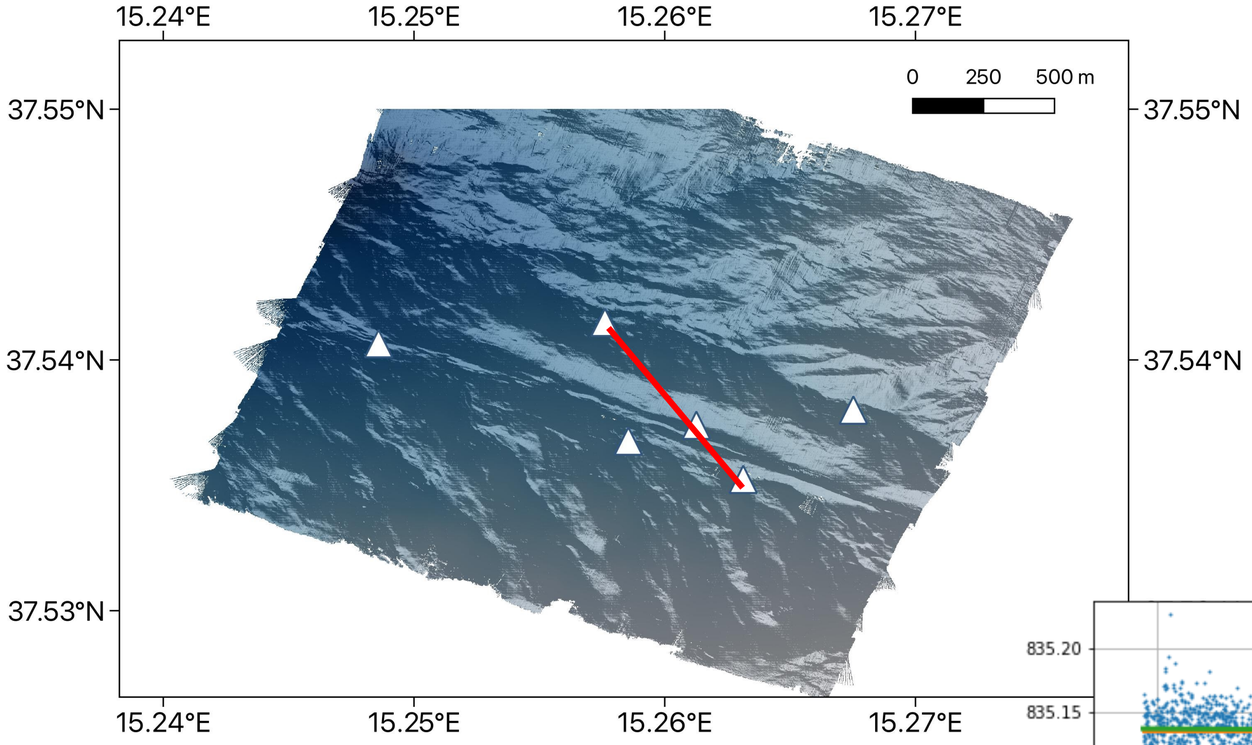
Mean over all
Mean of start vs. end

- Ongoing shortening in acoustic distance since August 2020.
- Baseline change equals ~8 micro strain between transponders 4 – 5.

Deployment in August 2020

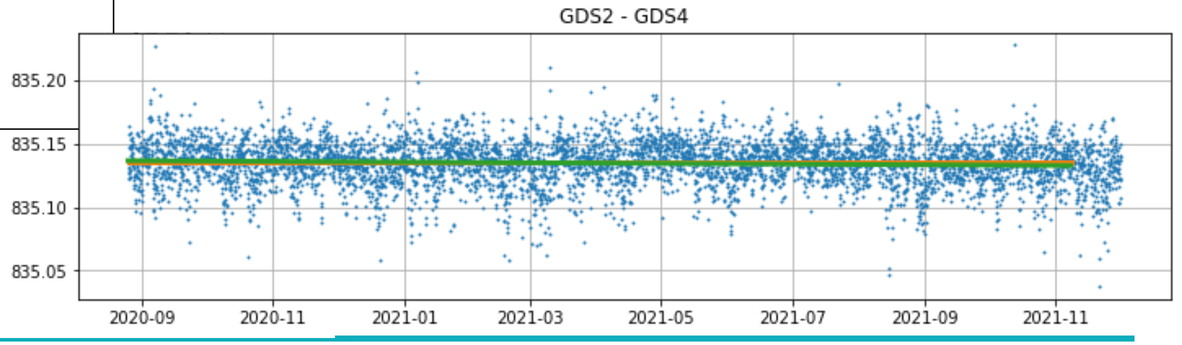
- 6 transponders with 3 stations close to the fault





Mean over all
Mean of start vs. end

- Ongoing shortening in acoustic distance since August 2020.
- Baseline change equals ~4 micro strain between transponders 4 – 2.



Short-term deformation:

- Detection of one slow-sip event with up to 4 cm displacement in 18 days.

- Slow-slip event revealed fault motion behavior (right-lateral strike-slip and possible releasing bend deformation).

- Combination of short and longer baselines across a distinct strike-slip fault are the most promising network configuration for a direct-path ranging network.

Long-term deformation:

- Possible monitoring of long-term deformation in late 2017 with up to 8 -10 micro strain and in 2020 with up to 4 - 8 micro strain.

- Longer observation periods needed to provide evidence of long-term seafloor deformation.

- Both longer (< 2 km) and short baselines are able to monitor long-term deformation.