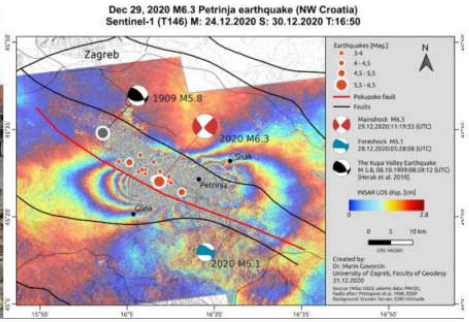


Danijel Šugar

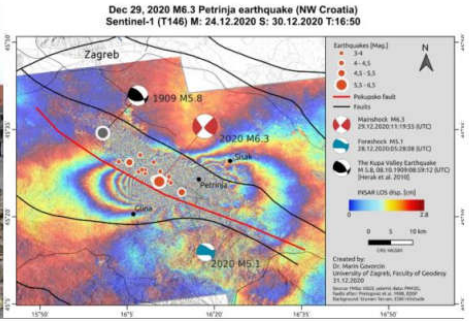
EO4GEO training: Fast disaster response – satellite technologies for surface displacement monitoring

GNSS

July 12th – 14th, 2021

University of Zagreb – Faculty of Geodesy

Co-funded by the Erasmus+ Programme of the European Union



Danijel Šugar

EO4GEO training: Fast disaster response – satellite technologies for surface displacement monitoring

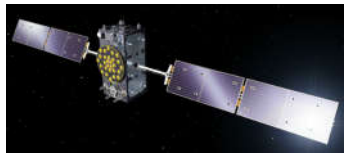
Kinematic behavior of CROPOS ZAGR station during the M5.5 earthquake (22nd March 2020) assessed by GNSS method

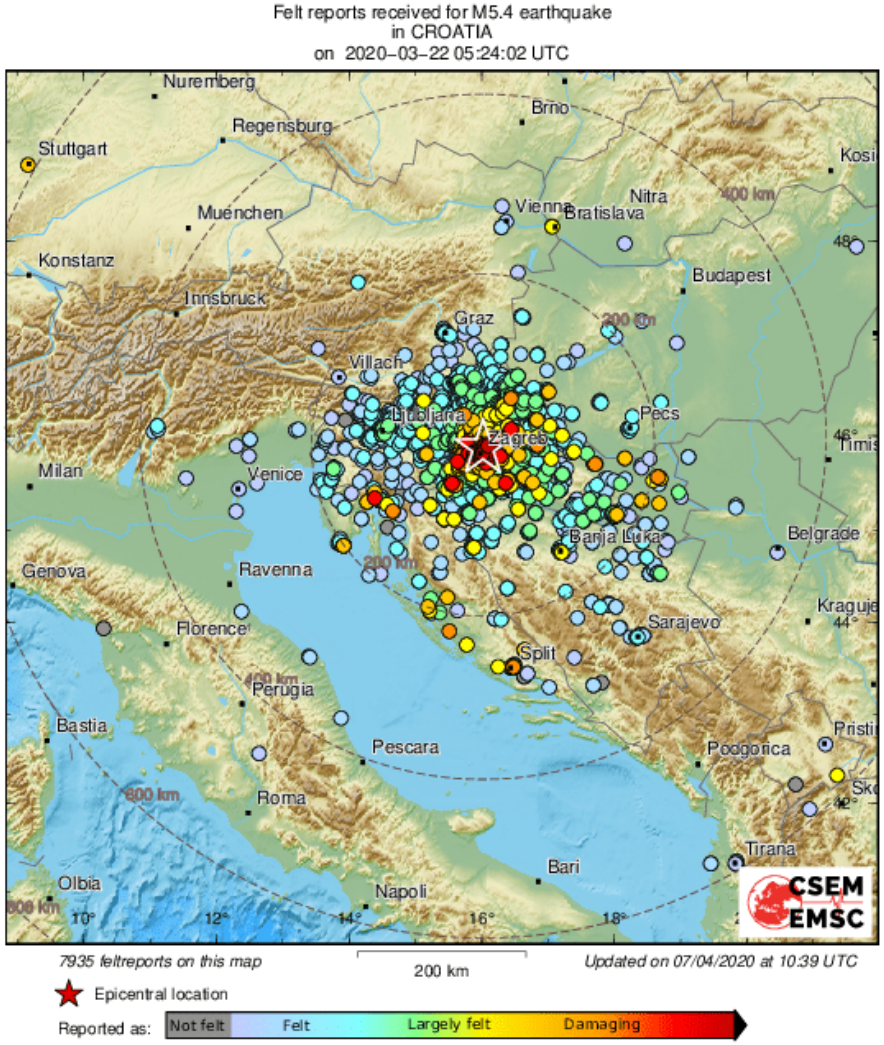
University of Zagreb – Faculty of Geodesy

E04GEO training 13 & 14 July 2021

Co-funded by the Erasmus+ Programme of the European Union

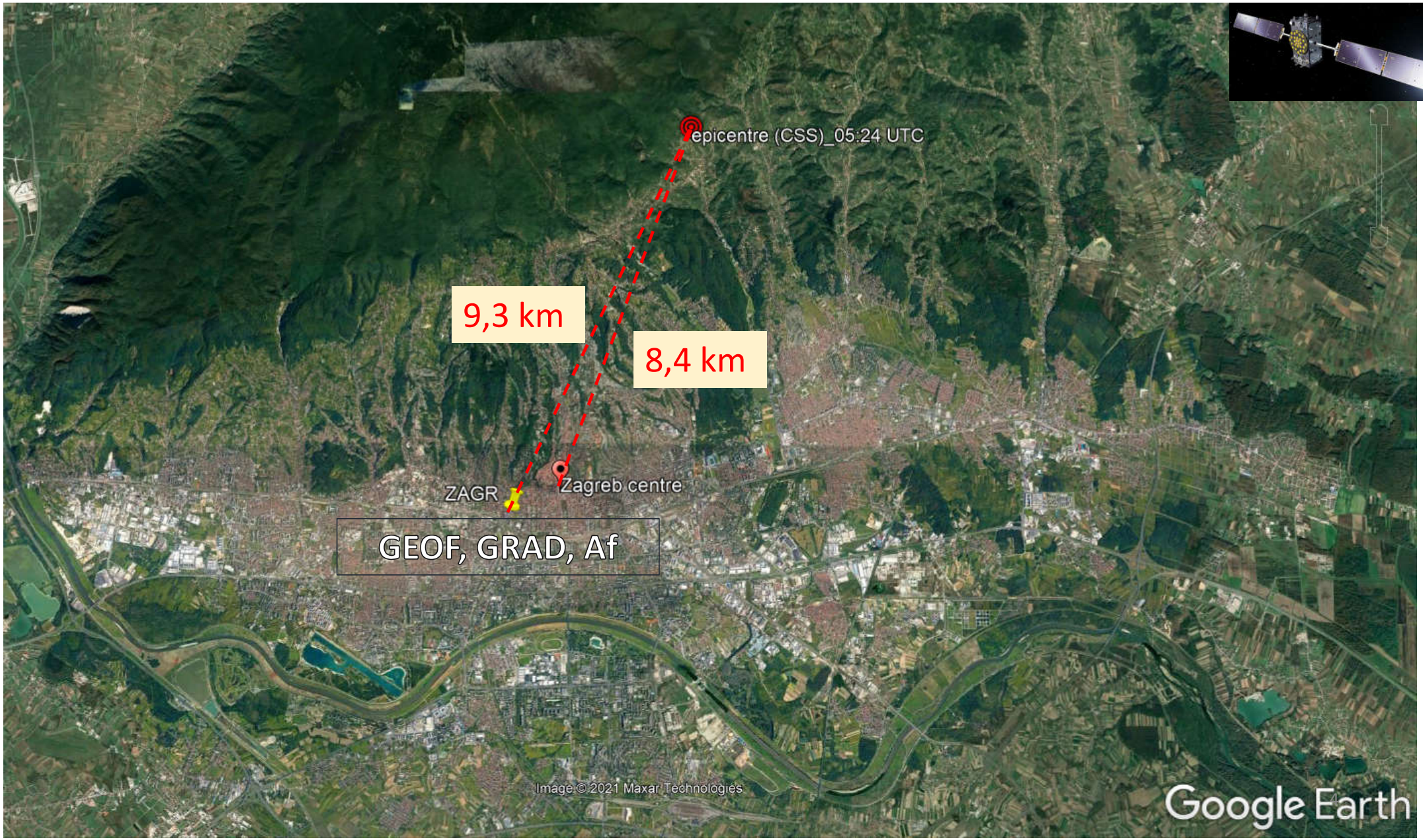
Zagreb earthquake, 22nd March 2020



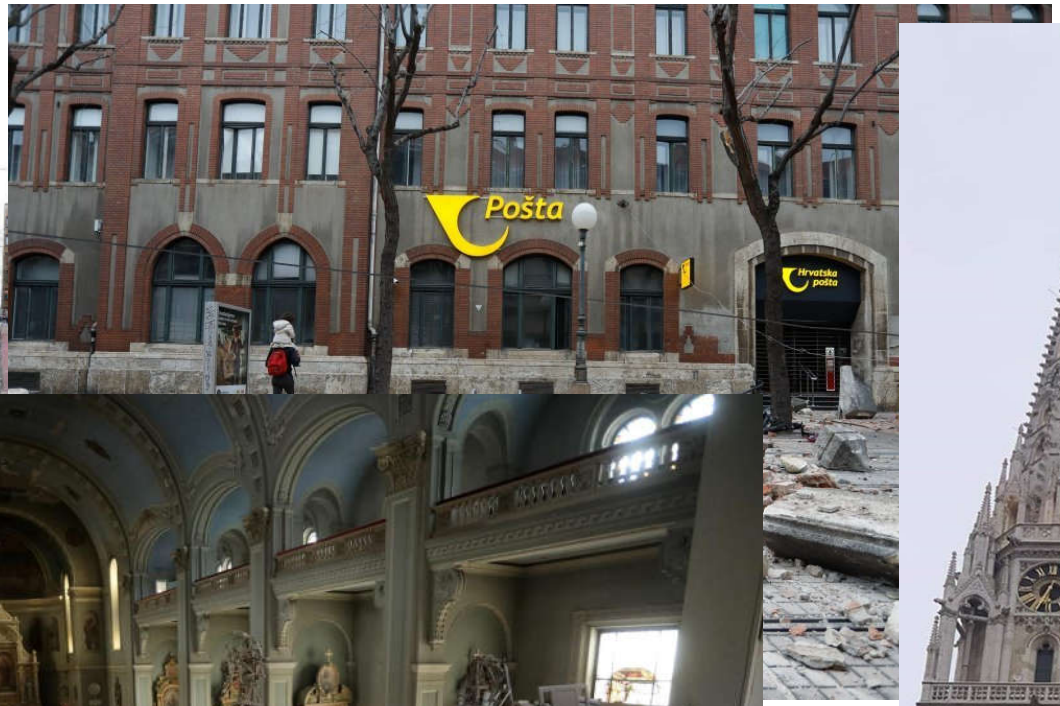


https://www.emsc-csem.org/#2

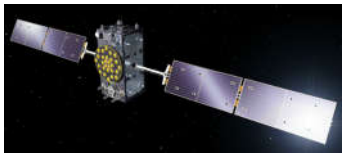
Source	Croatian Seismological Survey (CSS)
Latitude	45.884°
Longitude	16.013°
Depth	8.3 km
Magnitude	M_L = 5.5
Time of origin	05:24:03.1 UTC

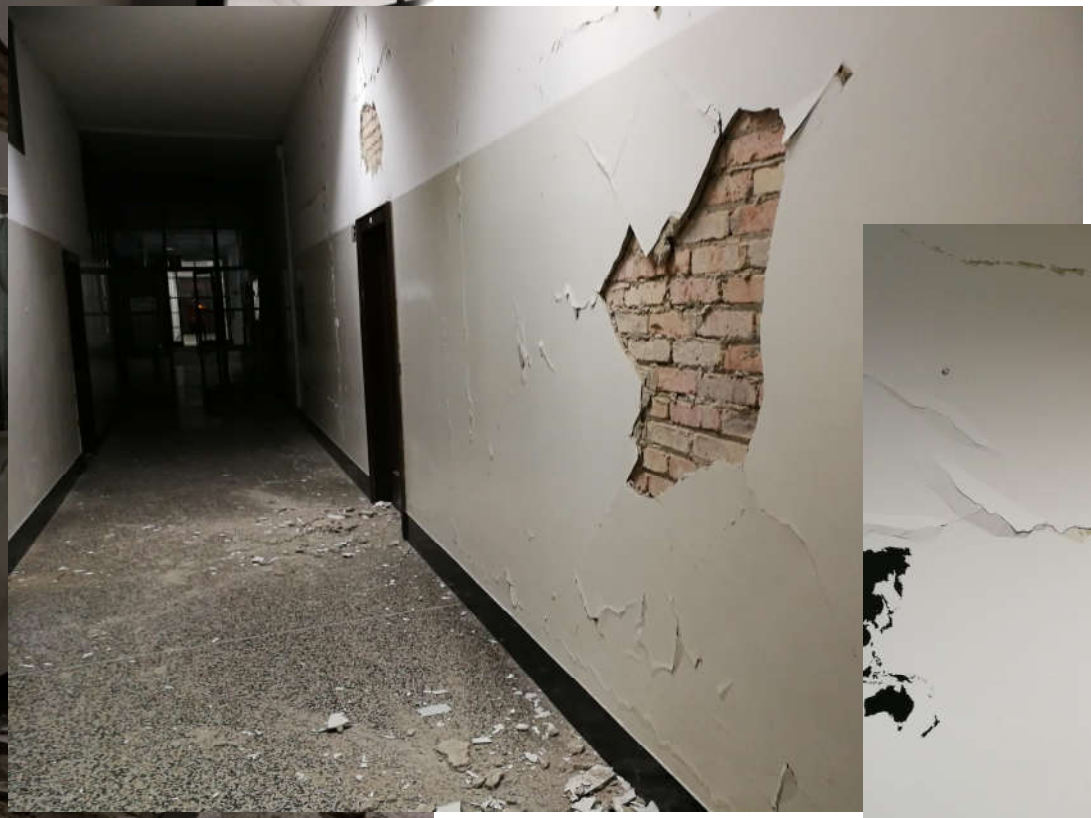

epicentre (CSS)_05:24 UTC
9,3 km
8,4 km
ZAGR
Zagreb centre
GEOF, GRAD, Af
Image © 2021 Maxar Technologies
Google Earth

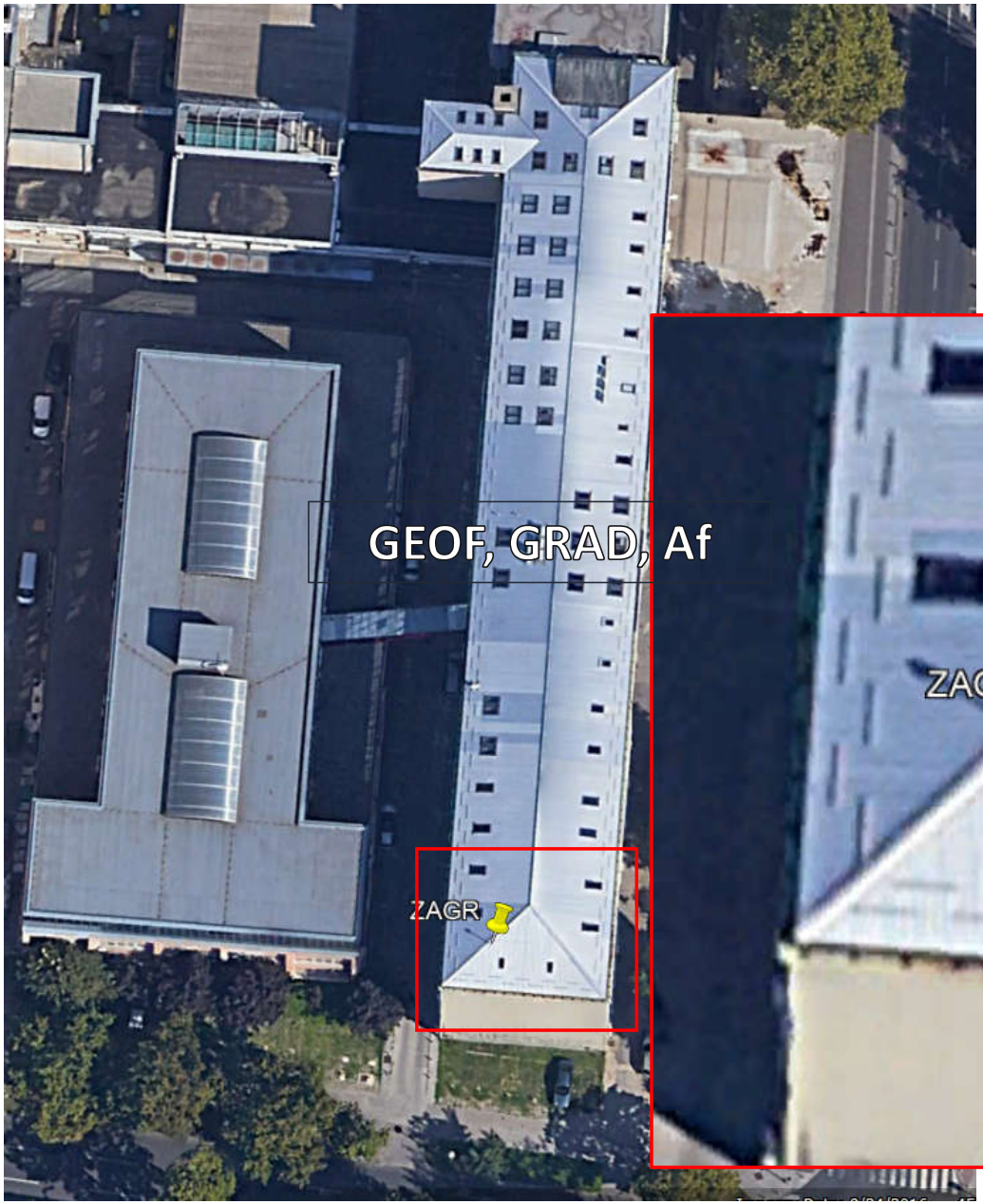
Zagreb centre, 22nd March 2020



GEOF, GRAD, Af: 22nd March 2020



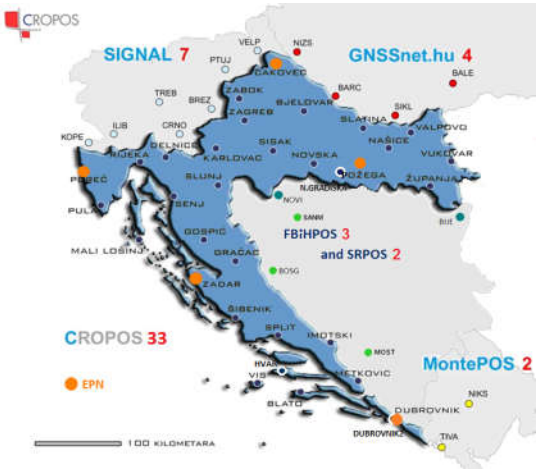



GEOF, GRAD, Af
ZAGR


ZAGR

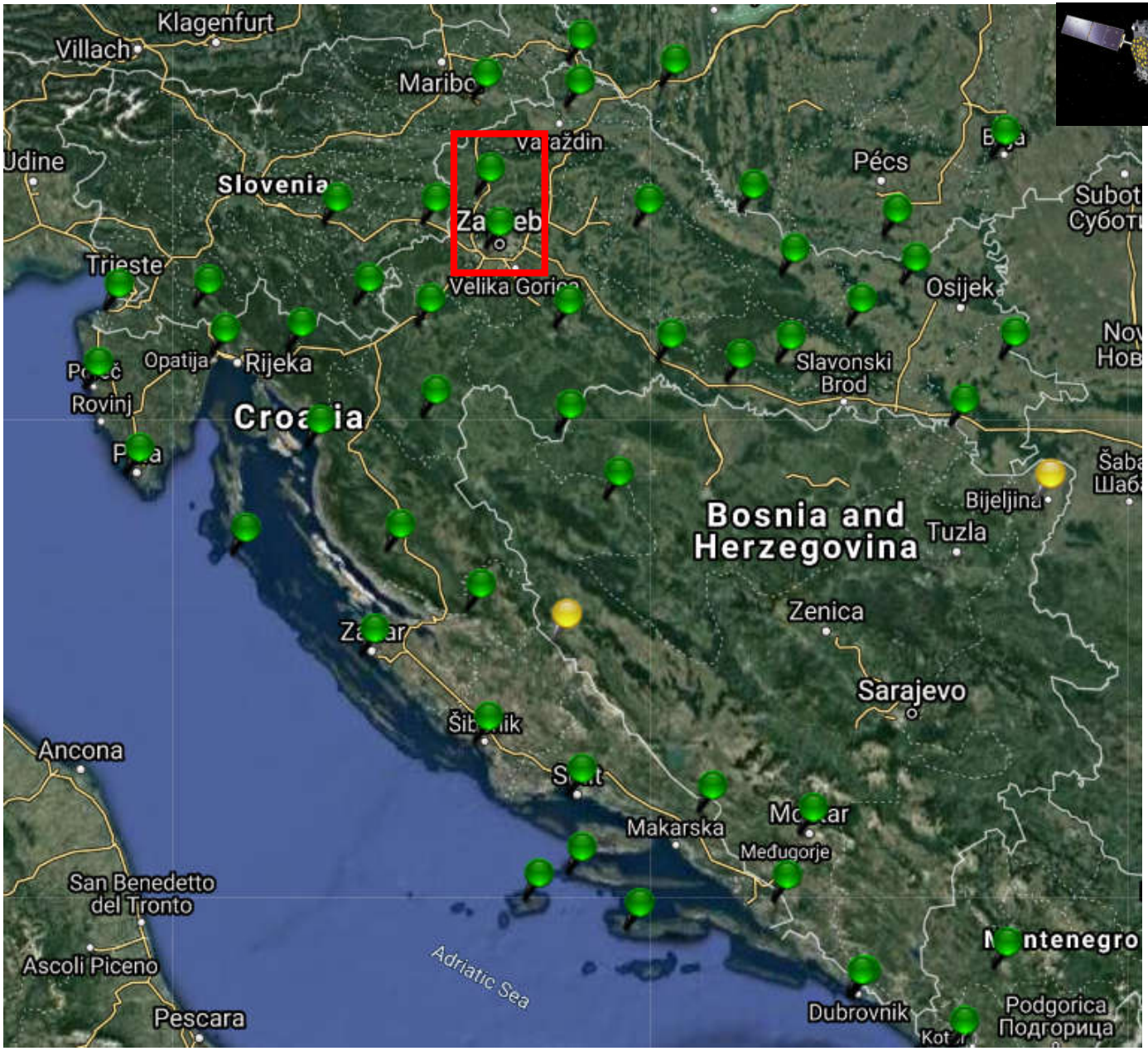
CROPOS

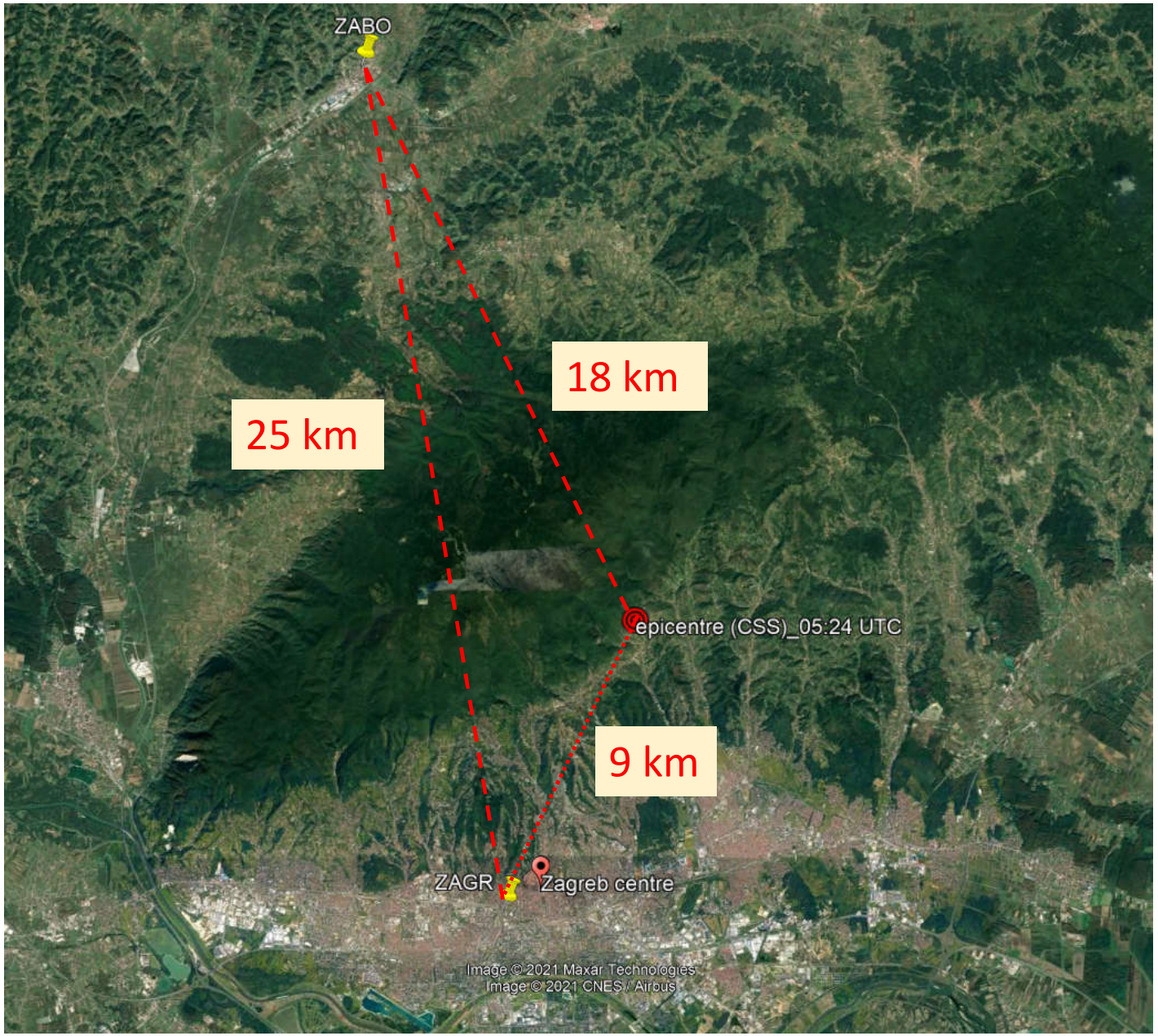
- 33 stations (HR)
- 18 stations from neighboring networks
- Σ = 51 stations

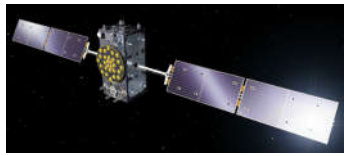


CROPOS

https://www.cropos.hr/




ZABO
18 km
25 km
epicentre (CSS)_05:24 UTC
9 km
ZAGR
Zagreb centre
Image © 2021 Maxar Technologies
Image © 2021 CNES / Airbus



CROPOS

- established in 2008 (GPS, GLO)
- modernized in 2019 (GPS, GLO, GAL, BDS)

CROPOS &GALILEO

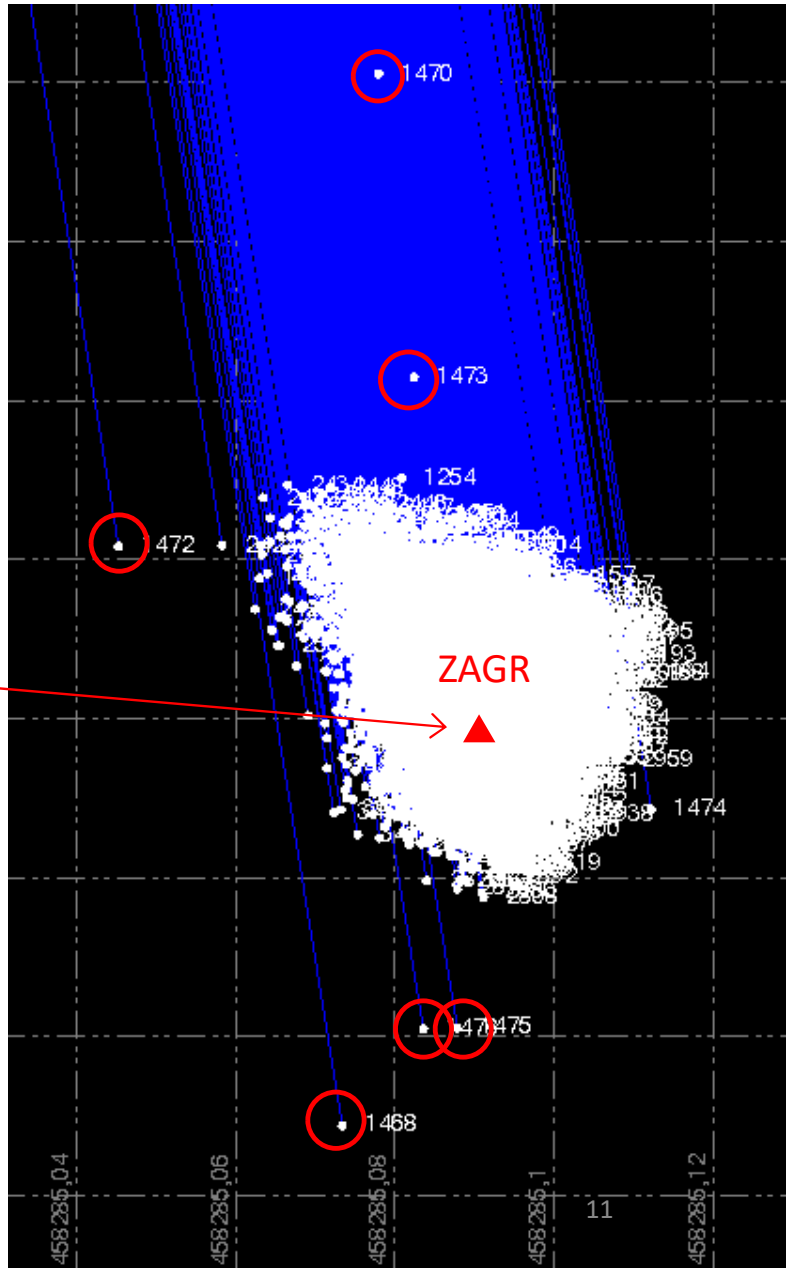
CROPOS

ZAGR

ZABO

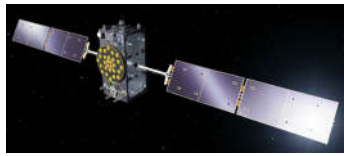
GNSS observations & processing

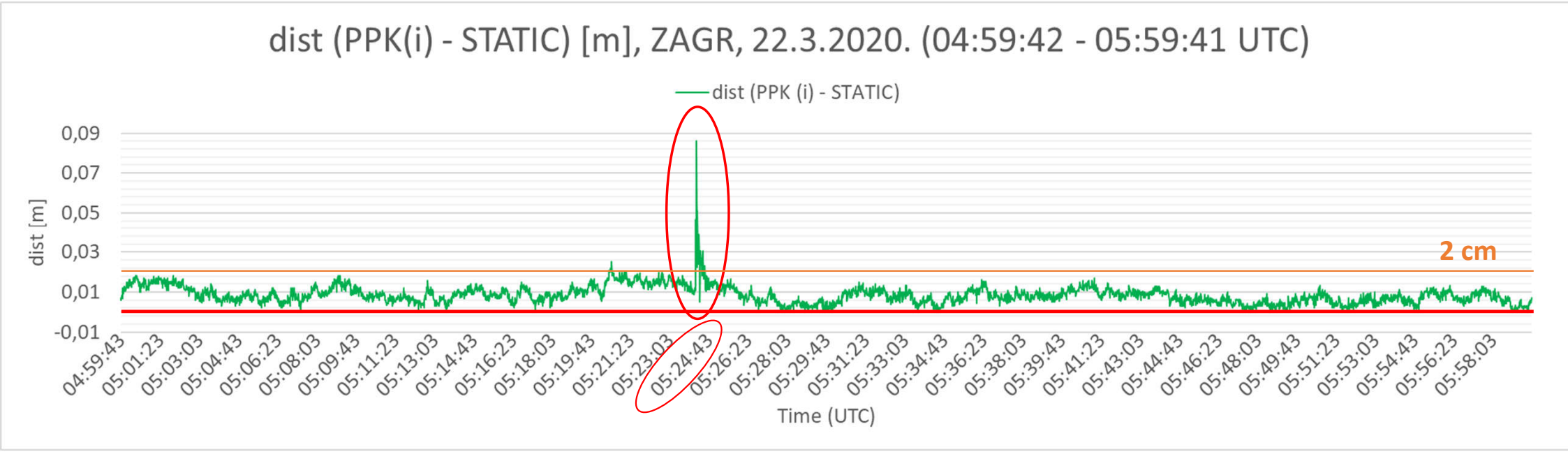
- Relative positioning (static, kinematic)
- ZAGR, ZABO
- 22nd March 2020
- Observation Data: GPS, GLONASS, Galileo, BeiDou
- 24 hours (15 sec)→ STATIC solution
- 5-6 GPST (1 sec) → Post-Processed Kinematic (PPK) solution (3600)
- Trimble Business Center (TBC)
- 3D solution (E, N, H)
  - HTRS96/TM (Easting, Northing)
  - HVRS71 (Height)



PPK(i) – STATIC: (5-6 GPST)

UTC – GPST = +18 s



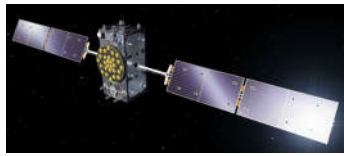


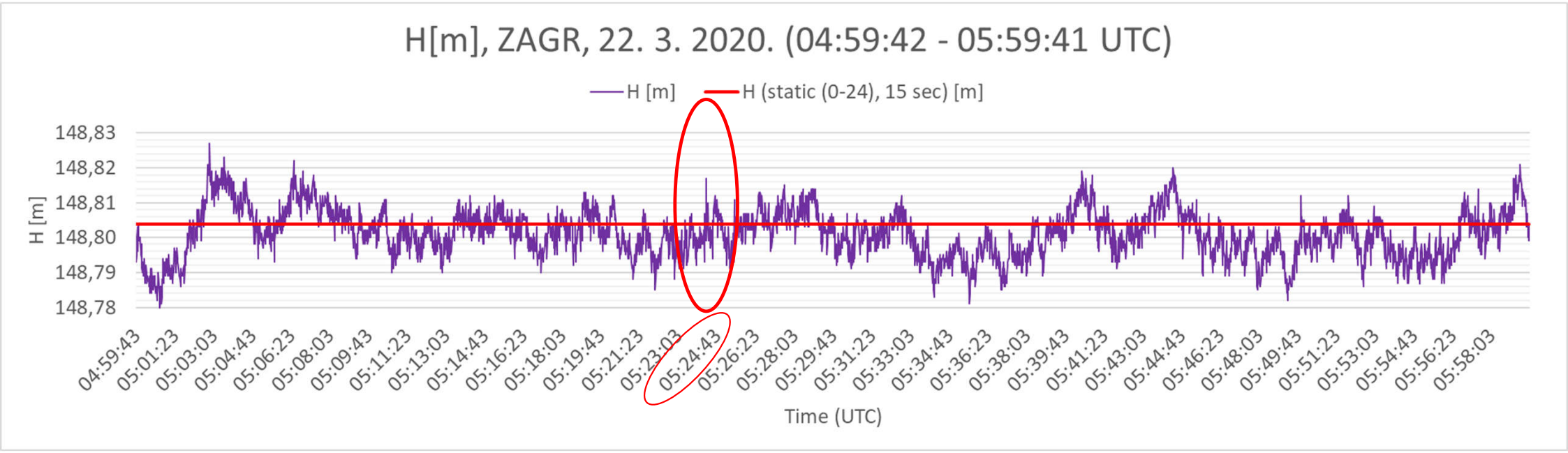
$$dist(PPK(i) - STATIC) = +\sqrt{(E(PPK(i) - E(STATIC))^2 + (N(PPK(i) - N(STATIC))^2}$$

- level of bias and noise: 2 cm (max 25 mm)
- no permanent displacement

PPK(i) – STATIC: (5-6 GPST)

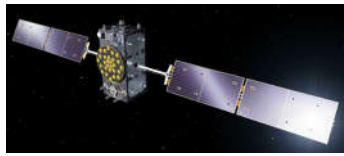
UTC – GPST = +18 s

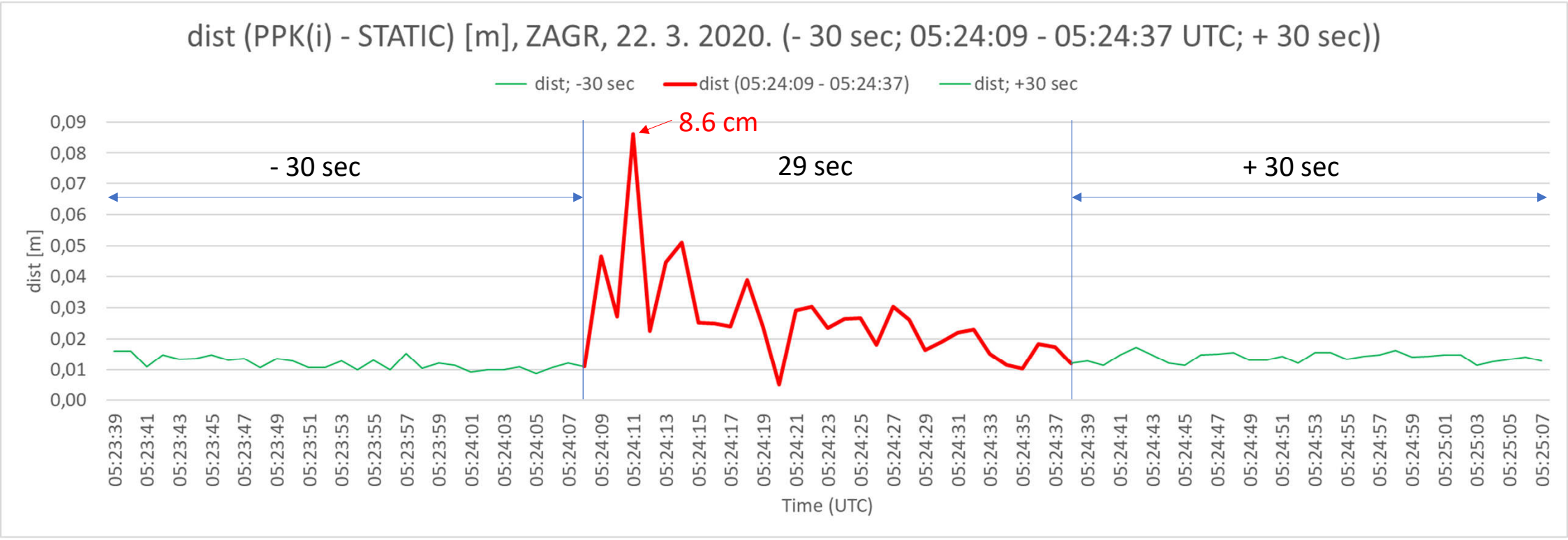




- level of bias and noise: ± 24 mm
- no permanent displacement

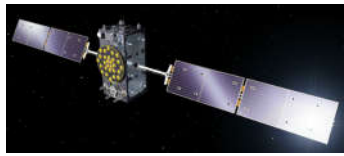
Kinematic assessment of the mainshock

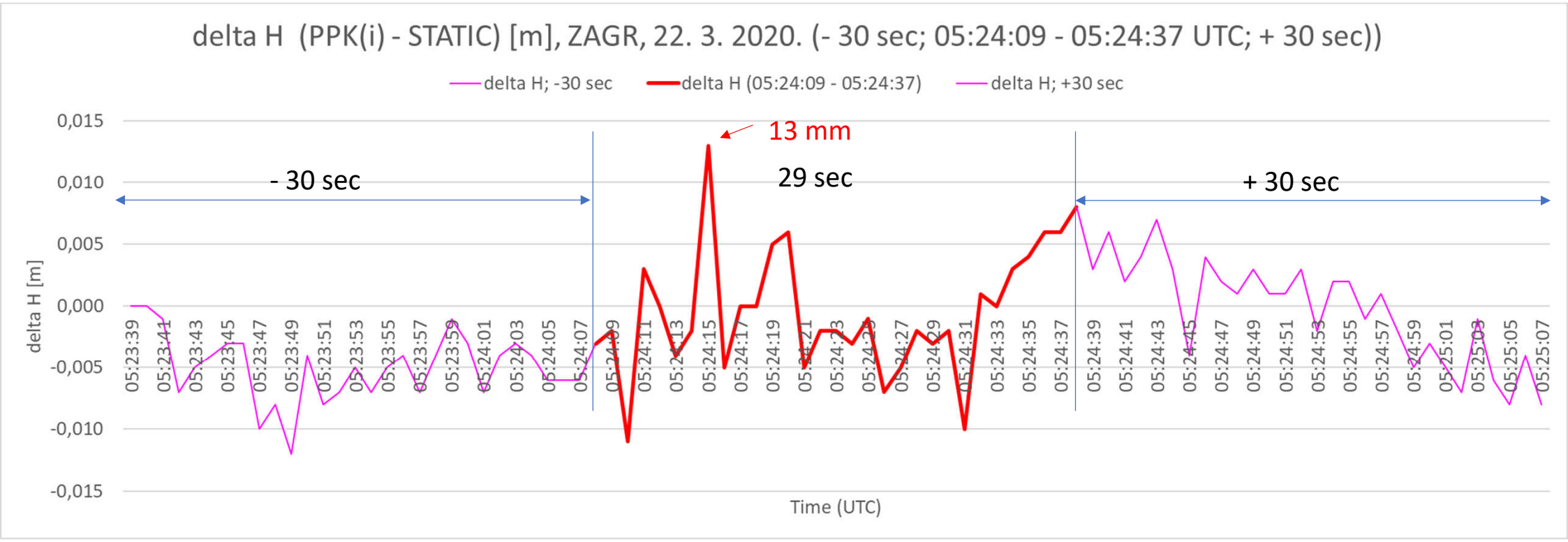




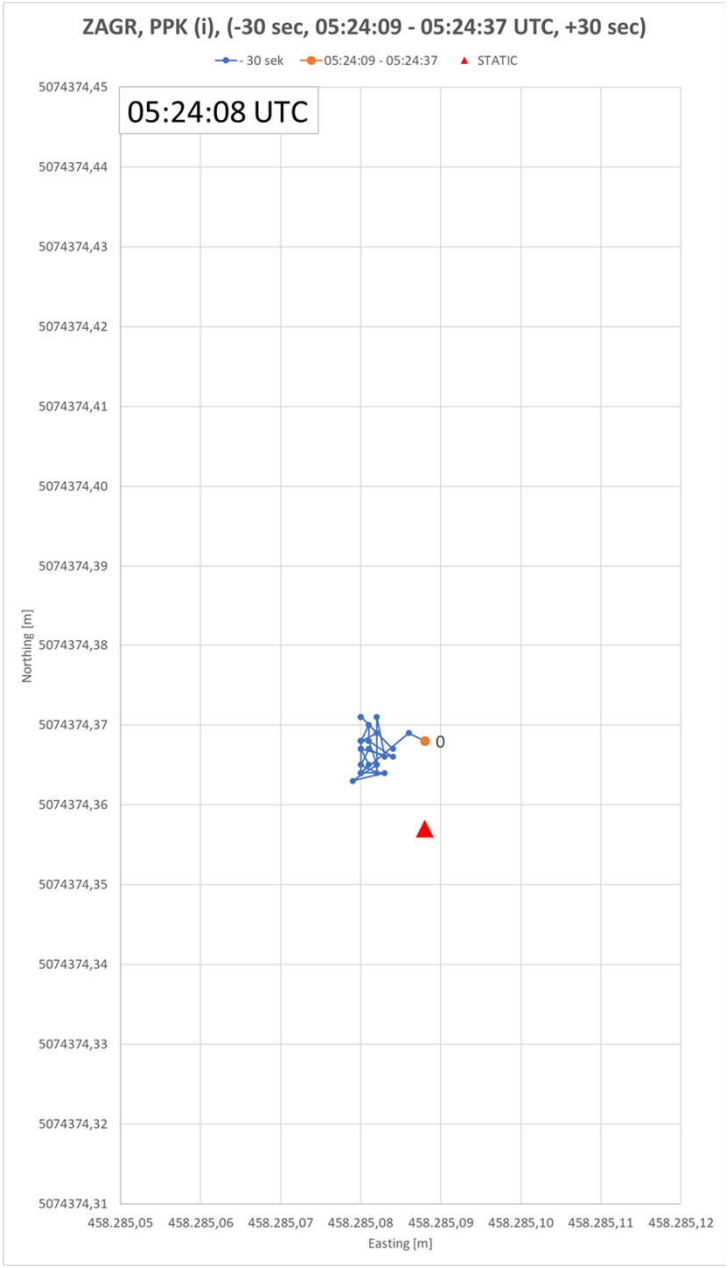
- level of bias and noise (< 2 cm)
- no permanent displacement

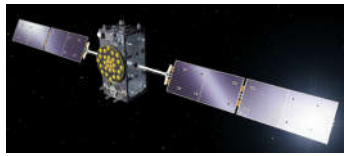
Kinematic assessment of the mainshock

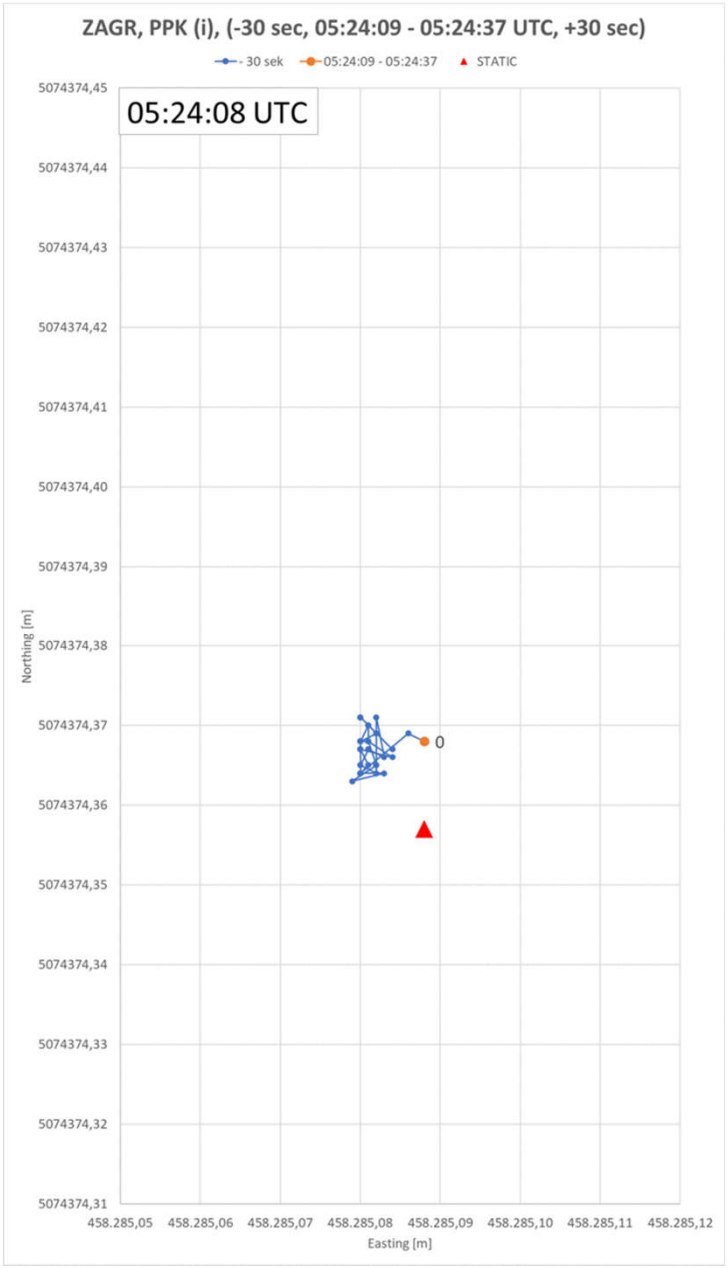


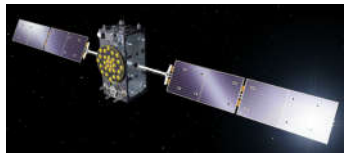


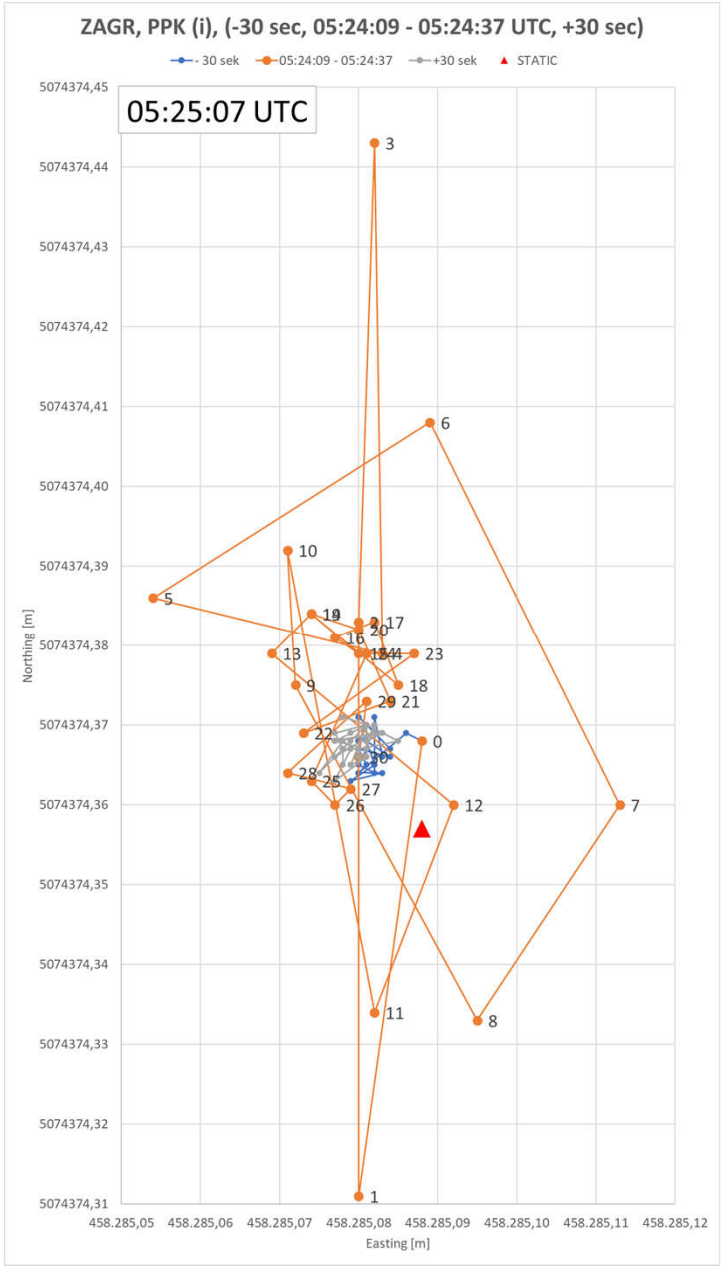
- present some level of bias and noise
- that could be a consequence of GNSS antenna swinging during the mainshock


ZAGR, PPK (i), (-30 sec, 05:24:09 - 05:24:37 UTC, +30 sec)
30 sek
05:24:09 - 05:24:37
STATIC
05:24:08 UTC
5074374,45
5074374,44
5074374,43
5074374,42
5074374,41
5074374,40
5074374,39
5074374,38
5074374,37
5074374,36
5074374,35
5074374,34
5074374,33
5074374,32
5074374,31
Northing [m]
0
458.285,05
458.285,06
458.285,07
458.285,08
458.285,09
458.285,10
458.285,11
458.285,12
Easting [m]




ZAGR, PPK (i), (-30 sec, 05:24:09 - 05:24:37 UTC, +30 sec)
30 sek
05:24:09 - 05:24:37
STATIC
05:24:08 UTC
5074374,45
5074374,44
5074374,43
5074374,42
5074374,41
5074374,40
5074374,39
5074374,38
5074374,37
5074374,36
5074374,35
5074374,34
5074374,33
5074374,32
5074374,31
Northing [m]
0
458.285,05
458.285,06
458.285,07
458.285,08
458.285,09
458.285,10
458.285,11
458.285,12
Easting [m]




ZAGR, PPK (i), (-30 sec, 05:24:09 - 05:24:37 UTC, +30 sec)
- 30 sek
05:24:09 - 05:24:37
+30 sek
STATIC
05:25:07 UTC
Northing [m]
Easting [m]
5074374,45
5074374,44
5074374,43
5074374,42
5074374,41
5074374,40
5074374,39
5074374,38
5074374,37
5074374,36
5074374,35
5074374,34
5074374,33
5074374,32
5074374,31
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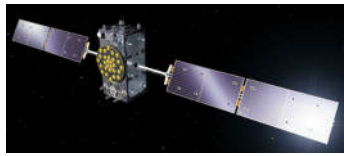
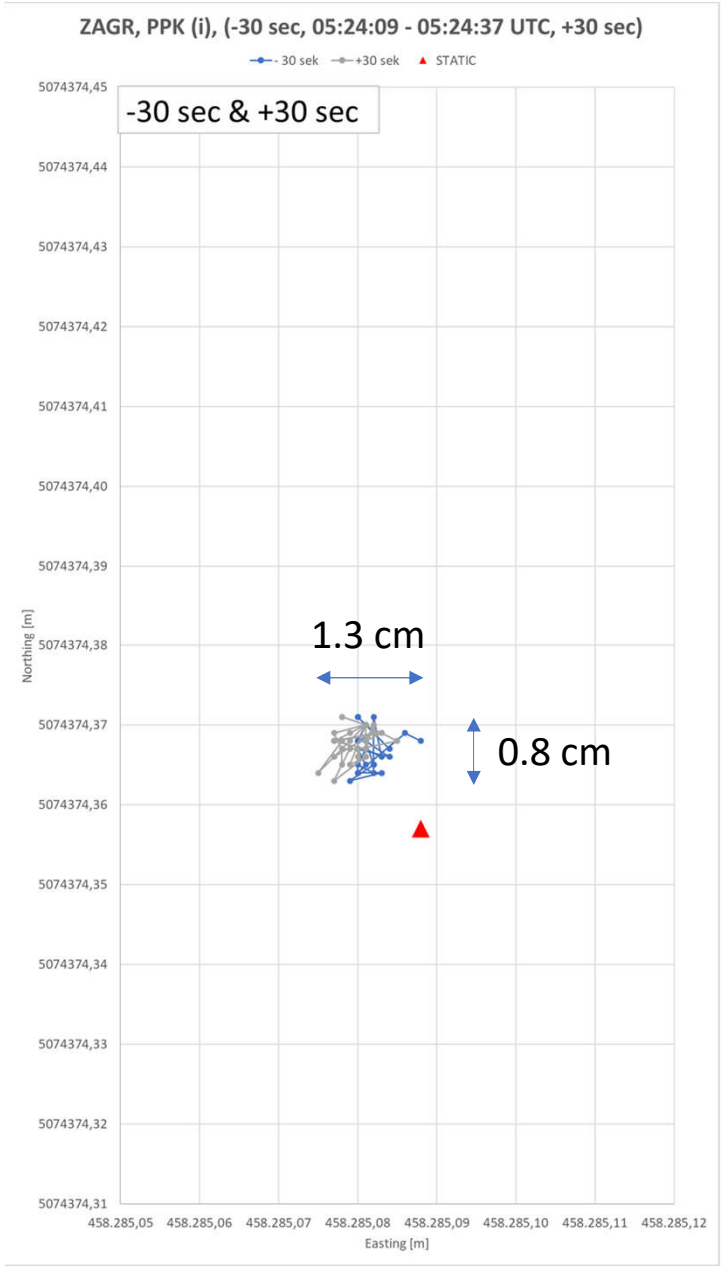
458.285,07
458.285,08
458.285,09
458.285,10
458.285,11
458.285,12




ZAGR, PPK (i), (-30 sec, 05:24:09 - 05:24:37 UTC, +30 sec)
- 30 sek
+30 sek
STATIC
-30 sec & +30 sec
1.3 cm
0.8 cm
Northing [m]
Easting [m]
5074374,45
5074374,44
5074374,43
5074374,42
5074374,41
5074374,40
5074374,39
5074374,38
5074374,37
5074374,36
5074374,35
5074374,34
5074374,33
5074374,32
5074374,31
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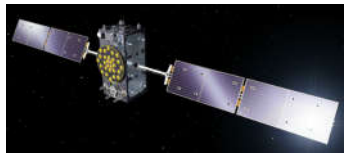
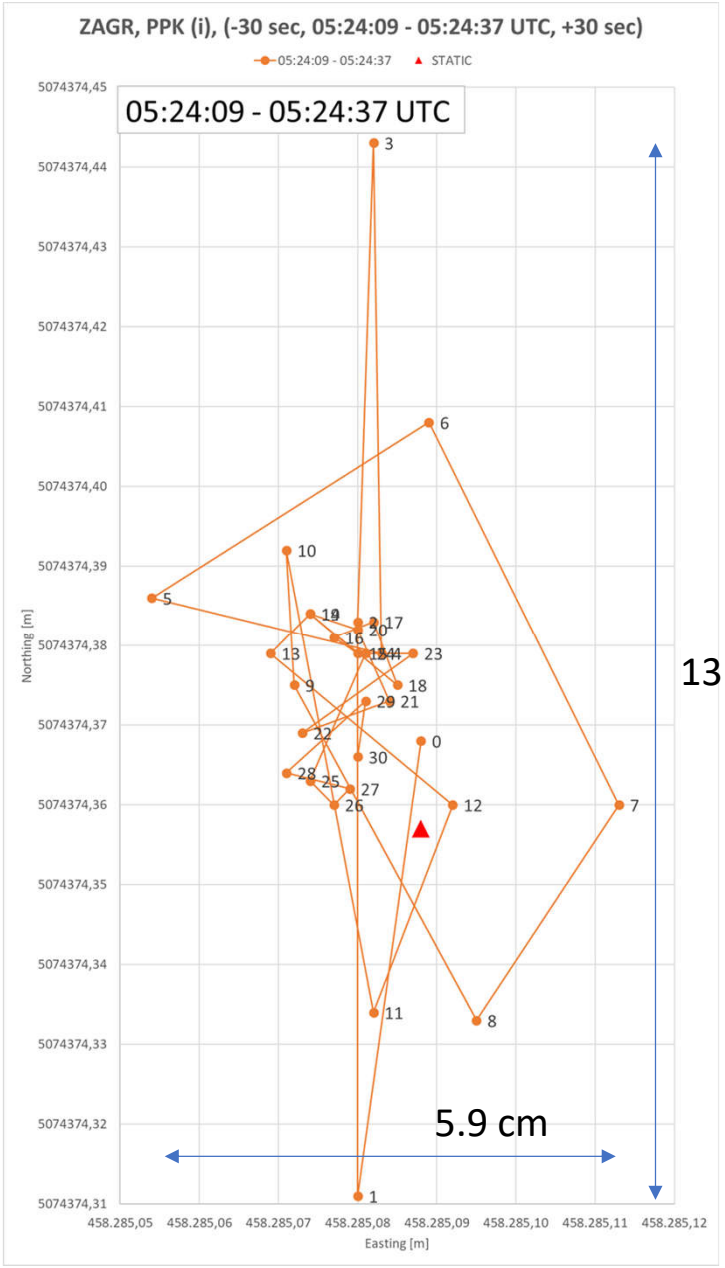
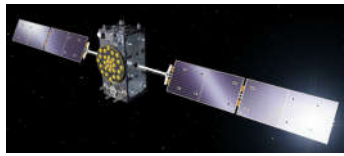
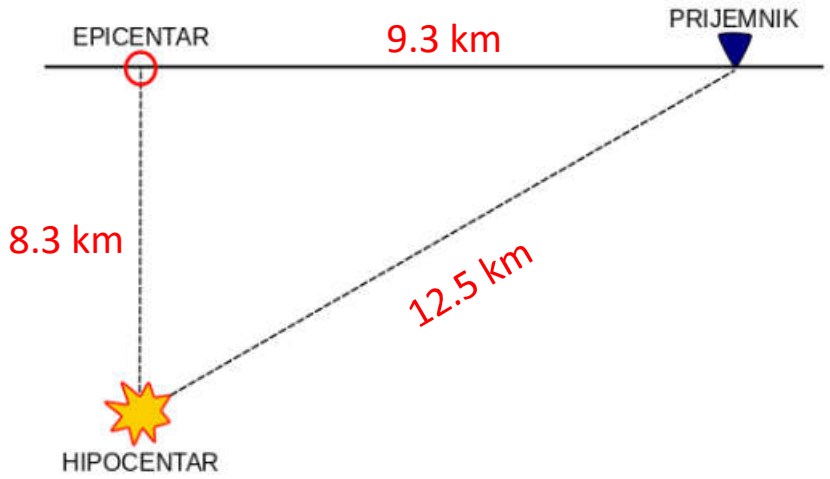
458.285,09
458.285,10
458.285,11
458.285,12







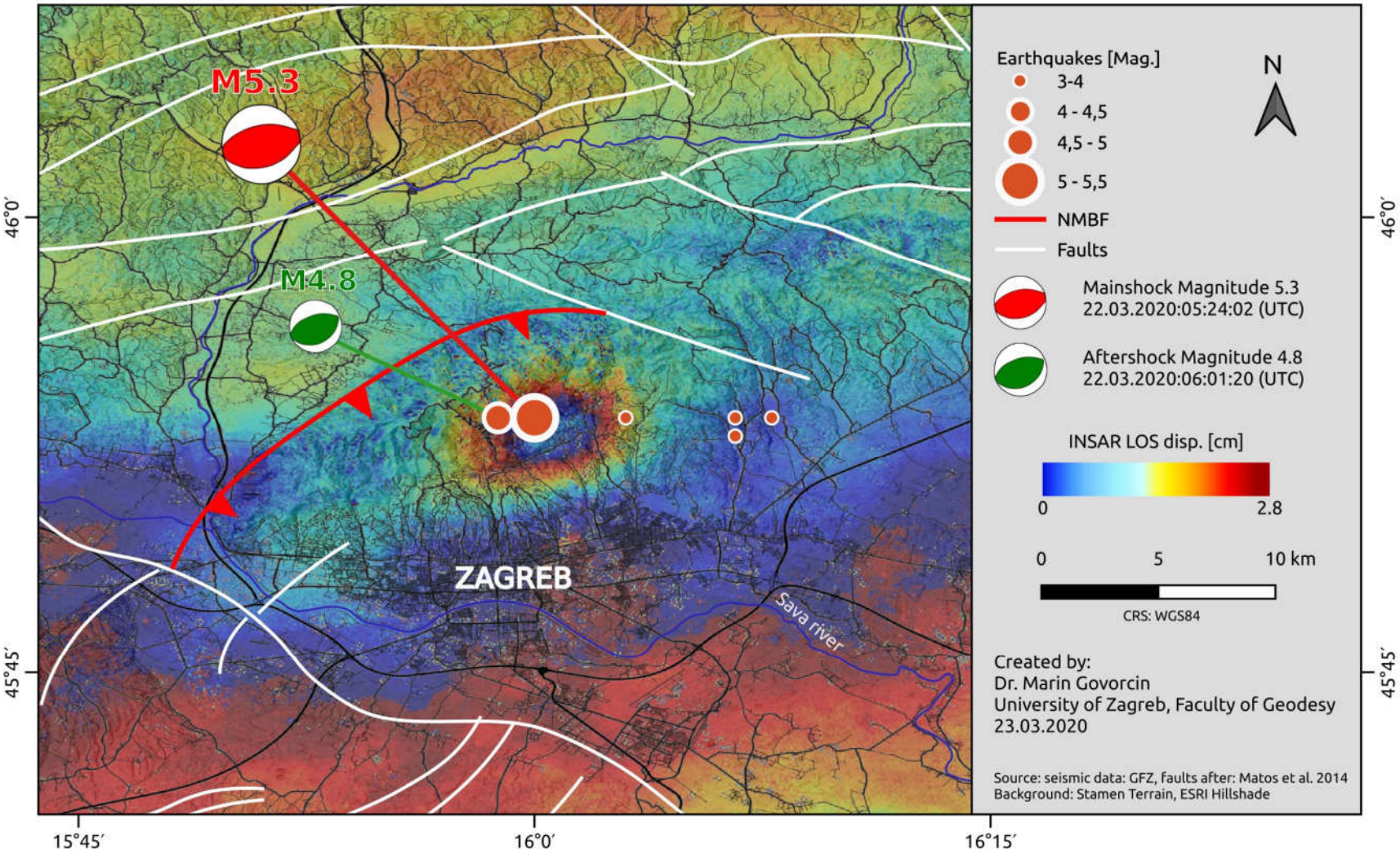


https://www.pmf.unizg.hr/geof/seizmoloska_sluzba/seizmoloski_pojmovnik

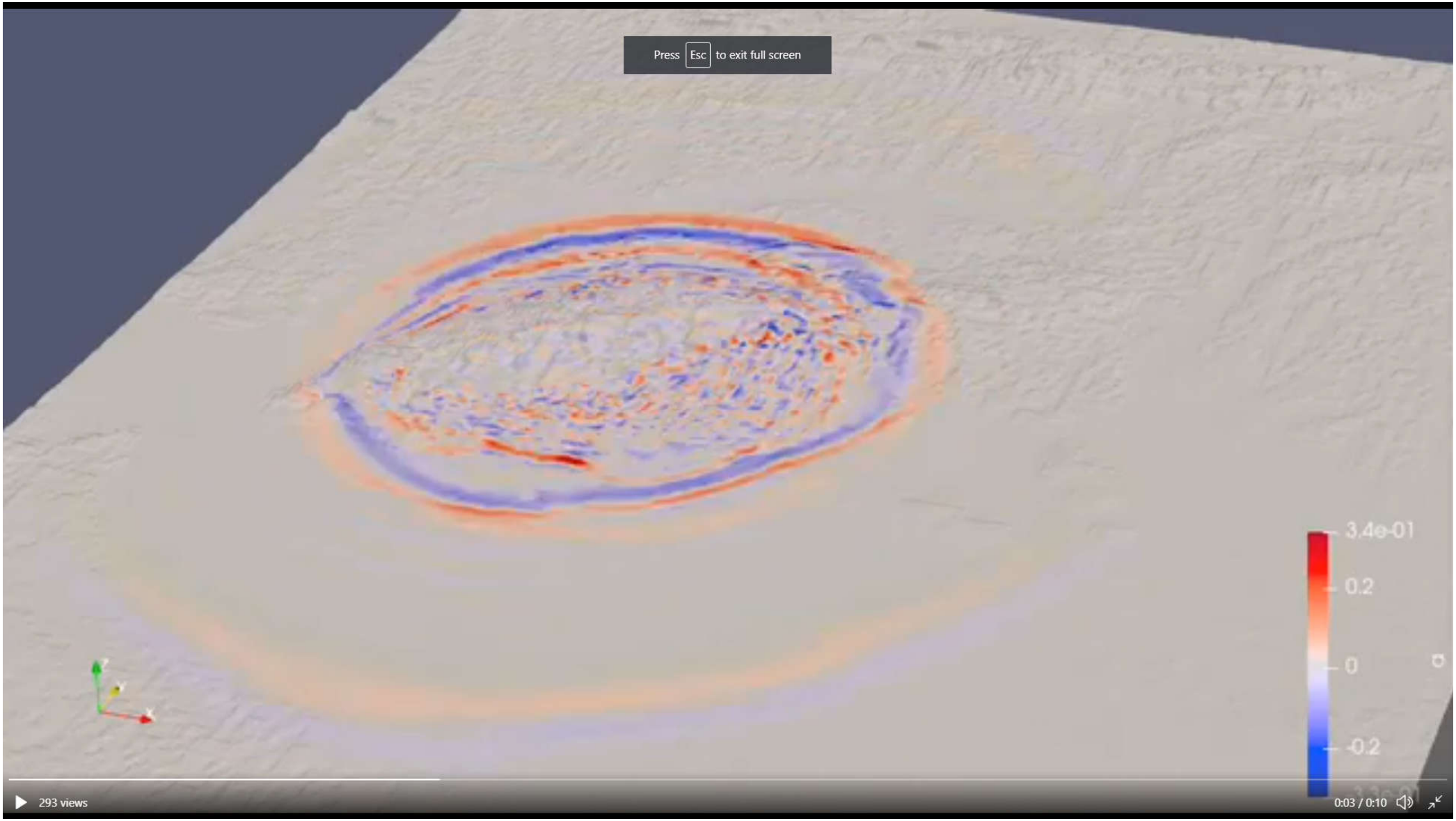
$$v = \frac{\Delta s}{\Delta t} = 12.5\ \text{km} / 6\ \text{s} \approx 2.1\ \text{km/s}$$

- average speed of seismic waves

Mar 22, 2020 M5.3 and M4.8 Zagreb earthquake (NW Croatia)
Sentinel-1 (T146) M: 17.03.2020 S: 23.03.2020 T:16:50



https://twitter.com/Govorcin/status/1242433684168413186/photo/1



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