Assessing GNSS-derived displacements at the near and far-field of the 2023 Turkey earthquake doublet

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Introduction

On February 6th, 2023 at 01:17:35 UTC the M_w 7.8 Nurdağı-Pazarcık earthquake nucleated ~15 km southeast of the mapped trace of the East Anatolian Fault Zone. Relocations place the hypocenter at (37.0234° E, 37.2444° N, depth=12 km) and analyses of teleseismic data show a left-lateral source mechanism on a vertical or near vertical fault. A vigorous aftershock sequence followed and a little over 9 hours after the first event, at 10:24:49 UTC, the M_w 7.6 [2]

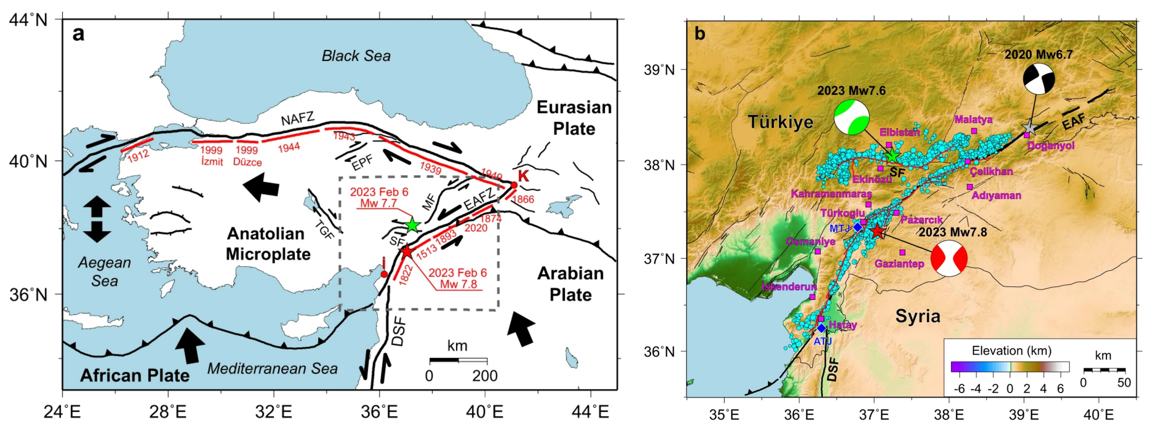

Figure 1:Tectonic backround (a) and focal mechanisms (b) of 2023 Turkey earthquake doublet [1].

GNSS Network & Data processing

Data from 57 continuously operating GNSS stations in distances ranging from 800km to 1500km from the epicentre were analyzed.

Station Equipment:

- Receiver type: LEICA (most of them GR30, also GRX1200GGPRO / GRX1200+GNSS)
- Antenna type LEICA LEIAR10 / LEIAS10 (few stations: LEIAX1202GG)
- Observation interval: 1s

Processing scheme:

- Precise Point Positioning with Ambiguity Resolution using PRIDE-PPPAR Software [3].
- Satellite systems: GPS / GLO / GAL / BDS-2/3
- Elevation angle: 7 deg
- Kinematic mode
- Reference Frame: IGS20
- Final IGS Products for satellite
- ANTEX File: IGS20_2247
- Tropospheric modeling: VMF1

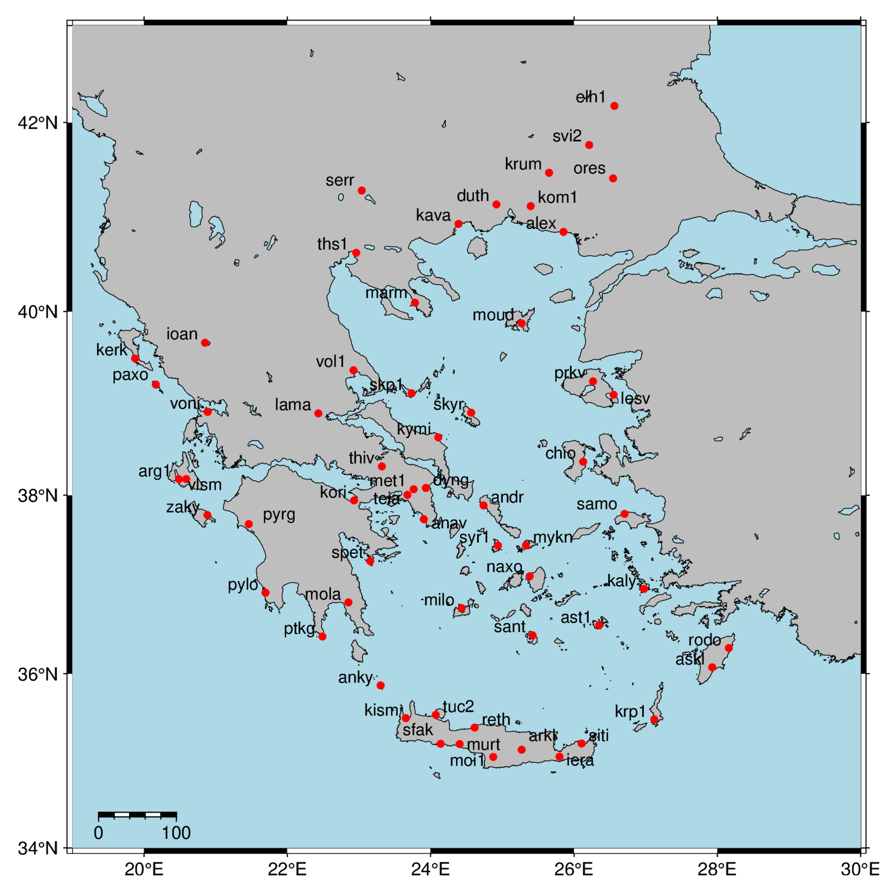

Figure 2:Distribution of permanent GNSS stations analyzed.

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Data Analysis

The low-frequency noise of the GNSS stations which could be due to various error sources (multipath error, unmitigated troposphere effect, etc.), potential seismic displacement of the GNSS stations was masked. Since no co-seismic displacement was expected at the stations (>800km distance from epicentres), we applied a high-pass 'Butterworth' filter with cut-off frequency of 0.1Hz to remove any low-frequency noise of the GNSS data and without affecting significantly the potential dynamic displacement of the GNSS stations.

The time interval of the transient seismic response of each GNSS was defined with starting time the time of the seismic event plus the required time of P-waves (assuming P-waves velocity of 6km/s) to travel at the respective GNSS station and covering a period of 400 seconds to ensure that all the transient response is captured.

For the defined period, the Peak Ground Displacement (PGD) of neu was defined as the max values of the respective time-series.

For the noise level estimation of the filtered neu time-series, we computed the standard deviation for the 10-minute period before the first seismic event. We defined as the noise level, the rather conservative 3σ value to ensure that any response larger than this threshold corresponds to the transient seismic response.

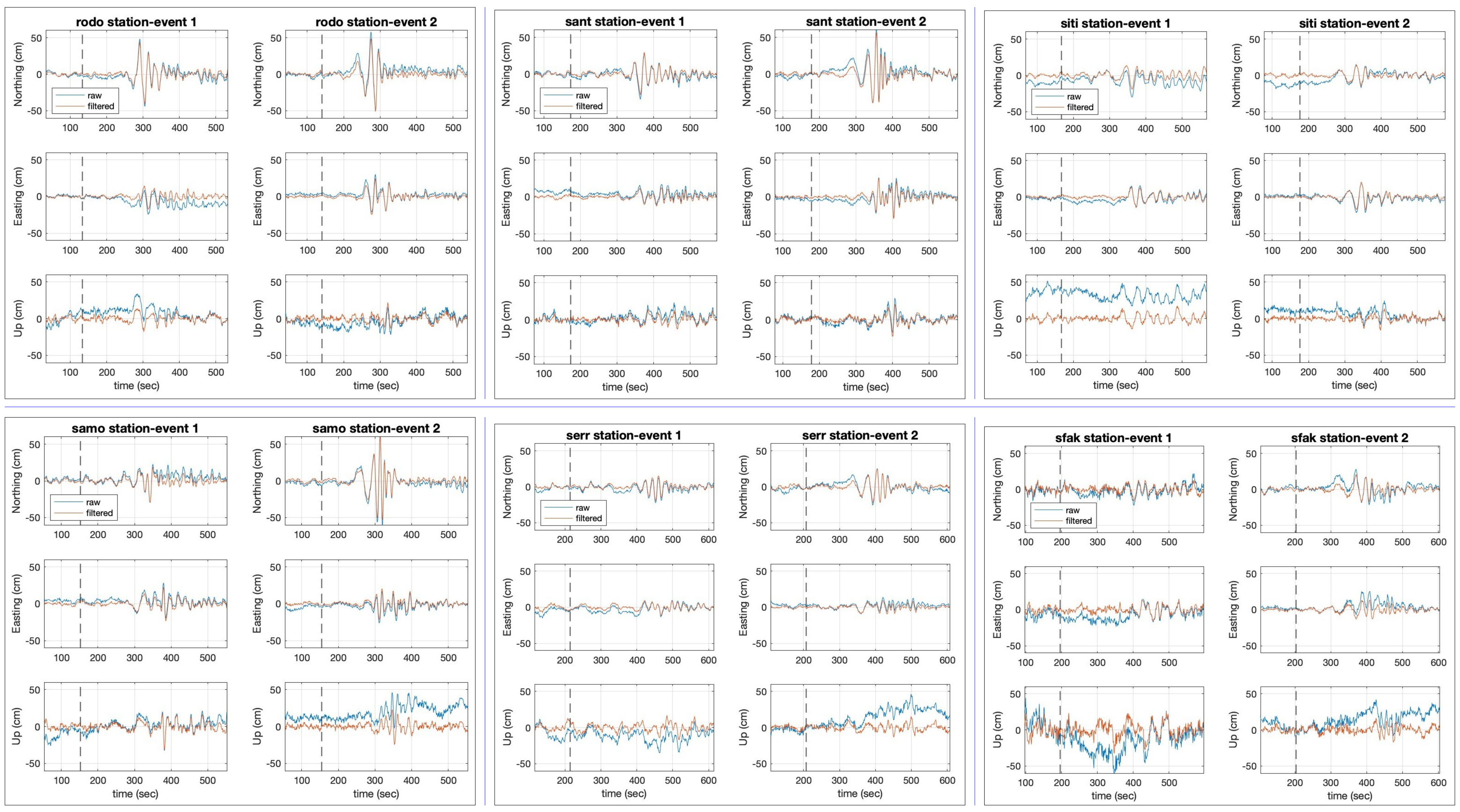

Figure 3:Raw and filtered time series analysis for six (6) stations.

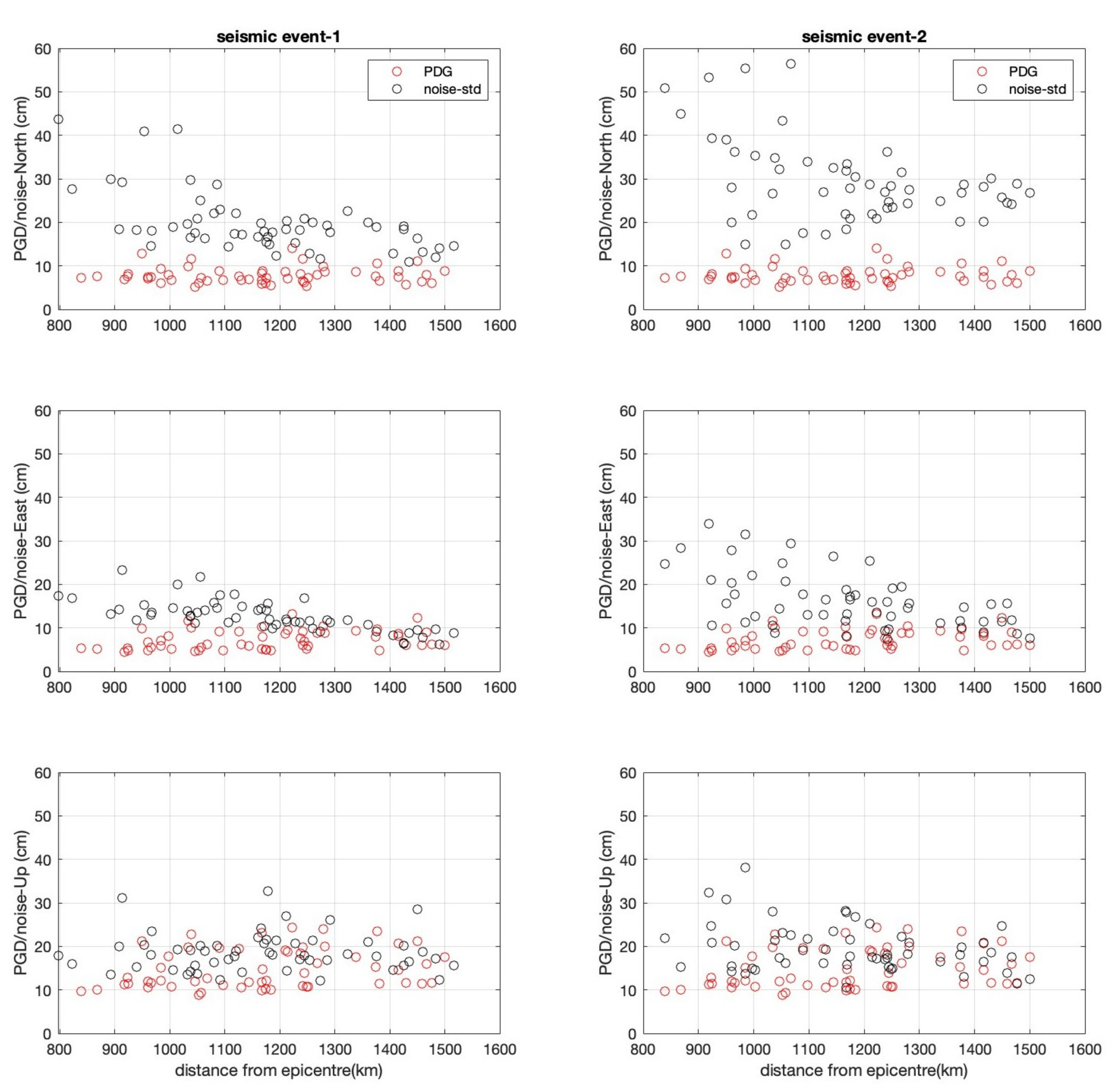

Figure 4:Diagrams of PGD maximum noise vs distance of all the stations for the two seismic events.

Discussion

From the first analysis of the PGD values the following points are observed:

- For both seismic events, in the northing component is observed the highest values of PGD indicating that the this direction is affected by the propagation of the seismic waves.
- The second seismic event has larger far-field impact probably due to the geometry of the seismic fault and the directivity of the seismic waves propagation.
- The Up component is not affected by the seismic events potentially due to the small impact that the S-waves may have for far-field stations.
- The PGD values tend to decrease with the distance from the epicentres. However it is obvious the impact of the directivity of the propagation of the seismic waves and the orientation of the seismic faults, as the PGD values of GNSS stations of similar distance from the epicentres has large range. For instance, the PGD values of the northing component of GNSS stations with 1000km epicentre distance for the second seismic event range between 20 to 60cm.

Next steps

- ◁ Investigate the far field of the directivity effect of the propagation seismic waves through the PGD of the GNSS stations.
- ◁ Investigate the frequency context of the seismic waves and its potential variation with the distance from the epicentre.
- ◁ Estimate of the seismic waves velocity as detected through the network GNSS stations displacement.

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[3] Jianghui Geng, Xingyu Chen, Yuanxin Pan, Shuyin Mao, Chenghong Li, Jinning Zhou, and Kunlun Zhang.
Pride ppp-ar: an open-source software for gps ppp ambiguity resolution.
GPS Solutions, 23(4), July 2019.