

GSeisRT: GNSS point positioning engine for wide-area geohazard monitoring in real time

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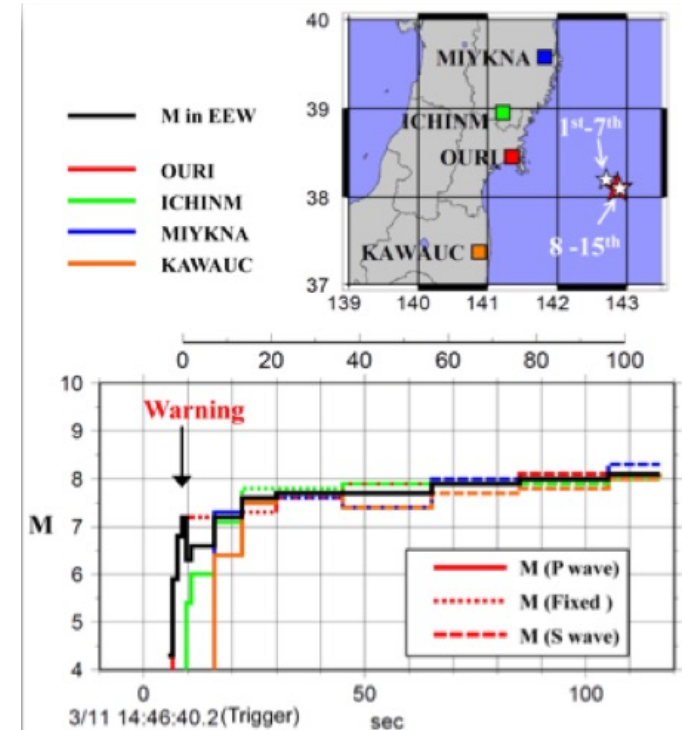
GNSS Research Center, Wuhan University, China

18 Oct 2023

Madrid, Spain

Rapid response to earthquakes/tsunamis

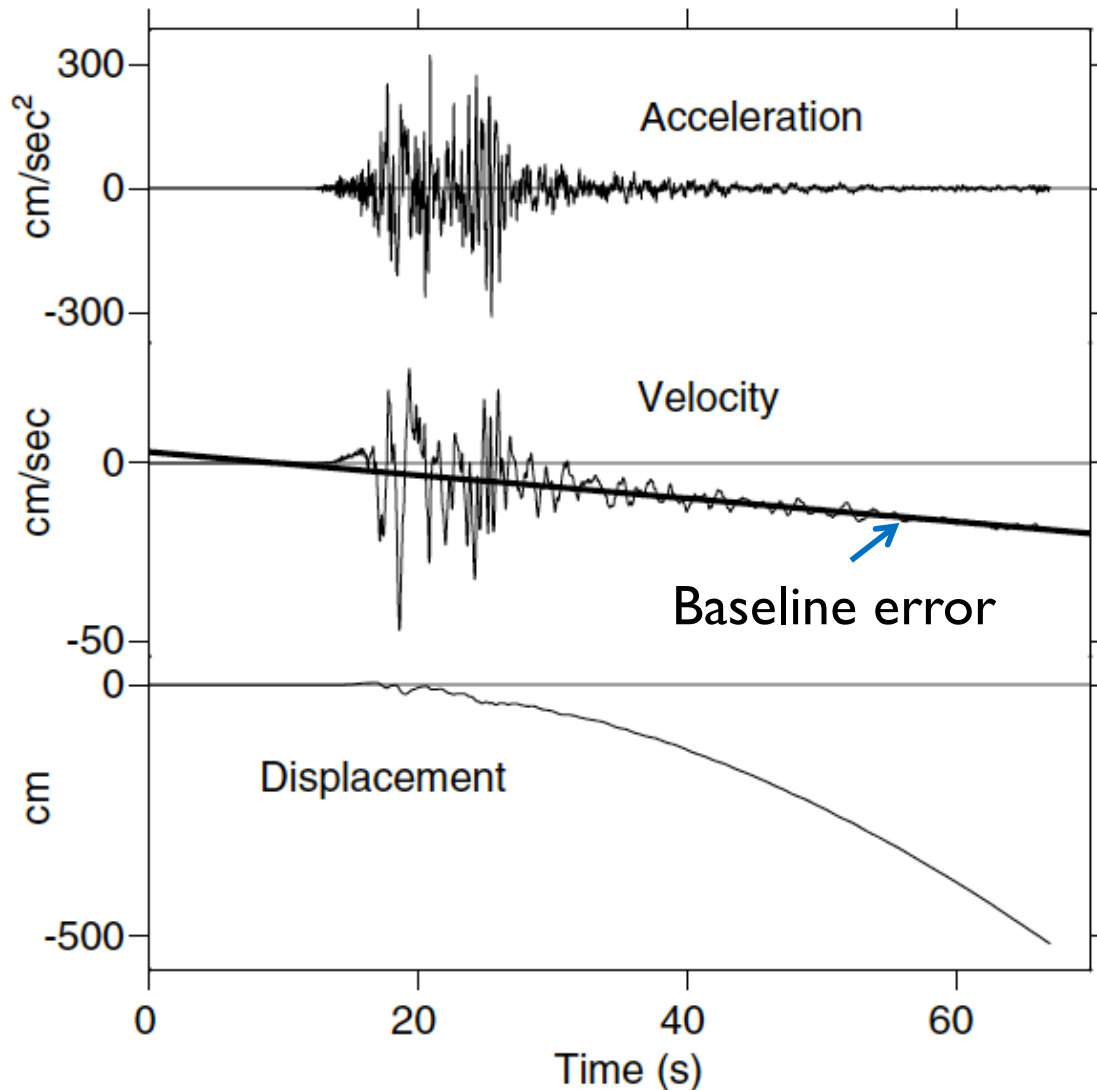
- Increasing resilience to earthquakes
 - Capture earthquake motions in real time
 - Rapid magnitude determination
 - Issue timely & accurate alerts
- However, lessons from 2011 M9.0 Tohoku-Oki earthquake/tsunami response
 - Seismic sensors to capture motions
 - M7.9 only until hours later
 - Underestimate evacuation regions
 - Tens of thousands of casualties



Ozaki 2011

Challenges to seismic sensors

- Drifting displacements of meter level recovered from accelerograph



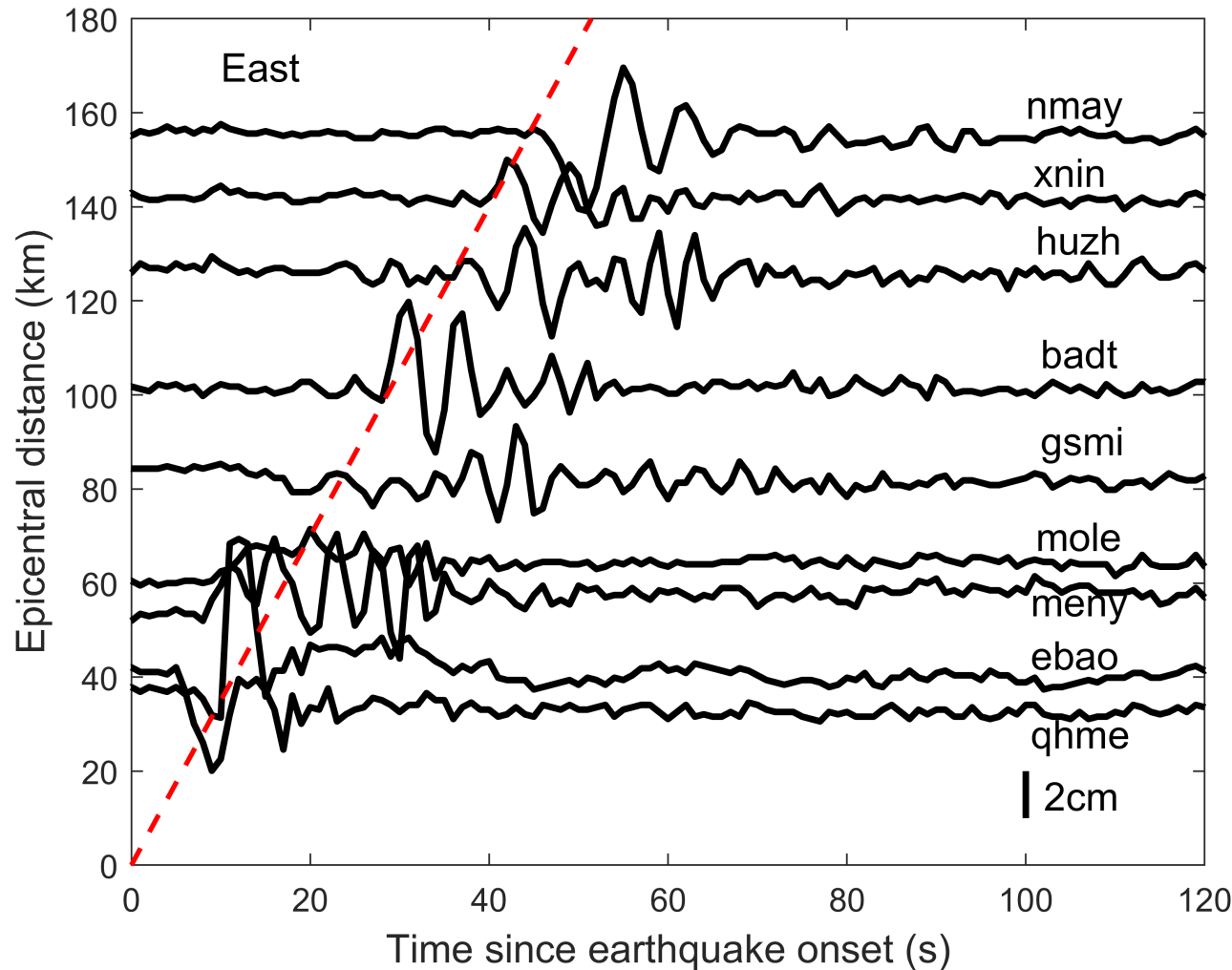
Raw accelerograph

Baseline corrections can hardly be done in real time

1.0 mm/s^2 baseline error results in 1.8 m displacement drift

GNSS displacements

- Ground displacements directed measured using real-time GNSS



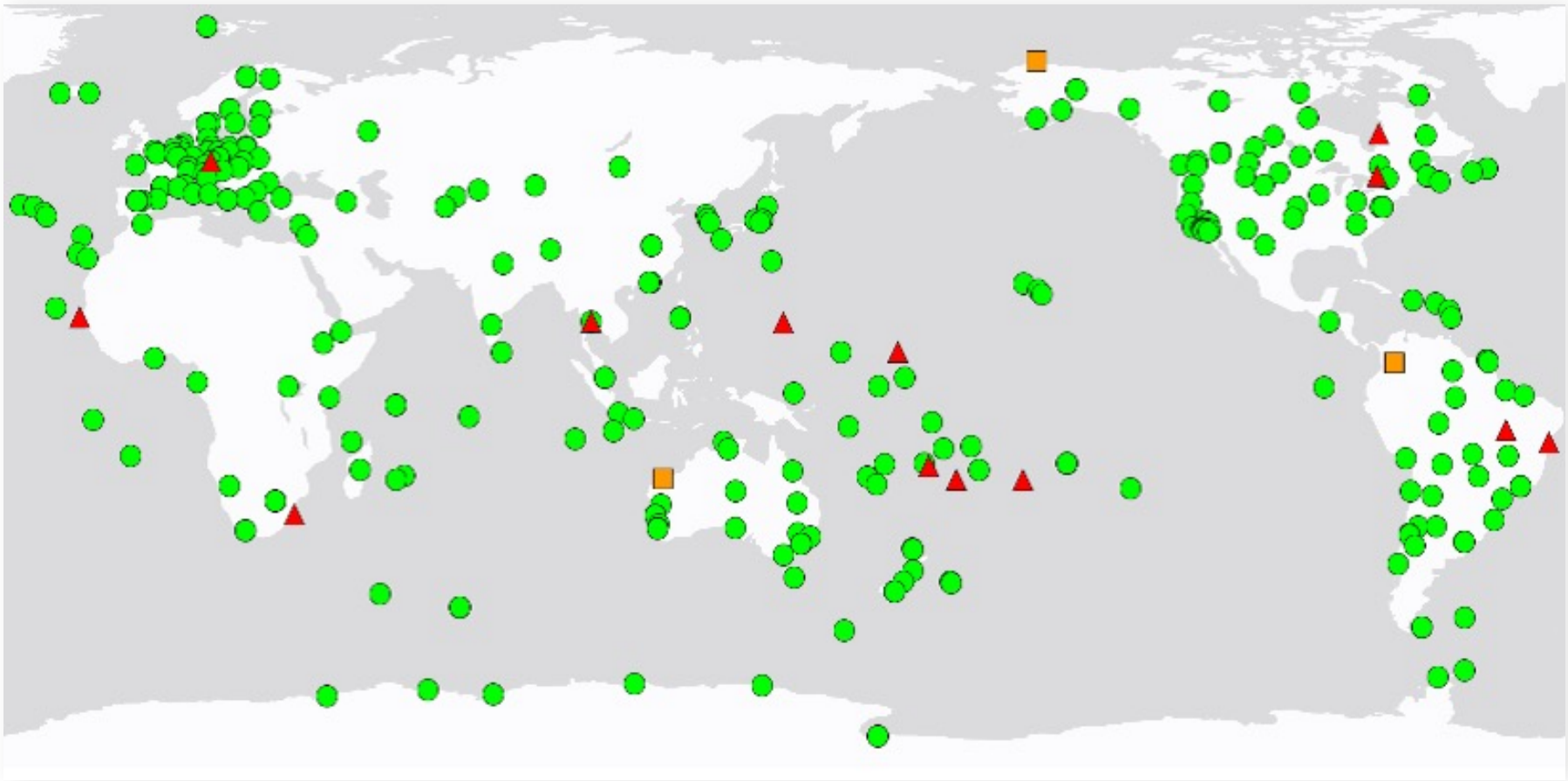
Broadband frequency

mm-cm level precision

Permanent displacements

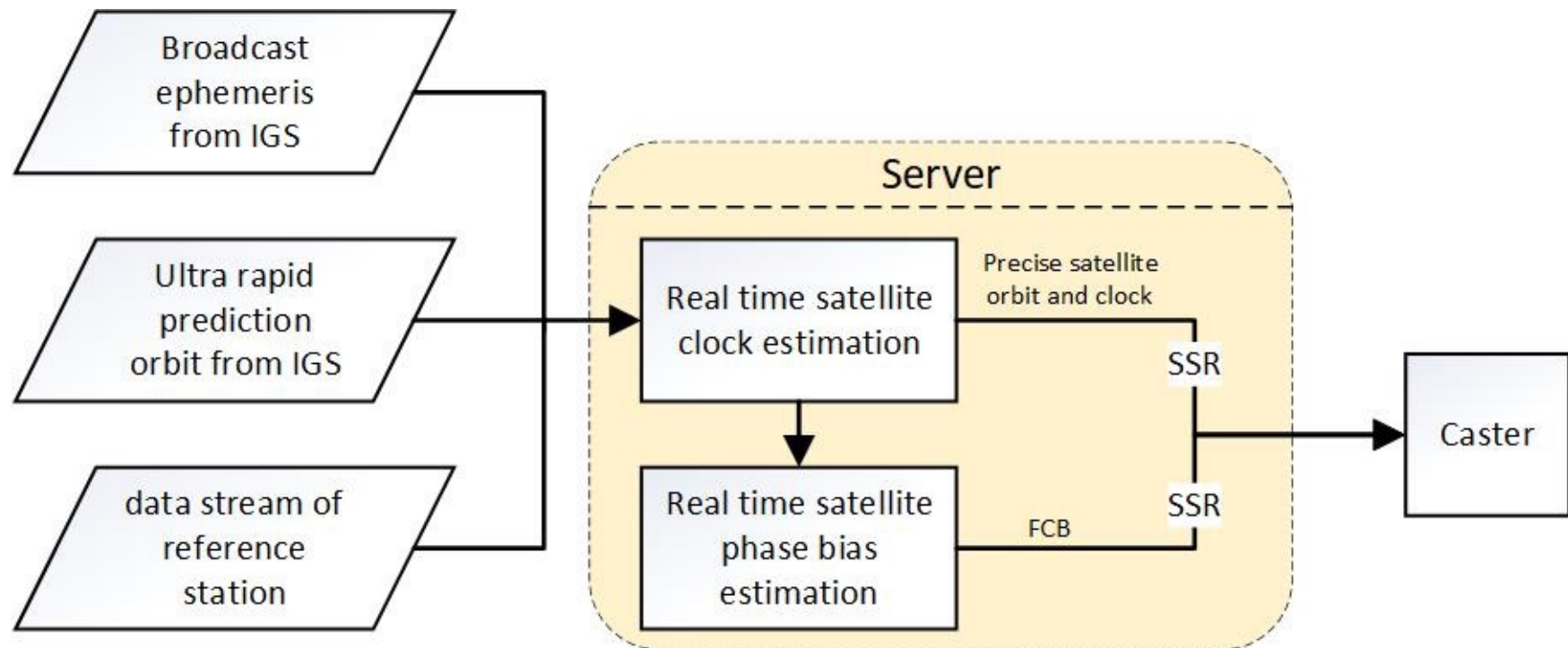
IGS-RT to provide globally applicable products

- IGS: International GNSS Service
 - 300+ stations for real-time (RT) satellite orbit/clock/bias determination

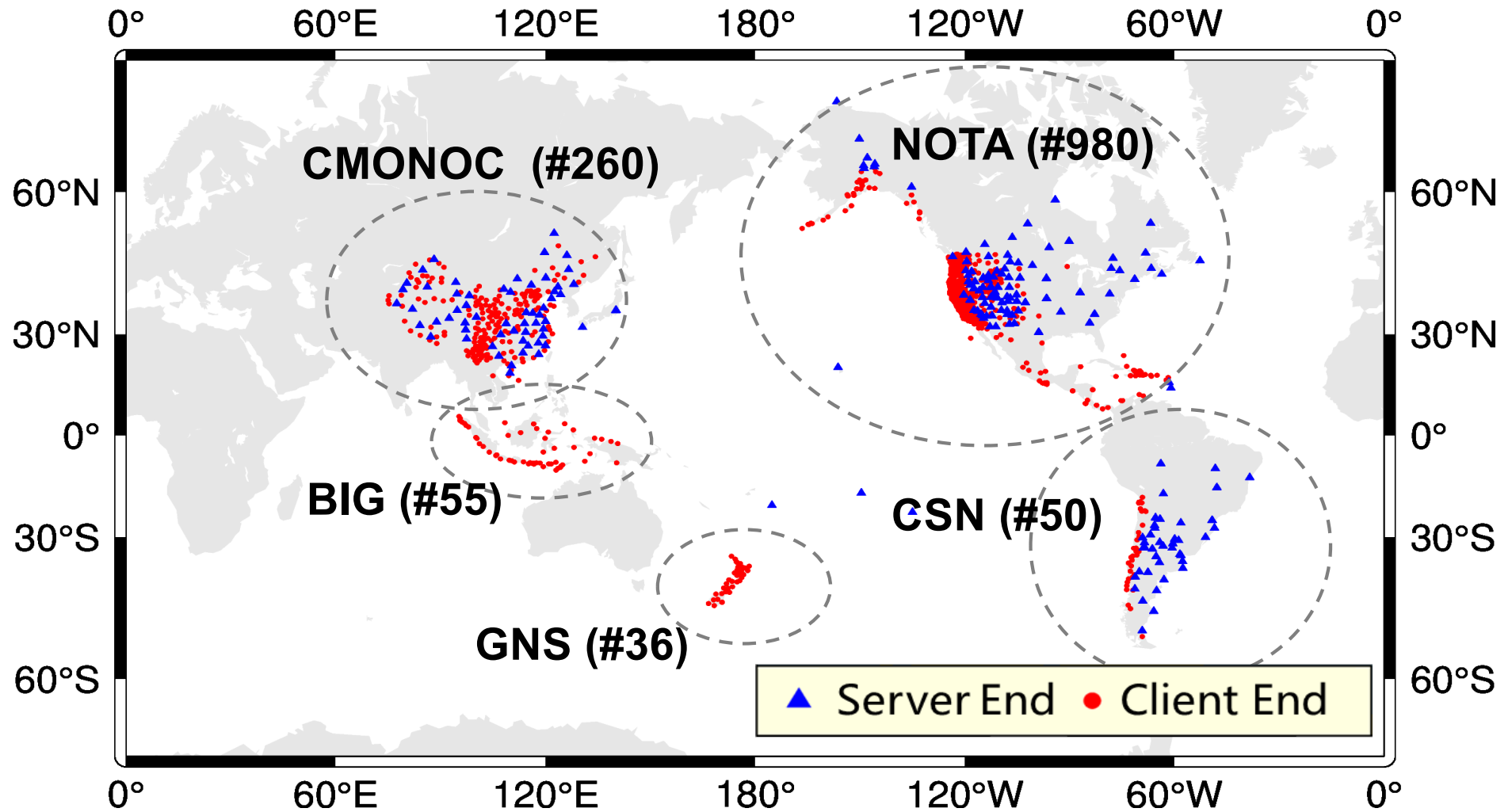


GSeisRT software

- Self-contained open-source point positioning engine
 - Undifferenced ambiguity resolution
 - Highest and steadiest positioning precision



GSeisRT has been applied to five areas



Madrid 2023.10.18

BIG: Badan Informasi Geospasial

CSN: National Seismological Center of Chile

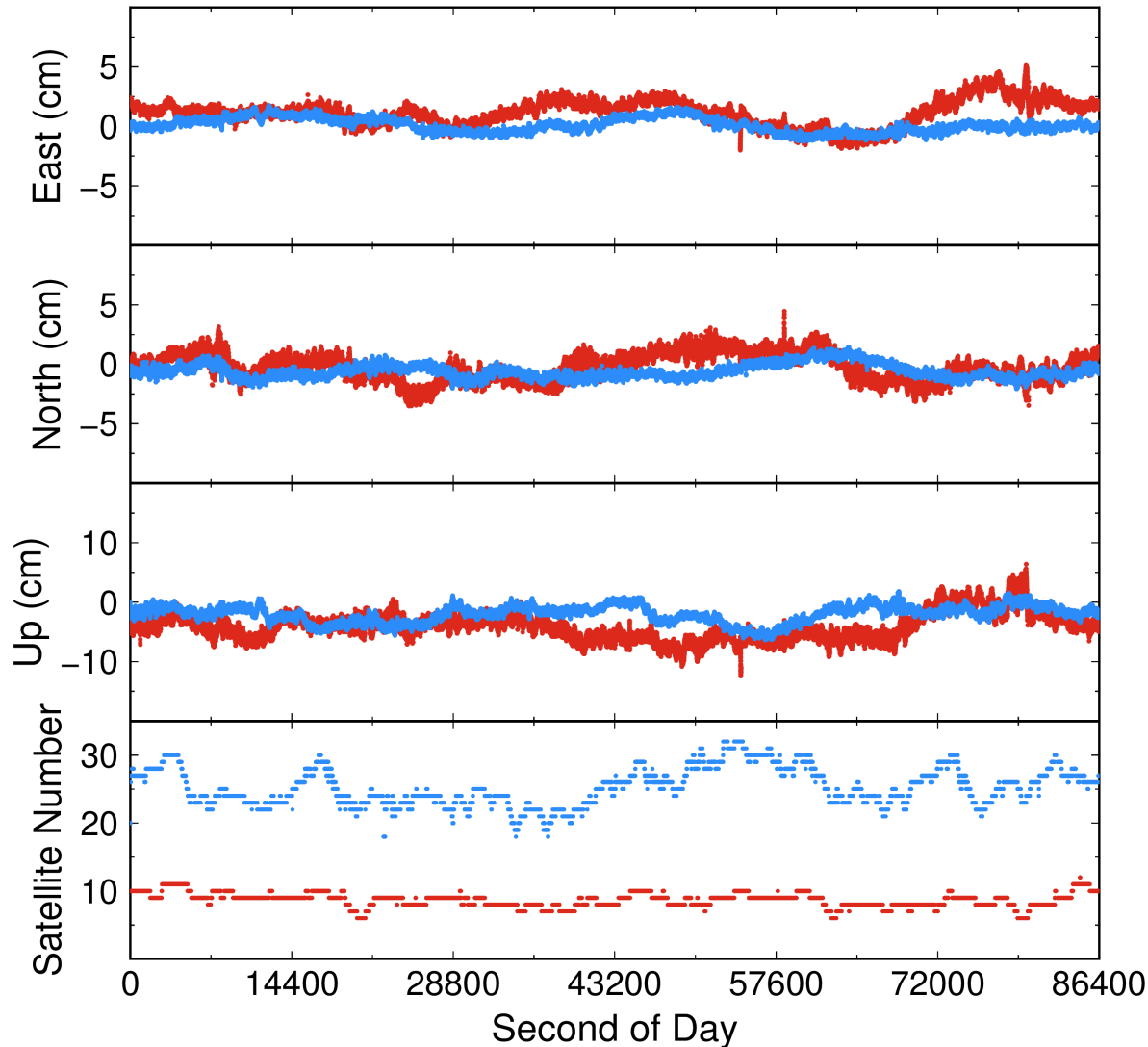
CMONOC: Crustal Movement Observation Network of China

NOTA: Network of the Americas

GNS: Institute of Geological and Nuclear Sciences Limited

GPS-only vs. Multi-GNSS

- More satellites mean lower noise and smaller biases



GPS-only

E/N/U: 1.6/1.2/4.7 cm

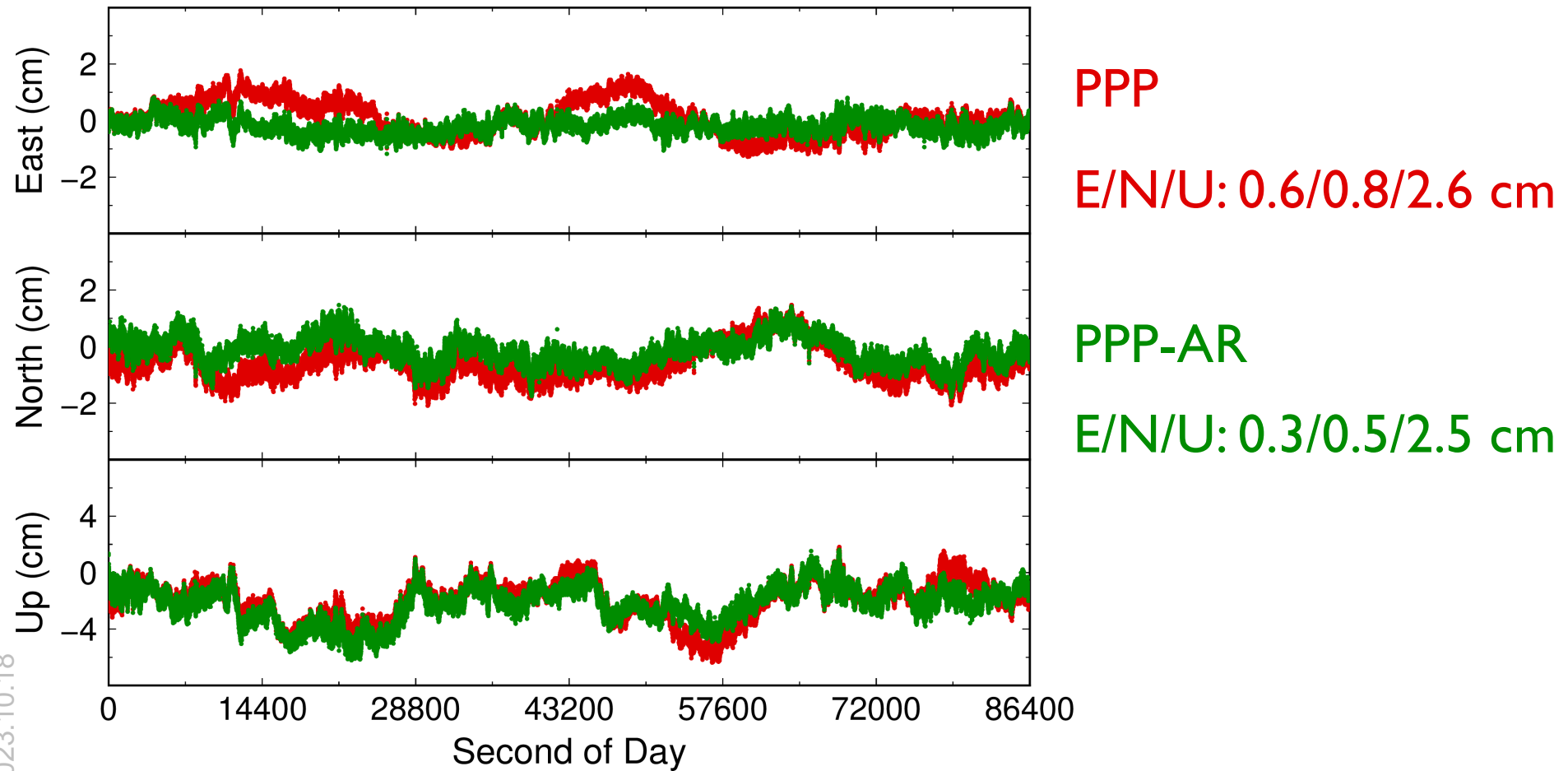
Multi-GNSS

E/N/U: 0.6/0.8/2.6 cm

No. of Satellites

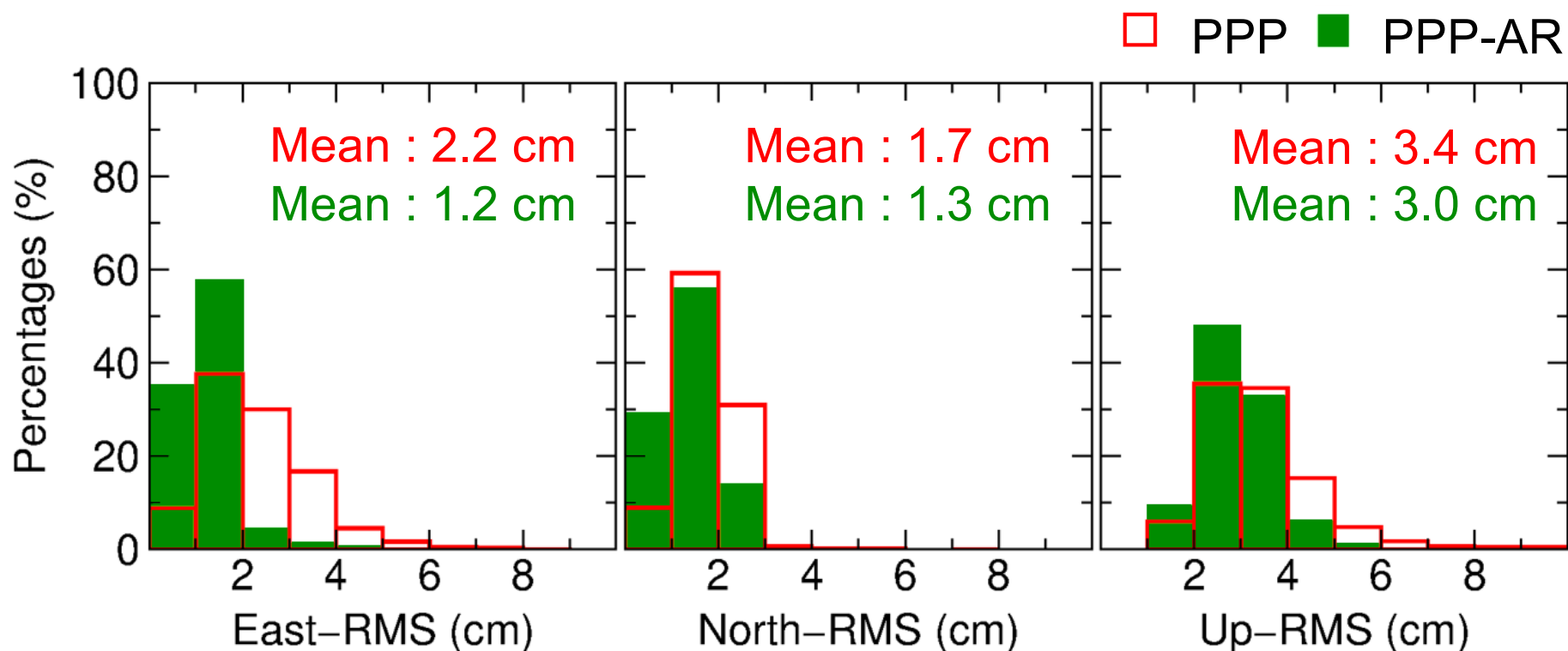
PPP vs. PPP-AR

- Ambiguity fixing at a single station suppresses long-term variations



PPP vs. PPP-AR

- 980 NOTA stations within 10 days
- RMS against IGS weekly solutions



GSeisRT GUI

Functions

- ❑ Real-time positioning
- ❑ Ionospheric monitoring
- ❑ Teaching Demo
- ❑ ...

The screenshot shows the GSeisRT GUI with the following components:

- User Input:** Fields for IP:Port (**.**, **.**, **.**, ***:2101), StaInfo (C:\Pride\GSeisRT\StaInf), Username (PrideGSeisRT), and Password (masked).
- Data Streams:** A table with columns: IP:Port/Mountpoint, Coding, System, Received.

IP:Port/Mountpoint	Coding	System	Received
1 **.**, **.**, **.**, ***:2101/BCEP01BKG0	RTCM_3.1	G	619.516 kB
2 **.**, **.**, **.**, ***:2101/MAC100AUS0	RTCM_3.3	GRECJ	3.96006 MB
3 **.**, **.**, **.**, ***:2101/SSRC00CNE0	RTCM_3.1	GREC	1.09753 MB
- Log Results:** Text output including epoch end markers and ionosphere delay data.

```
### Epoch End! ###
23-07-04 02:25:37 60129_8739.00 MAC100AUS0
Position(m):
=> XYZ: -3464039.0549 1334173.3064 -5169223.8359
=> NEU: +0.0112 +0.0209 +0.0631
Ionosphere Delays(m):
G05 G07 G08 G09 G14 G16 G20 G27 G30
5.09 1.08 2.29 2.53 4.56 3.97 4.56 2.45 1.44
R03 R13
-3.25 -2.40
### Epoch End! ###
```
- Dynamic Graph:** A line graph titled "Displacement" and "Delta Slant Iono." showing displacement (m) over time for station MAC100AUS0. The y-axis ranges from -0.15 to 0.15, and the x-axis shows time from 02:23:00 to 02:25:30. Three data series are plotted: N (red), E (yellow), and U (blue).

→ User Input

→ Data Streams

→ Log Results

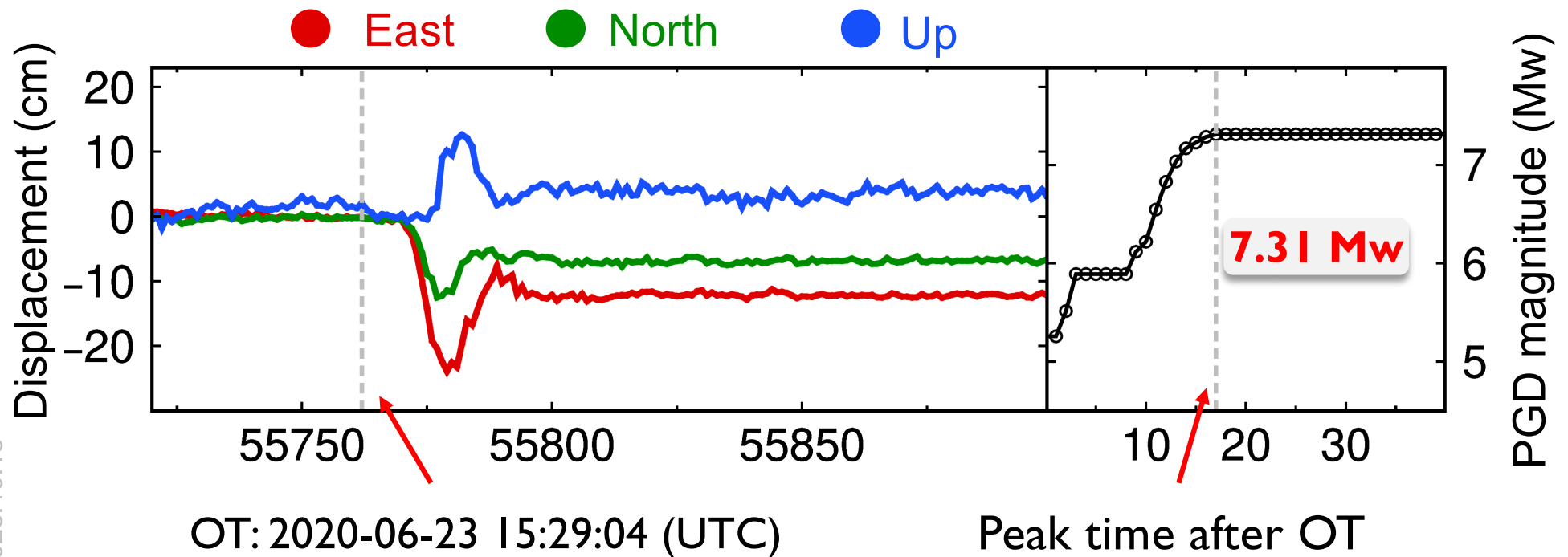
→ Dynamic Graph

Earthquakes captured by GSeisRT in real time

□ 2020-06-23 **M7.4** Oaxaca, Mexico

Station : OXUM (58 km from the epicenter)

□ Real-time magnitude is **M7.3** from PGD scaling

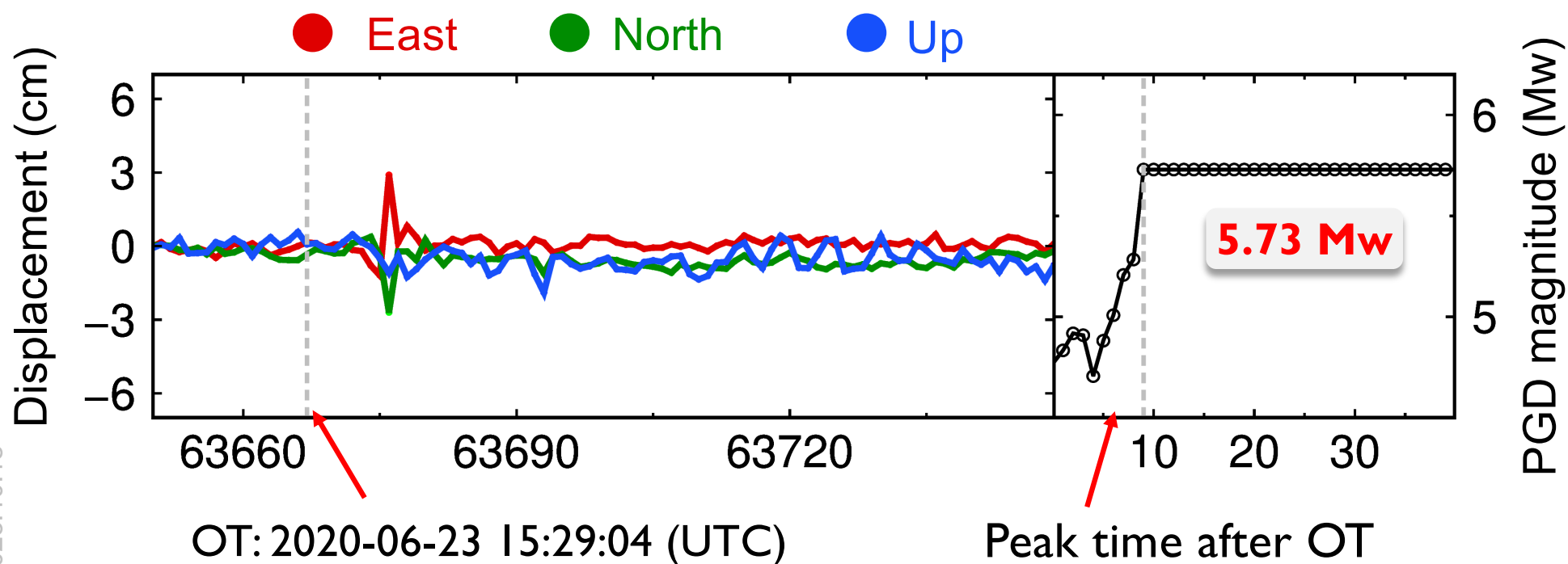


Earthquakes captured by GSeisRT in real time

□ 2020-06-24 **M5.8** California, USA

Station : P466 (17 km from the epicenter)

□ Real-time magnitude is **M5.7** from PGD scaling



Summary

- GSeisRT can realize multi-GNSS PPP, ambiguity resolution and achieve cm to sub-cm precision in real time
 - The more satellites, the better positioning precision and robustness
 - Ambiguity resolution lead to higher accuracy and steady time series
- GSeisRT is open and free to the science community for joint geophysical research efforts



Thank you very much!

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