Geodetic Components of a Tsunami Early Warning Systems

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The GGOS Contribution to GEOSS and an Observing System for Geohazards and Disaster Prevention
GEO Workshop organized by GGOS
November 5-6, 2007
Frascati, Italy

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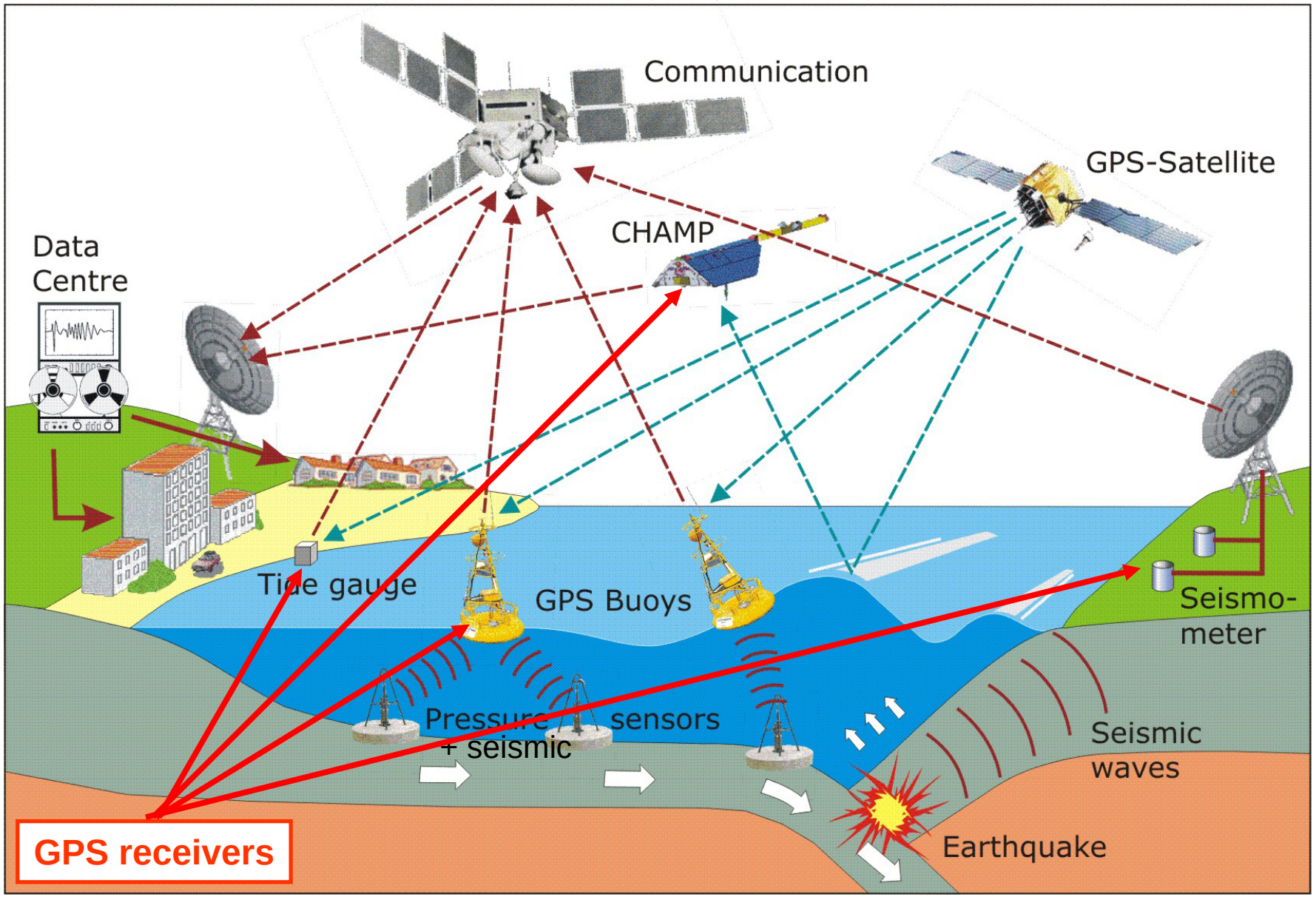
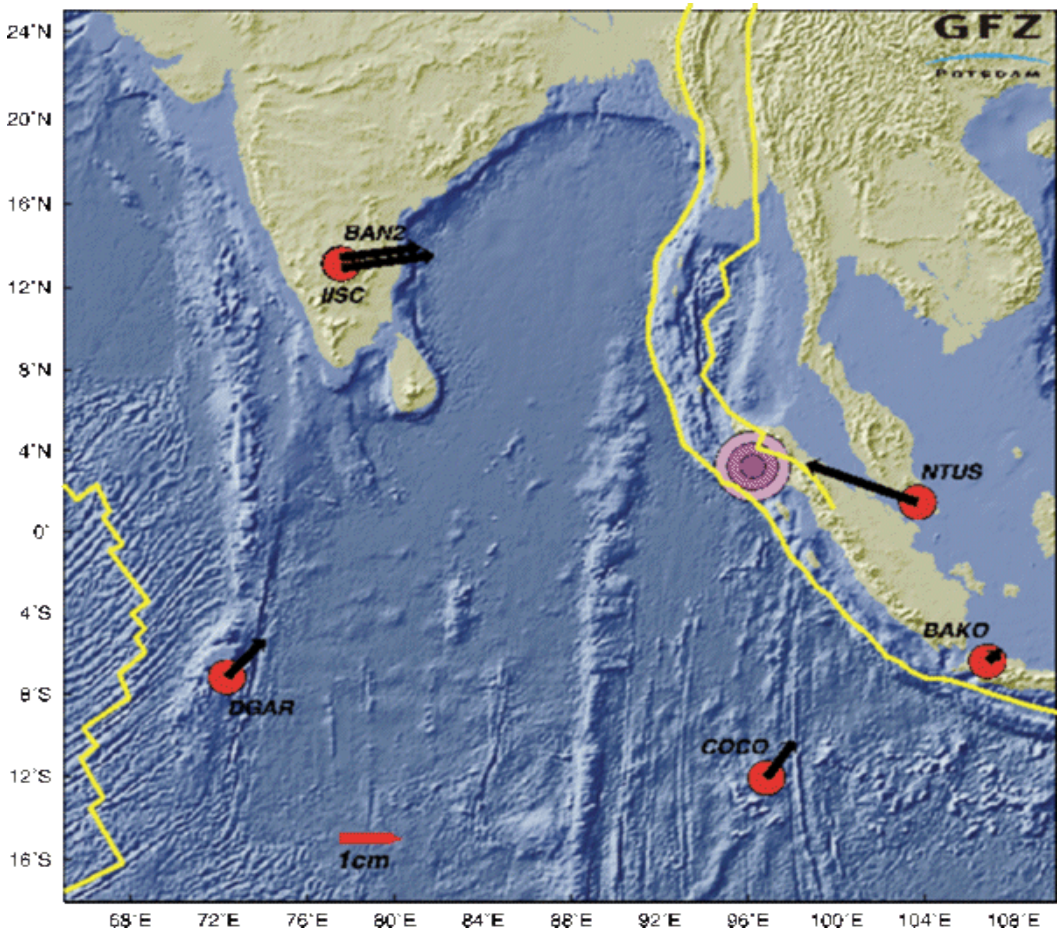
- Tsunami Early Warning System (TEWS)
- Ground-Based GPS Technology
- Tide Gauges and GPS
- GPS Buoys
- Space-Based GPS
- Summary and Conclusions

Large Earthquake of Lissabon (1. 11. 1755)

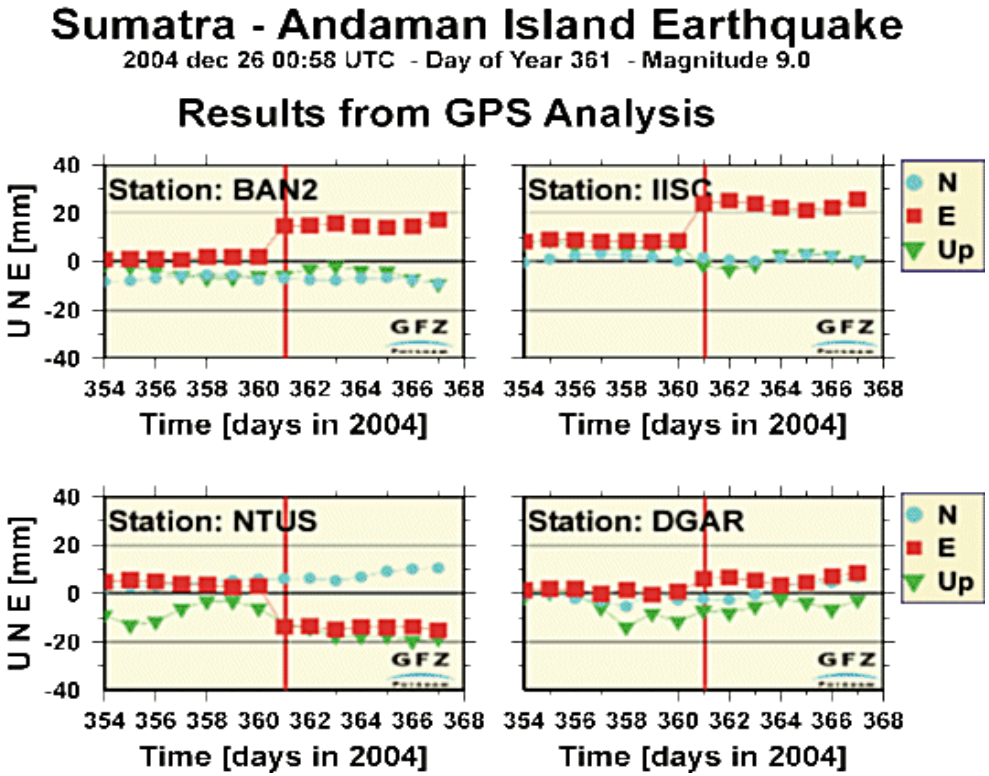
Tsunami Early Warning System



GPS Ground-Based Technologies: Deformation

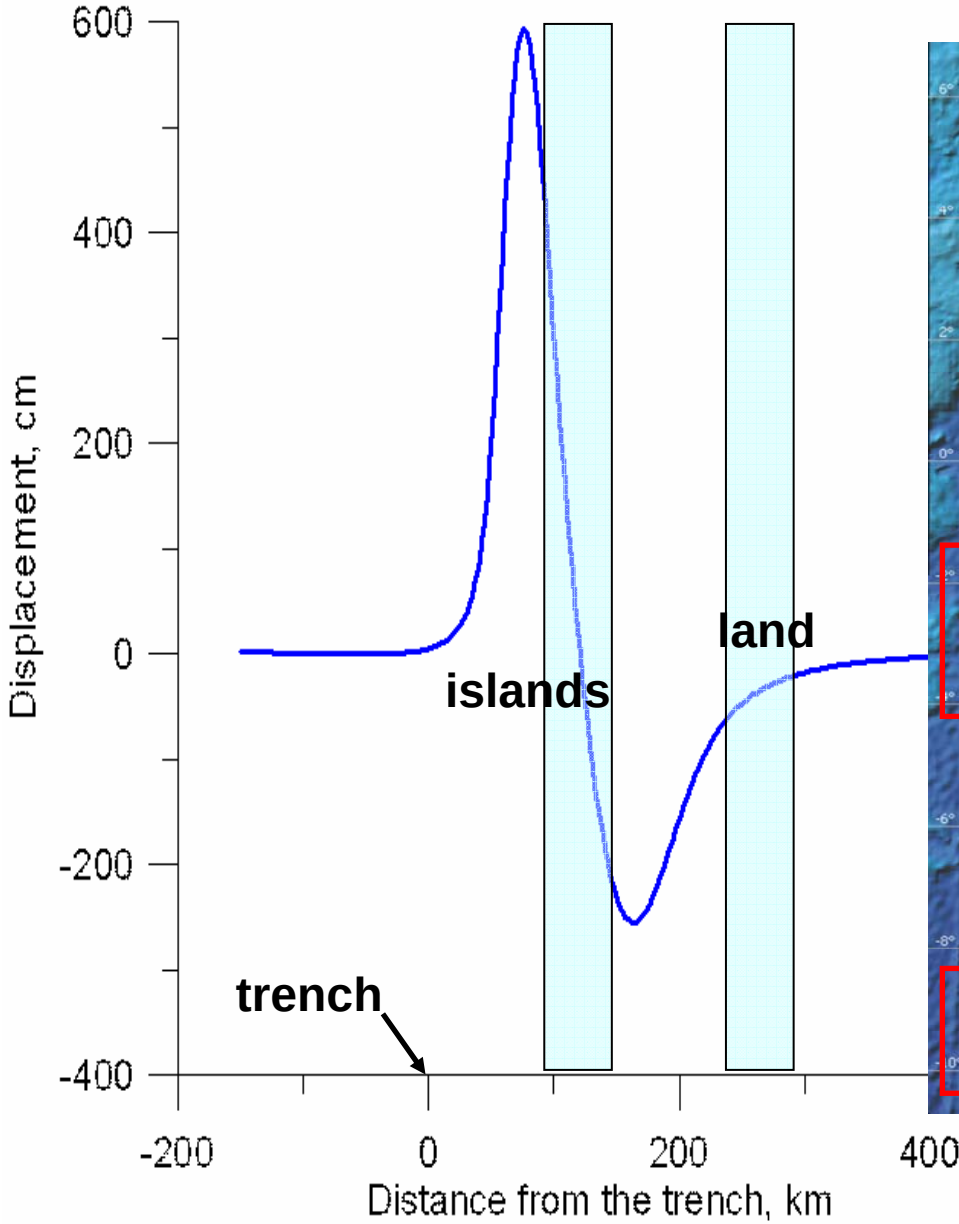


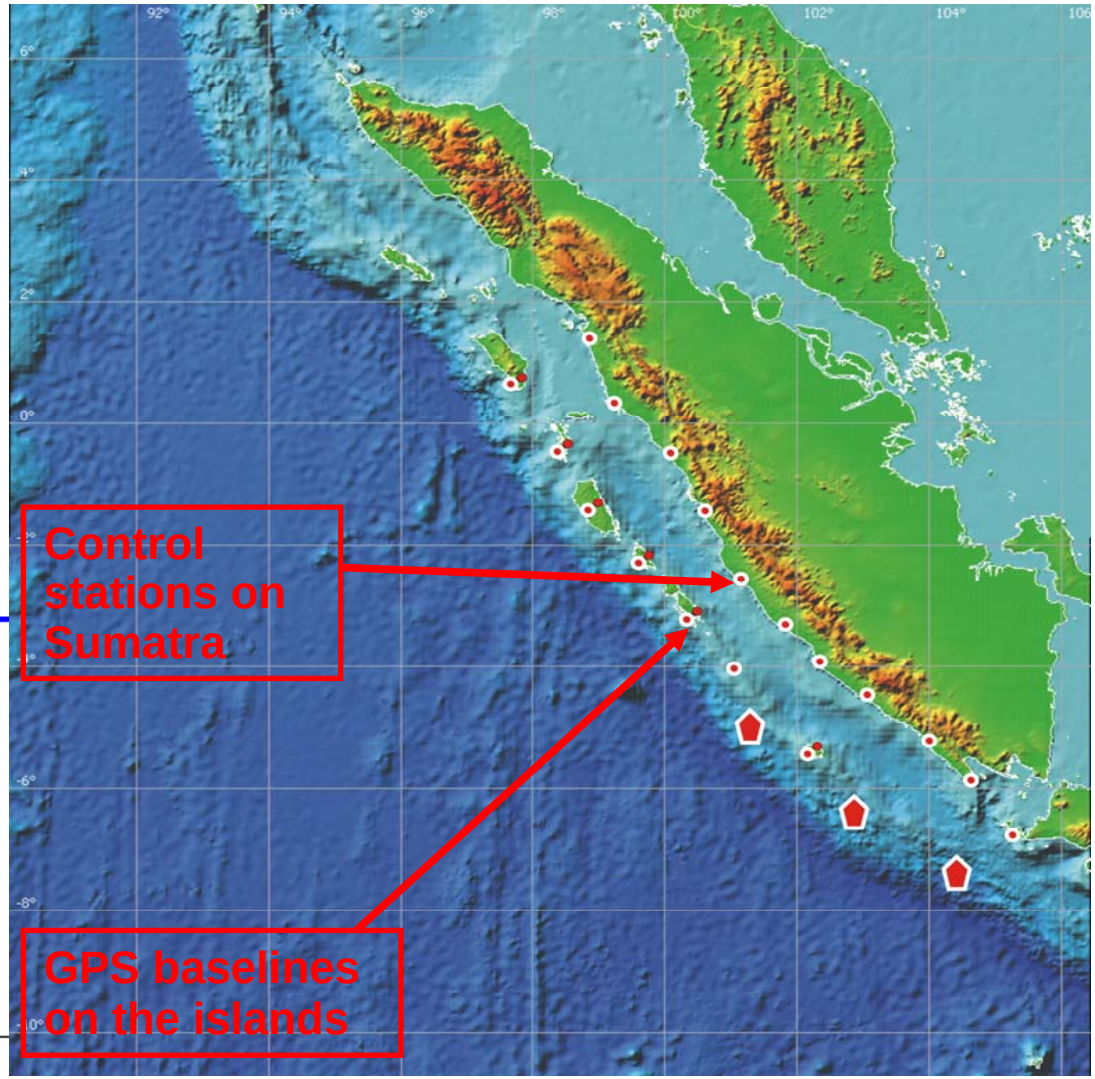
Sumatra Earthquake: Deformation from the postprocessing of the IGS network



Future: 10-Hz GPS data
Detection of the station motion during the earthquake

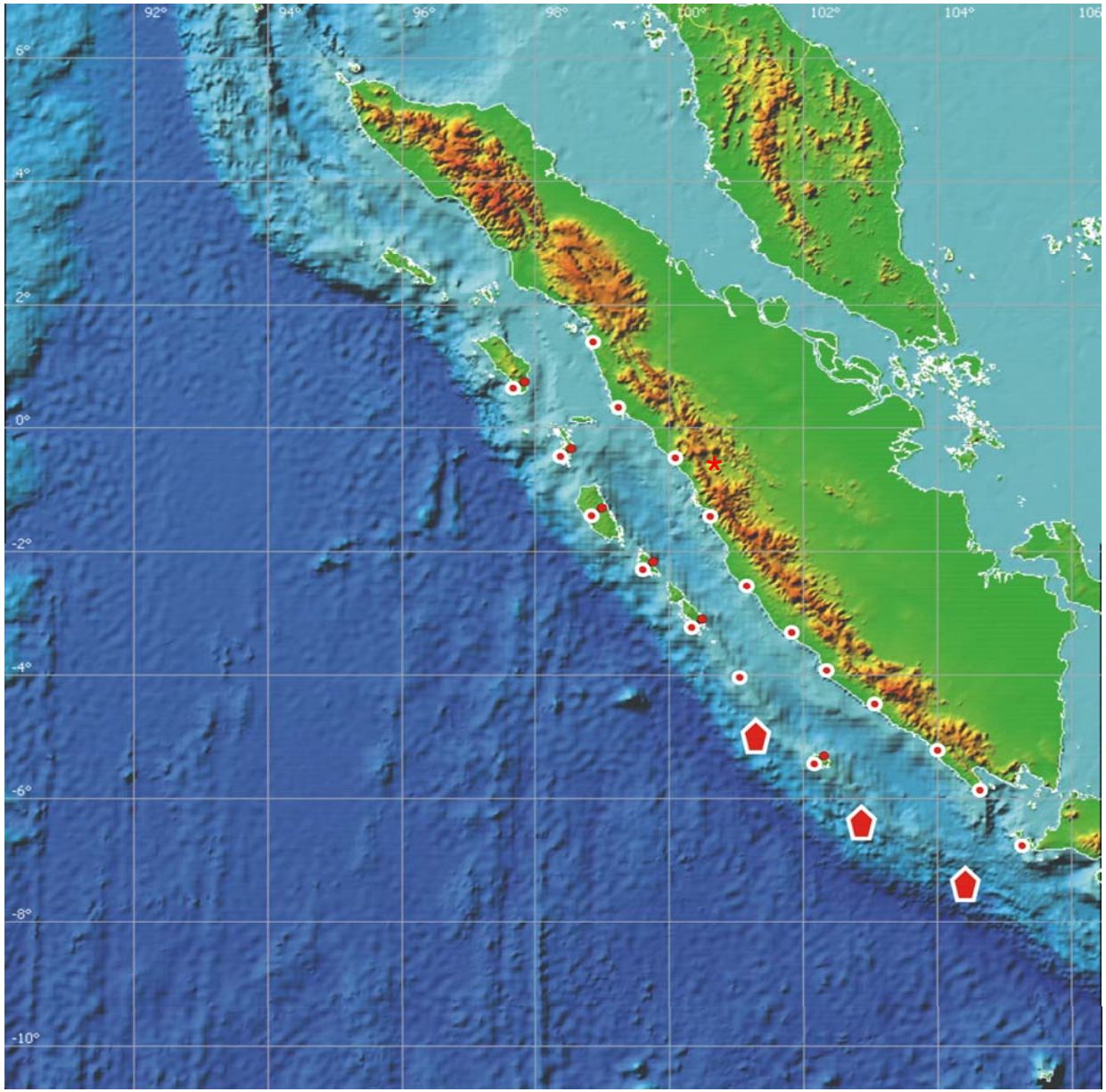
Land Stations for the “GPS Shield” Concept





(Sobolev et al., 2007; JGR)

GPS Shield for Sumatra



10 s: P-wave at the closest island station– triggering high GPS sampling rate

1 min: initial tsunami wave formed; strong GPS signal at island station

2 min: GPS signal at island station established—first estimation of fault parameters

3 min: GPS signal at control (land) station established—first verification of fault parameters

4-5 min: Tsunami at island tide-gauge—second verification of fault parameters

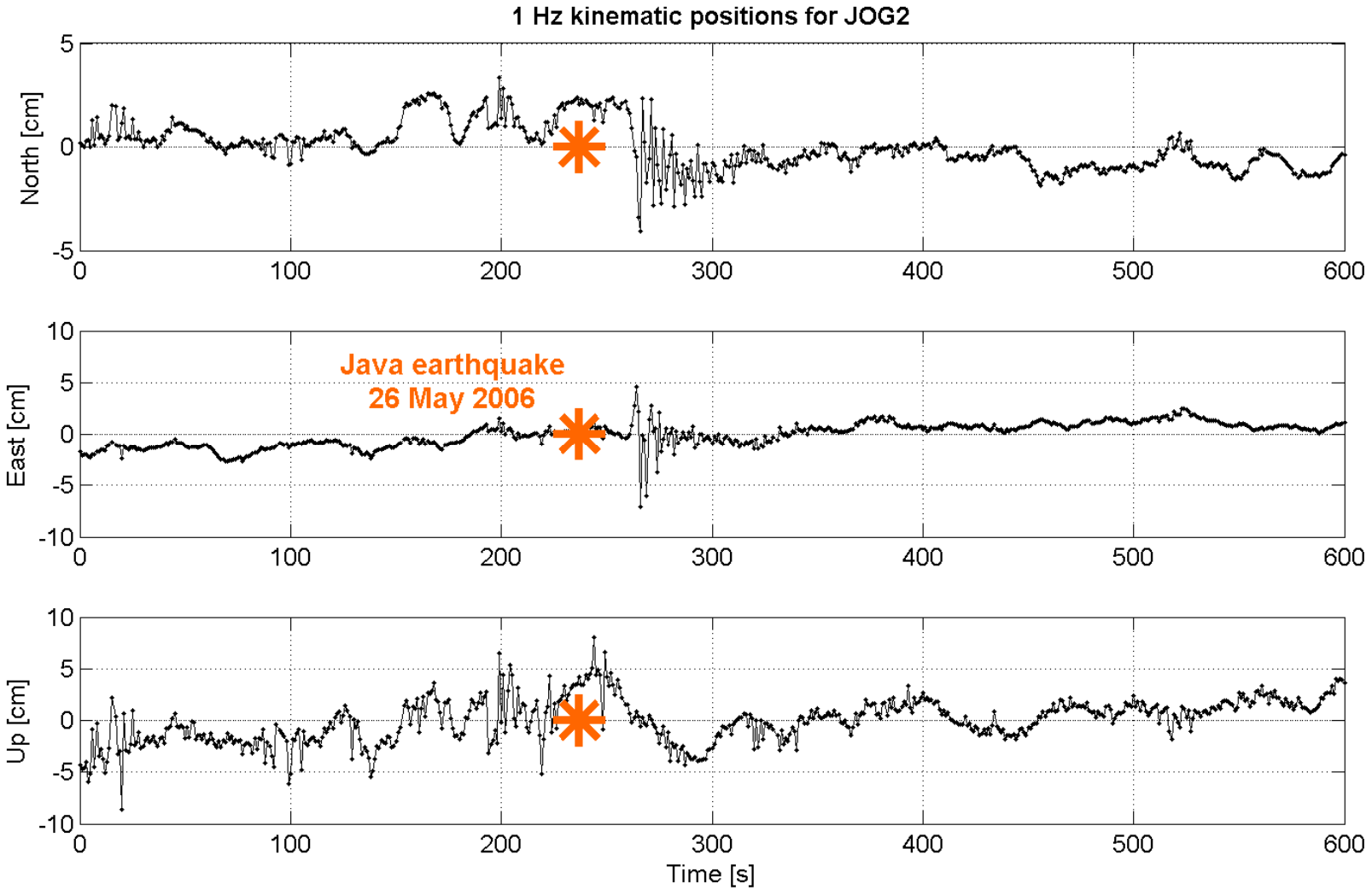
GPS/Seismological Station in Yogyakarta

Combined GPS/seismolog-iscal station close to Yogyakarta (smart stations)

GPS and met data sensors working since March 2006.

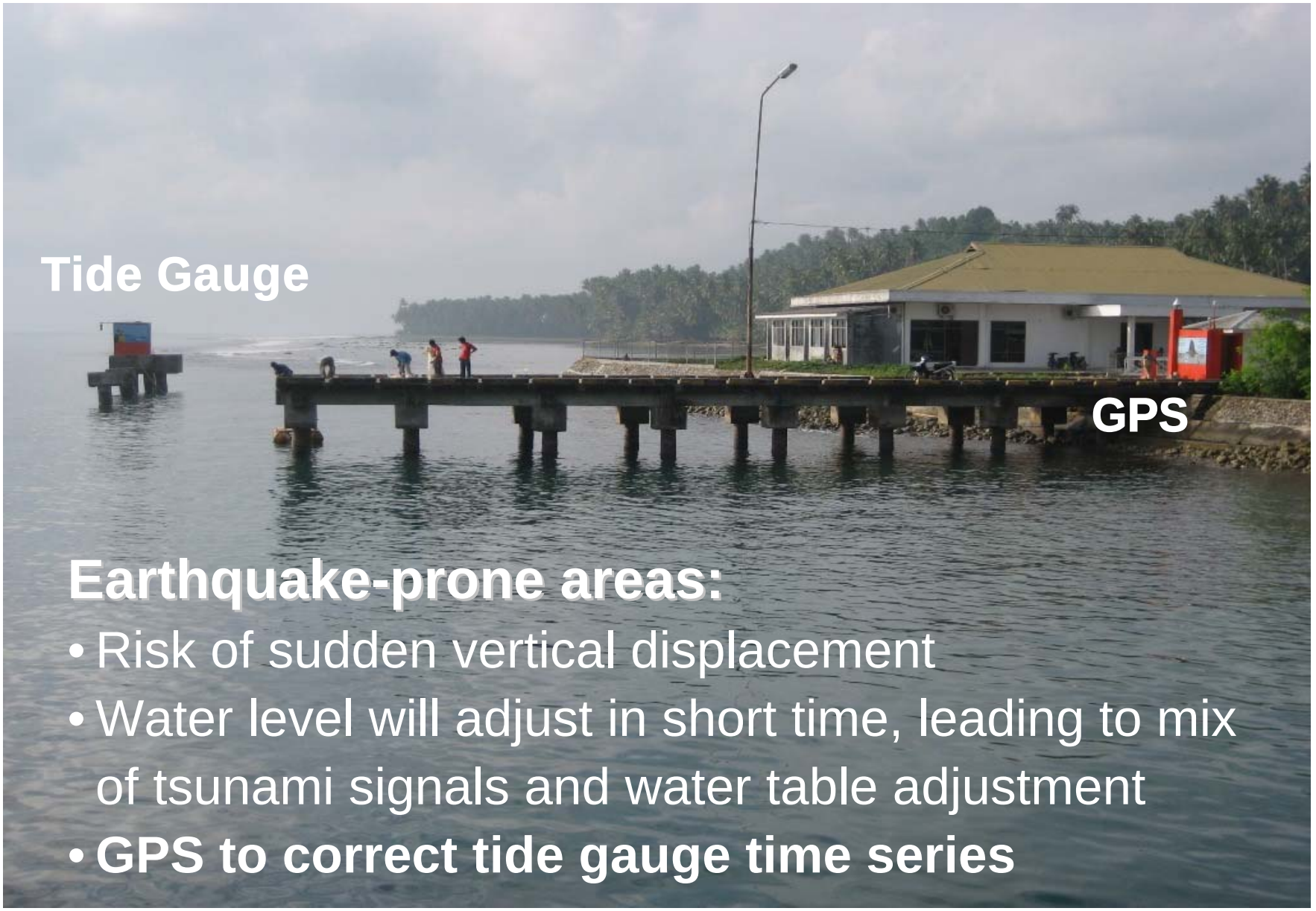
Future: use together with seismometers for GPS seismology (10-20-Hz data measuring the Earthquake motion)

Combination GPS/Seismology



- Earth‘s motion during the earthquake
- Deformation due to the earthquake (magnitude determination, rupture process)

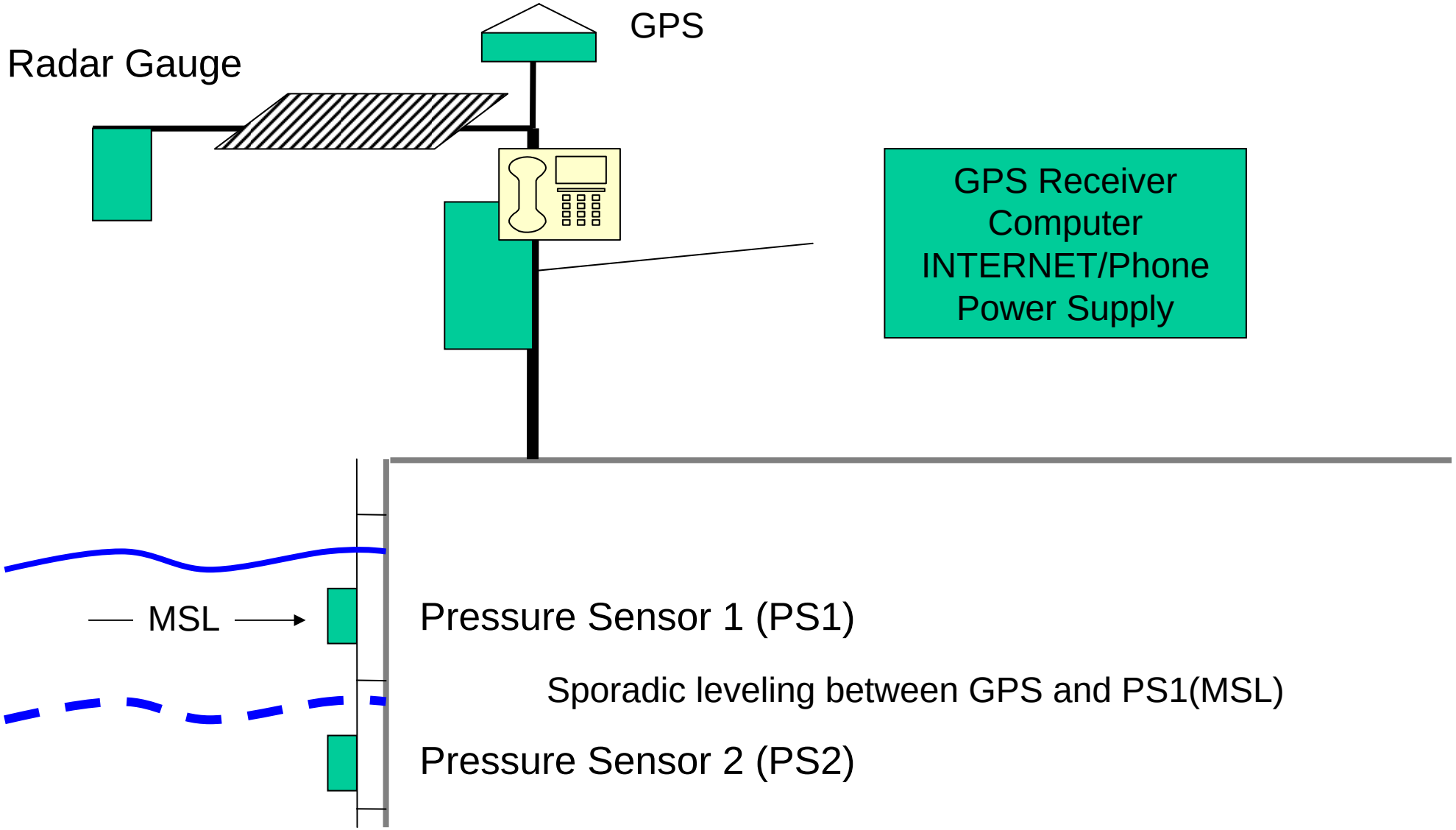
Continuous GPS (cGPS) @ Tide Gauges

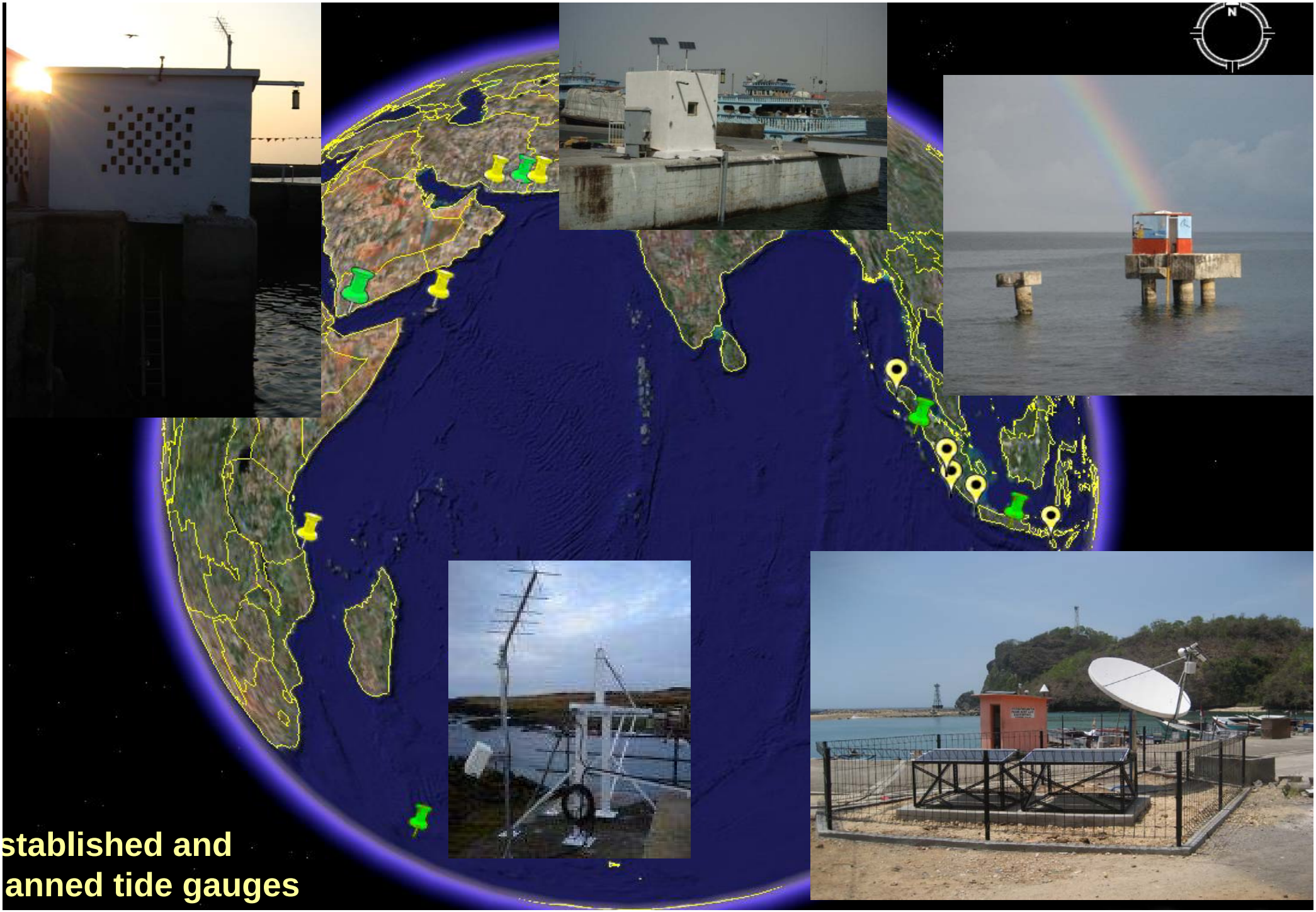


Earthquake-prone areas:

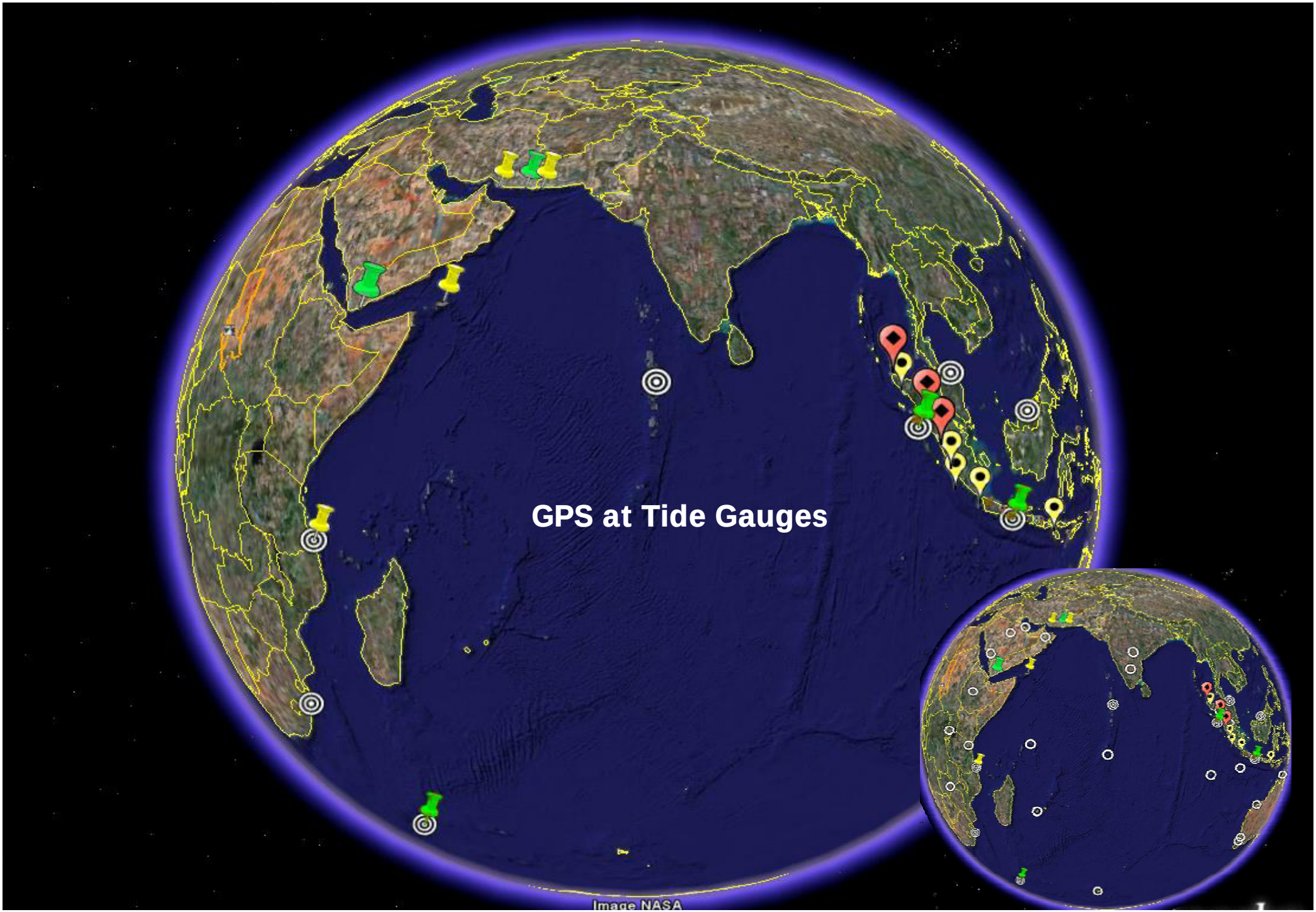
- Risk of sudden vertical displacement
- Water level will adjust in short time, leading to mix of tsunami signals and water table adjustment
- **GPS to correct tide gauge time series**

Design of the Tide Gauge Station

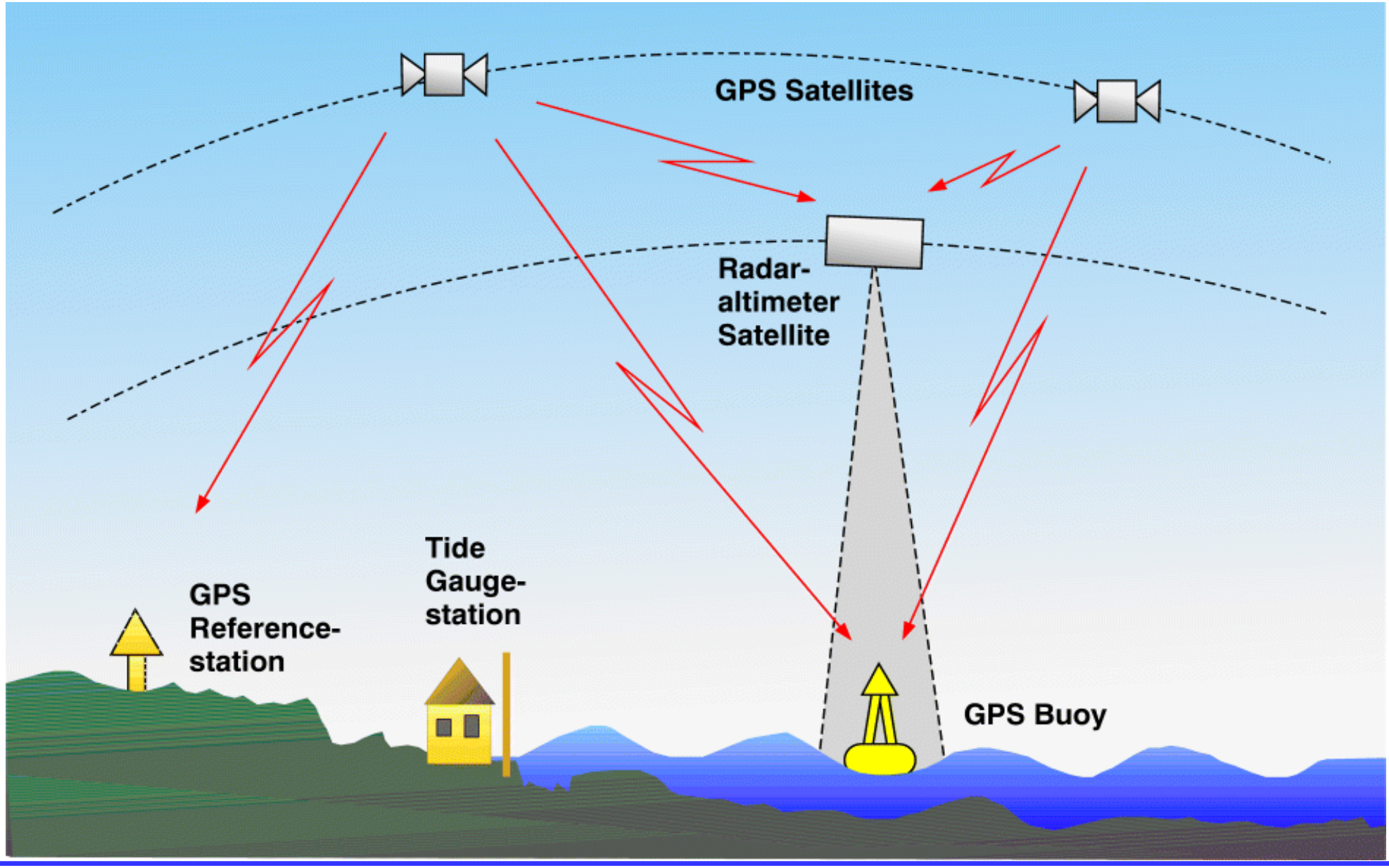




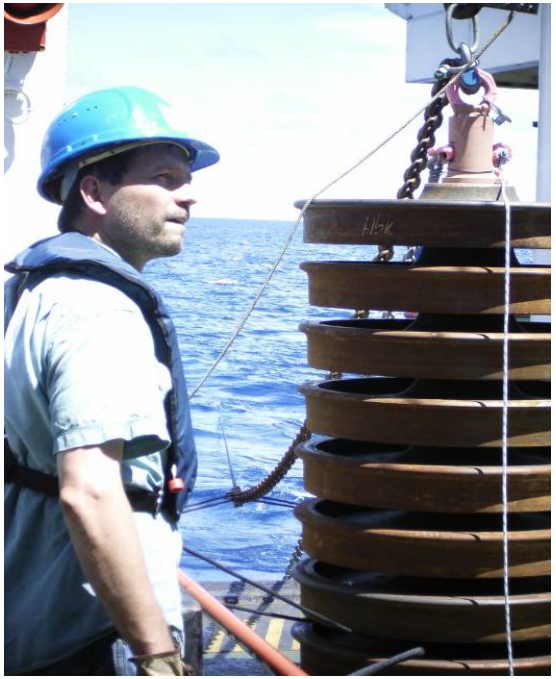
stablished and
anned tide gauges

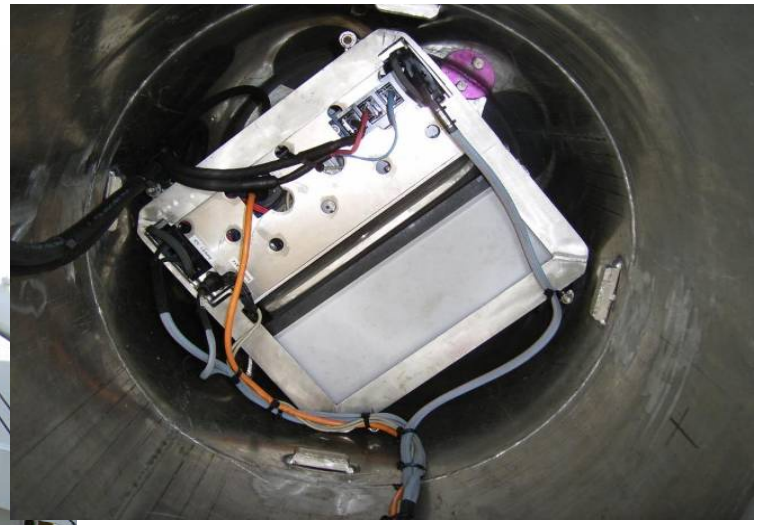

GPS at Tide Gauges
Image NASA

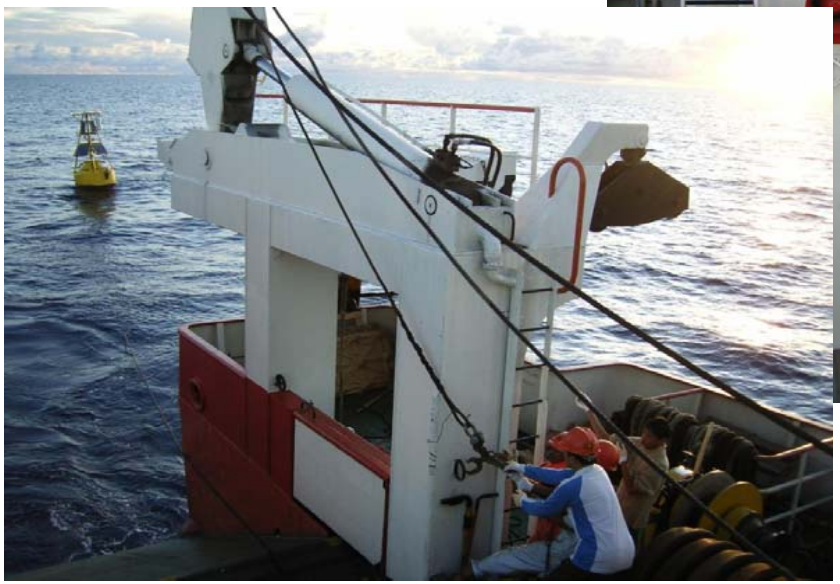
GPS Buoys for Instantaneous Sea Level Measurements

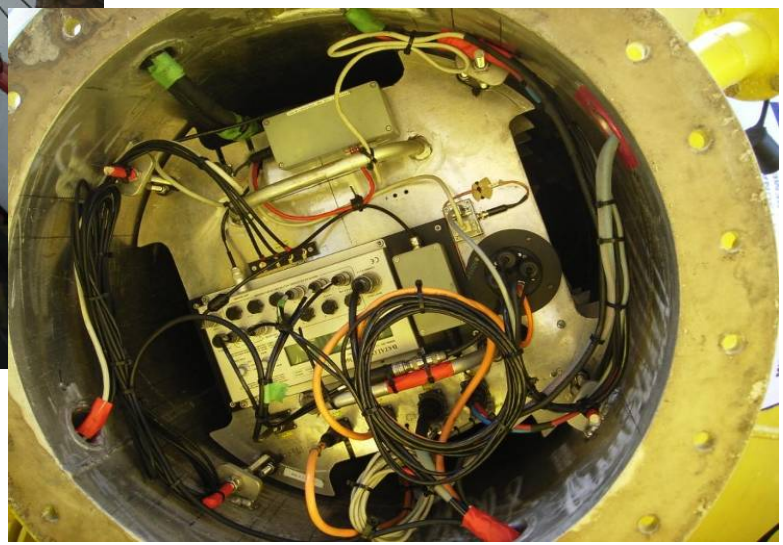


GPS Tsunami Buoy



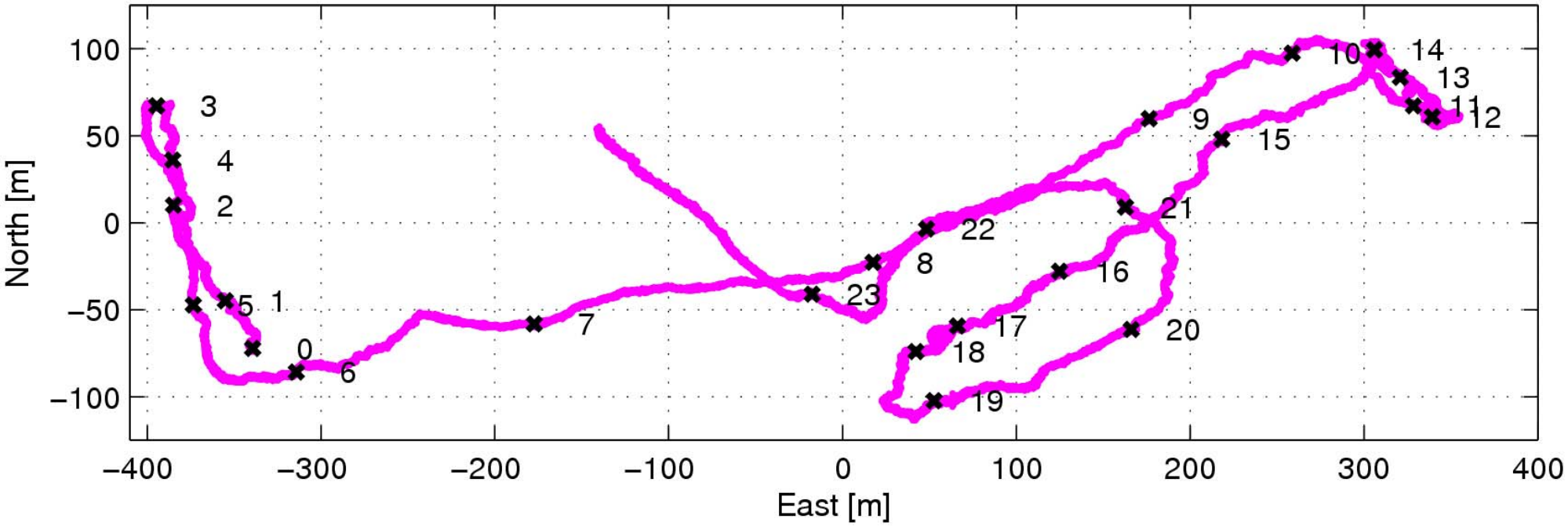




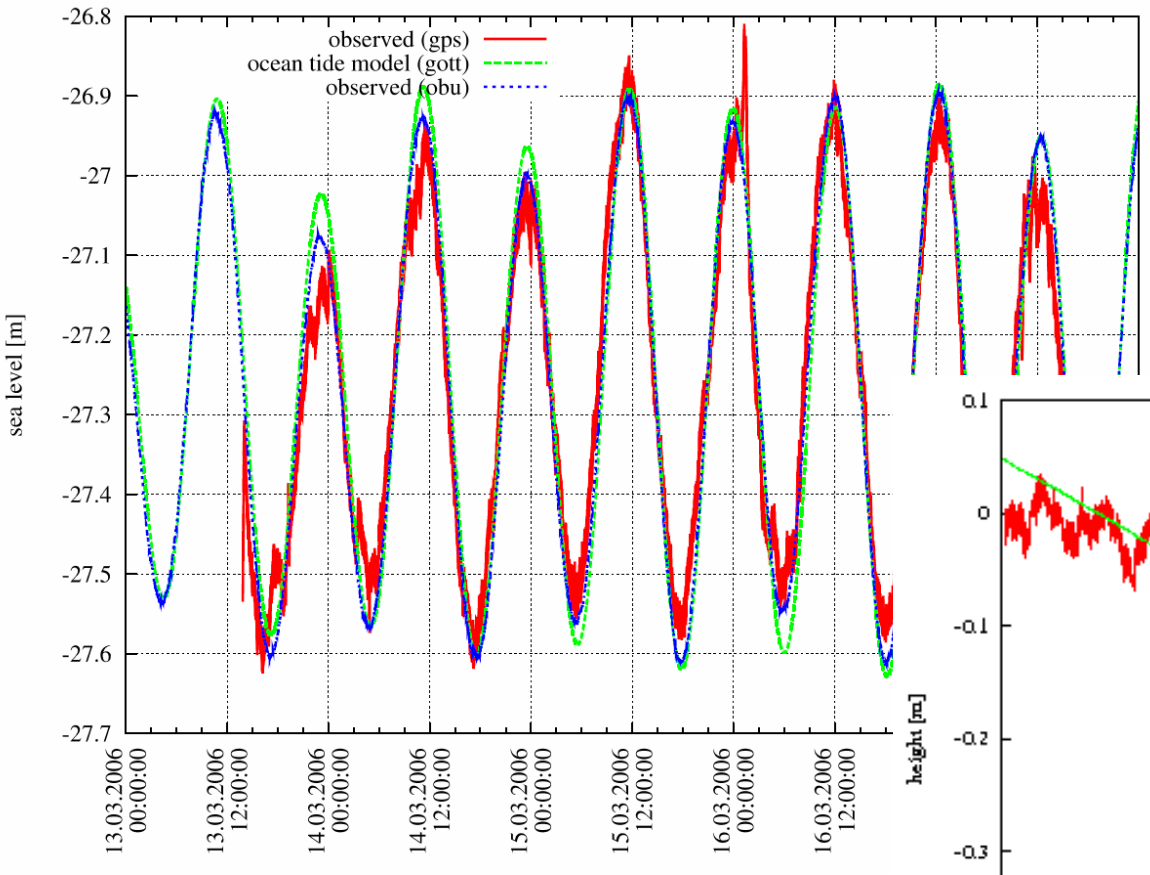


Ocean Bottom Pressure Unit / Seismometer

GPS Tsunami Buoy: Motion



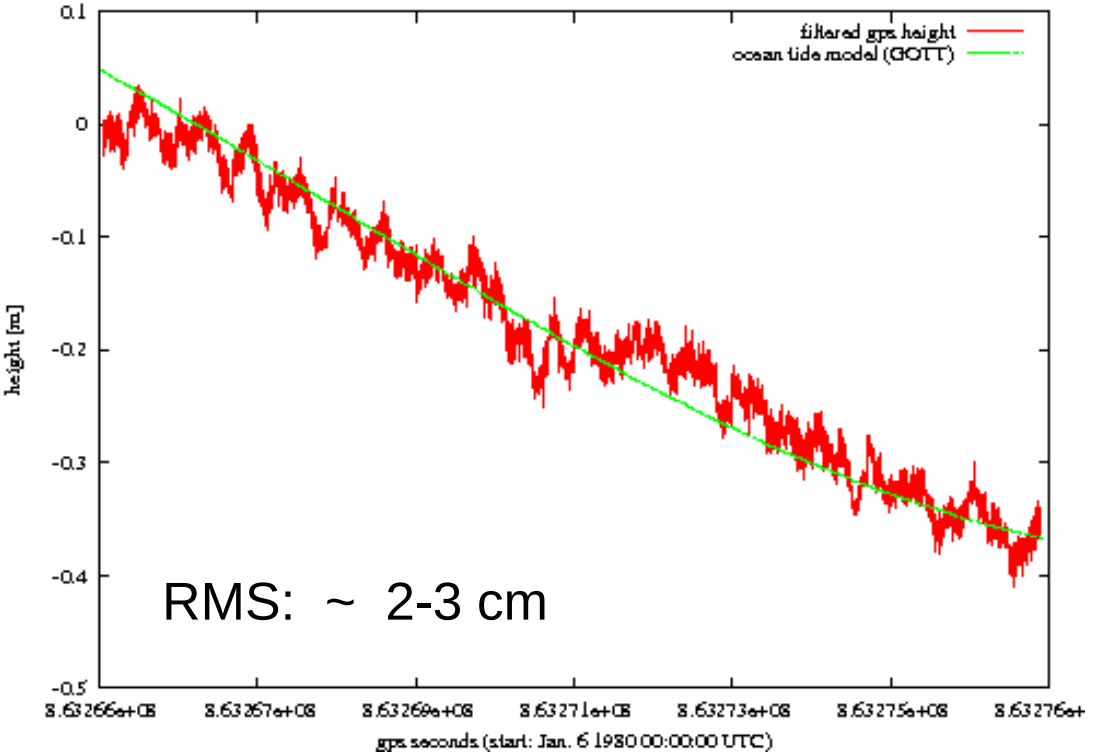
GPS Tsunami Buoy: Ocean Heights



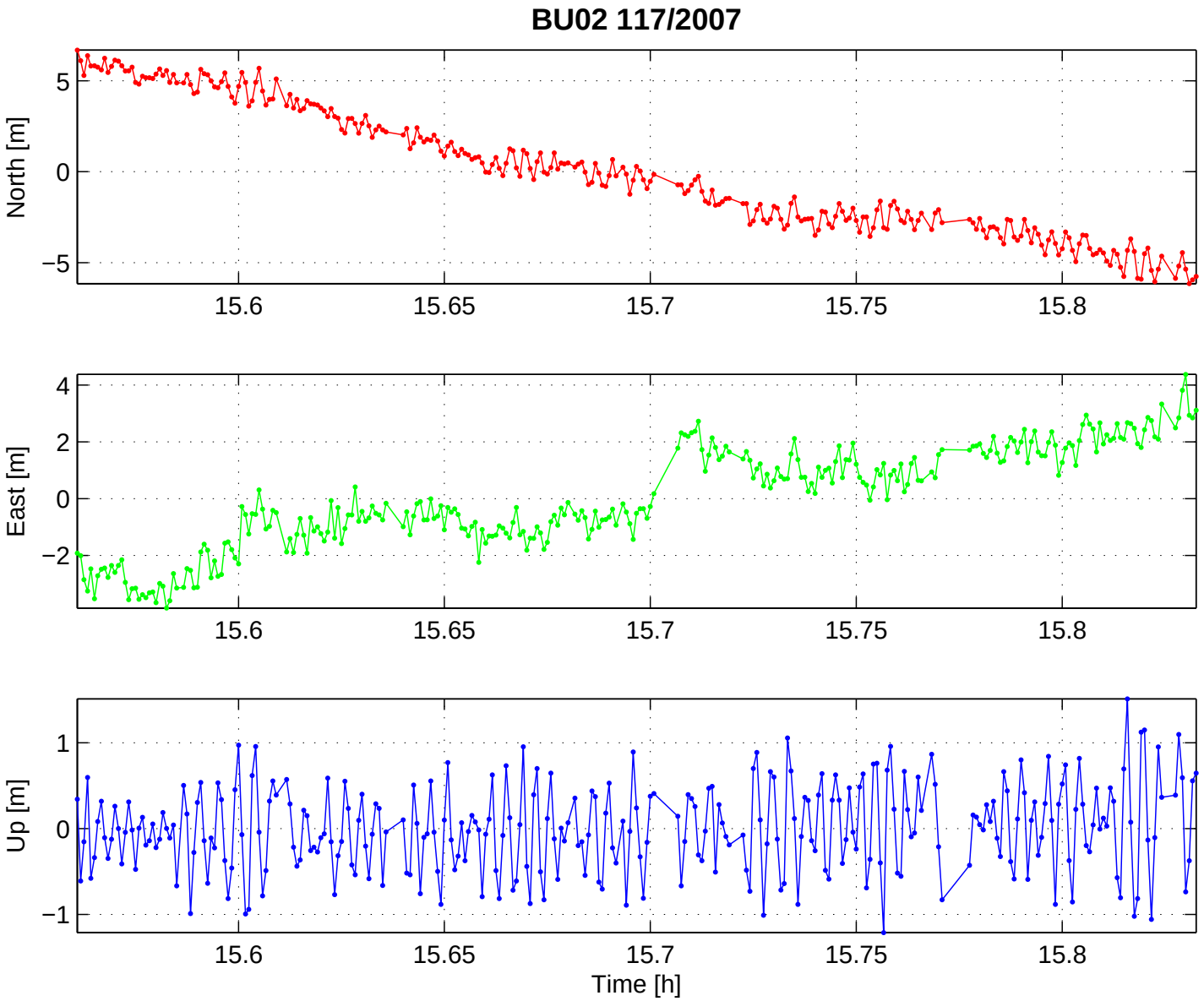
Filtered GPS heights

Ocean Tide Model (GOTT)

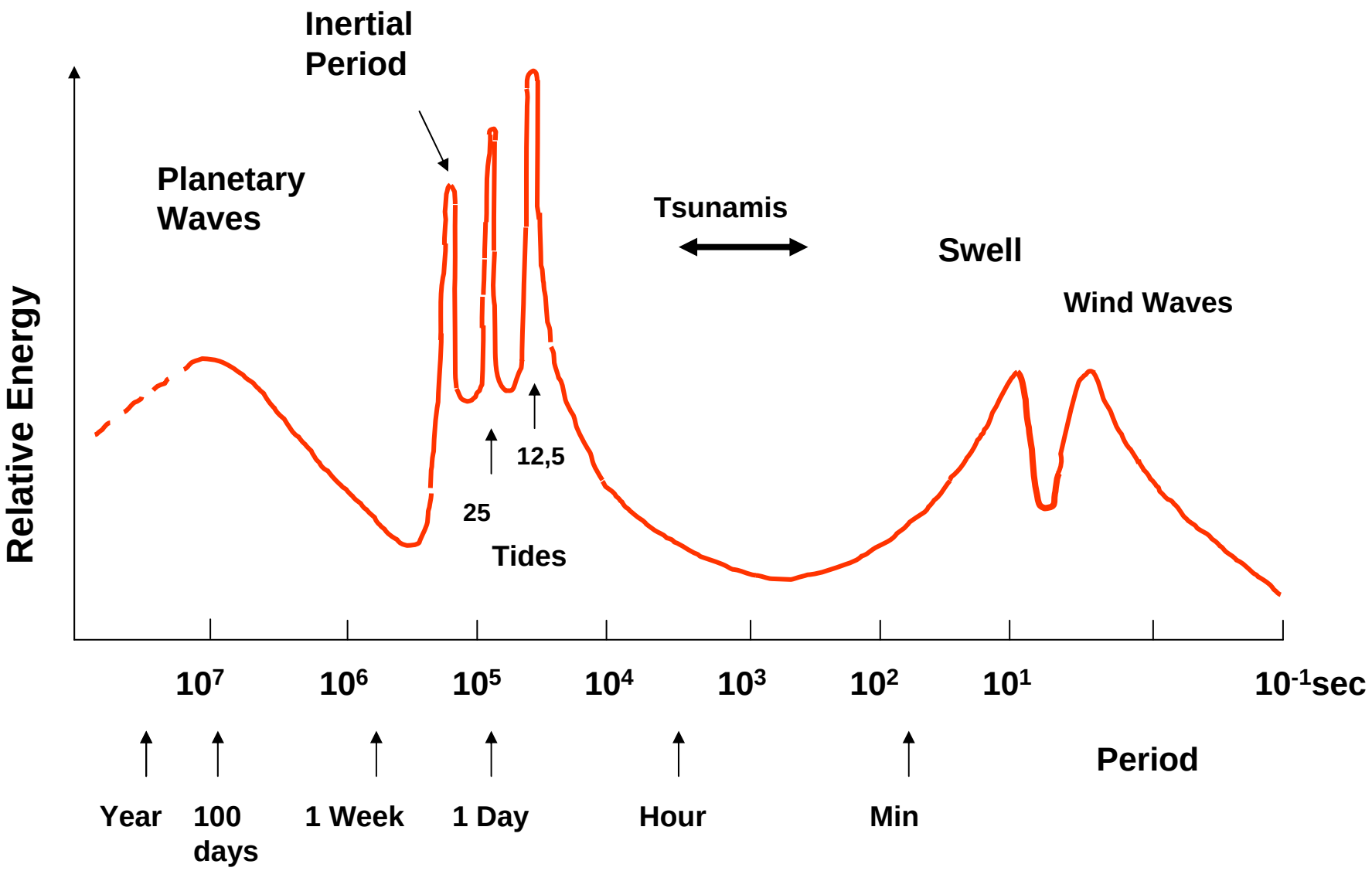
Ocean Bottom Pressure



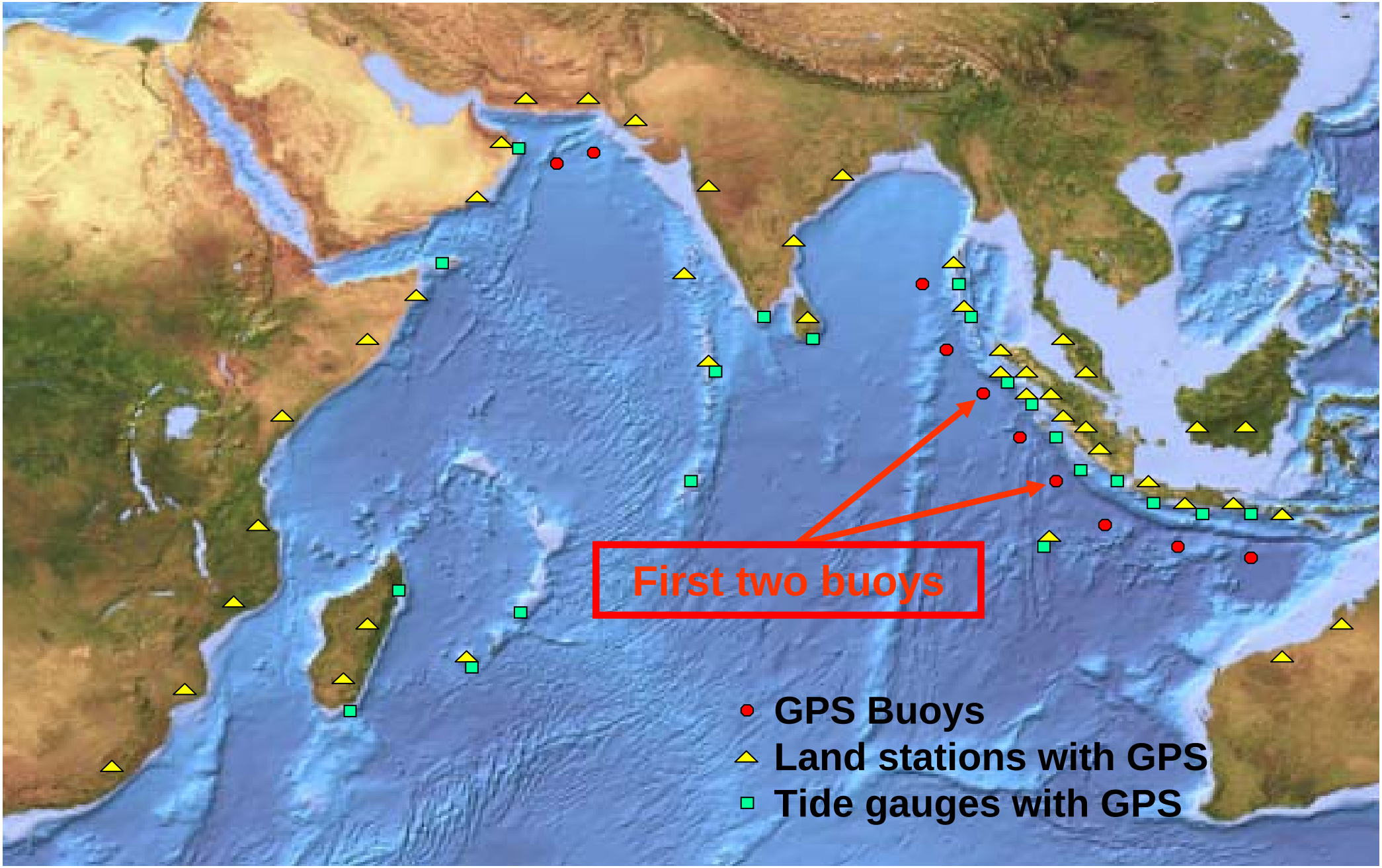
GPS Tsunami Buoy: Waves



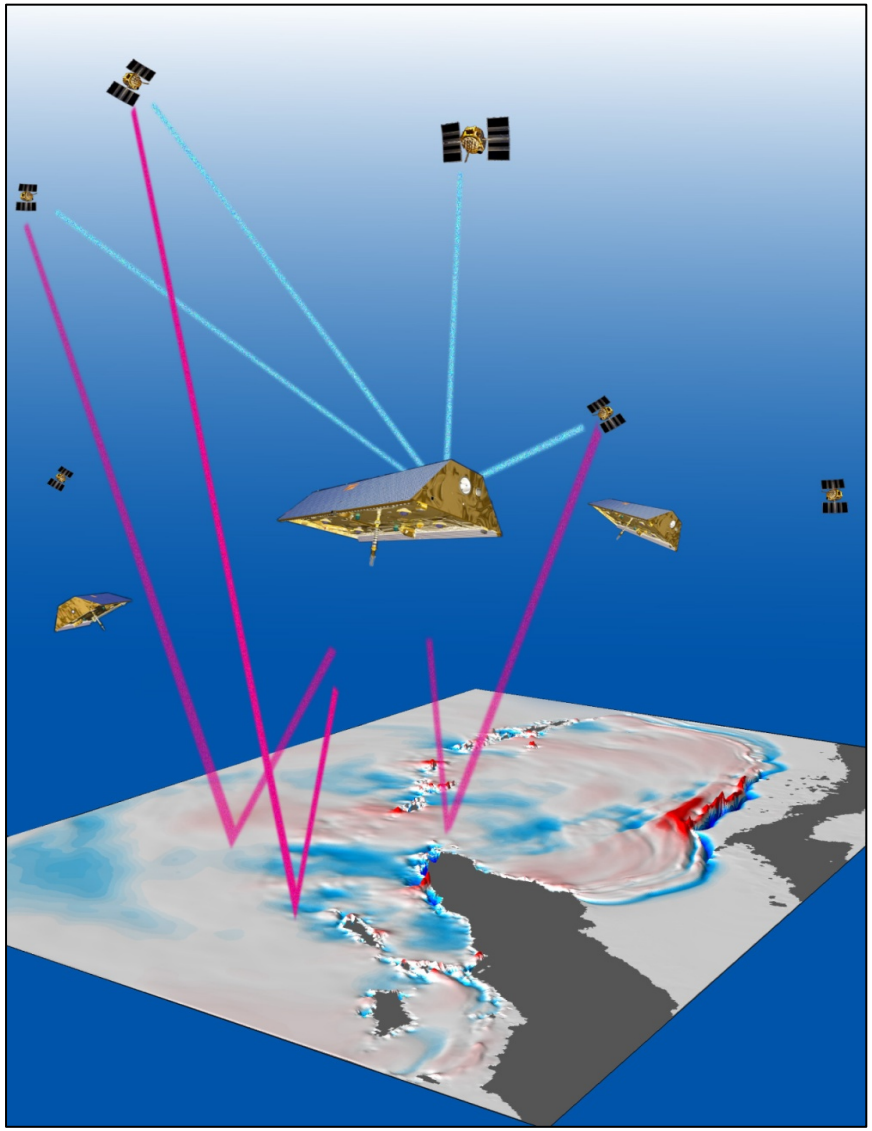
GPS Buoys: Tsunami Detection by Filtering



GPS Buoys and Other Instrumentation



Space-Based GPS Reflectometry



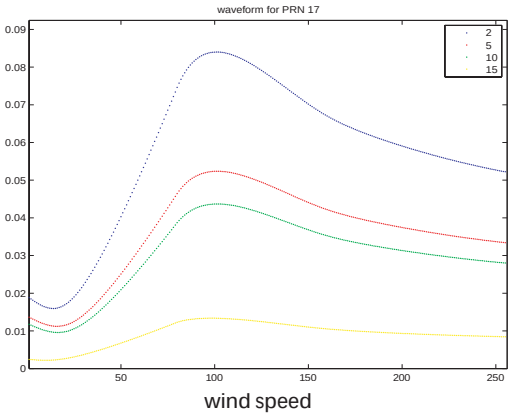
GPS ALTIMETRY

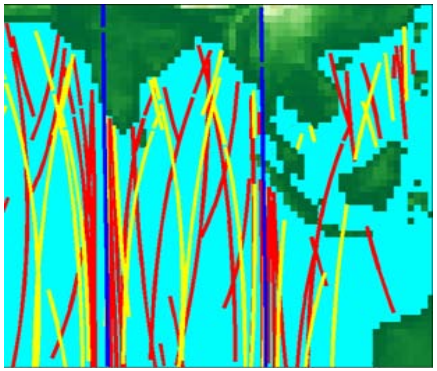
GORS SPACE RECEIVER DEVELOPMENT

with JAVAD

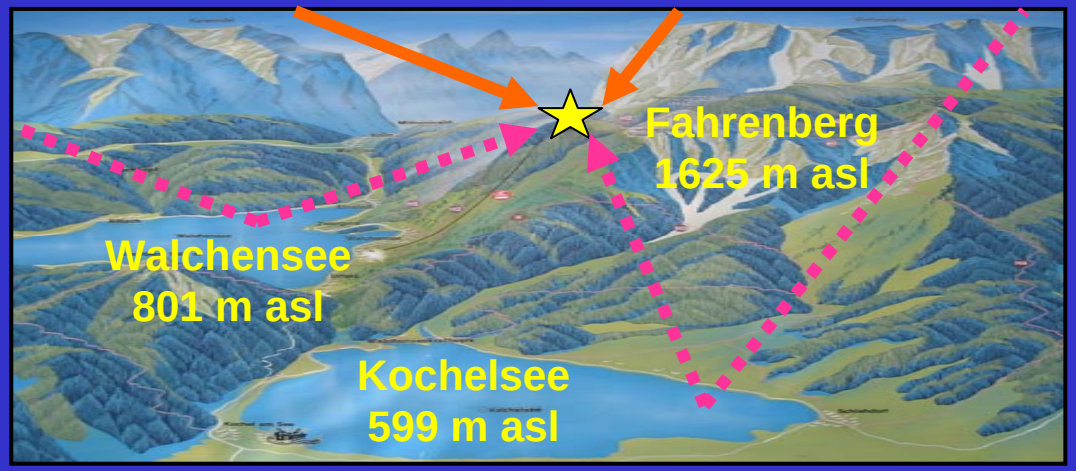
GPS SIGNAL SIMULATION & MISSION DESIGN STUDY

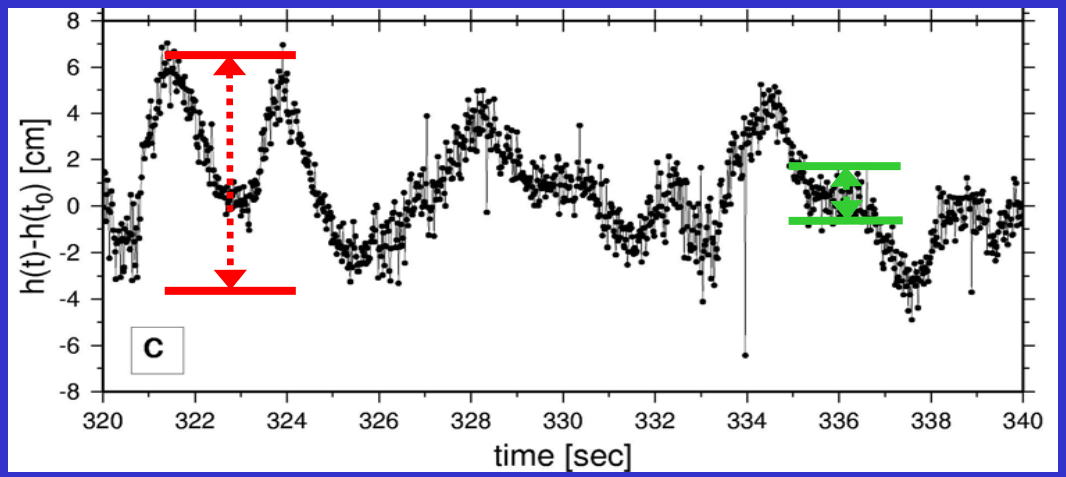
IEEC ICE





First Tests: GPS Reflectometry on the Ground





Wave amplitude up to 10 cm

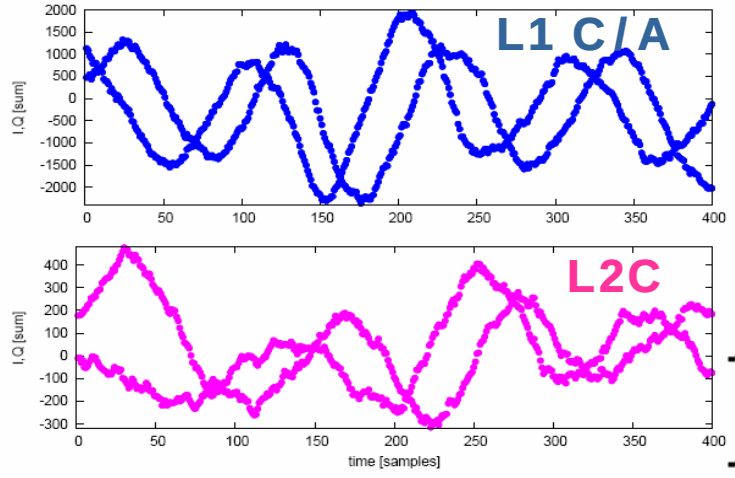
Precision approx. 2 cm

Instrument:
Reflectometry GPS receiver designed and developed by GFZ

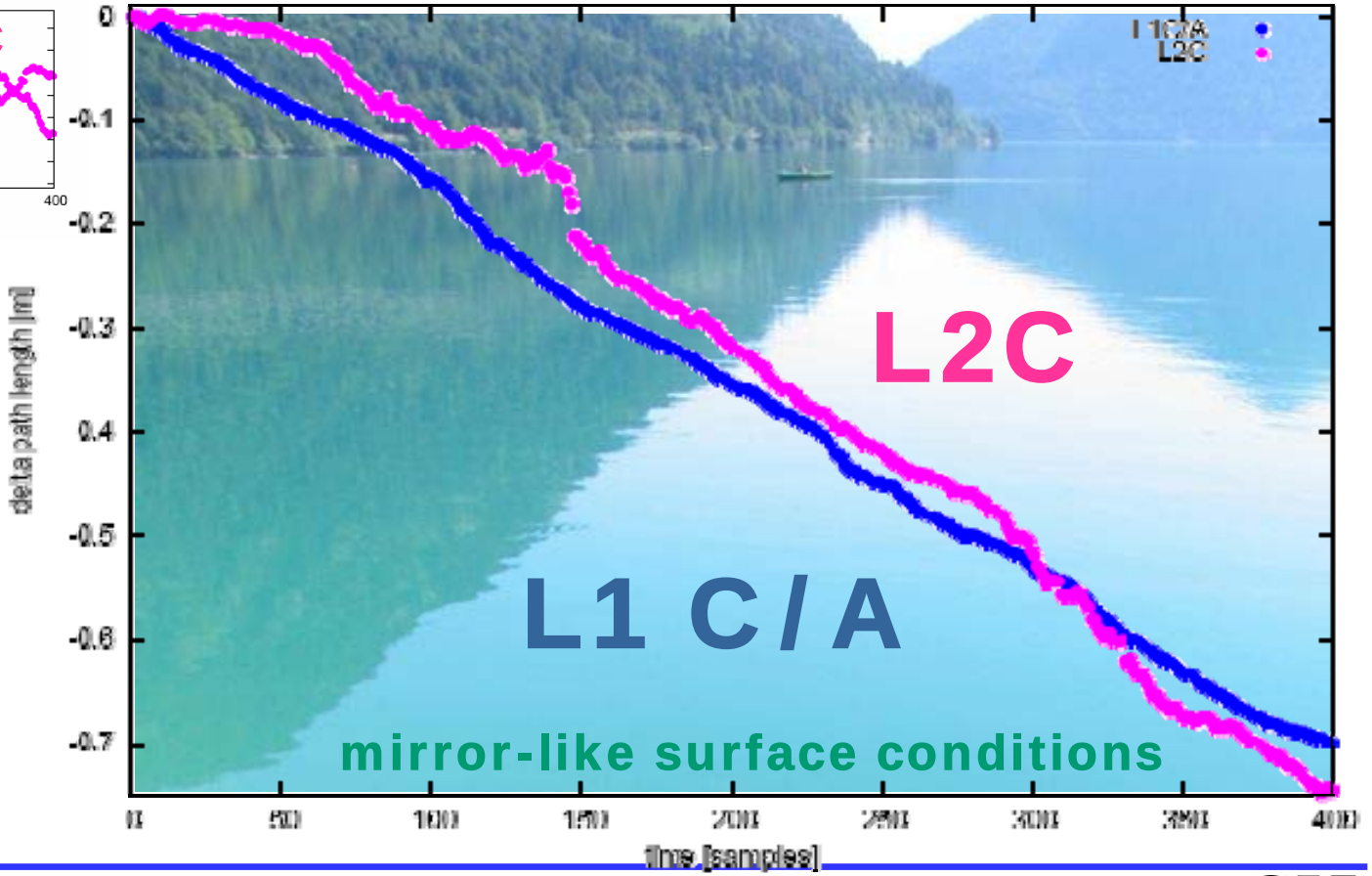
Measurement technique:
Interference between the reflected and the direct GPS signal

Result:
Relative height change with centimeter accuracy

First L1 C/A and L2C Reflections at Lake Walchen



Path difference between direct and reflected GPS signal



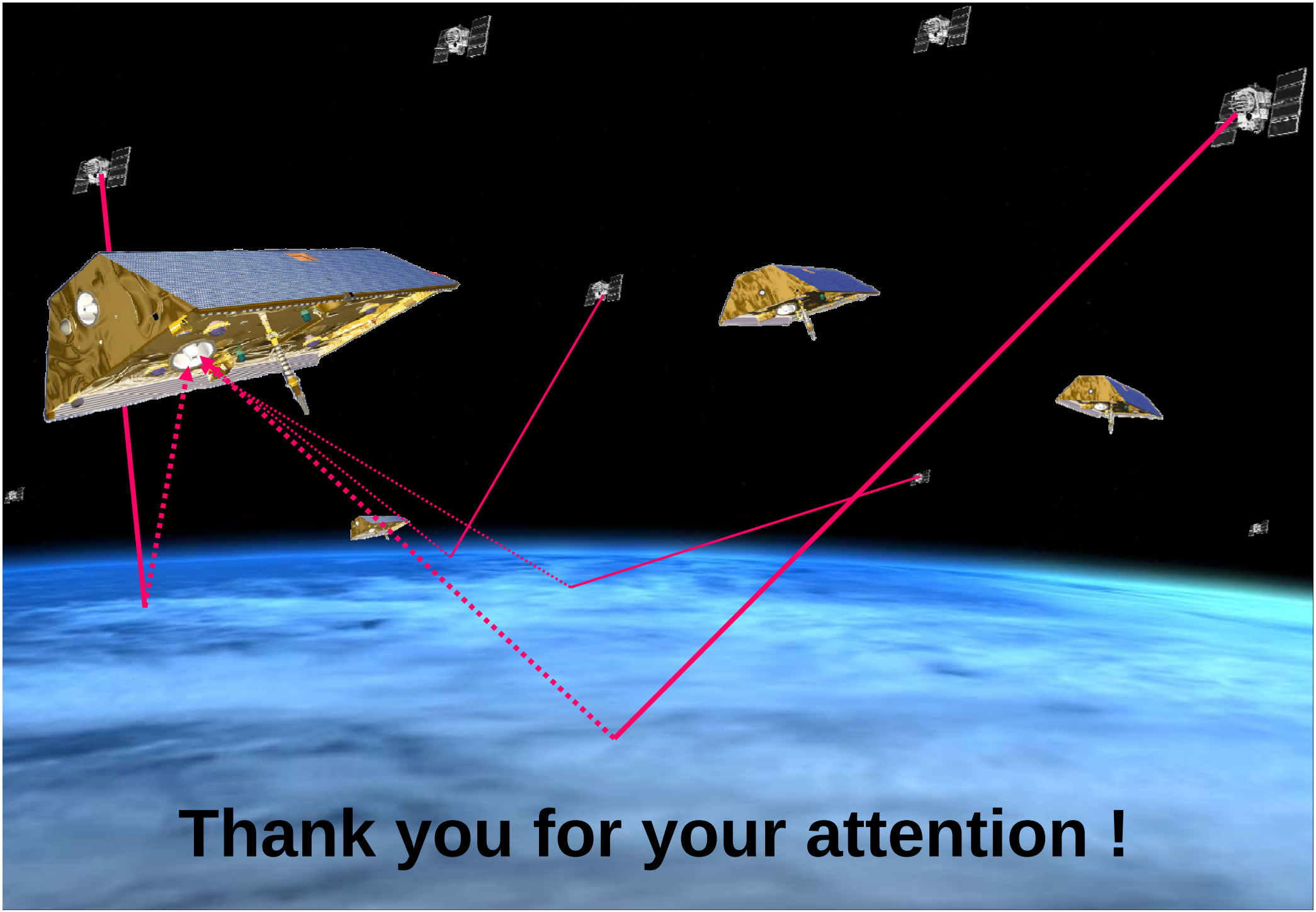
Summary and Conclusions

Geodesy's contributions to TEWS:

- High-precision and stable global reference frame (all space techniques)
- Detection of displacements with GPS for determination of Earthquake model parameters (e.g., "GPS shield")
- GPS seismology: measuring the motion during the Earthquake, integration with seismometers (→ co-location of instruments)
- Tide gauges with GPS to distinguish between motion of land and sea
- GPS buoys to measure the tsunami wave independently of OBP unit
- Future: satellite constellation with GNSS reflectometry and scatterometry, global multi-hazard monitoring/warning system

Requirements:

- Real-time (RT) capabilities (incl. communication) and system reliability
- Earthquake-prone areas: a backbone of globally distributed RT GPS station is needed (→ IGS/GGOS)
- RT GPS clocks and orbits would enable Precise Point Positioning (PPP) at stations with limited bandwidth (→ IGS/GGOS)


Thank you for your attention !