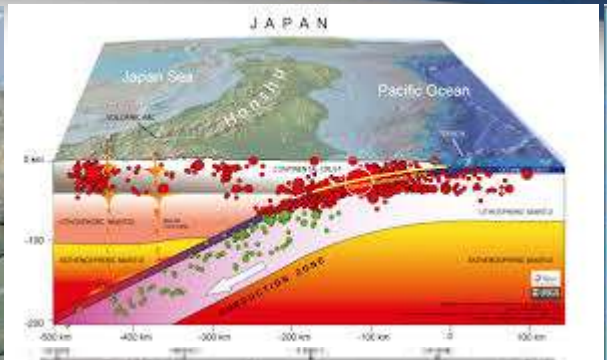
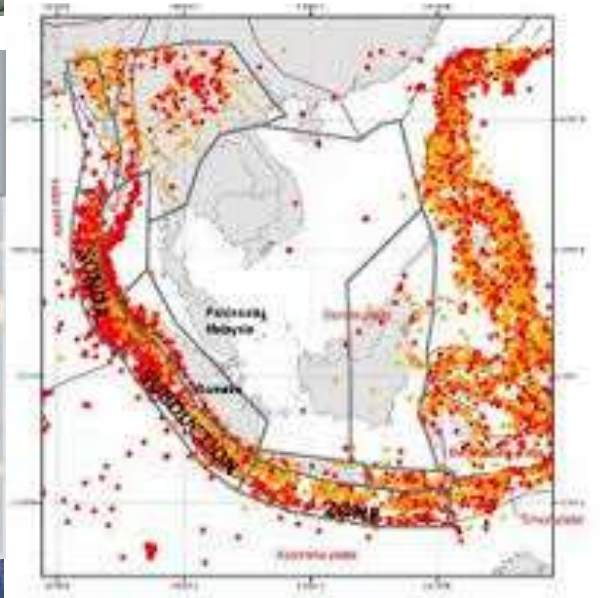
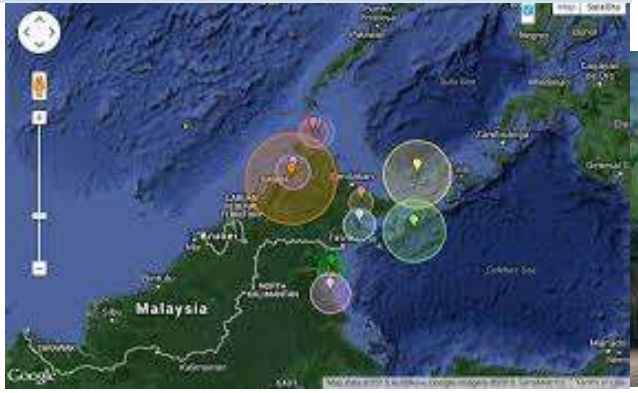
Trimble SG160-09 SeismoGeodetic For Earthquake Early Warning

GeoSmart KL, Malaysia
1ST October , 2015

TAN SIEW SIONG







source: INTERNET

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Earthquake Early Warning

Source: USGS

What is EEW?

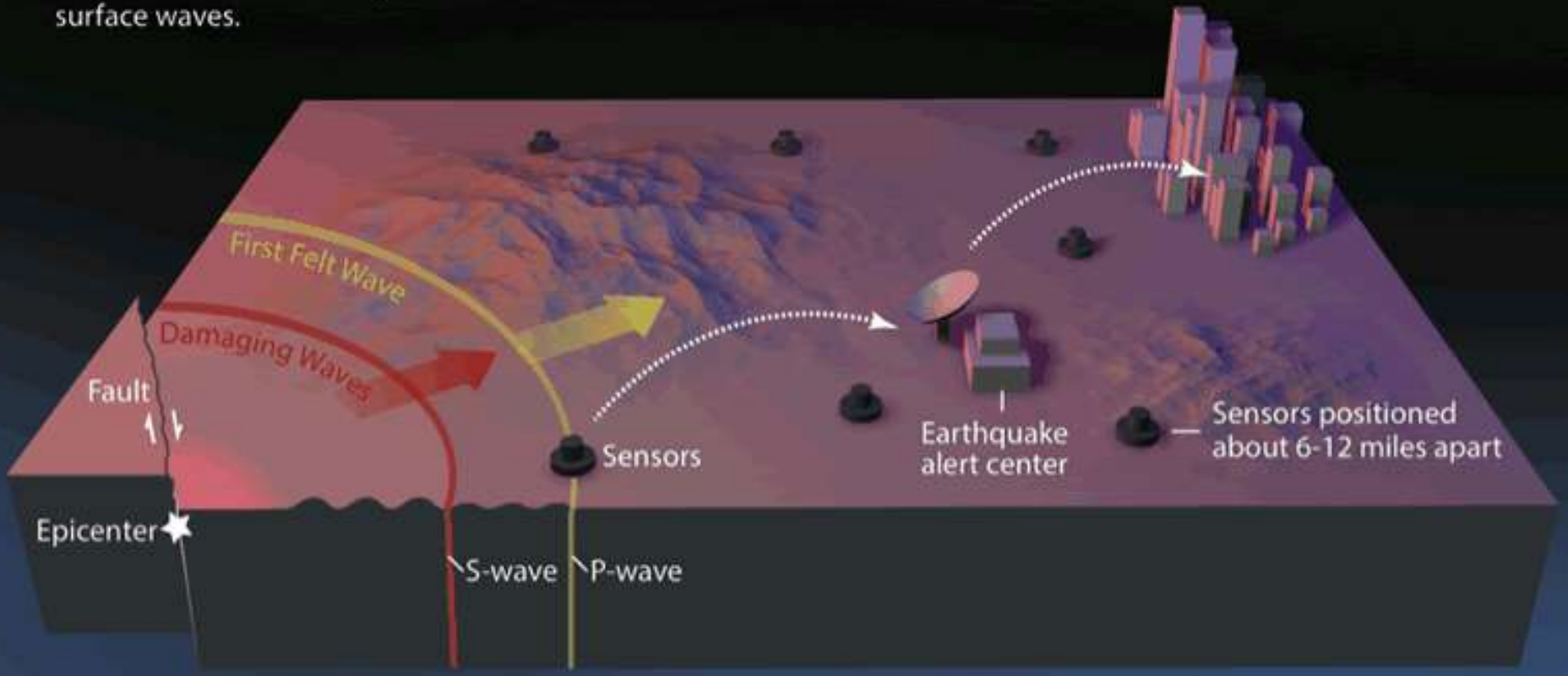
- “Earthquake early warning systems use earthquake science and the technology of monitoring systems to alert devices and people when shaking waves generated by an earthquake are expected to arrive at their location. The seconds to minutes of advance warning can allow people and systems to take actions to protect life and property from destructive shaking” [source: USGS]

Earthquake Early Warning Basics

1 In an earthquake, a rupturing fault sends out different types of waves. The fast-moving P-wave is first to arrive, but damage is caused by the slower S-waves and later-arriving surface waves.

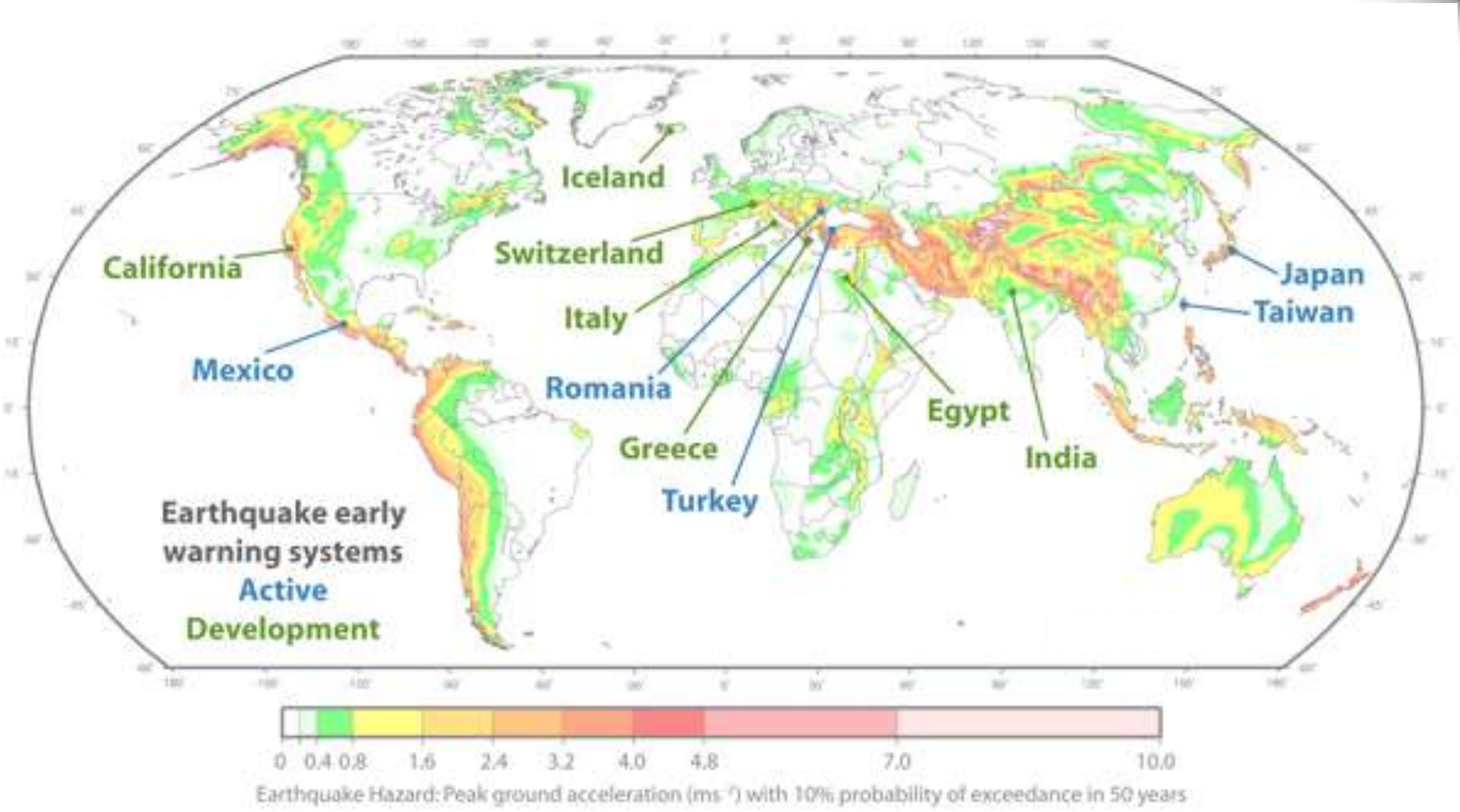
2 Sensors detect the P-wave and immediately transmit data to an earthquake alert center where the location and size of the quake are determined and updated as more data become available.

3 A message from the alert center is immediately transmitted to your computer or mobile phone, which calculates the expected intensity and arrival time of shaking at your location.



Source: USGS

GLOBAL EEW



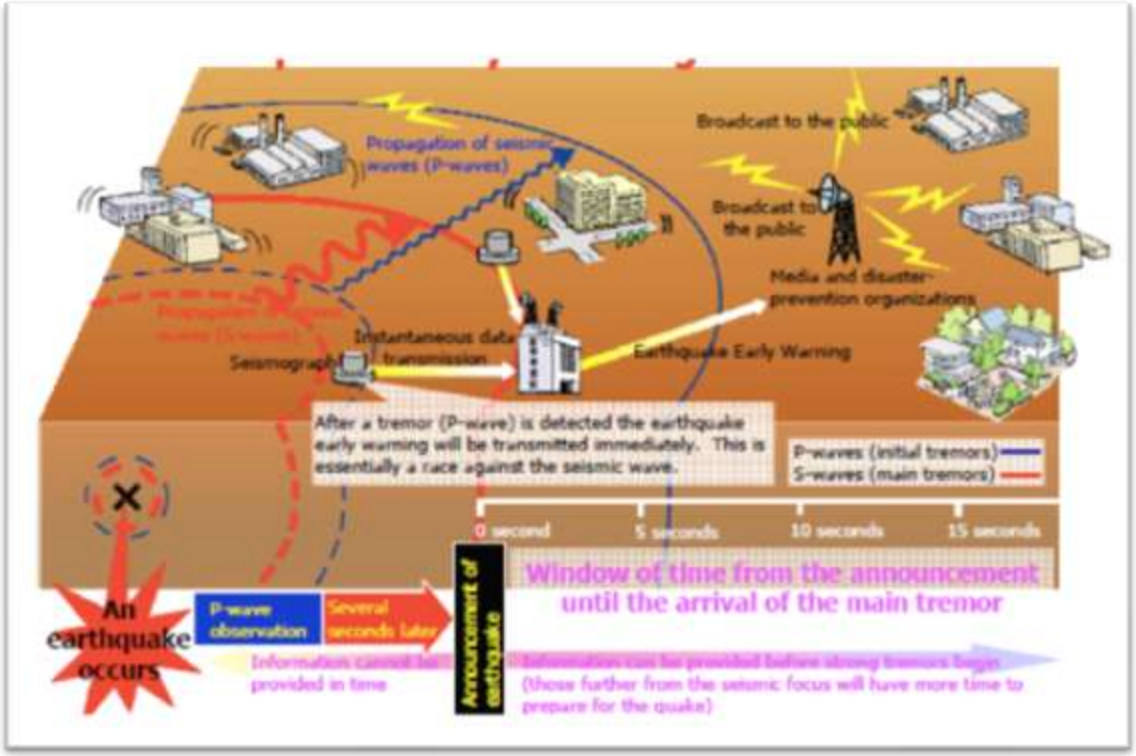
Source: University of California Berkeley

EEW - Benefits

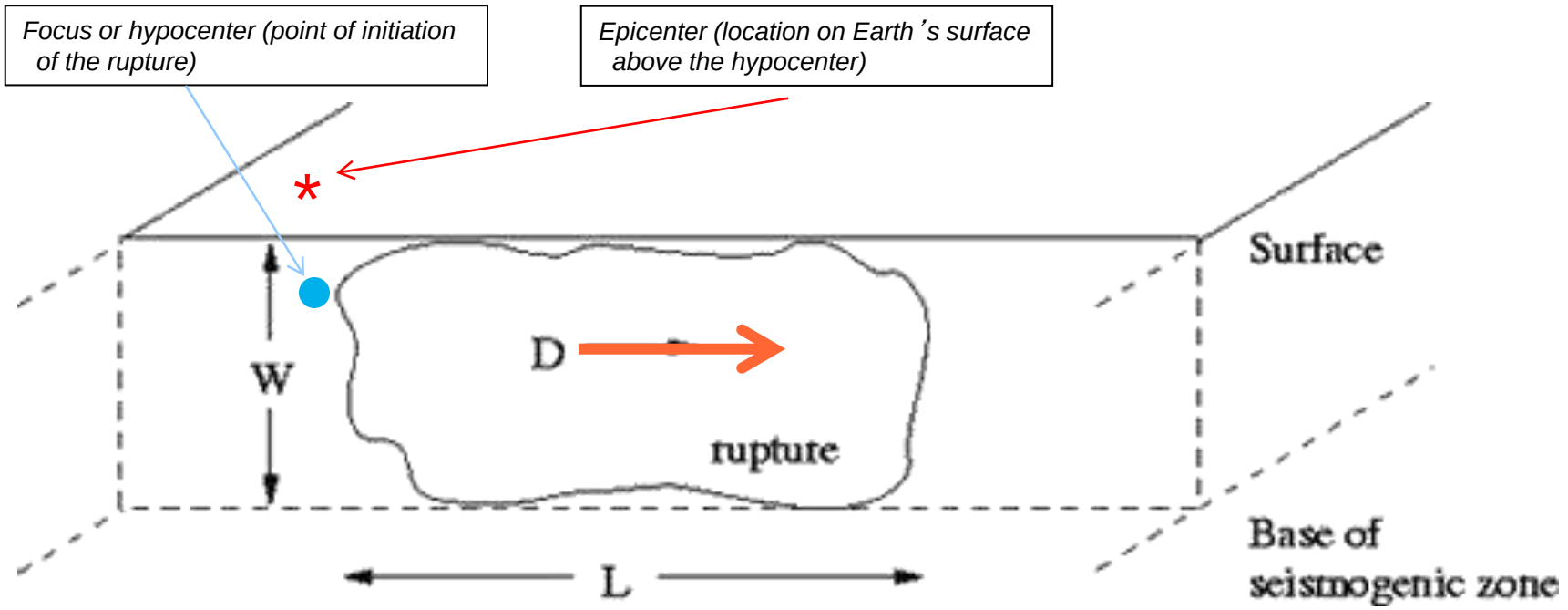
- Public: Taking cover; stop vehicle; turn off appliances
- Businesses: Move folks to safe location; shut down elevator, production line, etc.
- Medical services: Stop dedicate surgery procedure;
- Emergency responders: Civil & firefighting preparedness for emergency response
- Power Infrastructure: Protect Power and Grid facility from shaking (eg. Nuclear Power Plant) [source: USGS]

Epicenter & Magnitude

- Earthquake induced site displacement is key information for locating the epicenter and estimating the magnitude of earthquakes.
- For earthquake early warning (EEW) systems, the estimation of accurate co-seismic displacements and waveforms is needed in real time to inform decisions about public safety and infrastructure shutdown.



Moment Magnitude (**Mw**; also called ***Magnitude*** or ***M***, as in, "*an **M8.0** earthquake*")



Moment = Mo = μ A D (dyne-cm)

μ = shear modulus ~ 32 GPa in crust (~3.2 x 10^{11} dynes/cm^2), ~75 GPa in mantle

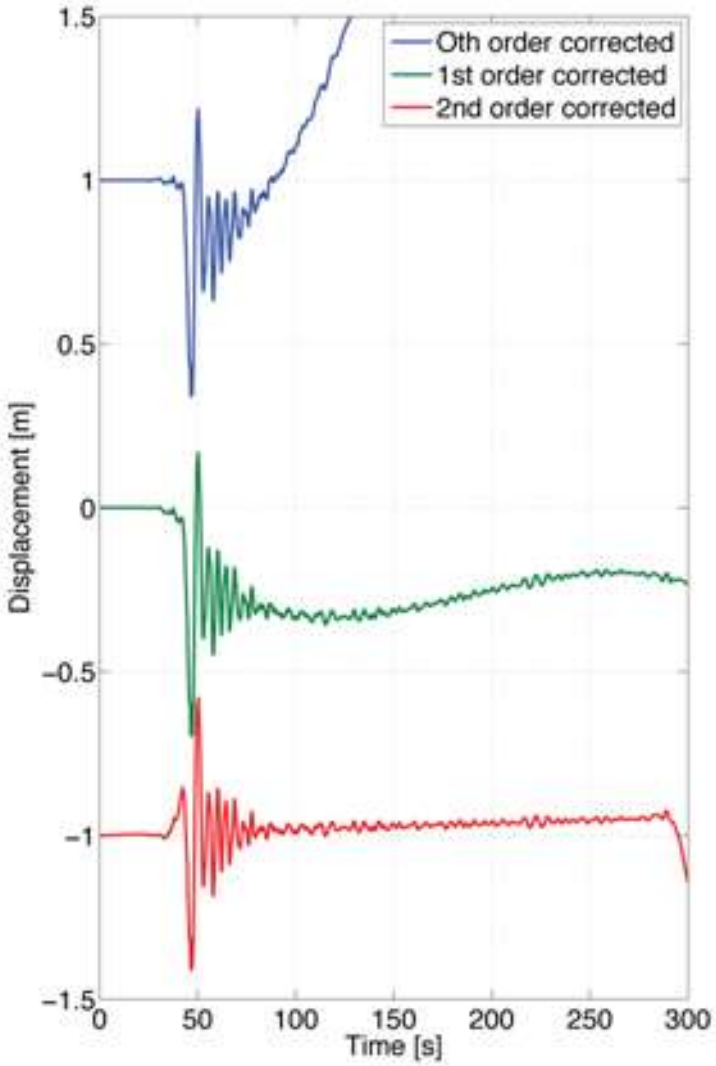
A = LW = area (cm^2)

D = average displacement during rupture (cm)

http://neic.usgs.gov/neis/general/measure.html
http://earthquake.usgs.gov/image_glossary/seismic_moment.html

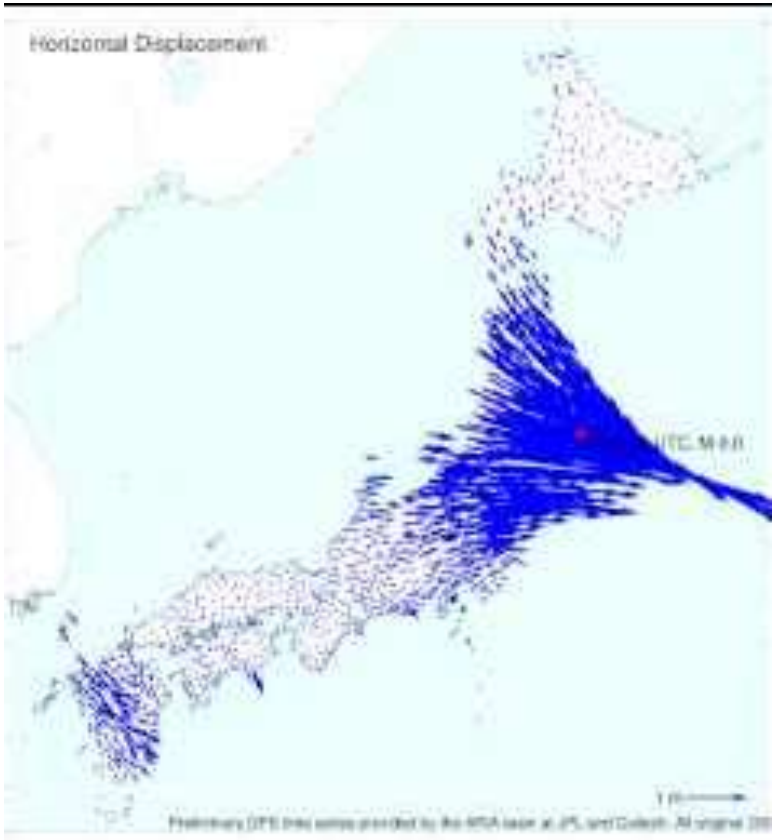
Seismic Displacements

- Seismic displacements are obtained by double integration of observed accelerometer signals and or single integration of velocities observed with broadband seismometers
- Seismic instruments that are subject to drifts (accelerometer) or signal clipping in case of large earthquakes (broad-band seismometer)



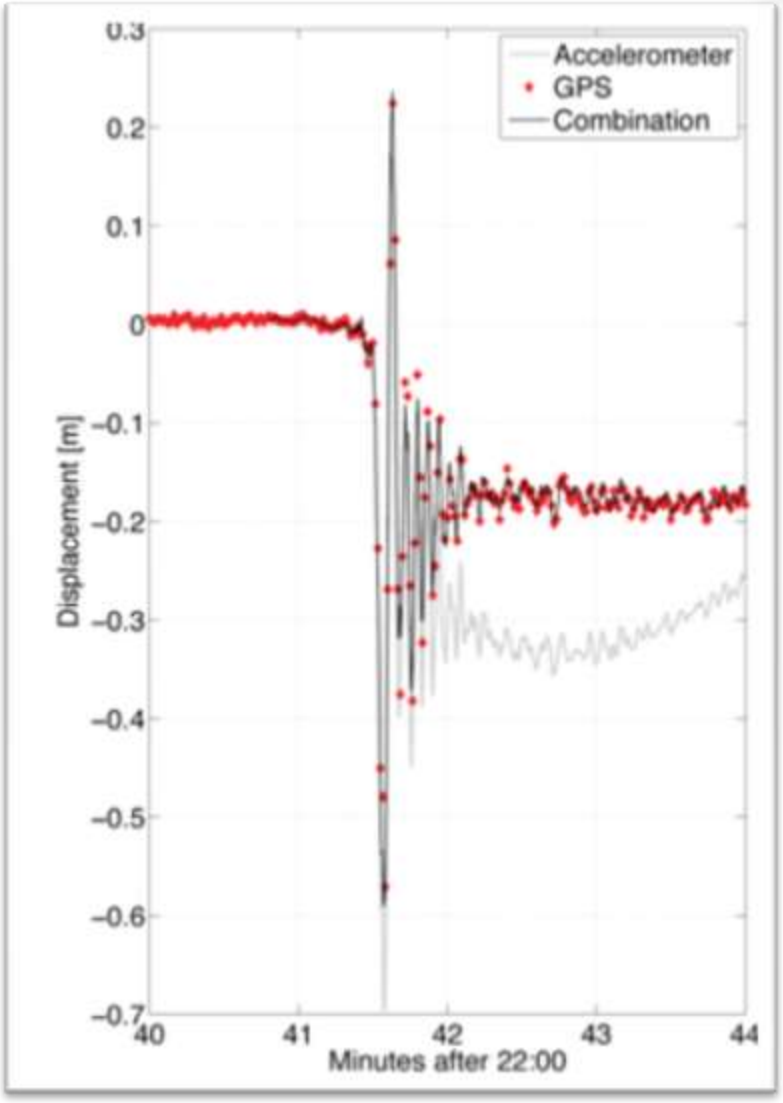
GNSS Displacements

- GNSS receiver displacements are precise and don't suffer from drift or scale issues of seismic systems.
- GNSS displacements processed by relative methods (post-processed or RTK based) are provide a relative displacement with respect to (at least) one reference station, which might itself be subject to shaking.
- Trimble CenterPoint™ RTX™ using Trimble orbit and clock products can be used to determine an provide "absolute" co- seismic displacements with respect to a global reference frame .



EEW - MOVITATION

- **A filtered combination of GNSS and accelerometers provides optimum, accurate, and high rate estimate of displacement needed for Earthquake Early Warning**



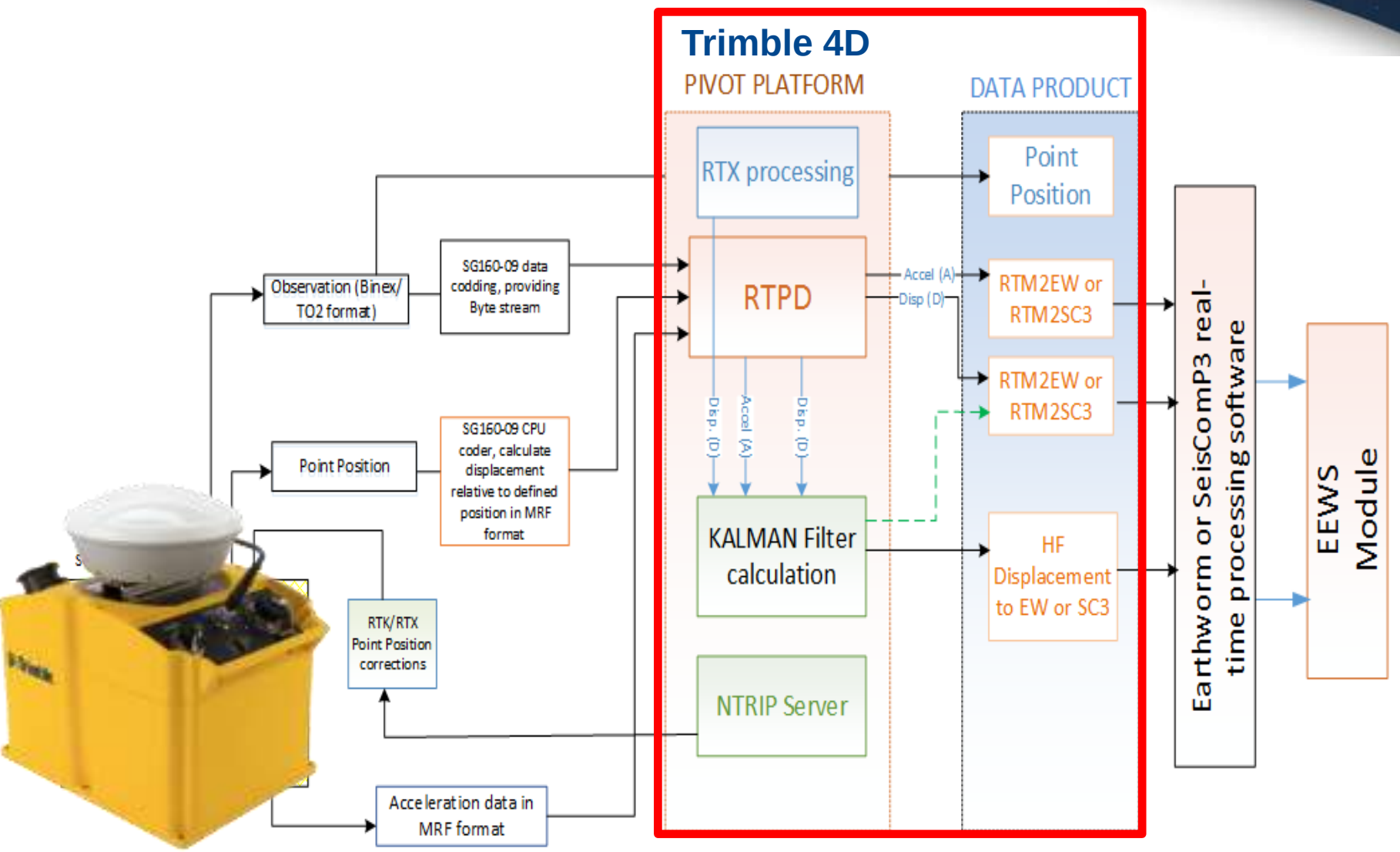
Design Concept - Trimble SeismoGeodetic System

- An Integrated System, combining high resolution GNSS and seismic measurements to estimate accurate displacements and acceleration needed in real time for Earthquake Early Warning.

- Simplify field installation and reduce the system maintenance.

- Fast and Reliable Error Corr. Comm. Protocol

SG160-09 Data Flow Schematic



Rapid Event Notification (REN) algorithm

Field Station

Real-time

Communication Cloud

Processing Facility

Real-time

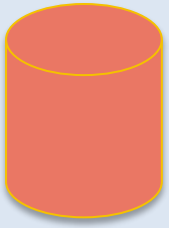
- Close packets every 0.2 sec. Additional 0.05 sec to process Mutiplex Recording Format (MRF). Total time from start of packet to send <0.25 sec.
- Sliding window with positive acknowledgement of received data by event number and sequence number

Ack.

Packet 1

Error checked.

Packet1



Data Archive with backfill capability

Interface to Real-time data processing software: Earthworm SeisComp3

Rapid Event Notification (REN) algorithm

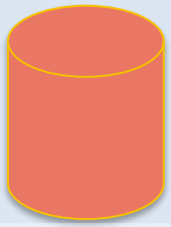
Field Station
Backfill Real-time

Processing Facility
Backfill Real-time

- Close packets every 0.2 sec. Additional 0.05 sec to process Mutiplex Recording Format (MRF). Total time from start of packet to send 0.25 sec.
- Sliding window with positive acknowledgement of received data by event number and sequence number

Backfill queue **Not ack-ed**

Error checked



Data Archive with backfill capability

Real-time data output to processing interface
Earthworm
SeisComp3

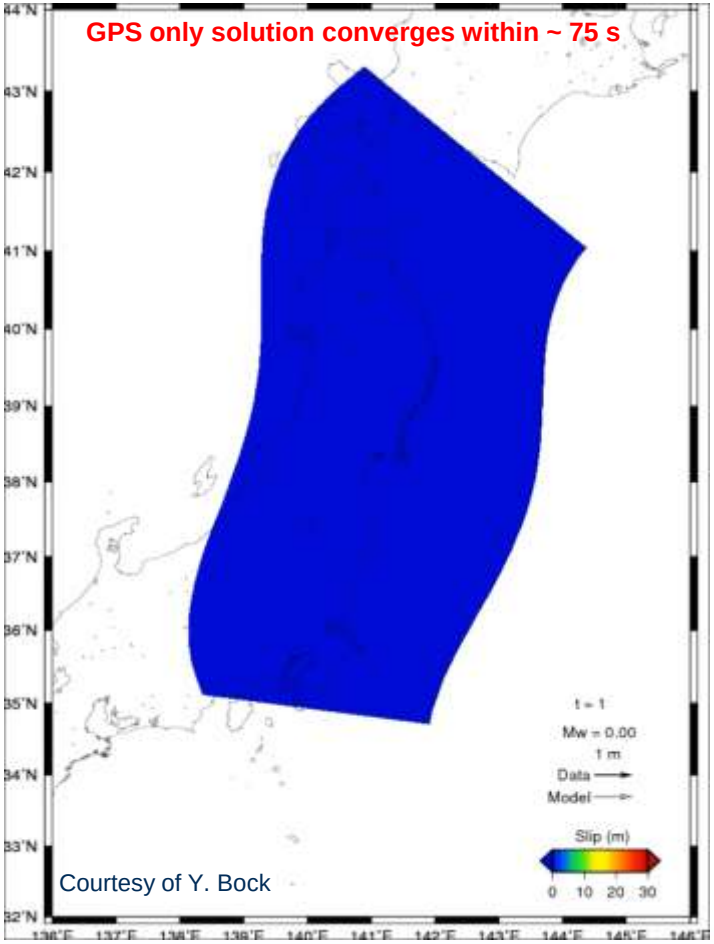
Simplified Field Installation:

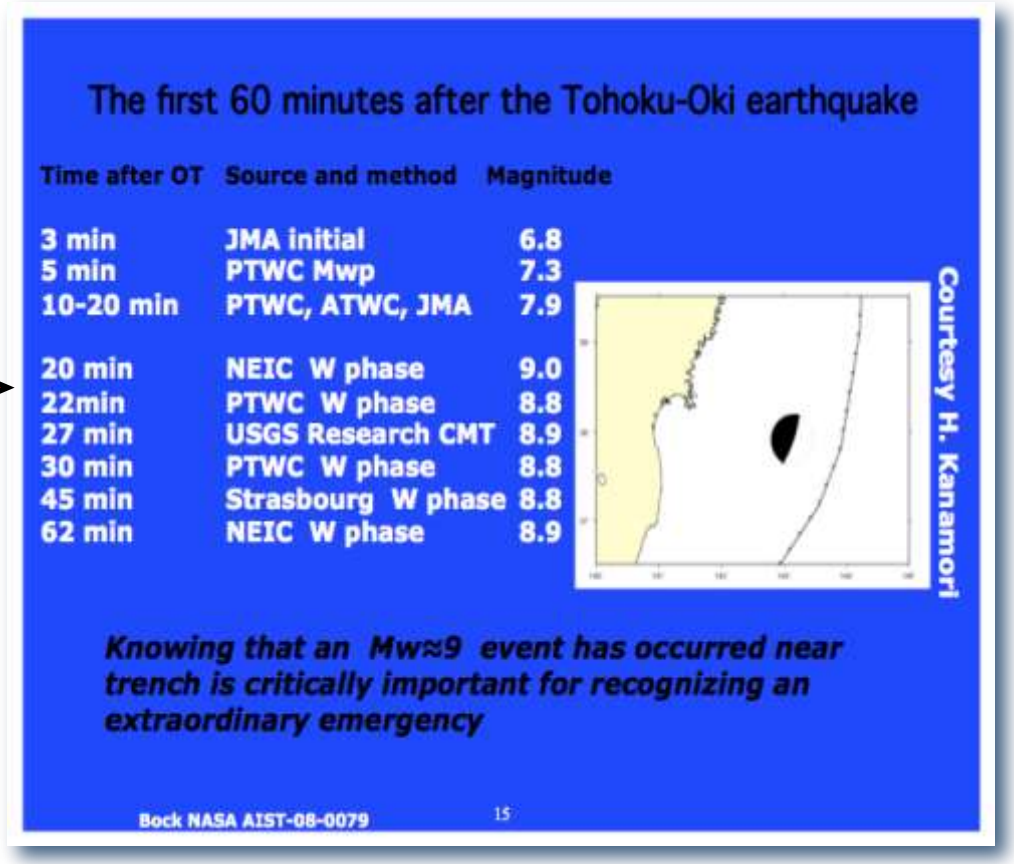
- Easy installation; occupies less space on site; consumes less power, utilizes an existing communications media.
- Integrated seismic and geodetic acquisition can replace the myriad of seismic acquisition hardware currently in use.
- Minimal interconnection cables thus providing less possible points of failure, which reduces the routine maintenance cost.

Applications:

Seismic and Earthquake Early Warning System

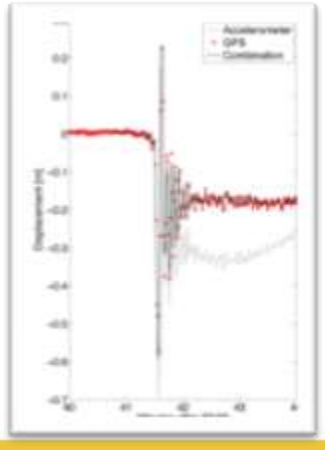
For Earthquake Early Warning (EEW) systems, the SG160-09 calculates accurate co-seismic displacements and seismic information in real time to alert decision makers about public safety and infrastructure shutdown.

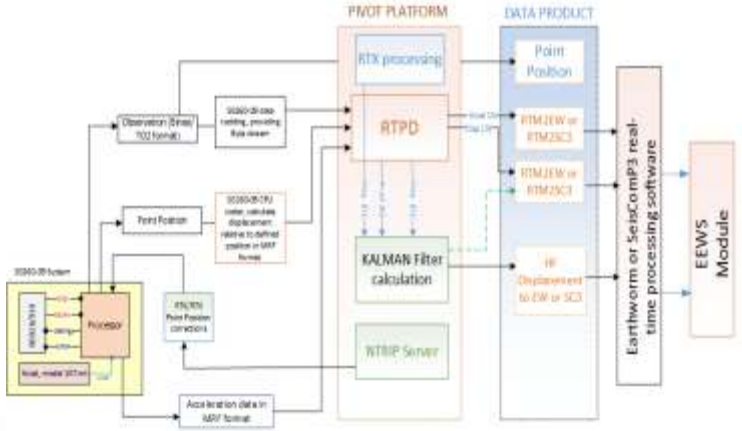




Summary: SG160-09 EEW

- Combined true acceleration (200 sps) and displacement (10 sps) observations: on board GNSS displacements processing (Trimble RTX PPP)
- Instantaneous Displacements processed, recorded and transmitted from receiver
- Unified recording format of both seismic and geodetic data (MRF)
- Low power , Low Maintenance
- Fast data delivery algorithm (REN)
- Error-correction communication protocol with Backfill algorithm for data integrity
- Real Time data display in Trimble 4D for high resolution acceleration and displacement data to real-time processing s/w to Earthworm and SeisComp3 for a complete EEW – To Protect Life & Property from Shaking





QUESTION?