Adapting GNSS Receivers for Earthquake Early Warning Systems

IRIS Seismic Instrumentation Technology Symposium 2018

www.Septentrio.com

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- The Company

- Why GNSS for EEW?

- The Equipment

- Adapting GNSS Receivers for EEW
  - On-Board Precise Point Positioning (PPP)
  - Storage Integrity

- Summary

Septentrio – The Company

- Est. 2000, as a spin off of IMEC

- Headquarters: Leuven, Belgium

- Currently 100+ people worldwide; >50% in R&D

- Contracted @ European Space Agency (ESA) since 2002
  - Active role in Galileo and other strategic programs

- Veripos program initiated in 2008
  - Established global reference station network for PPP corrections

- Focused on Professional GNSS Segments:
  - Scientific Monitoring & Reference Stations
  - Machine Control & Automation
  - Land, Marine and Aerial Survey

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Septentrio Japan
Tokyo, Japan

Septentrio HQ,
Leuven, Belgium

Septentrio China
Shanghai, PRC

Septentrio Americas,
Torrance, CA,
Chicago, Miami

Leuven, Belgium: Home to world-class institutions

PolaRx5 GNSS Family: Hardware and Software Variants

		PolaRx5 Ref Station	PolaRx5e Ref Station	PolaRx5S Iono Monitoring	PolaRx5TR Time Transfer
Hardware	IP rating	IP65	**IP68**	IP65	IP65
	Internal batter	NO	**YES**	NO	NO
	Internal clock	TCXO	TCXO	**OCXO**	TCXO
	REF IN	**YES**	**YES**	NO	**YES**
	PPS IN	NO	NO	NO	**YES**
	External Clock Synchronization	**Frequency only**	**Frequency only**	NO	**Frequency and time**
	REF OUT	YES	YES	YES	YES
	PPS OUT	YES	YES	YES	YES
Software	PPP for seismic	**YES**	**YES**	NO	NO
	CGGTTS	NO	NO	NO	**YES**
	ISMR	NO	NO	**YES**	NO
	IQ Corr	NO	NO	**YES**	NO

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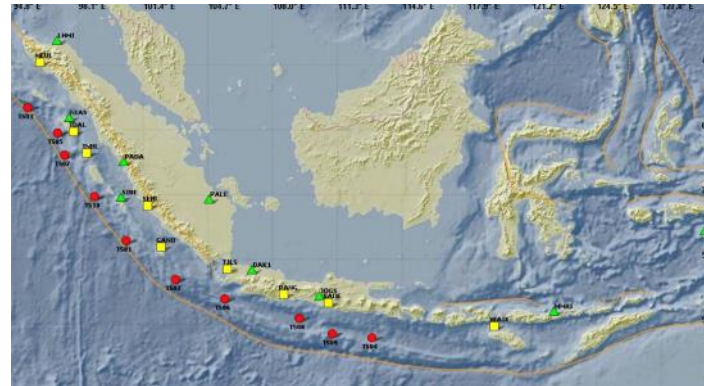# Septentrio in Geo-Science Applications

- **Crustal Deformation Monitoring**

- **Volcano Monitoring**

- **Tsunami Early Warning**

- **Landslide Monitoring**
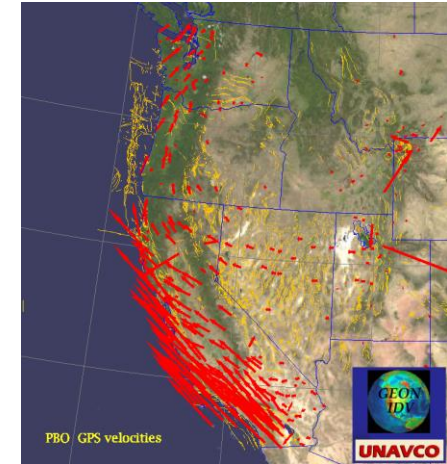
EarthScope – North American
Plate Boundary Observatory (PBO)

Slovenia (Stoze Mountain) –
Landslide Monitoring

Indonesia – Tsunami Early
Warning System (GFZ – Germany)

Montserrat Volcano Observatory
(photo credit: U. West Indies)

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Why GNSS for Earthquake Early Warning

- Ground motion data measured by GNSS receivers complement traditional seismic approaches for the development of Earthquake Early Warning (EEW) algorithms.

- GNSS data enables a reliable estimation of fault length and magnitude for the largest earthquakes.

- A real-time on board Precise Point Positioning (PPP) solution allows for the measurement of displacements at sub-decimeter level
  - No need for added complexity of a server-based solution

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The Equipment: GNSS Receiver & Antenna Overview

PolaRx5 or PolaRx5e GNSS Receiver

- 544 hardware channels for simultaneous tracking of all visible satellite signals
  - GPS, GLONASS, GALILEO, BEIDOU, IRNSS, QZSS
- Interference monitoring-built in spectrum analyzer
- Built-in L-band receiver
  - PPP for seismic applications (optional feature)
- SYNC+ Storage Integrity feature
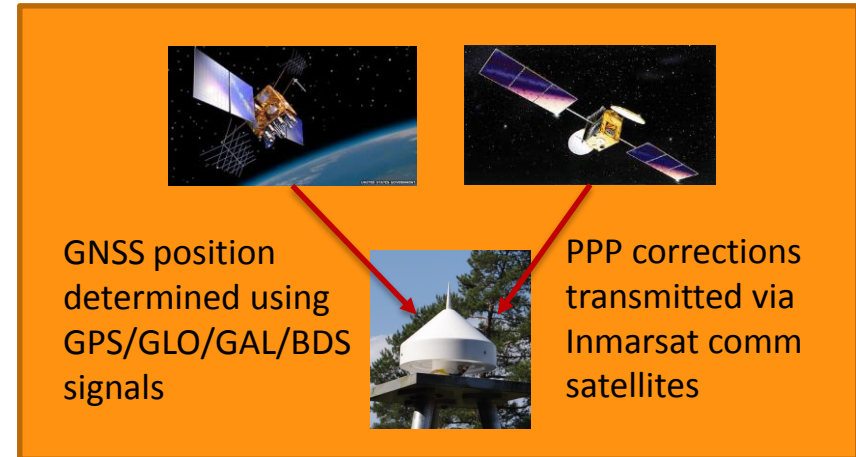- Lowest power consumption in its class

Choke Ring B3/E6 GNSS Antenna

- Supports all GNSS signals, incl. BeiDou B3 and Galileo E6 and L-band capability
- IGS calibration available with or without radome

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# Adapting GNSS for EEW: On-board PPP

- Standard GNSS positioning suffers from systematic errors which limit the GNSS positioning accuracy to the meter level. Error sources include:
  - Satellite position and clock
  - Propagation delays in the ionosphere and troposphere
  - Local scattering effects
- PPP enables sub-decimeter-level accurate position calculations, independent of the users location
  - A global GNSS reference station network provides the raw data needed to derive orbit and clock corrections

GNSS position determined using GPS/GLO/GAL/BDS signals

PPP corrections transmitted via Inmarsat comm satellites

- The accuracy and resolution are enhanced by the PPP solution:
  - 4 cm horizontal accuracy
  - 6 cm vertical accuracy
- PolaRx5 provides real-time recording of the high-frequency vibrations typically accompanying earthquakes
  - PPP algorithms tuned to respond to the typical dynamics for earthquakes
  - Enhanced Septentrio LOCK+ algorithm to maintain tracking during earthquakes

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Adapting GNSS for EEW: Storage Integrity

- The PolaRx5 series includes a smart telemetry system for efficient use of data bandwidth and storage integrity

- Automatic transfer of data from a receiver to a remote server can result in lost data or the unnecessary retransmission of complete data files.

- PolaRx5 features SYNC+, a fast differencing algorithm that analyses data files at the remote location and transfers only the missing packets.

Septentrio in Confidence
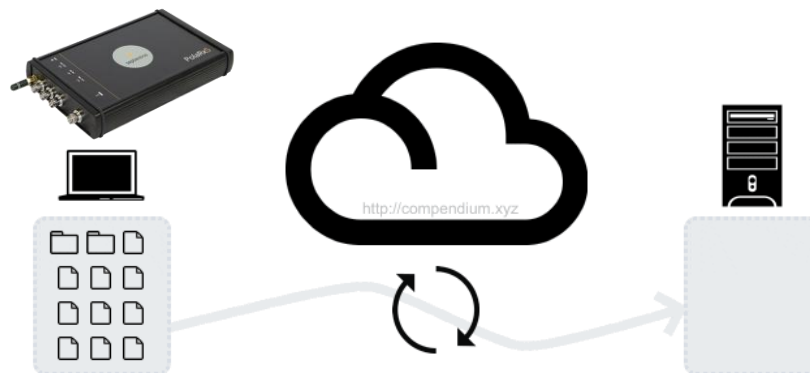
- Summary
  - Septentrio's experienced scientists and engineers are addressing the technical challenges faced by geophysicists across various disciplines
  - Multi-frequency GNSS technology should play an integral role for Earthquake Early Warning programs
  - On-board PPP enables accurate measurement of displacements at sub-decimeter level
  - SYNC+ Storage Integrity will ensure that all data is transmitted from a receiver to a remote server
  - <u>We believe in Science</u>. How can we support you?

Acknowledgements

Francesca Clemente, PhD. – Product Manager, Septentrio
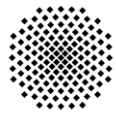
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