International Conference and Exhibition on
Satellite
August 17-19, 2015 Houston, Texas, USA

UNIVERSITY of HOUSTON

NCALM
The National Center for Airborne Laser Mapping
University of Houston • University of California, Berkeley

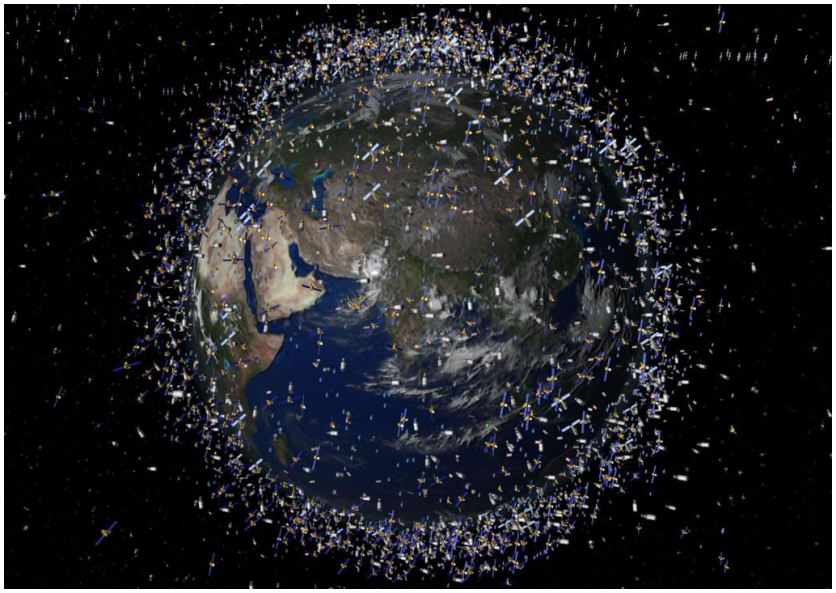
Large GPS Networks for Natural Hazards Study in North America and Caribbean

Guoquan (Bob) Wang

August 17, 2015



How many man-made satellites are in space?

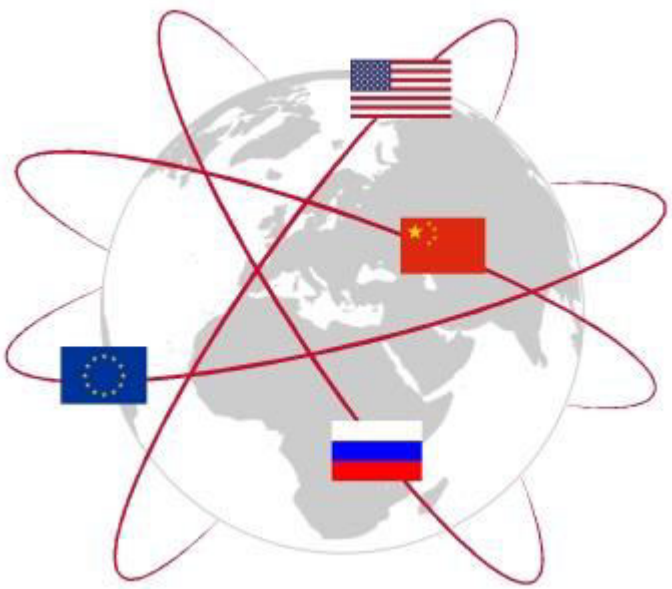




According to a report from NASA:

- About 6,600 satellites have been launched since 1957.
- About 3,600 remain in orbit.
- About 1,000 are operational; the rest have lived out their useful lives and are part of the space debris.
- Approximately 500 operational satellites are in low-Earth orbit
- **About 70 are in medium-Earth orbit (at 20,000 km)**

Satellites for Global Positioning and Navigation



GNSS



32+satellites



24 satellites



8, March 27, 2015
30, 20??

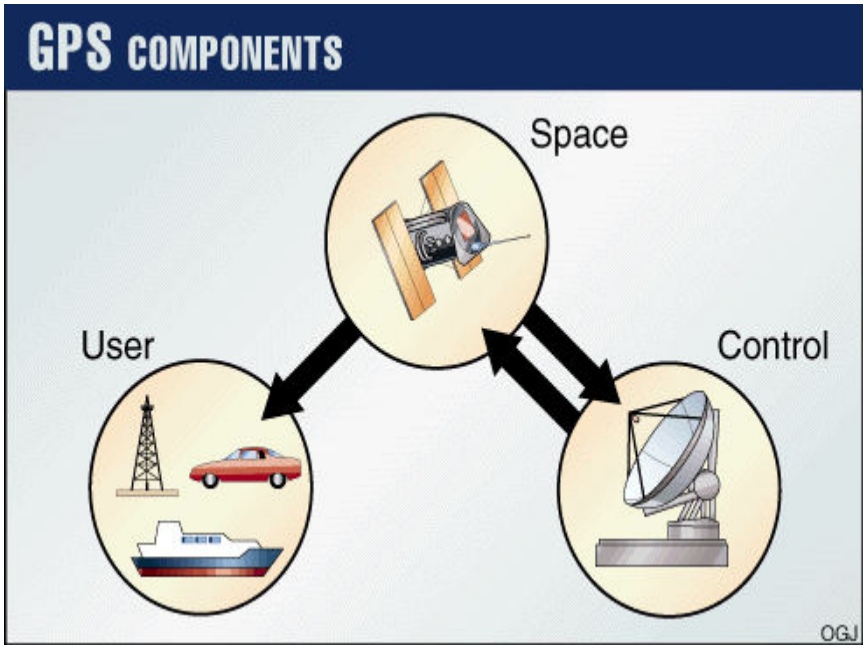


19, July 25, 2015
35, 2020

GNSS: Global Navigation Satellite Systems

GPS：Global Positioning System (U.S.)

GPS for Geological Hazards Study





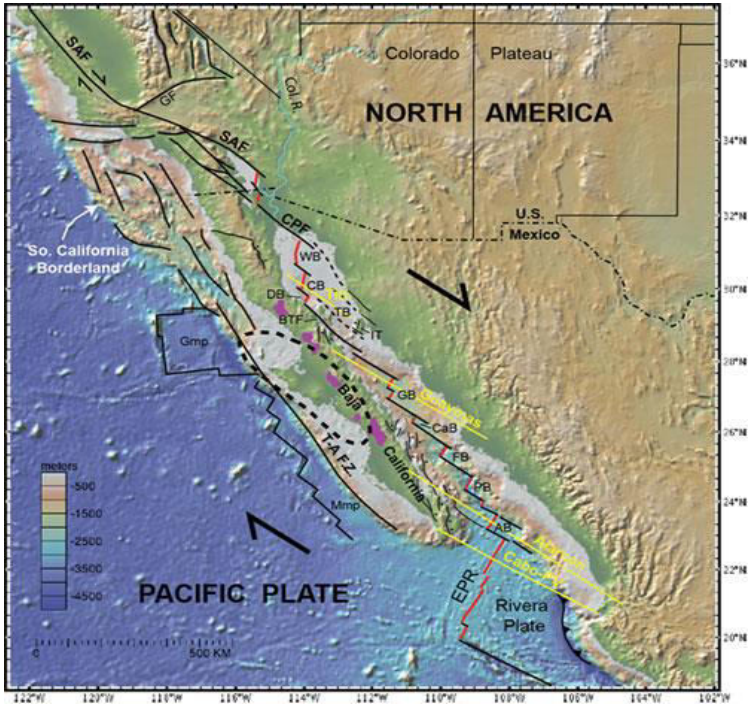


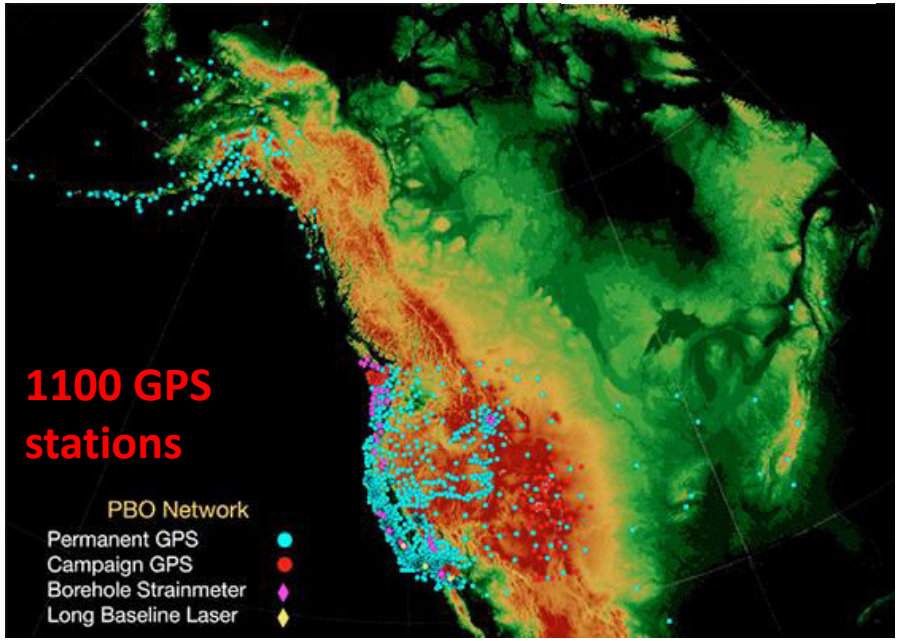
Geoscience Community (1980s—xx)

- Plate tectonic study
- Large earthquake monitoring (High-rate GPS)
- Tsunami early warning
- Hurricane intensity forecasting (Water Vapor)
- Volcano monitoring
- Landslide monitoring
- Faulting
- Subsidence monitoring
- Groundwater study
- Sea level change

PBO: Plate Boundary Observatory GPS Network

- The PBO was design to measure Earth deformation resulting from the constant motion of the Pacific and North American tectonic plates in the western United States.
- Proposed to NSF in 2001
- Funded by NSF (2003-2008, 2008-2018)
- Operated by UNAVCO (2003-2018)

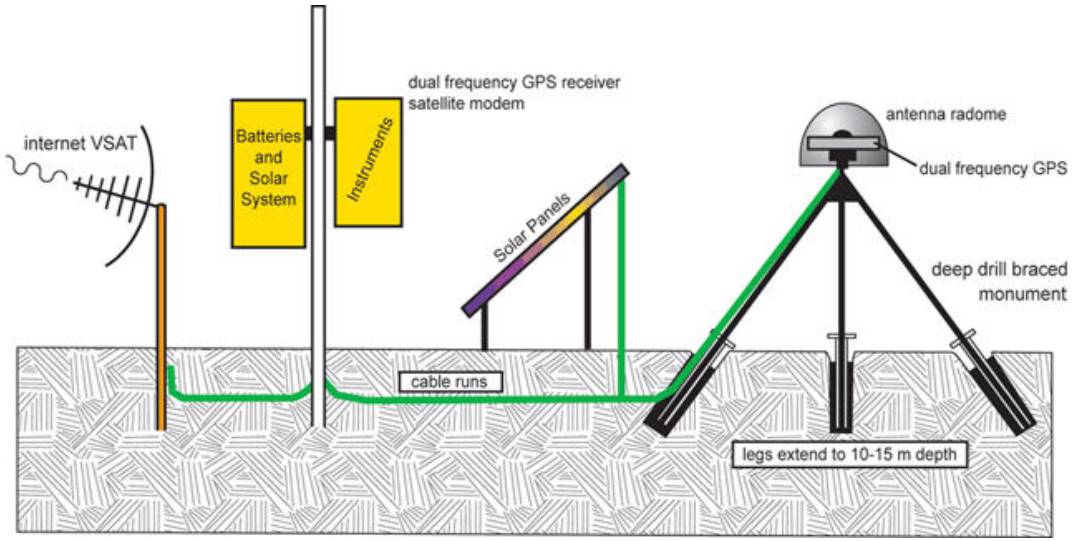


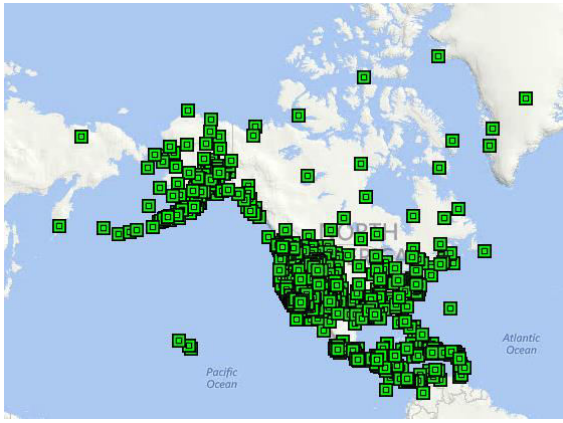




1 sample/30 seconds

A Standard PBO GPS Station





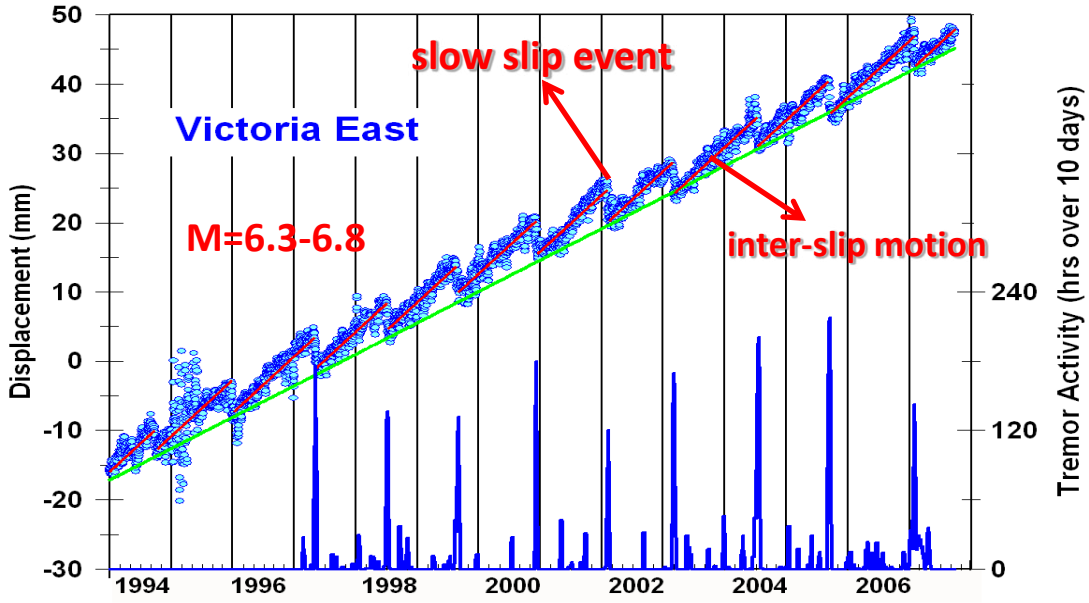


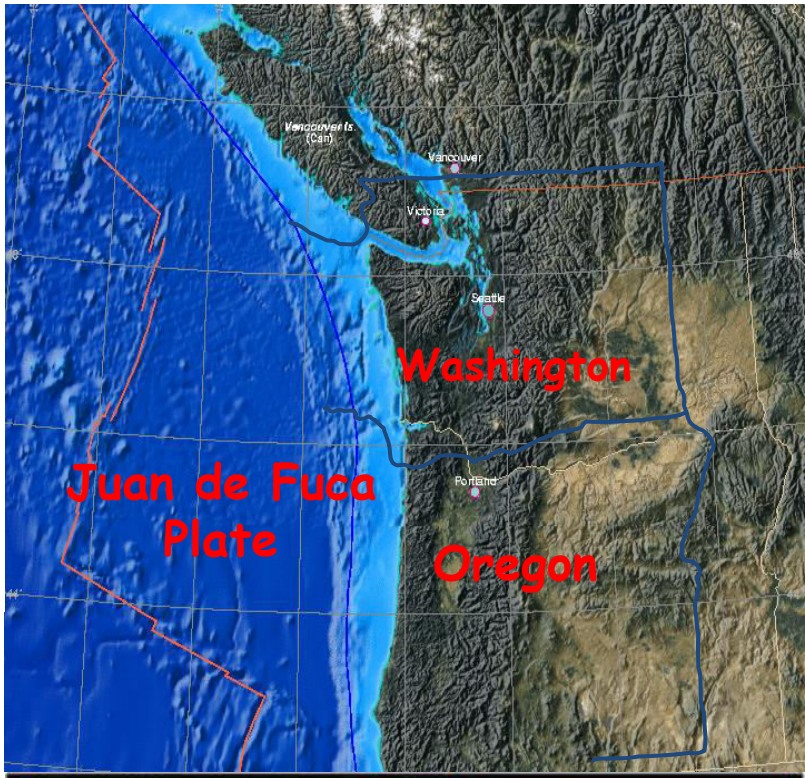
All data are archived at UNAVCO and freely available to the public.

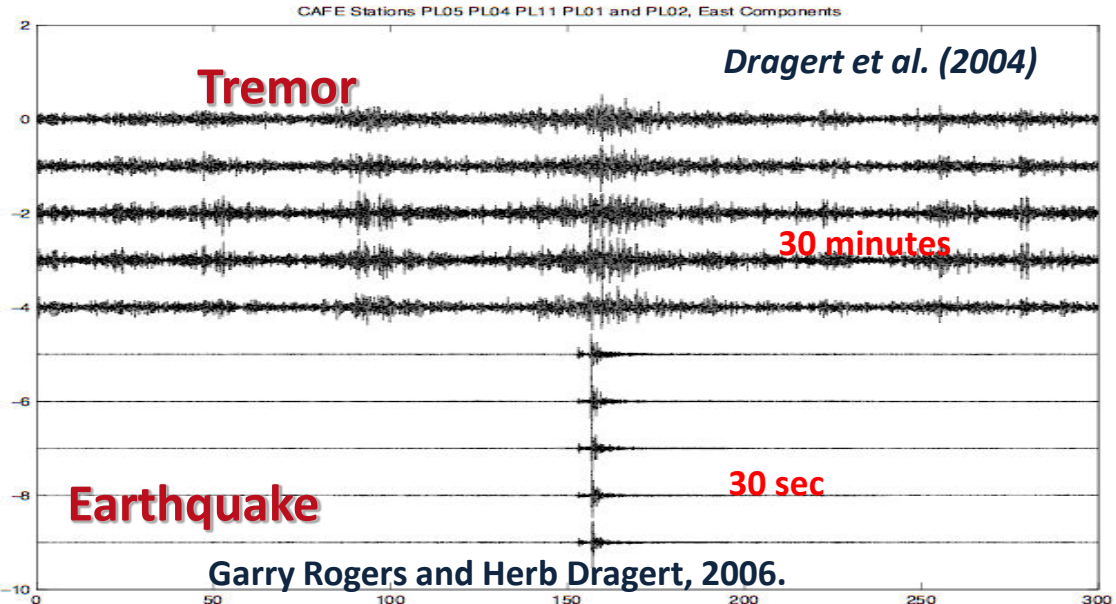
$10,000-$200,000/station

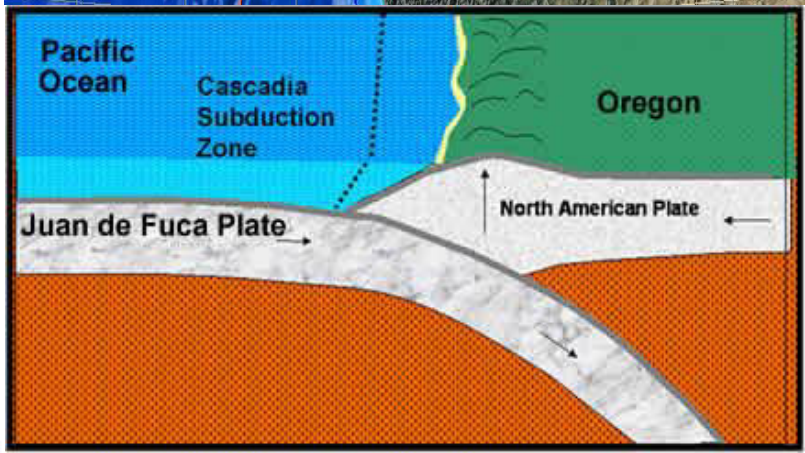
Significant Results from PBO:

Slow Earthquake (Episodic Tremor & Slip, Silent Earthquake)



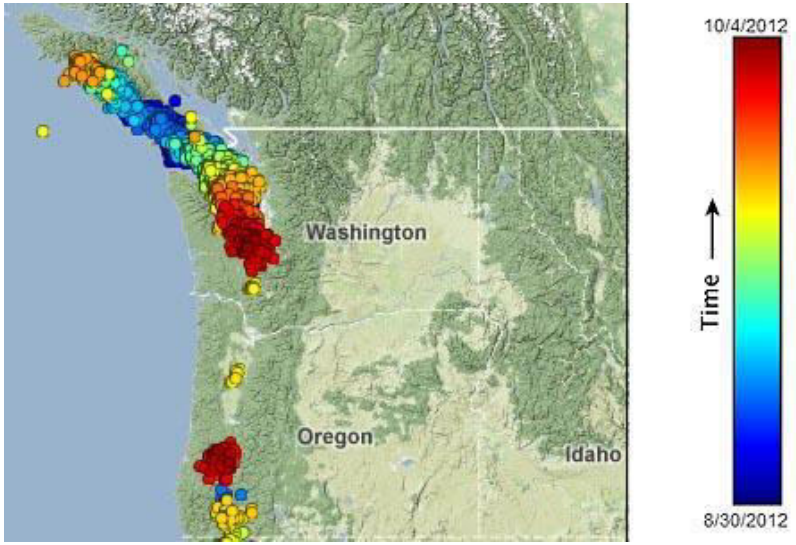




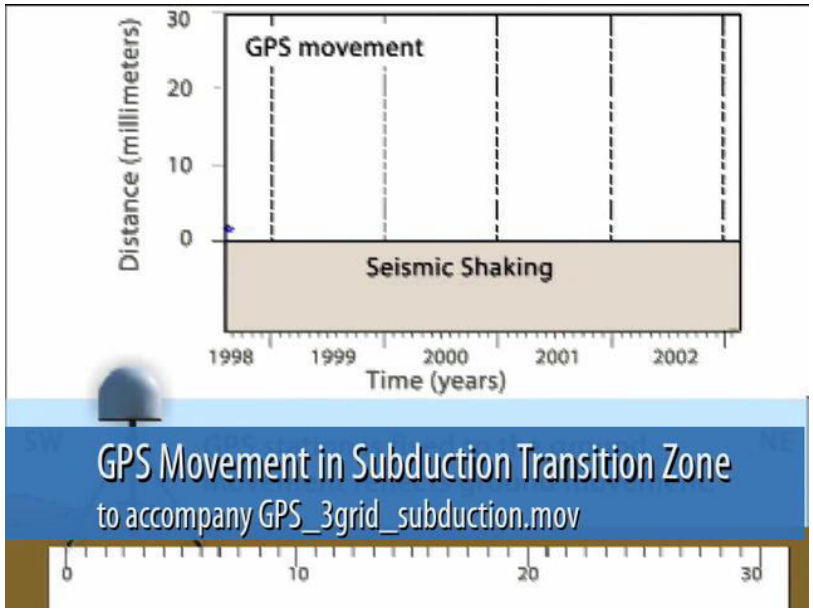


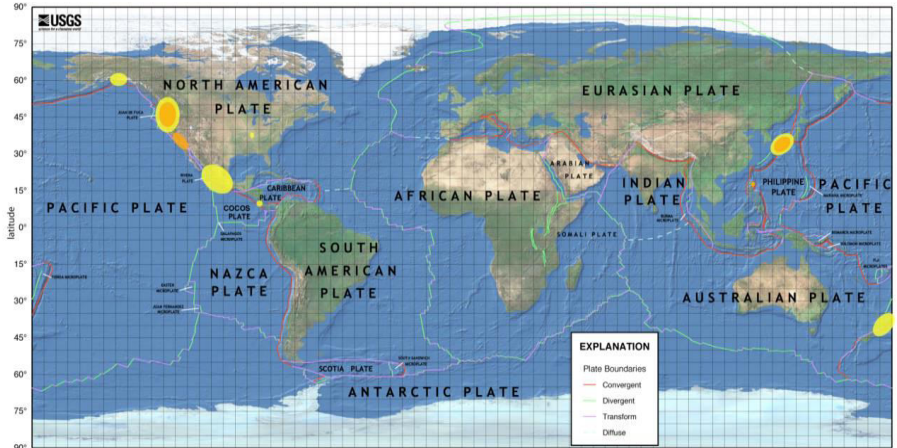
Are there connections between Slow Earthquake and Large Earthquake?

'Silent Earthquakes' Ripple Under Cascadia



Tom Banse, 2012



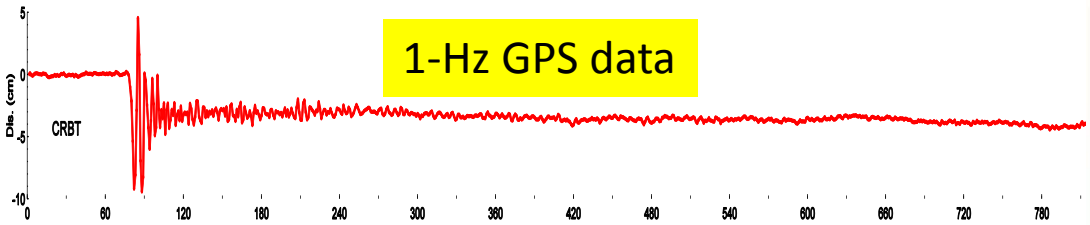


Large earthquake prediction!

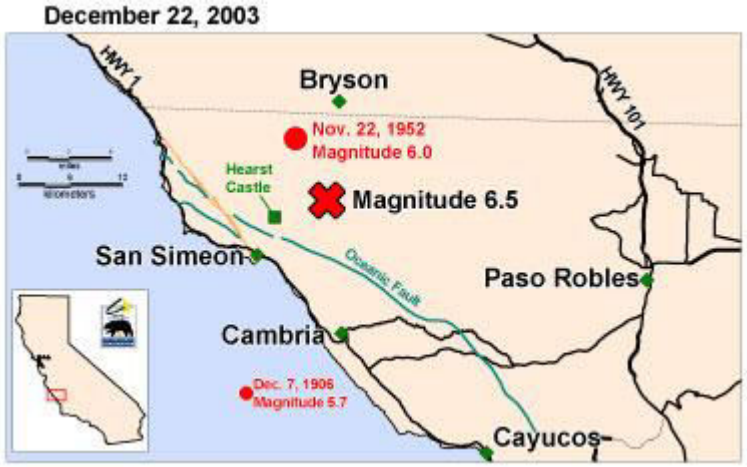
TRIGGER

Significant Results from PBO:

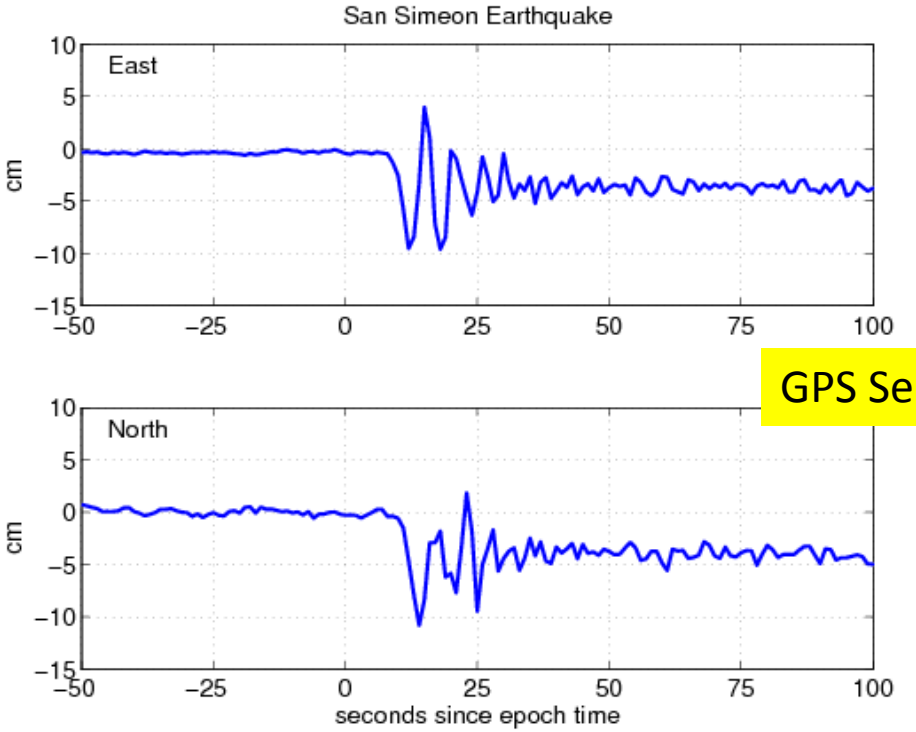
High-Rate GPS



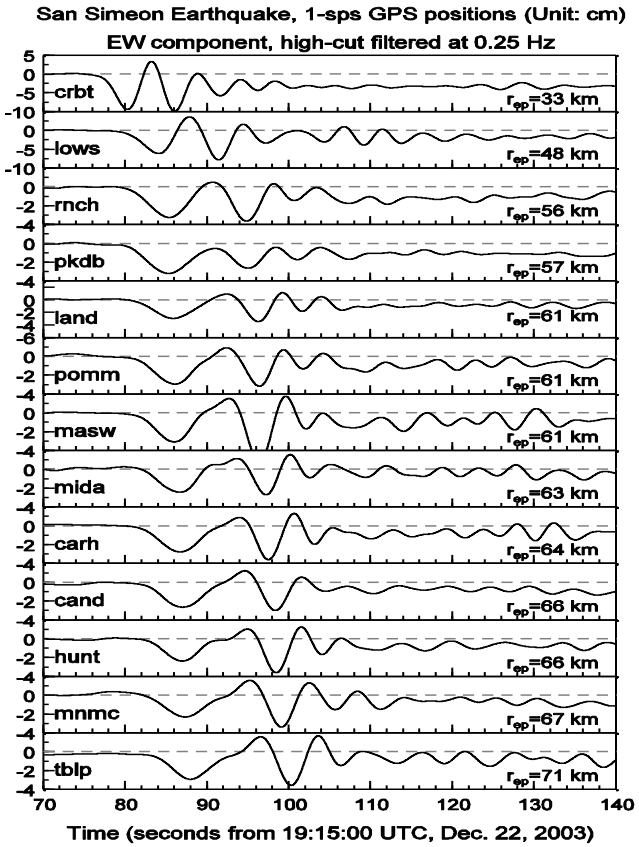
1-Hz GPS data



2013 San Simeon Earthquake (M 6.5)



GPS Seismology



Wang et al., 2006, 2007

High-rate GPS is a great tool for recording long-period ground motions!

- High-rate GPS is able to precisely record long-period ground motions (e.g., period > 10 sec).
- Seismometers often underestimate the magnitude of large earthquake (M>8).
- Quick identify Tsunamigenic Earthquakes!!

2004 Indian Ocean Tsunami



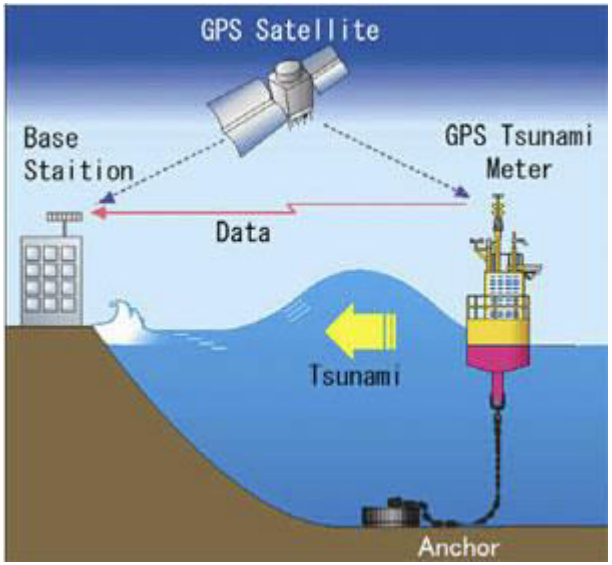
Tsunamigenic Earthquake----Tsunami Earthly Warning

The Consequence of False Tsunami Alarms:

Since 1982, tsunami warnings based on earthquake magnitude have produced false alarms 16 out of 16 in Pacific (U.S. Government Accountability Office, GAO-06-519).

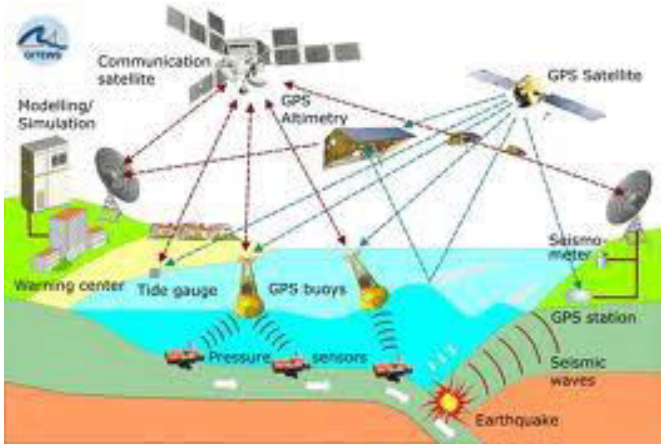
State of Hawaii's estimation: an evacuation from a tsunami alarm would have cost the state $58.2 million in economic losses (Eddie Bernard, 1996).

GPS Buoys: Directly measure ocean water level using GPS

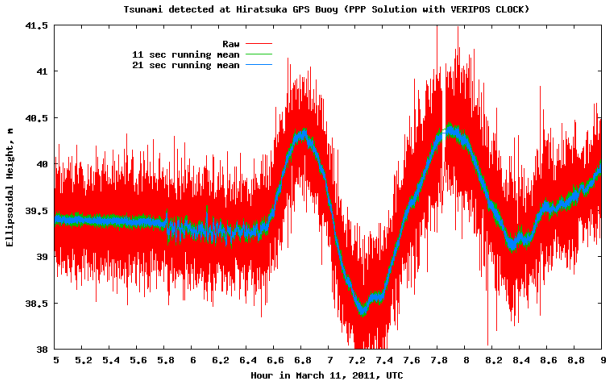












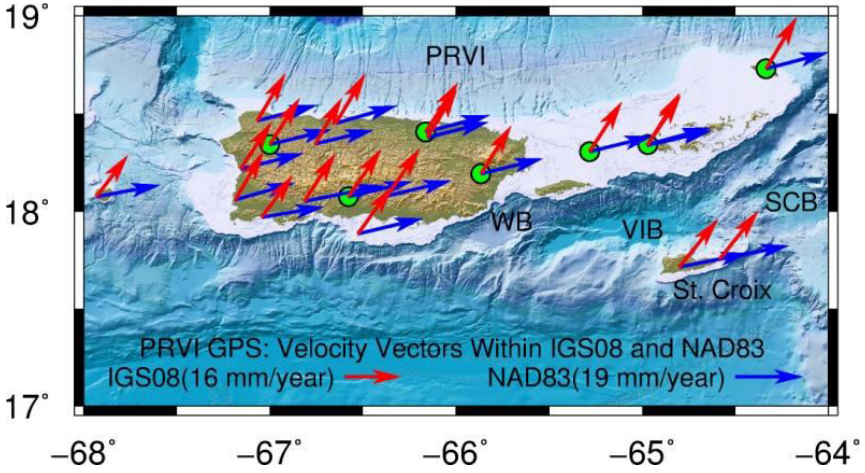
2011 Tohoku Earthquake: Tsunami Signal Detected by GPS Buoy.

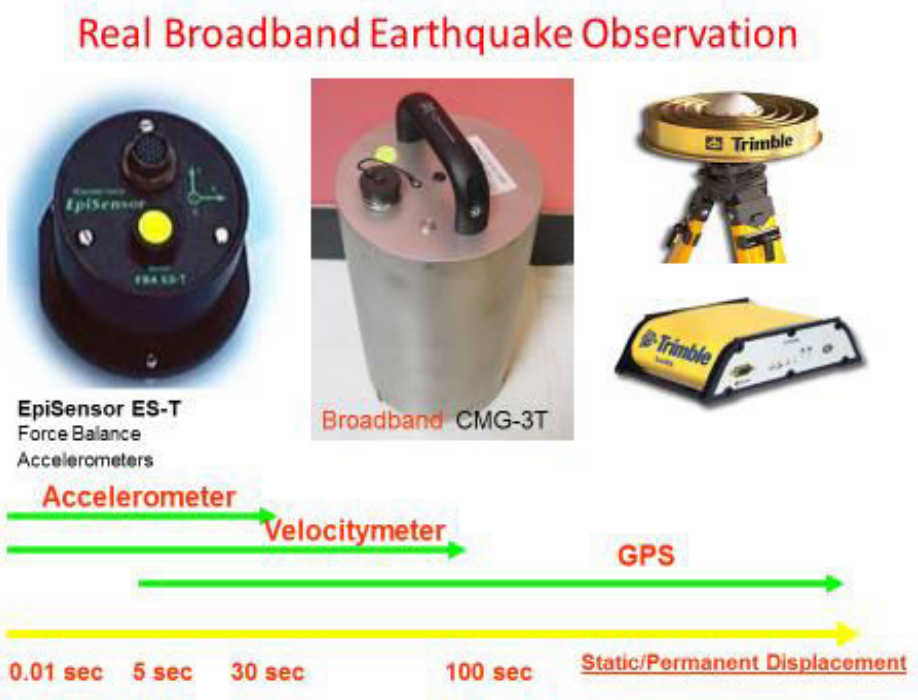
GPS Solution Inc., 2011

Puerto Rico and Virgin Islands (PRVI) GPS Network

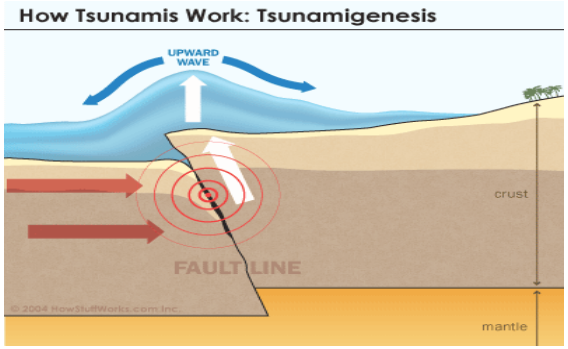
University of Puerto Rico at Mayaguez (UPRM)
2006-2011

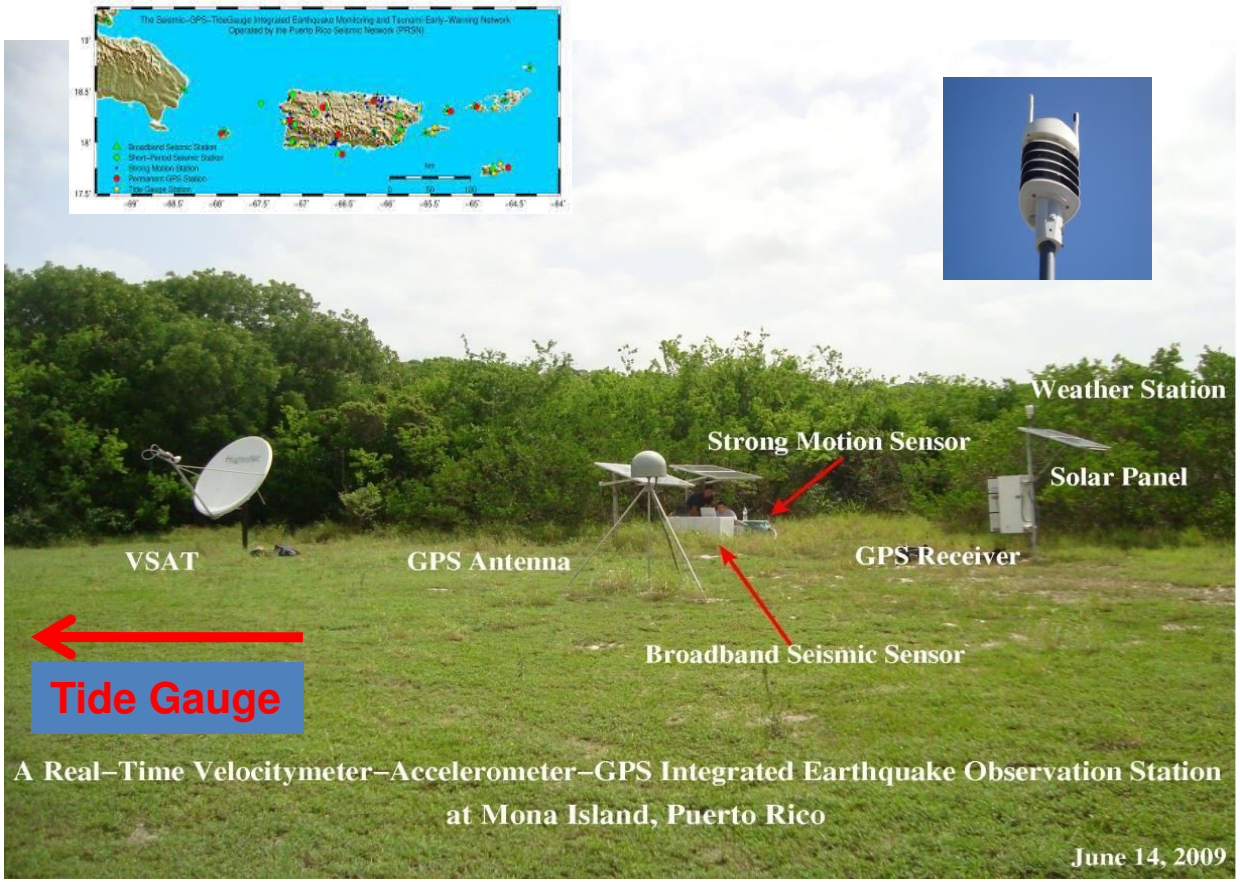


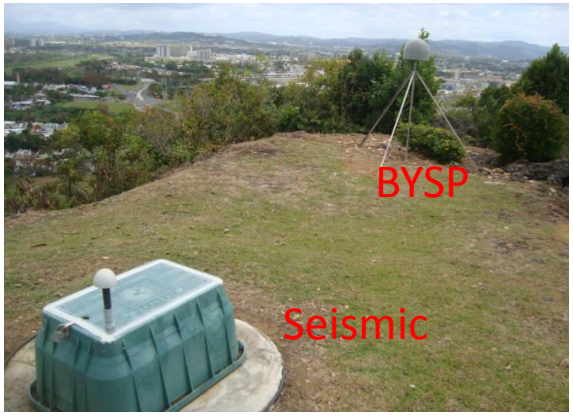




GPS+Accelerometer+Velocitymeter+TideGauge



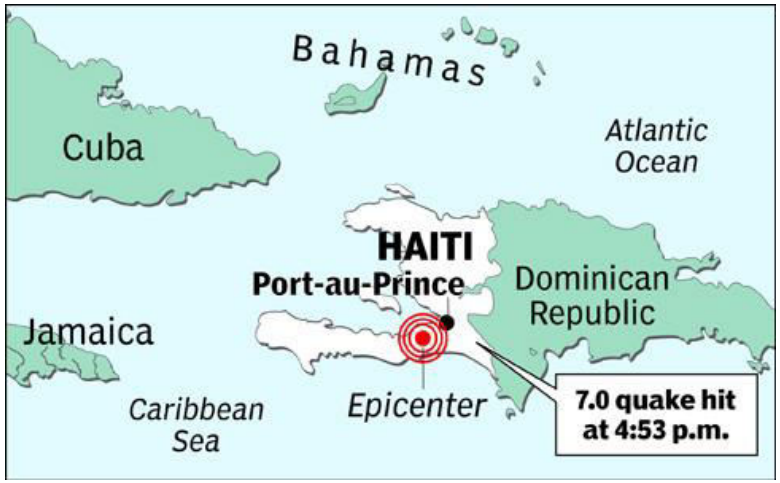






Mona Island Seismic Observation Station

COCONET: The Continuously Operating Caribbean GPS Observational Network



Feb. 12 2010 Haiti Earthquake (M7)

UNAVCO

UNIVERSITY OF HOUSTON

UCAR
UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

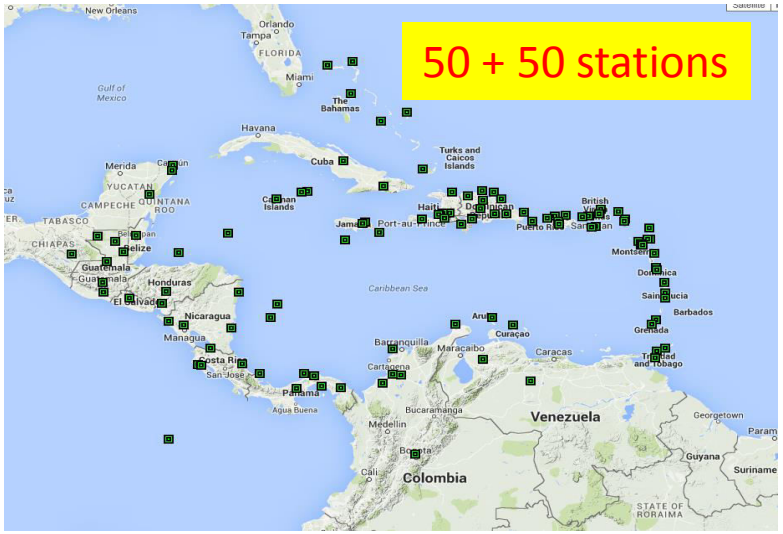
COCONet
CONTINUOUSLY OPERATING CARIBBEAN GPS OBSERVATIONAL NETWORK

NSF

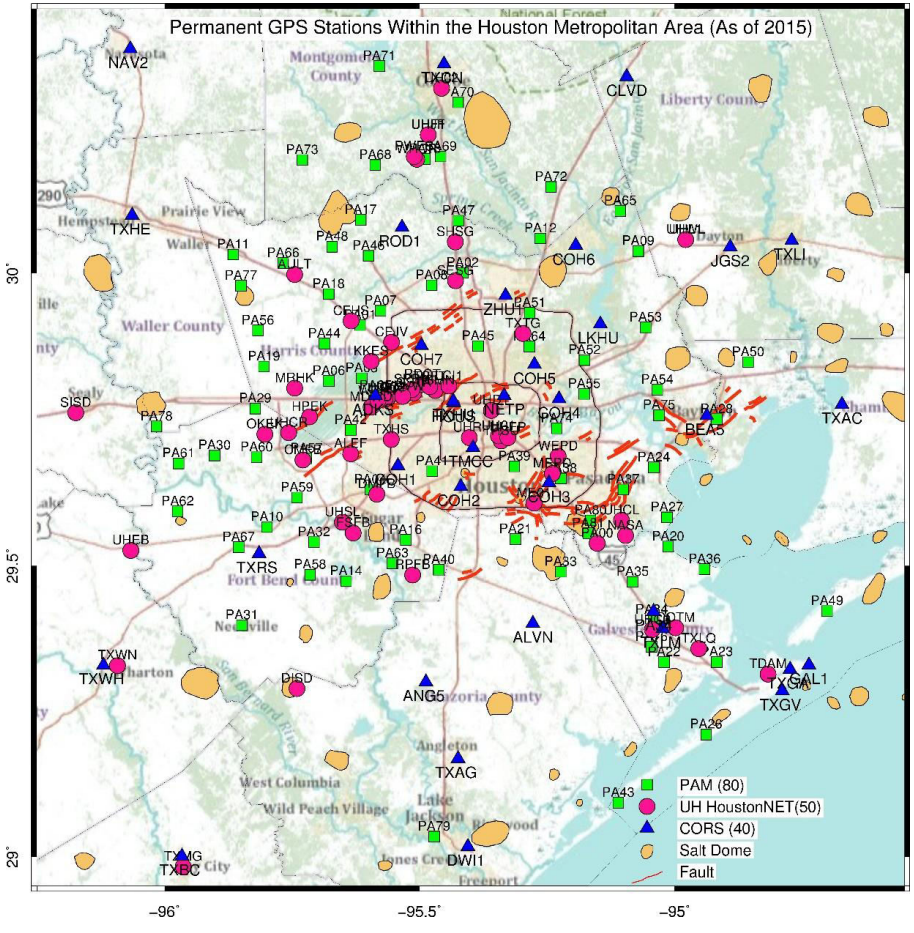
(2010-2015)

Natural hazards:

- Large earthquake monitoring
- Tsunami early warning
- Hurricane intensity forecasting
- Volcano monitoring and early warning
- Landslide monitoring
- Structural monitoring
- Seal level study



HoustonNet: Houston GNSS Network



Houston is one of the first places employed GPS for subsidence monitoring in the early 1990s

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2011-2015

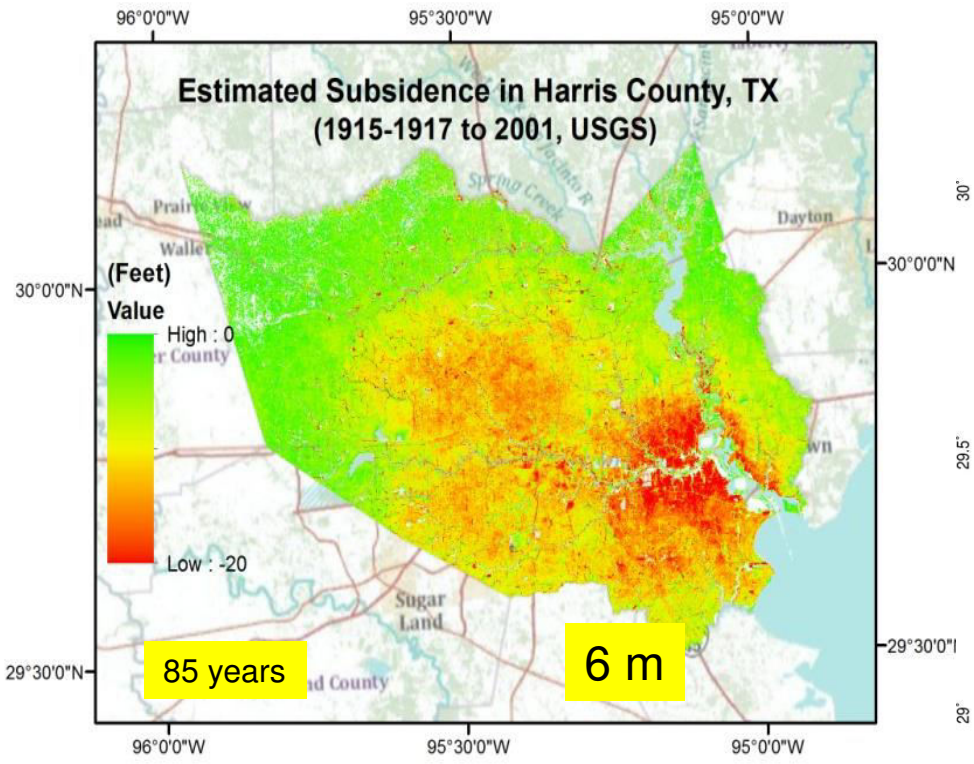
Community Sharing:

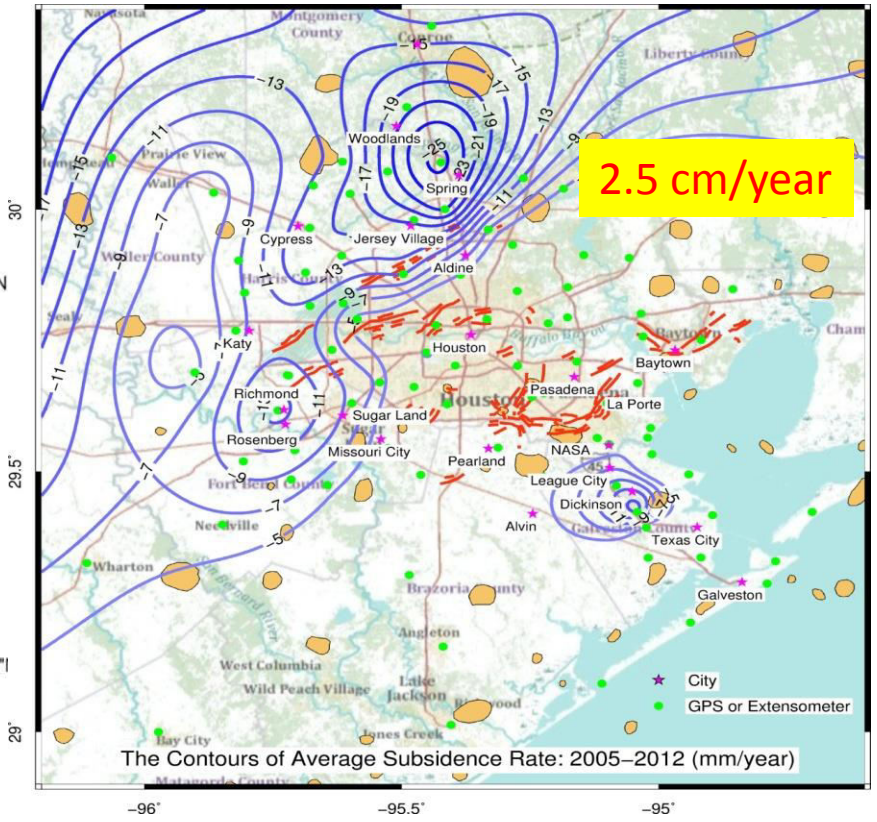
- University of Houston (UH)
- Harris-Galveston Subsidence District (HGSD)
- National Geodetic Survey (NGS)
- TX-DOT
- Houston City
- Smart Network

Subsidence
Faulting
Salt dome uplift
Hurricane



Recent Subsidence Mapping (2005-2012)

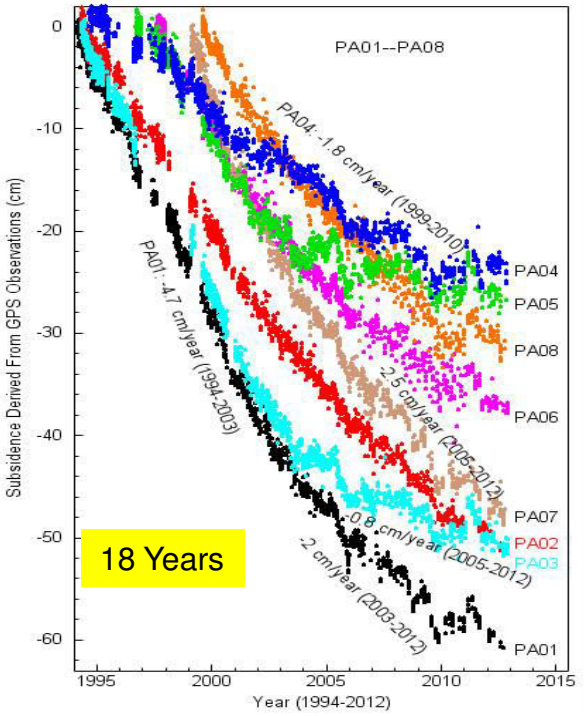




80 GPS +11 Extensometers

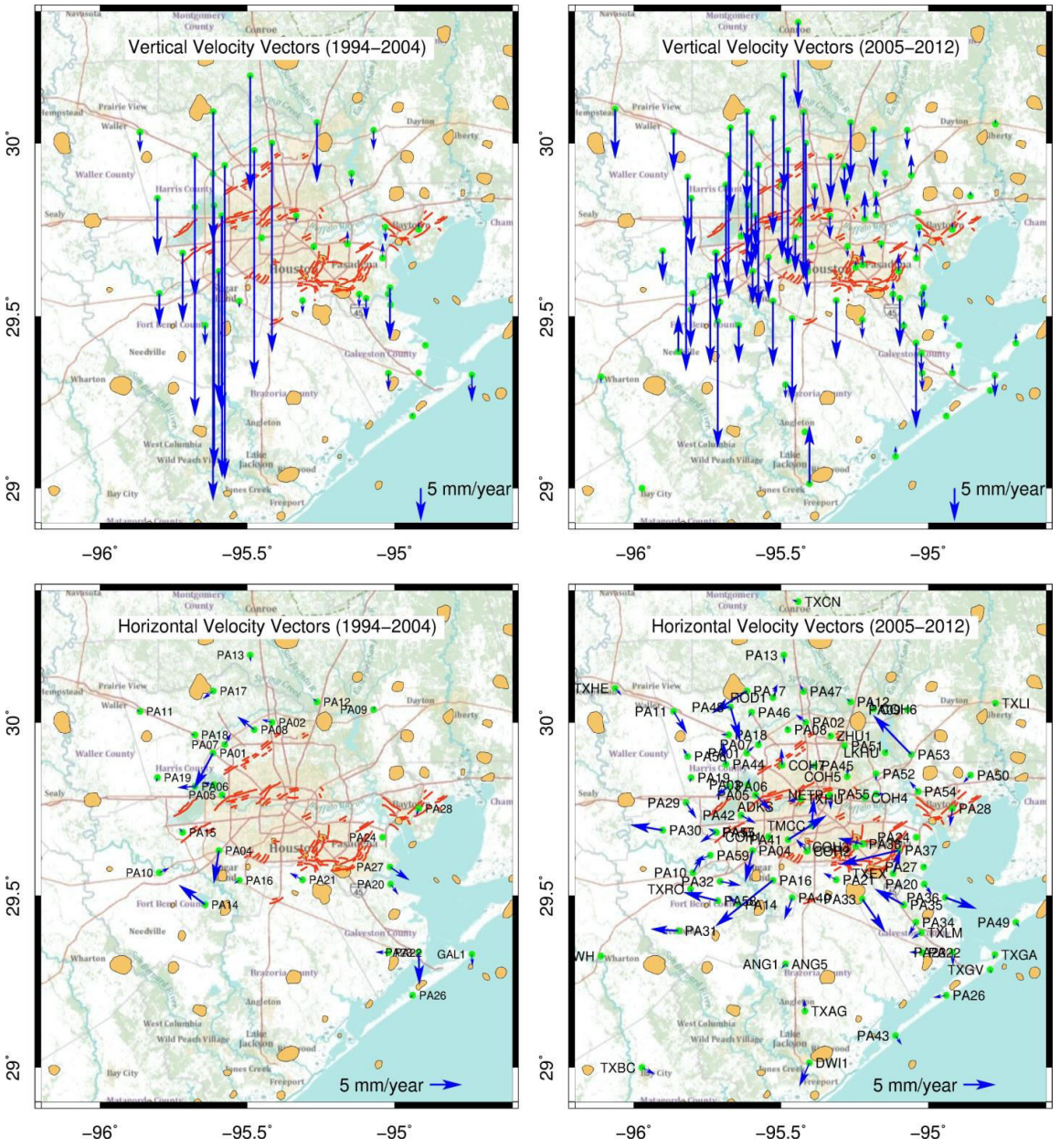
Kearns et al., 2015

No-linear subsidence rate



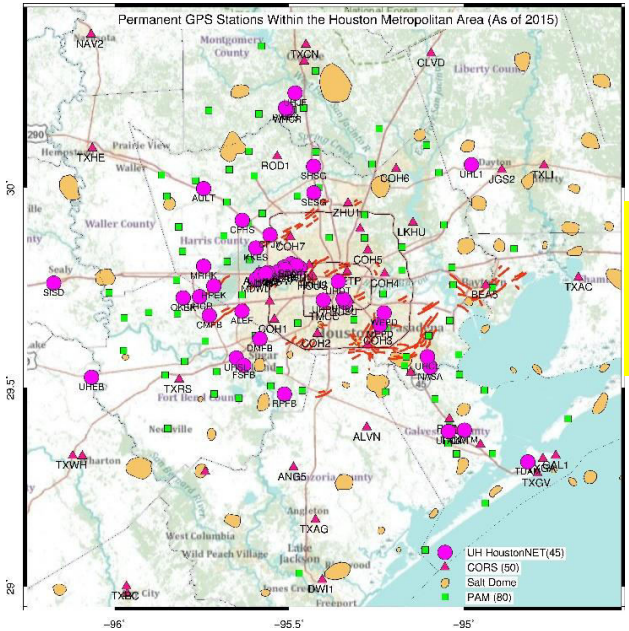
Jersey Village

Spatial and temporal variation of subsidence



Kearns et al., 2015

HoustonNet GNSS Stations



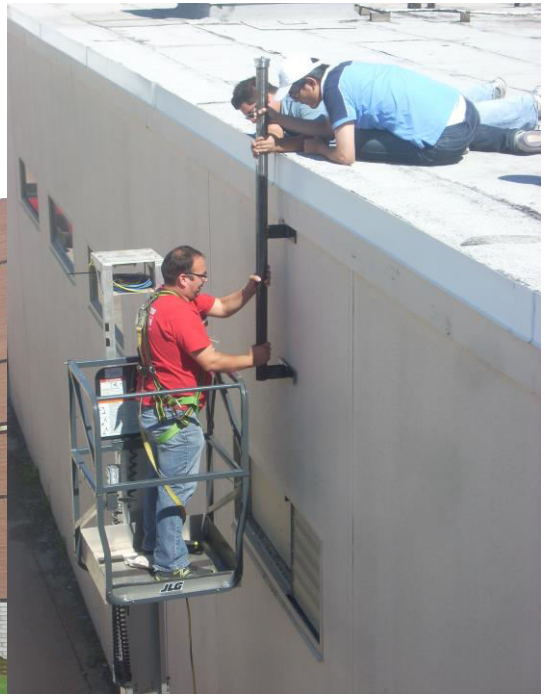
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UH has installed 50 GNSS stations on one- or two-story school buildings.











Ground-based vs. Building-based GPS Monument









PBO:

- Solar panel + VSAT
- 2 - 4 people, 1 week
- > $10,000

HoustonNet:

- On-site AC power
- Free internet
- 2 - 4 people, half day
- $200-300







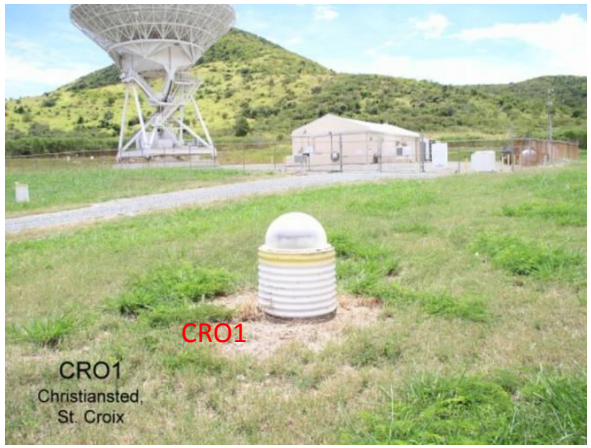
Can building-based GPS be used for precise scientific research?


STVI


VITH

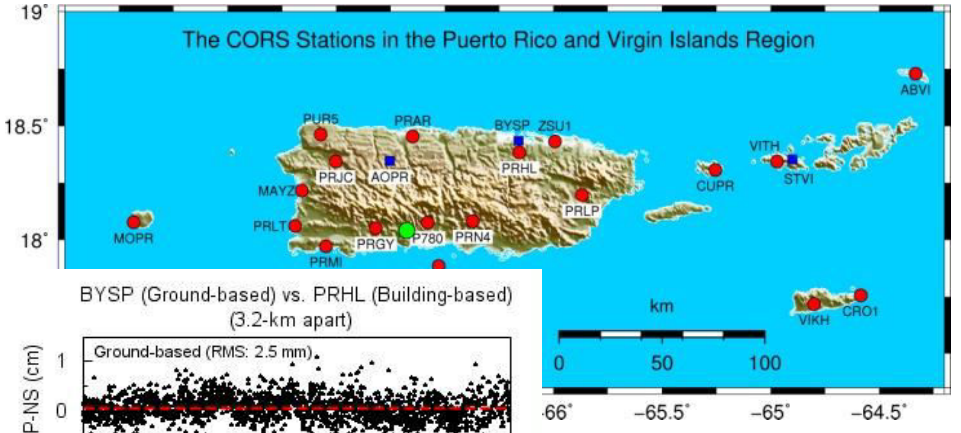

BYSP

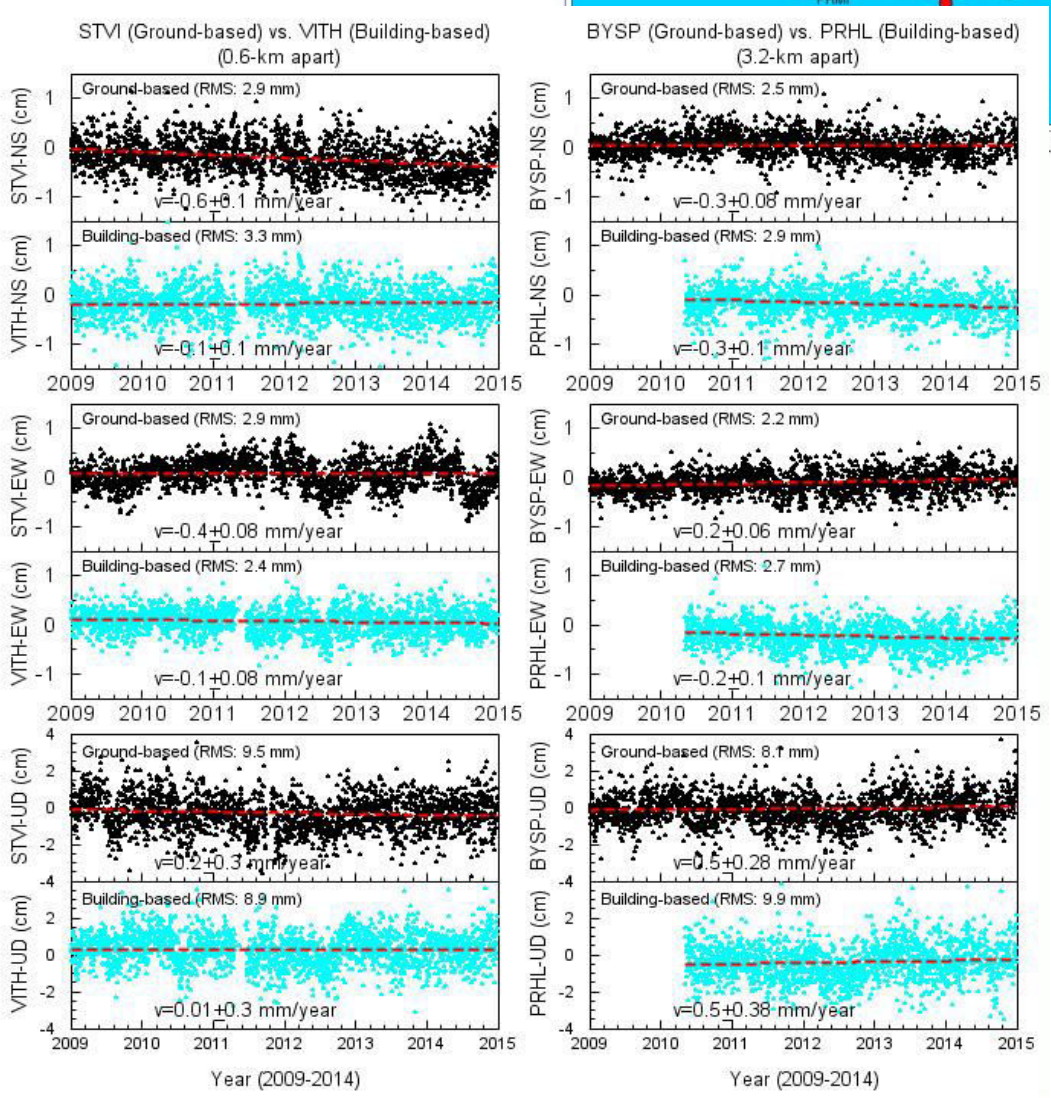

PRHL


CRO1
CRO1
Christiansted,
St. Croix

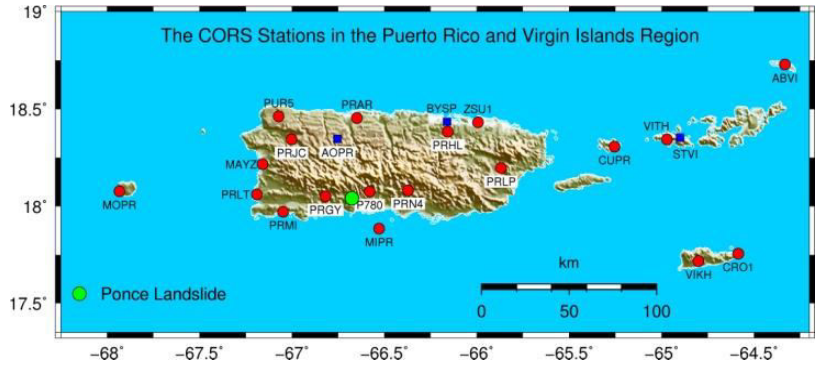

VIKH

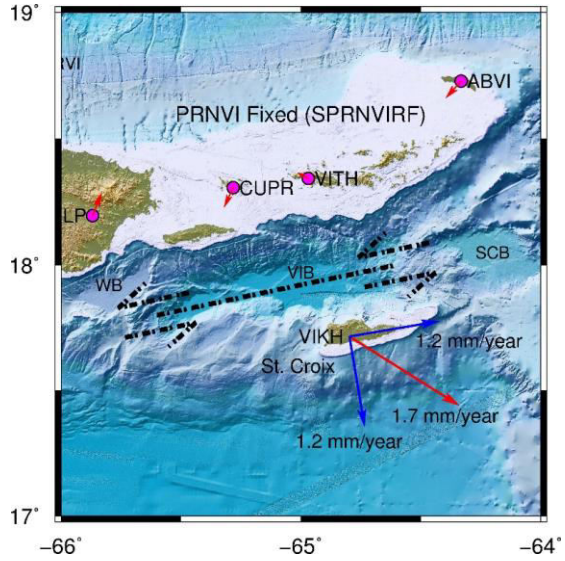
Ground-based vs. Building-based GPS Monuments

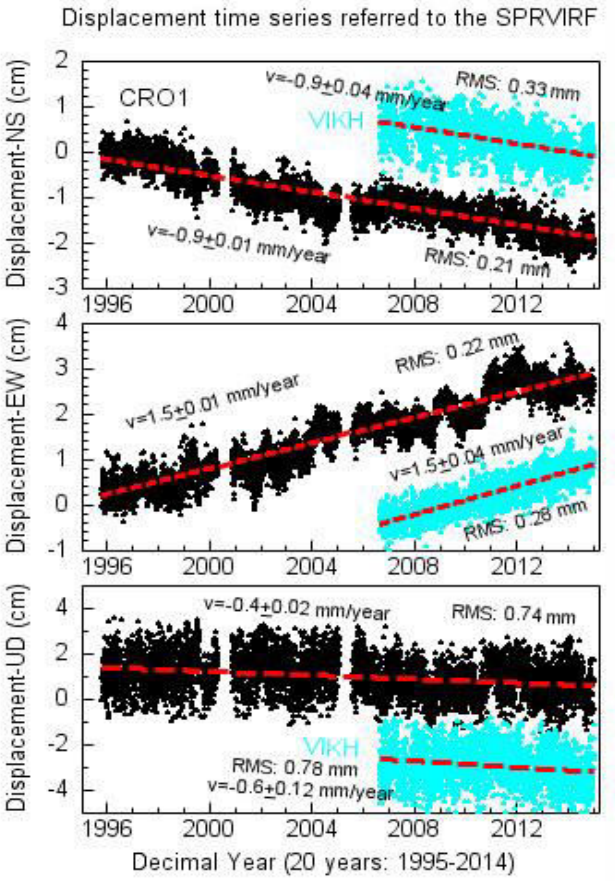




Yang et al., 2015







Results:

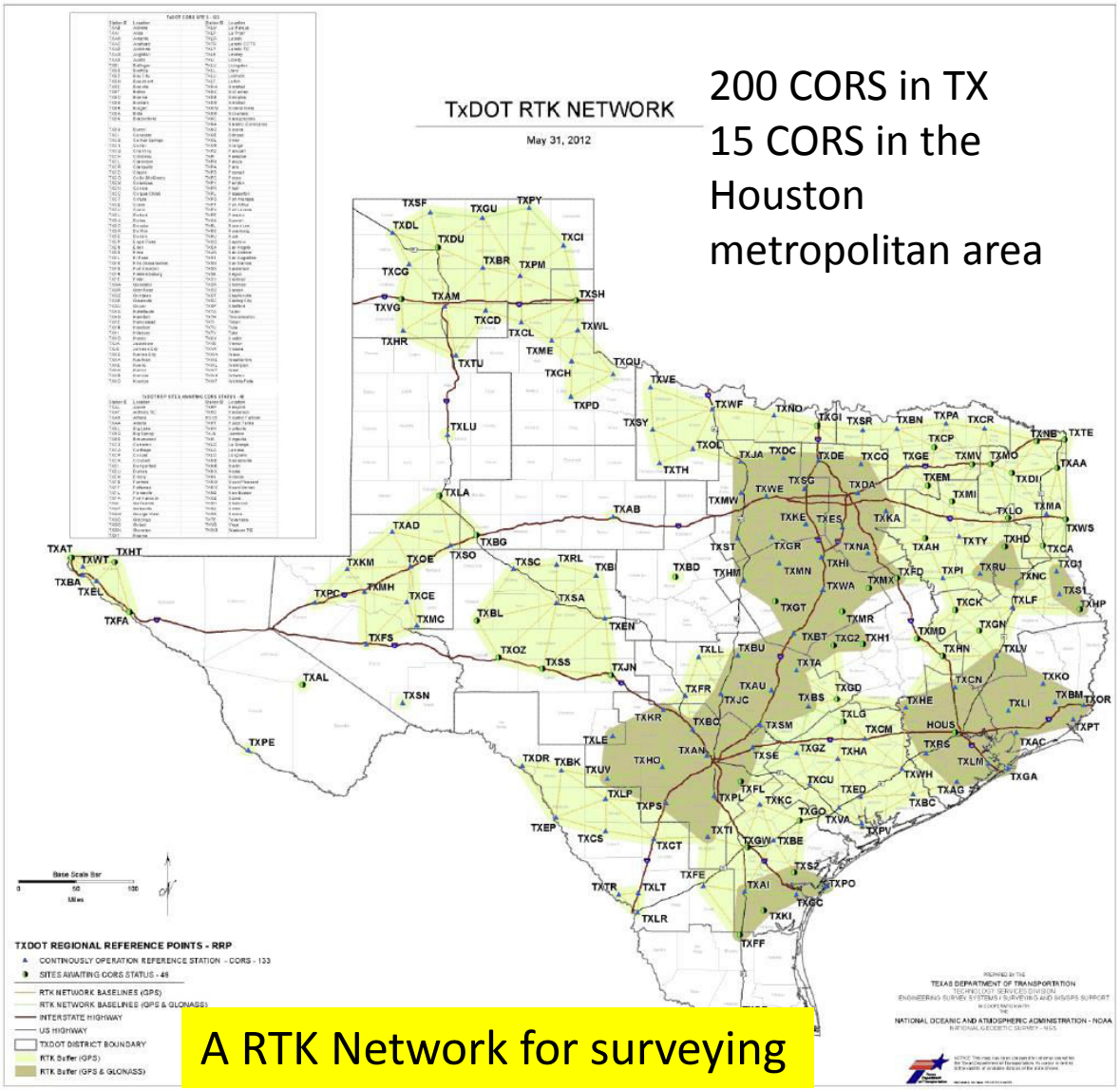
(1) There is no considerable difference between building-based and ground-based CORS with regard to the accuracy of daily positions and the reliability of long-term site velocities.

(2) Building-based CORS can retain more complete GPS observations and provide a more stable multipath environment.

(3) The large and heavy mass of a building and its foundation can degrade the amplitude of seasonal signals and filter certain short-period motions.

(4) Building-based CORS have the potential to perform better than the ground-based CORS as long as their monuments are firmly fixed on one- or two-story concrete buildings and the buildings themselves are stable.

Urban GNSS Stations:
TX-Department of Transportation (DOT)



200 CORS in TX
15 CORS in the Houston metropolitan area

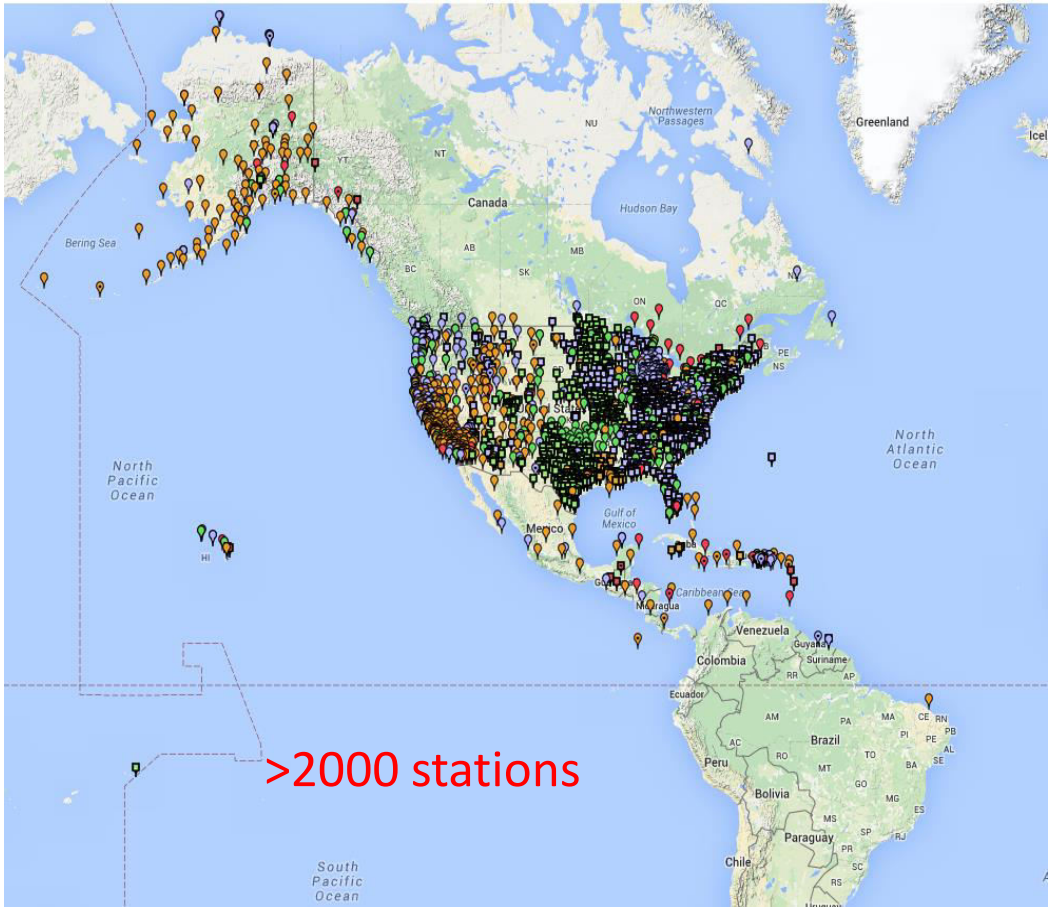
A RTK Network for surveying





National Geodetic Survey (NGS) CORS Network

http://www.ngs.noaa.gov/CORS/



- The CORS network is a multi-purpose cooperative endeavor involving government, academic, and private organizations.
- The sites are independently owned and operated. Each agency shares their data with NGS, and NGS in turn analyzes and distributes the data free of charge.
- As of January 2014, the CORS network contains more than 1,900 stations, contributed by over 200 different organizations, and the network continues to expand.

CORS: Continuously Operating Reference Station

OPUS: Online Positioning User Service
http://www.ngs.noaa.gov/OPUS/



High-Accuracy GNSS Positioning for Engineers

A technician with basic GPS knowledge can conduct precise landslide and subsidence monitoring!

OPUS for Horizontal Subcentimeter-Accuracy Landslide Monitoring: Case Study in the Puerto Rico and Virgin Islands Region

Guoquan Wang[1] and Tomás Soler, M.ASCE[2]

Abstract: This study demonstrates the usefulness of an approach based on the Online Positioning User Service (OPUS) provided by the National Geodetic Survey (NGS) of the National Oceanic and Atmospheric Administration (NOAA) to process Global Positioning System (GPS) data and conduct long-term landslide monitoring in the Puerto Rico and Virgin Islands region. Continuous GPS data collected at a creeping landslide site during 2 years were used to evaluate different scenarios for landslide surveying: continuous or campaign, long duration or short duration, morning or afternoon (during different weather conditions). OPUS uses the Continuously Operating Reference Station (CORS) network managed by the NGS as control points and user-collected data to solve for the position of the occupied station (rover). In July 2011, there were 19 NGS CORS sites in the Puerto Rico and Virgin Islands region. This dense GPS network provided a precise and reliable reference frame for subcentimeter-accuracy landslide monitoring in this region. OPUS static solutions (OPUS-S) for sessions as short as 4 h, and OPUS rapid static solutions (OPUS-RS) for sessions as short as 15 min, can achieve subcentimeter horizontal accuracy if the collection of data during extreme weather conditions is avoided. The uncertainty (peak-to-peak error) reported by a single OPUS-S solution differs from the "true" accuracy by a factor of 1.7 for the horizontal components and 1.3 for the vertical component. The uncertainty reported by a single OPUS-RS solution differs from the accuracy by a factor of 1.4 for horizontal components, while the uncertainty of vertical component statistically agrees with the vertical accuracy. This study also indicates that rainfall events can seriously degrade the performance of high-accuracy GPS. Field GPS landslide surveying should avoid rainfall episodes when accompanied by thunderstorms and the passage of detrimental weather fronts. Once appropriate precautions are taken, the results of this investigation show that OPUS-S and OPUS-RS are ideal alternative tools for subcentimeter-accuracy landslide monitoring. **DOI: 10.1061/(ASCE)SU.1943-5428.0000079.** *© 2012 American Society of Civil Engineers.*

CE Database subject headings: Landslides; Monitoring; Puerto Rico; U.S. Virgin Islands; Case studies.

Author keywords: OPUS; CORS; Observational accuracy; Landslide monitoring; Puerto Rico; Virgin Islands.

Using OPUS for Measuring Vertical Displacements in Houston, Texas

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Abstract: The Houston area has been suffering from subsidence for several decades. Therefore, continuously operating reference stations (CORS) in this area may have experienced considerable vertical displacements. The Online Positioning User Service (OPUS), provided by the National Geodetic Survey (NGS), uses CORS as references in its data processing. This study investigated what effects, if any, the subsidence experienced by these CORS around Houston contributes to the accuracy of OPUS vertical results. Our OPUS results were determined from three long-term (over 10-year) blocks of continuous data using Global Positioning System (GPS) stations located in different parts of the Houston area. The OPUS results were compared with the vertical measurements from the precise point positioning with single receiver phase ambiguity (PPP-SRPA) solution implicit in the *GIPSY/OASIS 6.1.2* software. This particular study indicates that OPUS achieves 1.0-cm vertical accuracy for daily sessions (24 h) in the region around Houston, which is comparable to the OPUS accuracy previously reported in other investigations. Subsidence as slow as 0.5 cm/year can be detected by analyzing OPUS results spanning 5 or more years of data. Our main conclusion is that the subsidence experienced by NGS CORS in the Houston area does not considerably affect the accuracy of OPUS vertical results. For those users who require a few centimeters of vertical accuracy for daily sessions, OPUS is a good choice, because users do not need to establish any control stations and do not need to install any GPS software packages on their local computers. **DOI: 10.1061/(ASCE)SU.1943-5428.0000103.** *© 2013 American Society of Civil Engineers.*

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Do we need more GNSS stations?



More GNSS satellites
More ground GNSS stations
More GNSS data
A better undersanding of natural hazards….
We will find more problems….
We need more …..

Thank you for attending the satellite conference!