Tectonic Hazard Monitoring for Korean Nuclear Sites

June 13-17, 2011
Jakarta, INDONESIA

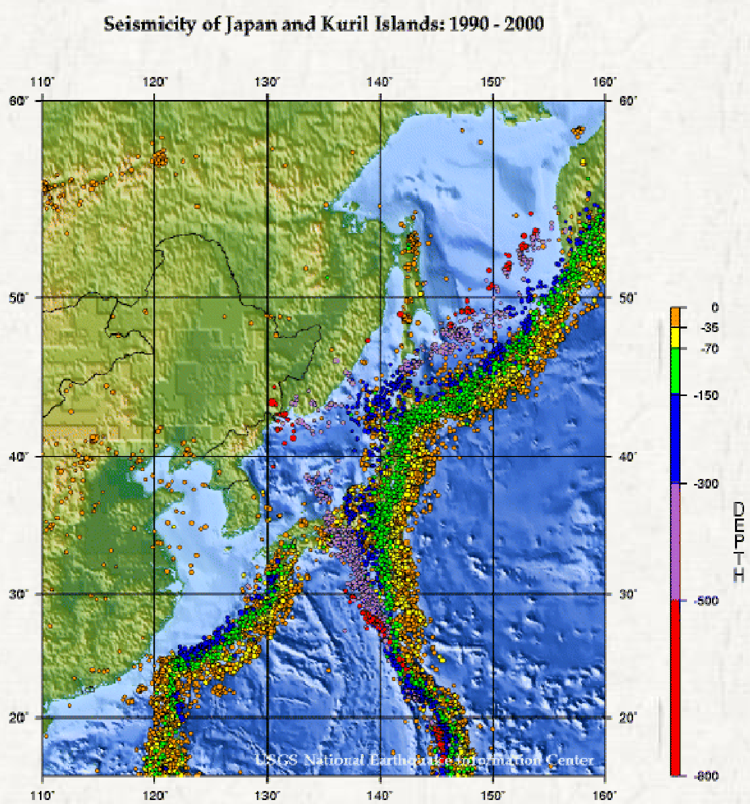
Hyunwoo LEE (heanu@kins.re.kr)
Korea Institute of Nuclear Safety

CONTENTS

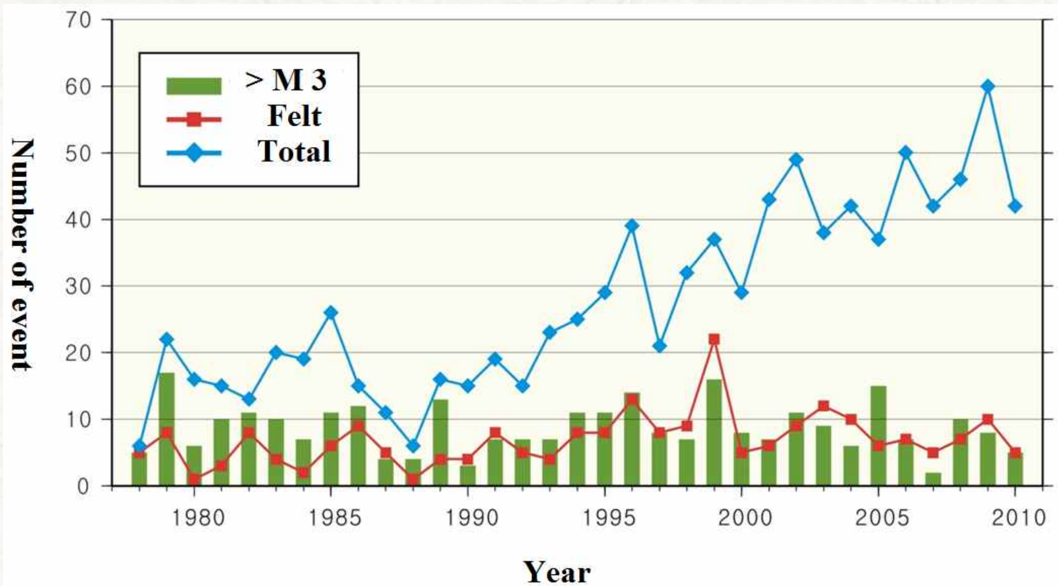
Introduction

Korean site is

- **Located in the Eurasian Plate**
  - About 1,000km away from the nearest plate boundary



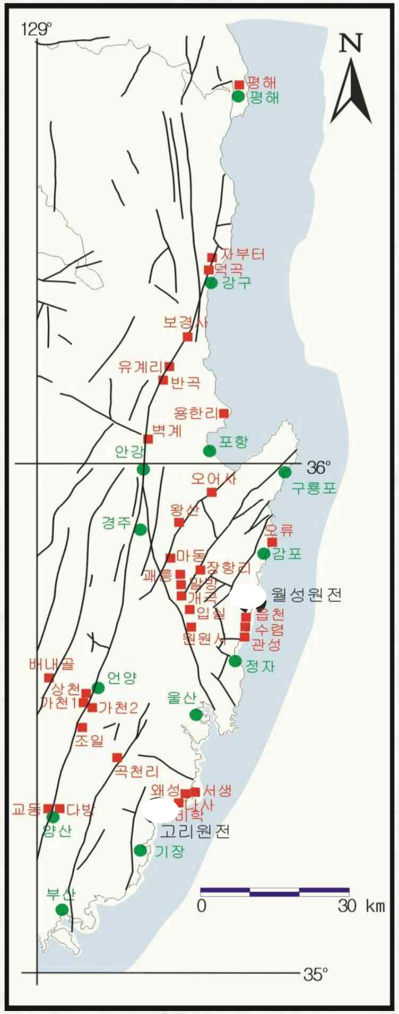
- **Quiet**
  - About 10 earthquakes (≥ Mw 3) per year
- **Showing relatively slow tectonic movement**
  - ≤ 10^{-1} to 10^{-2} mm/yr



Korean site is (cont.)

- However, geologic evidences tell us Korea was
  - active during Tertiary and Quaternary
  - not quiet as of today according to historical records

KINS (2006)



Background

- Long-term Research Project (2000 ~)
- Countermeasure study of earthquakes exceeding design earthquake of nuclear facilities (2007 ~)
  - 2007 Niigata Earthquake (Mw 6.8) & Kashiwazaki-Kariwa NPP
- Sinweolseong NPP #1,2 (2007 ~)
  - Conditional Construction Permit
  - Setup & operate a proper monitoring system around Eupcheon fault
- LILWR Site Monitoring (2008 ~)

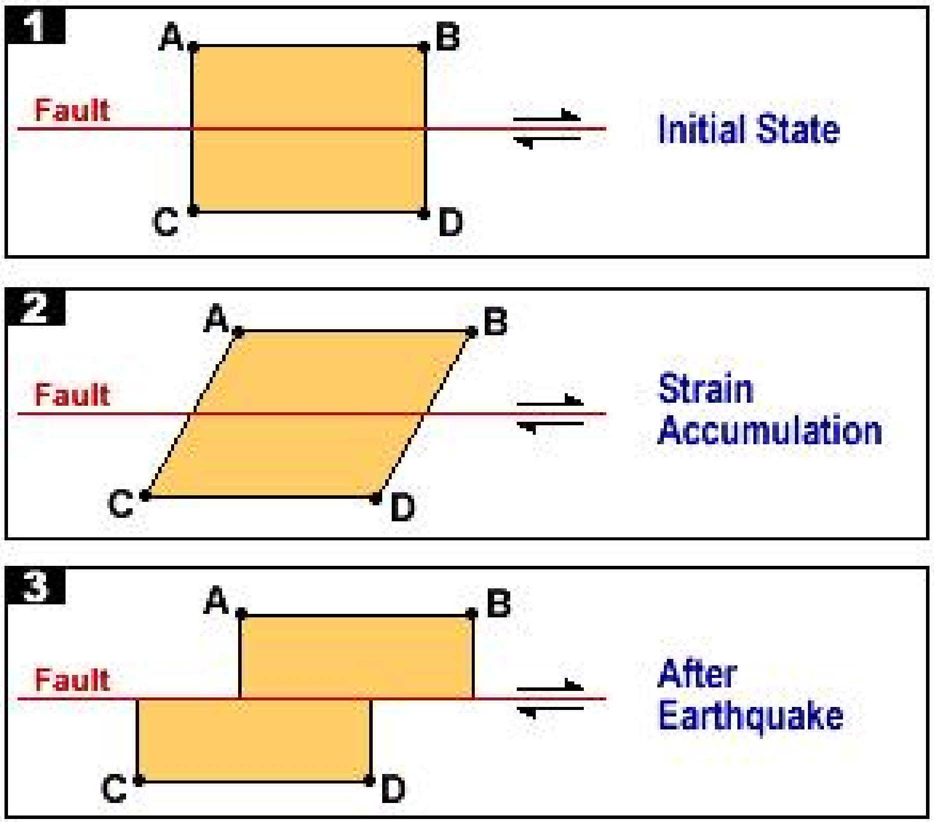
This presentation provides information on..

- Introduction to Tectonic Monitoring Systems
- EMC, EFMS, LILWR Site Monitoring System
- KINS Nuclear Site Monitoring Center

TMS is…

How the monitoring works?

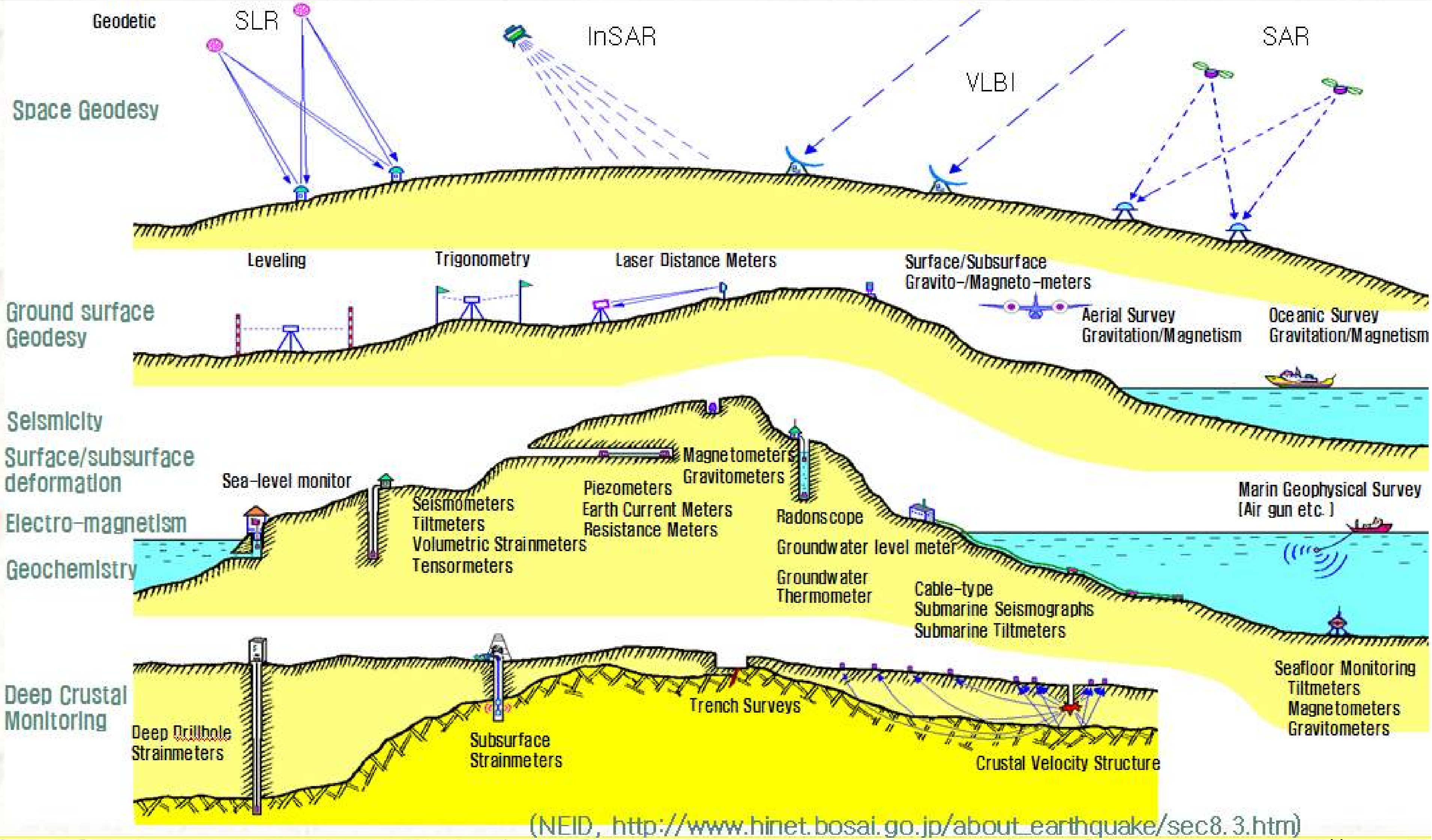
- Relative Movements of points on the Earth's surface



TMS consists of

- Global Positioning System (GPS)
- Two Color Electronic Distance Meter (EDM)
- Borehole & Near-Surface Strainmeters
- Tiltmeter
- Creepmeter
- Gravimeter
- Water Level Monitor & Pore Pressure Transducer
- Seismic array (c.f., USArray)
- Interferometric Satellite Aperture Radar (InSAR)
- Very Long Baseline Interferometer (VLBI)

Schematic Example of Tectonic Monitoring



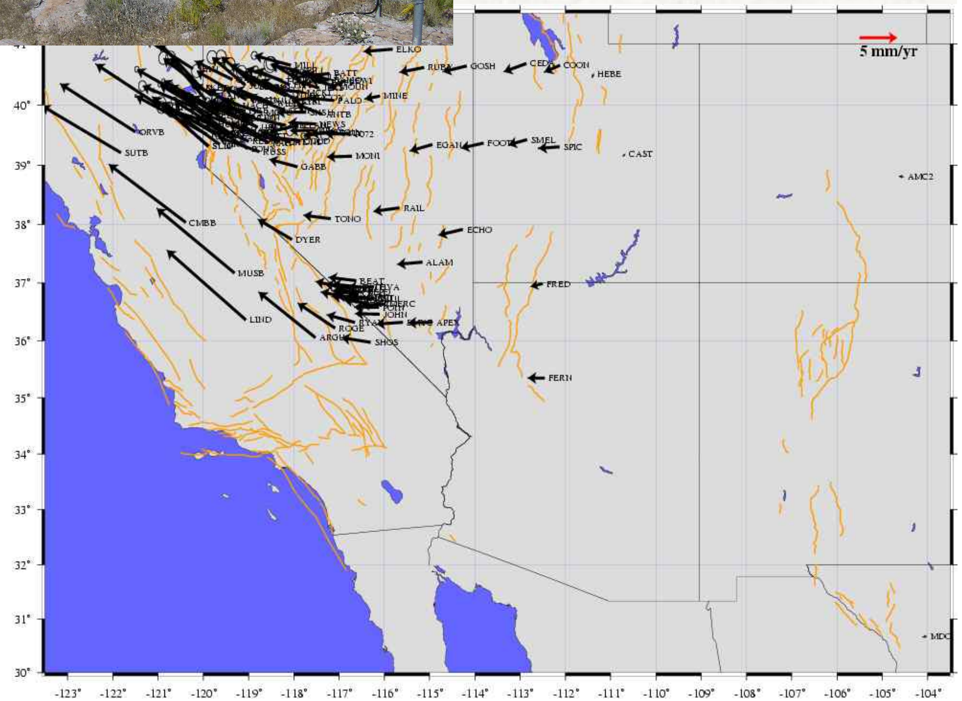
(NEID, http://www.hinet.bosai.go.jp/about_earthquake/sec8.3.htm)

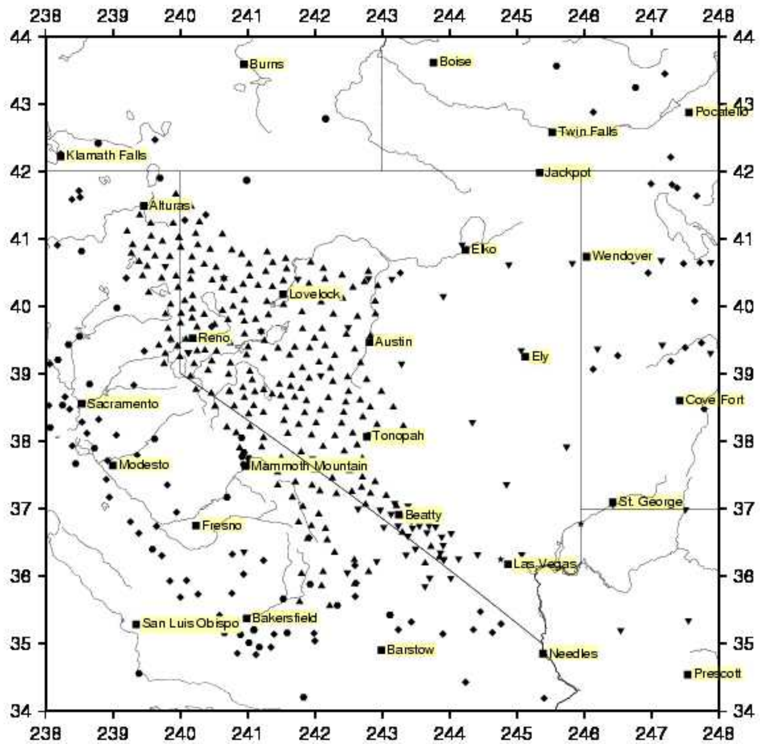
GPS (Global Positioning System)

- Need to be well designed
  - GPS network to cover surface deformation due to the fault activity
  - Need well established geology, fault geometry and tectonic setting of the region
  - Distance between the stations is generally double to triple of the depth of earthquake
- Precision : 1mm/yr for velocity, 5 to 10mm/yr for the coordinates
- Noise : Earth tides, weather, gravity, geology, traffic, earthquake
  - c.f., Herring (MIT), Segall (Stanford), Blewitt (UNR)

GPS : examples

- GPS stations at the Basin & Range area and the YM site

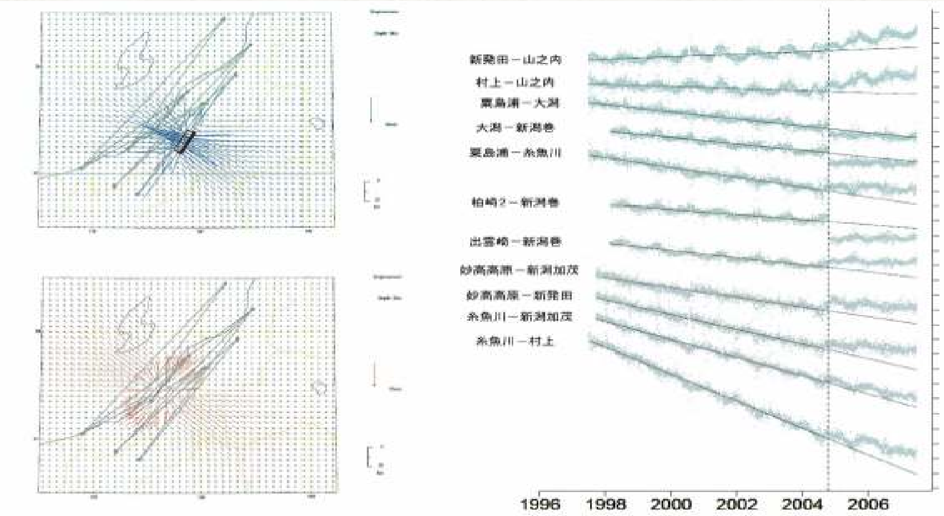




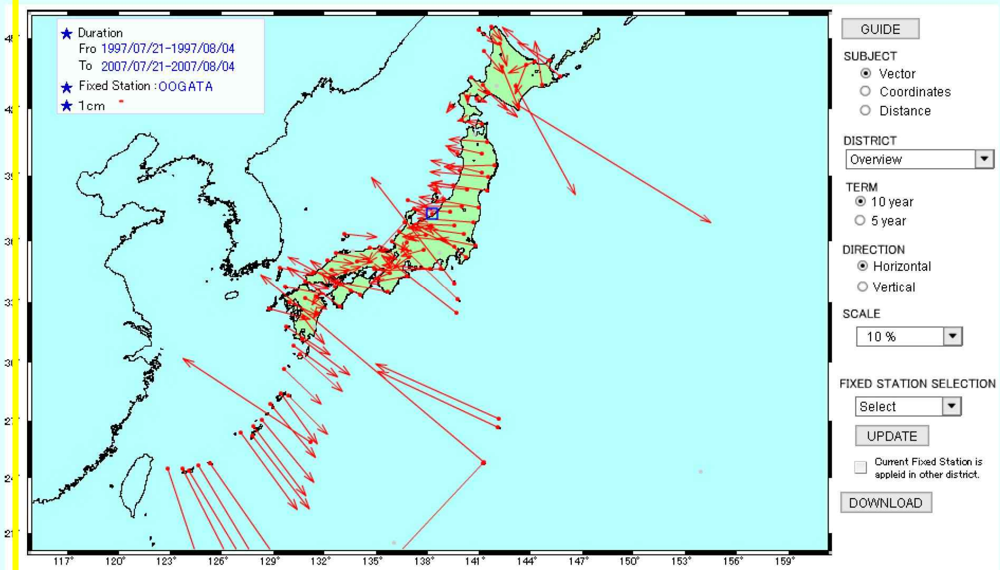
NGL (2007.1)

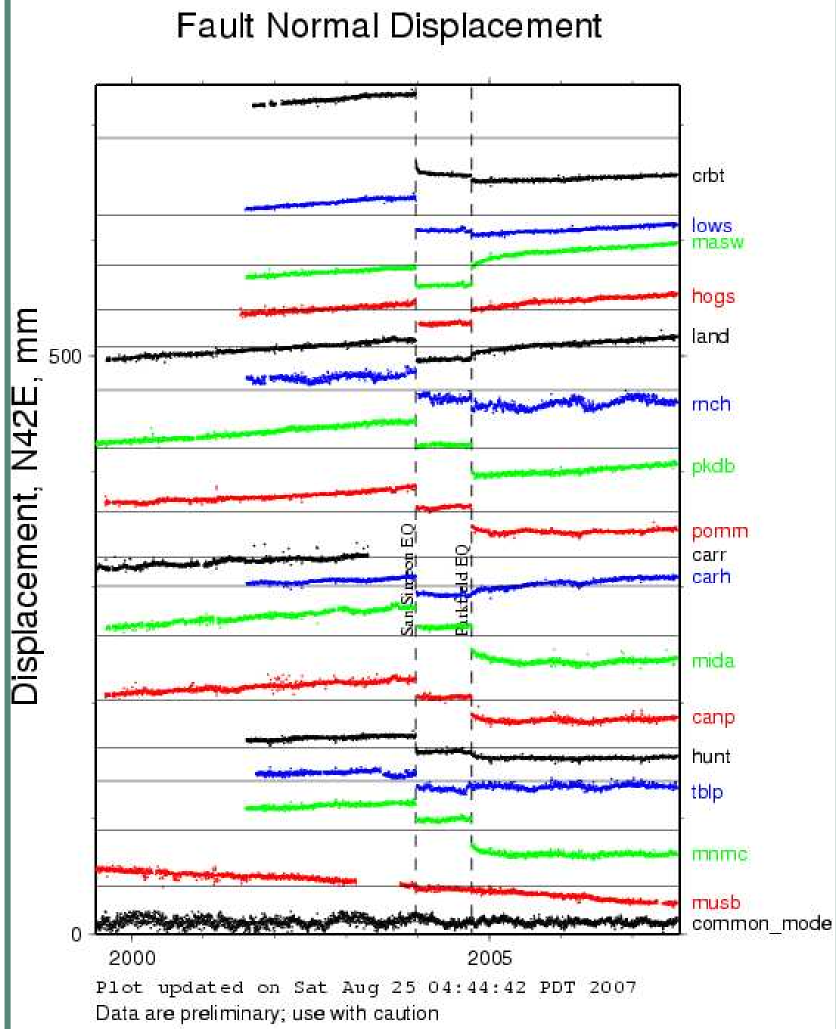
GPS : examples & records

(Geological Survey of Japan)



第6図。2007年中越沖地震の断層周辺を跨ぐ，GEONETの基線(左側図の灰色の線分)の間の距離の時系列（右側図）。左上図は2004年中越地震の余効すべりの，コサイスミックな変動と同様な断層内のすべりによる場合の，地表の変動分布（格子点上の

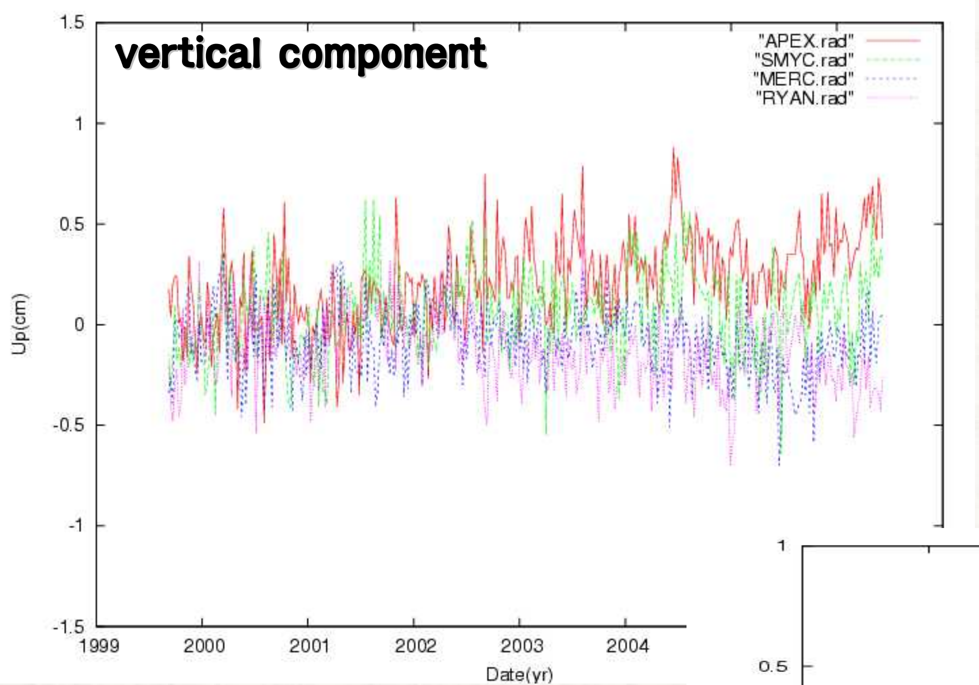




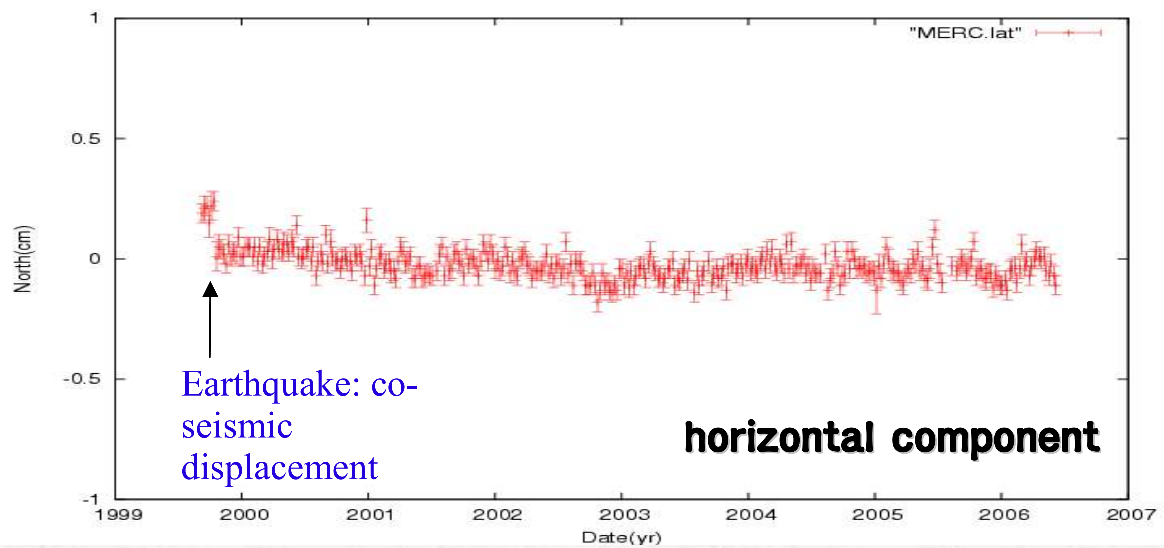
(Parkfield site, USGS (2007. 8))

GPS : examples & records

- Vertical motion is more difficult to characterize:



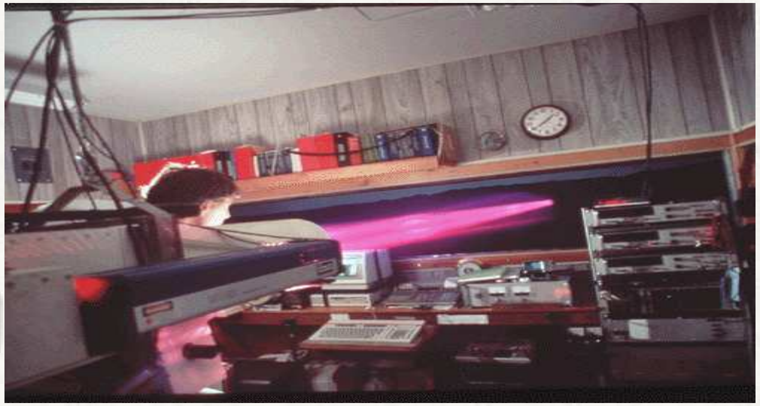
- noisier
- atmospheric refraction
- highly correlated time series
- seasonal effects
- loading effects



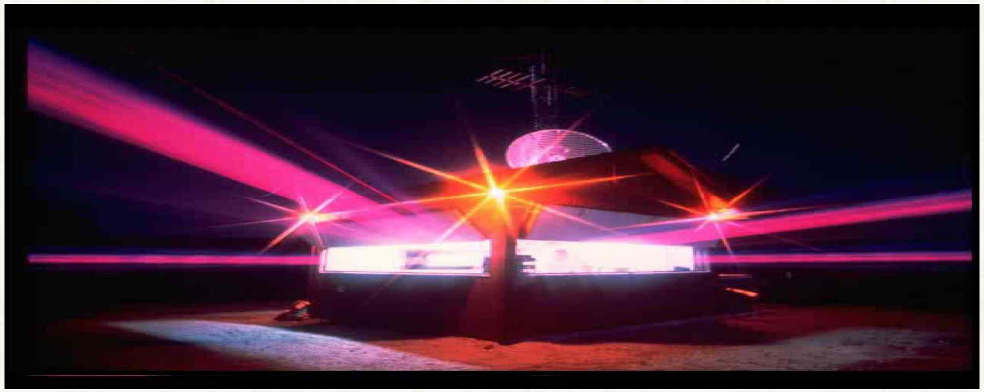
NGL (2007.1)

Two Color EDM (Electronic Distance Meter)

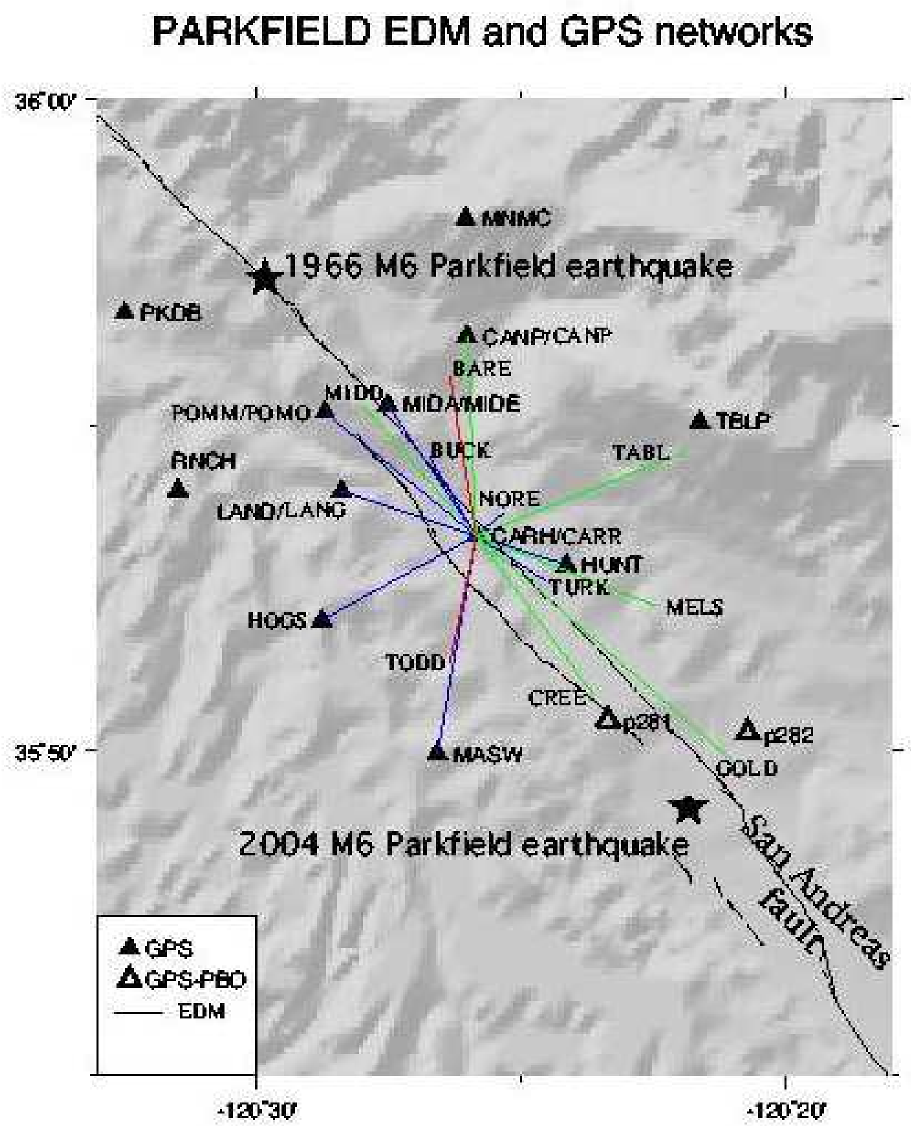
USGS (2007.8)

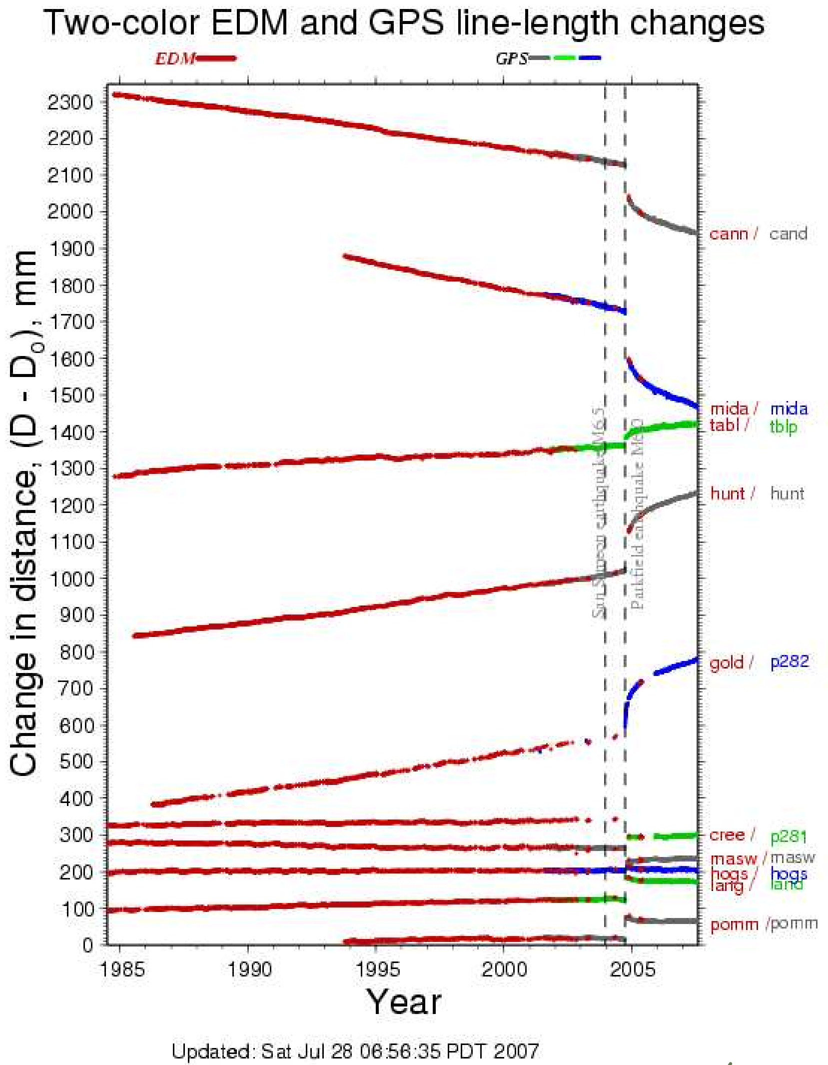


- Early type of the FMS
- Measures a long distance using travel time difference between two color laser beams & monitors changes in the distance with time
- Precision : 0.5-1mm/1-15km
- Hill to hill installation
- Replaced with GPS recently
  - Parkfield site, Yucca Mt site



Two Color EDM : examples & records





USGS (2007.8)

Borehole Strainmeter

- Measures three components
- Precision : 1mm/1,000 km (nano strain)
- Install in drill core at 10 to 300 m depth to avoid noise (weathering, traffic, weather, construction) and to mount in hard rock
- Location : remote area, less traffics & constructions, constant weather if possible
- Expensive. $50k (drill), $50k (strainmeter)

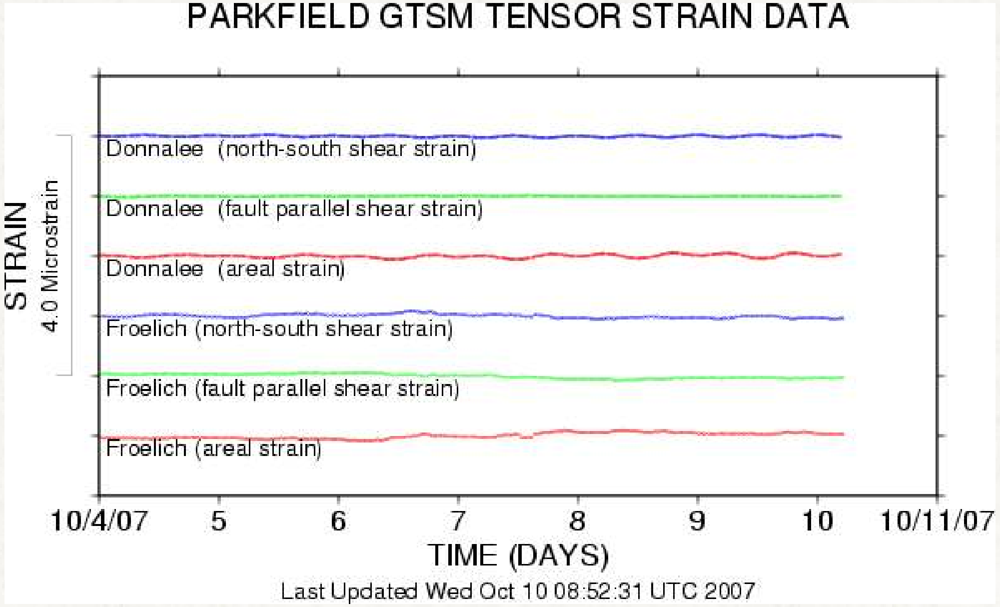
USGS (2007.8)

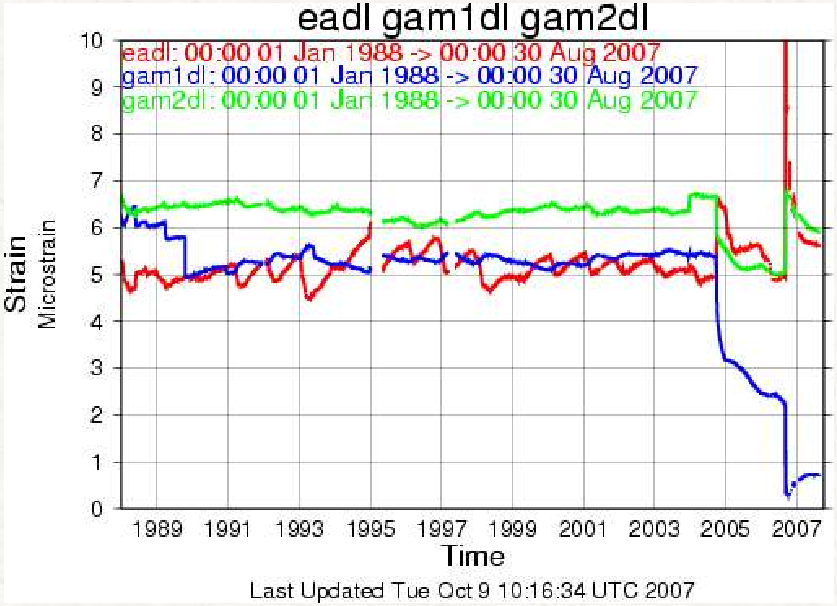
Borehole Strainmeter (cont.)

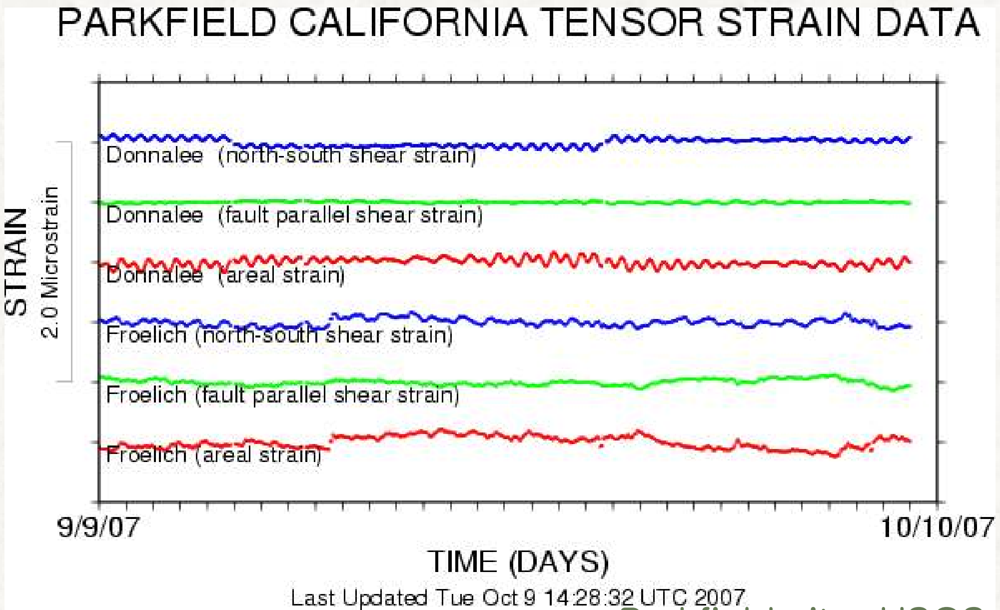
- Test grout material
  - Must not shrink otherwise the strainmeter picks up noises
- Stable power supply, very important
- Power backup
  - c.f., 2 weeks at the Parkfield site
- Maintenance : remote control, cctv etc.
- Life time : 10 ~ < 30 yrs
- Install with other instruments
  - Seismographs,
  - Tiltmemter,
  - GPS
  - Gravimeters
  - Thermometers, barometers
- Build against strong earthquakes

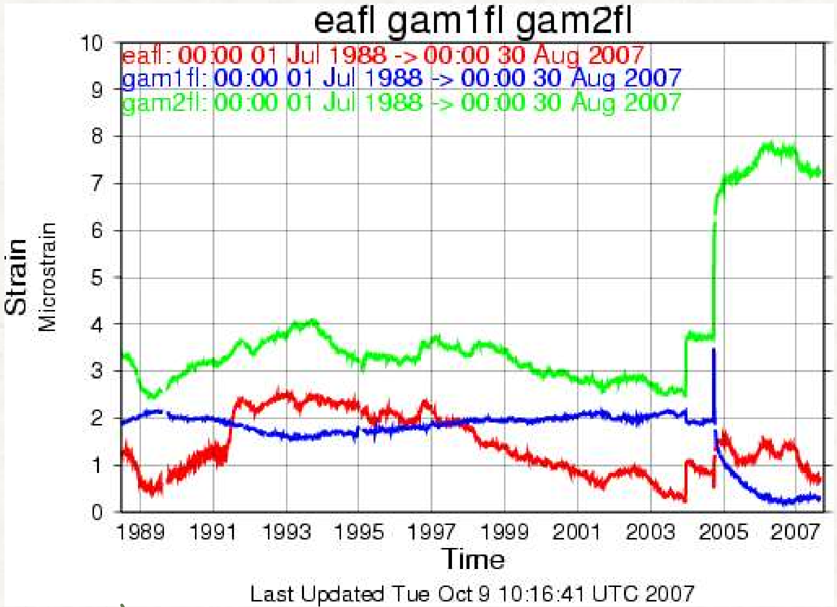
USGS (2007.8)

Borehole Strainmeter : examples & records



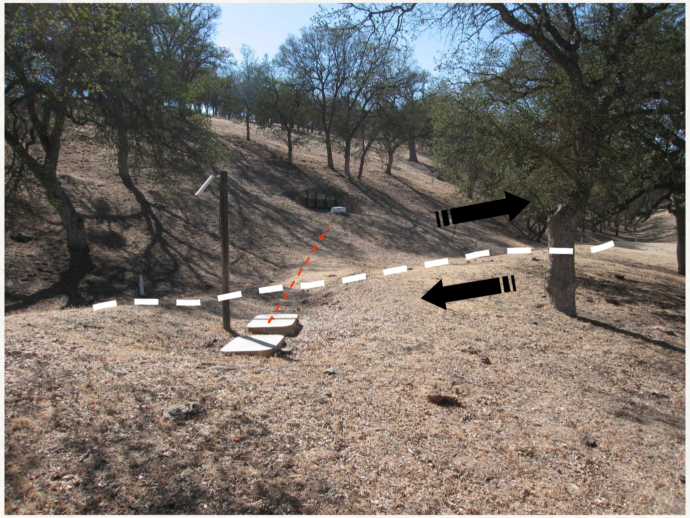




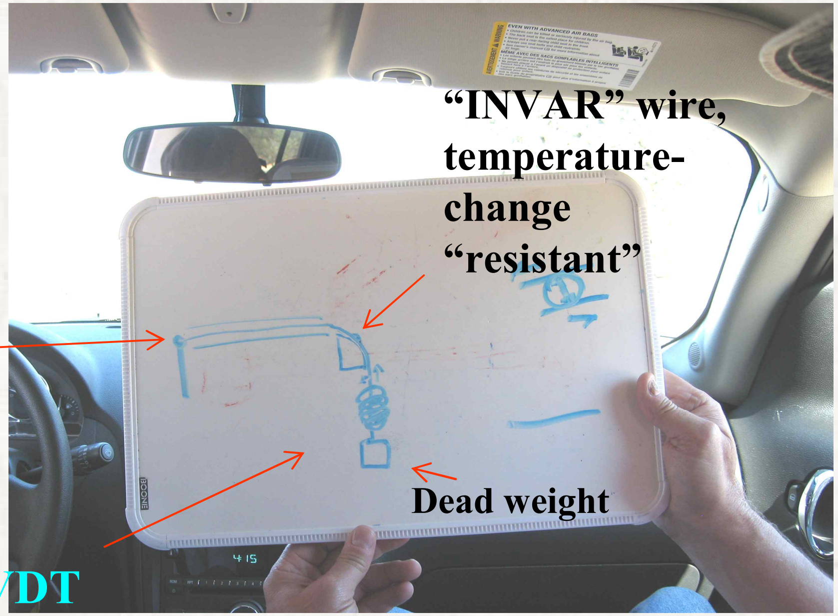


Parkfield site, USGS (2007.8)

Creepmeter



- To record creeps & temporal changes in the creep rate across the fault line
- "INVAR" wire is installed ideally at 30° to the fault strike to record more signal
- Precision : detectable down to 0.1mm
- Noises : Seasonal/annual cycle, rainfalls, earthquakes.

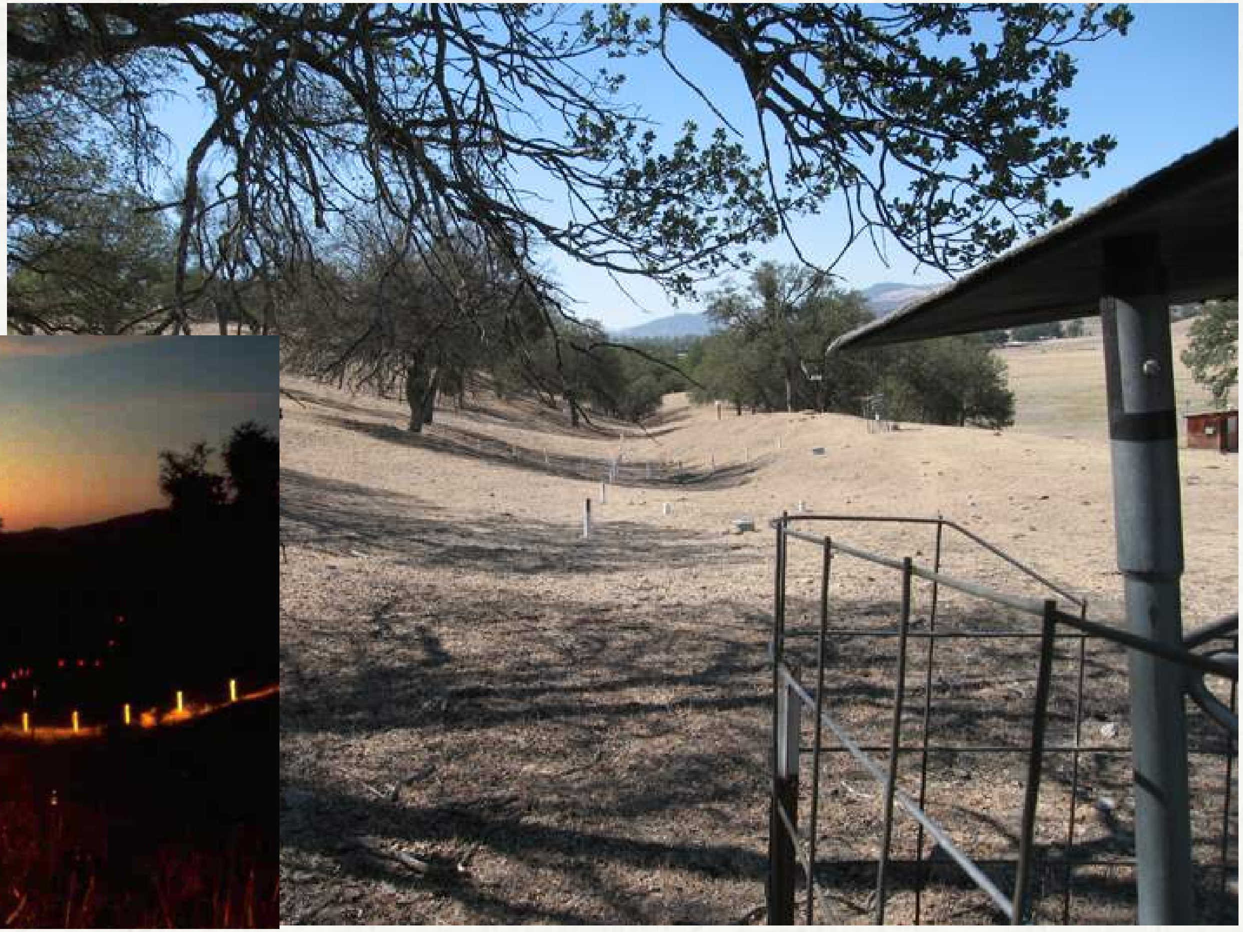


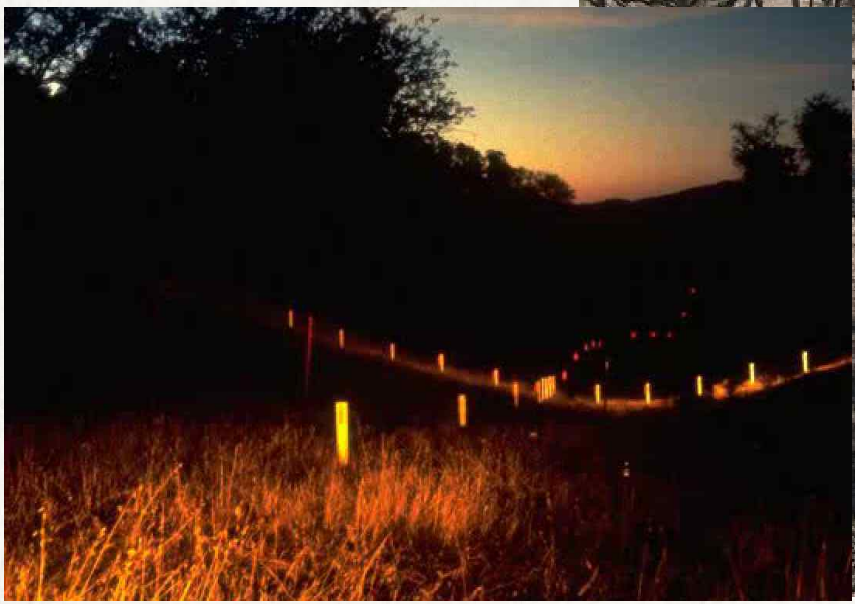
LVDT

USGS (2007.8)

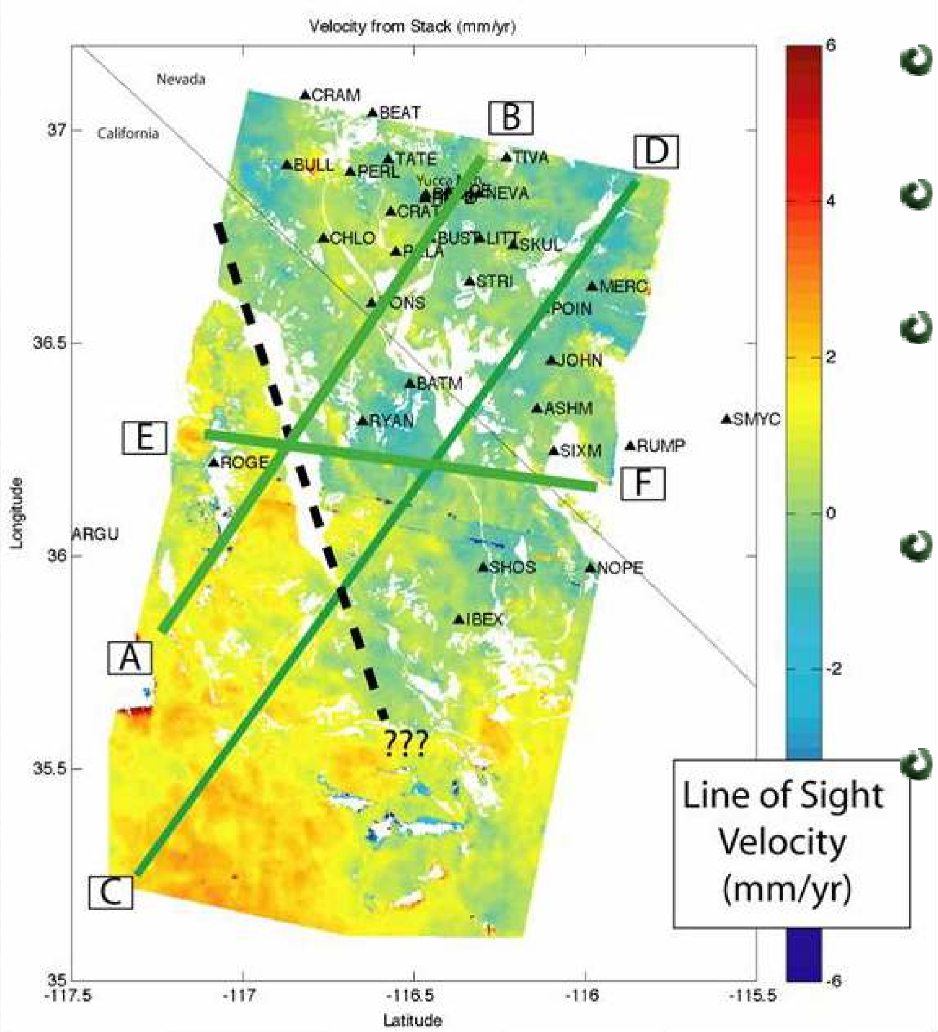
Land markers & movie recorders

- Movie recorders start capturing the movement of a series of aligned marker stick (white in the picture) mounted on the ground along & across the SAF at an electronic signal by certain level of earthquake induced ground shaking





InSAR (Interferometric Satellite Aperture Radar)



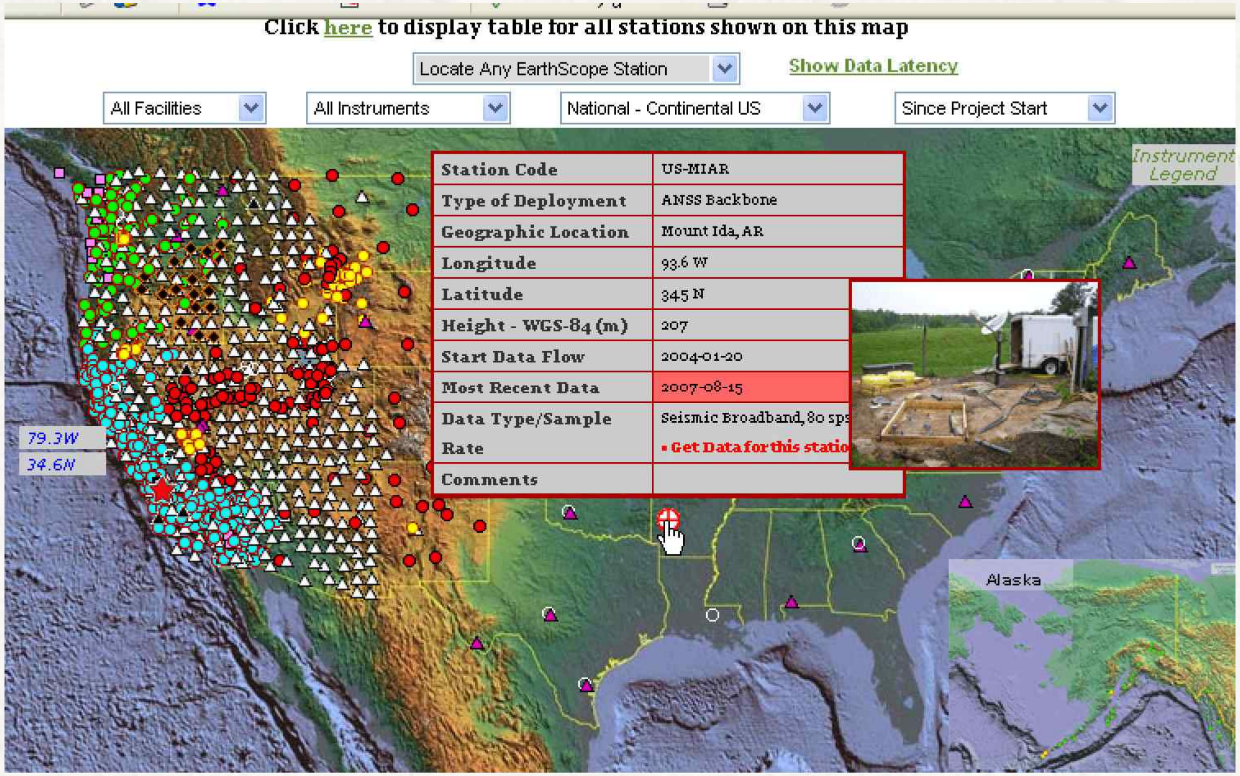
- Precision : mm/hundreds km
- 2-D distribution of displacement
- Frequently used in combination with GPS network
- Limits in woods and agricultural areas
- New techniques (Japan)
  - **Very long wave length**
  - **Permanent Scatter Method**

NGL at RENO (2007.1)

Strong Seismometer Network : example of USArray

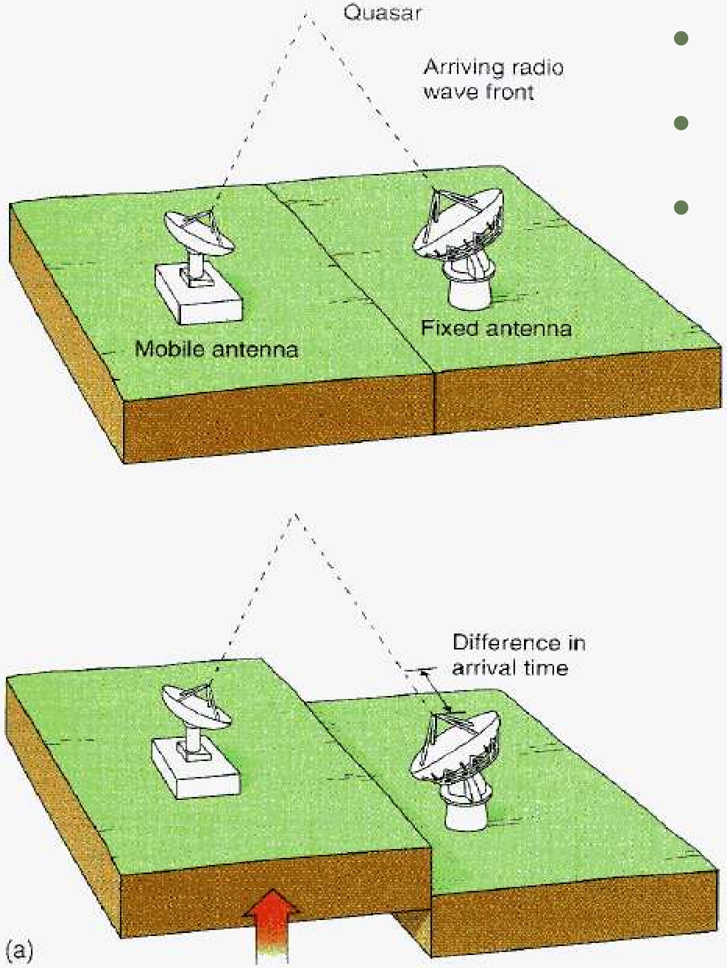
- Need to be well designed
  - Well spaced array, distance between the stations are generally 2 to 3 times of the depth of the earthquake
  - 390 Seismographs as of July 1, 2007
- Precision : record down to Mw 1

Earthscope (2007.6)



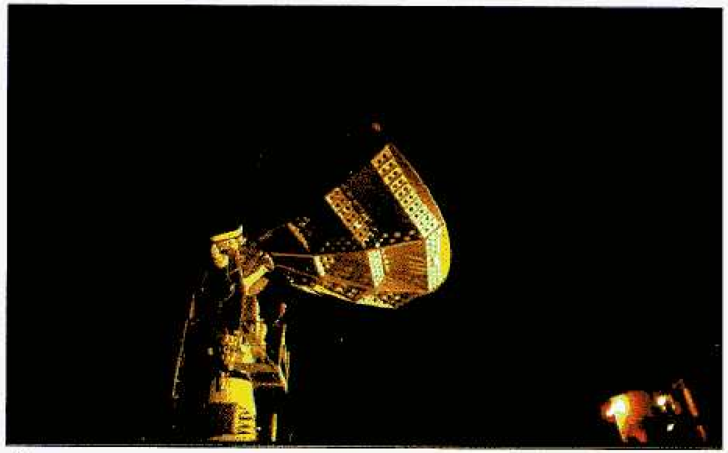
VLBI (Very Long Baseline Interferometry)

- Principal of the VLBI is similar to GPS, except for using external reference frame, that is Quasars



(a)

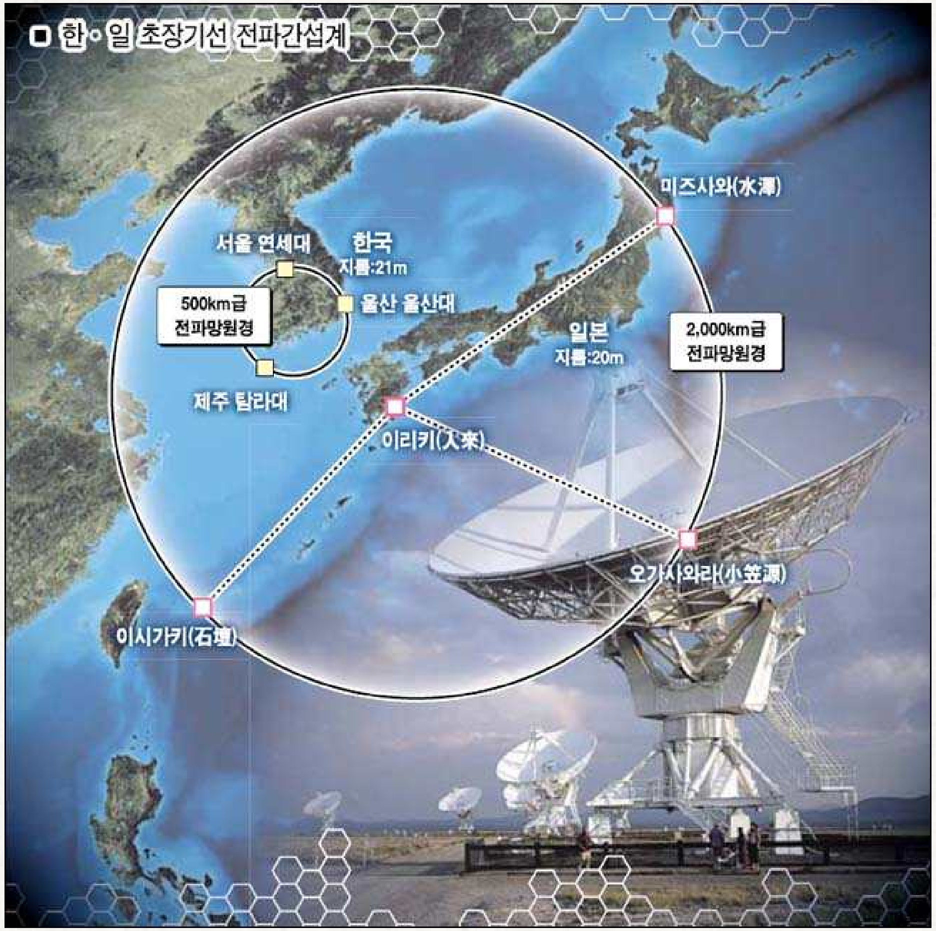
- Precision : < 1mm/thousends km
- Expensive. Several million dollars
- Applicability yet to be tested

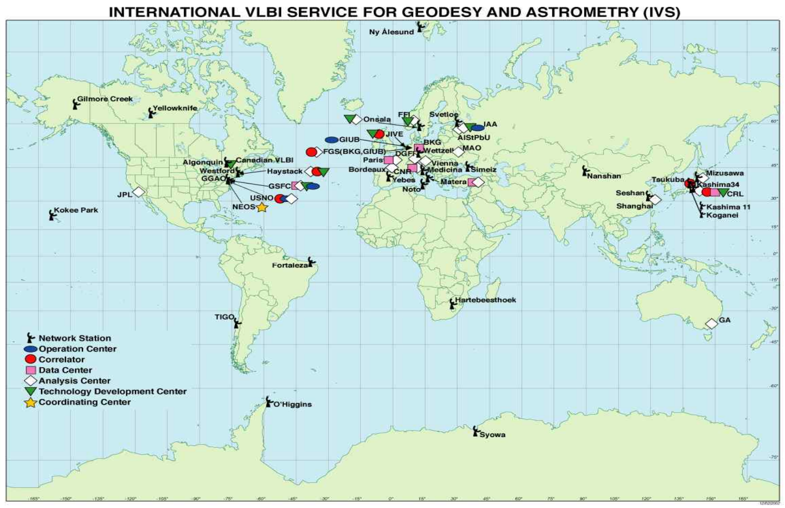


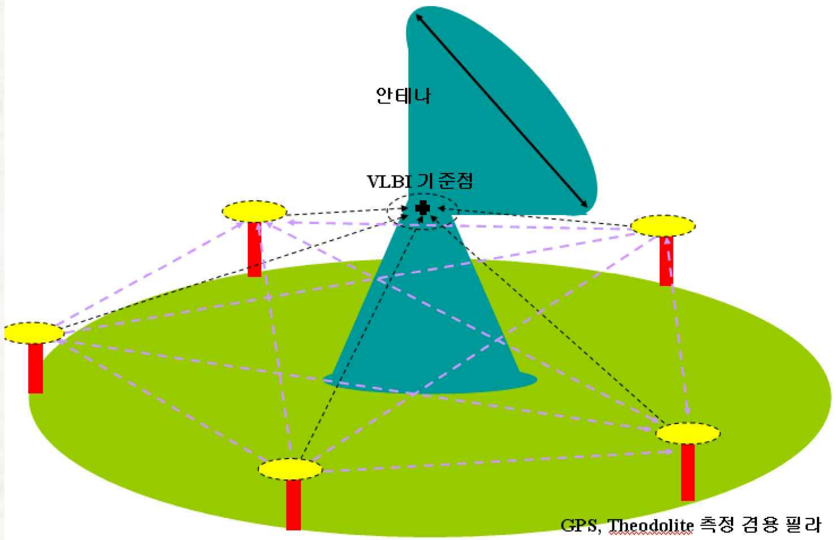
(b)

from: http://www.earth.nwu.edu/personal/seth

VLBI : International network & application







KASI (2007.7)

Eupcheon Fault Monitoring System

Korea Hydraulic Nuclear Power Co.

PURPOSE

Follow-up Action Item of the CP of Shin-Weolsung #1,2 (2007.6.4)

Alarm to abnormal signals at or near the target fault

Site characteristic database and application to the site evaluation

Nuclear Site Monitoring Center

Korea Institute of Nuclear Safety

PURPOSE

Independent cross-check system

Integrated site monitoring system for Korean nuclear sites

Improvement of public acceptance through sharing information

Establishment and use of the instrumentally recorded site-specific DB

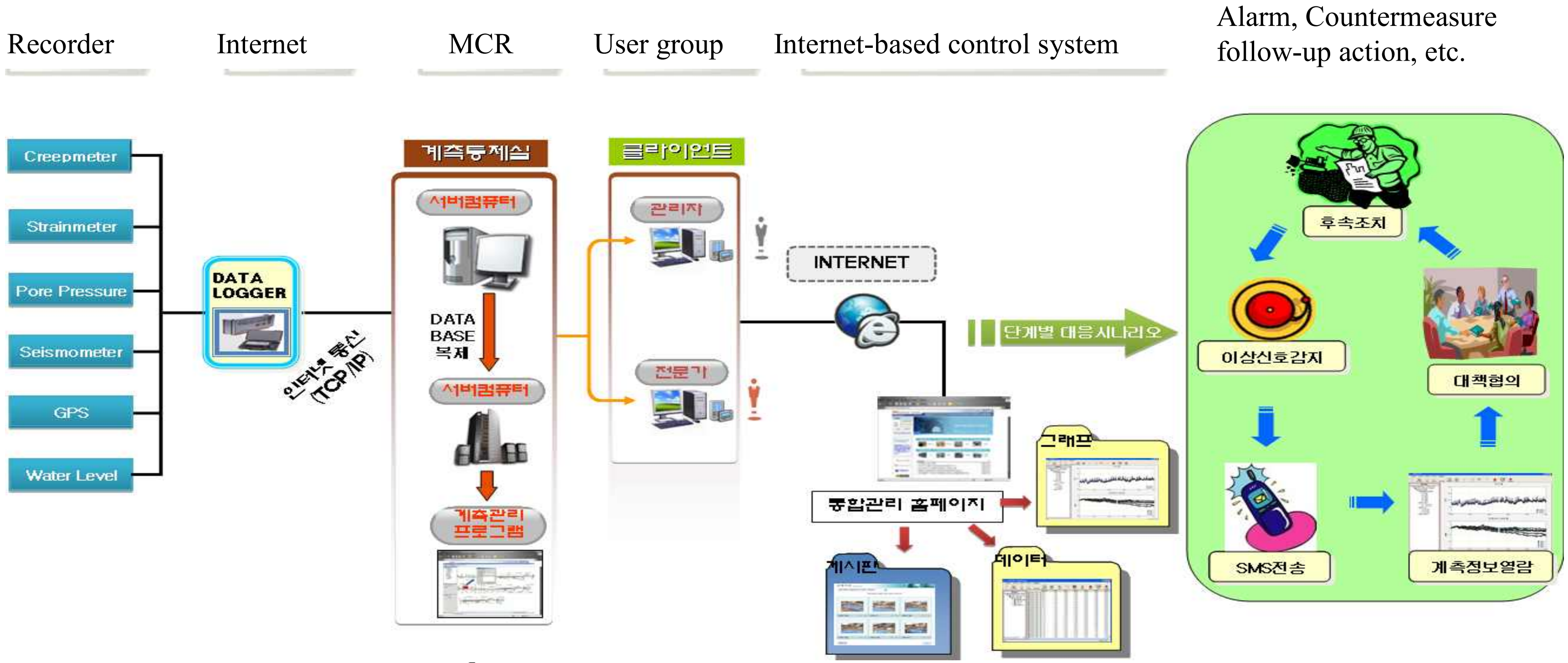
- Regulatory reviews and inspections
- Reference baseline for Korean sites
- Site-specific regulatory criteria and standards

❑ Time History of Tectonic Monitoring for Korean NPP Sites

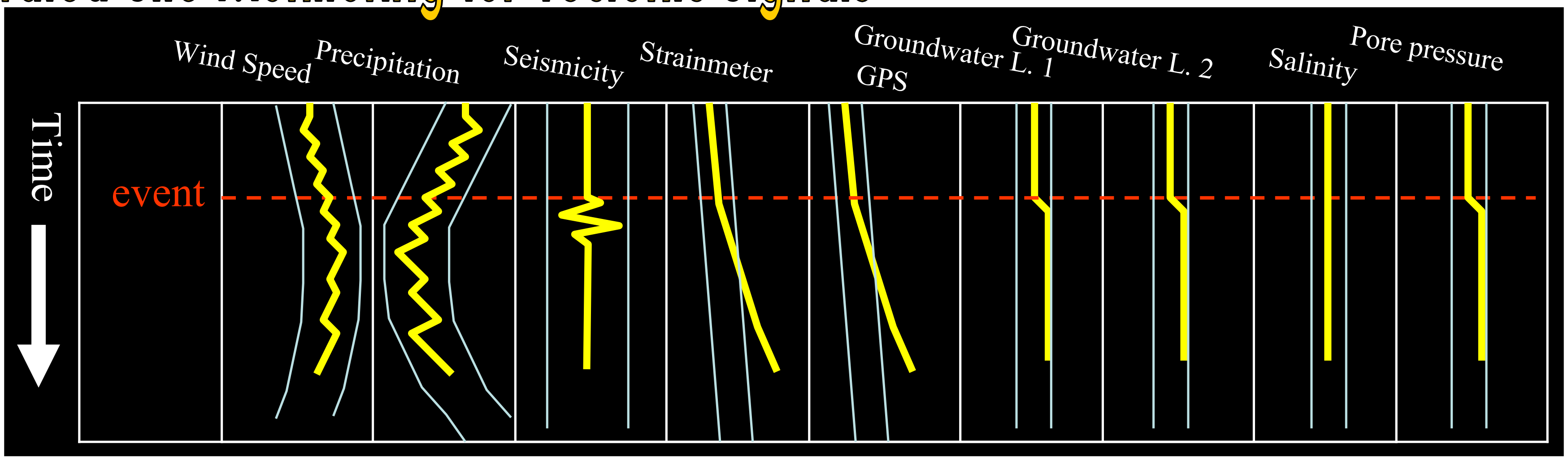
- Earthquake Monitoring Center for Korean NPP Sites (EMC, KINS)
  - Establishment of Seismic Hazard Mitigation Plan for Korean NPPs (1997.07.25)
  - Initiation of the Action Plan (1997.7.29)
  - KINS Earth Monitoring Center in Operation (1998, 2001 ~)
- Eupcheon Fault Monitoring System (EFMS, KHNP)
  - Follow-up Action Item of the CP of Shin-Weolsung #1,2 (2007.6.4)
  - Site survey, Design, Installation & Test (~ 2011.6)
  - Official Operation of the EFMS for the period of OL
- LILWR Site Monitoring System (KRMC)
  - Ordinance of the Minister of Education, Science and Technology
    - ✓ MEST Notice No.2009-37 (ST-Waste-021)
    - ✓ LILWR SAR 2.3 (Site Monitoring and Survey)
  - Operation (2006 ~)
  - Installation and Operation of FMS
- Nuclear Site Monitoring Center (KINS)
  - Establishment and Initiation of the Action Plan (2009.10)
  - Design and Installation of Facilities, Hardware/Software, D/B system (2010 ~ 2012)
  - Official Operation of the Monitoring Center (2013 ~)

- Integrated Site Monitoring System for Korean Nuclear Sites
  - Data Transmission Network
  - Instrumentation Sensor for fault monitoring Installation
    - Tectonic, Hydraulic, Seismic Monitoring Instruments
  - Integrated Site Monitoring System for Korean Nuclear Sites
- Monitoring Data Evaluation Techniques
  - Data Process Tool Development
    - DB program, Noise screening processor, Alert at abnormal signals
  - Human-Machine Interface, etc.
- Web-based Data Management and Sharing System
  - Monitoring center facilitation for operators and visitors
  - Data sharing and cross-checking among member organization
  - Public website

Data Flow Process



Integrated Site Monitoring for Tectonic Signals



Key Factors for TMS

Prescision & Noise Reduction

- Site characterization
  - Need well-defined geology, geometry, kinematics, mechanics of the fault system and the vicinity
  - e.g., Install strainmeters above the hypercenter not on the surface exposure for a low angle reverse fault.

Prescision & Noise Reduction (cont.)

- Well designed set of instruments and the network
  - Precise at least down to 10^{-2} mm/yr for the Korean tectonic settings
- Noise reduction
  - Characterize the noise at the site (earth tides, seasonal changes, traffics & constructions etc.)
  - Installation in a stable & firm basement, avoid traffics
- Cross-referencing the data and the system
  - With the regional system, not just for a fault of interest
  - With varieties of monitoring instruments/systems

Buffer & Back-up System

- Headquarters are designed against strong earthquakes
- Stable power supply
  - Main AC, Solar, Thermoelectricity, Wind
  - Up to 2 weeks at the failure of the major power supply
- Multiple data transmissions
  - Telephone, radio, DSL, satellite etc.
- Mirror system

Public acceptance

- Open to the public and member organizations
  - Website for data acquisition and feedback
  - EARTHSCOPE, PBO, UNAVCO, NCEDC, KISS etc.
- Automatic data processing & public services
  - Raw data come to public on websites with cleaned data after automatic filtering & calculations
  - Member organizations exchange raw data, produce own interpretations & cross-referencing the interpretations
- Stable maintenance of the facilities/operating systems
  - Sustainable organizations and continuing funds

Useful Sources

- USGS Crustal Deformation Data Service http://quake.wr.usgs.gov/research/deformation/monitoring/data/lftable.html
- International Continetal Scientific Drilling Program http://www.icdp-online.org/contenido/icdp/front_content.php?idart=1017
- Nevada Geodetic Laboratory http://geodesy.unr.edu/
- EARTHSCOPE http://www.earthscope.org/
- UNAVCO http://pboweb.unavco.org/?pageid=4
- NCEDC http://www.ncedc.org/ncedc/access.html
- GTSM Technologies, 2011, GTSM Technologies: Tensor Strain for NSF's PBO, http://www.gtsmtechnologies.com/index_files/Page658.htm

Conclusions

- **Independent, Systematic, Integrated Nuclear Site Monitoring**
  - **Cross-check** and improve the credibility of the data produced by each organization
  - Preparedness to abnormal signals from the earth

- Instrumentally recorded long-term site monitoring data provides
  - **Site-specific characteristics and database (geological, geo-hydrological, seismological properties)**
  - Reduction of arguments caused by uncertainty of tectonic phenomena **(e.g., capable fault, subsidence)**
  - Basic input data for site safety evaluation
  - Application of the DB to the establishment site-specific regulatory criteria and standards
- Information Sharing
  - Open and transparent data treatment and information sharing will **improve the public acceptance to nuclear safety**