Seismology and Geology Monitoring Using Satellite Navigation Systems

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GPS and InSAR

GPS Constellation and Network

Synthetic Aperture Radar
Handheld Versus Precise GPS Equipment

Global GPS Network
Southern California is Actively Deforming

Large California Earthquakes

If the 1906 earthquake were to happen today it would be a $1 trillion event.

Northridge was a $30 Billion event

Earthquake damage is related to both the size and location of the earthquake.
Recent GPS Results Show Concentrated Deformation Near Downtown Los Angeles

Los Angeles is moving, literally

GPS Results from the Southern California Integrated GPS Network

- Shortening is occurring in a narrow band just south of the mountains.
- Shear is observed across the San Andreas fault.
- The mountains are behaving as a block.
- Suggests active faults at the front of the mountains and near downtown Los Angeles.
The Northridge Earthquake Affected the Sierra Madre Fault 30 Km Away

The earthquake probably triggered shallow slip on the Sierra Madre Fault.

This was the first time that long range fault interactions were observed.

Earthquake Faults Interact and Can be Monitored from Space
GPS Results Indicated Active Faults

"...would yield an earthquake of moment magnitude $M_w \approx 6.4$... and a $M_w \approx 6$ earthquake is still large and potentially damaging."


Northridge Occurred on a Blind Thrust Fault
Aerial View of Northridge Showing Region Above the Fault Rupture

The Northridge Earthquake was Observed with Synthetic Aperture Radar
Postseismic Motion was Observed with InSAR and GPS

90% of the motion was quiet and not observable with seismometers.

Oat Mountain GPS Station

This mountain grew 40 cm in the Northridge Earthquake.
Stress is Transferred Between Faults

Subsequent earthquakes occur in regions of increased stress.

Earthquakes on One Fault May Turn Earthquakes On or Off on other faults

Southern California Seismicity

Space-time Stress Diagram

Faults

Courtesy John Rundle
Pattern Recognition Techniques Show Promise for Earthquake Forecasting

- Red regions indicate anomalies detected through Principal Component Analysis.
- Blue triangles and circles are earthquakes
- Recent earthquakes have occurred in the anomalous regions.

Comparison of InSAR and Seismic Anomalies

- Similar anomaly shows up in both the postseismic deformation indicated by GPS and InSAR (Donnellan et al) and seismic anomalies identified using Principal Component Analysis (Rundle and Tiampo).
- Mojave desert shows a similar correlation near Barstow and the Blackwater Fault (Rundle and Tiampo; Peltzer)
Space-Based Methods are Showing an Increasing Number of Slow Events

- Slow "earthquakes" are observed in Cascadia and Japan along the subduction zones.
- In Canada, these events take about 15 days, propagate northward, and occur every 16-18 months.

August 1999 Transient Displacements Versus Long Term Velocities

Slip Occurs on the Deep Part of the Subduction Zone

Cross-section viewed from south

Courtesy Herb Dragert, Natural Resources, Canada
Periodic Slow Earthquakes in Cascadia

Differential GPS can be used for Geologic Applications
Measuring Shorelines to Estimate Mantle Viscosity

Differential GPS can Provide Sub-Meter Accuracy in Near Real Time
Earthquakes in Continents

Mongolia

Figure 1: Elevation map of Mongolia. The red box designates the territory covered on our reconnaissance trip in September, 1996. See below for details of the trip route.
Antarctica

Post Glacial Rebound

- The thick ice sheet pushes down on the earth
- As the ice thins the mantle flows back
- The surface of the earth rebounds
Horizontal Velocities
Results

- Little or no extension.
- Significant right lateral motion between east and west Antarctica
- Dome of uplift centered near the Rockefeller Mountains with a maximum uplift rate of about 10 mm/yr.