Block Models, Cluster Analysis and Space Geodetic Data Needs to Better Estimate Fault Slip and Intra-block Strain Rates in Southern California

Wayne Thatcher, Bob Simpson and Jim Savage
U.S. Geological Survey, Menlo Park California

Assumed California GPS Block Geometry
(Parsons, Johnson et al, 2012)

Block Geometry Derived from Mojave GPS Cluster Analysis
(Savage & Simpson, JGR, in review, 2012)
But GPS Velocity Field Alone Constrains Location of Major Active Fault Boundaries

>1400 edited velocity vectors

Courtesy of T. Herring, MIT, to UCERF3
Schematic Illustration of Cluster Analysis Method

Example of Clustering (Hierarchical Agglomerative Clustering)

(N clusters = 1)  (N clusters = 4)  (N clusters = 7)
Cluster Analysis of GPS Vectors Identifies Major Tectonic Elements of California

• No subjective assumption of block geometry
• Simple, intuitive analysis method
• Major active tectonic features delineated:
  - faults of San Andreas system
  - Mojave Desert faults
  - Sierra Nevada-Great Valley microplate
  - Western boundary of Basin & Range
  - Cascadia subduction zone boundary
Cluster Analysis with Four GPS Clusters Determined

Four San Francisco Bay Area Blocks Clearly Identified Solely by Cluster Analysis

See Graymer & Simpson G23B-931 Poster This Afternoon
Cluster Analysis Applied to Mojave Desert GPS with UCERF3 Block Boundaries (Grey Lines) & GPS Sites (Dots)
5 Statistically Significant Clusters are Spatially Coherent

Main Features

- Cluster Distribution Similar to UCERF3 Block Geometry
- However, Some Differences too
- Garlock Fault Not “Seen” by Cluster Analysis
- Existence of Smaller Blocks Not Precluded by Cluster Analysis
- Large Block Rotation in NEMD Does Not Contaminate Analysis

Savage & Simpson, 2012 JGR, submitted
Data Needs for Better Modeling of Steady-State Surface Velocity Field in Southern California

• Better Precision in GPS Velocities Everywhere (e.g. Better Define Clusters in Cluster Analysis)

• Better Spatial Density for Measuring Intra-Block Strain (InSAR?, Sandwell, pers. comm. 2013) (More GPS sites too!)
ADVANTAGES OF CLUSTER ANALYSIS

Offers **simple, visual, first-step reconnaissance** to organize GPS velocities

Provides an **objective method for identifying major block boundaries**

Works best where Euler poles are distant and blocks ~translate

**Statistical tests** of block-like behavior of clusters **build confidence in results**

**Fault slip rates estimated** by difference in mean velocity between adjacent clusters

Application to other regional GPS data & including block rotations now underway
LIMITATIONS

Only a relatively small number of statistically significant clusters, typically 5 or less

Even random data can appear clustered, so use method with appropriate caution!

Smaller blocks not precluded & cannot yet be confidently identified by cluster analysis

GPS precision & spatial density limit cluster resolution & can cause spurious clusters

Large rotations of blocks with nearby Euler poles may contaminate analysis

Other space geodetic data (e.g. InSAR) not yet incorporated into method
San Francisco Bay Area Velocity Field

Simpson, Thatcher & Savage  GRL, 2012
Analysis with 5 Statistically Significant Clusters

Savage & Simpson, 2012 JGR, submitted
Analysis with 4 Statistically Significant Clusters

Velocity Field Map

Velocity Profiles N35°W & N55°E