Development (AIST):

QuakeSim: Multi-Source Synergistic Data Intensive Computing for Earth Science

Production (ACCESS):

GEO GATEWAY

Analysis | Modeling | Response

For Geodetic Imaging

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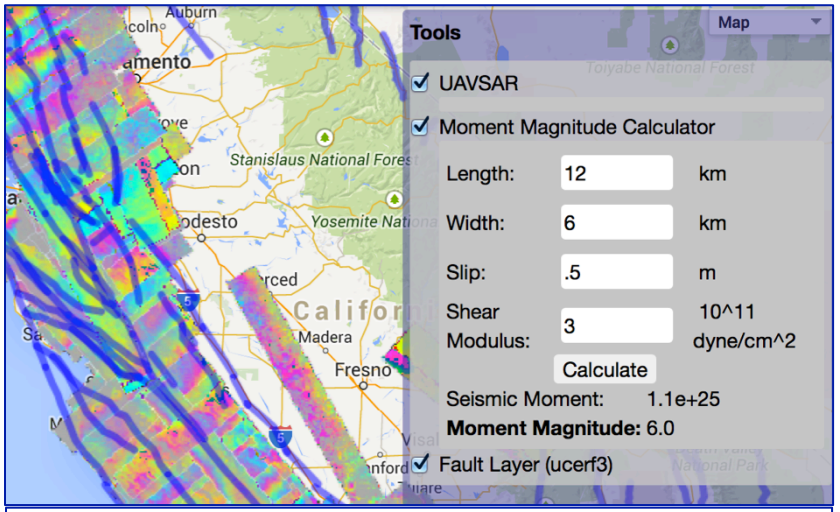
Marlon Pierce, Jun Wang, Yu Marie Ma (Indiana University)

Lisa Grant Ludwig (UC Irvine)

John Rundle (UC Davis)

End Use Objective

- Develop a web-enabled and map-based data product search and analysis gateway
  - For scientific discovery, field use, and disaster response
- Users require
  - Data overlay
  - Visualization
  - Interactive analysis features
  - Data product download
  - Sharing and collaboration
- Focus on NASA's UAVSAR and GPS
  - Integrate with faults, seismicity, and models



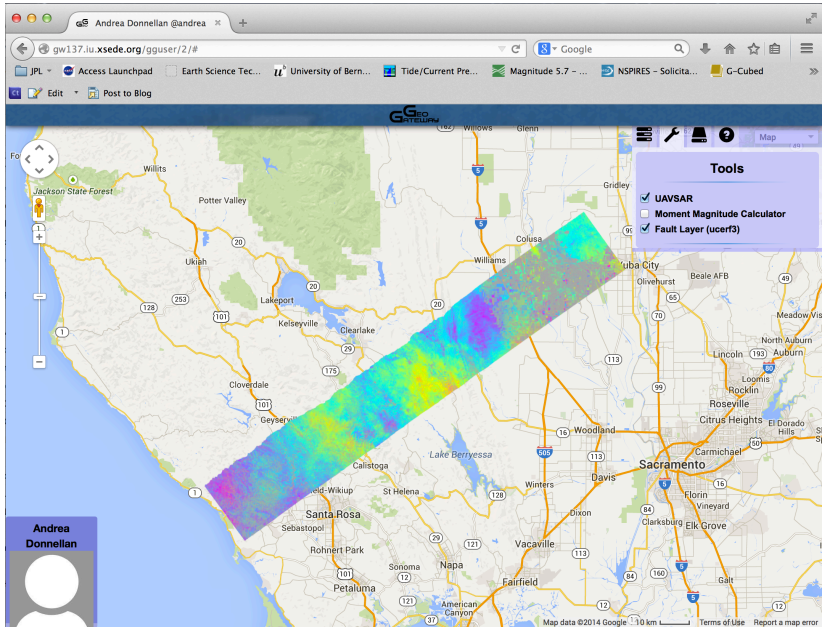
Moment magnitude calculator

Backend Objectives

- Update QuakeSim services to integrate and rapidly fuse data from multiple sources to support comprehensive efforts in data mining, analysis, simulation, and forecasting for earthquakes
- Extend QuakeSim infrastructure to include tiered publishing mechanisms and data provenance, trust, and history tracking
- Develop and deploy a cloud computing architecture to access and analyze large and heterogeneous data products and integrate them with earthquake models and simulations in collaboration with the Earth Science Division - Earth Surface and Interior focus area

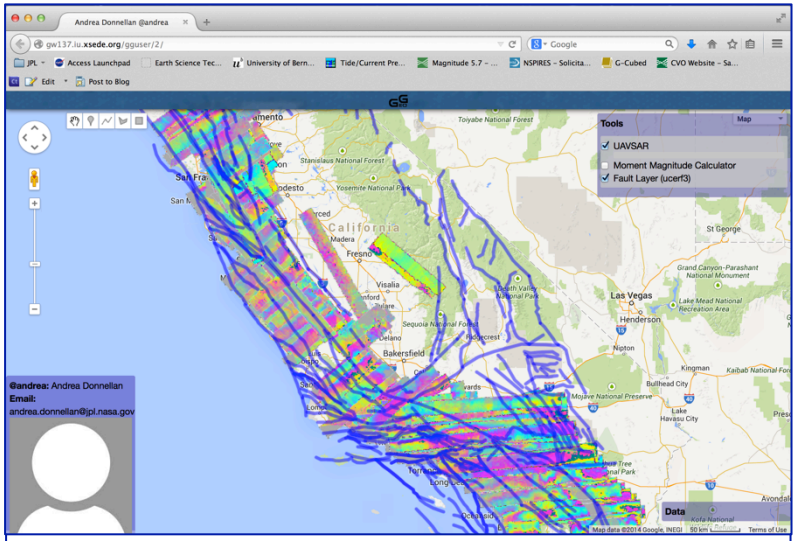
Philosophy

- Focus on science analysis, modeling, and simulation
- Use existing data products
- Let the experts process the data
- GPS model has worked well
- Focus on developing tools for routine workflow
- Make products and output available for further offline analysis



Approach

- Re-architect QuakeSim site: GeoGateway
  - Still based on GeoServer
- Overlays
  - Tools and data
  - Note taking
  - Collaboration
    - At different levels



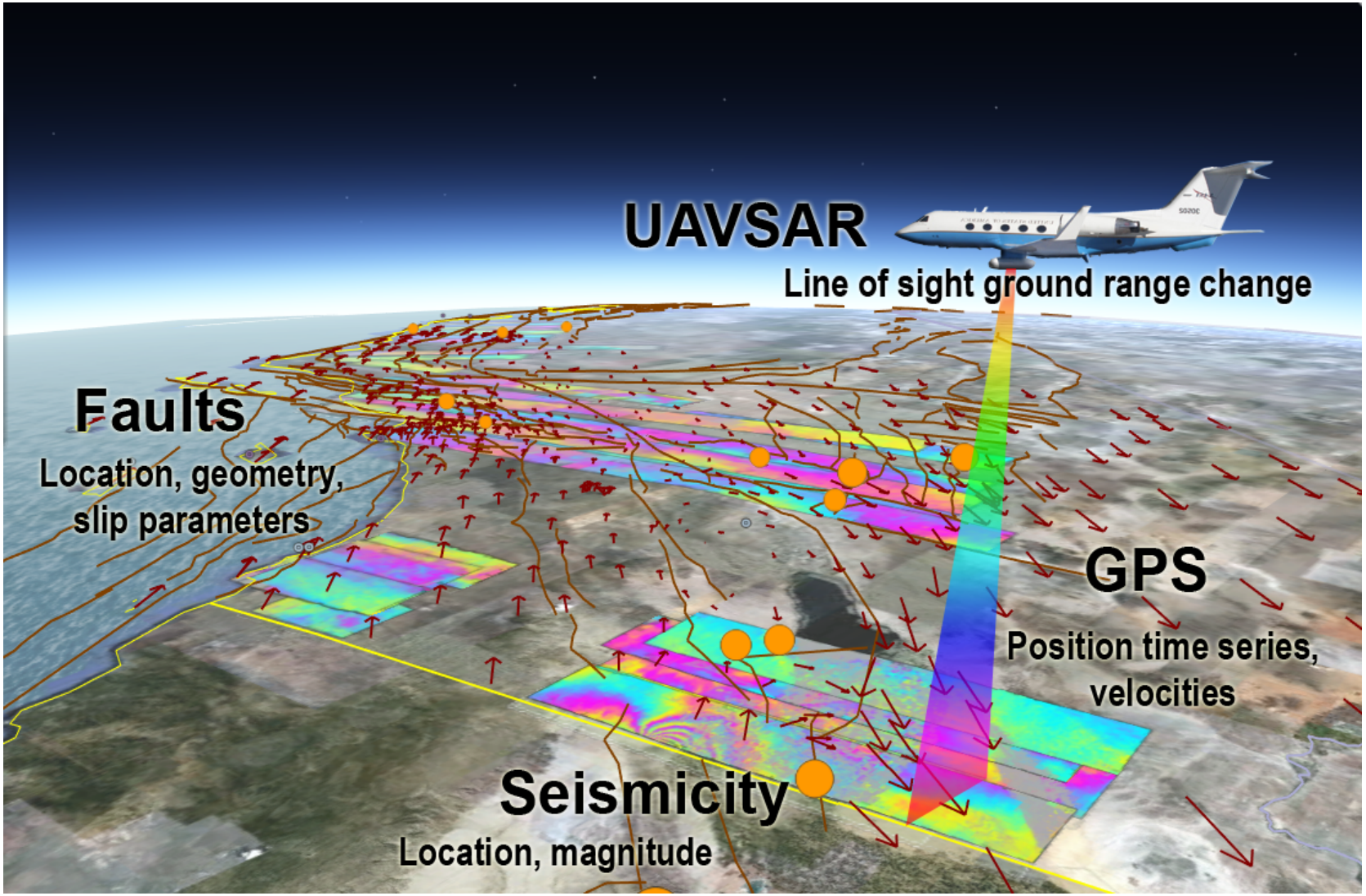
Faults overlaid on UAVSAR RPI Products

- Designed like a tablet app for easy use in field
  - Responsive to screens, phones, tablets

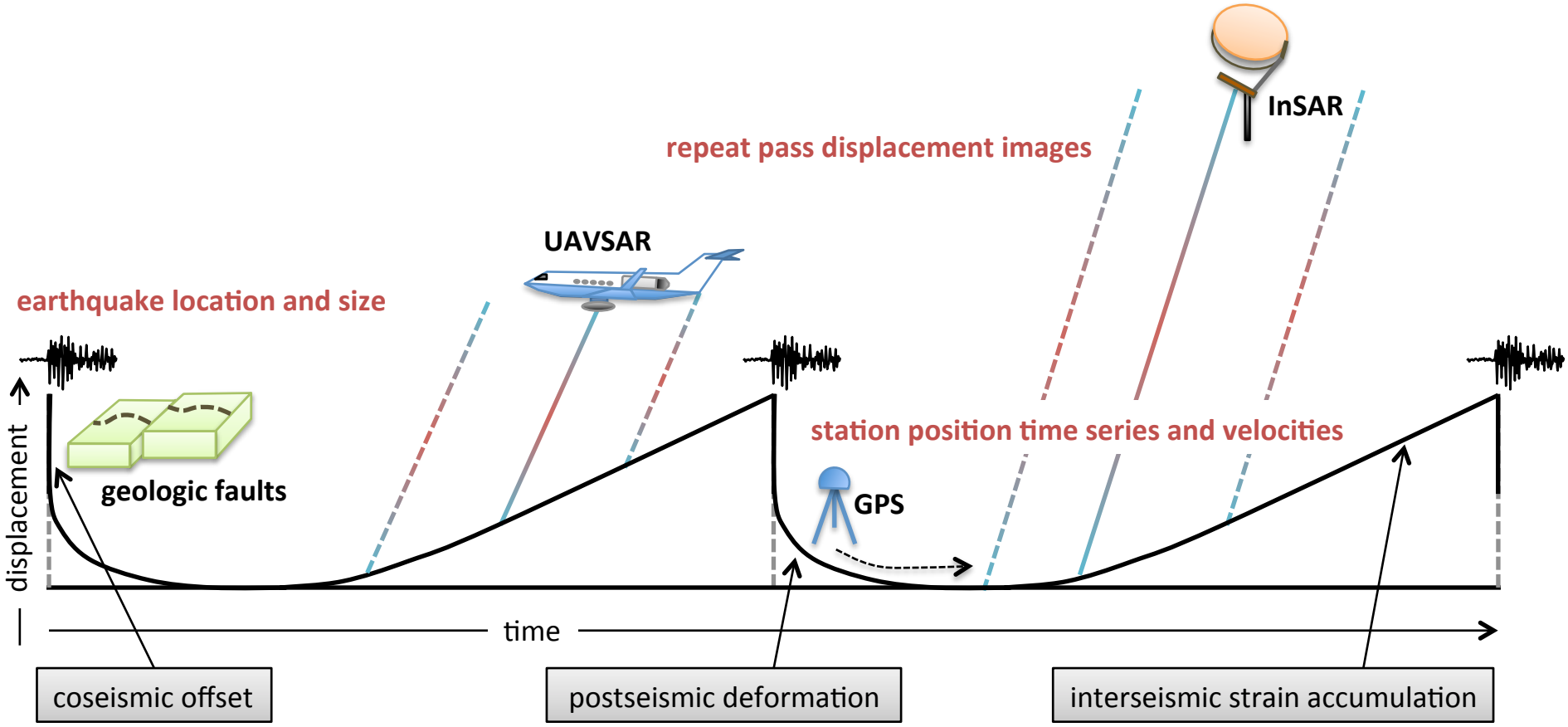
Backend Approach

- Integrate multi-source data from NASA, USGS, NSF and others through bridging services
- Support fault model optimization by integrating multiple data types in a Cloud Computing framework
- Integrate model contribution, provenance, version tracking, commenting, and rating of fault models produced by the optimization framework

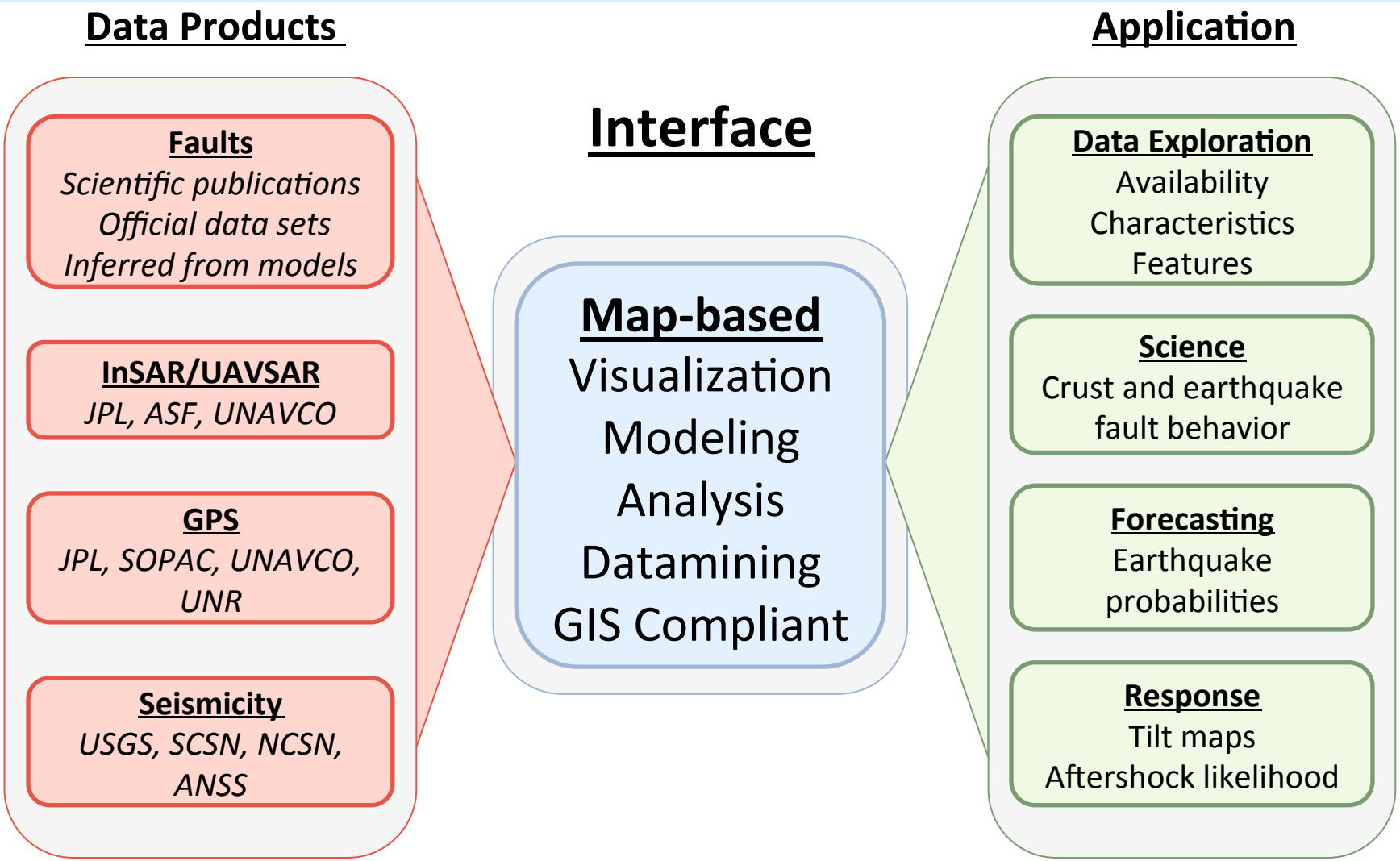
Observations



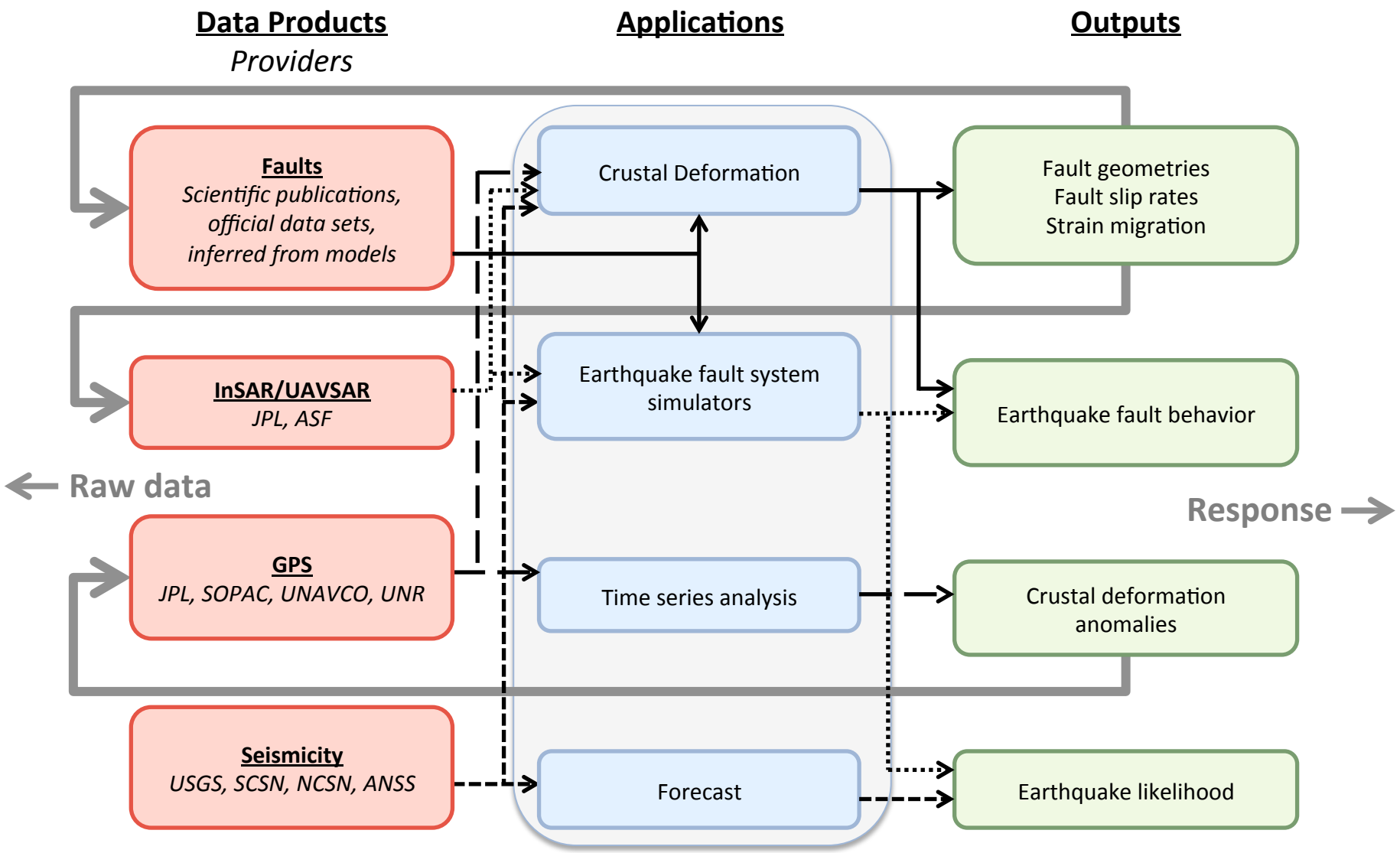
Key data products related to earthquake cycle



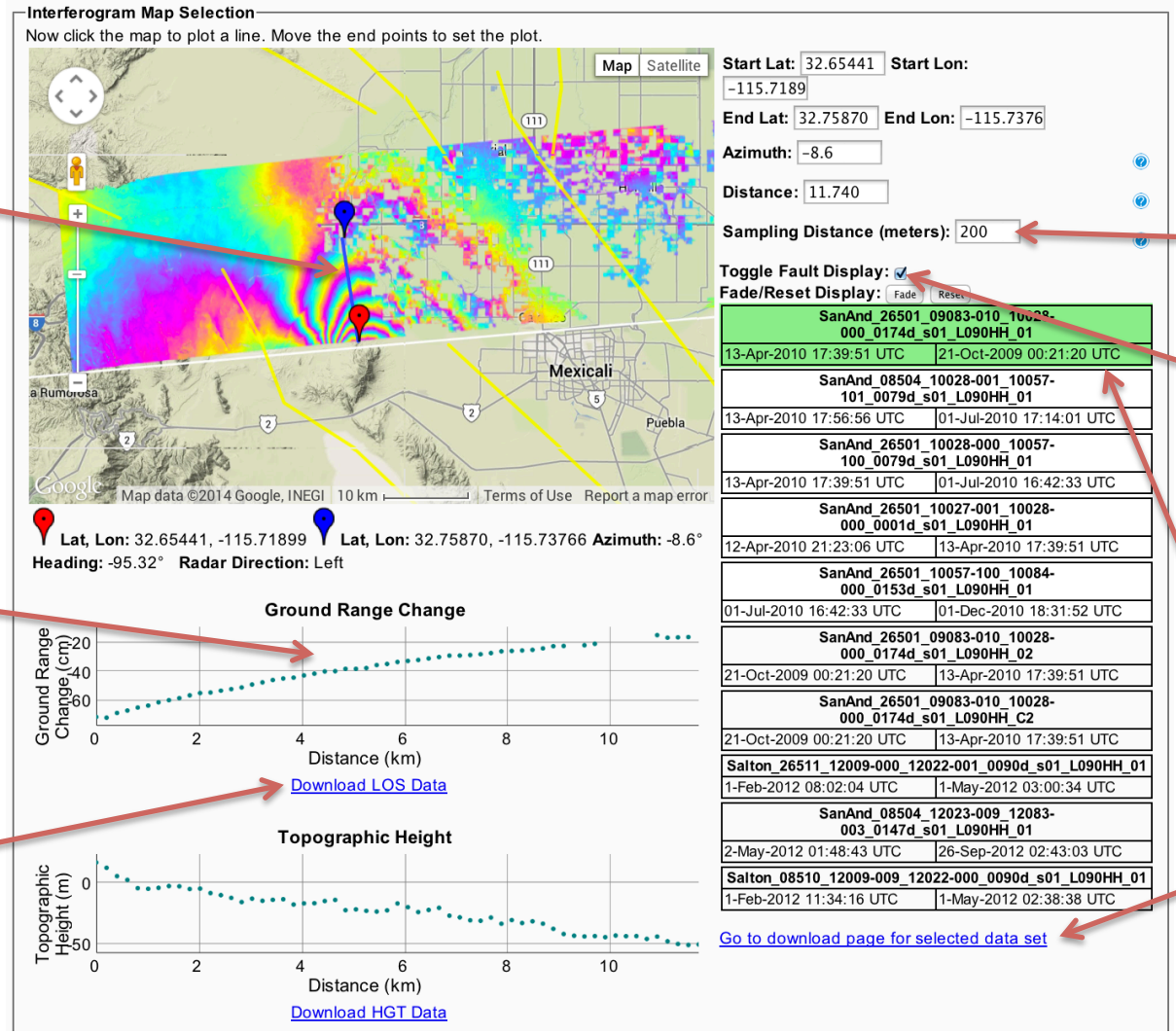
Inputs and Outputs



Workflow


Data Products
Providers
Applications
Outputs
Faults
Scientific publications, official data sets, inferred from models
InSAR/UAVSAR
JPL, ASF
GPS
JPL, SOPAC, UNAVCO, UNR
Seismicity
USGS, SCSN, NCSN, ANSS
Raw data
Crustal Deformation
Earthquake fault system simulators
Time series analysis
Forecast
Fault geometries
Fault slip rates
Strain migration
Earthquake fault behavior
Crustal deformation anomalies
Earthquake likelihood
Response

InSAR Profile Tool



Select profile line

Set sampling interval

Toggle fault display

Select interferogram data product

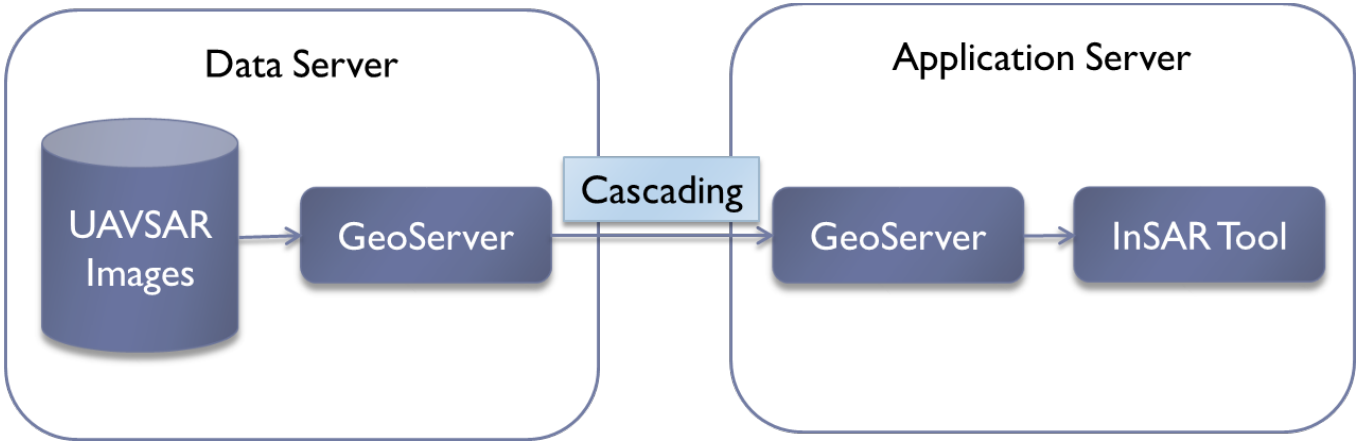
View profile

Download profile

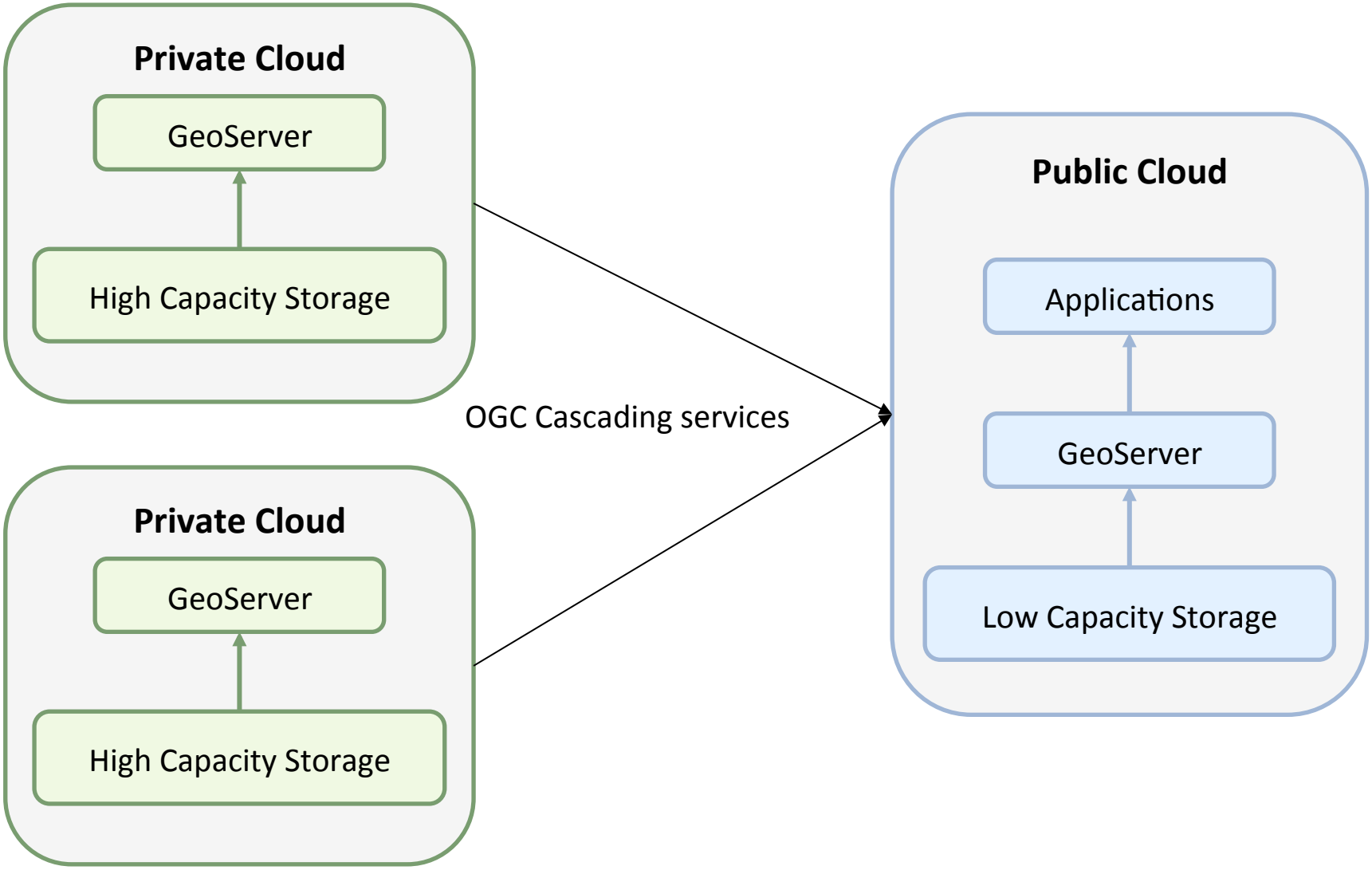
Download data products

Two-Tier Data Server and Application Server

- Bundling data inside the application server quickly becomes expensive and impractical for auto-scaling with a large amount of raster data
  - EBS volumes cannot be shared among multiple instances
- One simple solution
  - Separate the application services from data storage
    - Have a dedicated high performance server for data hosting
    - Application servers can access the data through OGC cascading services while remain flexible for ELB and autoscaling (AS)

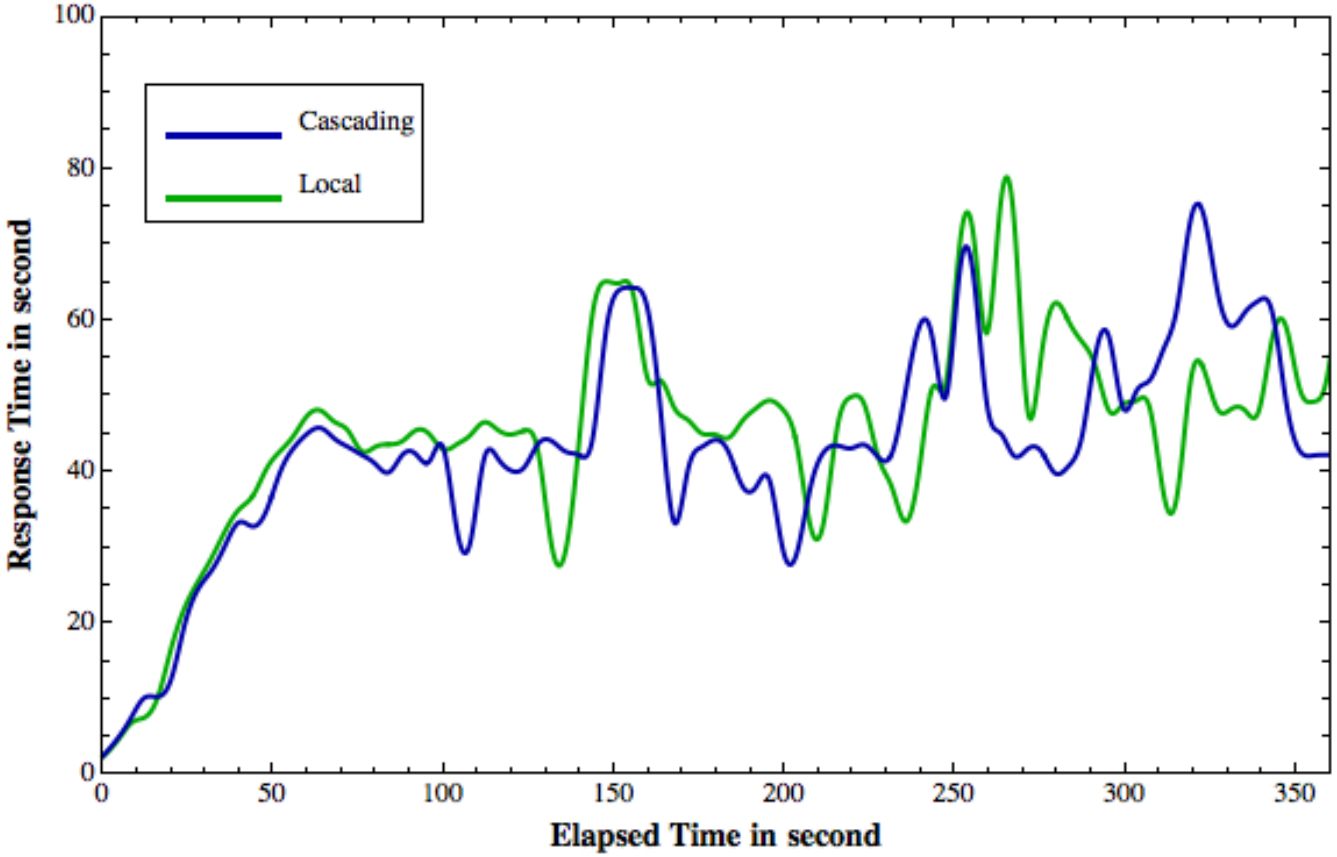


Cloud Computing: hybrid solution



Cascading versus Locally Hosted Services

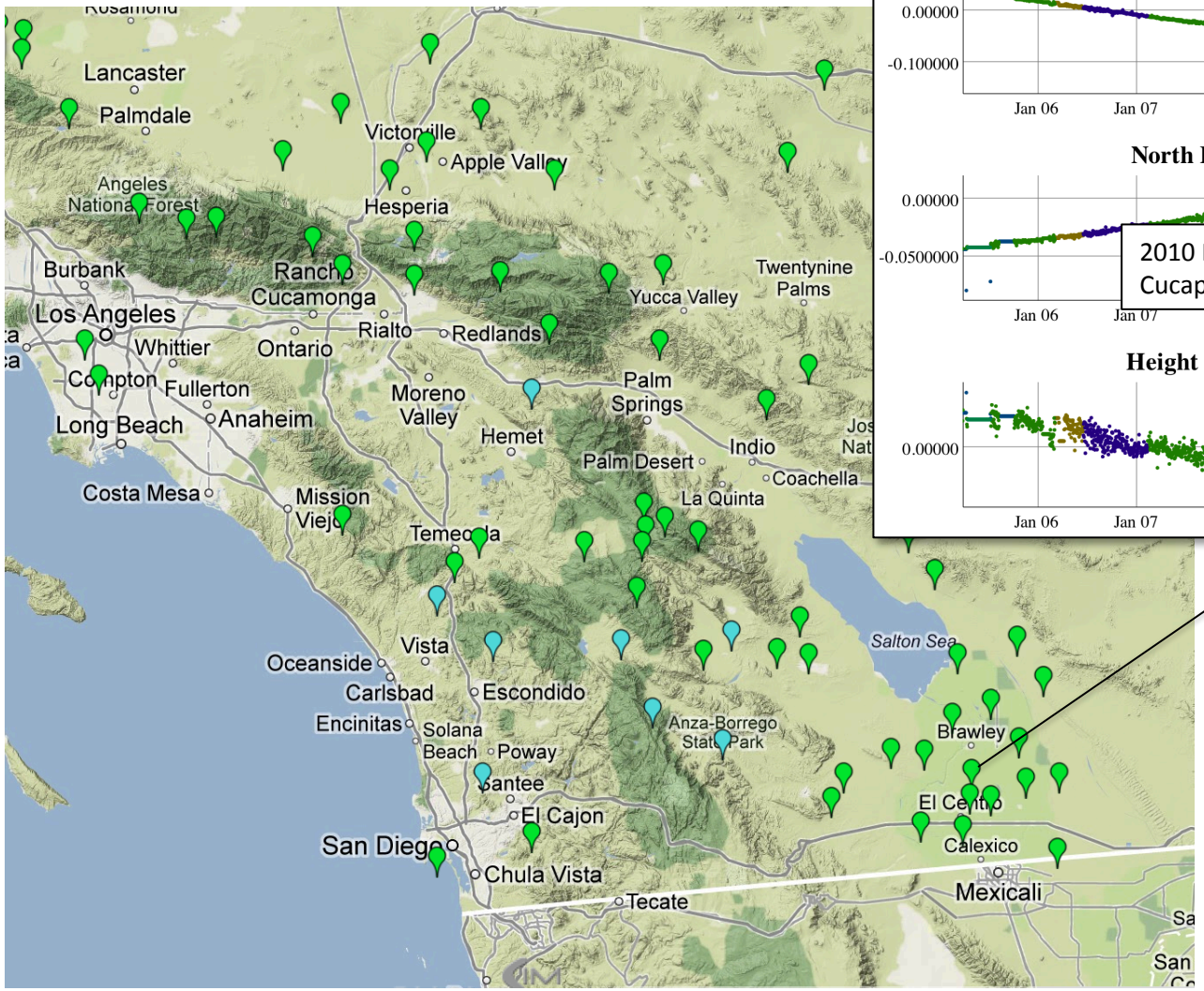
- No noticeable penalty for two-tiered service

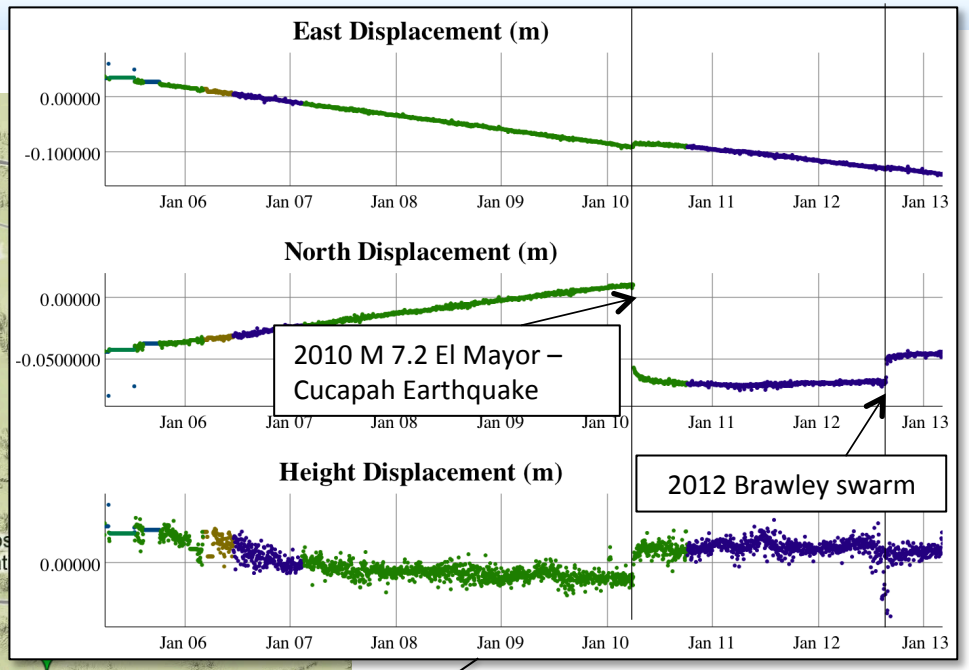


Donnellan, A., J.W. Parker, J. Wang, Y. Ma, M. Pierce, Cloud Computing for Geodetic Imaging Data Processing, Analysis, and Modeling, IEEE Aerospace Conference, Big Sky, MT, March 2–7, 2014.

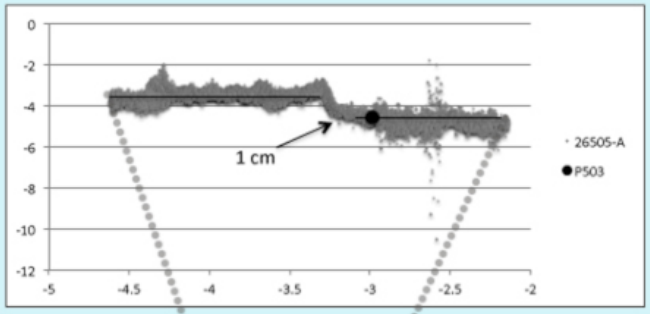
GPS Time Series

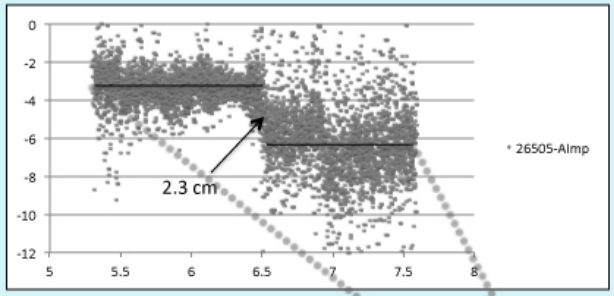
Incorporating high data rate GPS

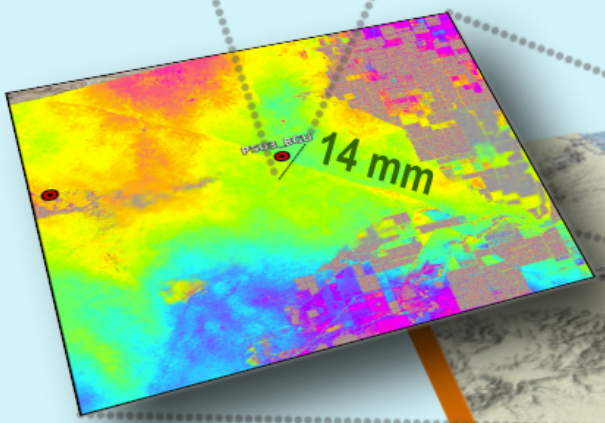


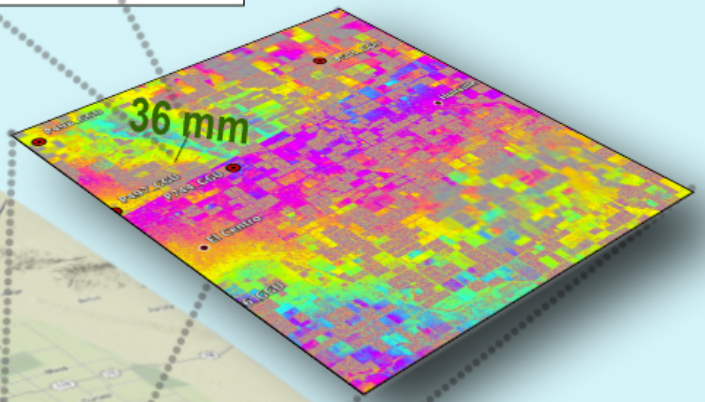


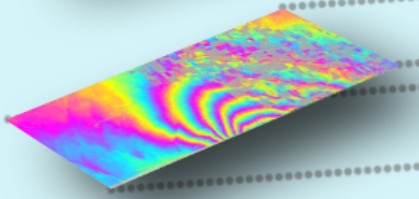
Salton Trough

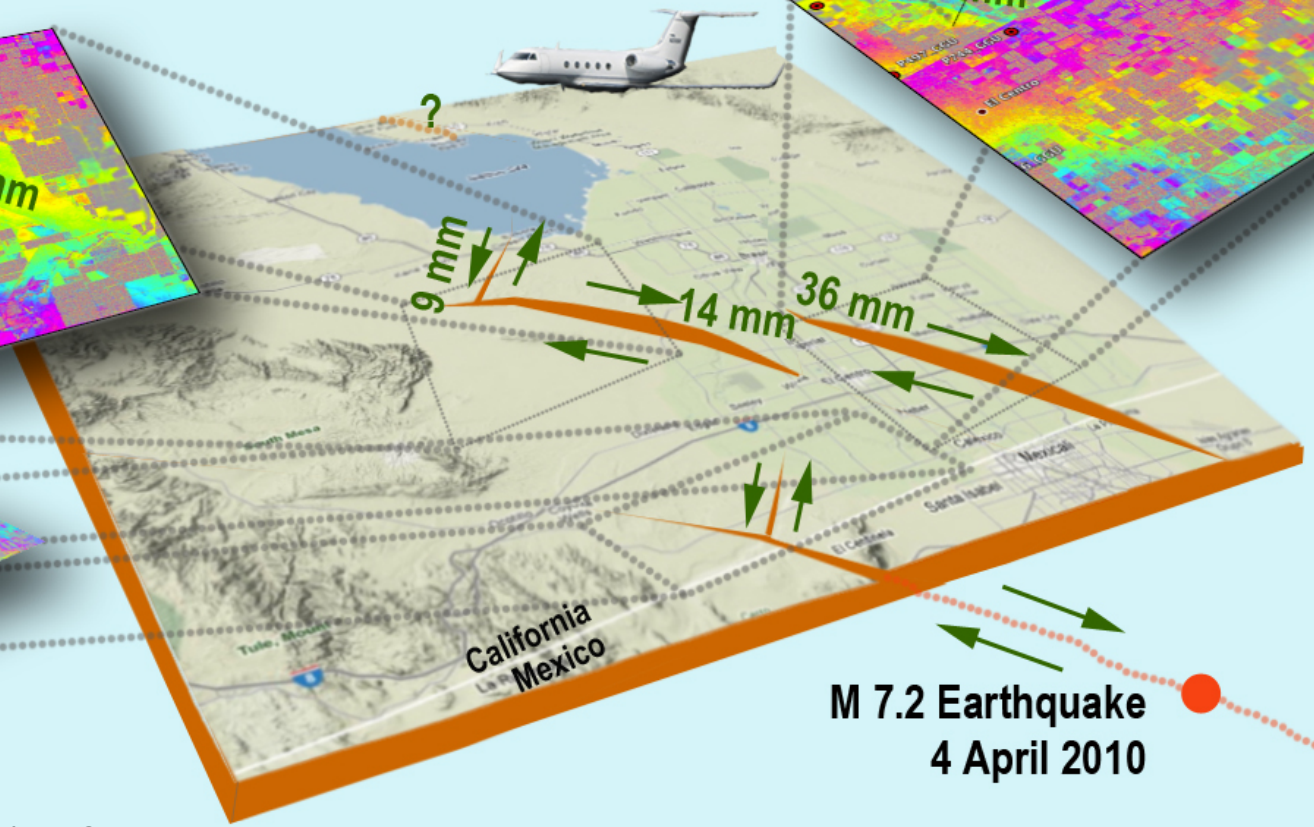






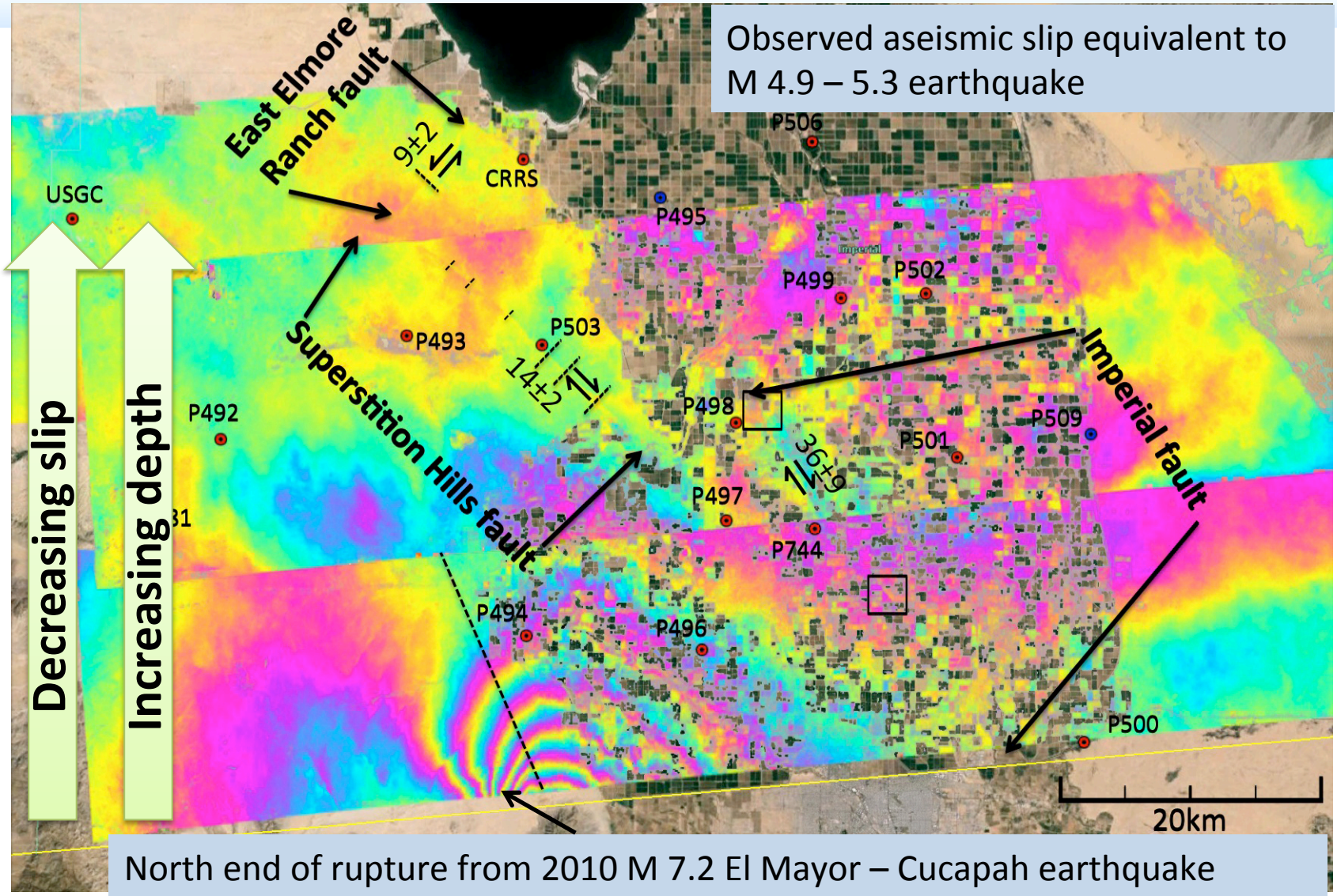






Donnellan, et al, 2014
Geochemistry, Geophysics, Geosystems

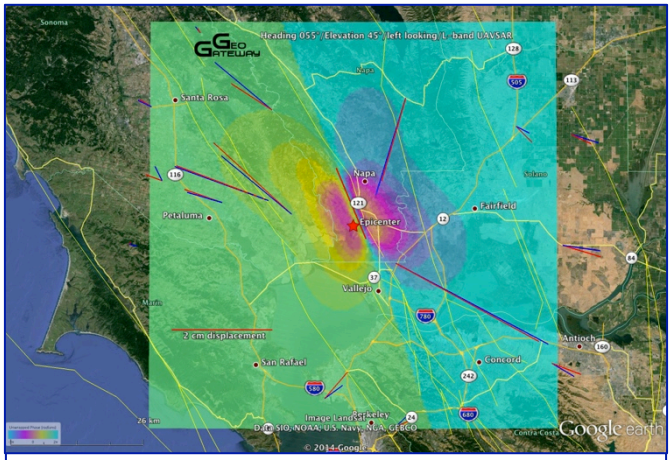
Triggered Fault Slip in the Salton Trough Observed with UAVSAR



Donnellan, A., J. Parker, S. Hensley, M. Pierce, J. Wang, J. Rundle, UAVSAR Observations of Triggered Slip on the Imperial, Superstition Hills, and East Elmore Ranch Faults Associated with the 2010 M 7.2 El Mayor - Cucapah Earthquake, Geochemistry, Geophysics, Geosystems, 15, doi: 10.1002/2013GC005120, 2014.

South Napa Earthquake Response

- Produced inversion of JPL/Caltech ARIA rapid GPS solutions for the earthquake fault
- Provided results:
  - Southern California Earthquake Center
  - State of California
  - UNAVCO Consortium
- Identified incorrectly unwrapped UAVSAR RPI data products

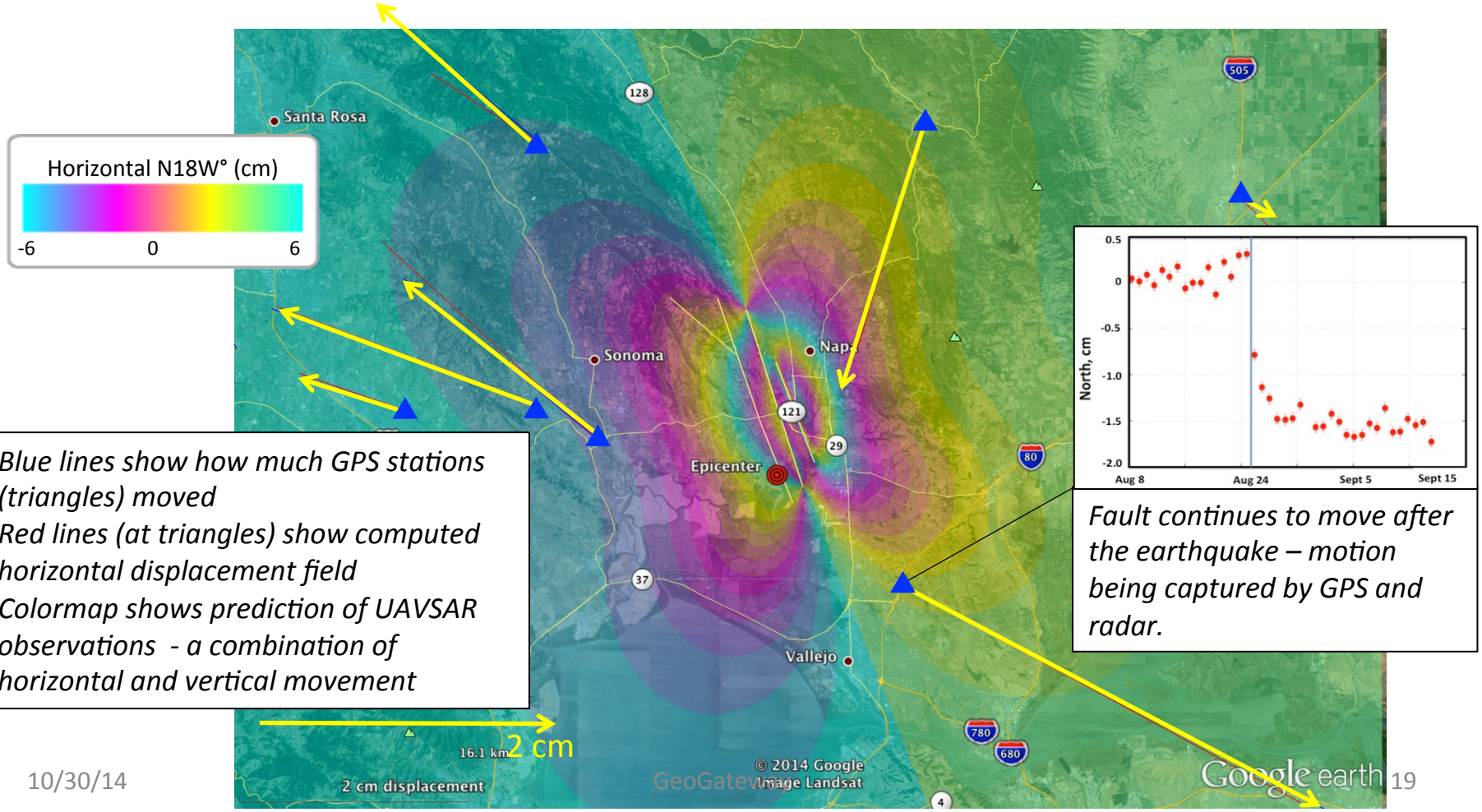


South Napa earthquake inversion as simulated UAVSAR

Observing Permanent Deformation with GPS, Models – Day 2

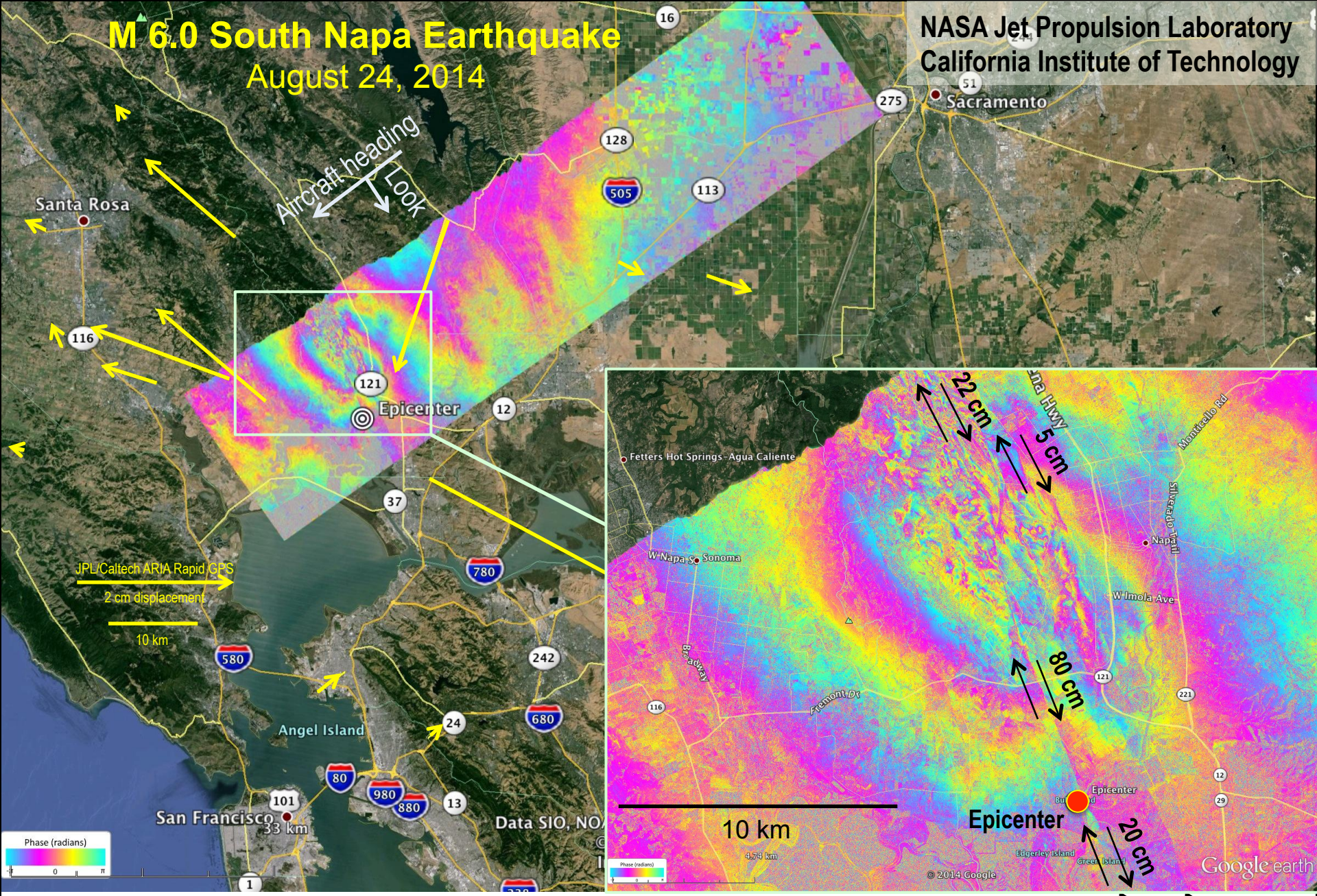
Jet Propulsion Laboratory
California Institute of Technology

- GPS results were provided to Clearinghouse, USGS, and scientists.
- Models use GPS results to estimate how much fault moved below surface of the earth, important for understanding how much earthquake affected other nearby faults.



- *Blue lines show how much GPS stations (triangles) moved*
- *Red lines (at triangles) show computed horizontal displacement field*
- *Colormap shows prediction of UAVSAR observations - a combination of horizontal and vertical movement*

Fault continues to move after the earthquake – motion being captured by GPS and radar.

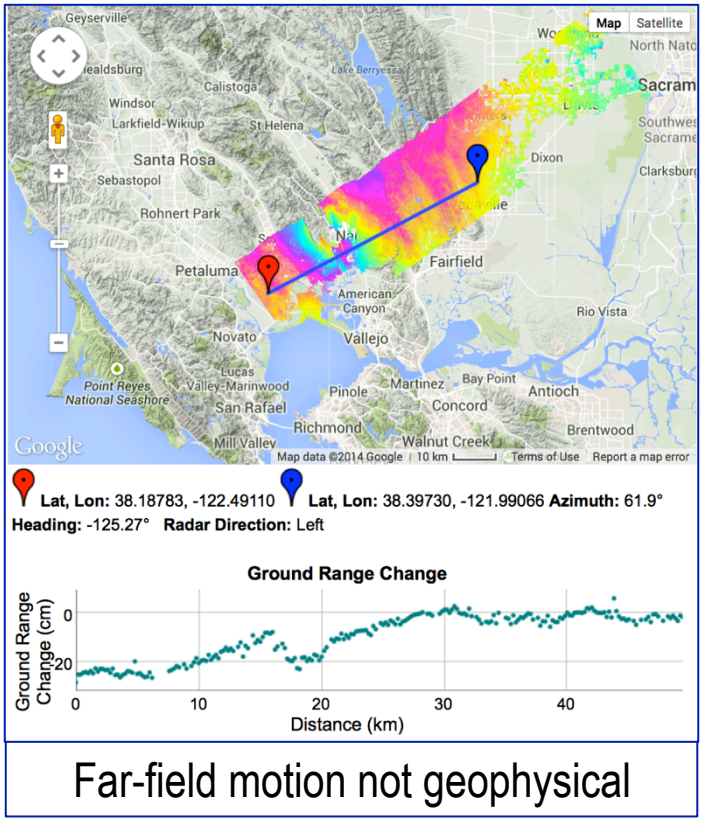


JPL UAVSAR results showing multiple fault offsets from the earthquake
Each color band fringe is 12 cm displacement toward the instrument

GEO GATEWAY

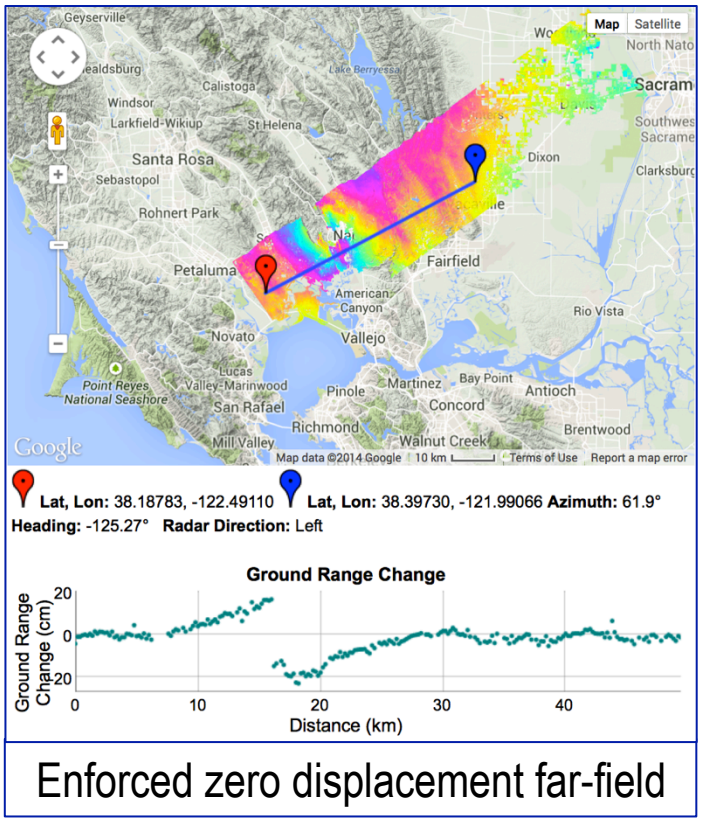
Identified Processing Unwrapping Error

Original



Far-field motion not geophysical

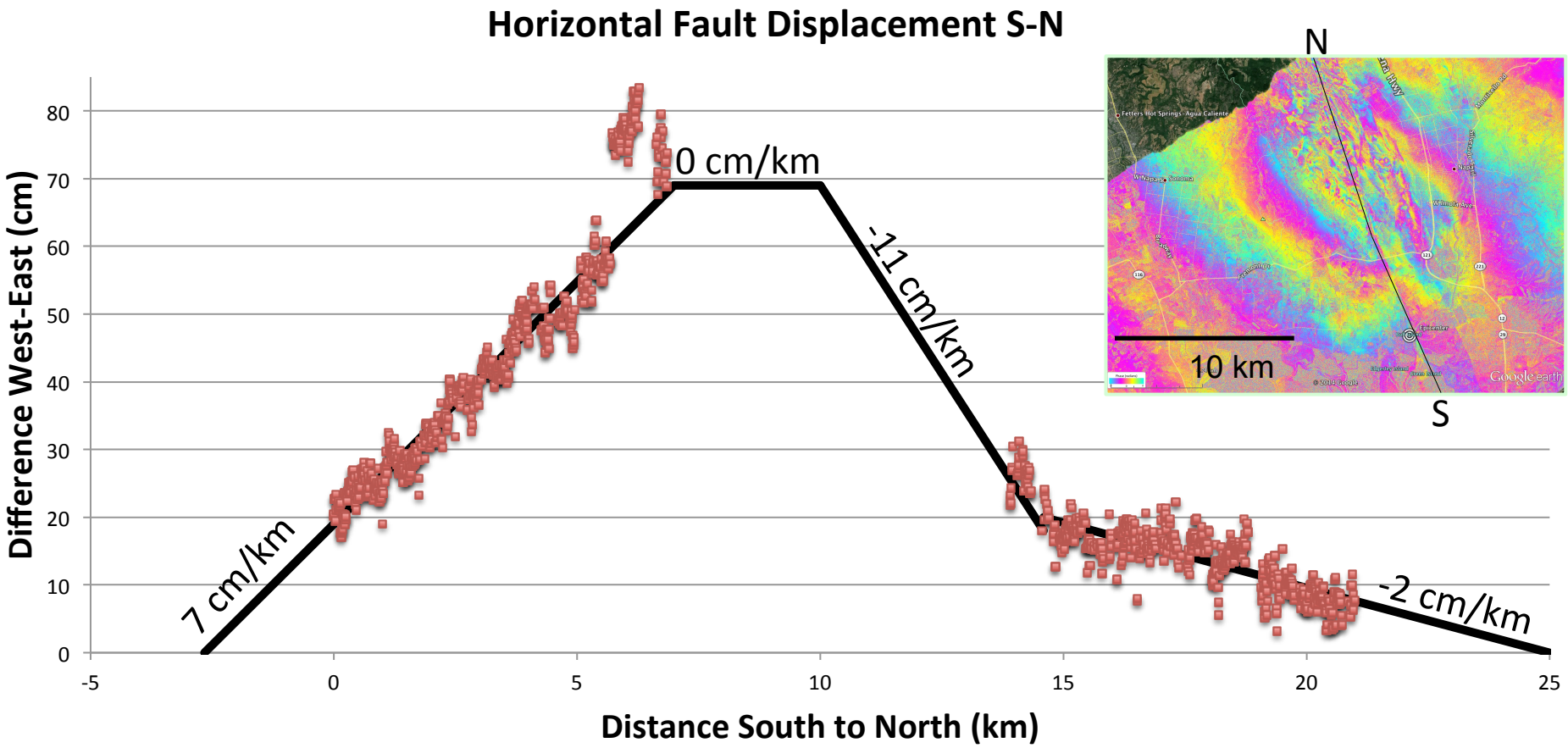
Corrected



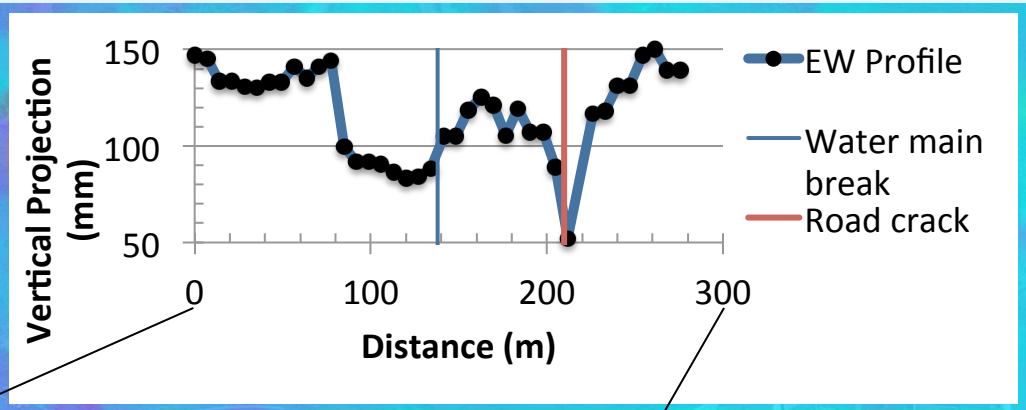
Enforced zero displacement far-field

"… the phase unwrapper is both working as intended and giving us the wrong answer … this method completely breaks down when the fault spans the entire scene … The input data set violates the basic assumptions of the algorithm." Brian Hawkins 9/23/2014

South Napa Earthquake



Chantilly Lane, La Habra



~5 cm subsidence

275 m

Water main break

Road crack

119 m

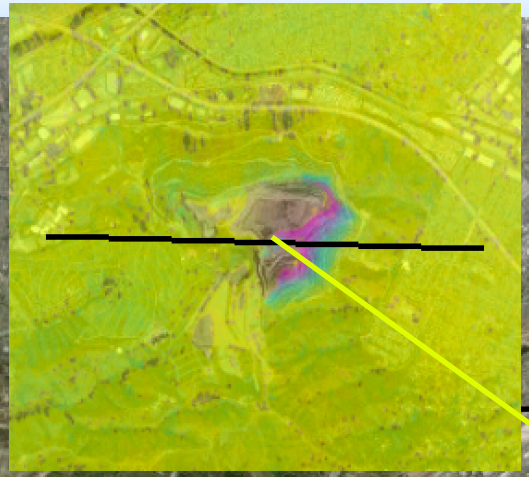
10/30/14

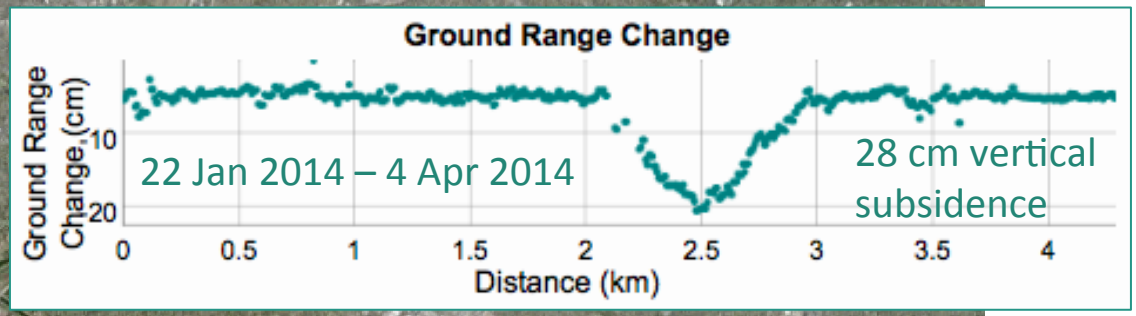
GeoGateway

USGS

Google earth

Puente Hills Landfill





La Puente

Hacienda Heights

Whittier

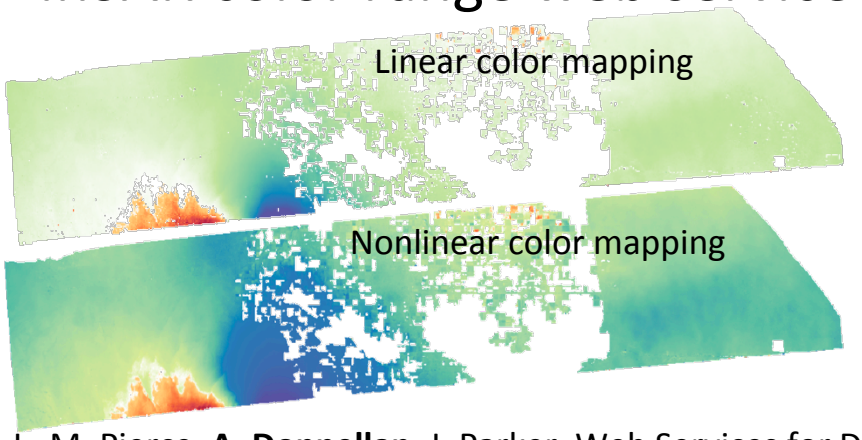
Compaction of several landfills is observed in UAVSAR observations over many timespans from 2009 - present

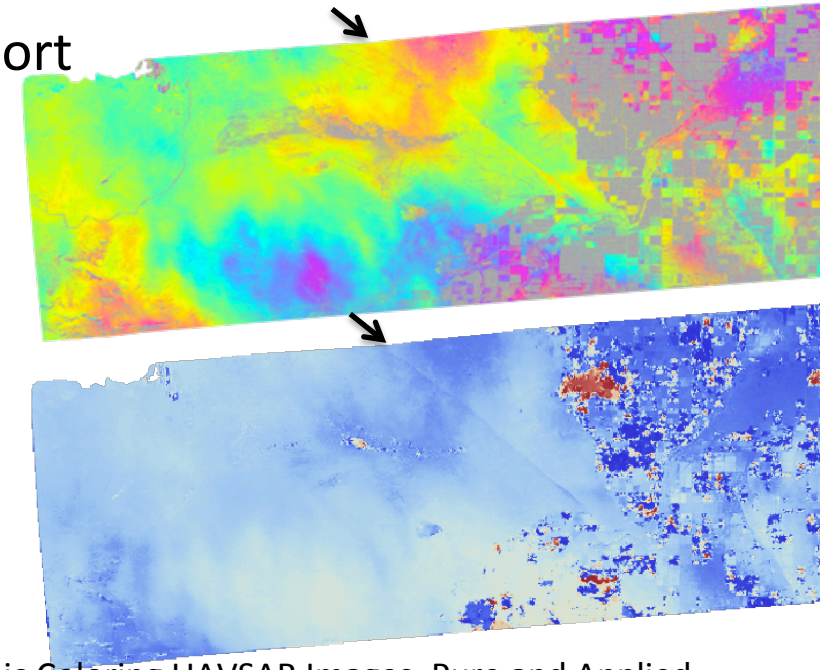
Current Beta Testers of Line of Sight Tool

- Jerry Treiman – California Geological Survey
  - Mapping surface rupture
- Erik Fielding – JPL
  - Studying landslides and fault slip
- Roland Burgmann – UC Berkeley
  - And his students: "*I have a couple of students in my Active Tectonics class that are interested in looking at some Napa earthquake-related topics for their course projects. Exploring some features in the UAVSAR data, in part with your profile tool, seems worthwhile and might make for interesting science along the way.*"
  - Studying landslides and fault slip
- John Fletcher - Ensenada Center for Scientific Research and Higher Education (CICESE)
  - Baja, Mexico UAVSAR analysis
- Michael Oskin – UC Davis Geology Professor
  - Use in graduate class focused on South Napa earthquake

New features under development

- New function to extract pixel values
  - Based on WCS (Web Coverage Service) and GDAL library
  - In addition to the current WMS getfeatureinfo method
  - Better sampling on native pixels to reduce aliasing
  - Better performance: 3X faster
  - More advanced spatial query support
- Profiling across overlap images
- InSAR color range web service





Wang, J., M. Pierce, **A. Donnellan**, J. Parker, Web Services for Dynamic Coloring UAVSAR Images, Pure and Applied Geophysics, Report Topical Volume, Multihazard Simulation and Cyberinfrastructure, in press.

Multiproject Cloud Coordination

- GeoGateway focuses on display and analysis of data products
- InSAR Scientific Computing Environment (ICSE) focuses on InSAR processing
- Link two projects for backend processing of lower level data and front end display and analysis higher level products

Conclusions

- Keeping scientists in the development loop helps drive development
- Cascading cloud services allow for use of private and public cloud without degradation of performance
- Merging processing and display/analysis projects through common data standards and APIs