

The Community Geodetic Model: Overview

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The Community Geodetic Model

Motivation:

Spatially and temporally dense time series of ongoing deformation provide unique input for addressing the fundamental problems of earthquake physics targeted by the SCEC community.

Expanded GPS coverage, new SAR missions, and maturing data analysis techniques that leverage the complimentary features of both data types now enable us to record deformation at unprecedented resolution.

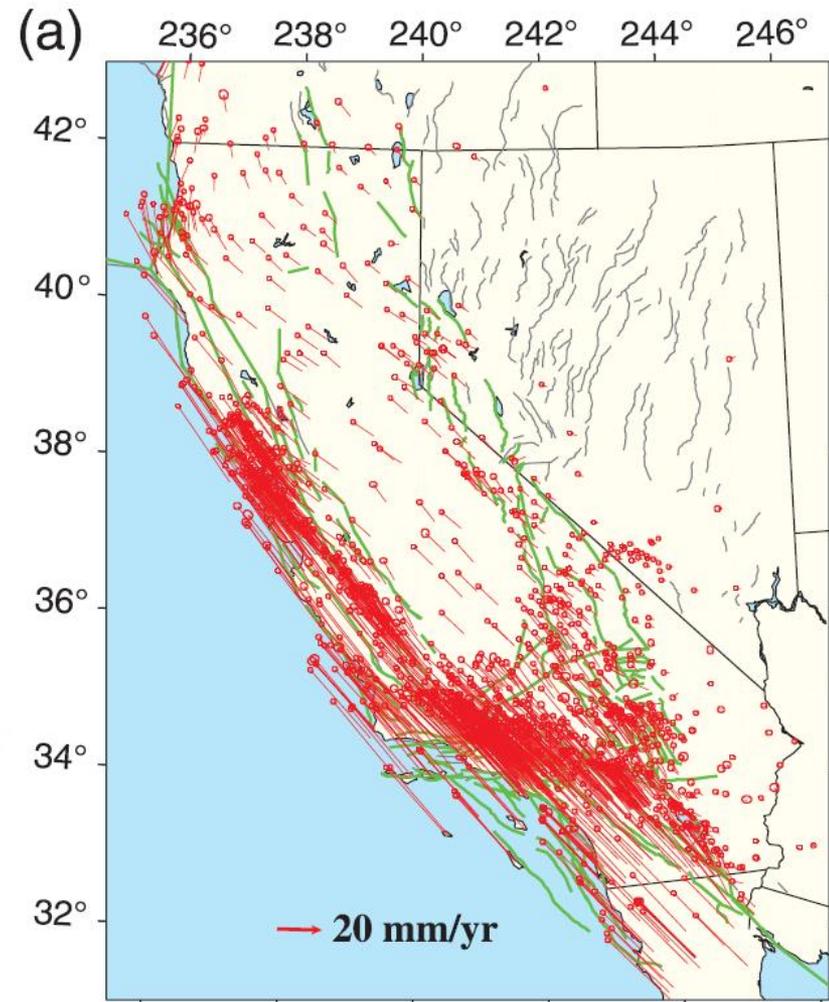
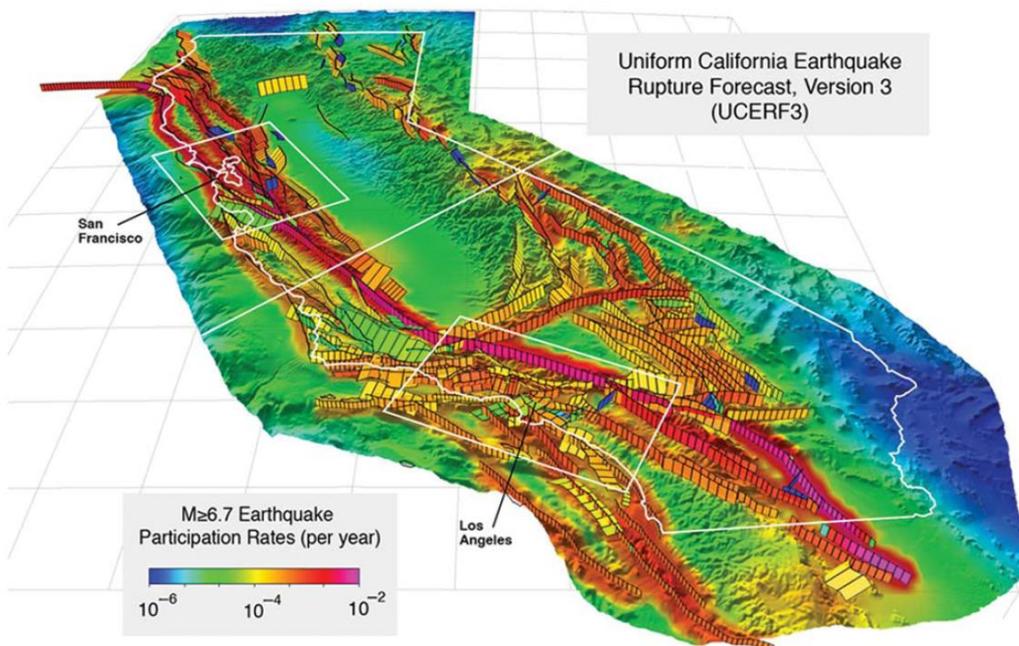
Community models bring together broad expertise and diverse perspectives often revealing the effect of modeling choices and providing a window into the scope of epistemic uncertainty.

SCEC4 Fundamental Problems of Earthquake Physics:

Stress transfer from plate motion to crustal faults: long-term fault slip rates

- Geodetic data included as input for quantifying slip rates and strain rates in three of four UCERF3 deformation models

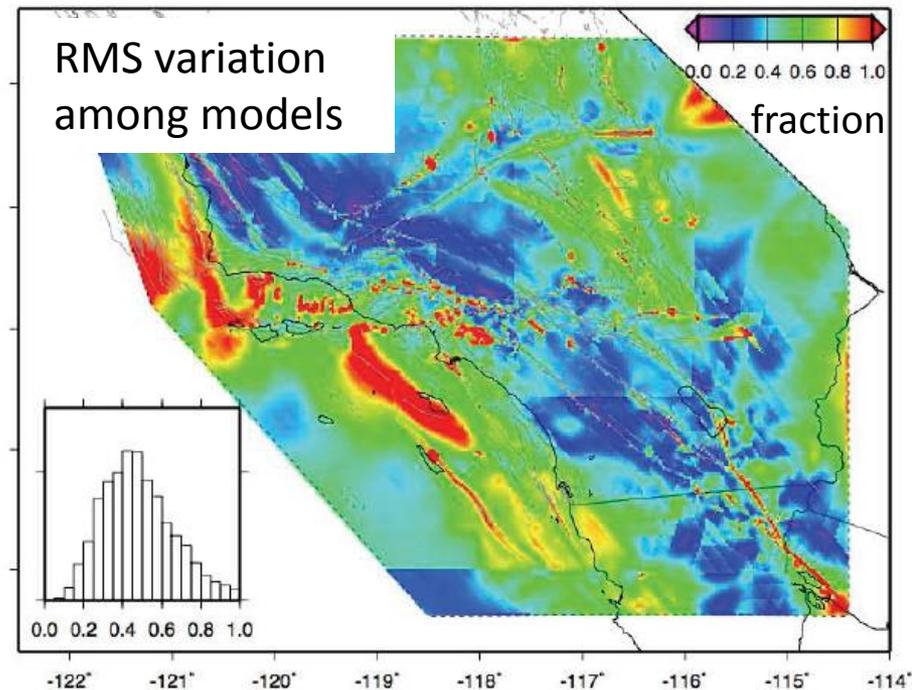
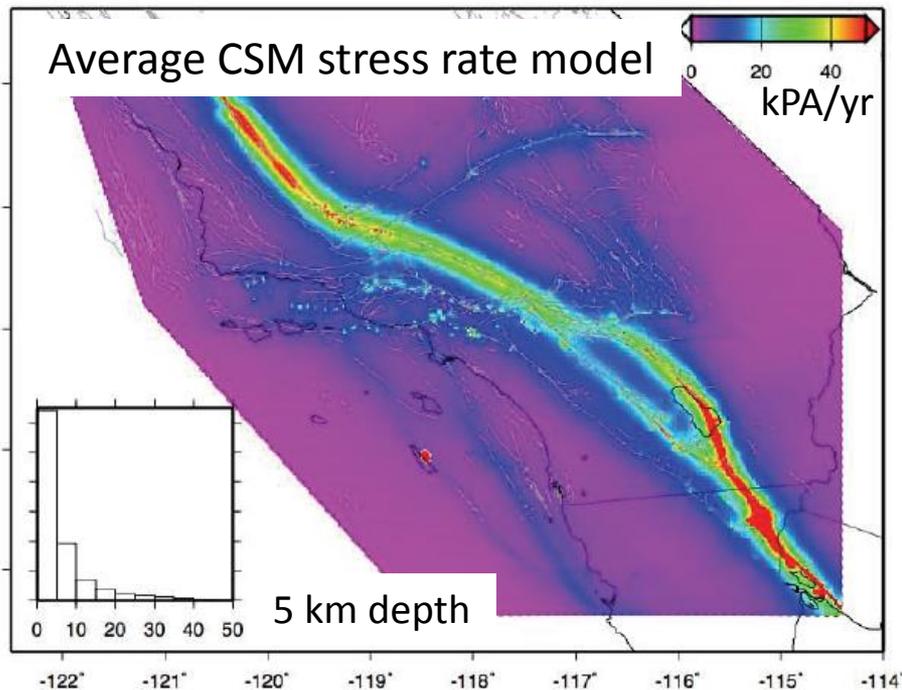
→ Requires well-constrained velocities and realistic uncertainties



SCEC4 Fundamental Problems of Earthquake Physics:

Stress-mediated fault interactions and earthquake clustering: evaluation of mechanisms

- Geodetic crustal velocities constrain regional tectonic stressing rate models for the CSM
→ Requires well-constrained velocities with broad regional coverage



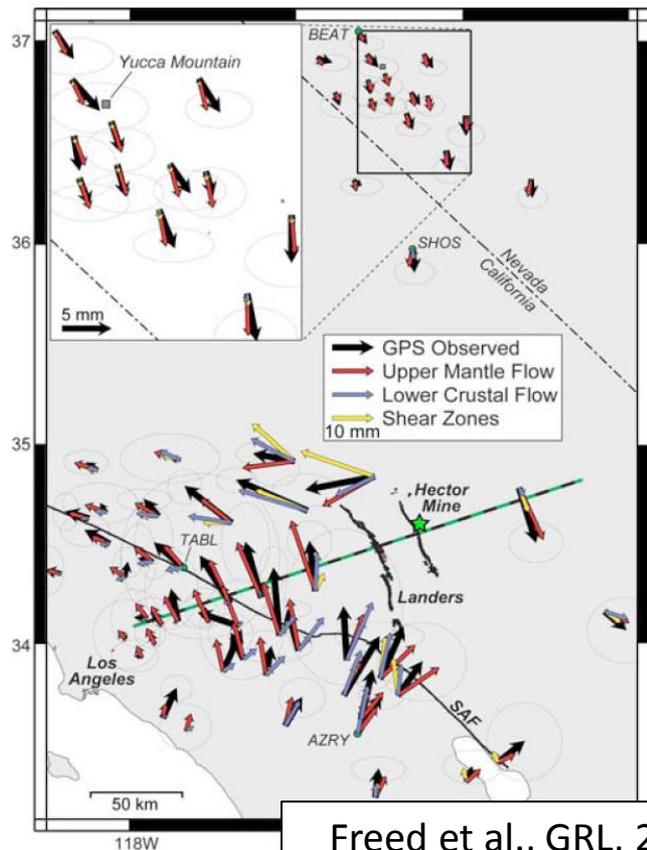
Models: Loveless & Meade, Smith-Konter & Sandwell, Strader & Jackson, Cooke & Marshall, UCERF3 ABM, UCERF3 NeoKinema, UCERF3 Zeng

SCEC4 Fundamental Problems of Earthquake Physics:

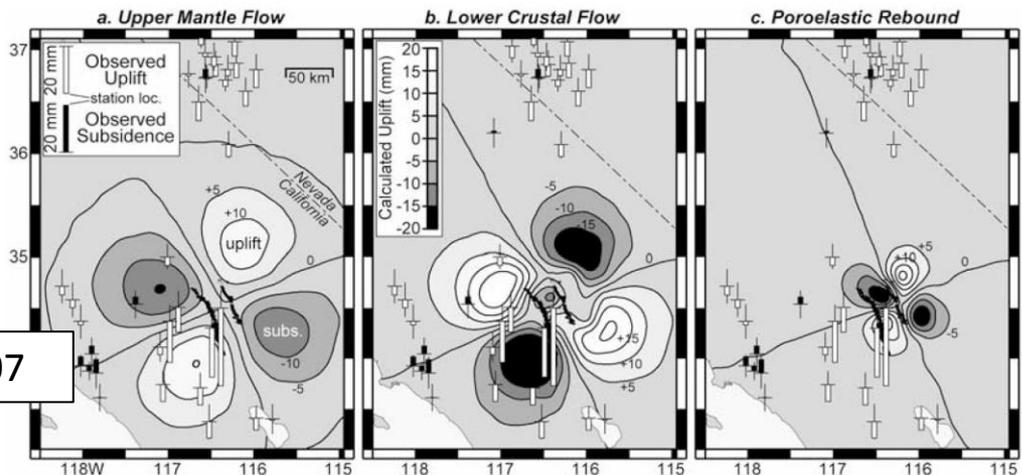
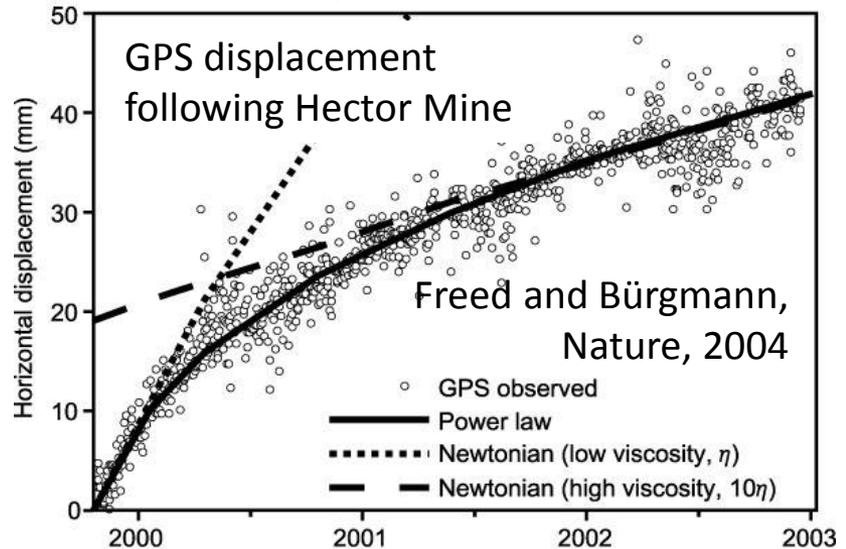
Stress transfer from plate motion to crustal faults: long-term fault slip rates

- Postseismic deformation illuminates causative physical processes, frictional properties, and rheology with implications for fault loading throughout the earthquake cycle

→ Requires spatially and temporally dense **three-component** decadal time series over broad region



Freed et al., GRL, 2007

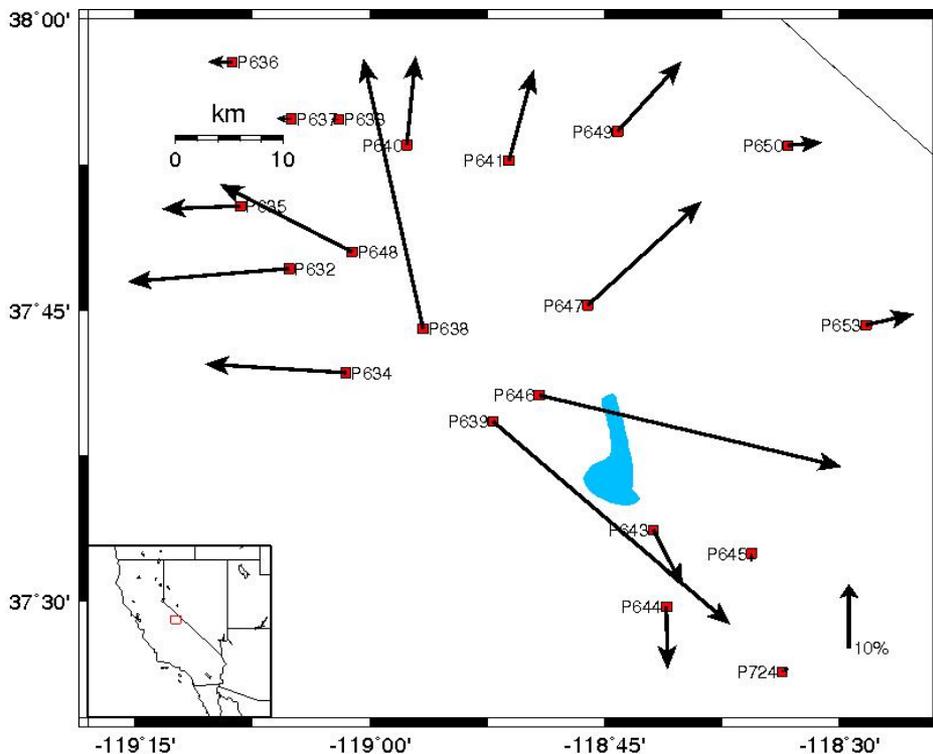


SCEC4 Fundamental Problems of Earthquake Physics:

Causes and effects of transient deformations: slow slip events and tectonic tremor

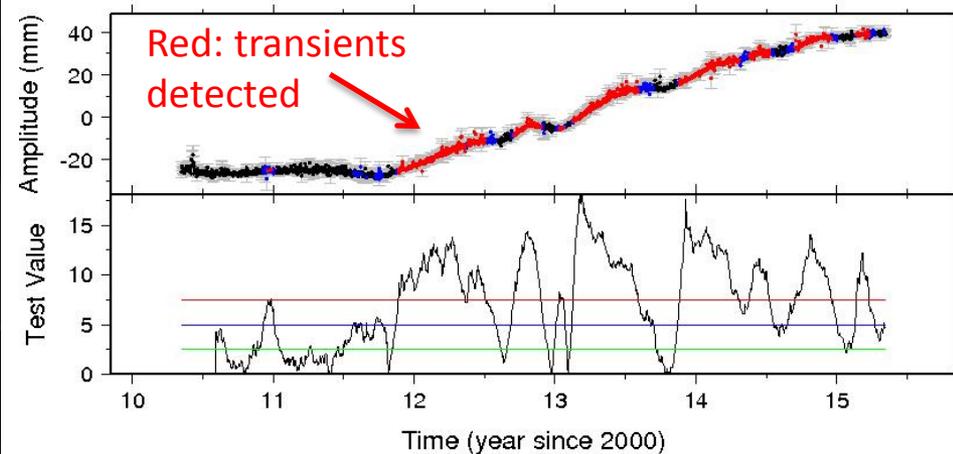
- Geodetic time series constrain location and evolution of aseismic transients for physical modeling, anomaly detection, and possible future use in time-dependent forecasting
 - Requires spatially and temporally dense three-component time series, *perhaps filtered to remove trends, seasonal, or other signals*

Spatial template based on previously observed transient event



Example: Online transient detector applied to GPS time series flags repeated deformation events at Long Valley caldera.

Detections based on how well spatial template fits data at a given epoch

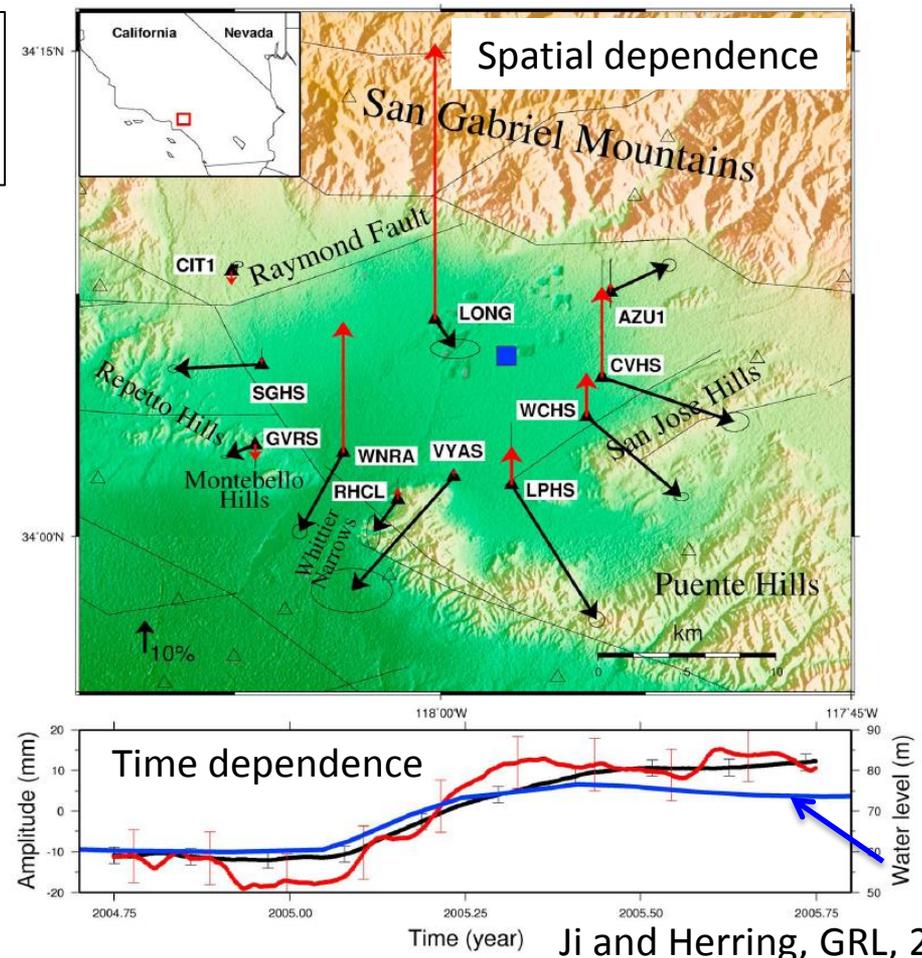
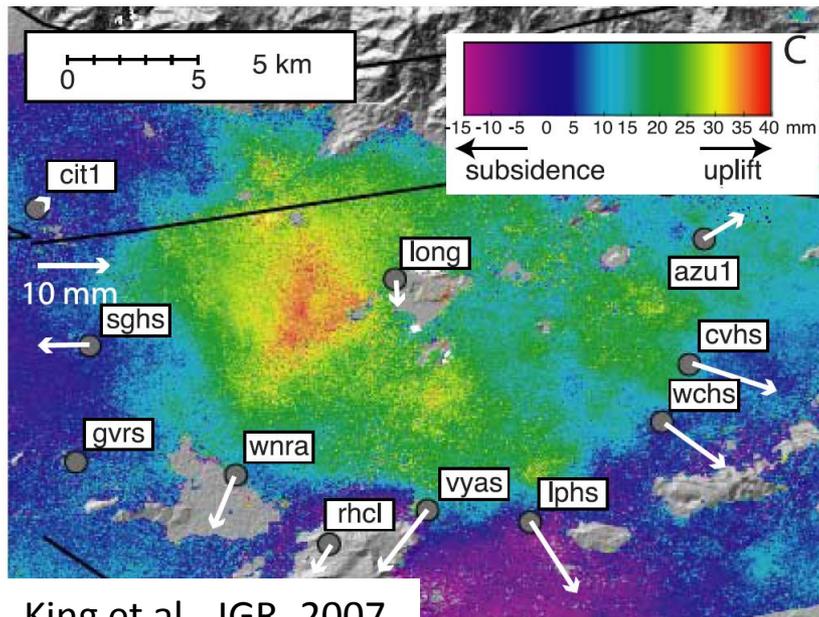


SCEC4 Fundamental Problems of Earthquake Physics:

Causes and effects of transient deformations: slow slip events and tectonic tremor

- Southern California GPS and InSAR data provide high spatial and temporal resolution observations for detecting and modeling hydrologic transients
 - Requires spatially and temporally dense three-component time series, *perhaps filtered to remove trends, seasonal, or other signals*

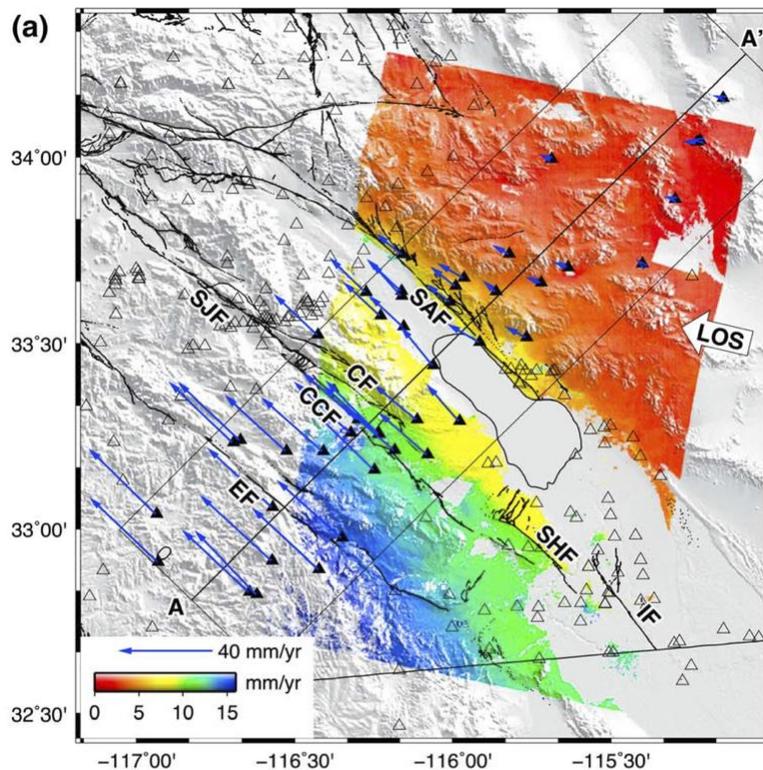
Example: Transient deformation due to San Gabriel Valley aquifer recharge and signal detection using Principal Component Analysis.



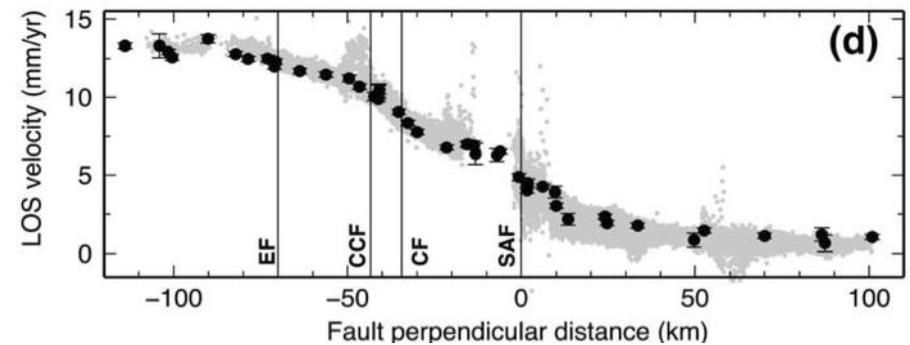
New geodetic data and analysis techniques:

We know that InSAR complements GPS, providing spatially dense line-of-sight measurements of interseismic deformation.

Example: Joint analysis of GPS and InSAR velocities shows that assumed fault dip influences San Andreas and San Jacinto fault slip rate estimates more than elastic heterogeneity does.



GPS and InSAR velocity profile, aligned at wavelengths >70 km



GPS: CMM4 and PBO velocities

InSAR: ERS-1/2 1992 - 2007 (Manzo et al., 2011)

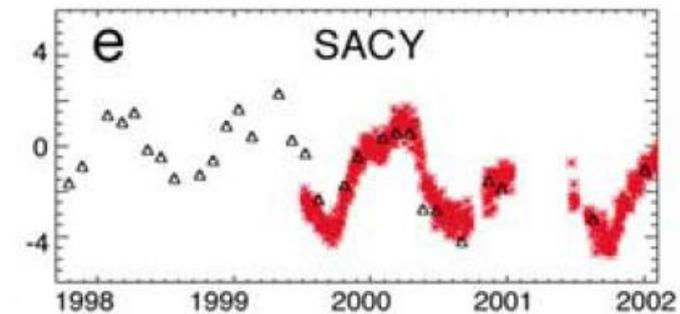
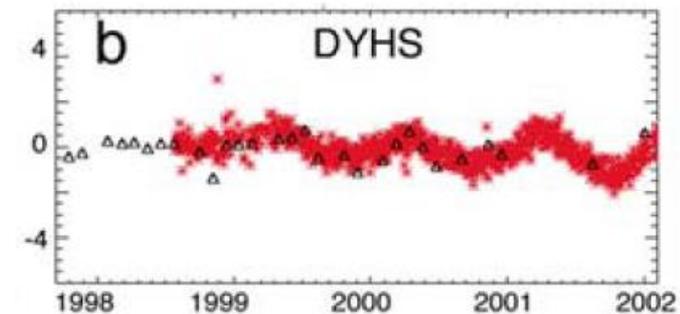
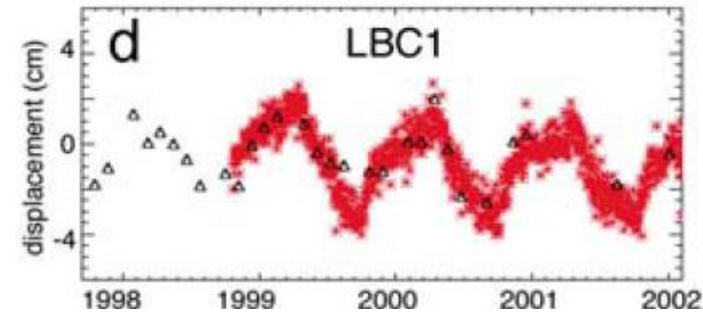
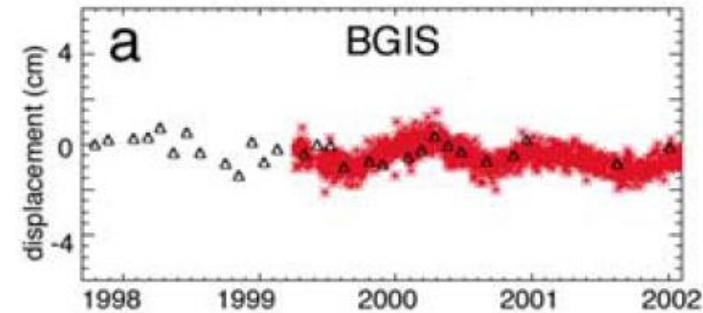
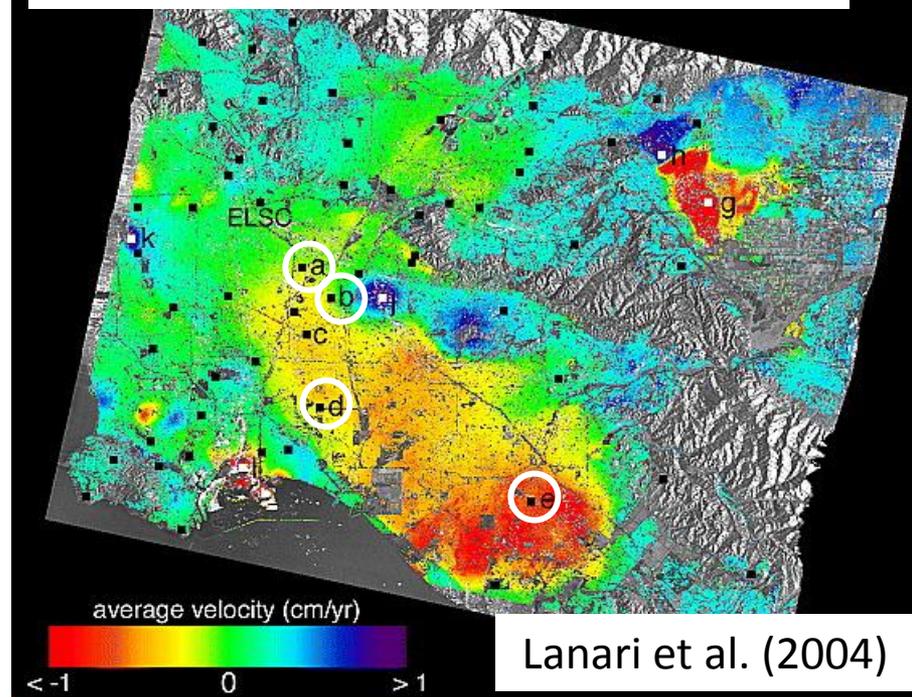
Lindsey and Fialko, JGR, 2013

New geodetic data and analysis techniques:

We can extend dense, coherent near-field spatial coverage to track temporal changes – in a few areas

- InSAR time series analysis techniques using small-baseline (SBAS) or persistent scatterer (PS) approaches exist.
- Recovered time-varying motion agrees well with GPS under certain assumptions (e.g., temporal/spatial smoothness).
- Accuracy: $\sim 5\text{-}10$ mm displacement, $\sim 1\text{-}2$ mm/yr rate

Example: L.A. Basin aquifer effects

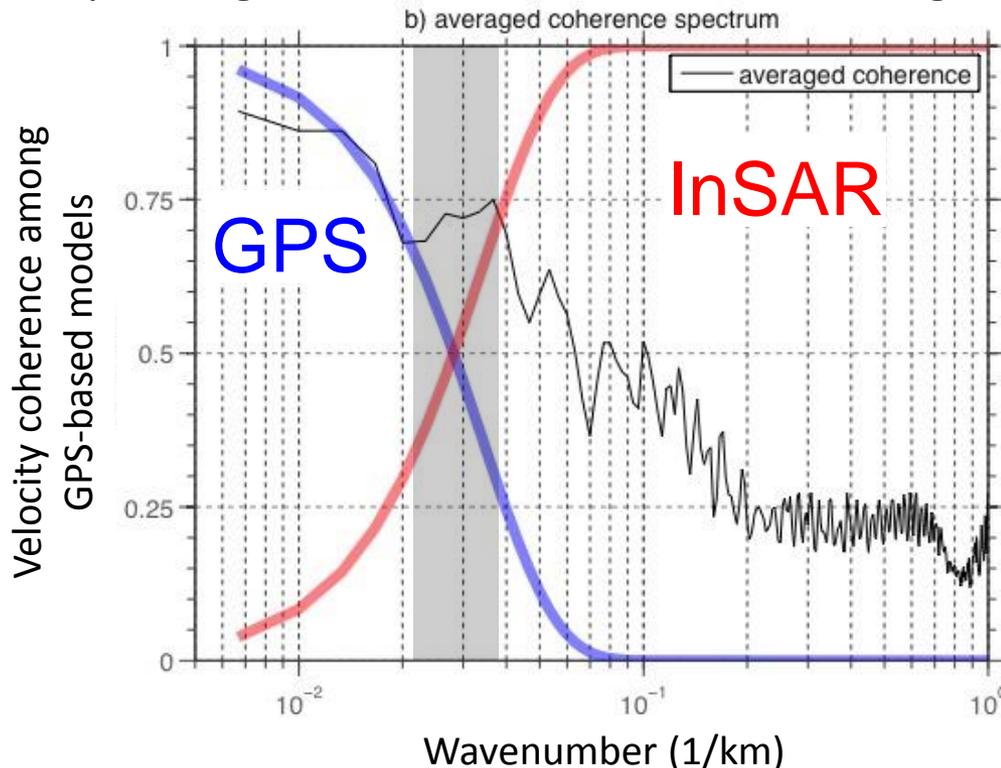


CGM development:

Integrating InSAR and GPS

- GPS provides high accuracy 3D vector data.
- GPS cannot measure small spatial scales (e.g., fault creep) due to sparse station spacing (median SoCal spacing 8 km).
- InSAR has superb spatial coverage for LOS motion.
- InSAR has large spatial scale errors due to troposphere, ionosphere, and orbital errors.
- Temporal coverage currently possible through InSAR time series analysis aliases some signals.

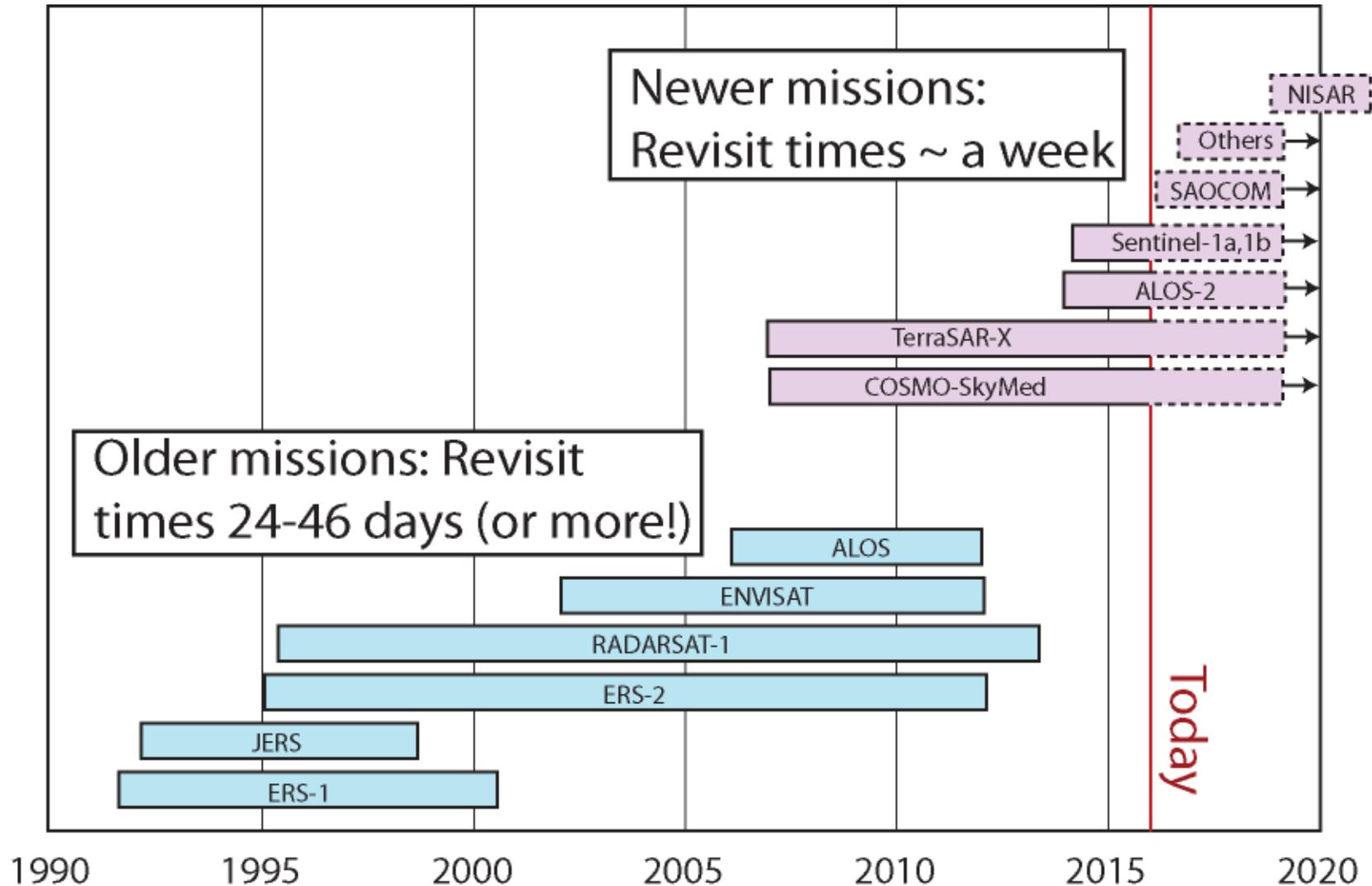
We **need both GPS and InSAR** to provide multi-component deformation measurements that span length scales of 30 m to 2000 km with good spatial and temporal coverage.



GPS constrains signals with wavelength $\geq \sim 40$ km

New geodetic data and analysis techniques:

More frequent SAR satellite repeat passes, ascending and descending orbits, and better baseline control will expand InSAR's role in detailed tracking of deformation.



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The Community Geodetic Model

What will it look like?

Some target attributes:

- Secular 3D surface deformation quantified at 1-2 mm/yr accuracy on 500 m to 2000 km length scales
- Deformation time series with better than seasonal temporal resolution at ~1 km spatial resolution
- Ancillary water loading and atmospheric delay information

The Community Geodetic Model

What will it look like?

A consensus suite of models consisting of

- GPS time series that synthesize processed continuous and campaign positions (north, east, vertical) from multiple sources in a common reference frame
 - GPS secular velocity field estimate(s) derived using one or more analysis strategies
 - Characterization(s) of seasonal signals and earthquake-related displacements for optional time series cleaning
 - Line-of-sight (LOS) velocity map(s) estimated from stacked interferograms and consistent with far-field GPS rates
 - One or more sets of LOS InSAR time series aligned with GPS
 - Realistic uncertainty estimates for time series and rates
- Allows users to choose model(s) based on their application of interest.

The Community Geodetic Model

How will we do it?

- Engage in a collaborative process to generate ideas, explore strategies, and vet results
- Develop GPS and InSAR components in parallel
- Maintain communication within and between GPS and InSAR groups
 - In-person workshops (May 2013, September 2014)
 - Virtual workshops (several throughout 2014 and 2015)
- Draw upon synergistic activities in the broader geoscience community

Today's workshop

Report on results of CGM activities to-date

- Included campaign and continuous GPS data collected since CMM4
- Synthesized position solutions from different groups to produce consensus time series.
- Evaluated effect of GPS processing strategy, error sources, analysis assumptions through comparison of time series and derived quantities.
- Compared InSAR time series analysis techniques for LOS velocity estimation.
- Generated initial InSAR-GPS LOS velocity field and standard deviation.
- Identified best practices for InSAR time series analysis.

Today's workshop

Discussion of ongoing research

- Quantify vertical deformation through individual and joint use of different data types
- Characterize seasonal signals, hydrologic loading, other non-tectonic crustal motion
- Address postseismic contamination of crustal velocity estimates
- Evaluate impact of and need for GPS constraints for InSAR analysis
- Develop and compare methods for mitigating atmospheric noise in InSAR data
- Develop and apply approaches that leverage existing and new SAR data to extend spatio-temporal coverage of deformation observations

Looking ahead - What are the next steps?

- Deliver time series, strain rate maps, and derived quantities with longer time-spans, improved vertical precision, and greater spatio-temporal resolution to allow separation of multiple signals and discrimination among models.
- How to best leverage new SAR data and new techniques/tools for analyzing GPS and InSAR (individually and jointly)?
- Do new data and new techniques expand our vision for the CGM?