Using Numerical Models to Investigate Distributed Deformation

The South Napa Earthquake as a Case Study

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Motivation

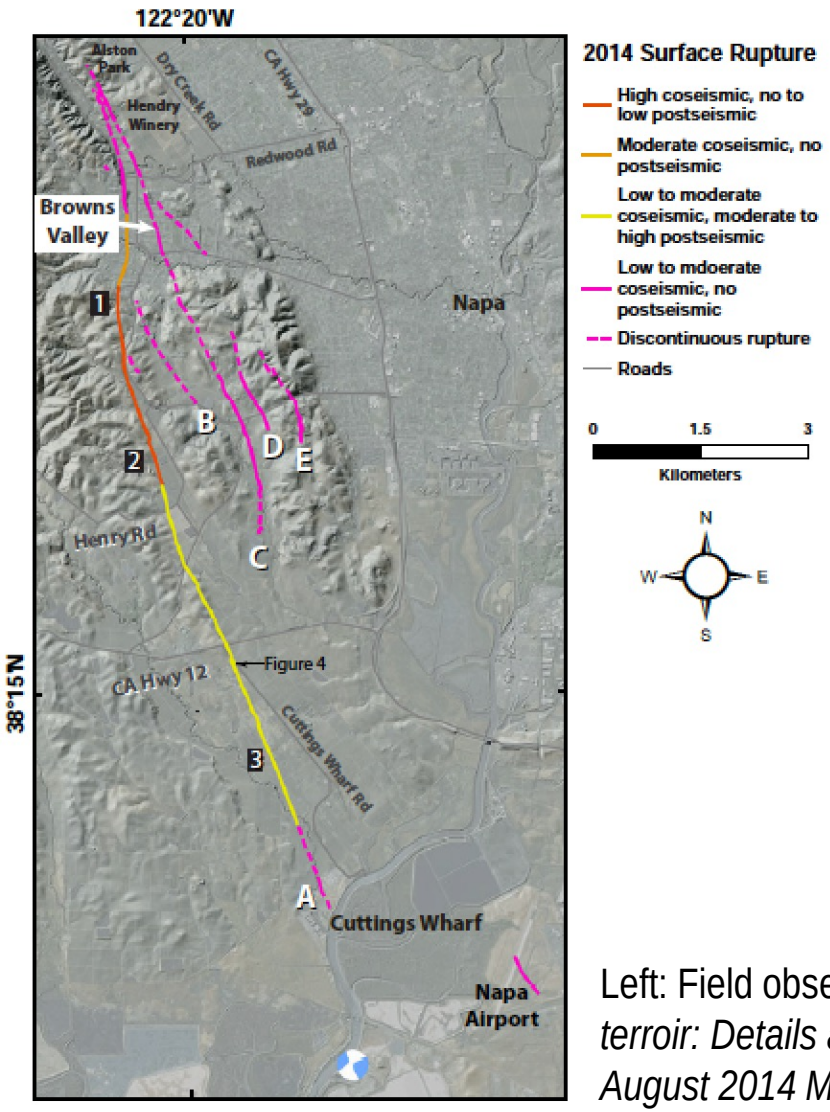
- Determining the distribution of slip and behavior of fault interactions is a complex problem
- Field and remotely sensed data often lack the necessary coverage to resolve fault behavior
- Realistic physical models may be used to more accurately characterize the complex behavior of faults
- Observed data such as InSAR, high resolution topography, and GPS may be used to constrain models

Goal: improve the utility of using combined models and data to estimate earthquake potential

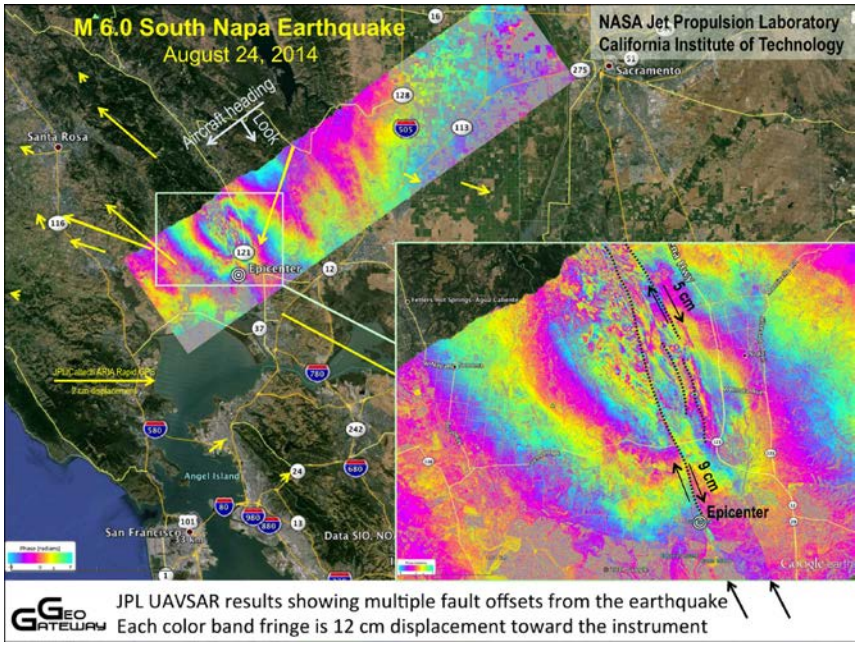
Slip on multiple fault strands and fault damage zones

- Recent earthquakes (e.g. the 2014 South Napa earthquake) have demonstrated slip on multiple fault strands
  - Shallow triggered slip on structures up to more than a fault dimension away from the mainshock rupture
- Damage zones surrounding faults are also observed in the field and with seismic observations
- We are exploring models to investigate how accurately they characterize observed behavior of faults

2014 M6.0 South Napa Earthquake: Field and Remote Sensing Observations of Complex Slip



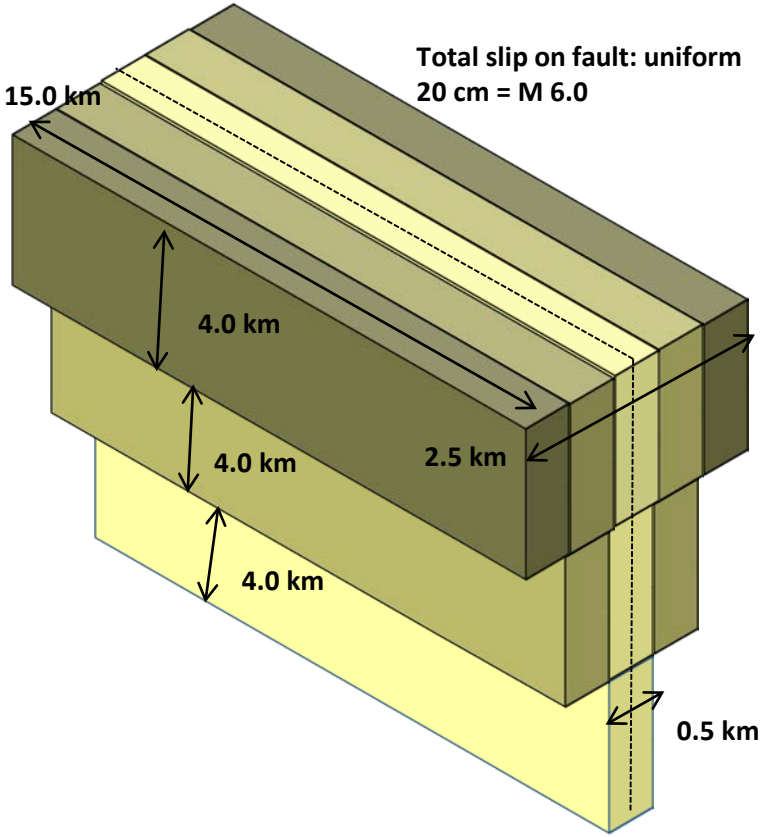
Below: An interferogram created from UAVSAR data collected May 29, 2014, three months before the South Napa earthquake, and August 29, 2014, five days following the event, indicates that slip occurred on several strands of the fault. Image courtesy NASA JPL/Caltech (http://www.jpl.nasa.gov/spaceimages/details.php?id=PIA18801).

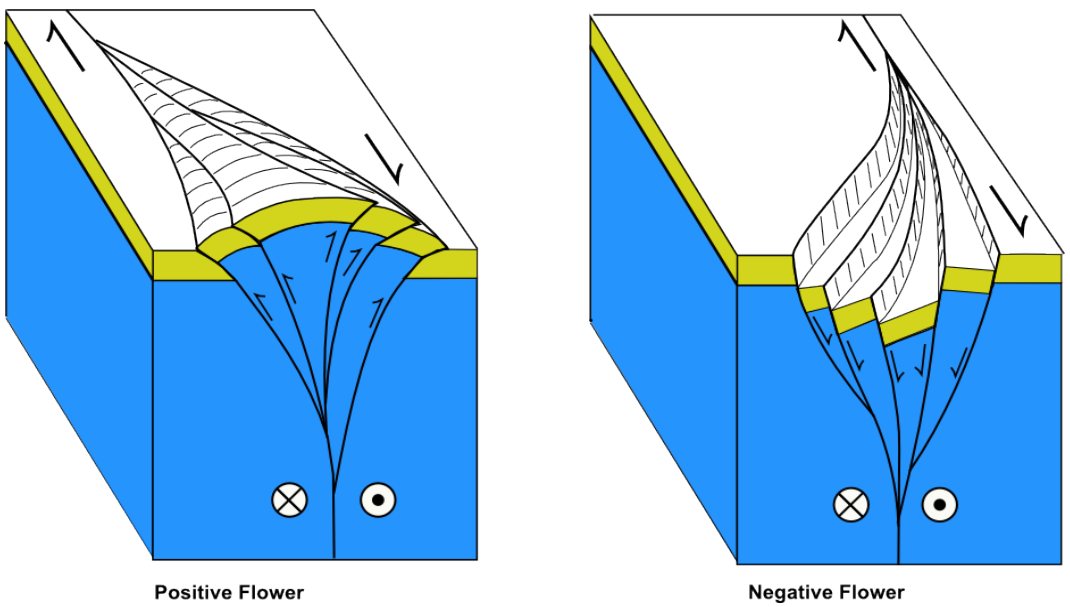


Left: Field observations of surface rupture from DeLong et al 2016, *Tearing the terroir: Details and implications of surface rupture and deformation from the 24 August 2014 M6.0 South Napa earthquake, California*, Earth and Space Science

Model

We model a fault embedded within a damage zone of reduced elastic rigidity that narrows with depth and forward model the shallow slip and resulting surface deformation.

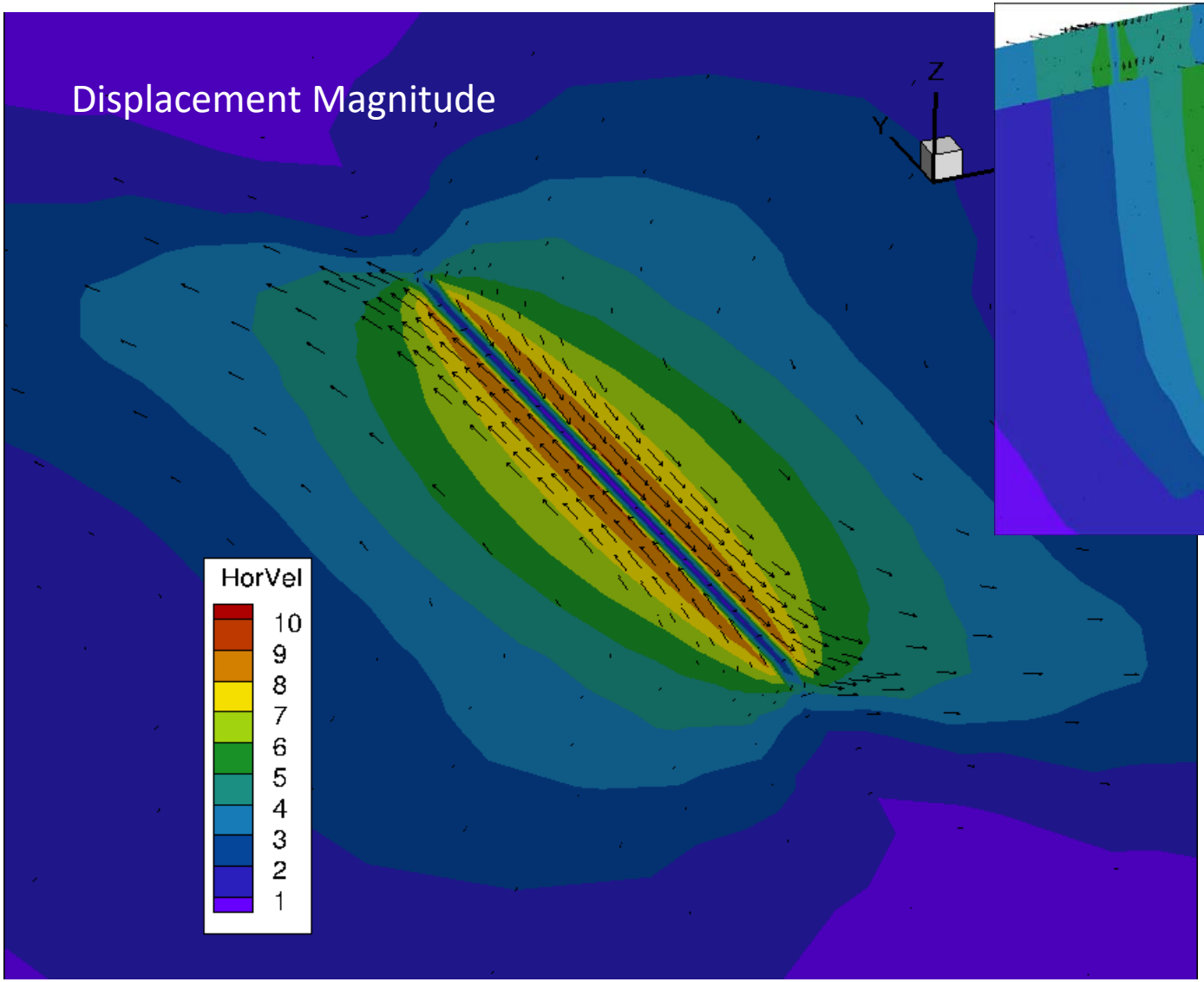


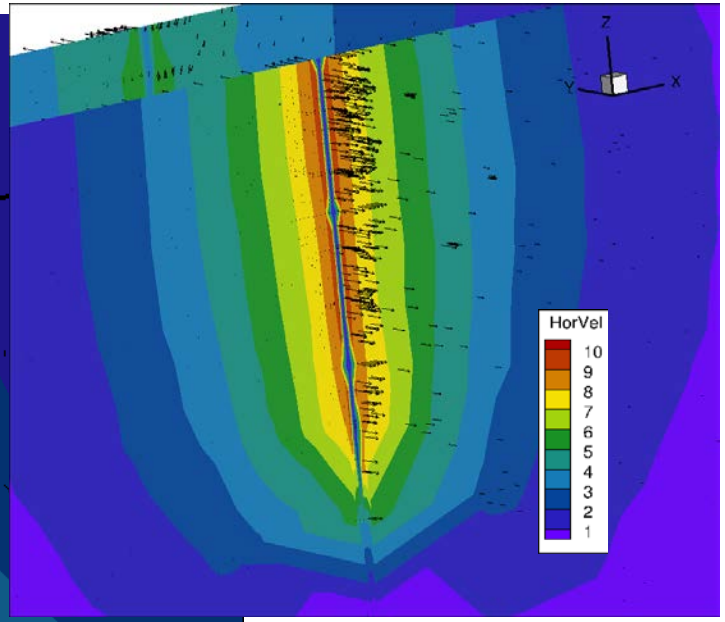


https://commons.wikimedia.org/wiki/File:Flowerstructure1.png

The model features a fault embedded in a damage zone that narrows with depth in which rigidity may be varied laterally

Examining differences in damage zone rigidity

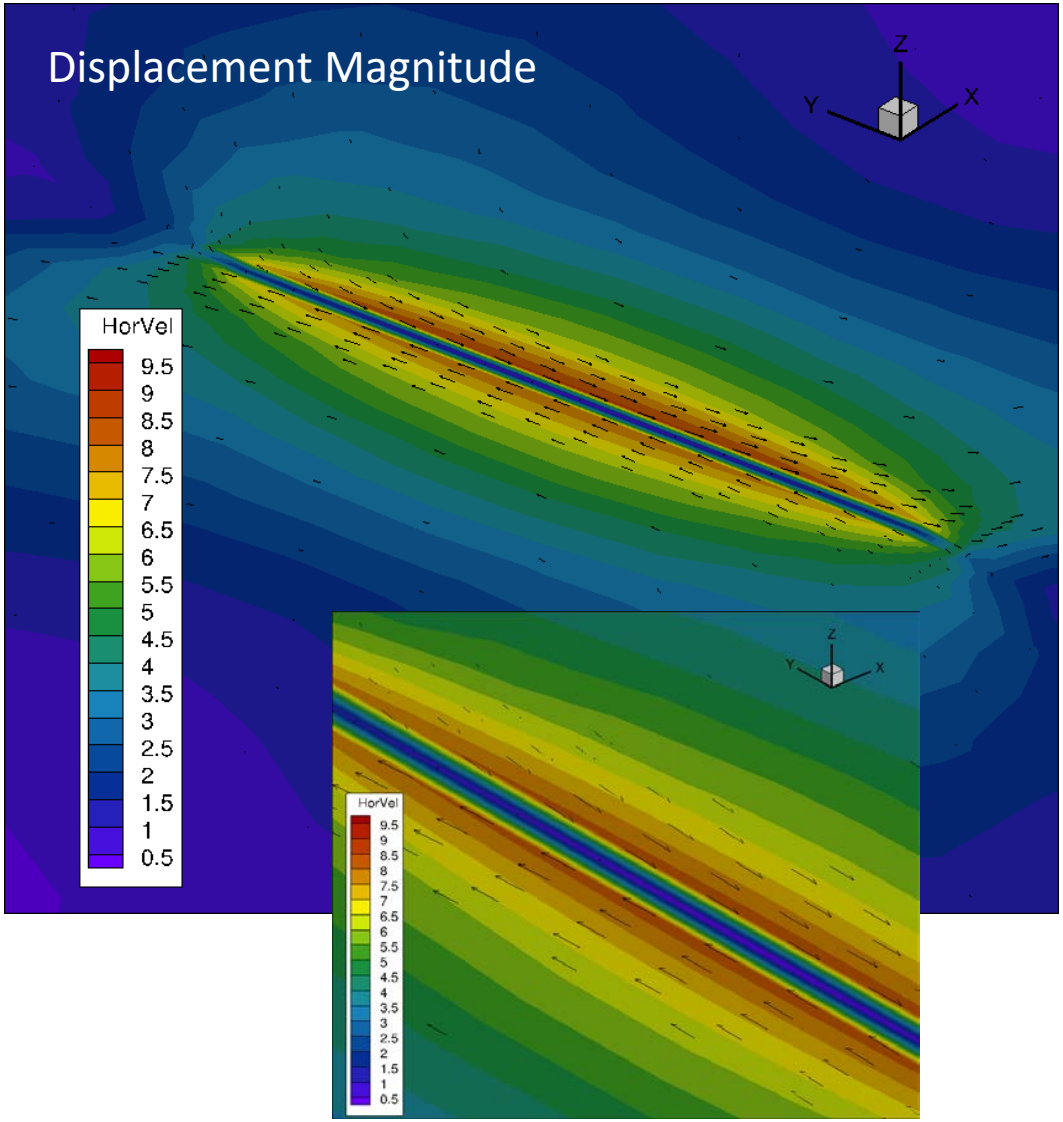




Observe zone of distributed deformation with concentrated high deformation near fault zone

Fault zone: 10 GPa
Damage Zones: 20, 30 GPa

Modifying fault zone rigidity

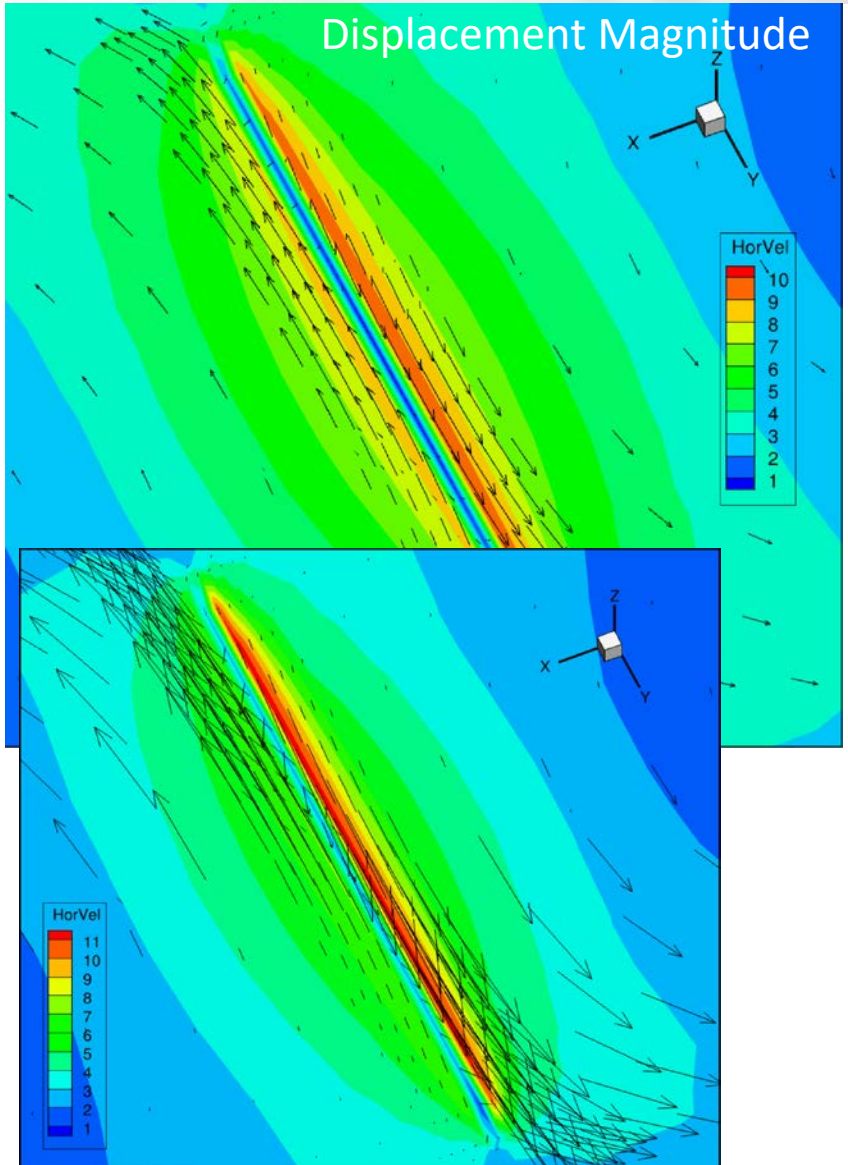


Fault zone: 5 GPa
Damage Zones: 20, 30 GPa

Observe zone of distributed deformation with concentrated high deformation near fault zone

Reducing rigidity by half reduces magnitude of displacement, but not distribution

Modifying fault zone viscosity

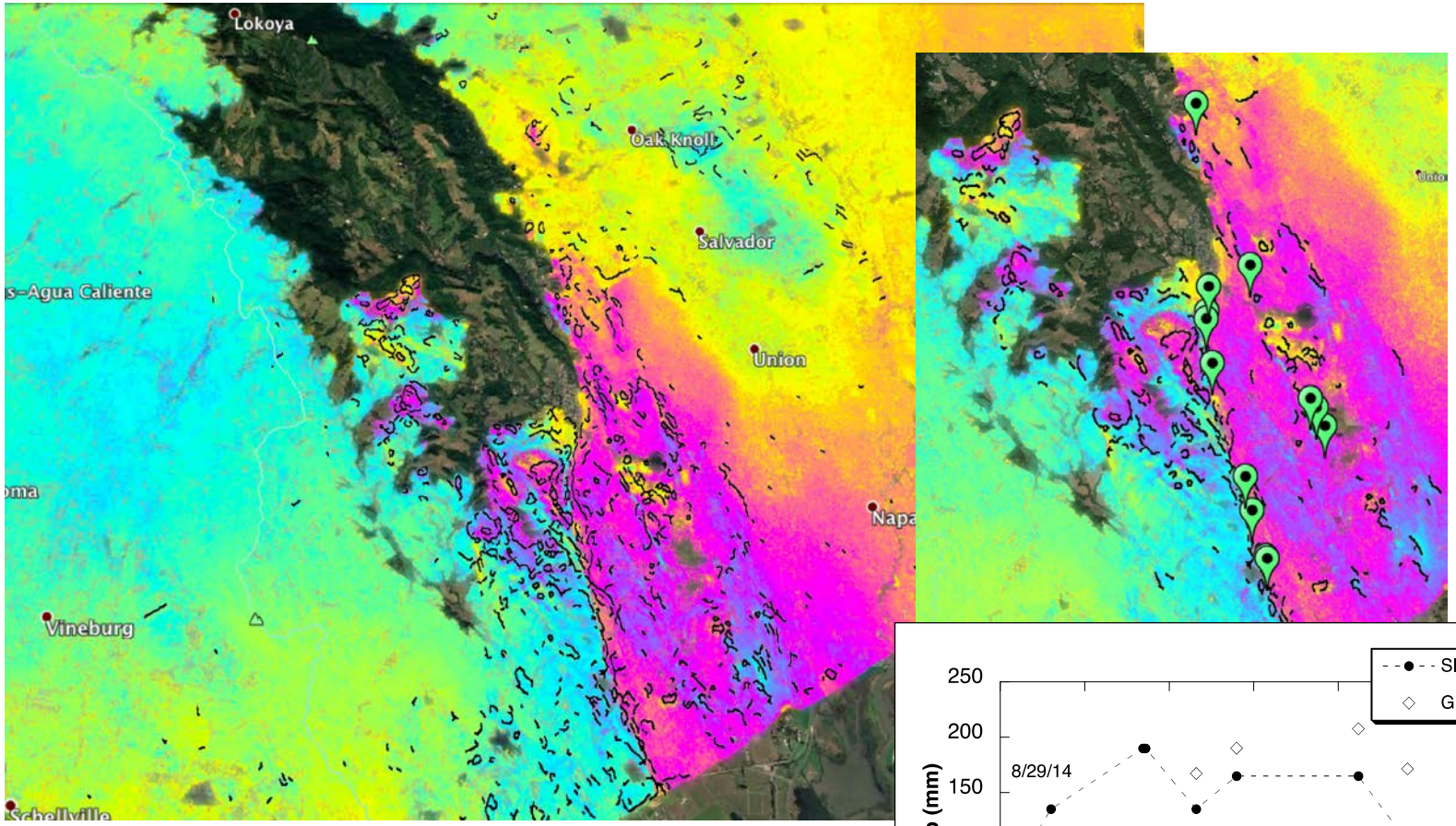


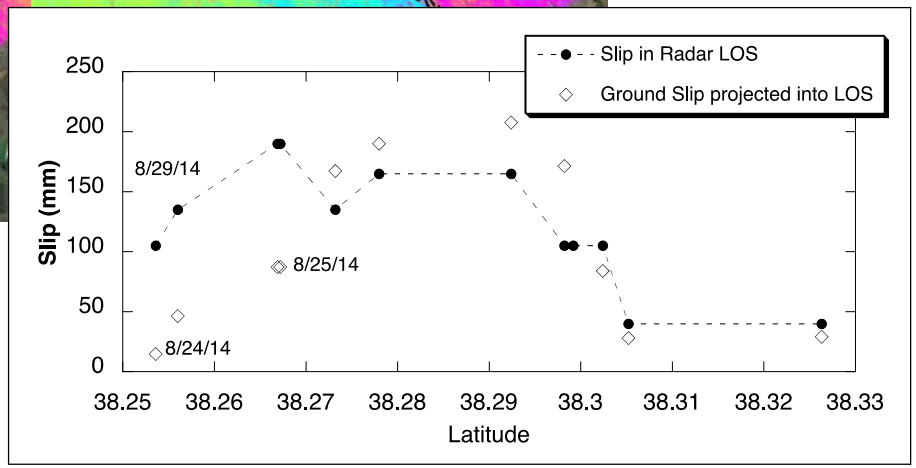
Fault zone: 10 GPa
Damage Zones: 20, 30 GPa
"West of fault" Maxwell times ~3-4 days

Observe zone of distributed deformation with concentrated high deformation near fault zone

As time progresses, see evolution of distributed slip

Edge Detection on UAVSAR Images





Parker et al 2016, *Radar Determination of Fault Slip and Location in Partially Decorrelated Images*, Pure and Applied Geophysics

Implications

- Question: how do faults root at depth and how is this reflected at the surface?
- Preliminary models show distributed deformation in the damage zone which could be related to observed deformation
- South Napa provides an excellent real world example to test hypotheses
- Remotely sensed data is extremely helpful in constructing and constraining models
- Future modeling with more realistic geometry and additional tests of material behavior will aid in better understanding of complex fault mechanics

Fusing observations and models aid in understanding complex slip and fault zone damage, which contribute to estimating earthquake potential