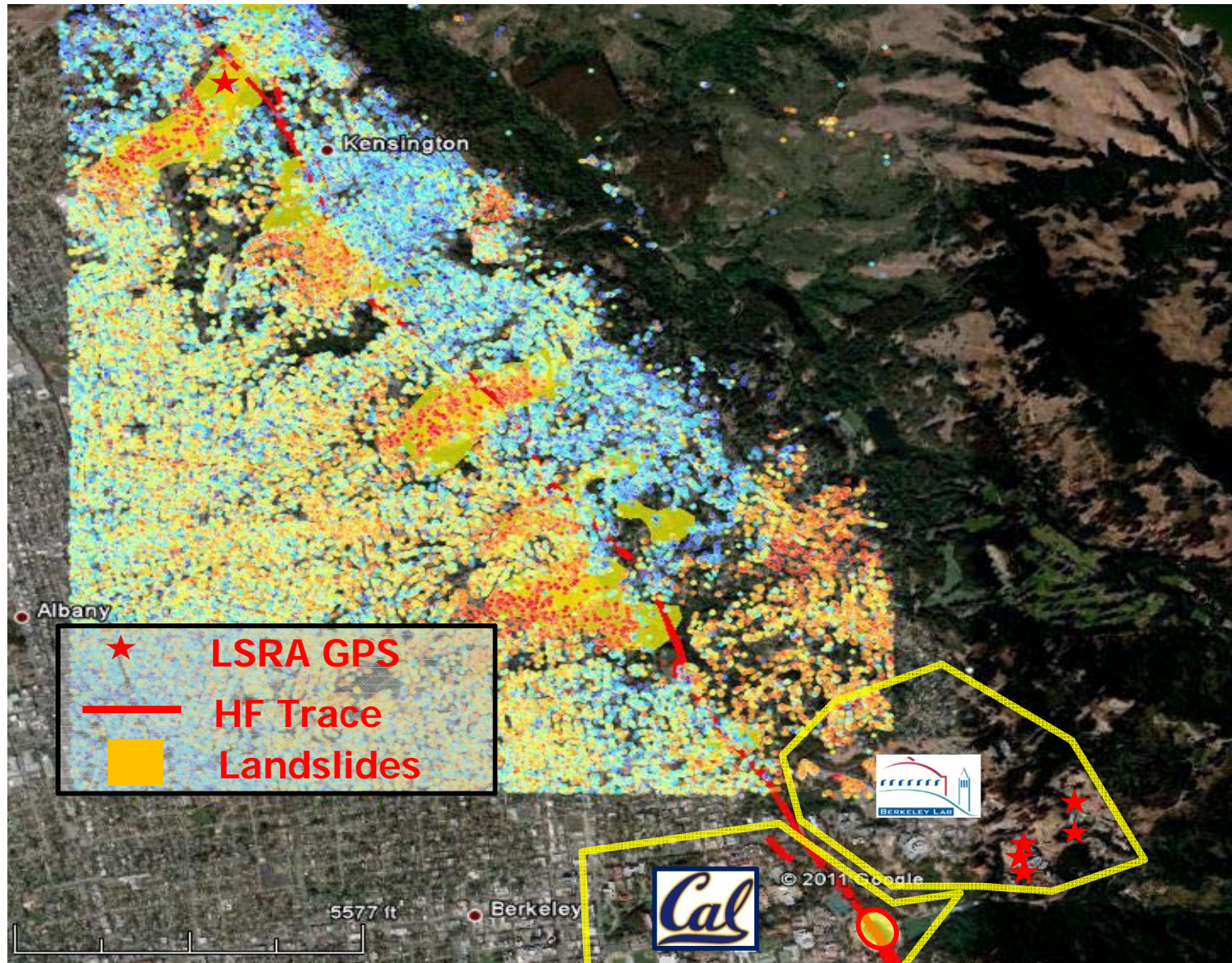


# InSAR and GPS Study of "Slow" Moving Landslides

2013 JPL UAVSAR Workshop , March 26-27

Julien Cohen-Waeber, University of California Berkeley



2008-2010 TerraSAR-X InSAR time series (Lei and Burgmann 2010)

# Acknowledgements

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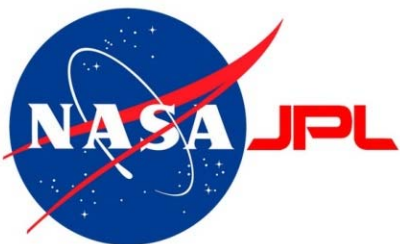
William Schulz

## Arizona State University:

Manoochehr Shirzaei

## Funding Sources:

Lawrence Berkeley Laboratory, NASA JPL, UC Berkeley



# Summary

❑ **Objective:** Spatial characterization and temporal analysis of deformation related to slow moving (cm/year – m/year) earth flows.

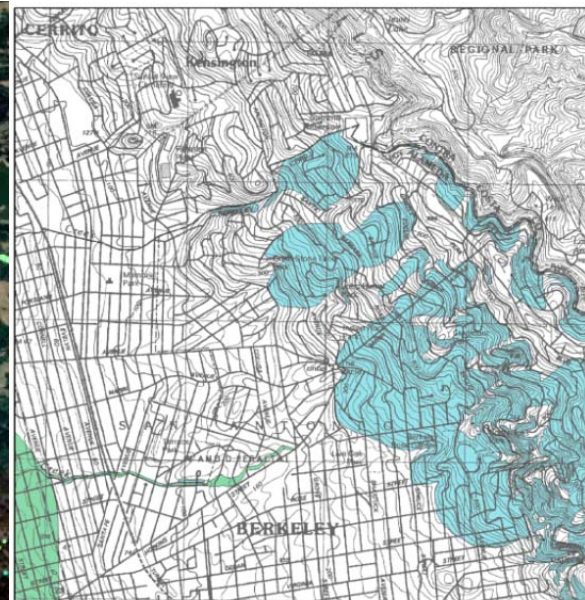
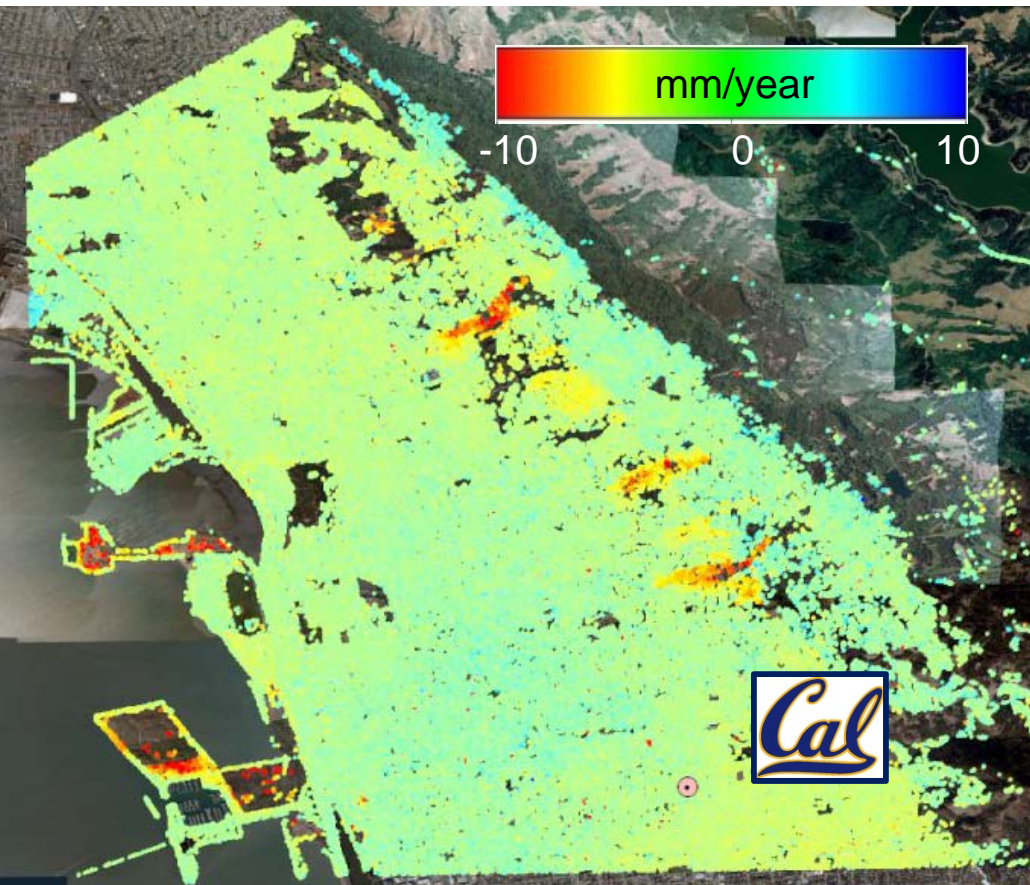
❑ **Methods:**

**Continuous GPS Network** (unique ground displacement measurements)

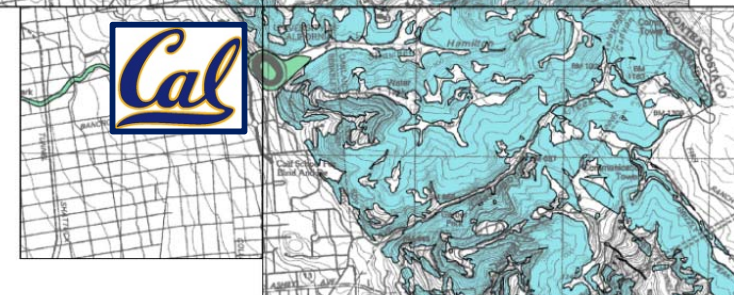
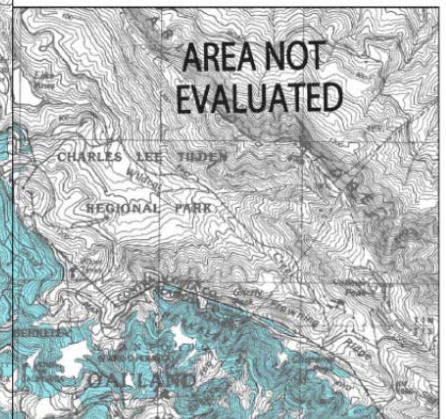
**Satellite InSAR Time Series Analysis** (higher spatial resolution)

**UAVSAR** (Flexible flight lines and repeat passes)

❑ **Motivation:** Model slide mechanisms, refine current landslide hazard mapping.

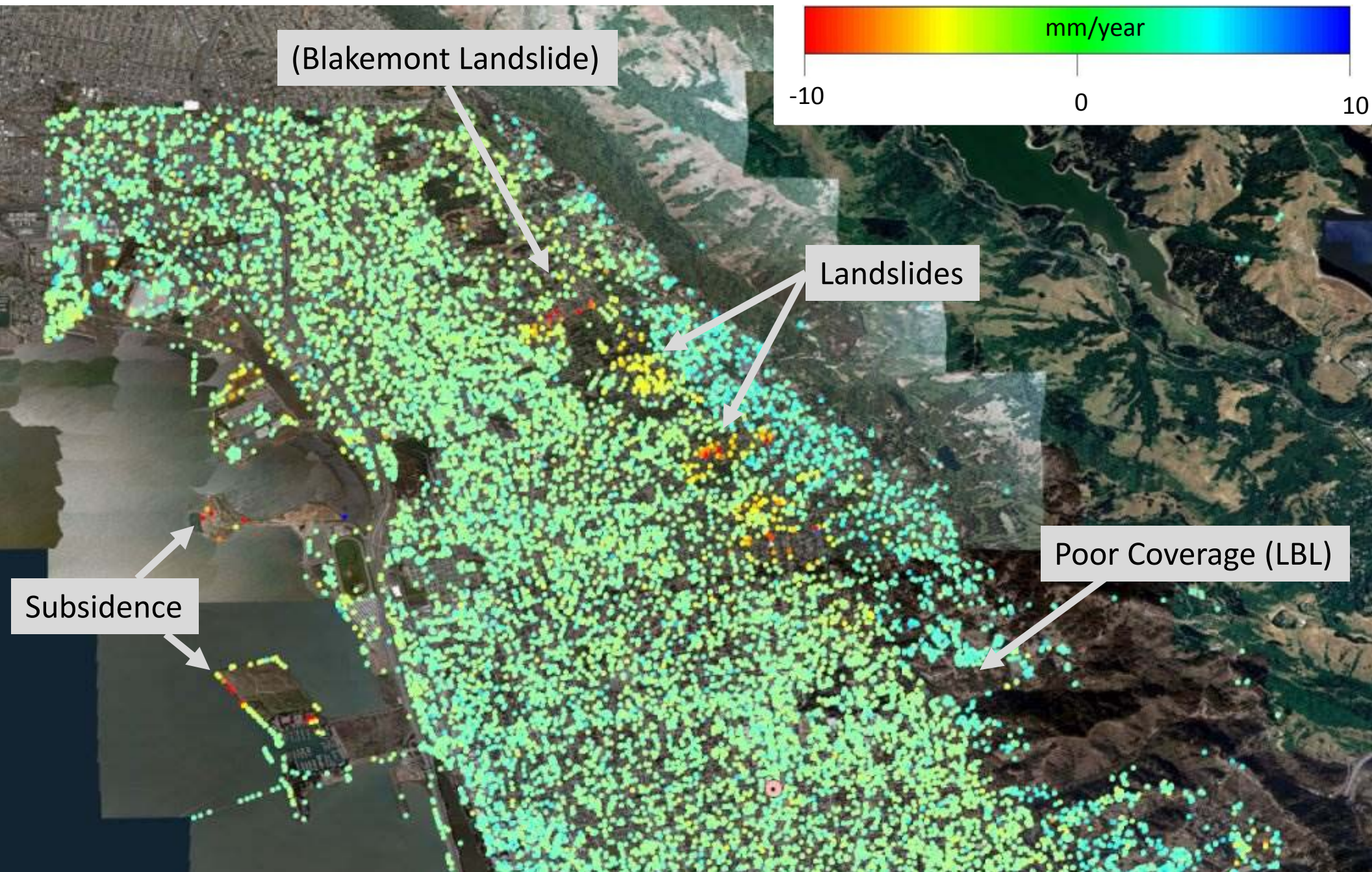


California Geologic Survey,  
Landslide Hazard Map,  
Berkeley Hills CA. (2003)



# ERS Velocity map 1992-2000

Hilley et al. (2004): using PS-InSAR

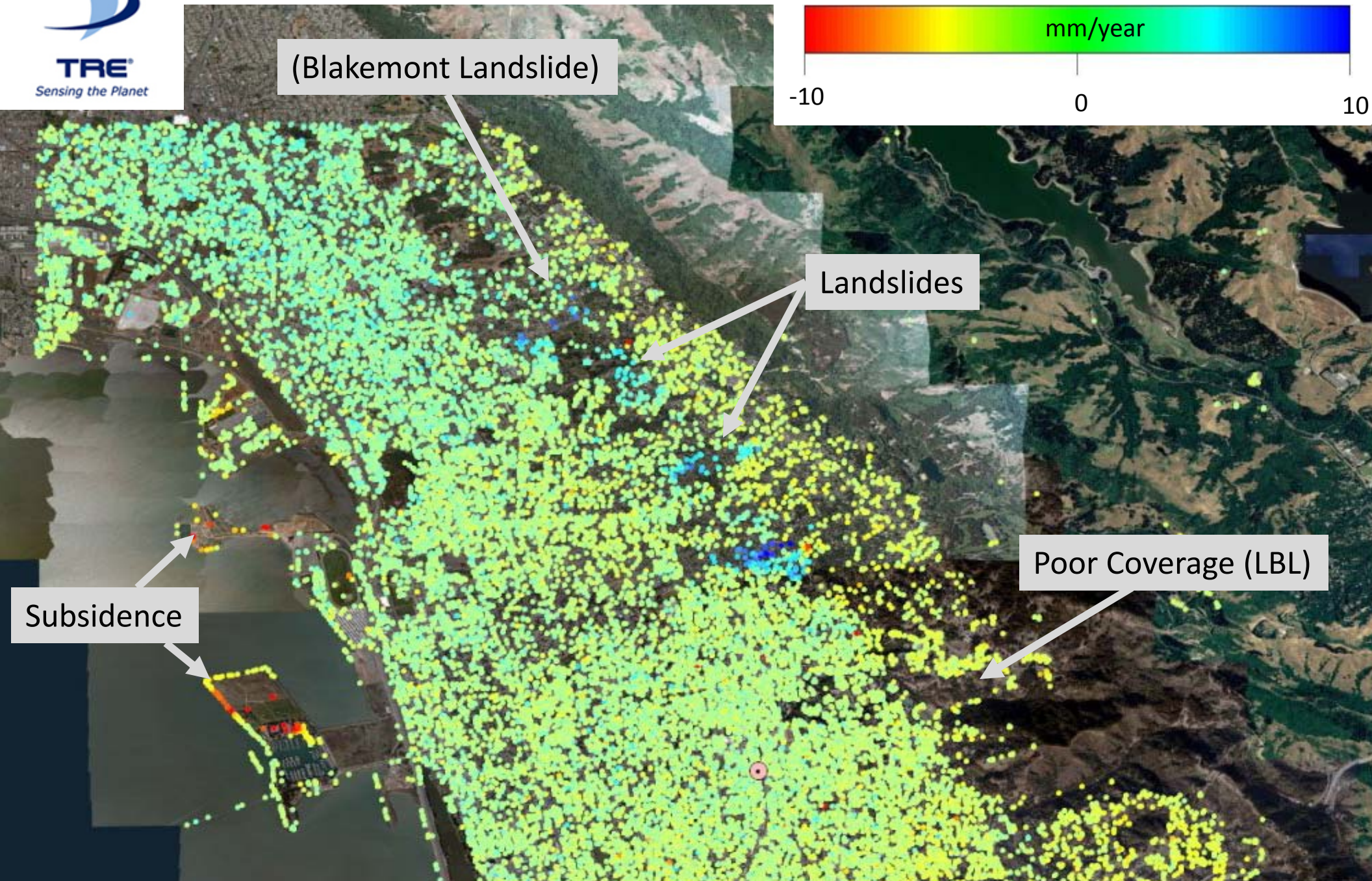


# Radarsat-1 Velocity map 2001-2006

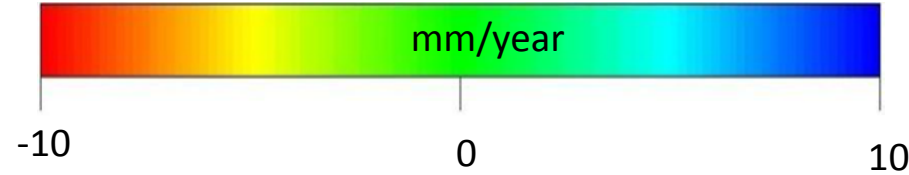
TRE: Improved PS-InSAR coverage



TRE  
Sensing the Planet



(Blakemont Landslide)



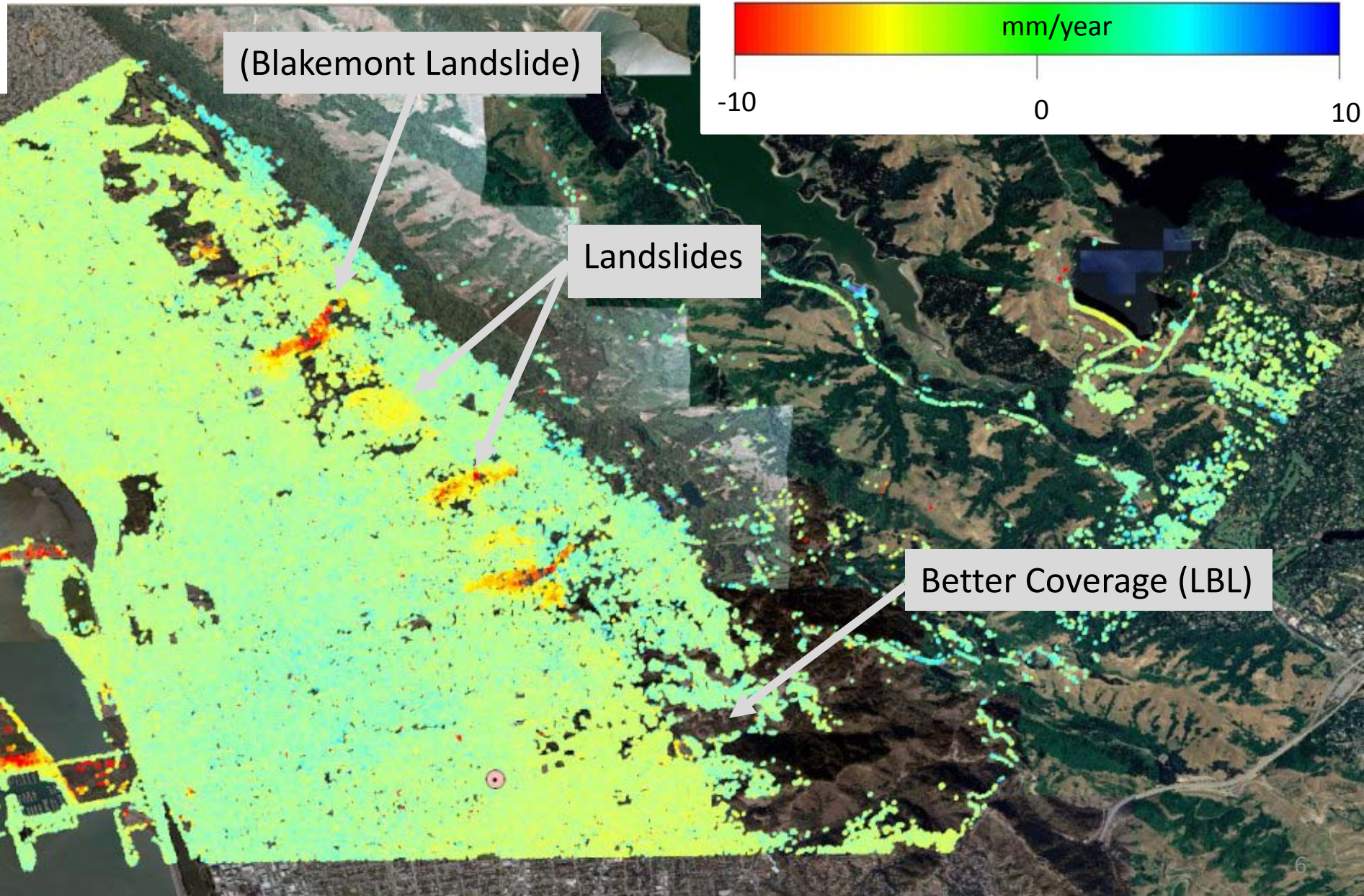
Landslides

Poor Coverage (LBL)

Subsidence

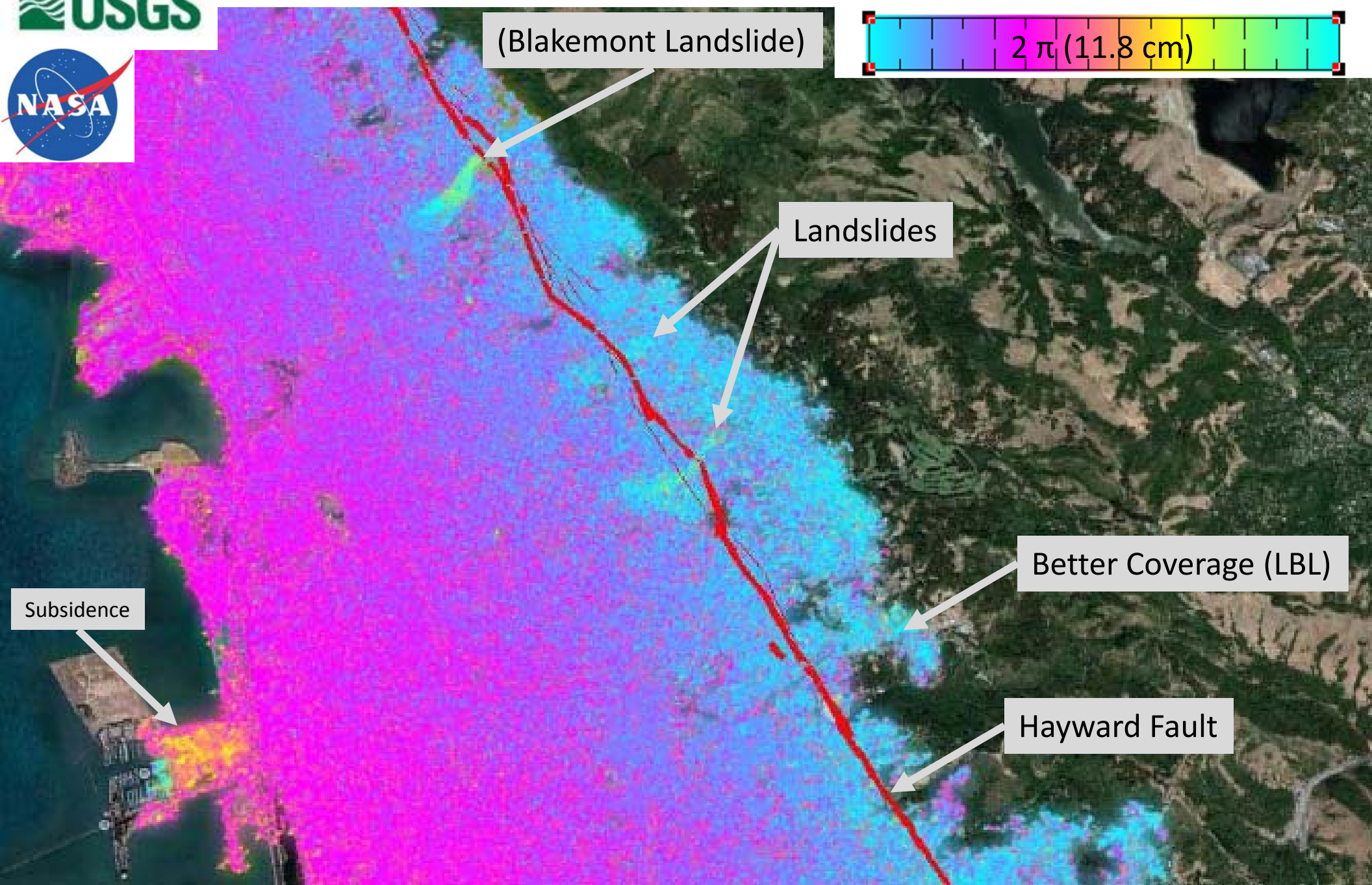
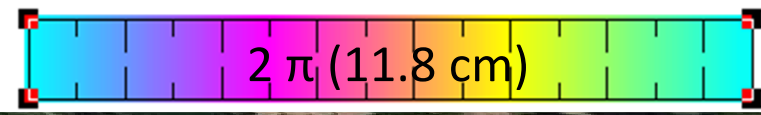
# TerraSAR-X - Velocity map 2009-2011

TRE (2011): SqueeSAR™ improved coverage using PS and DS InSAR method



# UAVSAR April 2010 – July 2011

JPL: 15302 Fault Parallel (153°) Unwrapped



(Blakemont Landslide)

Landslides

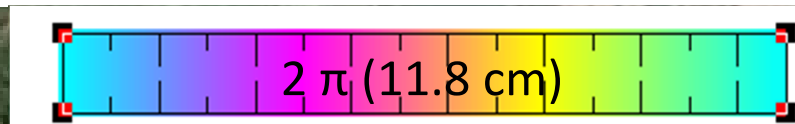
Better Coverage (LBL)

Hayward Fault

Subsidence

# UAVSAR April 2010 – July 2011

JPL: 34001 Fault Parallel (340°) Unwrapped

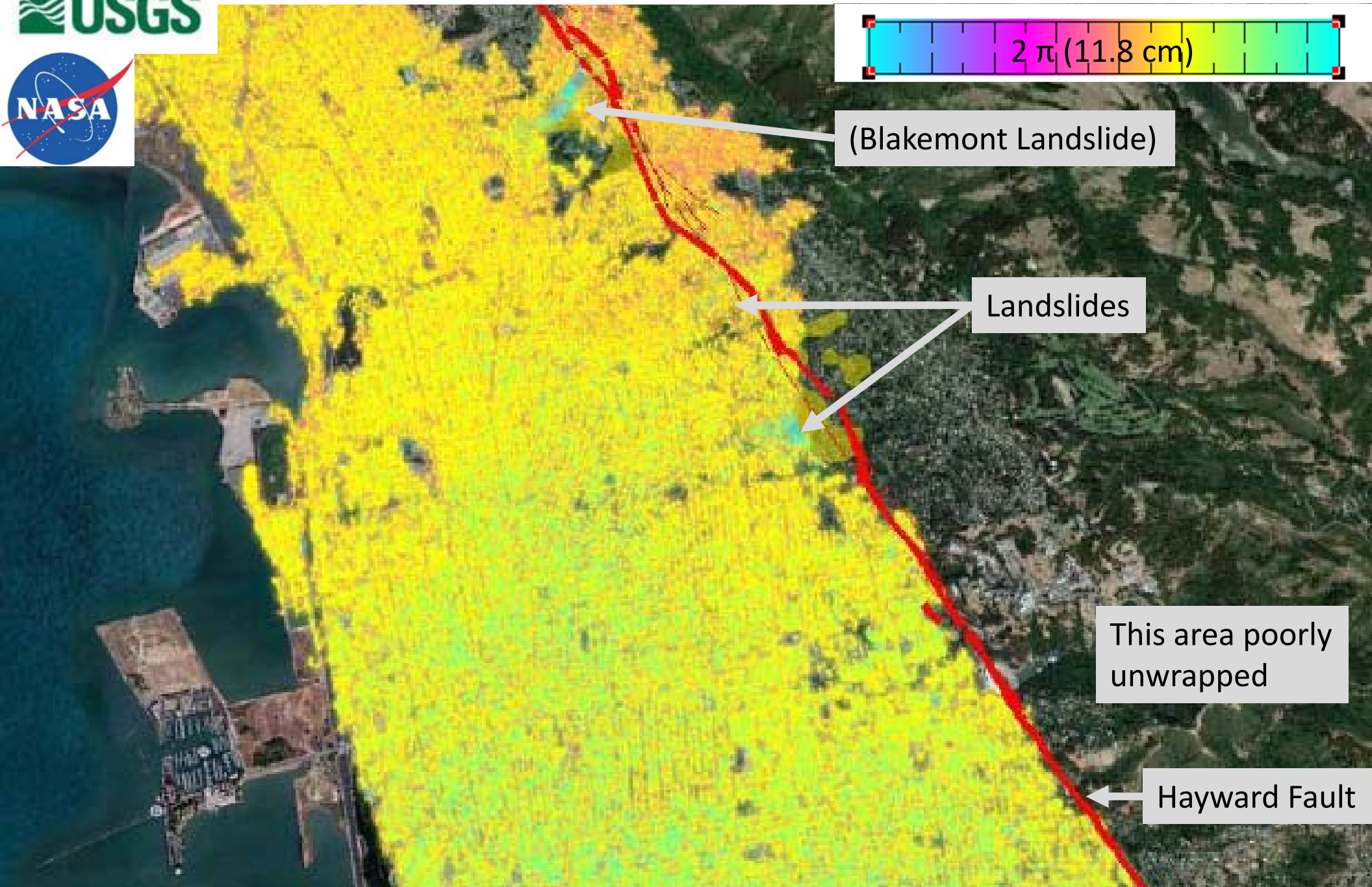


(Blakemont Landslide)

Landslides

This area poorly unwrapped

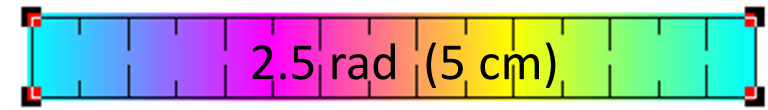
Hayward Fault





# UAVSAR April 2010 – July 2011

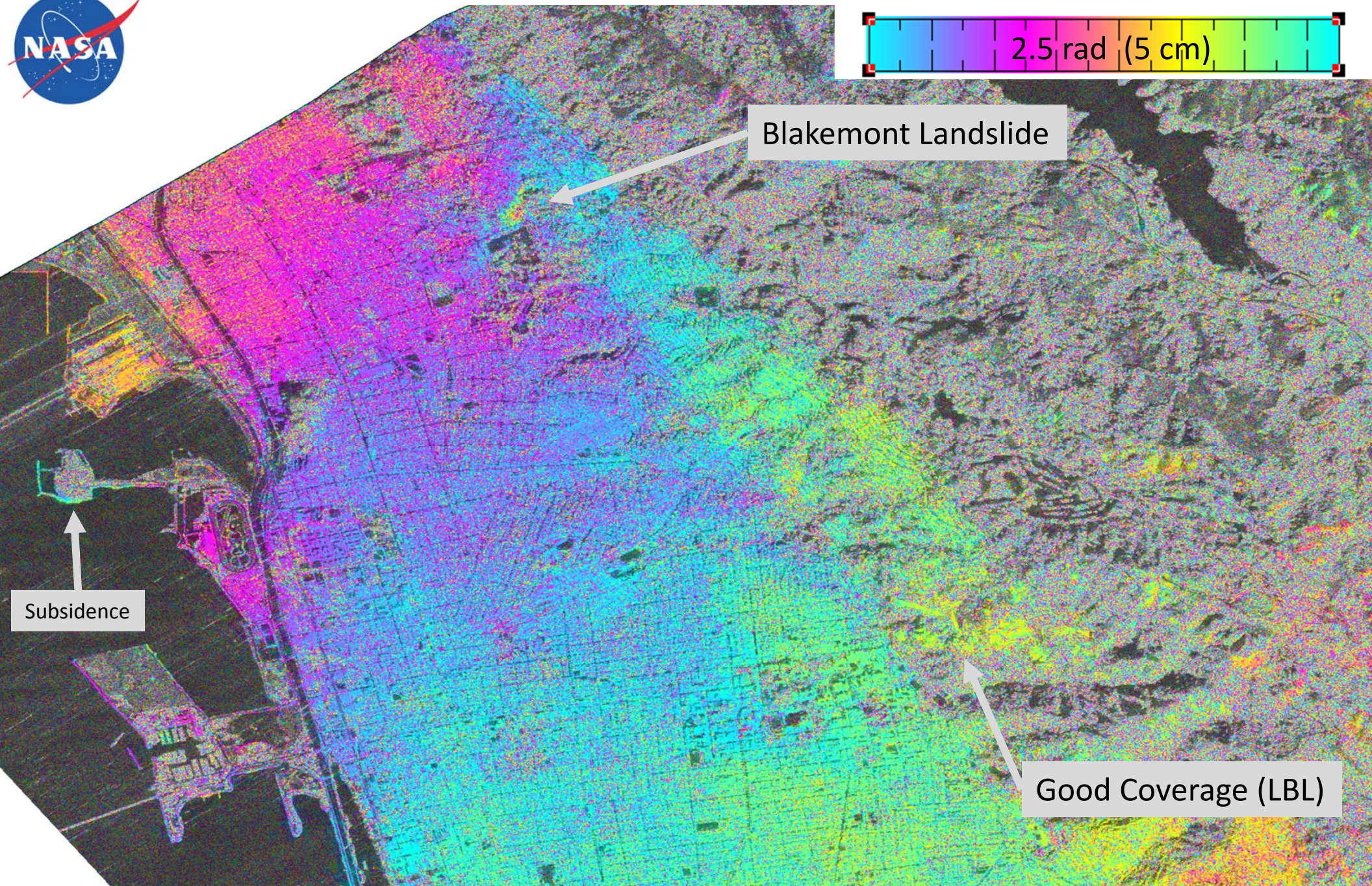
## JPL: 05524 Fault Normal Rewrapped



Blakemont Landslide

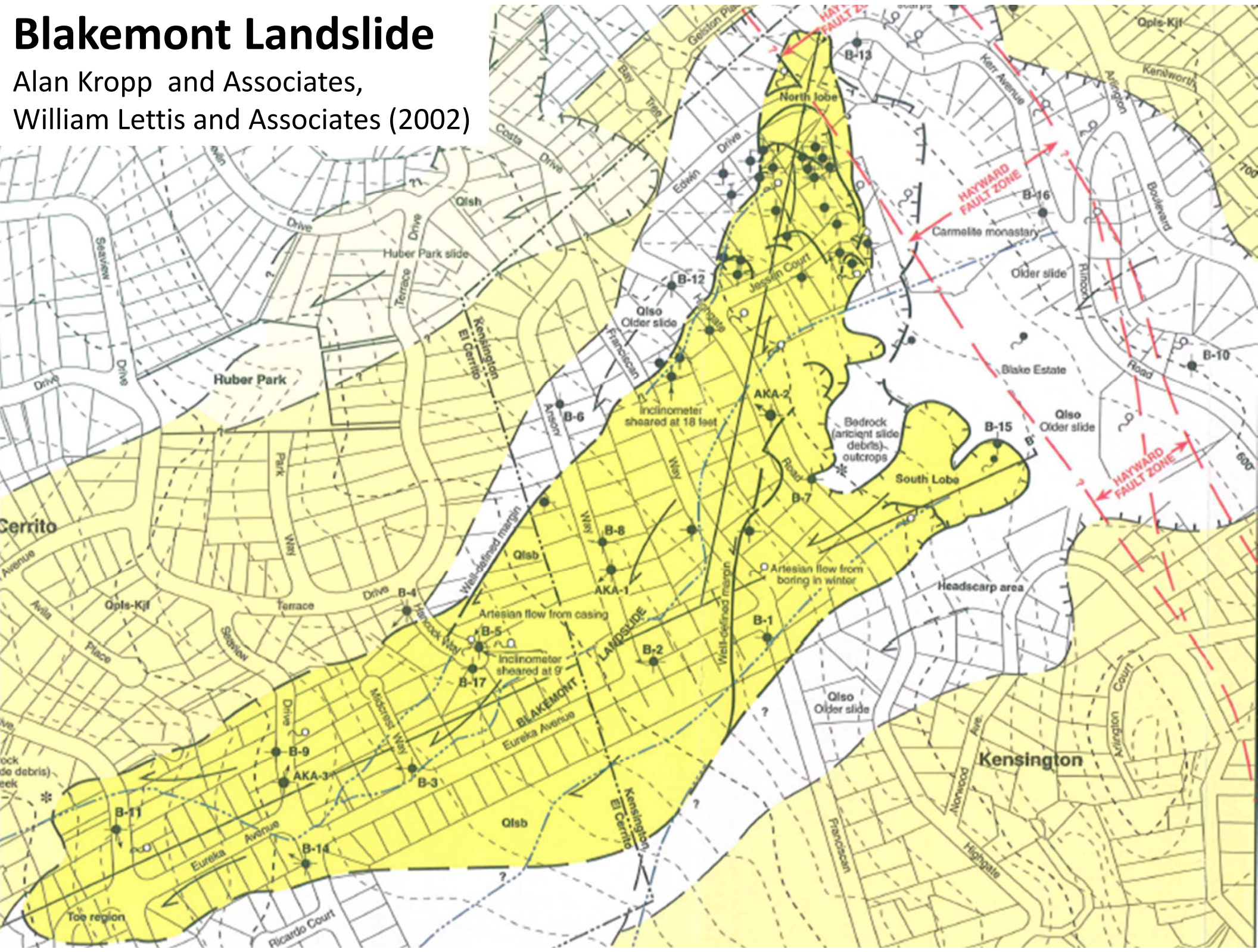
Subsidence

Good Coverage (LBL)

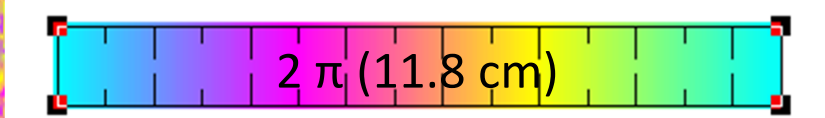
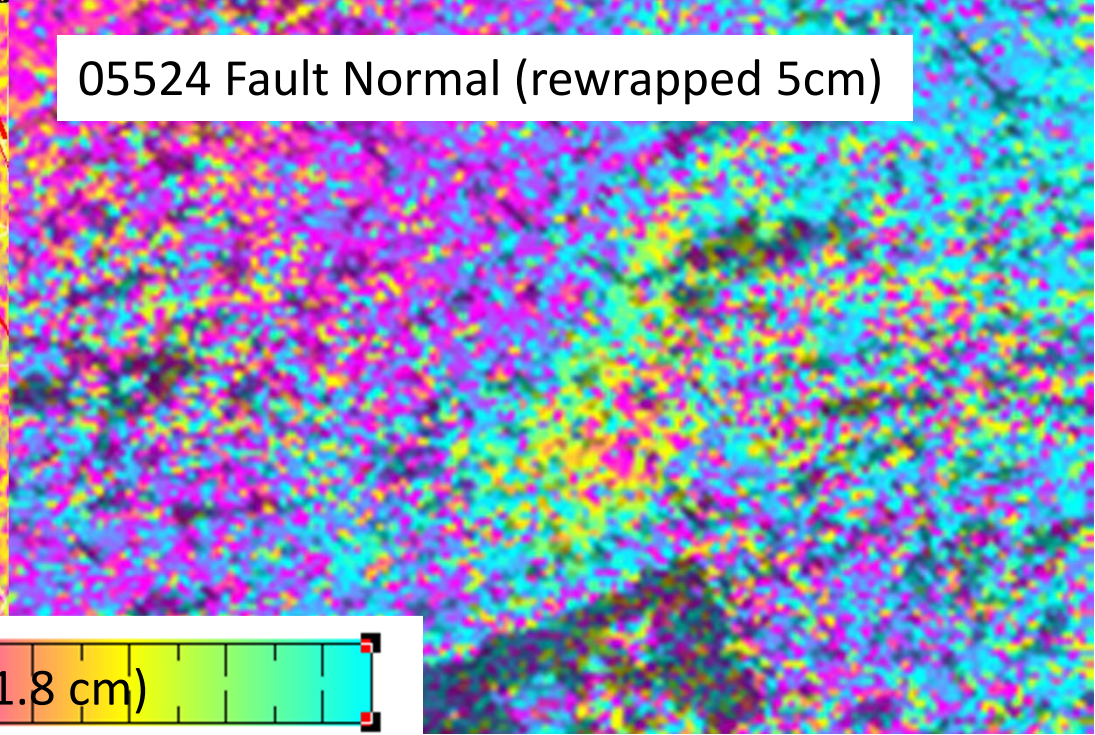
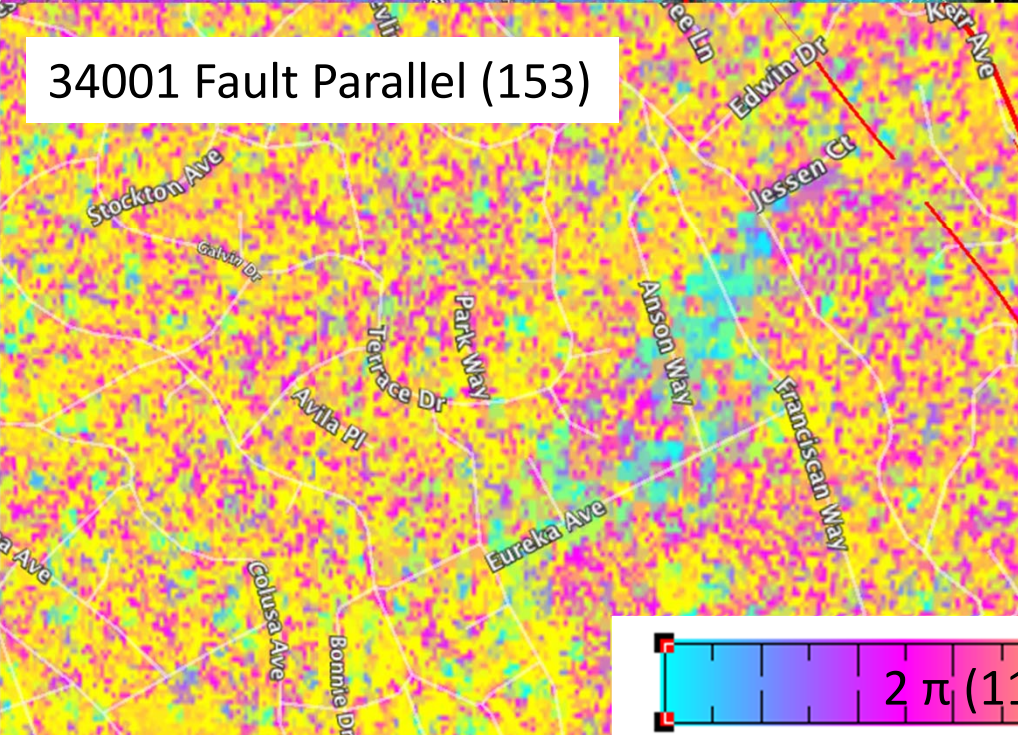
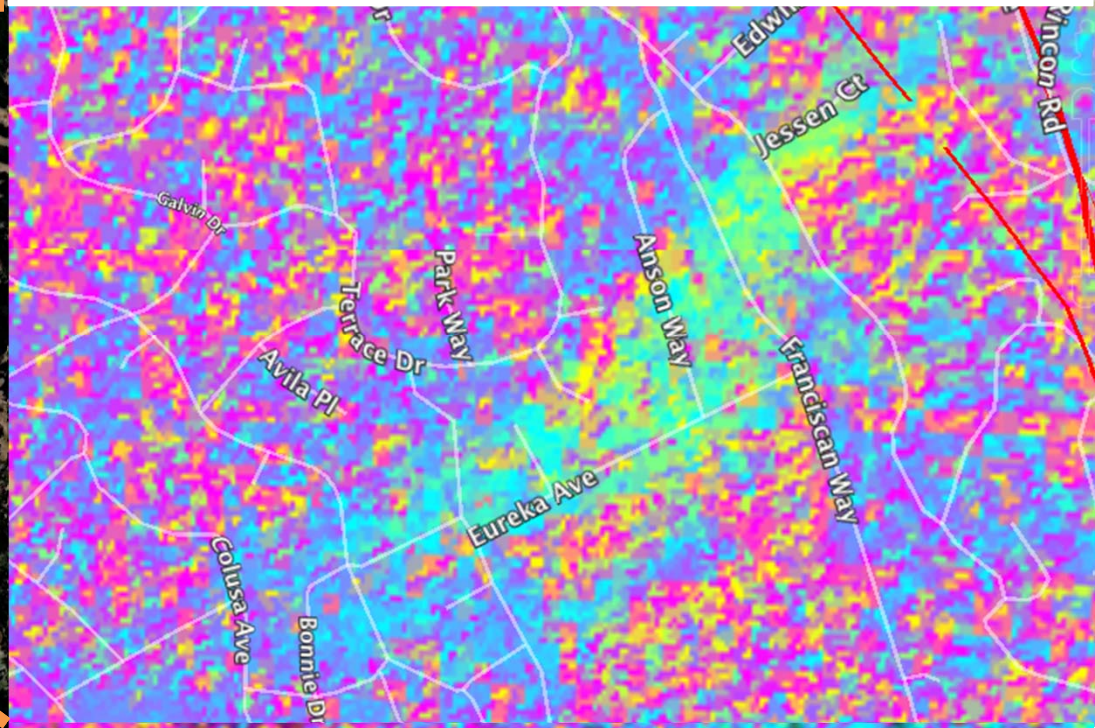
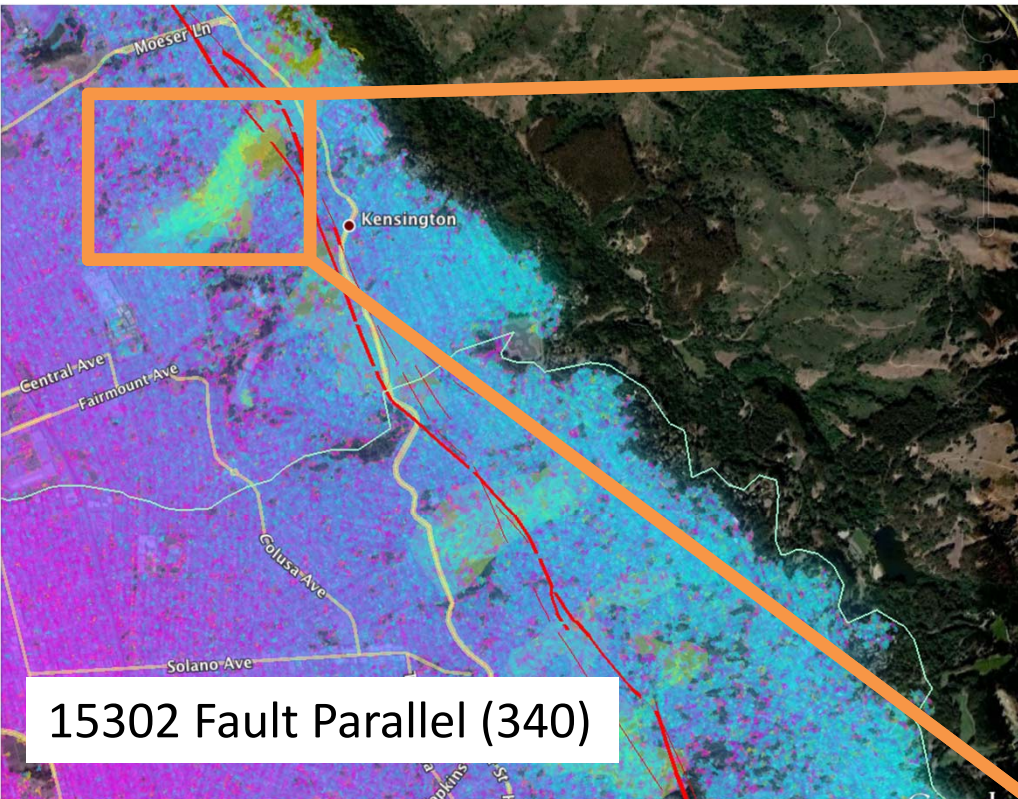


# Blakemont Landslide

Alan Kropp and Associates,  
William Lettis and Associates (2002)



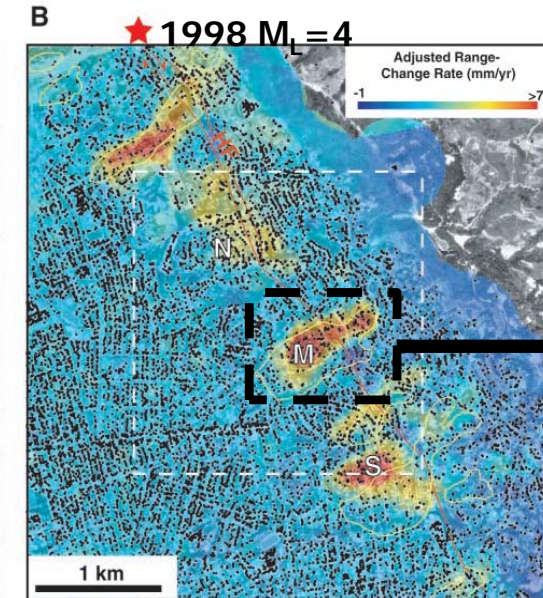
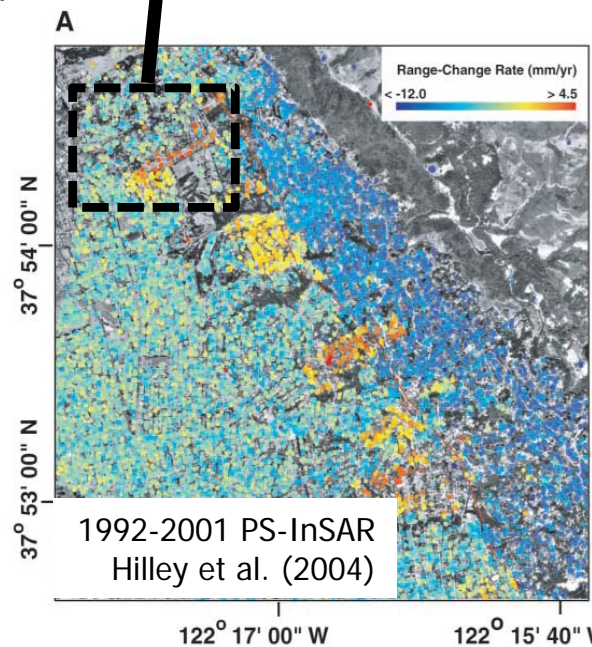
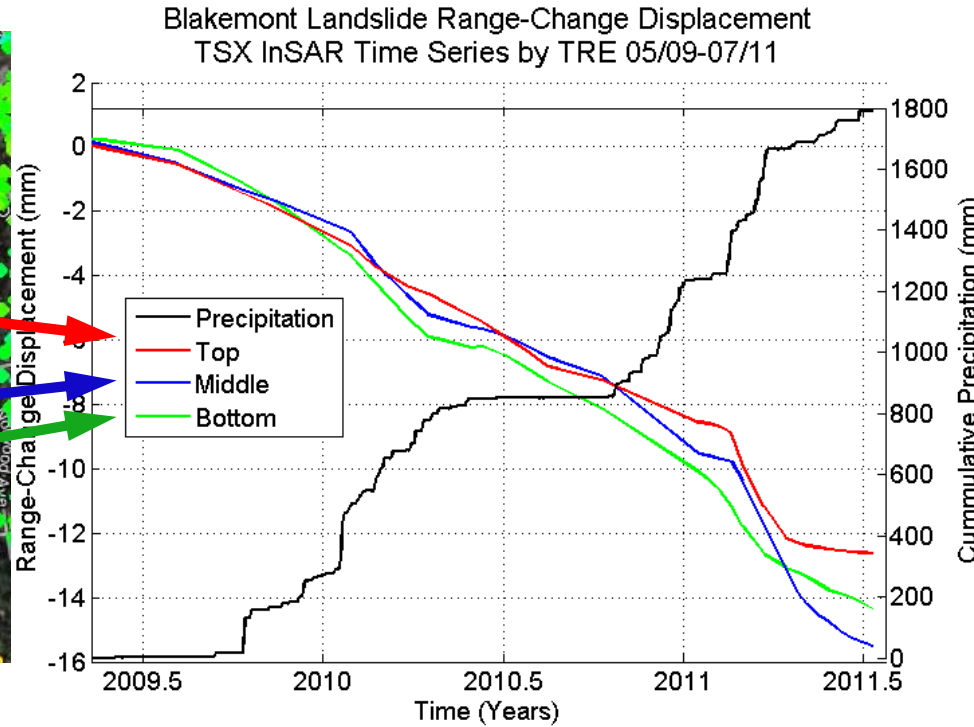
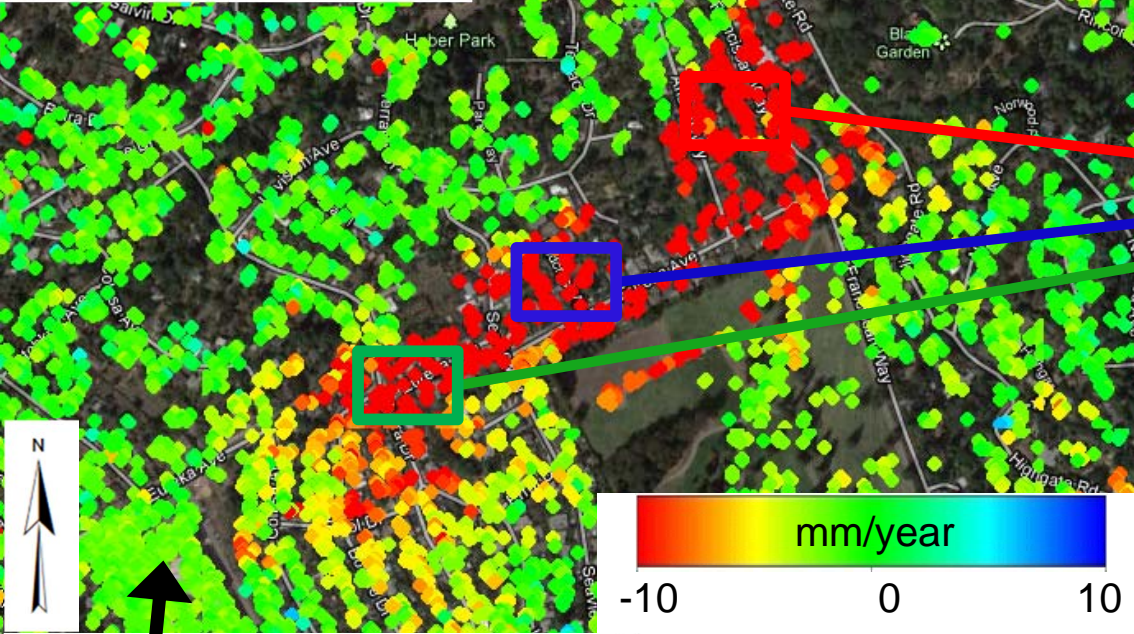
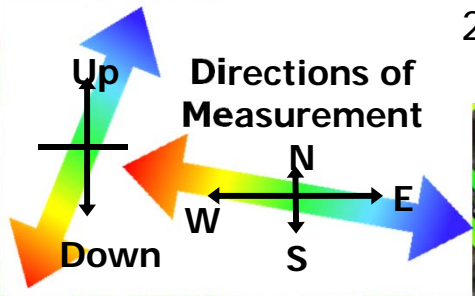
# UAVSAR: Blakemont Landslide



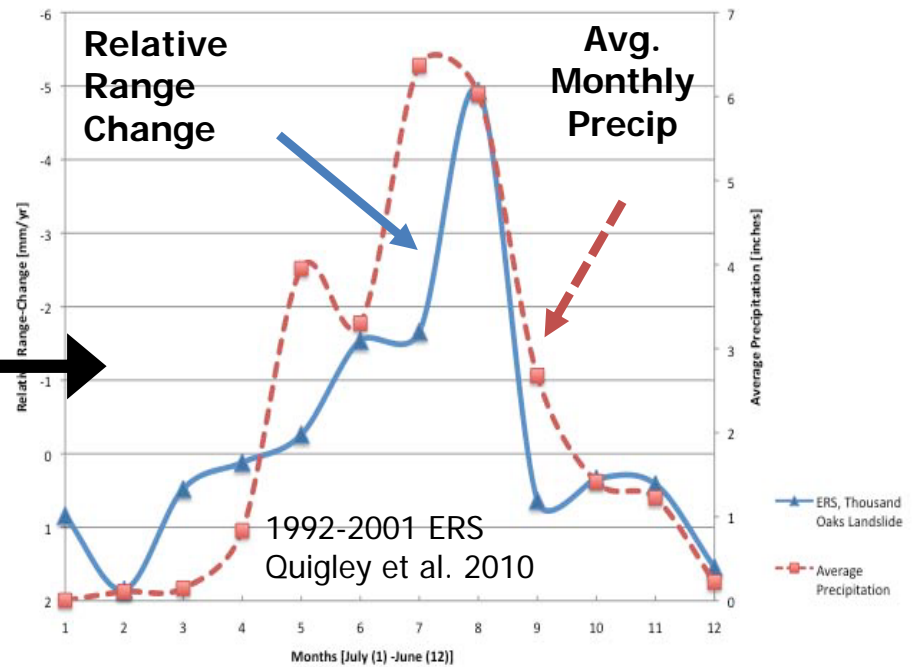
# Landslide Behavior

2009-2011 TerraSAR-X Velocity map, SqueeSAR™, TRE (2011)

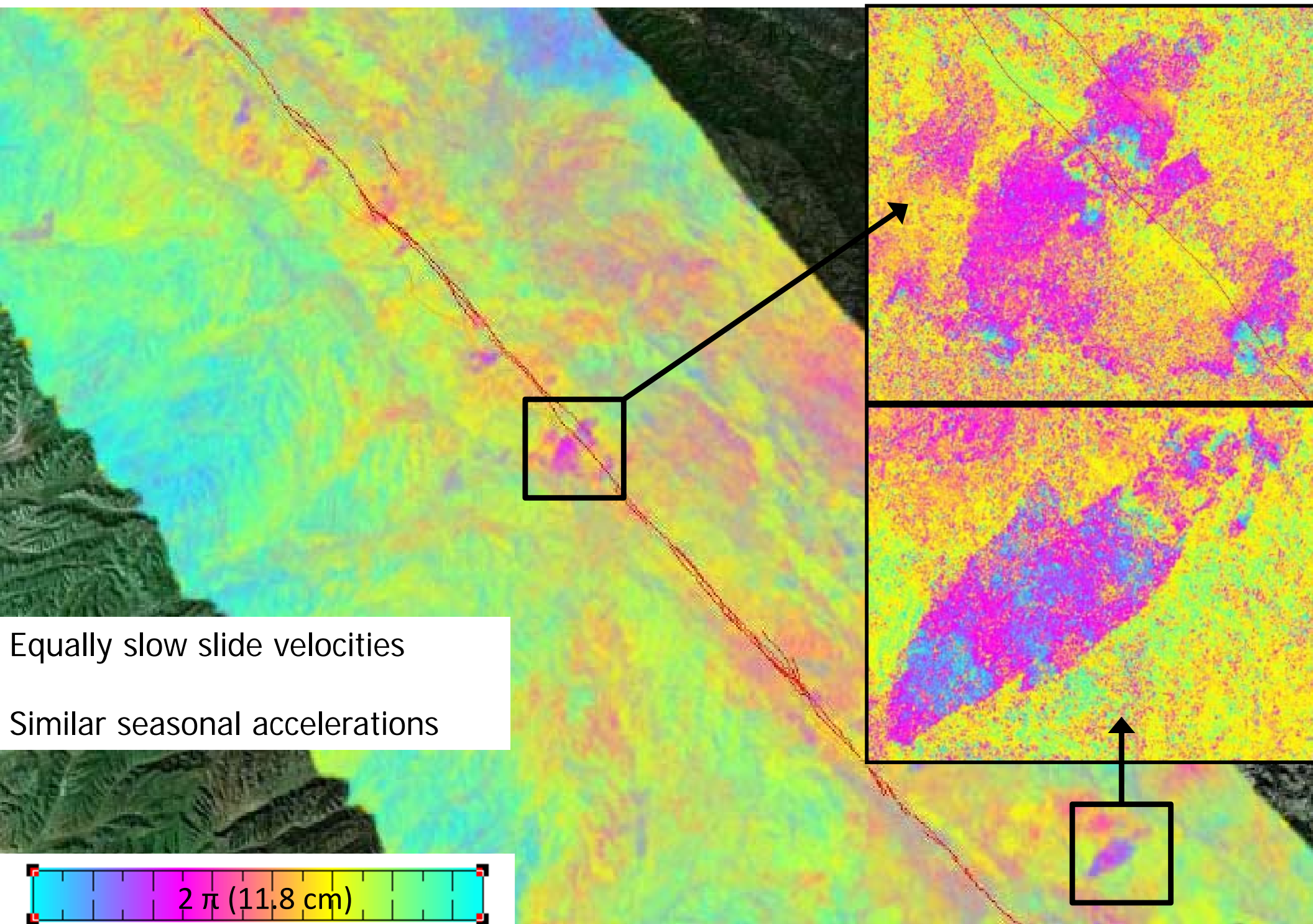
<https://tremaps.treuropa.com>



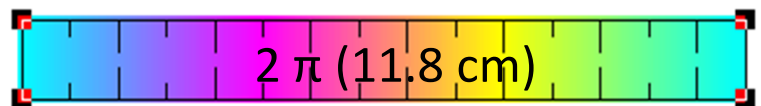
Range-Change Detrended and Stacked by Month 1992-2000 Thousand Oaks Landslide, ERS



# UAVSAR: Central San Andreas, Nov. 2010 – July 2011

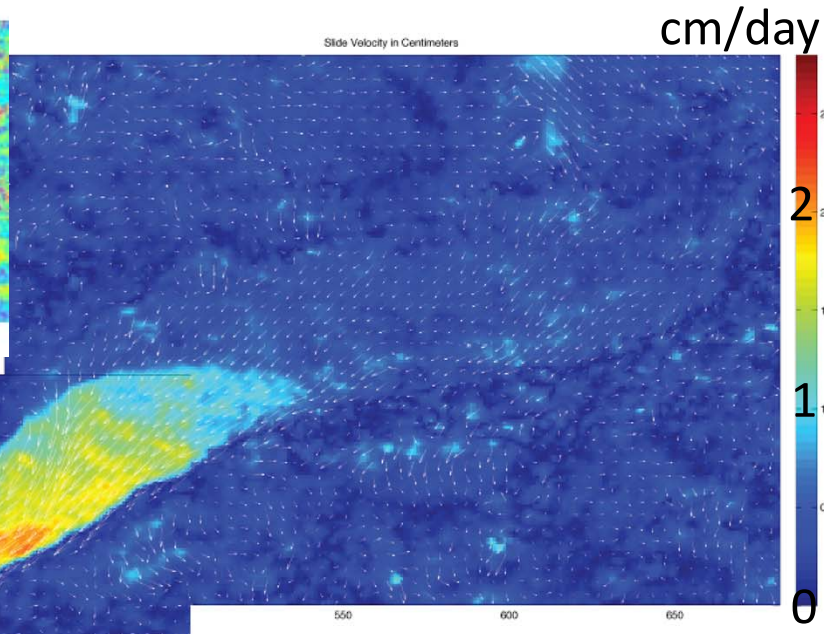
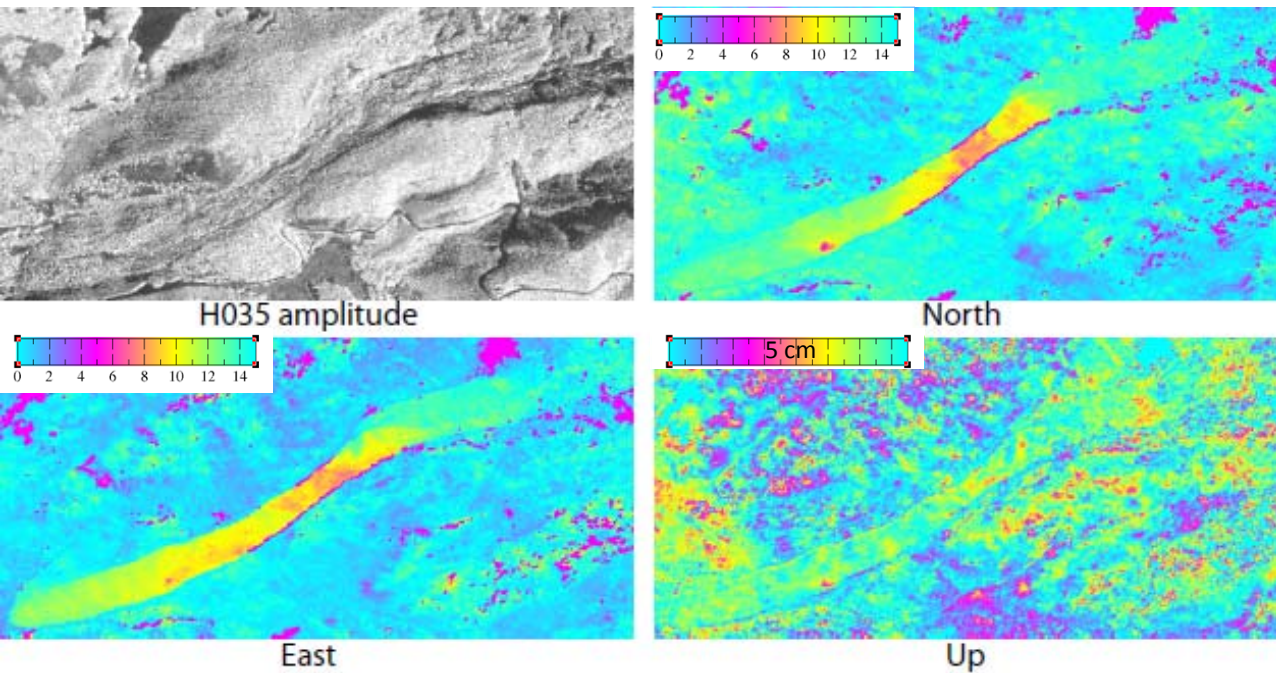


Equally slow slide velocities  
Similar seasonal accelerations



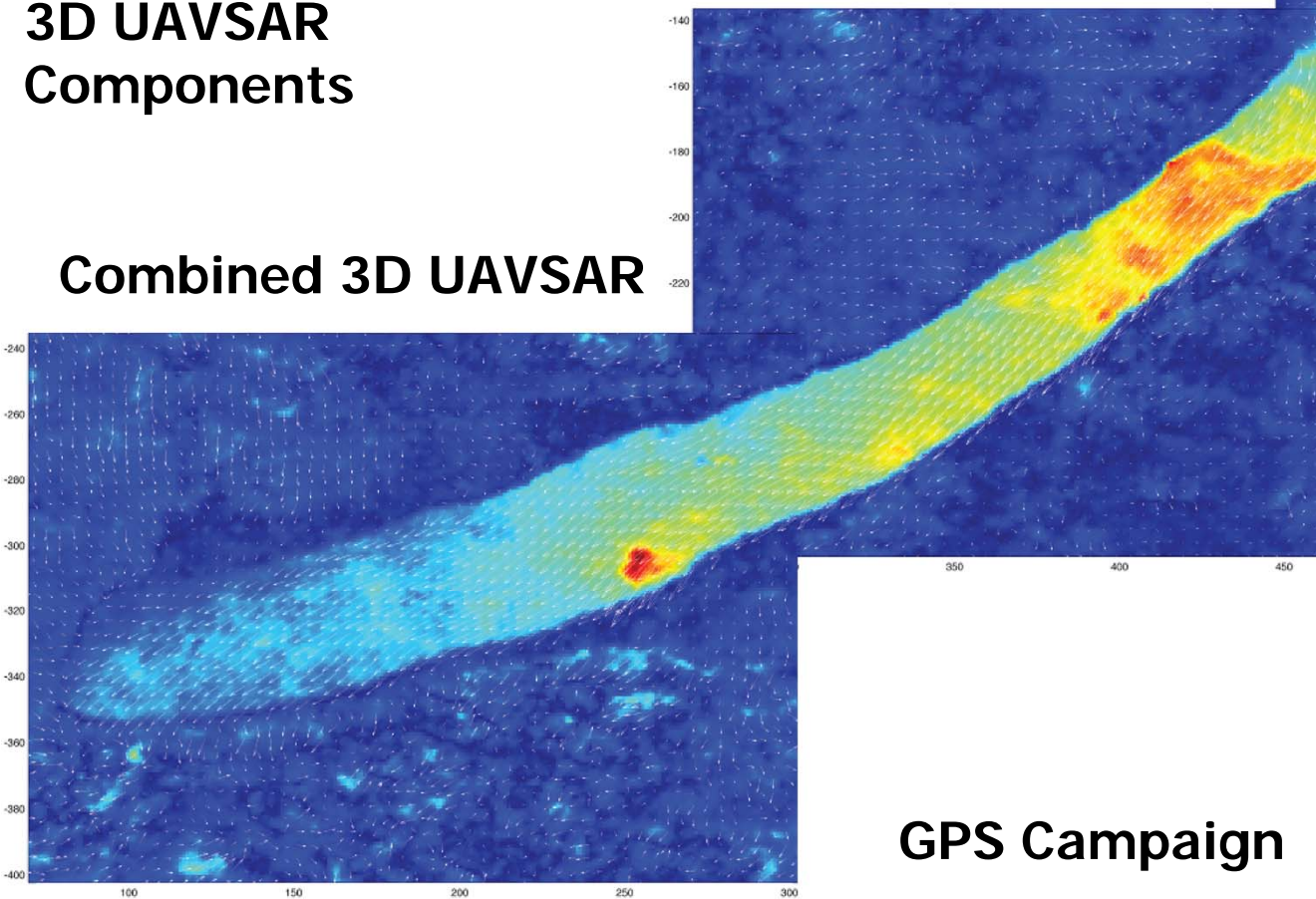
# Slumgullion Landslide

(2 orders of magnitude faster)



3D UAVSAR  
Components

Combined 3D UAVSAR



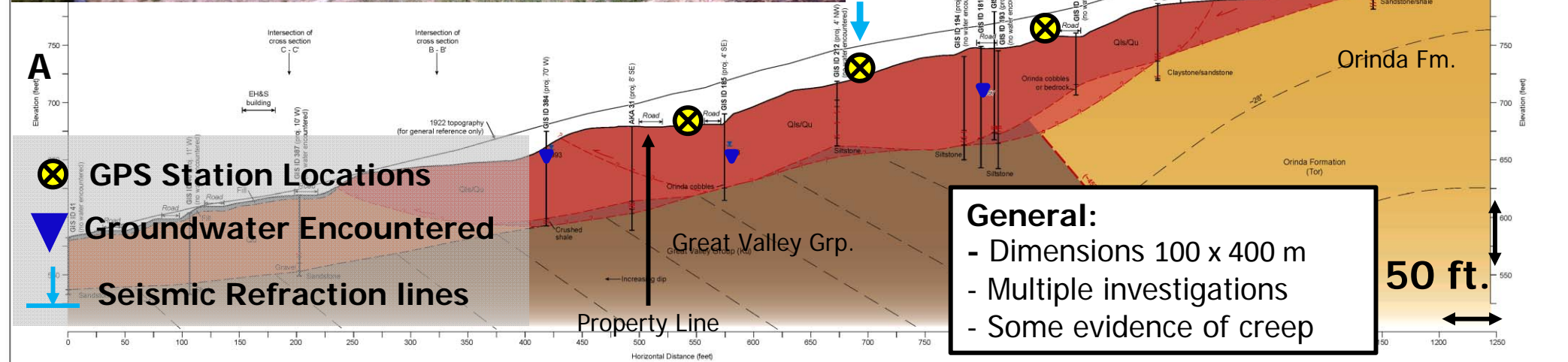
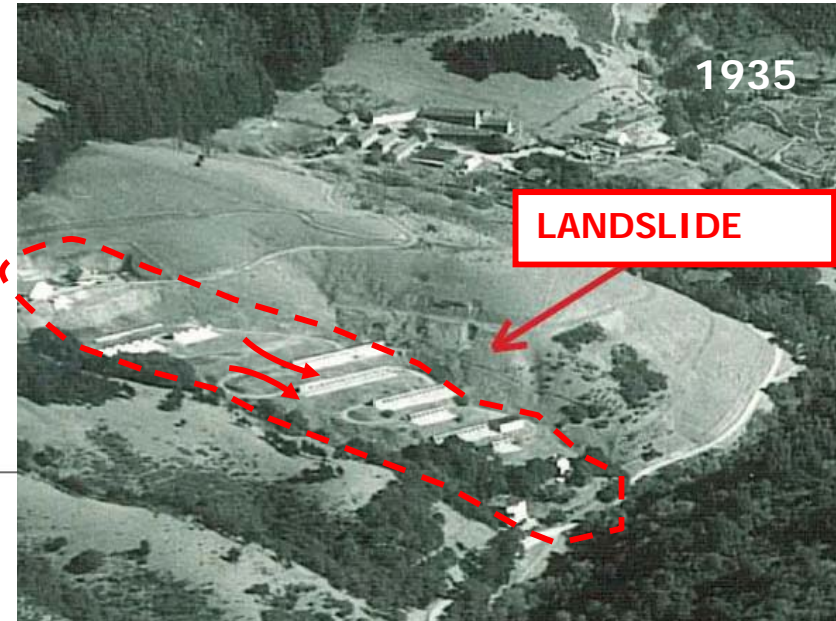
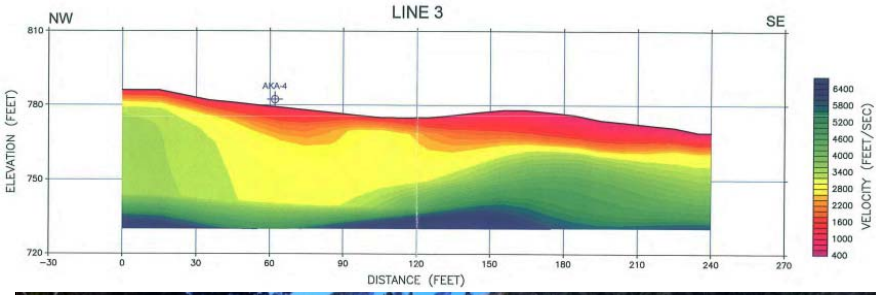
GPS Campaign



# GPS Monitoring of Slow Moving Landslides



# GPS Stations 1-3: Chicken Creek Landslide (LBL)



**General:**

- Dimensions 100 x 400 m
- Multiple investigations
- Some evidence of creep

**50 ft.**

Explanation	
	Artificial fill / with landslide overlay
	Quaternary colluvium / with landslide overlay
	Orinda Formation (Miocene) / with landslide overlay
	Great Valley Group (Cretaceous) / with landslide overlay
	Approximate location of fault
	Contact
	Potential landslide boundary
	Potential landslide direction
	Bedding dip, apparent
	1993 Depth to groundwater and year
	Boring Details
	Projection direction and distance
	GIS data identification (red indicates line data)
	Change in lithology or facies
	Potential offset/sheared feature observed

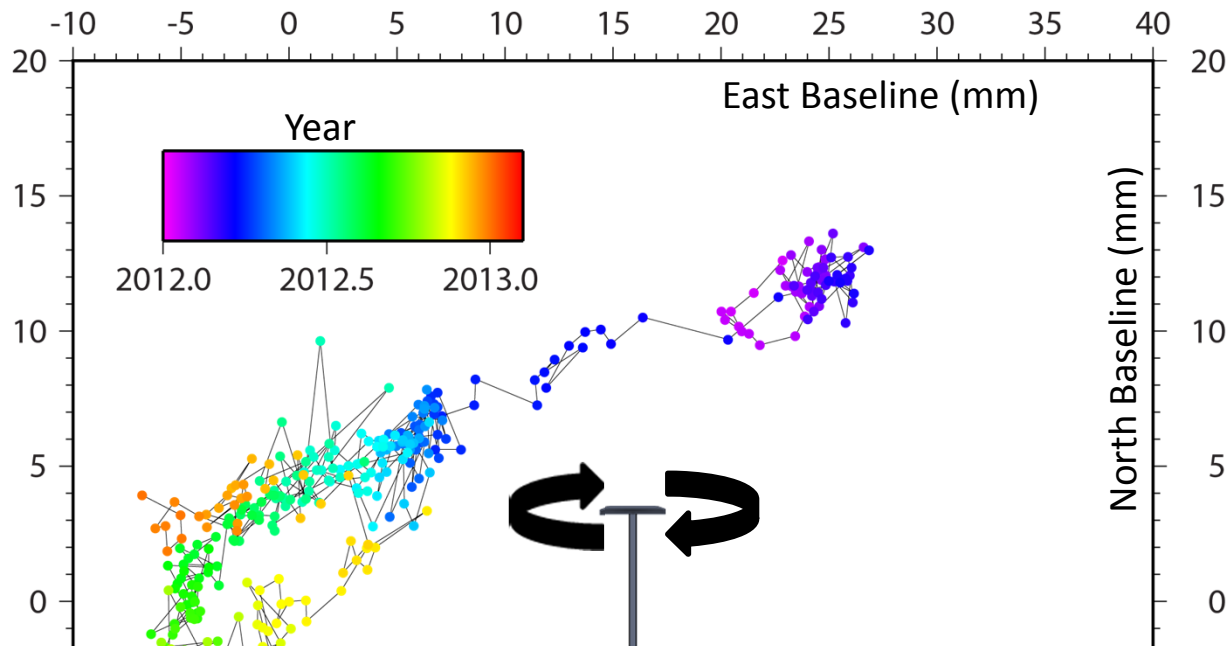
Notes: 1. Borings labeled by GIS ID (WLA project 2032)  
 2. Topography from October 2007 LBNL transmittal.  
 3. Coordinate system in University of California, Berkeley grid.

Alan Kropp and Associates (William Lettis and Associates)



# Station 2: Middle of Chicken Creek Landslide

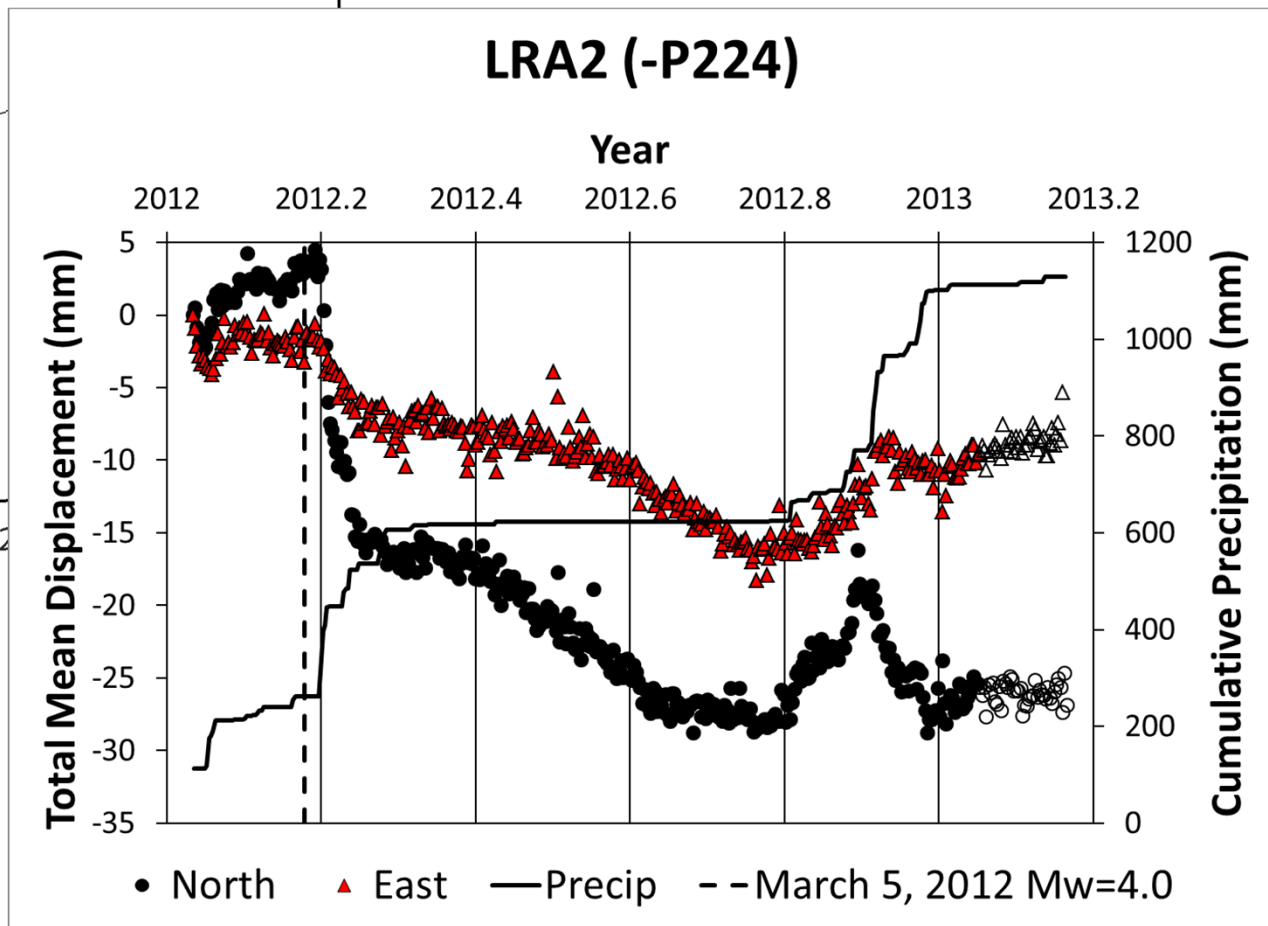
Differential signal tracking with Station P224 at ~5km  
 Clear sensitivity to precipitation



P224-LRA2 2D

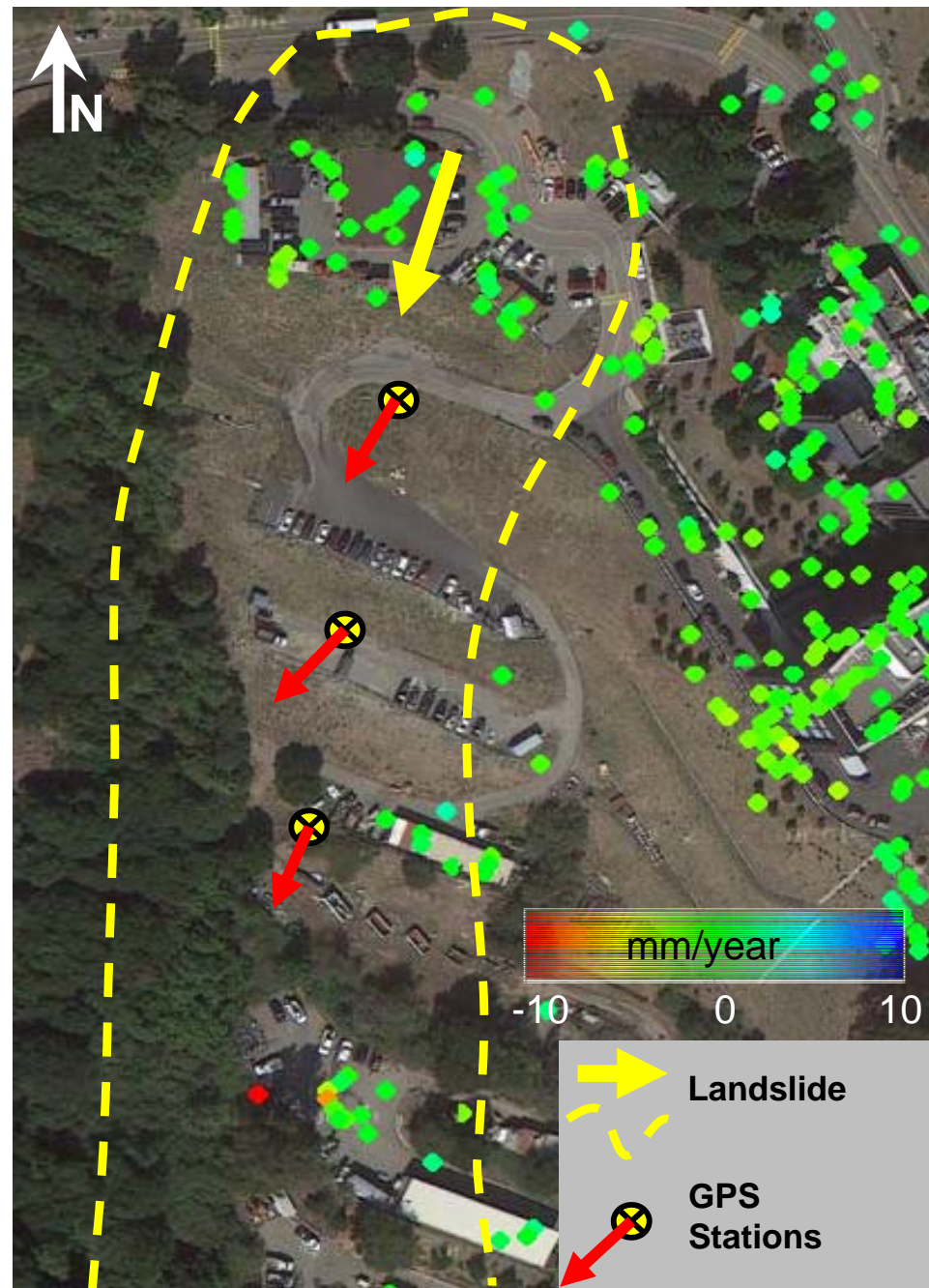
Unclear sensitivity to 03-05-12  $M_w = 4$  event @ <10km.  
 ~3 cm down slope displacement.

Antenna Wobble?



• North    ▲ East    — Precip    - - March 5, 2012  $M_w=4.0$

# Differential Displacement at Chicken Creek Landslide



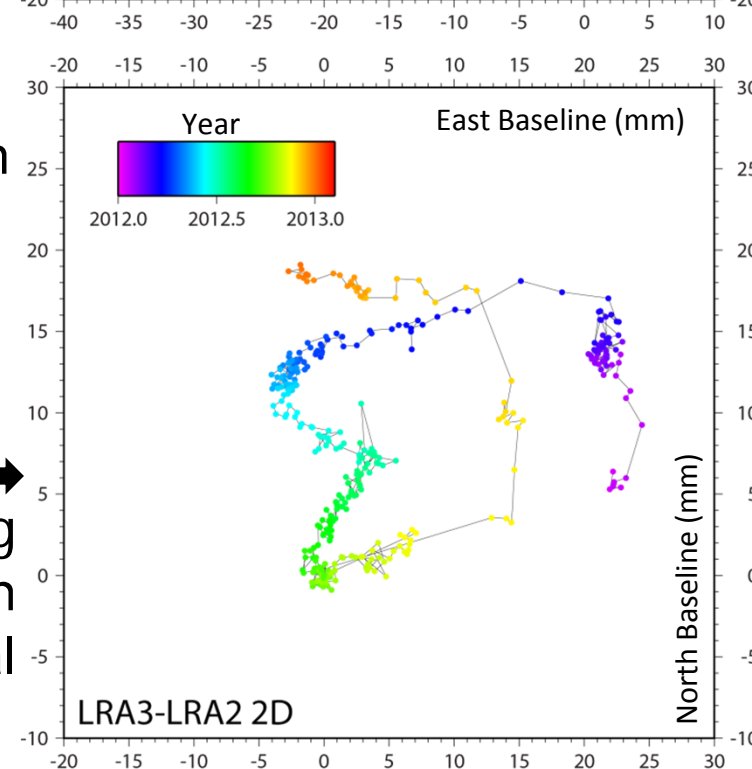
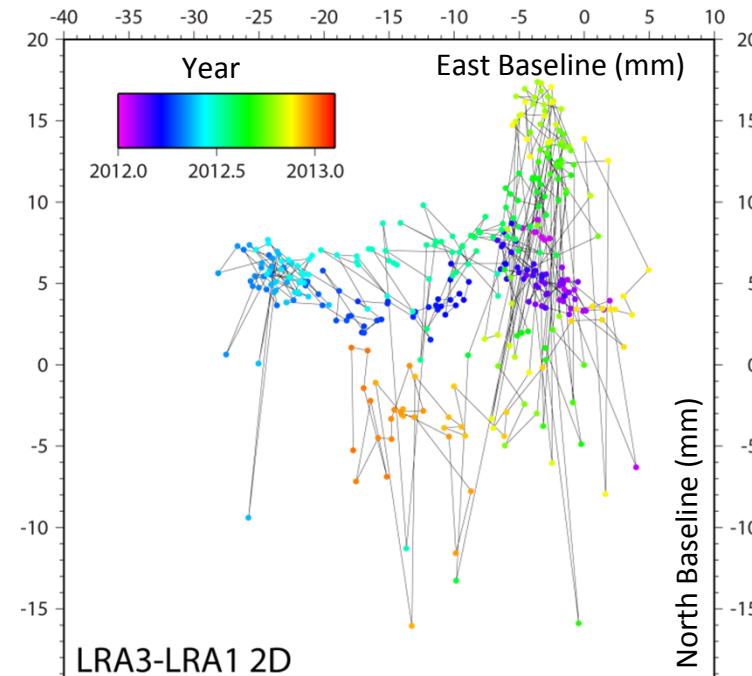
Generally uniform relative displacement of GPS stations



Poor InSAR coverage (TSX 2009-2011) but some suggestion of movement



Stations moving together with slight differential



# Conclusions

## □ InSAR

- X- and C- Bands give good coverage of Permanent Scatterers.
- New algorithms for better ground coverage (SqueeSAR Version 2).
- Expand TerraSAR-X series to overlap GPS study and focus on LBNL.

## □ UAVSAR

- Offers flexibility in flight lines and scene takes.
- Provides good 3D vector solutions of downslope movement.
- L-band provides coherence over larger areas.
- Does not require SqueeSAR type algorithms to extract motion.
- Unwrapping may give low correlation in areas of high relief.

## □ GPS

- Offers better time history of movement.
- Useful tool to proof 3D displacements.



**THANK YOU**

**[jwaeber@berkeley.edu](mailto:jwaeber@berkeley.edu)**