The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

2053-1

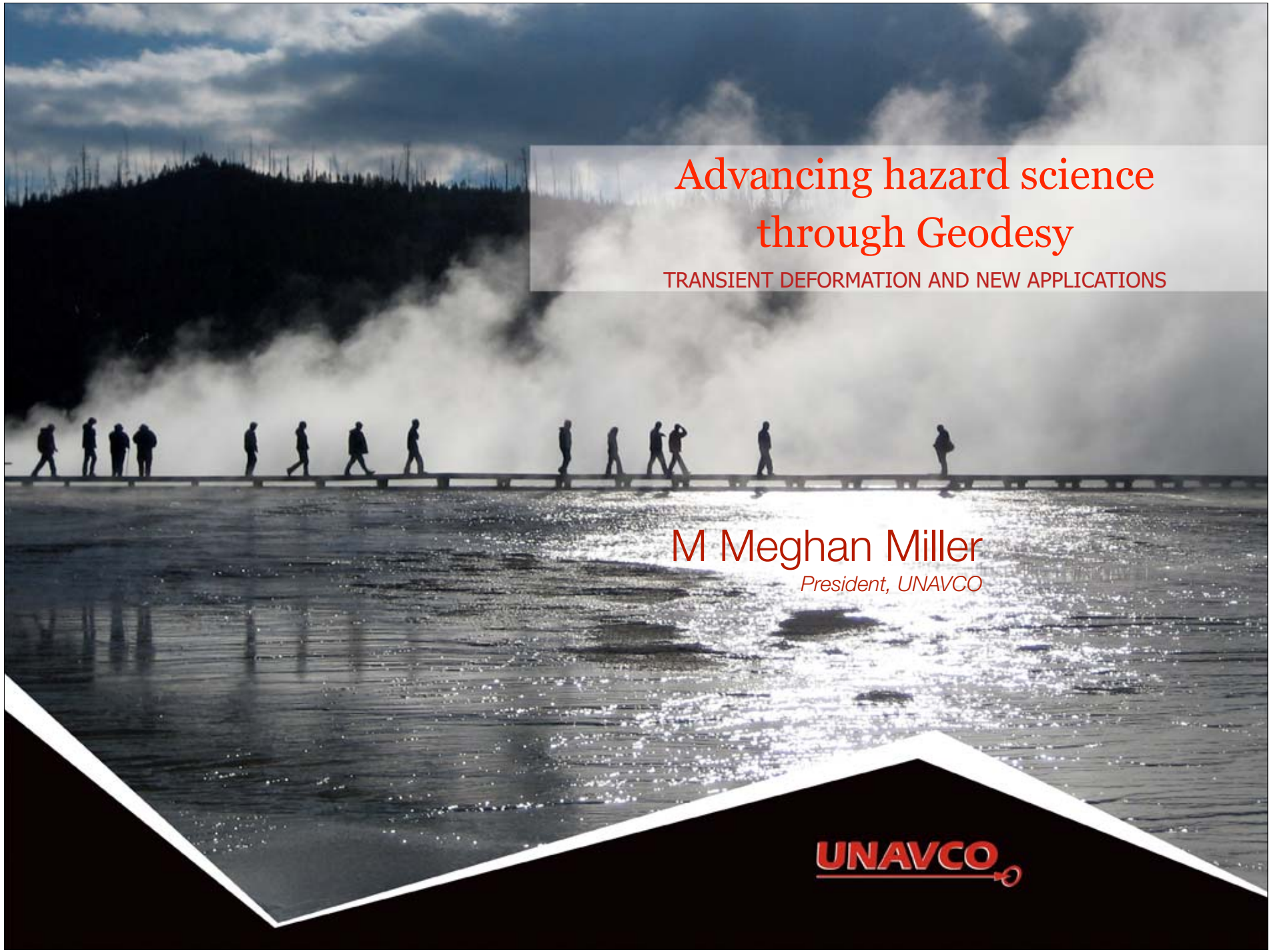
Advanced Workshop on Evaluating, Monitoring and Communicating Volcanic and Seismic Hazards in East Africa

17 - 28 August 2009

Geodesy Advancing Hazards Science

Meghan Miller
UNAVCO
Boulder
USA

Strada Costiera 11, 34151 Trieste, Italy - Tel. +39 040 2240 111; Fax +39 040 224 163 - sci_info@ictp.it, www.


Advancing hazard science
through Geodesy
TRANSIENT DEFORMATION AND NEW APPLICATIONS
M Meghan Miller
President, UNAVCO
UNAVCO

UNAVCO History

1984 University NAVSTAR Consortium – to support the application of GPS geodesy to geoscience problems

NSF Facility; 7 founding member universities wanting to share GPS receivers

1995 NSF – ARI community GPS equipment grant

mobile, high-precision receivers tailored for global geodetic studies

CGPS – time dependent deformation

2001 EarthScope & Plate Boundary Observatory

UNAVCO - an independent, non-profit organization; 23 founding members

2004 UNAVCO Education and Outreach program founded

2009 Plate Boundary Observatory completed; NASA support for GGN; Cryospheric sciences now fully integrated; WInSAR consortium hosted; the geodesy toolbox has expanded: InSAR, LiDAR, and TLS; 84 member institutions and 61 associate members

Science motivation

In order to advance understanding of Earth processes, two major scientific challenges face UNAVCO's research and education community:

- To understand the *dynamic evolution* of the lithosphere, cryosphere, hydrosphere, and atmosphere on temporal scales spanning seconds to millennia.

- To investigate the *processes* that control natural hazards, including earthquakes, tsunamis, volcanic eruptions, and long term changes in climate, ice mass, global sea level, and coastal subsidence.

VISION

We challenge ourselves to transform human understanding of the changing Earth by enabling the integration of innovative technologies, open geodetic observations, and research, from pole to pole.

UNAVCO

Advancing Geoscience

- Scope of activities
- Engineering & Science highlights
  - Global GNSS Network
  - PI science around the world
  - Polar services
  - Plate Boundary Observatory &
  - community data sets
  - Education and Outreach

Scope of UNAVCO Activities

- Project support to community PIs - engineering and data services
- Community equipment pools - GNSS, TLS, ...
- Data Archive - GPS, InSAR, Plate Boundary Observatory data sets
- Community software; Map tools
- Community science products
- Development and testing
- Global GNSS Network & IGS Central Bureau support
- Plate Boundary Observatory – Operations

  GPS, Borehole and laser strainmeters, tiltmeters & seismometers, Software Development & Data Products

  LiDAR, INSar, Geochronology services
- San Andreas Fault Observatory at Depth - Operations
- EarthScope Data Portal
- Community coordination for workshops and leveraged vendor agreements
- UNAVCO Short Course series
- Mentored student internships (such as RESESS)
- Educational workshops; Data for educators; Community curriculum development
- EarthScope education and outreach
- Community proposals

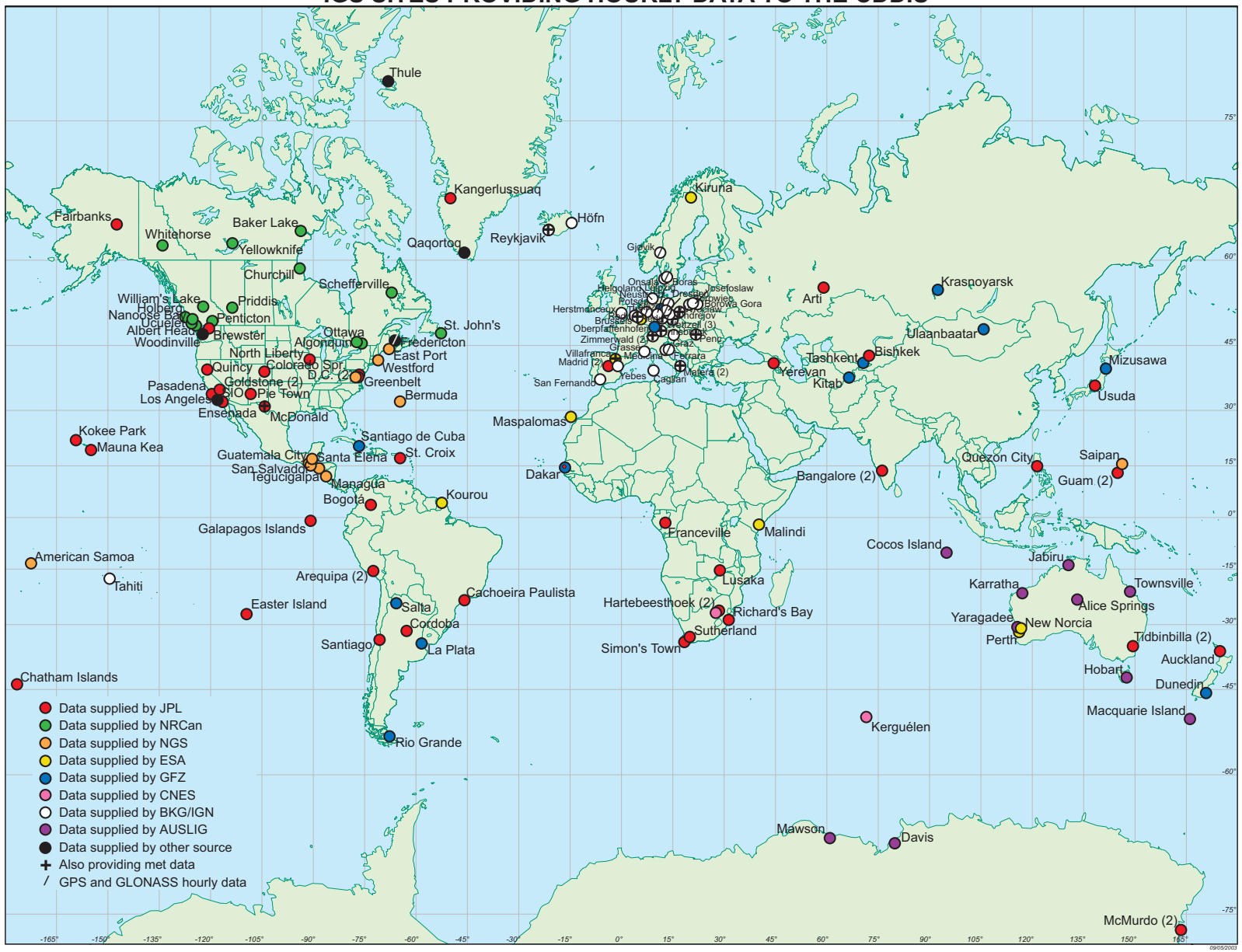
UNAVCO

Advancing Geoscience

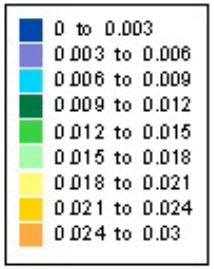
- Scope of activities
- Engineering & Science highlights
  - Global GNSS Network & Data Services
  - PI science around the world
  - Polar services
  - Plate Boundary Observatory &
  - community data sets
  - Education and Outreach

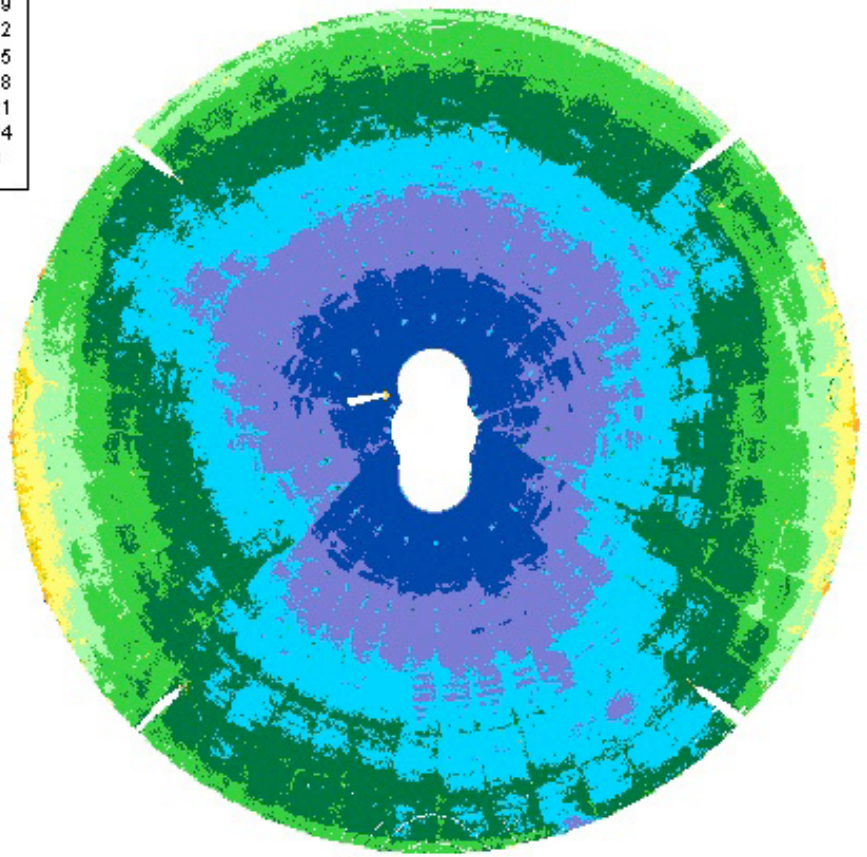
Global GGNS Network

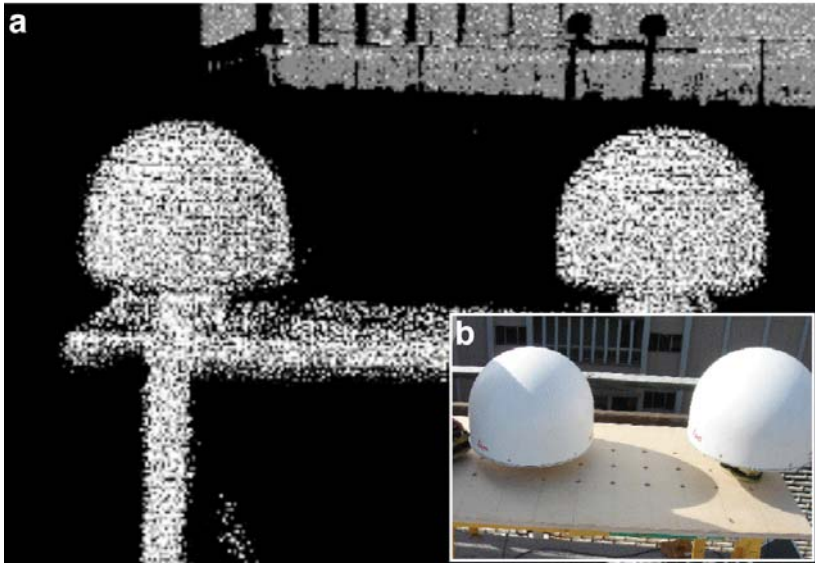
IGS SITES PROVIDING HOURLY DATA TO THE CDDIS



Towards mm-level global geodesy

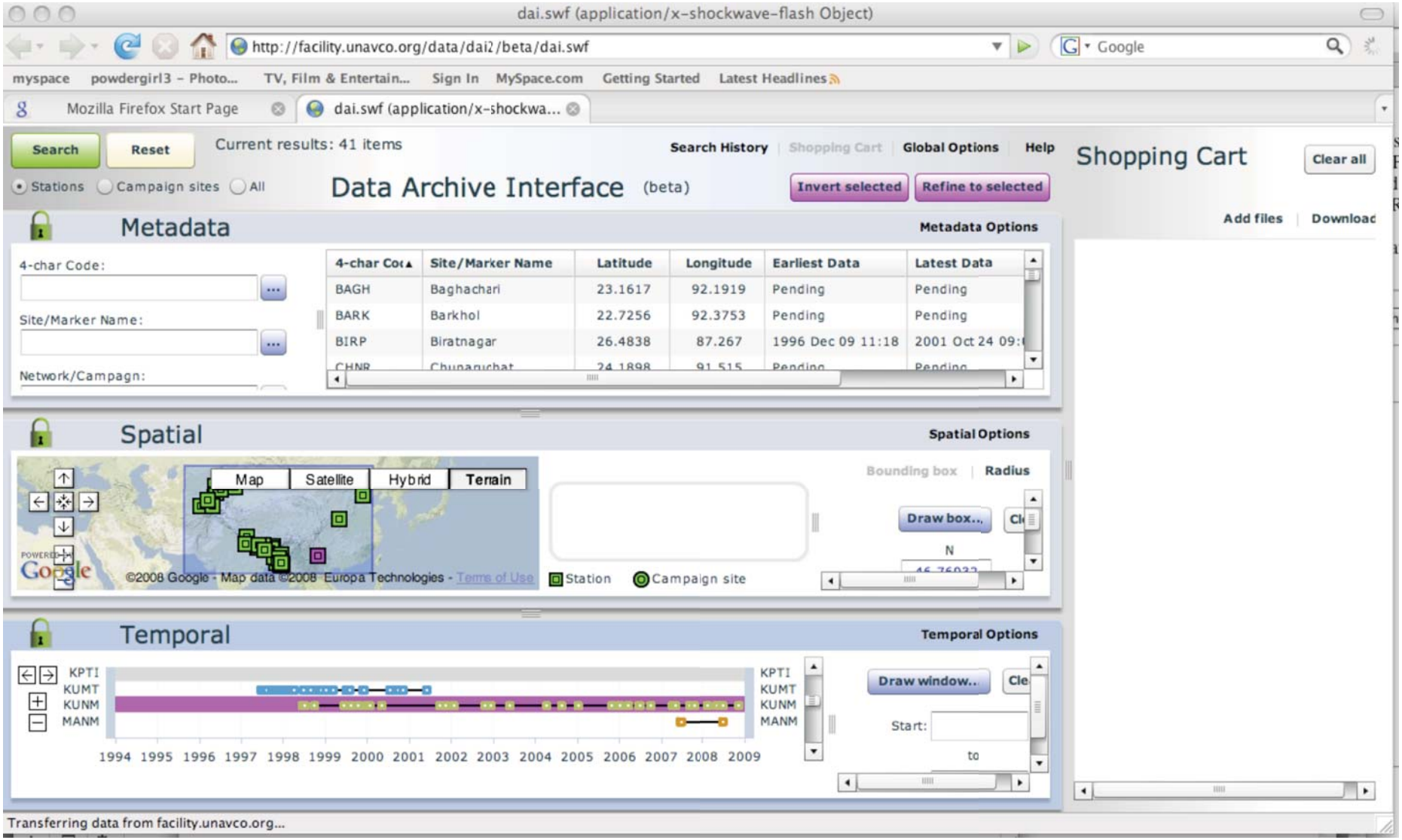






Informal Working Group on Measuring and Monitoring Site Ties

Gipson et al., AGU 2008


dai.swf (application/x-shockwave-flash Object)
http://facility.unavco.org/data/dai2/beta/dai.swf
Google
myspace
powdergirl3 - Photo...
TV, Film & Entertain...
Sign In
MySpace.com
Getting Started
Latest Headlines
Mozilla Firefox Start Page
dai.swf (application/x-shockwa...
Search
Reset
Current results: 41 items
Search History
Shopping Cart
Global Options
Help
Stations
Campaign sites
All
Data Archive Interface
(beta)
Invert selected
Refine to selected
Shopping Cart
Clear all
Add files
Download
Metadata
Metadata Options
4-char Code:
Site/Marker Name:
Network/Campagn:
4-char Co
Site/Marker Name
Latitude
Longitude
Earliest Data
Latest Data
BAGH
Baghachari
23.1617
92.1919
Pending
Pending
BARK
Barkhol
22.7256
92.3753
Pending
Pending
BIRP
Biratnagar
26.4838
87.267
1996 Dec 09 11:18
2001 Oct 24 09:
Spatial
Spatial Options
Map
Satellite
Hybrid
Terrain
©2008 Google - Map data ©2008 Europa Technologies - Terms of Use
Bounding box
Radius
Draw box...
N
Station
Campaign site
Temporal
Temporal Options
KPTI
KUMT
KUNM
MANM
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009
Draw window..
Start:
to
Transferring data from facility.unavco.org...

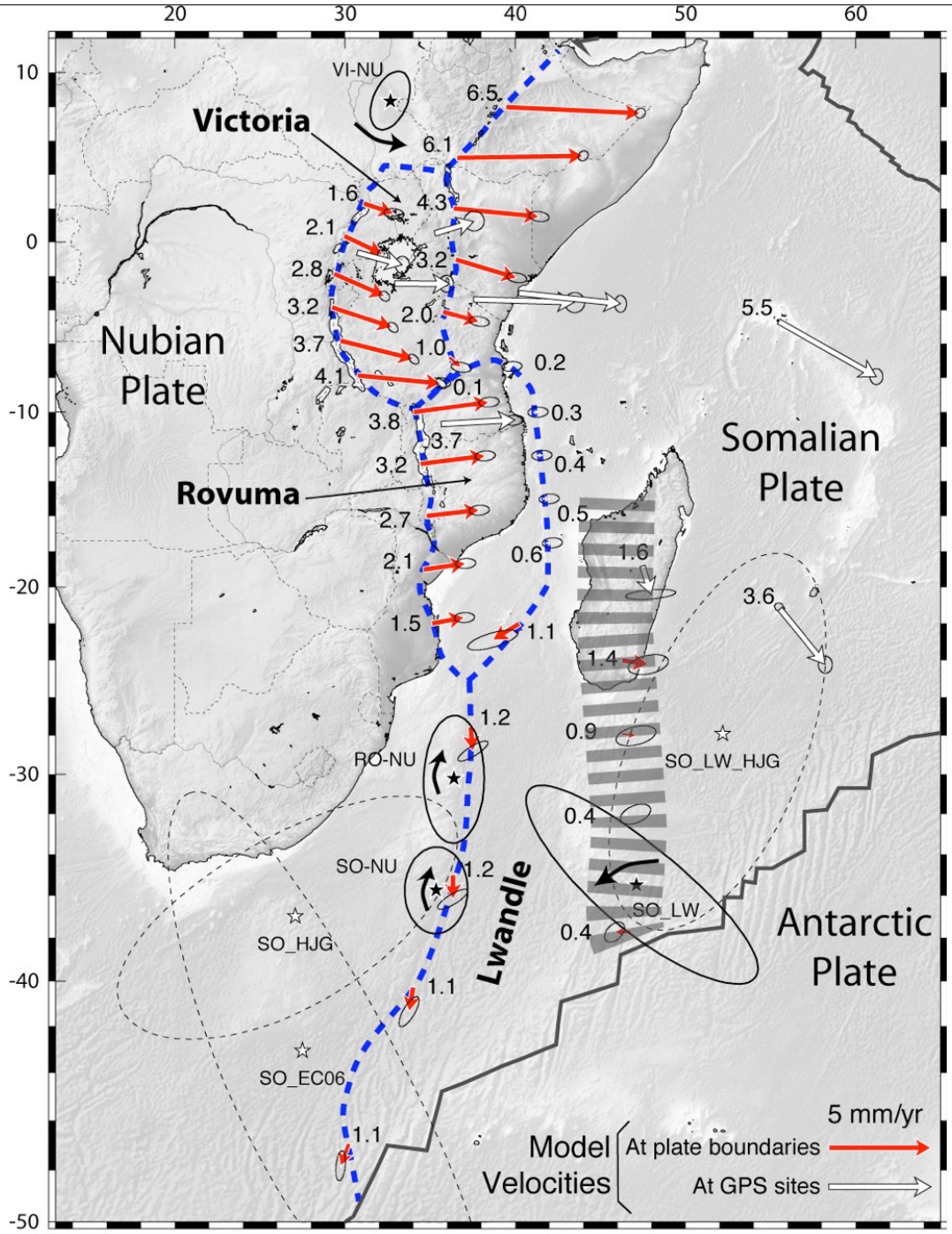
UNAVCO

Advancing Geoscience

- Scope of activities
- Engineering & Science highlights
  - Global GNSS Network & Data Services
  - PI science around the world
  - Polar services
  - Plate Boundary Observatory &
  - community data sets
  - Education and Outreach

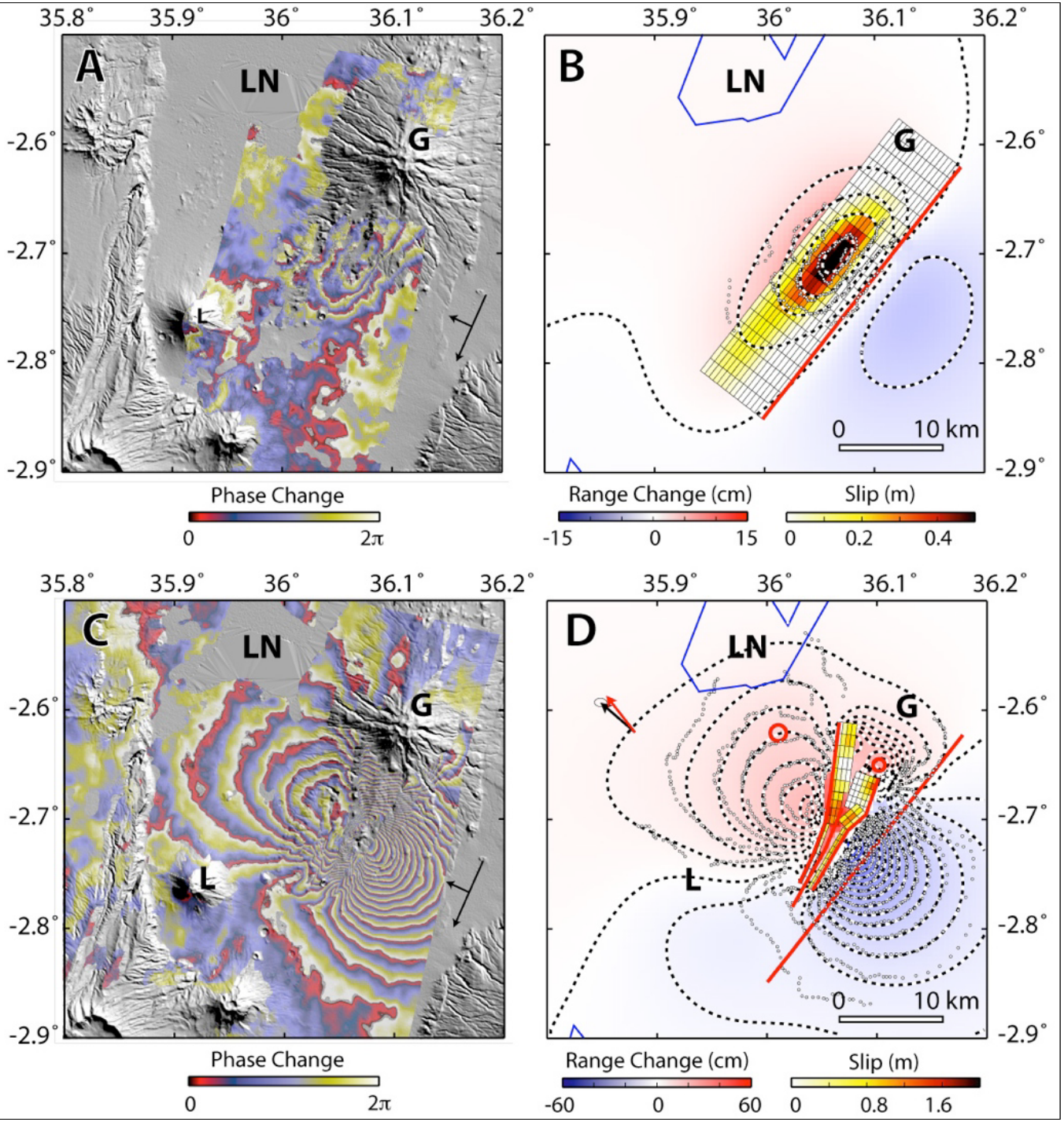
Doris/GPS/Slip vectors agree with 3.2 Ma average and transform azimuth constraints

Joint inversion reveals 3 coherent sub-plates separated by localized rifting



Stamps, D.S., E. Calais, E. Saria, C. Hartnady, J. Nocquet, C.J. Ebinger, and R.M. Fernandes, A kinematic model for the East African Rift, GRL 2008.

Strain partitioning by magma intrusion and faulting



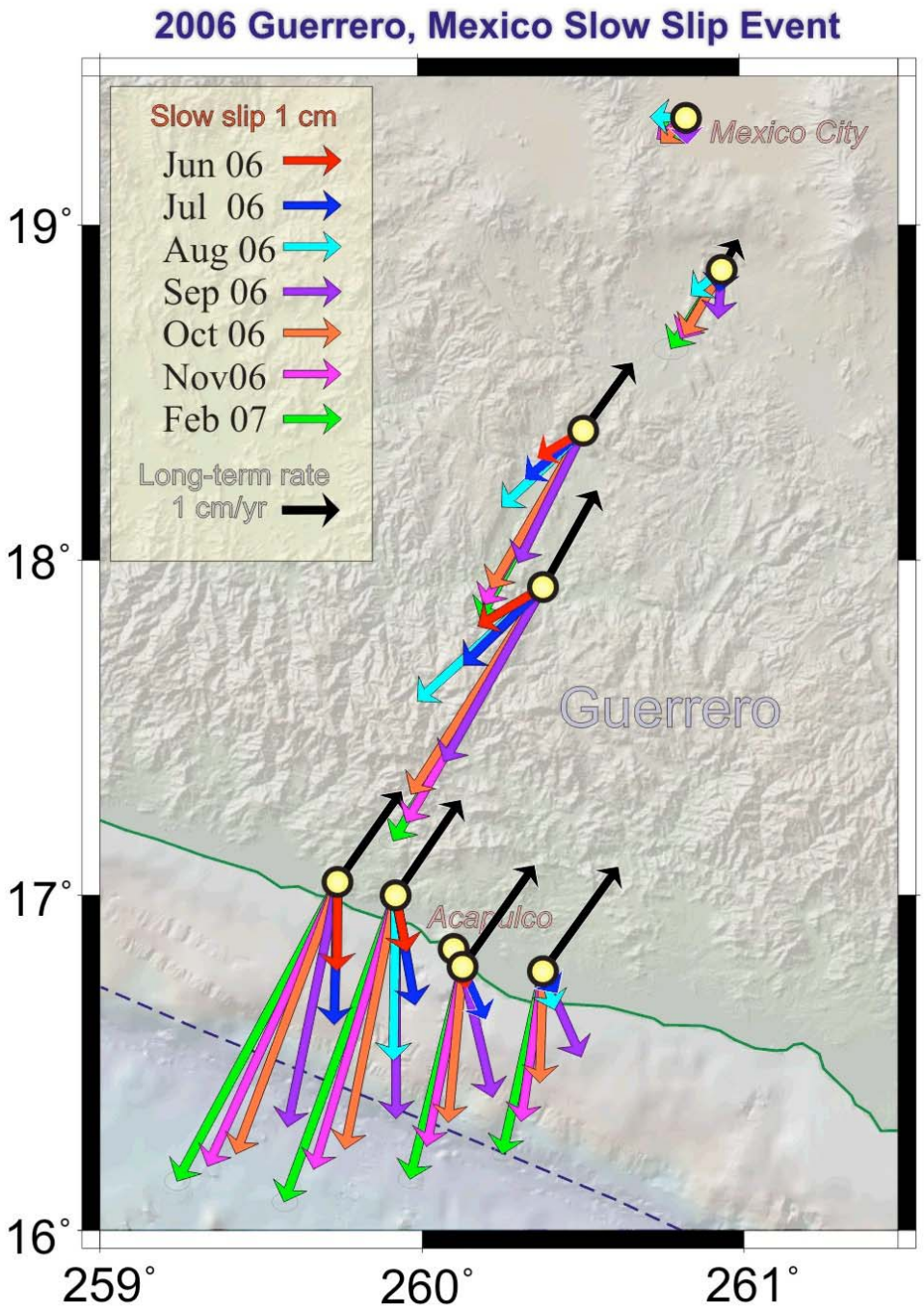
Calais and others,

Aseismic strain accommodation by dyking in a youthful continental rift, East Africa,

Nature, 2008

Transient slip on the Middle America subduction zone over 9 months

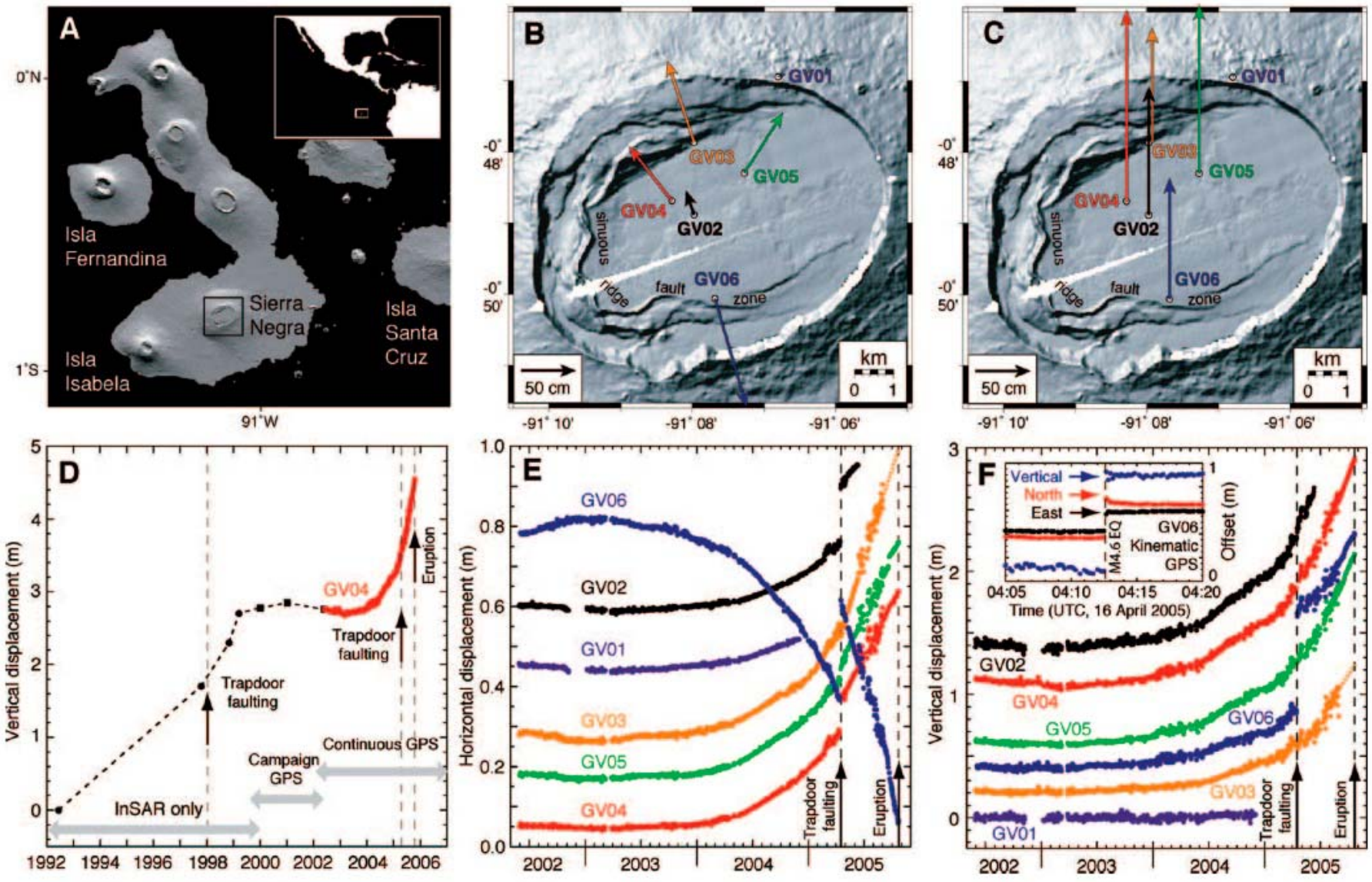
Accumulated displacement of up to 6 cm; Mw equivalent ≥ 7.5



Larson, K. M.,
V. Kostoglodov,
S. Miyazaki, and
J. Santiago,

An Aseismic Slow Slip Event
in Guerrero, Mexico:
new results from GPS,

GRL, 2007



Geist et al., 2008;
Chadwick et al., 2006

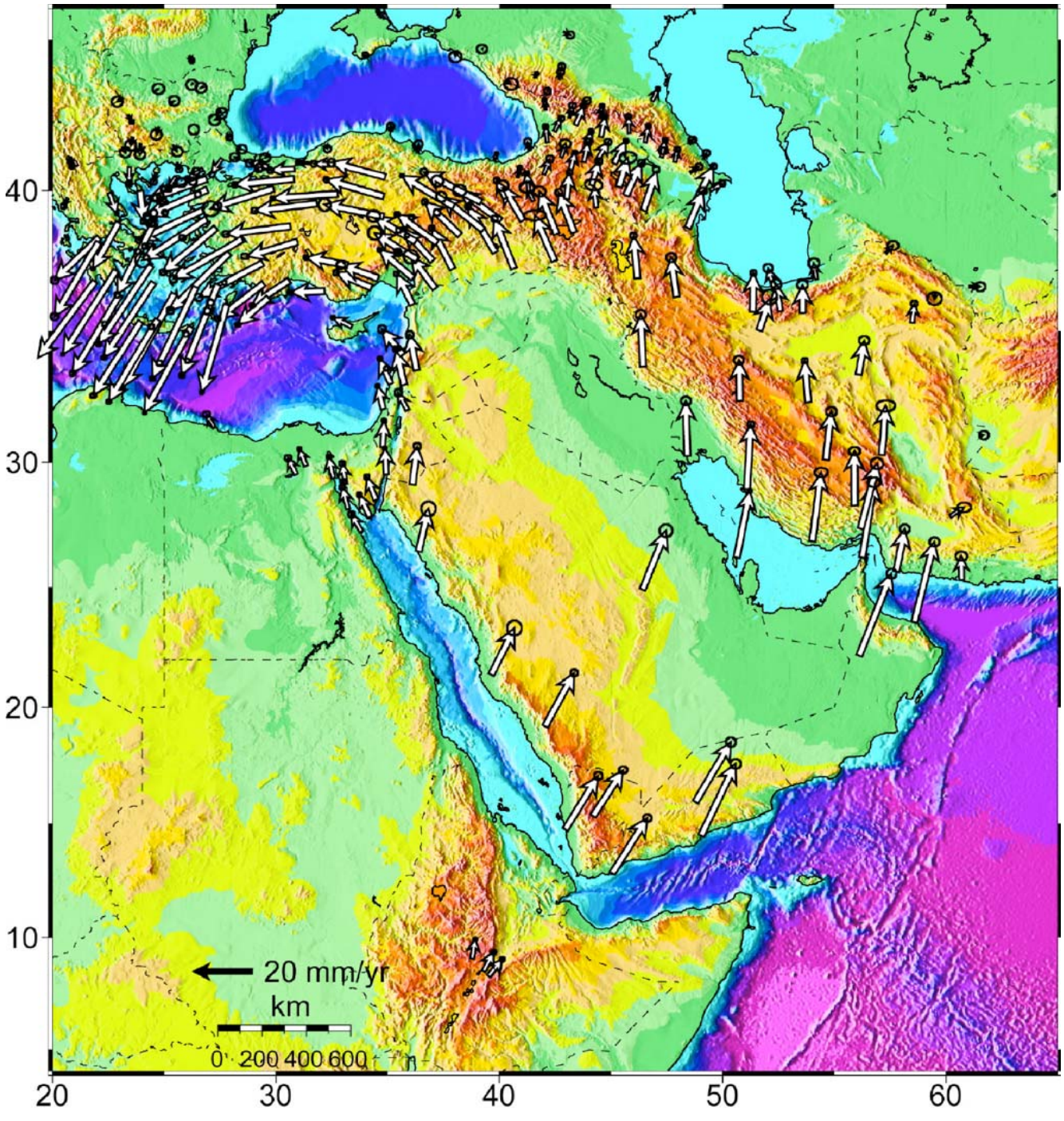
Galapagos Sierra Negra eruption, October 22-30, 2005
Inflation, faulting and eruption are intimately intertwined

Mediterranean/Middle East Crustal Motion Observatory (MECMO) Eurasia fixed reference frame.

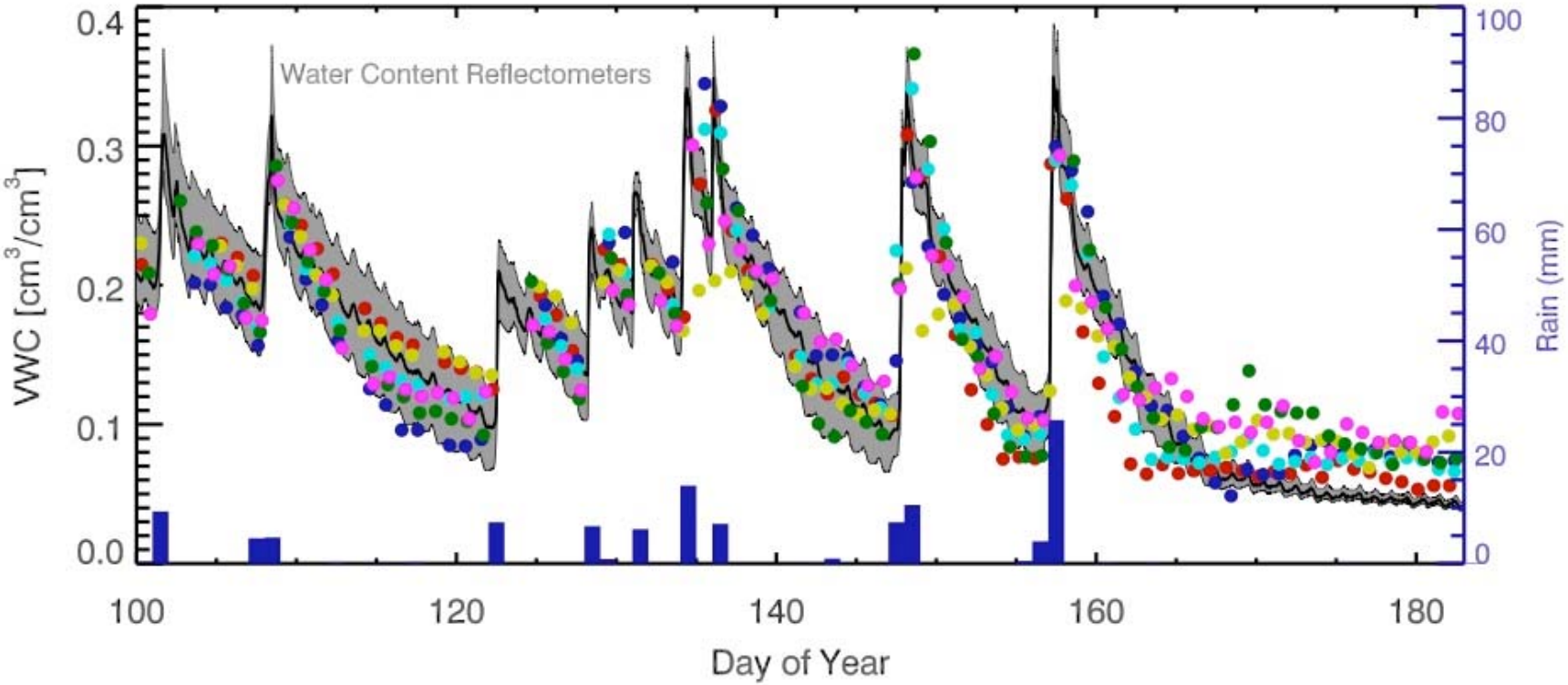
Constrains active tectonic processes in the Arabia-Africa-Eurasia continental collision zone with over 400 references in the published literature.

As part of this NSF funded project, MIT has transferred high precision GPS technology to 14 host-country partners in the Mediterranean, Middle East, and North Africa.

Reilinger et al., 2006

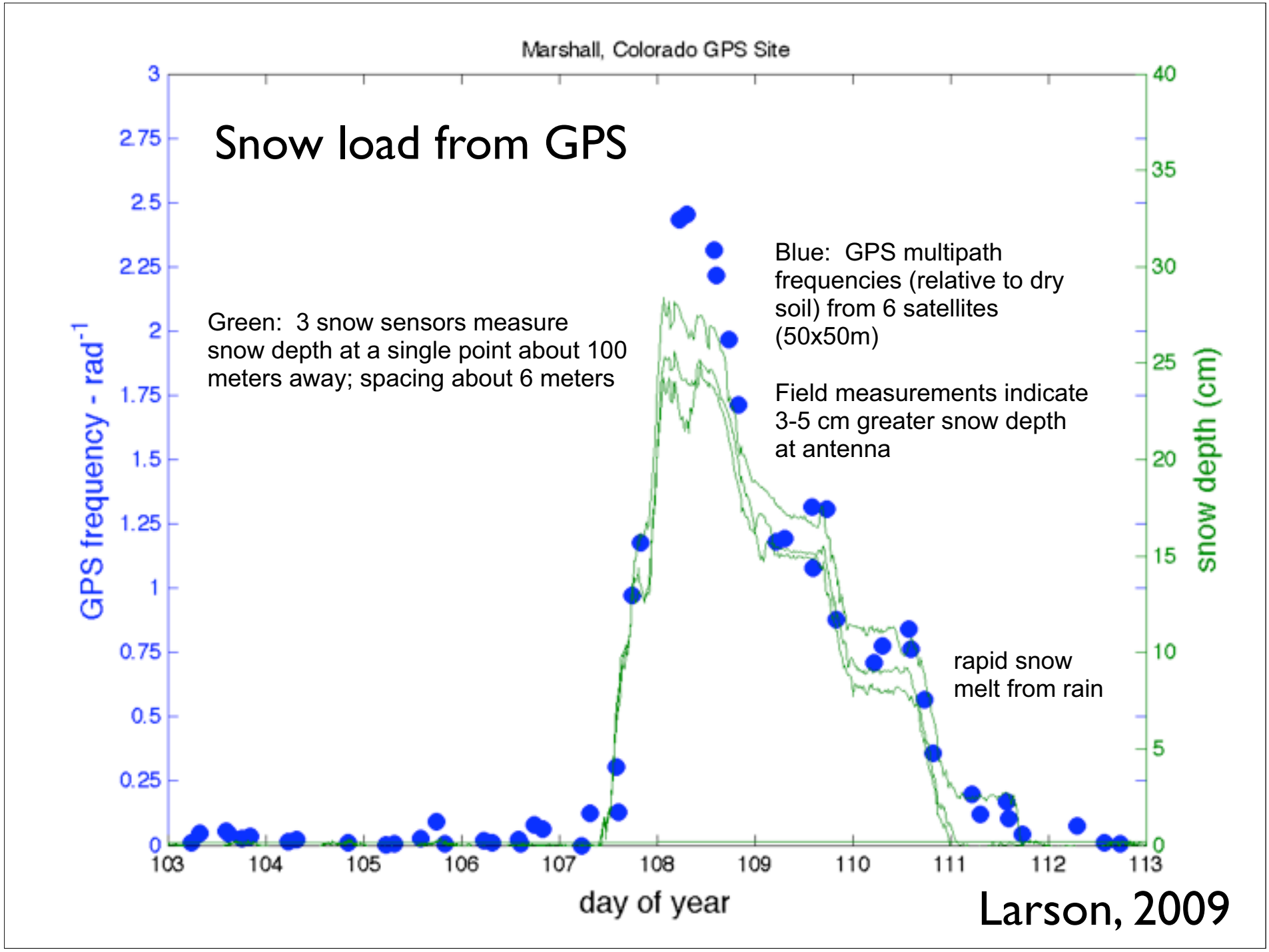


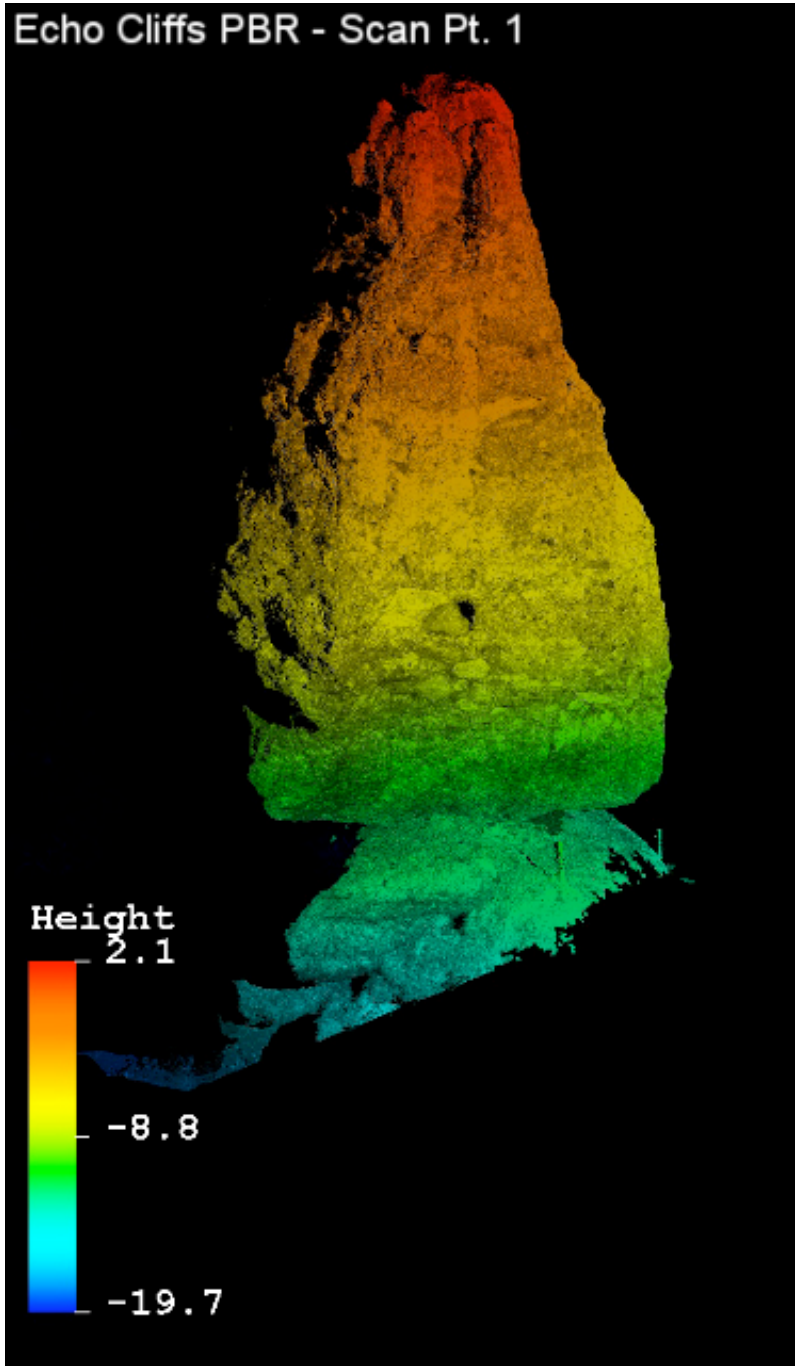
Soil moisture content from GPS



Variation in volumetric water content (VWC) inferred from multiple GPS satellites (colors) and water content reflectometers (gray; average shown by black line). Daily precipitation totals in blue.

Larson et al., 2008

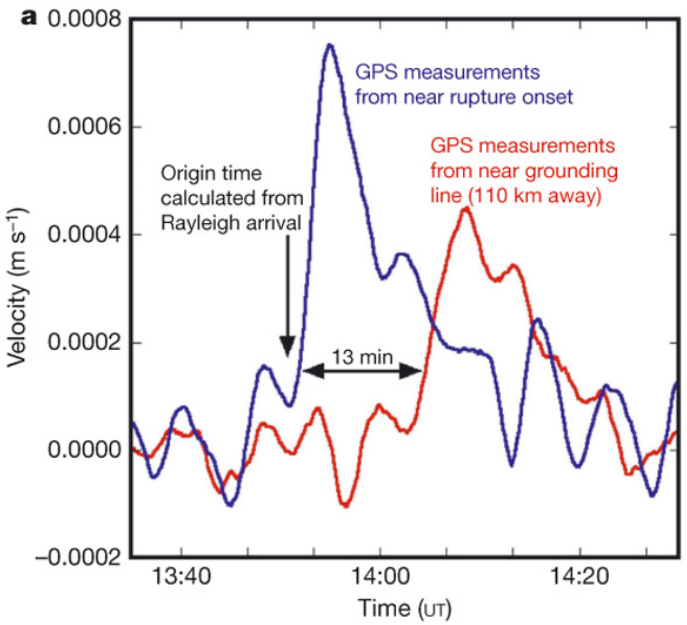

Marshall, Colorado GPS Site
Snow load from GPS
Green: 3 snow sensors measure snow depth at a single point about 100 meters away; spacing about 6 meters
Blue: GPS multipath frequencies (relative to dry soil) from 6 satellites (50x50m)
Field measurements indicate 3-5 cm greater snow depth at antenna
rapid snow melt from rain
GPS frequency - rad^{-1}
snow depth (cm)
day of year
3
2.75
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
40
35
30
25
20
15
10
5
0
103
104
105
106
107
108
109
110
111
112
113
Larson, 2009

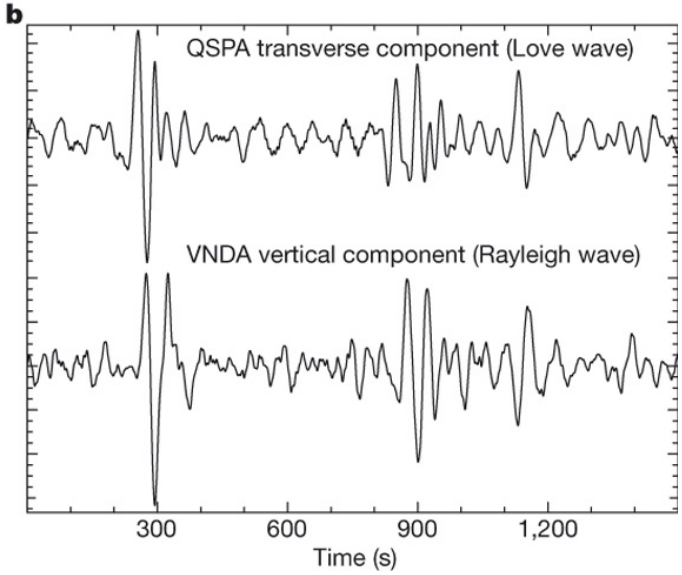

Echo Cliffs PBR - Scan Pt. 1
Height
2.1
-8.8
-19.7

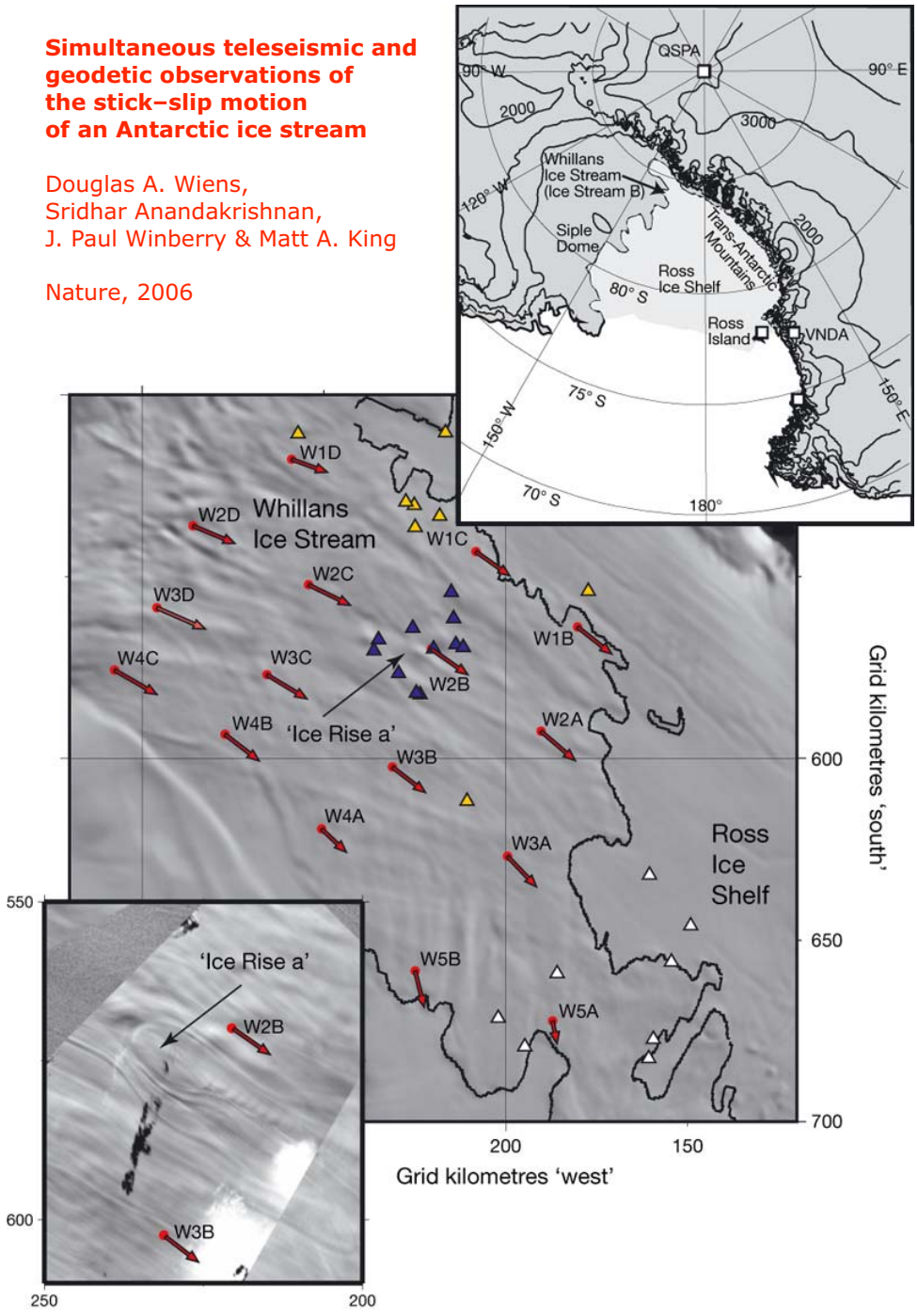
Simultaneous teleseismic and geodetic observations of the stick–slip motion of an Antarctic ice stream

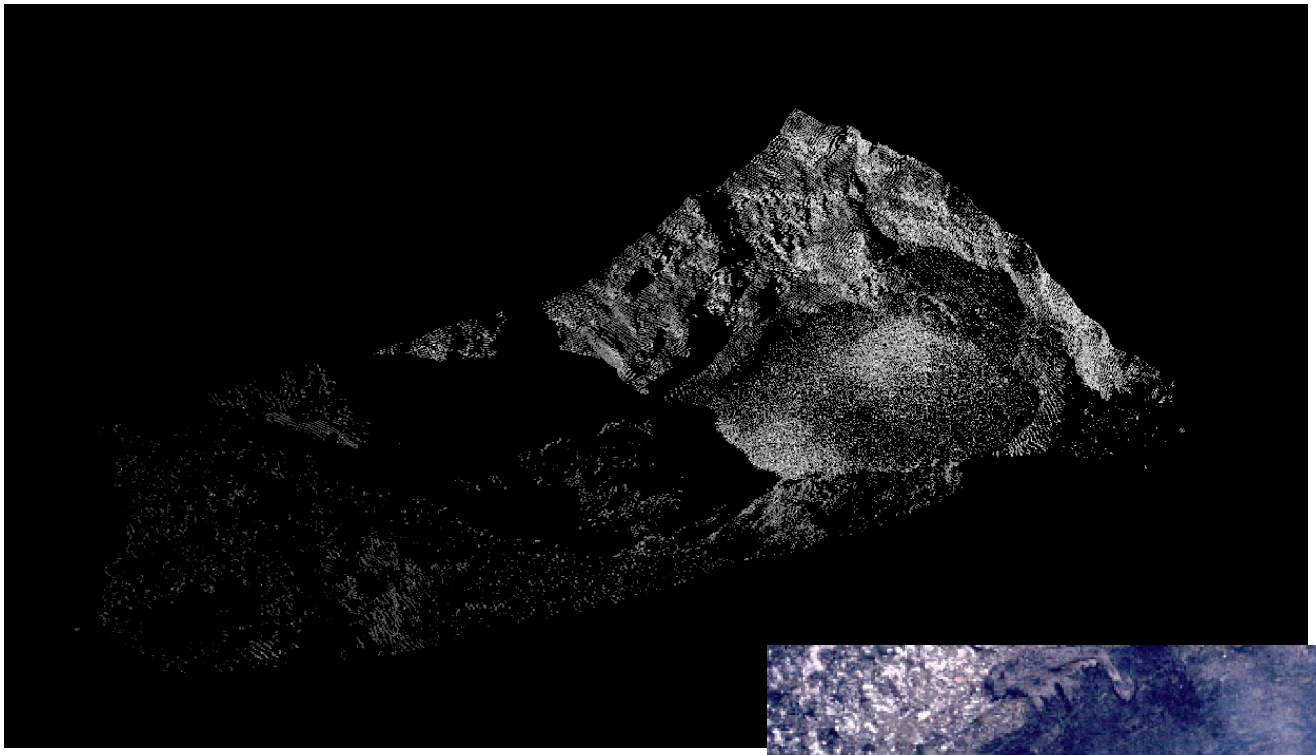
Douglas A. Wiens,
Sridhar Anandakrishnan,
J. Paul Winberry & Matt A. King

Nature, 2006



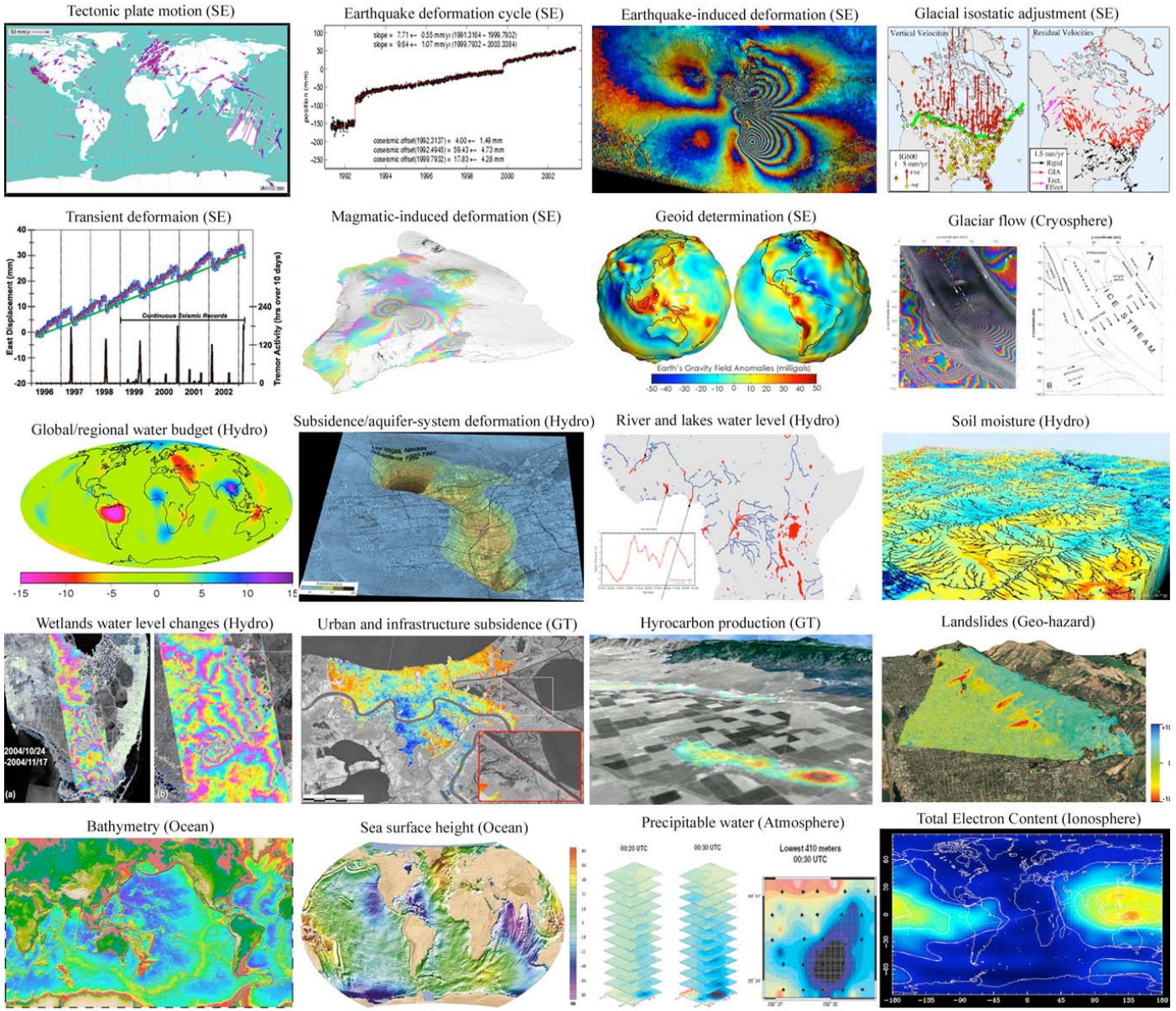






2009 TLS survey of Mt Erebus

Applications



Wdowinski & Eriksson, Eos, 2009

UNAVCO

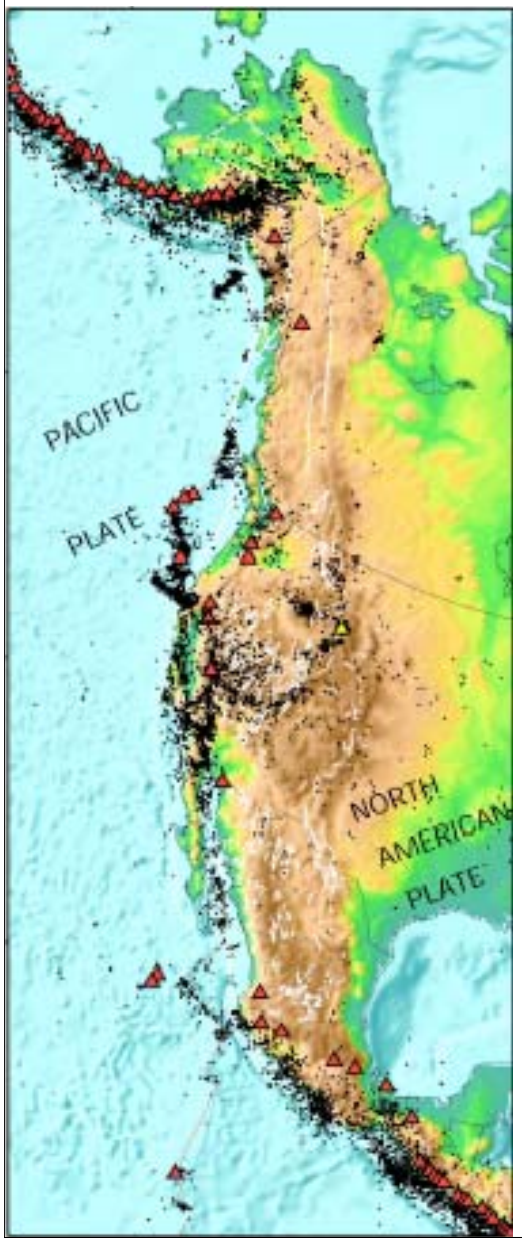
Advancing Geoscience

- Scope of activities
- Engineering & Science highlights
  - Global GNSS Network
  - PI science around the world
  - Polar services
  - Plate Boundary Observatory &
  - community data sets
  - Education and Outreach

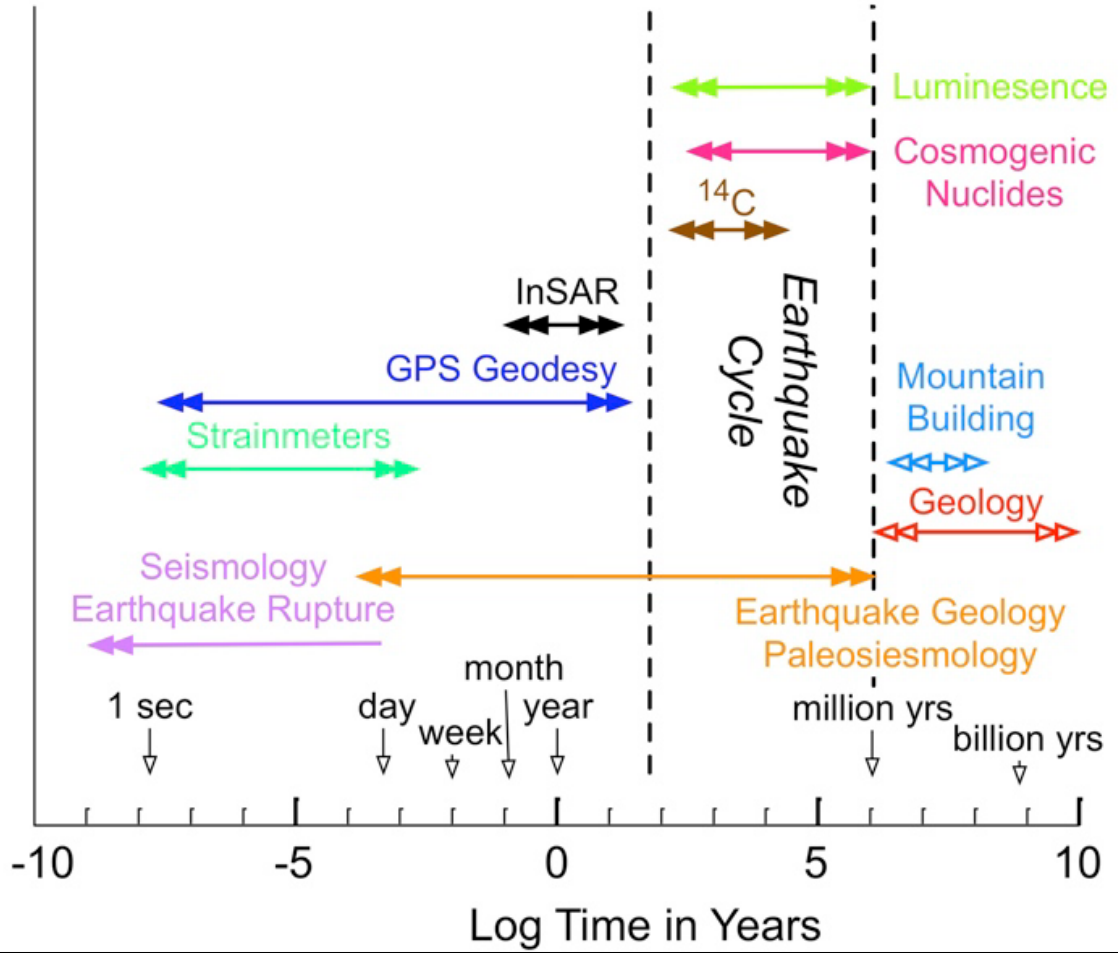
PBO Science Questions

- What are the forces and processes driving deformation at plate boundaries and in plate interiors?
- What is the rheological structure of the lithosphere and where is its strength?
- What drives strain release on active faults?
- Is there long-term transient deformation within the plate boundary zone? At what characteristic temporal scales? What are the underlying causes?
- How is magma transported within the crust and to the surface?
- How can we reduce risk associated with earthquakes and volcanic eruptions?

The temporal scales of Geodesy



- Instruments chosen for PBO Observatory cover broad frequency range
- For the study of the four-dimensional strain field



A new Community Toolbox

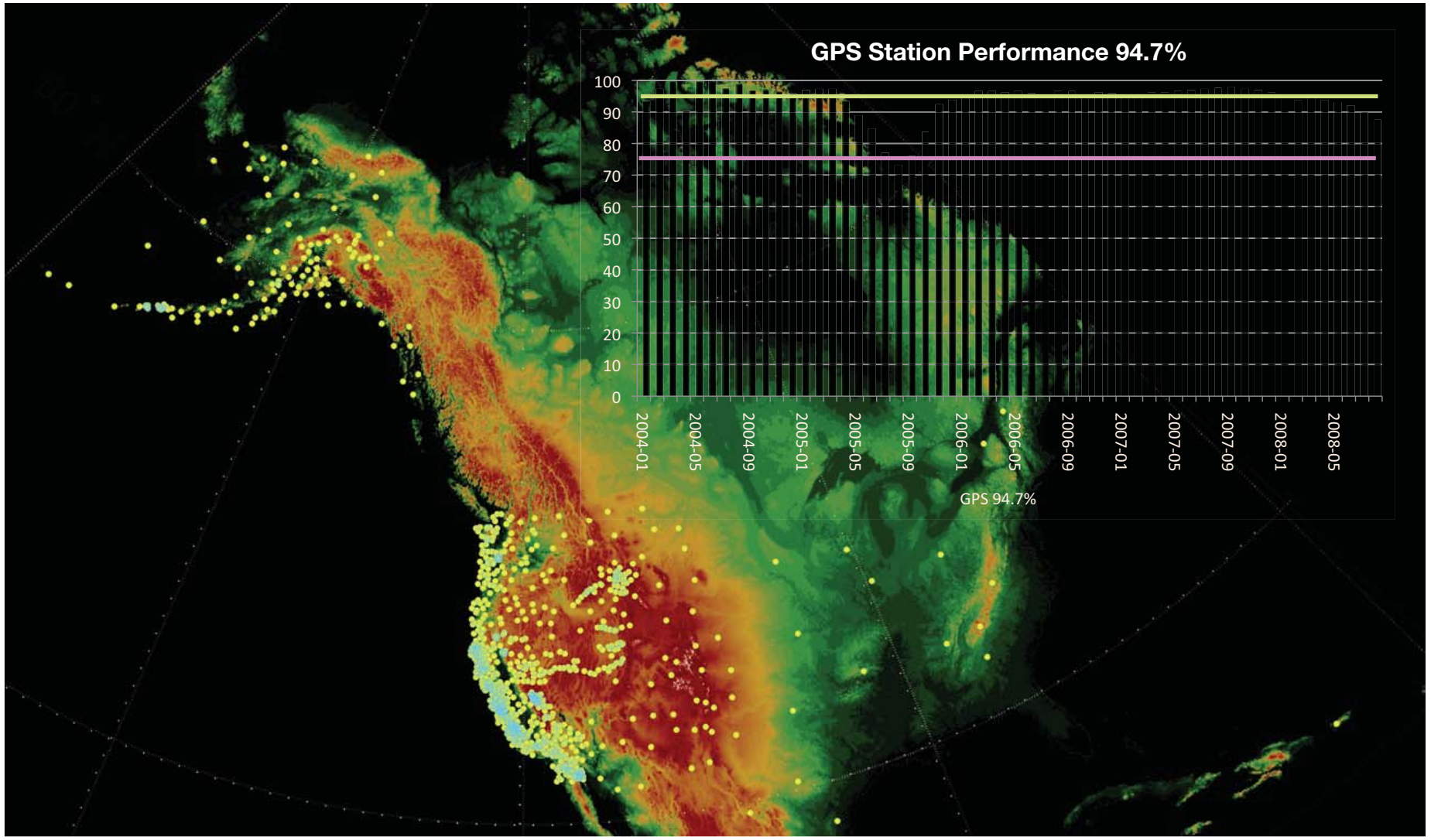
Plate Boundary Observatory

- Continuous GPS & data products (1100)
- High rate, low-latency (real time) GPS (~100+)
- Campaign GPS equipment pool (100)
- Borehole strain meters (74)
- Borehole seismometers (78)
- Long baseline strain meters (5)
- Tilt meters (26)

- ## Geo EarthScope
  - InSAR (15.3 Tb archive & DESDynI development)
  - LiDAR (covering 4,842 km^2)
  - Geochronology (7 techniques at 12 different labs)
- ## EarthScope and UNAVCO
  - EarthScope and PBO Education and Outreach
  - EarthScope Portal & pathways to USArray, SAFOD data
  - SAFOD operations

PBO GPS Buildout

GPS Network Performance



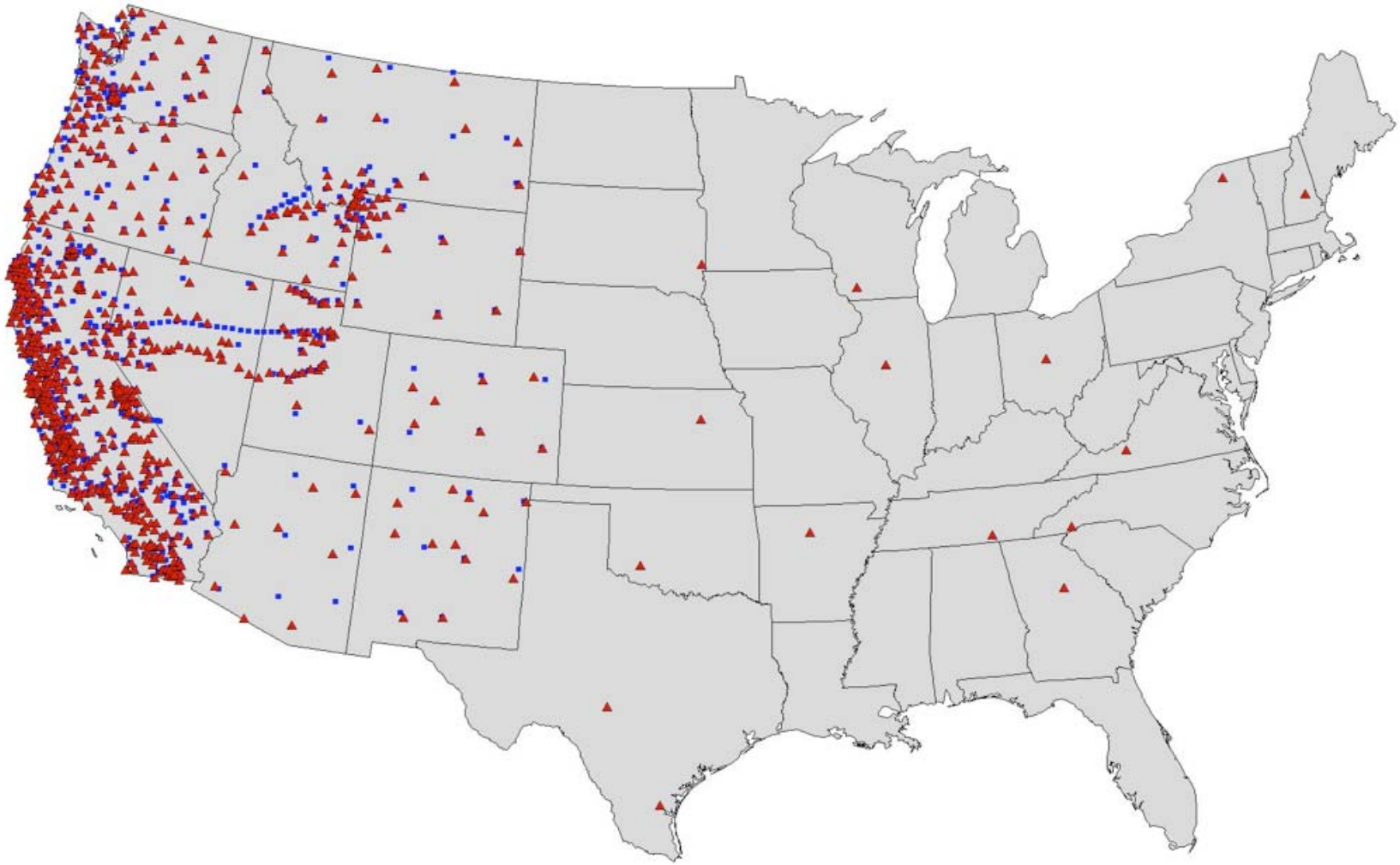
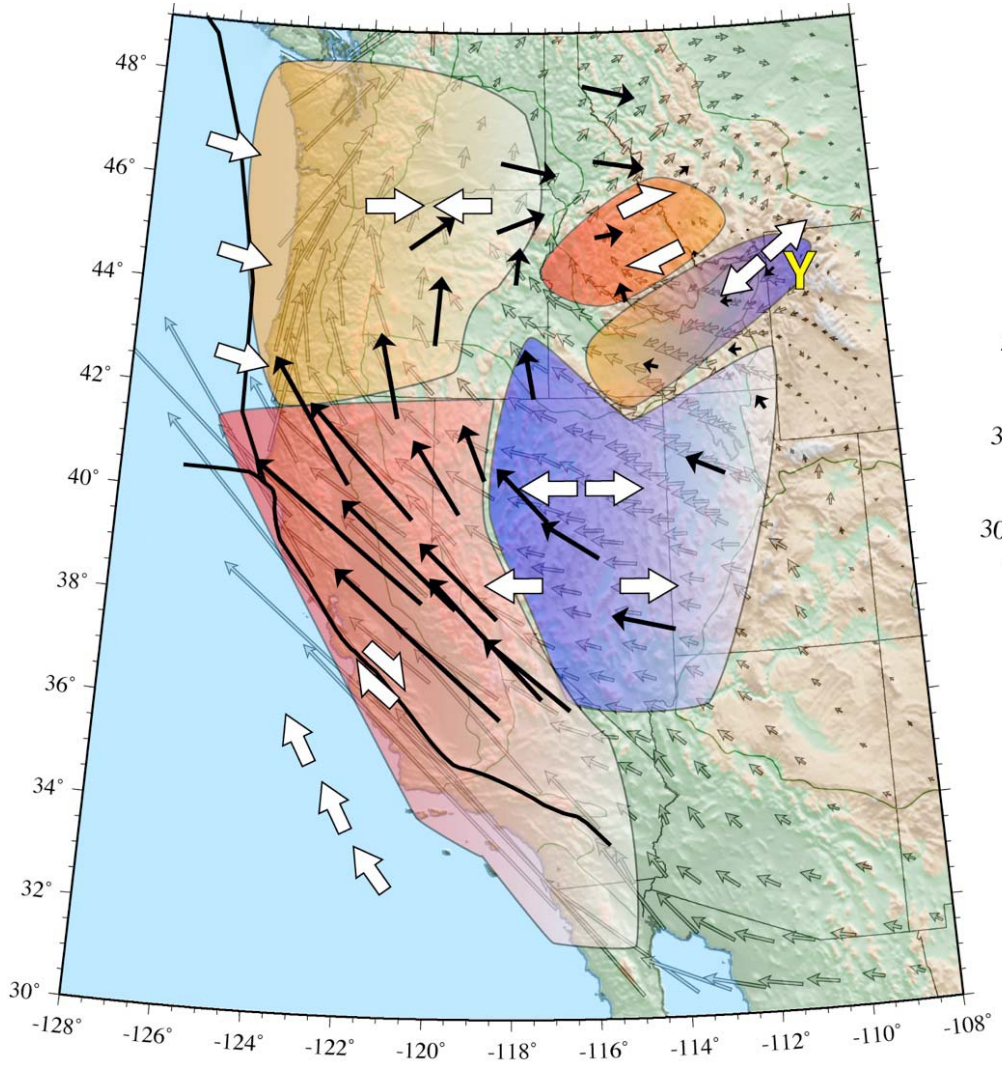
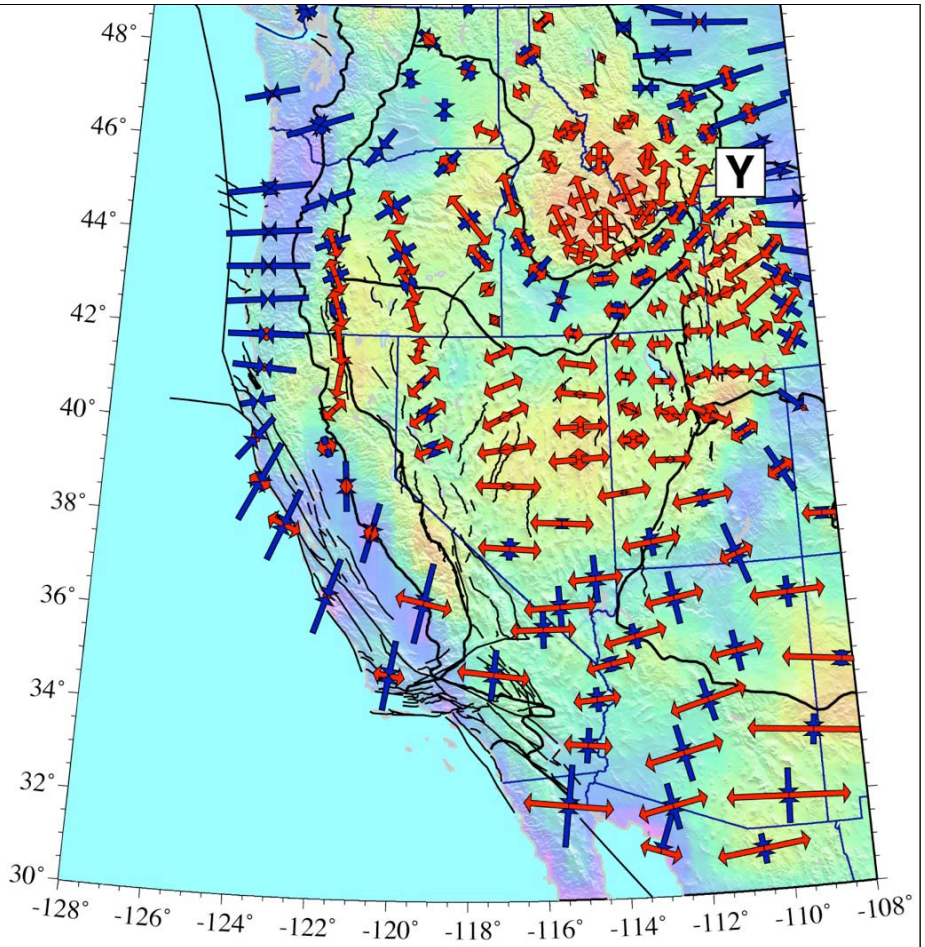


Plate scale kinemaics and geodynamics

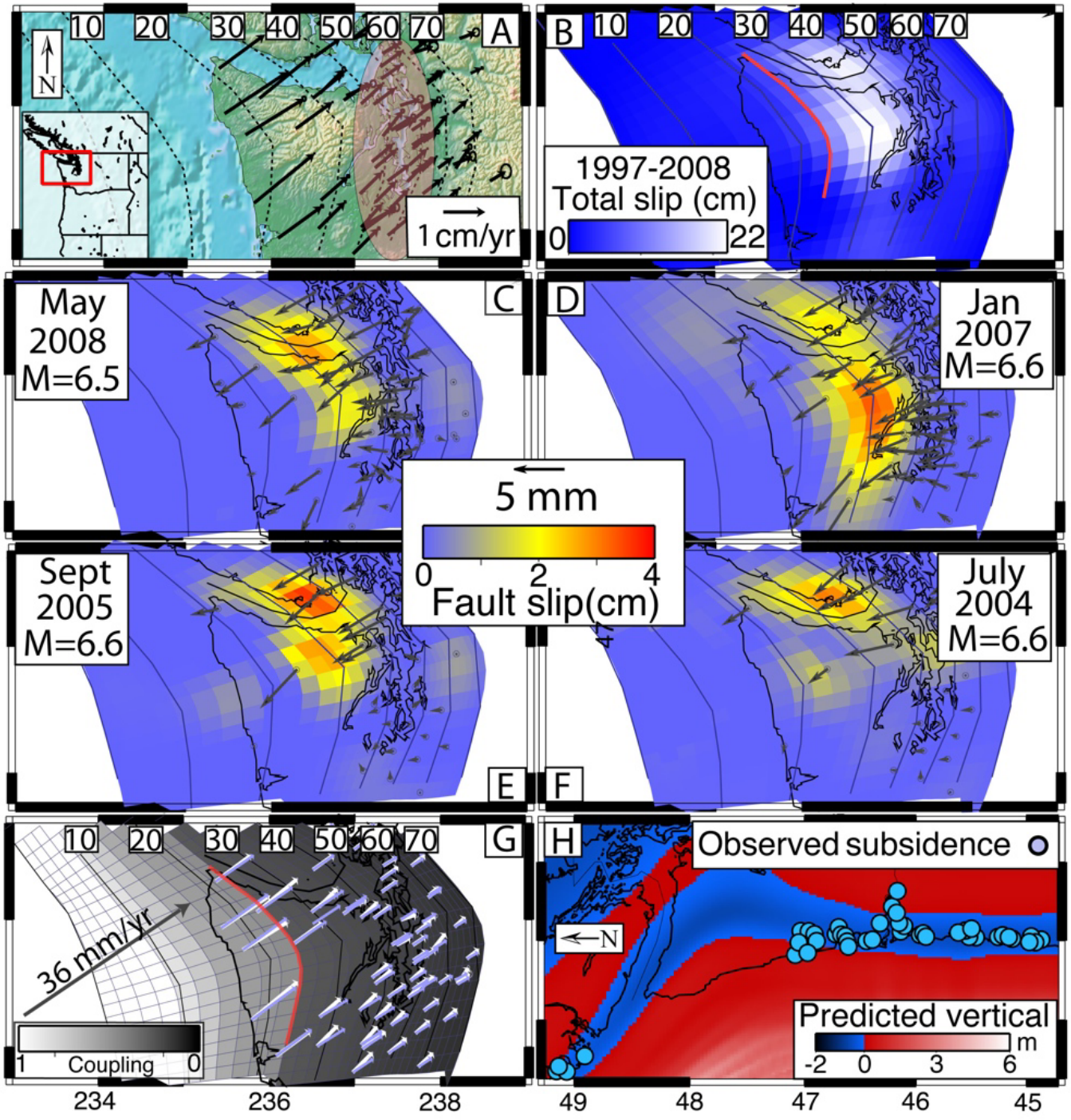




Christine Puskas et al.,,

2009

Cascadia Slow Slip



Chapman & Melbourne,

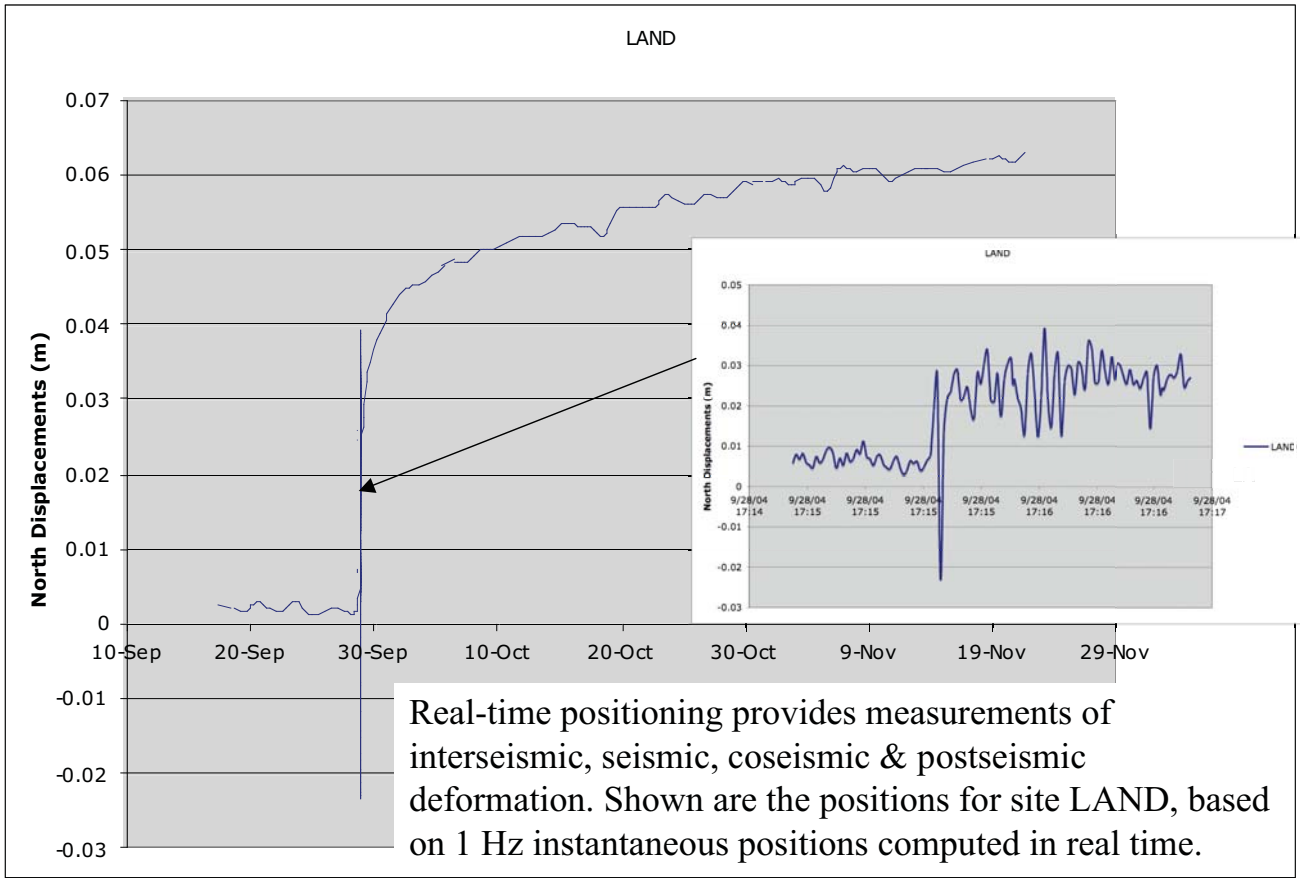
2009

Langbein and Bock, 2004

6 mm displacements in 1Hz data by differential solution...

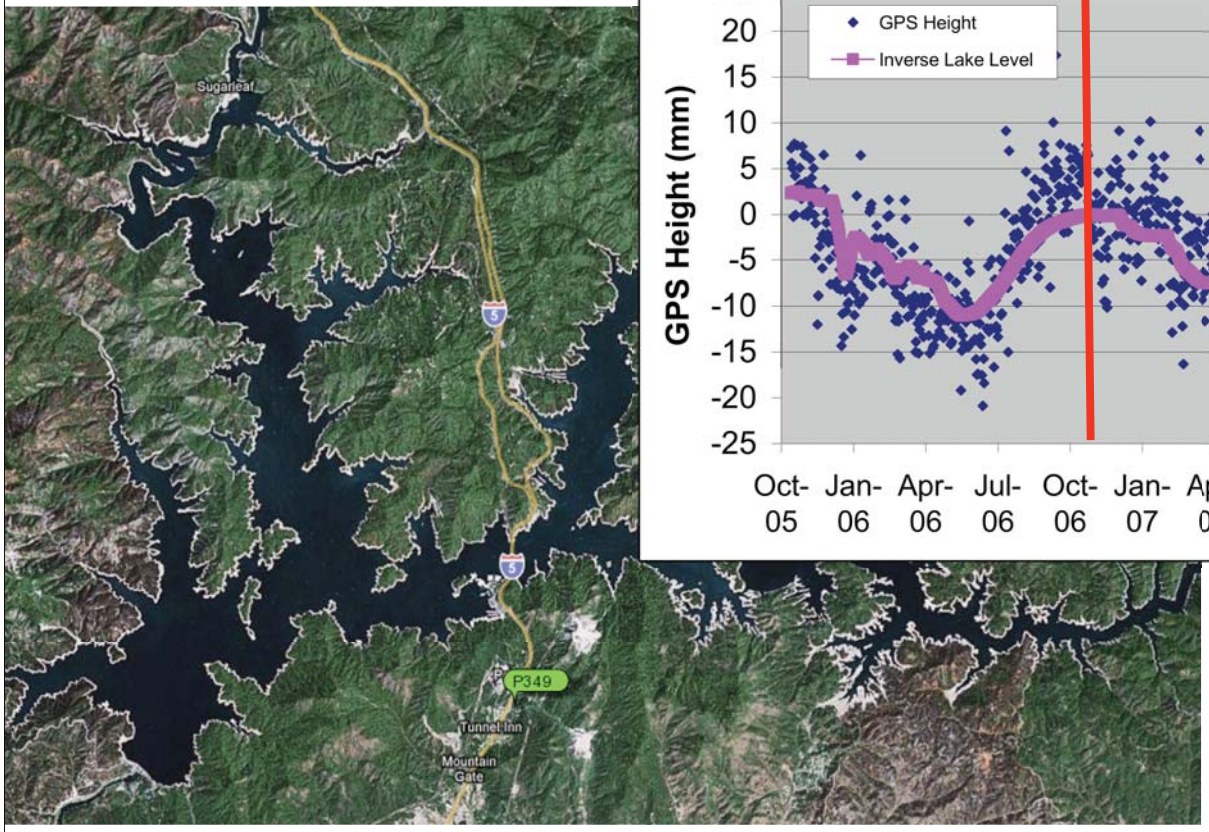
.... now performing epoch by epoch, on-the-fly network solutions

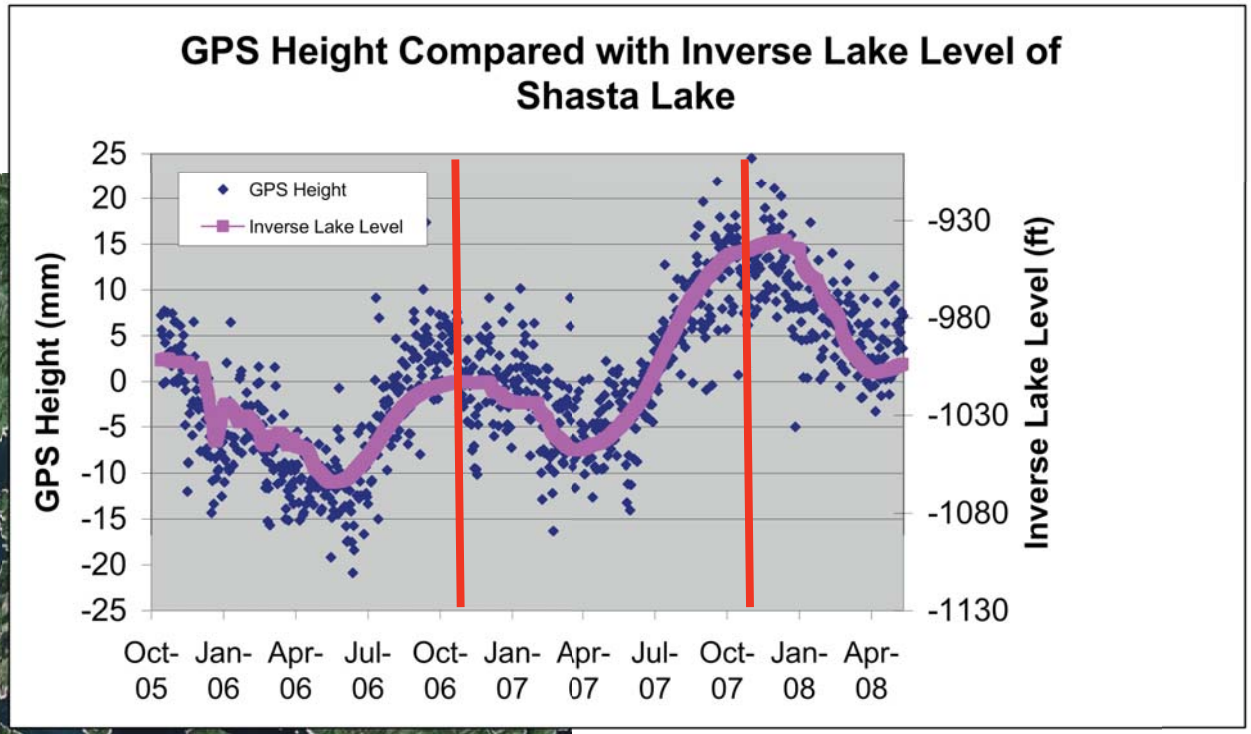
9/28/04 Mw=6.0 Parkfield Earthquake



Real-time positioning provides measurements of interseismic, seismic, coseismic & postseismic deformation. Shown are the positions for site LAND, based on 1 Hz instantaneous positions computed in real time.

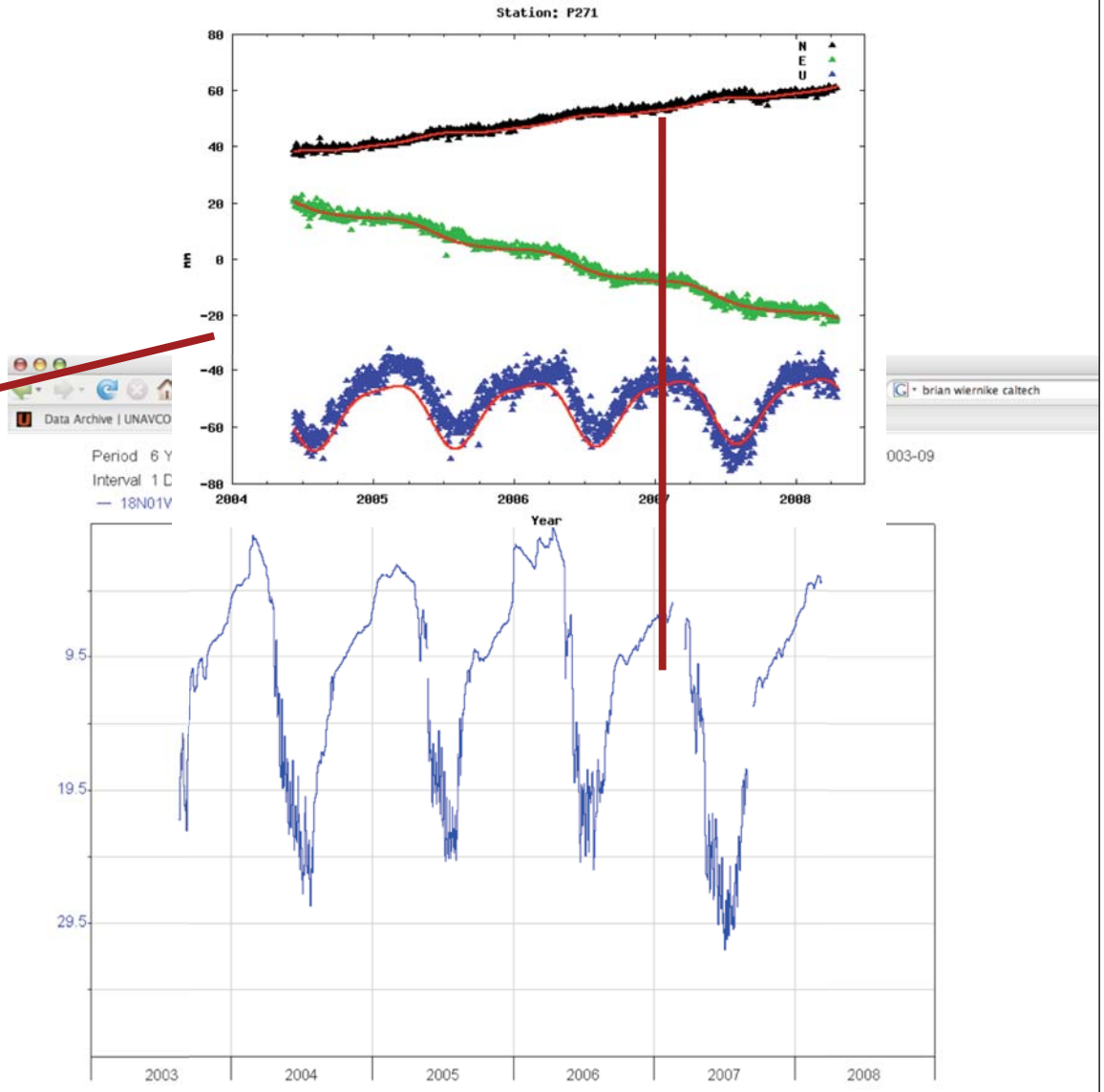
Y. Bock





-Peak uplift late October when lake level is lowest (opposite of when water table typically is lowest)

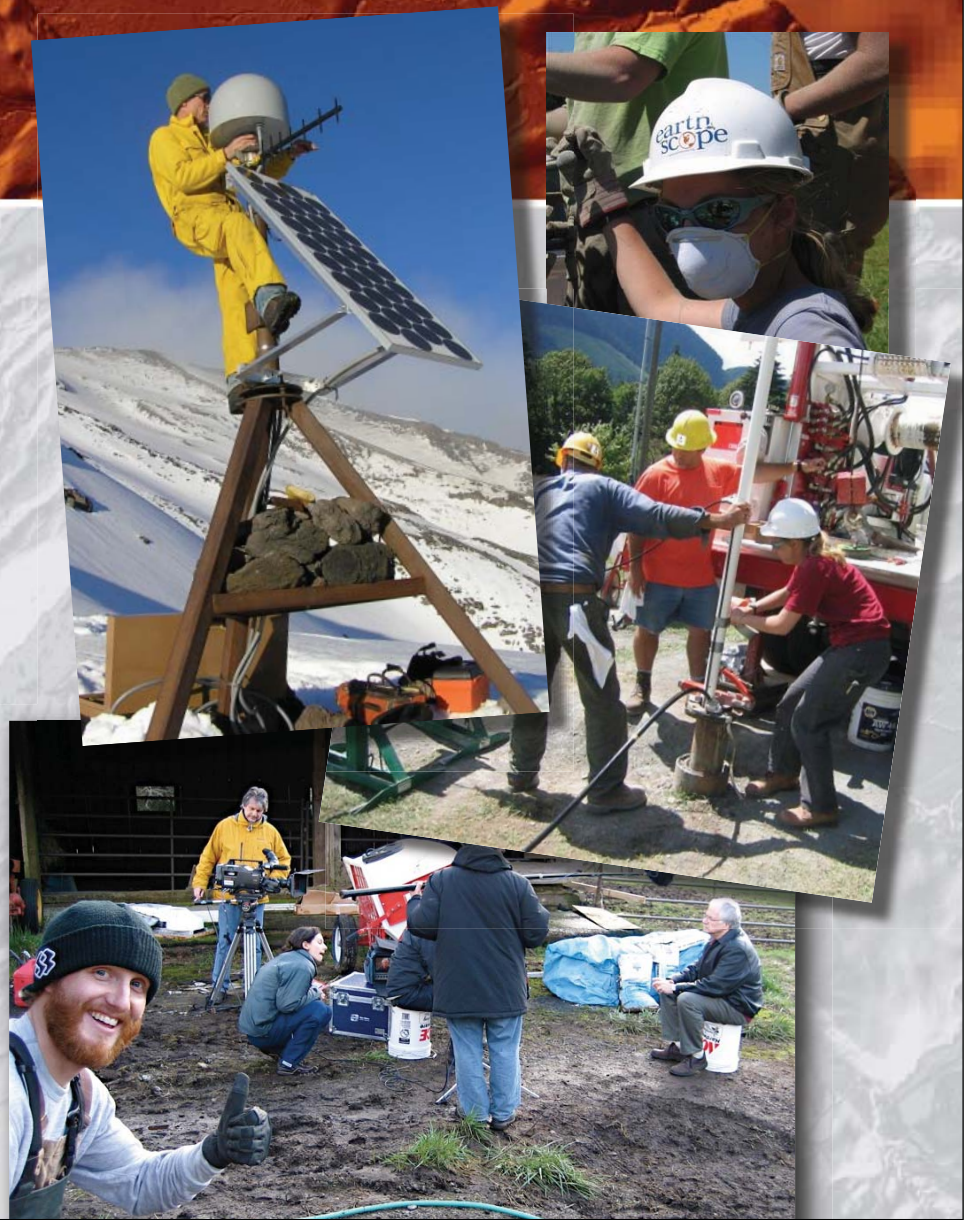
Deep-drilled braced in sediments in valley again peak of annual signal in March - in phase with water table height



UNAVCO

GeoEarthScope

- InSAR
  - InSAR imagery covering the western US
- LiDAR (ALS)
  - Airborne LiDAR Scanning, including the northern and southern San Andreas fault, Yellowstone Caldera, and faults in Cascadia and Alaska
- Geochronology
  - Seven techniques at 12 laboratories - through NSF review process



InSAR Imagery

Satellite Mission	Scenes	Frames	Gigabytes from ESA	Gigabytes from NASA/ASF	Total Gigabytes
ERS1	5,263	18,303	523 GB	3,288 GB	3,811 GB
ERS2	21,626	41,292	1,964 GB	4,489 GB	6,453 GB
ENVISAT	2,348	7,784	922 GB	0 GB	922 GB
RADARSAT1	7,629	40,893	0.0 GB	4,078 GB	4,078 GB
Total	**36,866**	**108,272**	**3,409 GB**	**11,855 GB**	**15,264 GB**

GeoEarthScope Data holdings status as of September 2008.

UNAVCO now hosts the WInSAR Consortium....

UNAVCO

ALS Imagery (Airborne Laser Scanning)

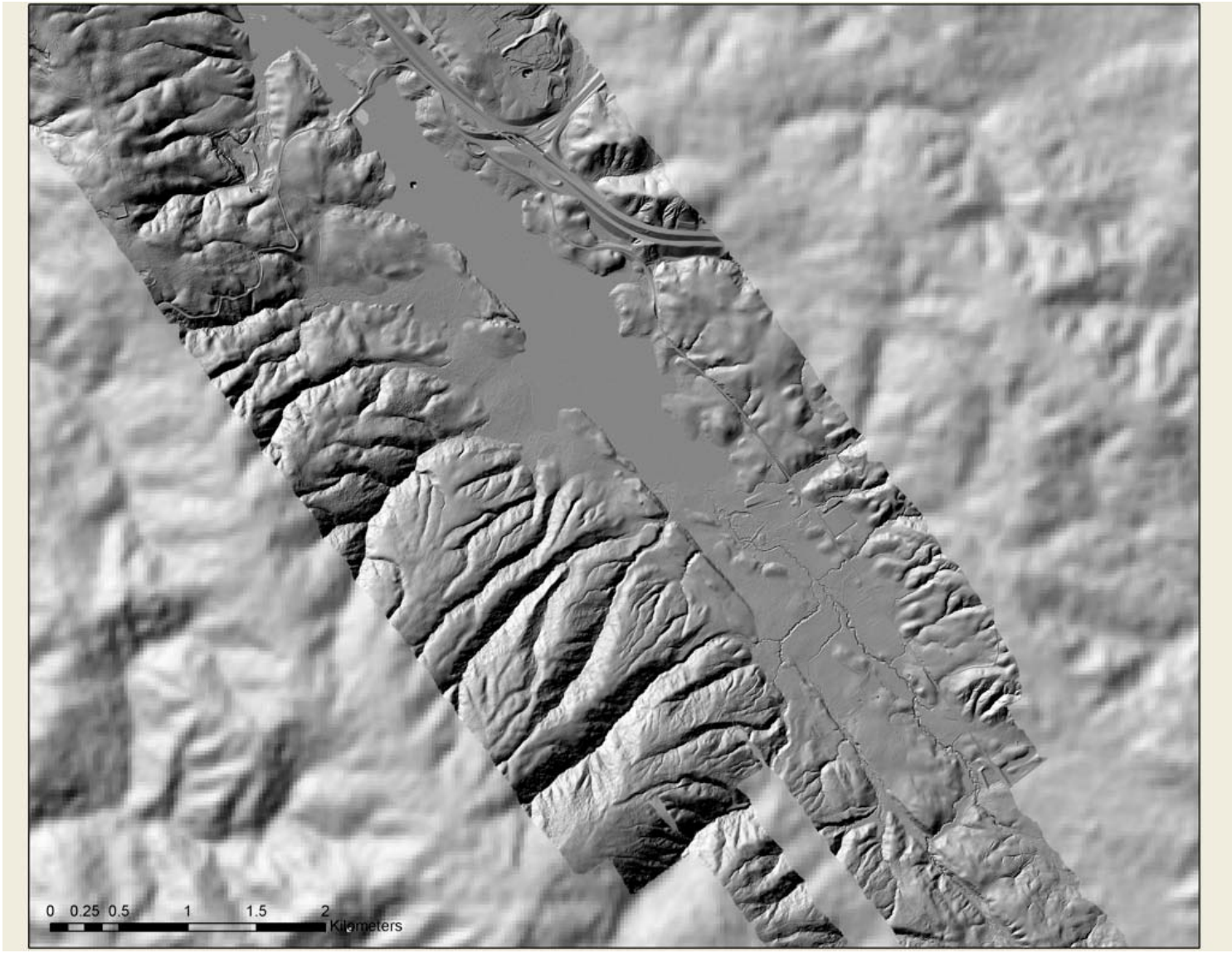
PROJECT REGION	MAJOR TARGETS	AREA	ACQUISITION DATES
Death Valley – Fish Lake Valley	Death Valley - Fish Lake Valley fault	~420 km^2	NOV 2006, OCT 2007
Northern California	San Andreas fault, Hayward fault, Maacama fault, Green Valley fault, Little Salmon fault	~1960 km^2 (including supplementary targets funded by USGS and other partners)	MAR–APR 2007
Southern California	Garlock fault, Elsinore fault, faults in Panamint, Owens, Death valleys	~1,270 km^2	APR 2008
Pacific Northwest	Yakima fold and thrust belt	~290 km^2	APR 2008
Yellowstone and Inter-Mountain Seismic Belt	Yellowstone, Teton fault, Wasatch (Nephi) fault	~666 km^2	JUL 2008
Alaska	Denali fault, Totschunda fault	~236 km^2	JUL-AUG 2008

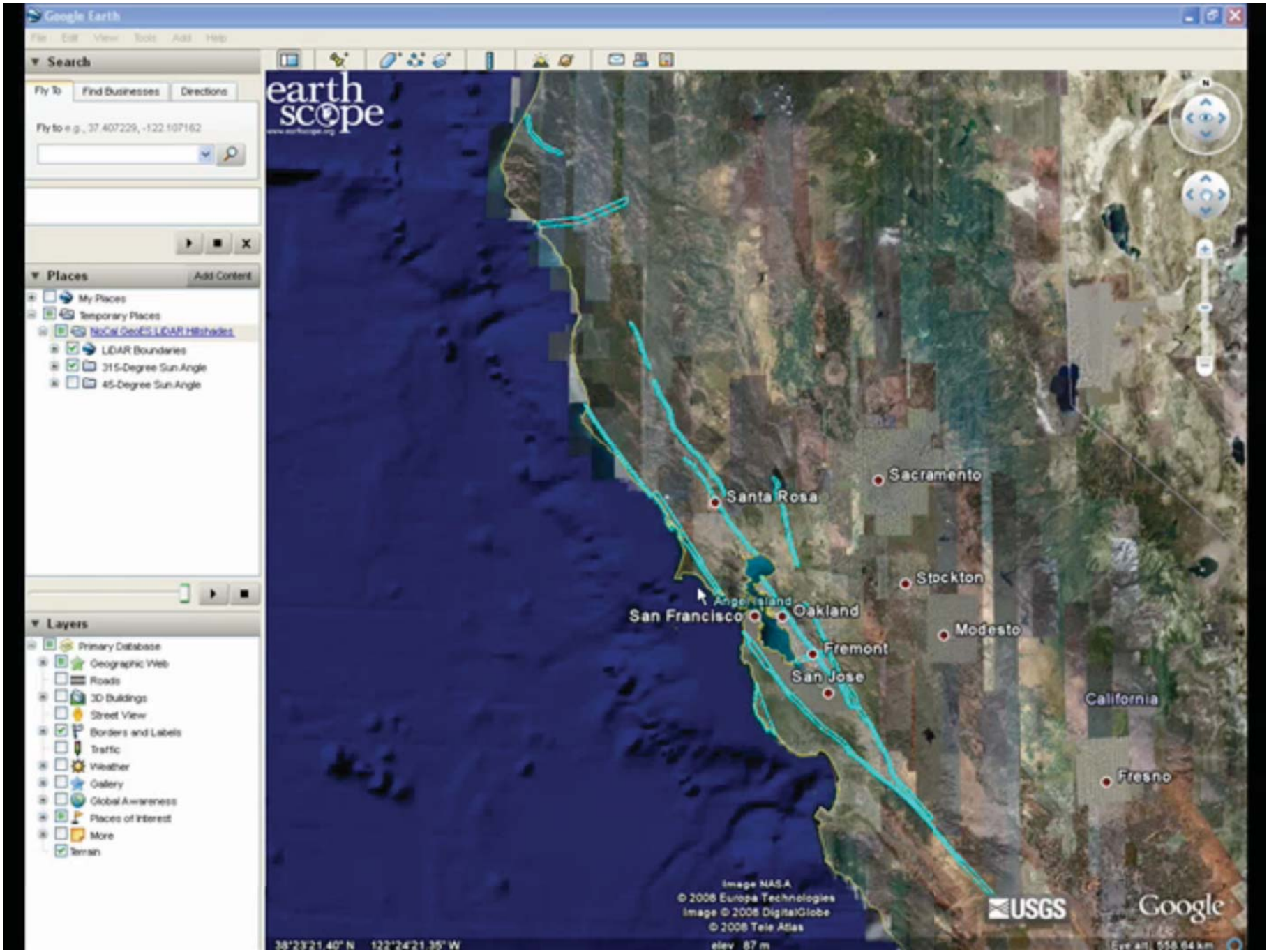
www.opentopography.org

Prentice et al. 2009 - Eos

All LiDAR data acquisitions have been completed successfully.

Northern California data are processed and available online, while other projects are in various stages of processing by NCALM. As final processing is completed, final products will be distributed by ASU and SDSC.


0 0.25 0.5 1 1.5 2
Kilometers


Google Earth
Search
Fly To
Find Businesses
Directions
Places
Add Content
My Places
Temporary Places
NoCal GeoEarthScope LiDAR Hillshades
LiDAR Boundaries
315-Degree Sun Angle
45-Degree Sun Angle
Layers
Primary Database
Geographic Web
Roads
3D Buildings
Street View
Borders and Labels
Traffic
Weather
Gallery
Global Awareness
Places of Interest
More
Terrain
earth scope
Sacramento
Santa Rosa
Stockton
Angel Island
San Francisco
Oakland
Modesto
Fremont
San Jose
California
Fresno
Image NASA
© 2008 Europa Technologies
Image © 2008 DigitalGlobe
© 2008 Tele Atlas
USGS
Google

UNAVCO

Advancing Geoscience

- Scope of activities
- Engineering & Science highlights
  - Global GNSS Network
  - PI science around the world
  - Polar services
  - Plate Boundary Observatory &
  - community data sets
  - Education and Outreach

Education and Outreach

- Short Courses & Workshops for researchers
- Workshops for K-12 teachers
- Data & curriculum for educators
- Student internships
- Resources for National Parks staff
- Public outreach and siting outreach
- Proposal assistance - broader impacts


June 10-12, 2008 BSM Short Course

Future Directions

- TLS (Terrestrial Laser Scanning)
- High rate and low latency data (“real time”)
- Regional initiatives, (re)new sub-disciplines, e.g.,
  - East Africa Natural Hazards
  - Mexico - meteorology and tectonics
- Enriching satellite data sets:
  - calibration & validation, bridge, environmental observations
- Geodesy curriculum development
- NSF - opportunities
-

NSF support for:

- Improved communication and data exchange between US-African-European collaborators;
- Strategy for development of networks, including real-time monitoring programs;
- Coordination of education and infrastructure in support of the development of permanent volcano observatories and regional geodetic and seismic networks

Products:

- Identification of key areas for additional research magmatic and faulting processes in the East African rift zone;
- Progress toward near-real-time seismic/GPS data exchange for early detection of eruptions and to pinpoint earthquake epicenters;
- Publication of the workshop results in multi-disciplinary journals;
- An international community research plan; and
- Workshop website for communication and collaboration
  - Science Discussion Forum: http://unavco.org/voce/
  - A social network: http://geoeastafrica.ning.com/