WinSAR and the Natural Laboratory/ Supersite approach to Geohazards

Falk Amelung, CSTARS, University of Miami
and the WinSAR members.

Outline:

1. Why do we need Natural Laboratories ?

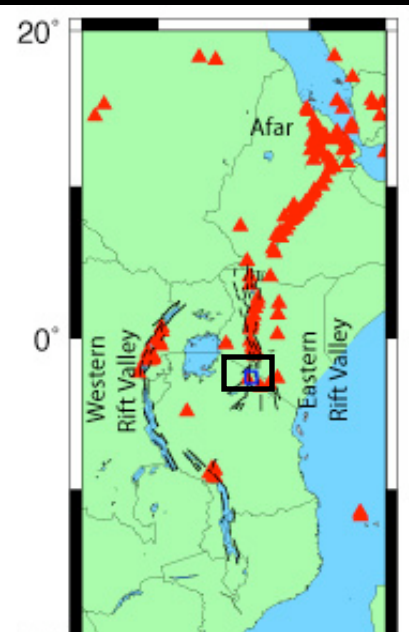
   Example 1: 2007 seismic crisis in Tanzania
   Example 2: The Sumatra earthquakes

2. Western North America Natural Laboratory, Earthscope and WInSAR.

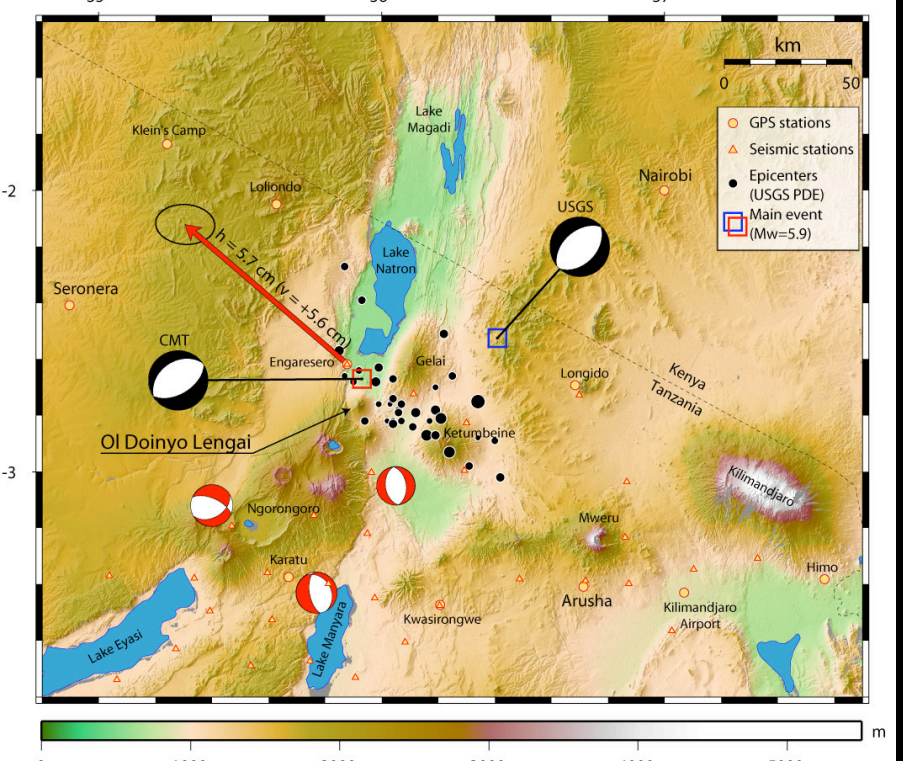
3. Current status of WinSAR at Unavco

4. International data sharing initiatives

Example 1: Tanzania seismic crisis, 7/2007



17 July 2007 M5.9 earthquake,
1-2 weeks of moderate events



Courtesy Elifuraha Saria, Erik Calais

Example 1: Tanzania seismic crisis, 7/2007

Courtesy Elifuraha Saria, Erik Calais

Example 1: Tanzania seismic crisis, 7/2007

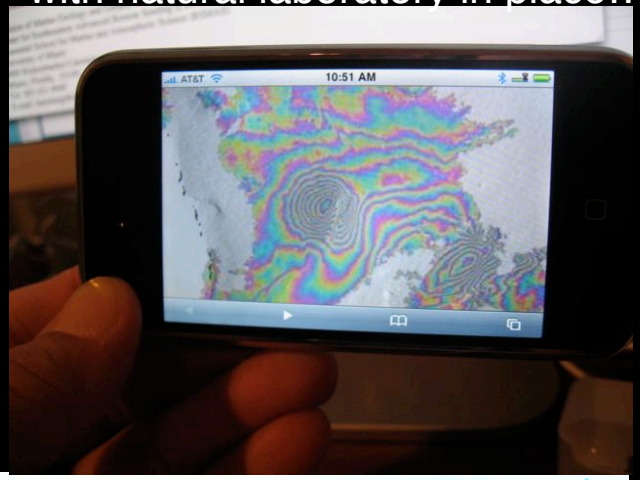
without natural laboratory …

?

Courtesy Elifuraha Saria, Erik Calais

Example 1: Tanzania seismic crisis, 7/2007

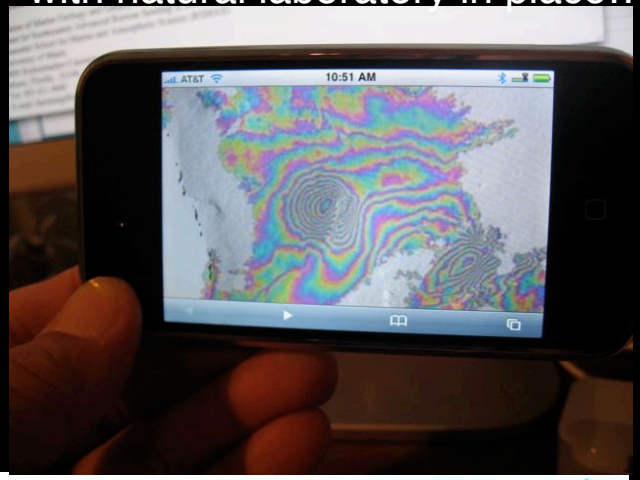
with natural laboratory in place…



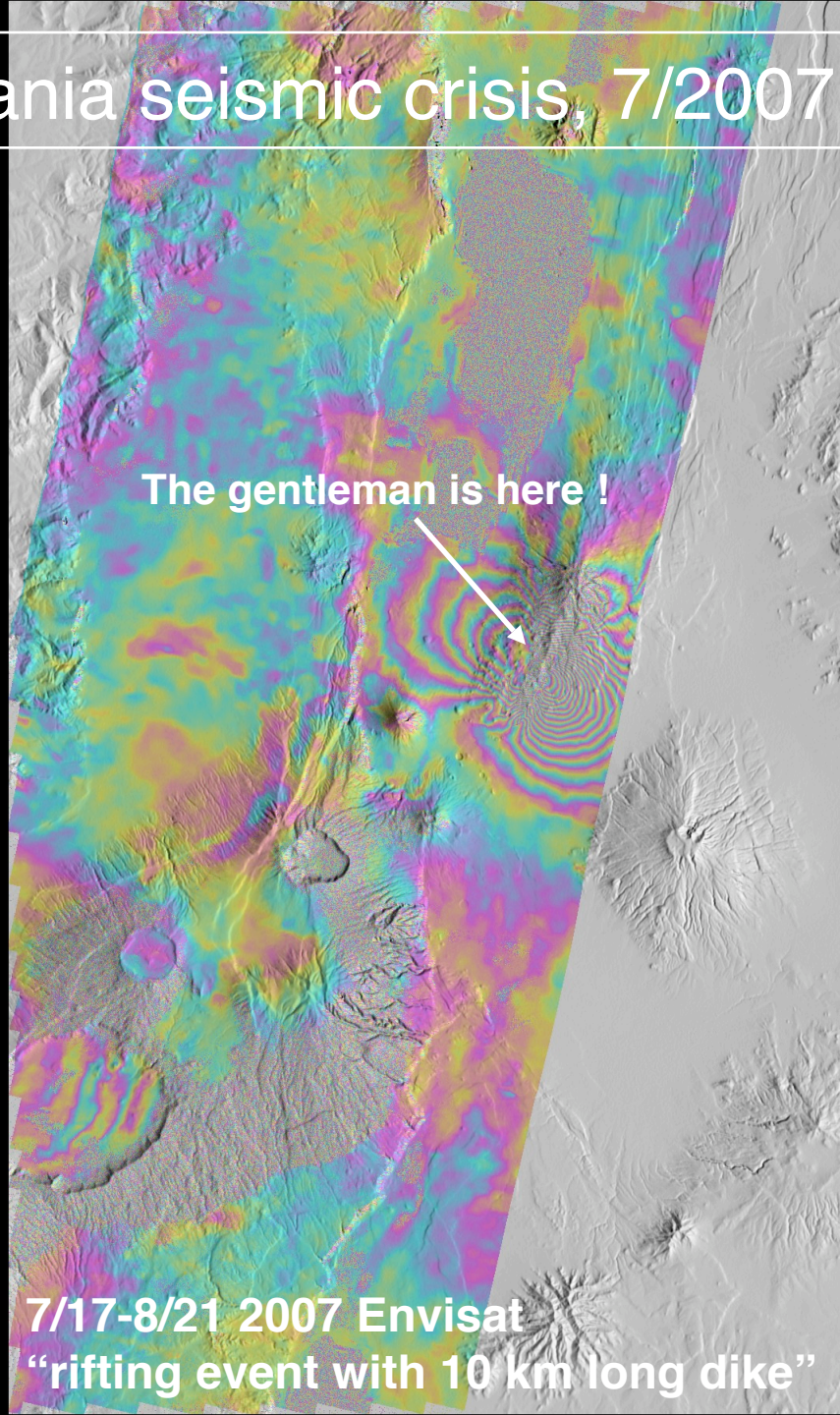
Courtesy Elifuraha Saria, Erik Calais

Example 1: Tanzania seismic crisis, 7/2007

with natural laboratory in place…



Natural laboratory provides data access
Research institution provides products



7/17-8/21 2007 Envisat
"rifting event with 10 km long dike"

Example 2: Sumatra 2004-2007

Science, News, 2007

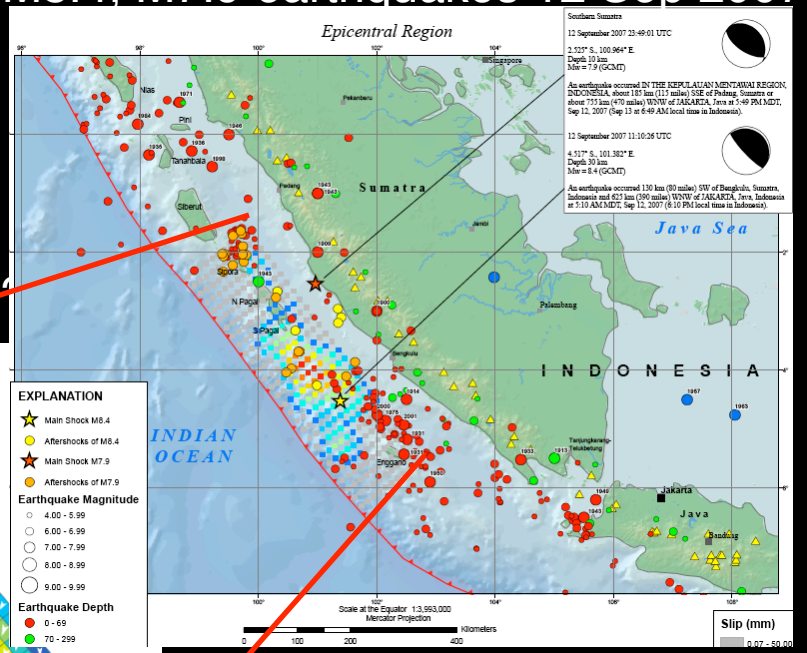
The M9.2 2004 and M8.7 2005 earthquakes increased the stress along the Mentawai segment

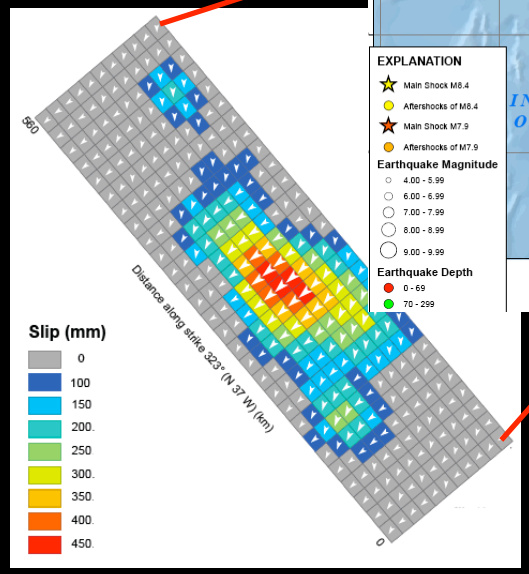
Key Questions:

1. Which fault segment did the 2007 events rupture?

2. How much they increased the stress on the Mentawai segment?

M8.4, M7.9 earthquakes 12 Sep 2007

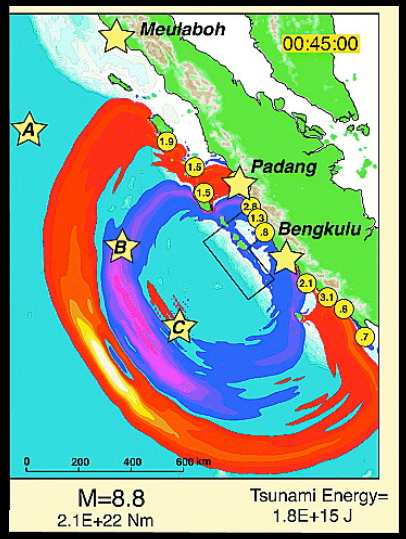




NEIC earthquake poster, 2007

Tsunami threat for Padang (7 m a.s.l)

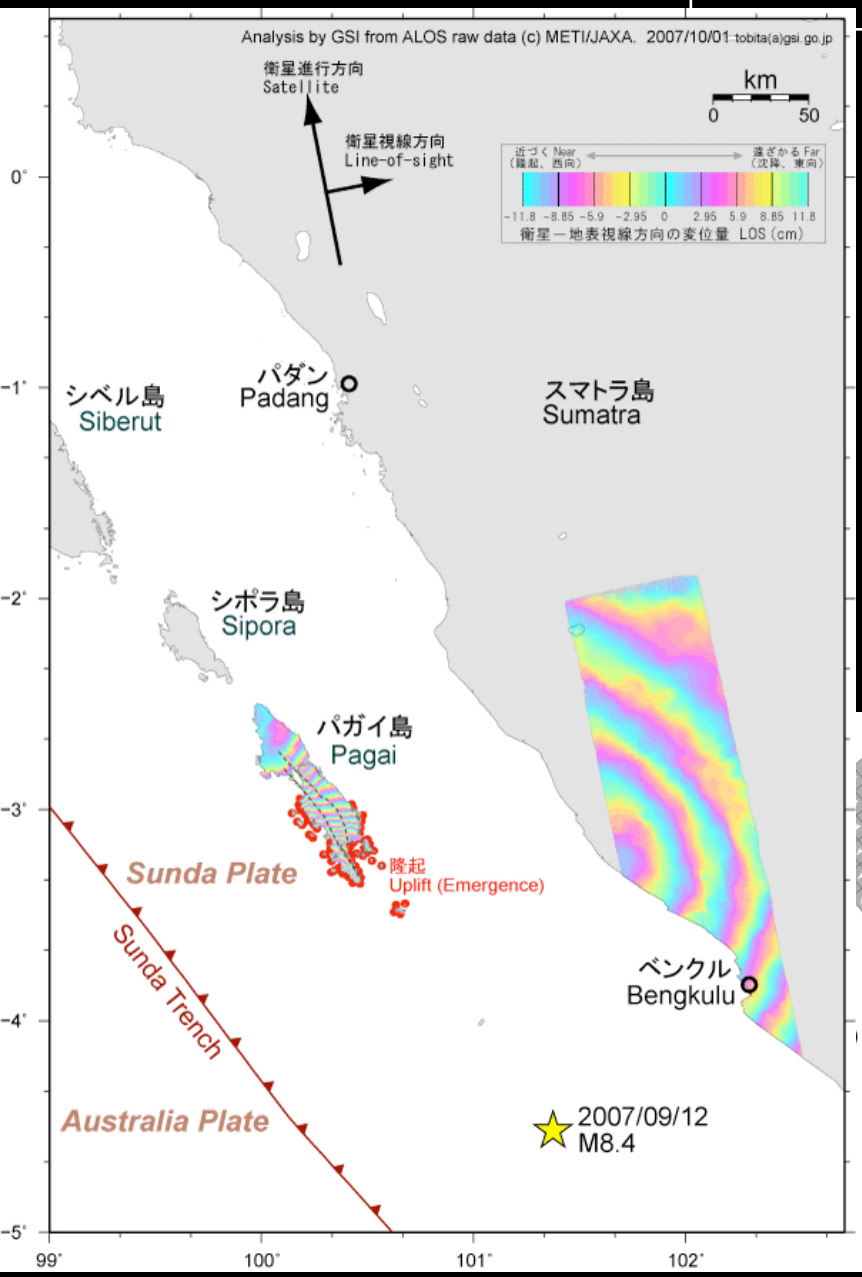
previous event in 1833



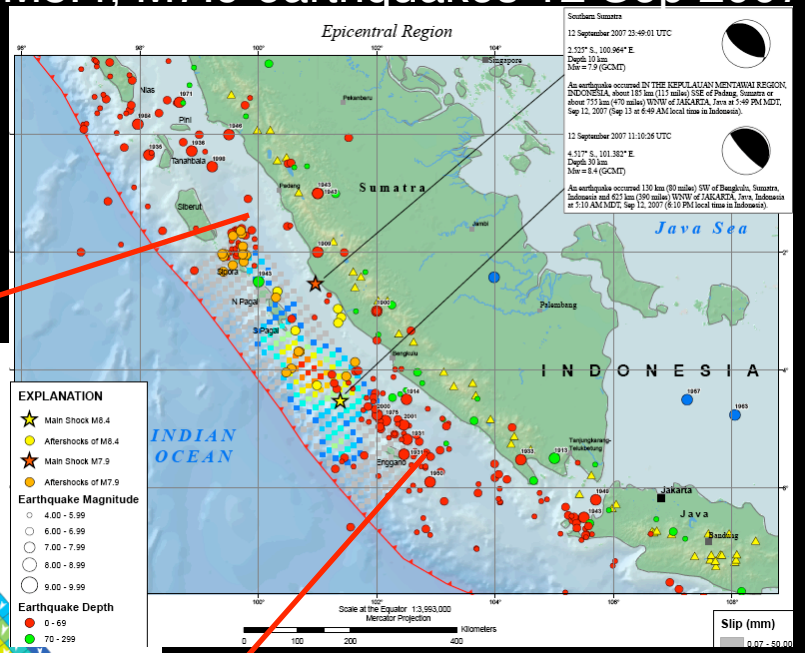
Natawidjaja et al., 2006

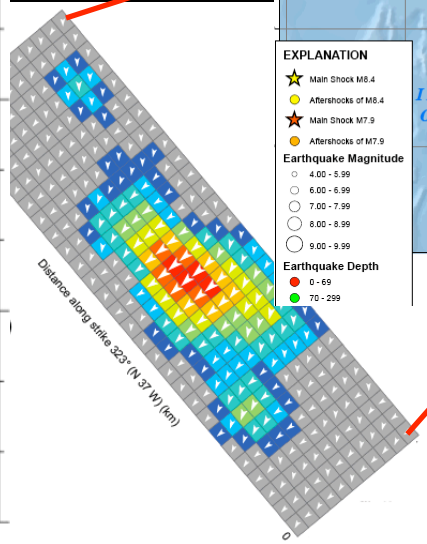
Fault slip distribution available from seismology hours after the earthquake, but was their significant aseismic slip?

Example 2: Sumatra 2004-2007



M8.4, M7.9 earthquakes 12 Sep 2007





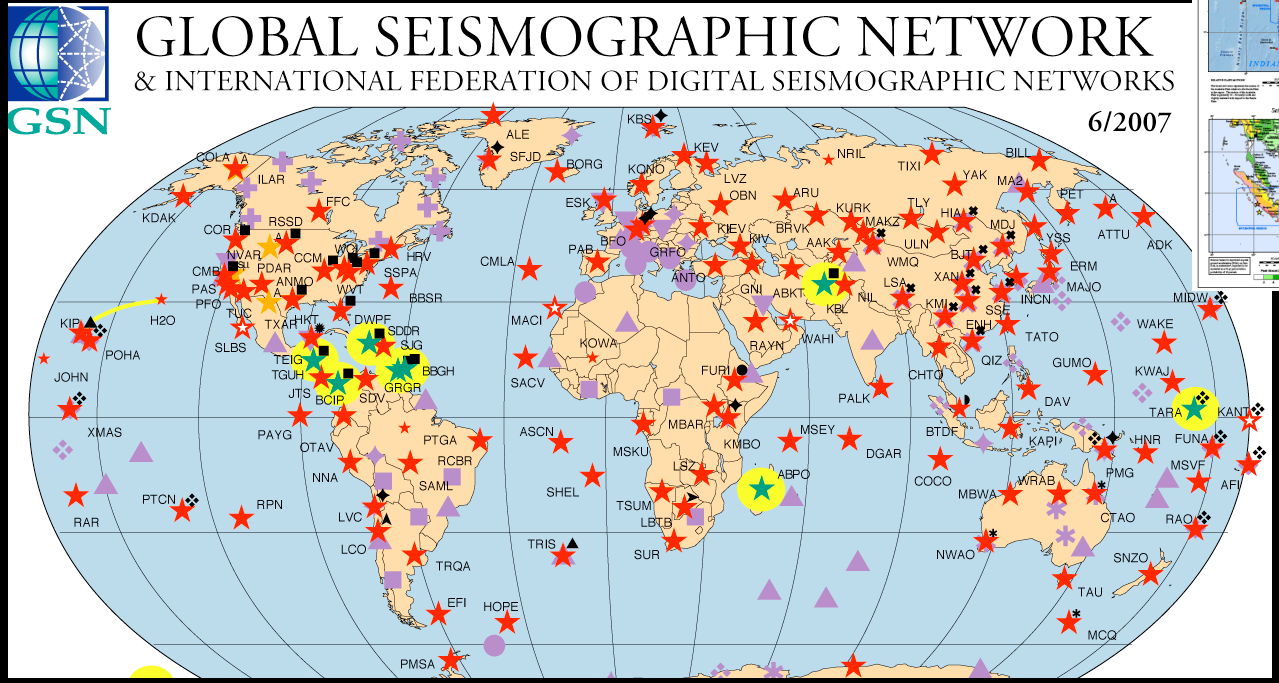
Fault slip distribution available from seismology hours after the earthquake, but was their significant aseismic slip?

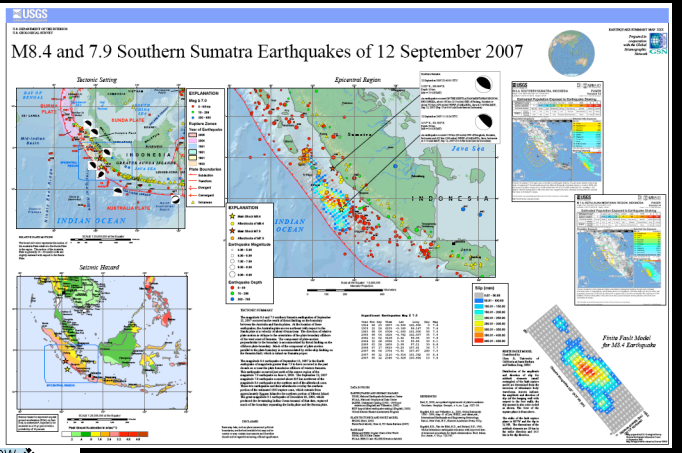
From Tobita's website at Geographical Survey Institute, Japan

NEIC earthquake poster, 2007

How do seismologists get near-real-time results ?

Distributed data sharing networks!





USGS NEIC interpretive posters available 2-6 hours after earthquake

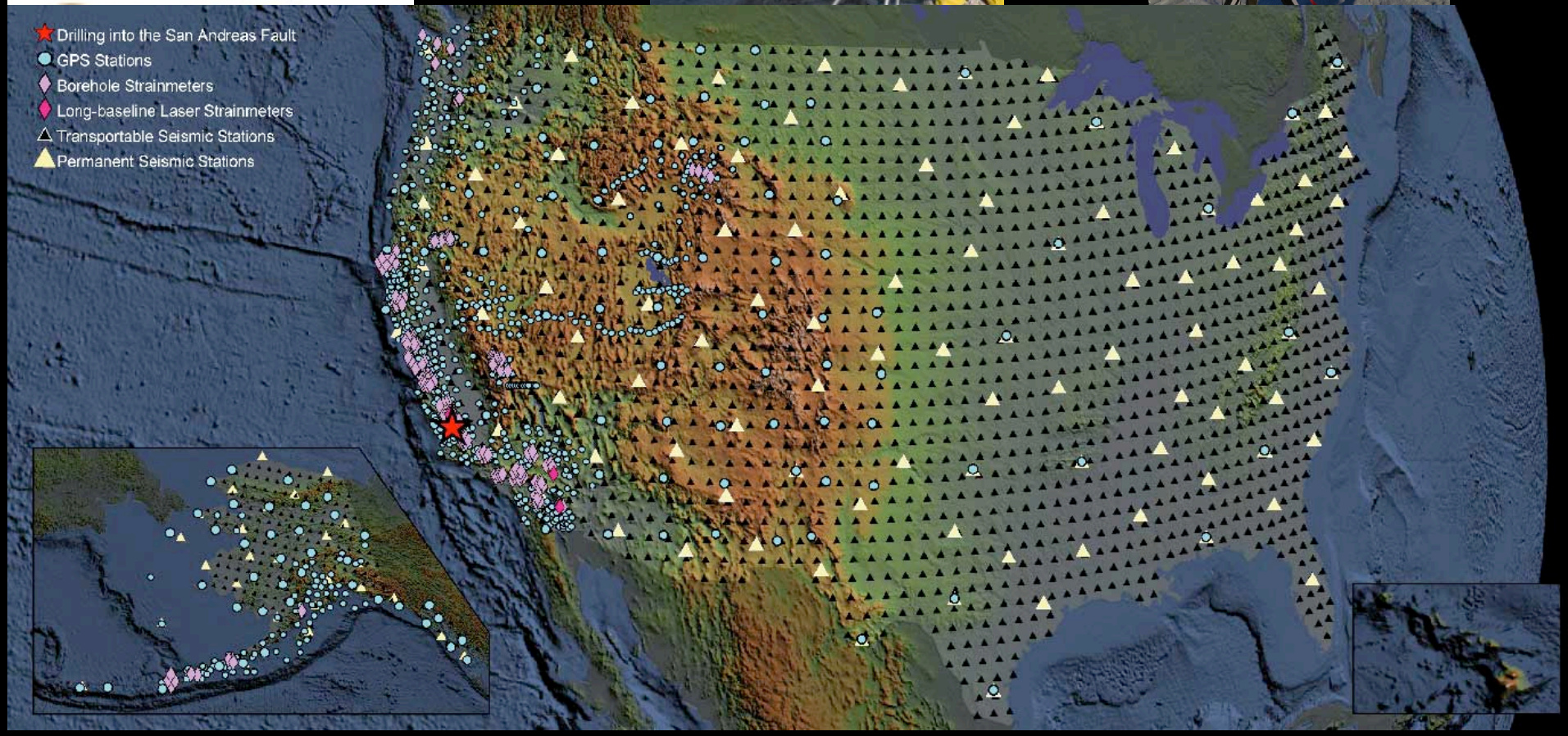
Standing Order for Data

IRIS's data sharing software

```
find_events -b 2007 -m 5 -R-130/-120/40/50 -r | \
find_seismograms -c BHZ -B -2P -E 5S
```

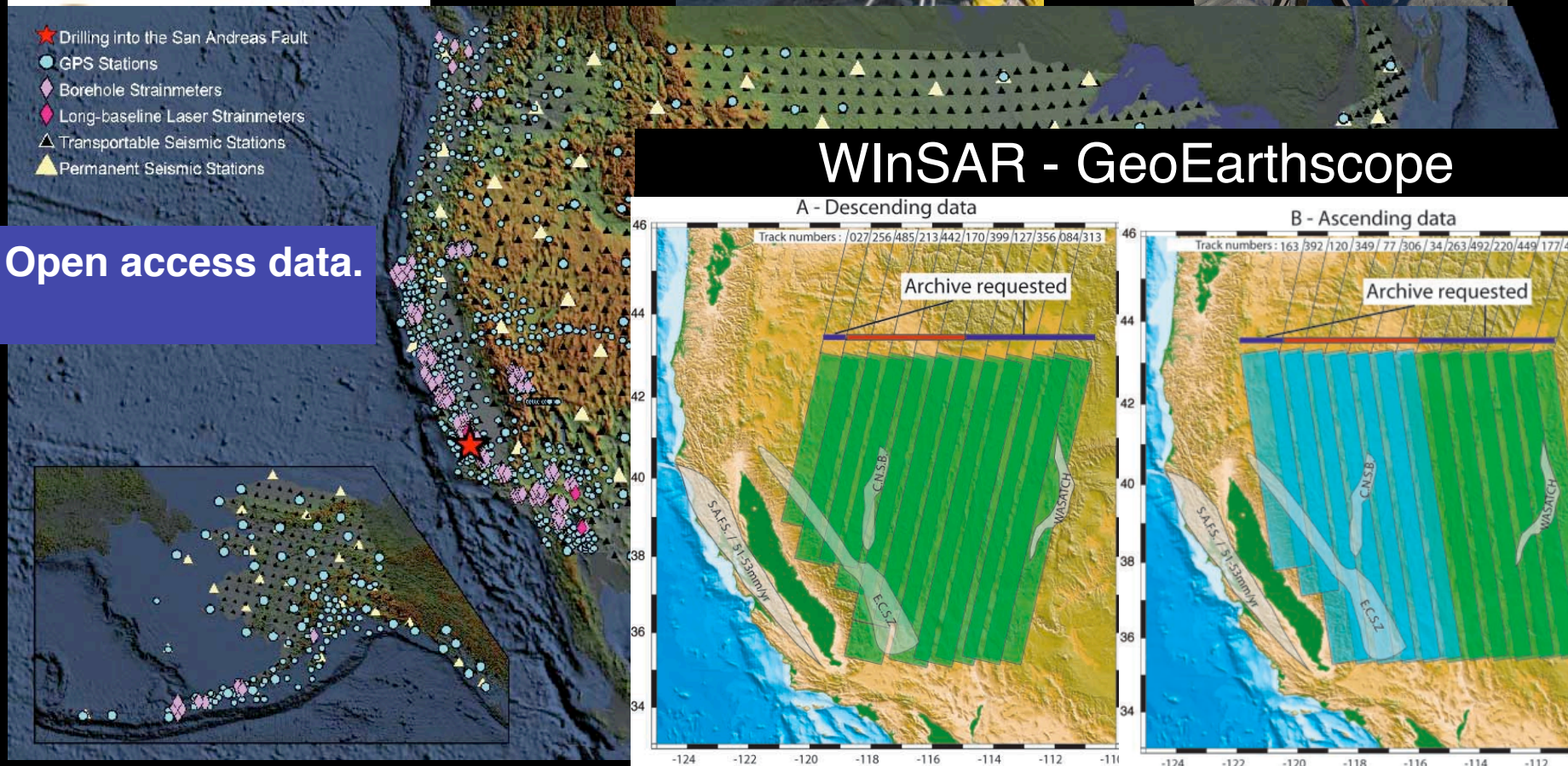
The Western North-America Natural Laboratory

earth scope



The Western North-America Natural Laboratory

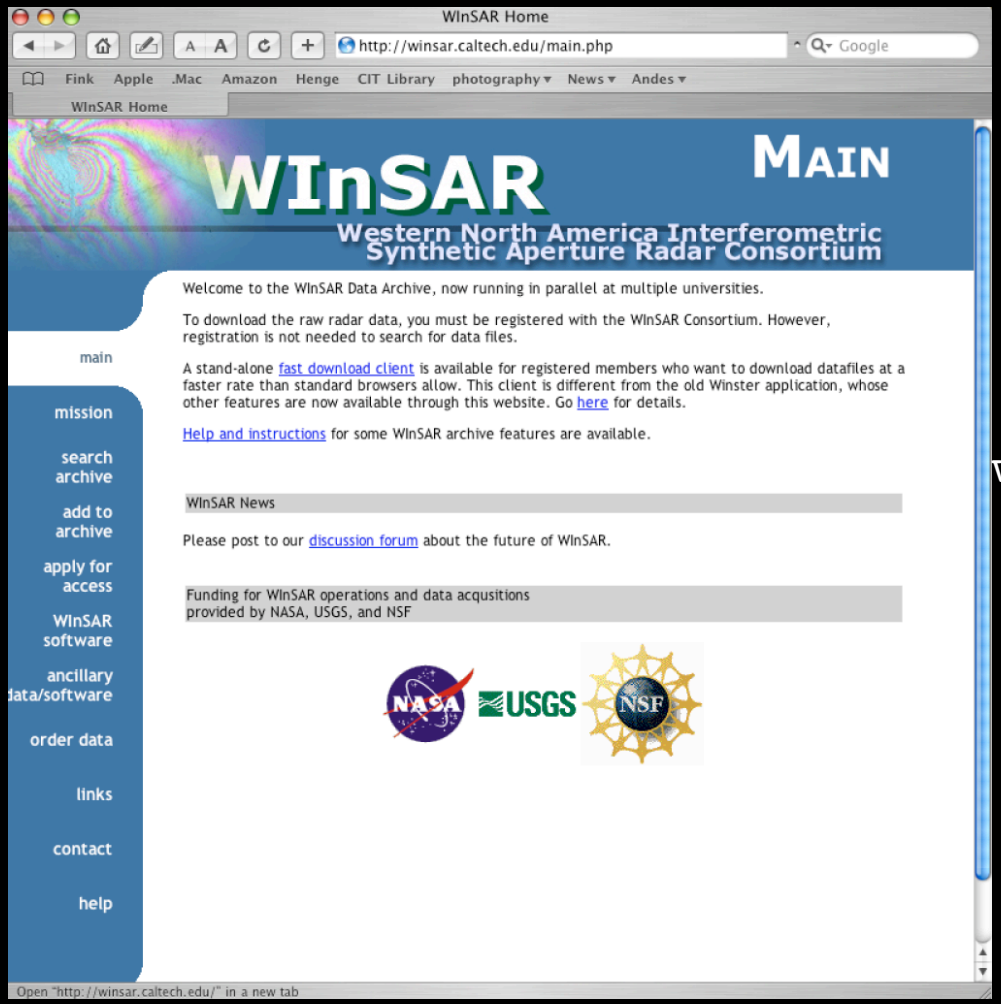
earth scope

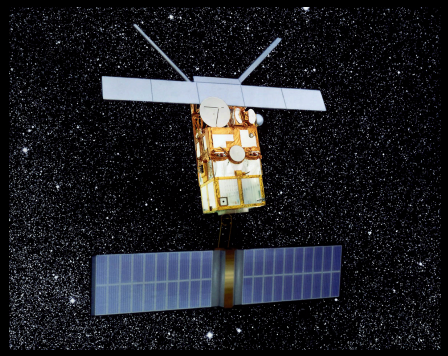


Open access data.

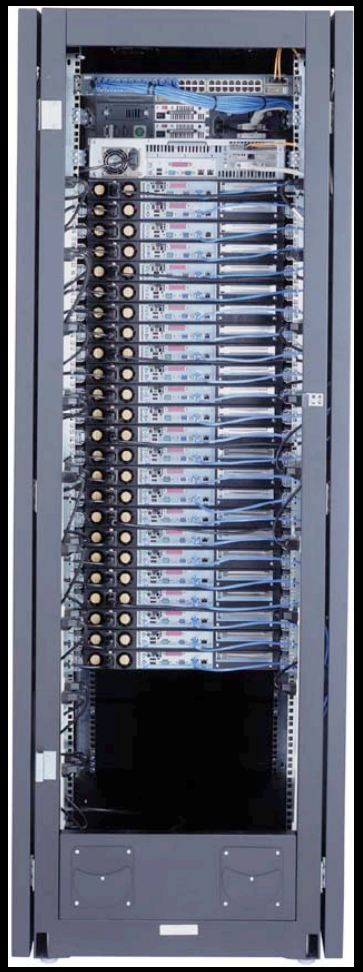
WInSAR - GeoEarthscope

Western North American InSAR (WInSAR) data consortium





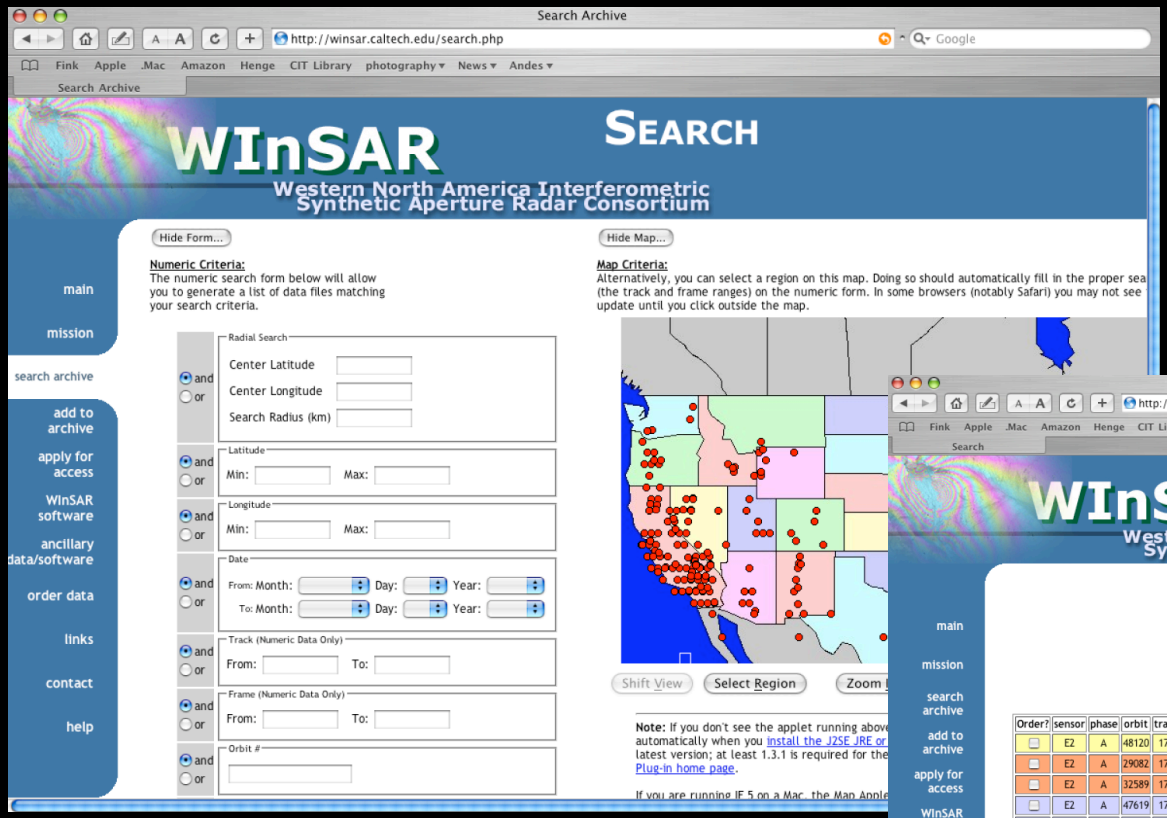
winsar.unavco.org

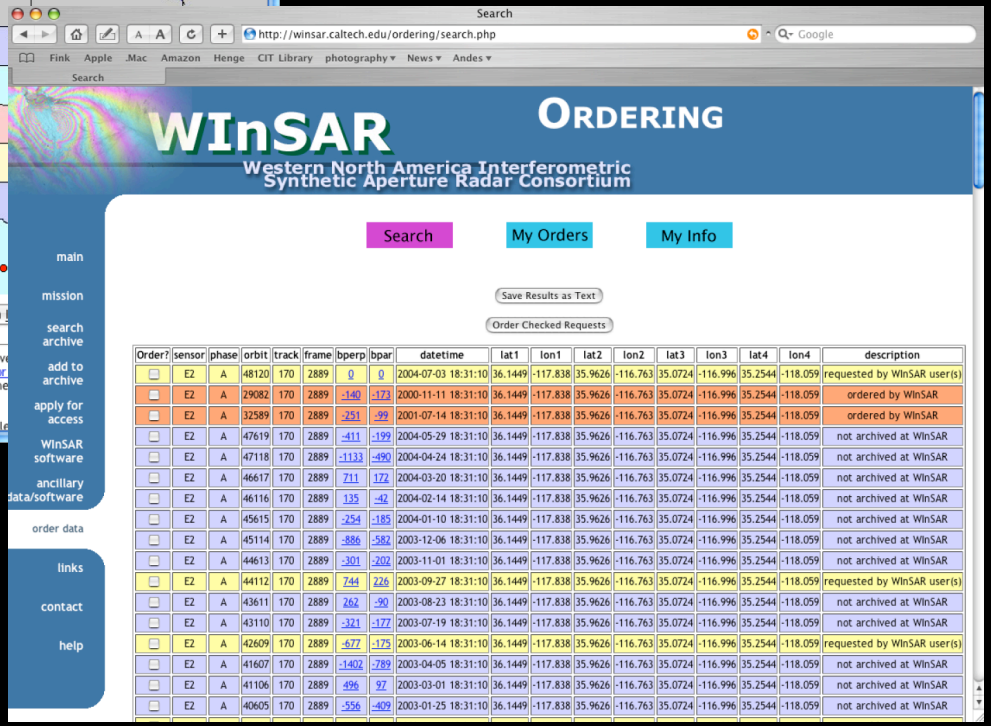


What is WinSAR ?

Internet SAR data portal for member institutions
(Password-protected SAR data sharing system)

Search and Order Data





Order?	sensor	phase	orbit	track	frame	bperp	bpar	datetime	lat1	lon1	lat2	lon2	lat3	lon3	lat4	lon4	description
☐	E2	A	48120	170	2889	0	0	2004-07-03 18:31:10	36.1449	-117.838	35.9626	-116.763	35.0724	-116.996	35.2544	-118.059	requested by WInSAR user(s)
☐	E2	A	29082	170	2889	-140	-173	2000-11-11 18:31:10	36.1449	-117.838	35.9626	-116.763	35.0724	-116.996	35.2544	-118.059	ordered by WInSAR
☐	E2	A	32589	170	2889	-251	-99	2001-07-14 18:31:10	36.1449	-117.838	35.9626	-116.763	35.0724	-116.996	35.2544	-118.059	ordered by WInSAR
☐	E2	A	47619	170	2889	-411	-199	2004-05-29 18:31:10	36.1449	-117.838	35.9626	-116.763	35.0724	-116.996	35.2544	-118.059	not archived at WInSAR
☐	E2	A	47118	170	2889	-1133	-490	2004-04-24 18:31:10	36.1449	-117.838	35.9626	-116.763	35.0724	-116.996	35.2544	-118.059	not archived at WInSAR
☐	E2	A	46617	170	2889	711	172	2004-03-20 18:31:10	36.1449	-117.838	35.9626	-116.763	35.0724	-116.996	35.2544	-118.059	not archived at WInSAR
☐	E2	A	46116	170	2889	135	-42	2004-02-14 18:31:10	36.1449	-117.838	35.9626	-116.763	35.0724	-116.996	35.2544	-118.059	not archived at WInSAR
☐	E2	A	45615	170	2889	-254	-185	2004-01-10 18:31:10	36.1449	-117.838	35.9626	-116.763	35.0724	-116.996	35.2544	-118.059	not archived at WInSAR
☐	E2	A	45114	170	2889	-886	-582	2003-12-06 18:31:10	36.1449	-117.838	35.9626	-116.763	35.0724	-116.996	35.2544	-118.059	not archived at WInSAR
☐	E2	A	44613	170	2889	-301	-202	2003-11-01 18:31:10	36.1449	-117.838	35.9626	-116.763	35.0724	-116.996	35.2544	-118.059	not archived at WInSAR
☐	E2	A	44112	170	2889	744	226	2003-09-27 18:31:10	36.1449	-117.838	35.9626	-116.763	35.0724	-116.996	35.2544	-118.059	requested by WInSAR user(s)
☐	E2	A	43611	170	2889	262	-90	2003-08-23 18:31:10	36.1449	-117.838	35.9626	-116.763	35.0724	-116.996	35.2544	-118.059	not archived at WInSAR
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☐	E2	A	42609	170	2889	-677	-175	2003-06-14 18:31:10	36.1449	-117.838	35.9626	-116.763	35.0724	-116.996	35.2544	-118.059	requested by WInSAR user(s)
☐	E2	A	41607	170	2889	-1402	-789	2003-04-05 18:31:10	36.1449	-117.838	35.9626	-116.763	35.0724	-116.996	35.2544	-118.059	not archived at WInSAR
☐	E2	A	41106	170	2889	496	97	2003-03-01 18:31:10	36.1449	-117.838	35.9626	-116.763	35.0724	-116.996	35.2544	-118.059	not archived at WInSAR
☐	E2	A	40605	170	2889	-556	-409	2003-01-25 18:31:10	36.1449	-117.838	35.9626	-116.763	35.0724	-116.996	35.2544	-118.059	not archived at WInSAR

2-5 minutes download time for 1 scene

Some institutions maintain mirrors (data processing from archive)

Western North American InSAR (WInSAR) data consortium

45 U.S. Member Institutions

Arizona State
Caltech
Central Washington
Cornell
Harvard
JPL
LLNL
MIT
SDSU
U. Ohio
Stanford
U. Memphis
U. Miami
UC San Diego
UC Santa Cruz
UC Los Angeles
UC Davis
UC Berkeley
USC
USGS
U. Utah
U. Texas
U. Hawaii
U. Alaska
Western Washington
U. Nevada
U. Missouri
Purdue U.

8 International Member Institutions

PHILVOLCS (Phillipines)
INGEOMINAS (Columbia)
Canadian Geological Survey
University College London (U.K.)
Simon Fraser U. (Canada)
U. of Western Ontario (Canada)
CICESE (Mexico)
University of Beijing (China)

New members accepted by vote of Executive Committee

No commercial companies !

Mission

To provide access to as much raw InSAR data to as many geophysicists as possible (within constraints imposed by international space agencies and their commercial vendors).

Philosophy

- Data must be free to members, "Seismology effect"
- Simple and low cost (Internet distribution system)
- Minimal points of contact for funding/data agencies

Holdings

- 8000 ERS 1 and 2 (1992 – present) + Envisat, Radarsat, ALOS
- 3 TB of data

87 publications using WinSAR data !

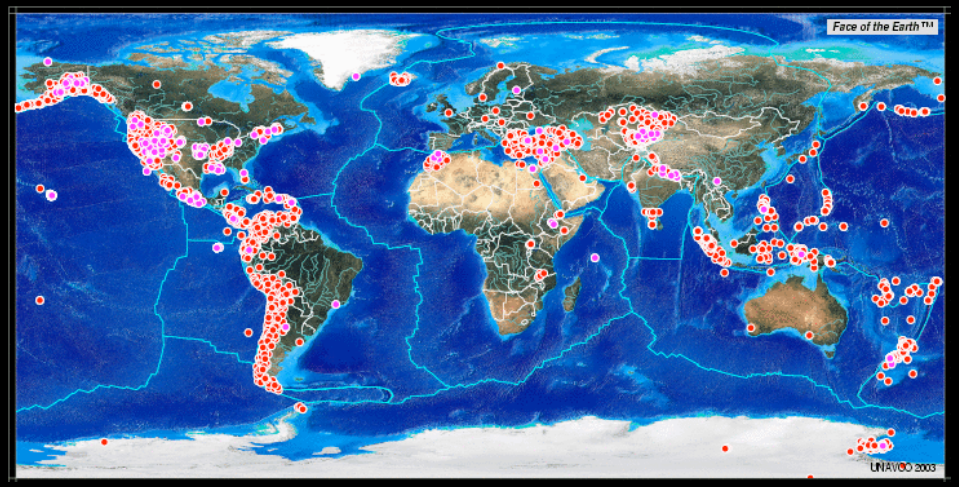
- 3 types of membership:

- Full: US institutions, full data access and order privilege.
- Adjunct-1: Canada and Mexico, full data access but no ordering.
- Adjunct-2: Rest of the world. Full access to all ALOS and Radarsat imagery. No ordering.

University NAVSTAR consortium

Mission: Promoting Earth science by advancing high-precision techniques for the measurement of crustal deformation

Activities: GPS support: permanent, campaign networks, data formats, data archiving
InSAR support: imagery acquisition and archiving (WinSAR, Natural labs)



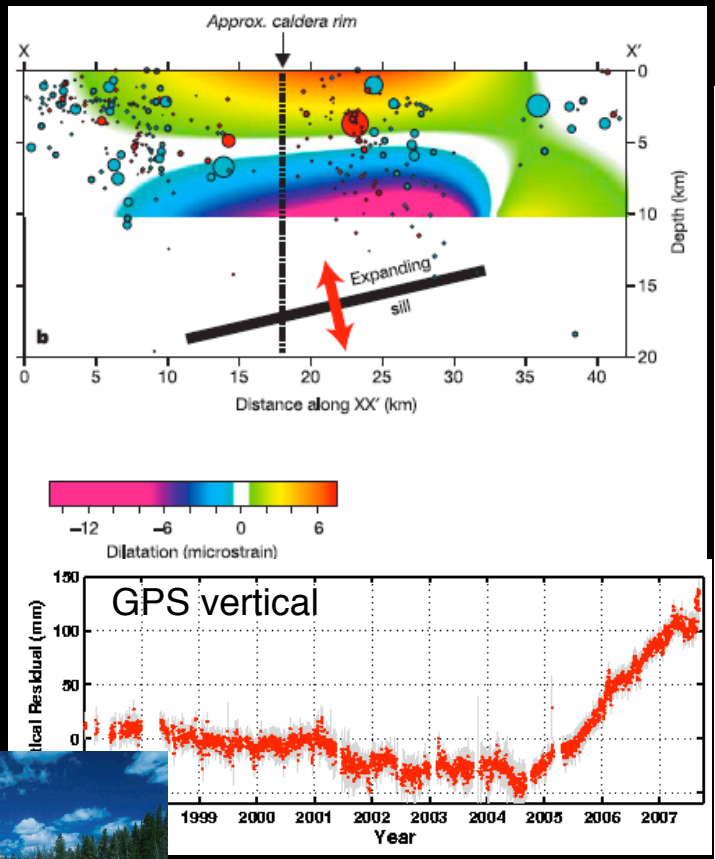
GPS stations maintained by UNAVCO

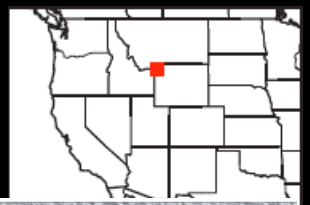
Members: 67 U.S. + 43 foreign

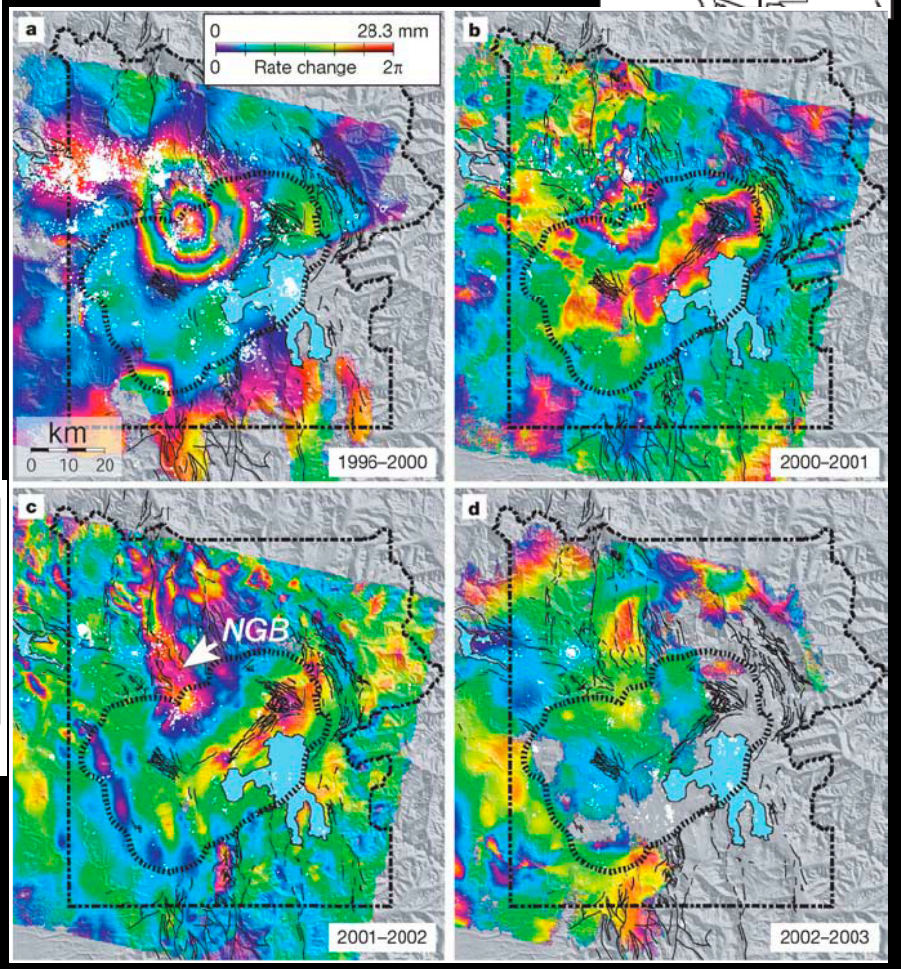
Sponsors:

WinSAR Science results (1): Yellowstone caldera

Model:



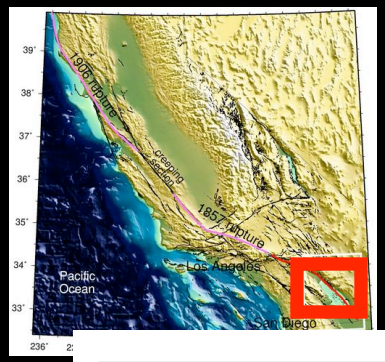




Wicks et al., Nature, 2006

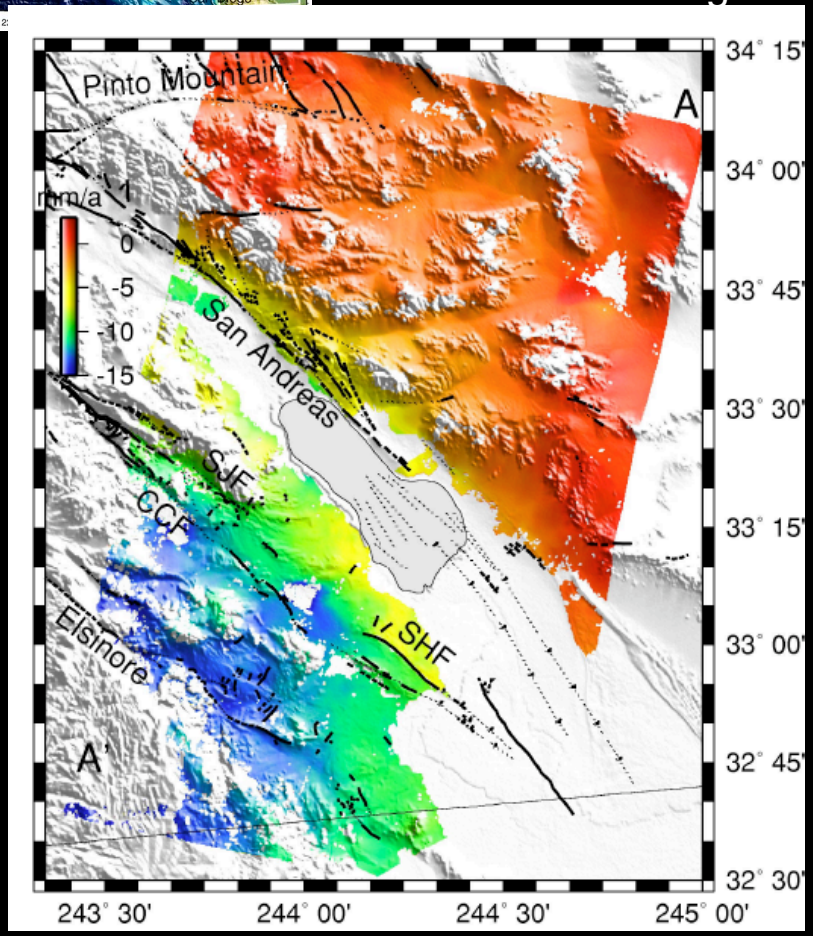
ERS1,2 SAR data

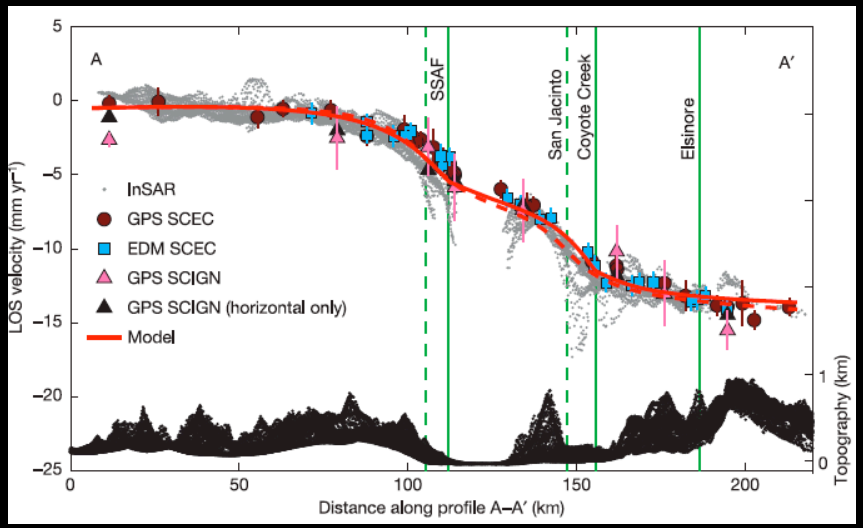
Science results (2): Southern San Andreas Fault



Equal strain partitioning between
San Andreas and San Jacinto faults

Stack of 35 interferograms



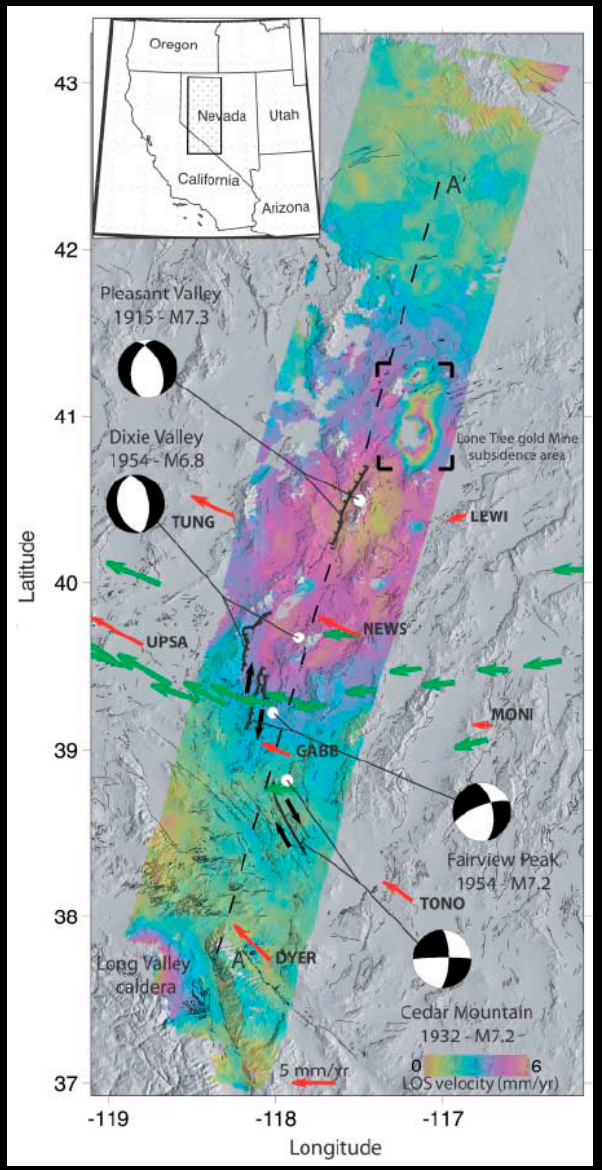


Fialko, Nature, 2006

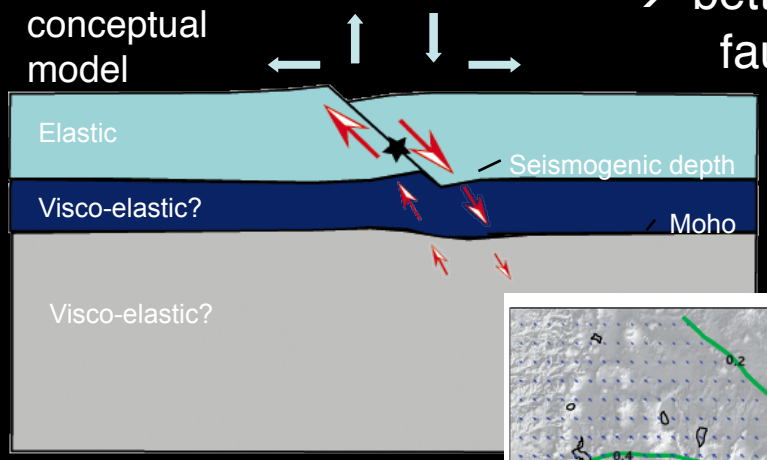
ERS1,2 SAR data

Science results (3): Nevada post-seismic deformation

Stack of 8 interferograms

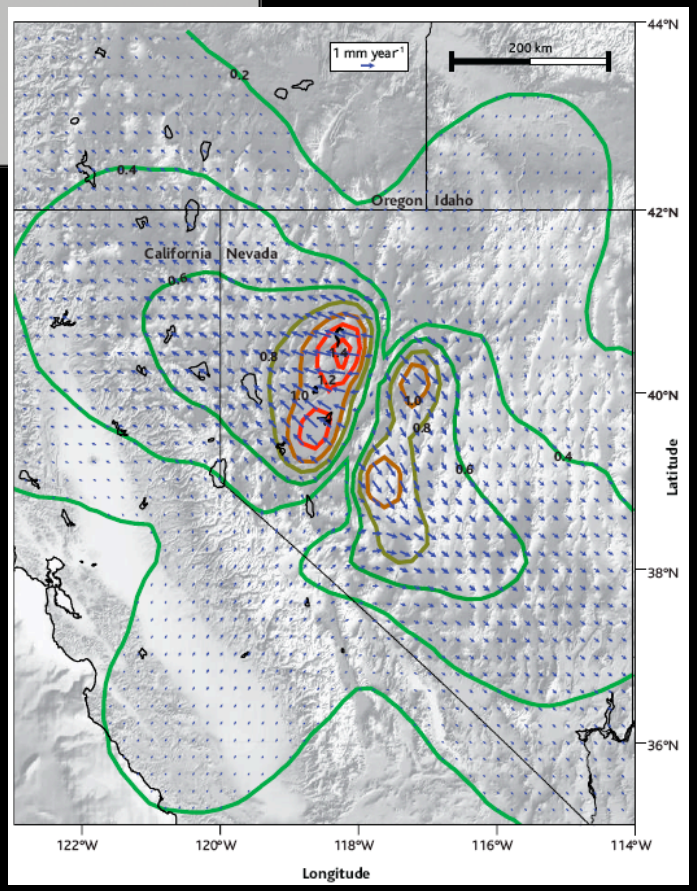


conceptual model



→ better understanding of fault loading rates

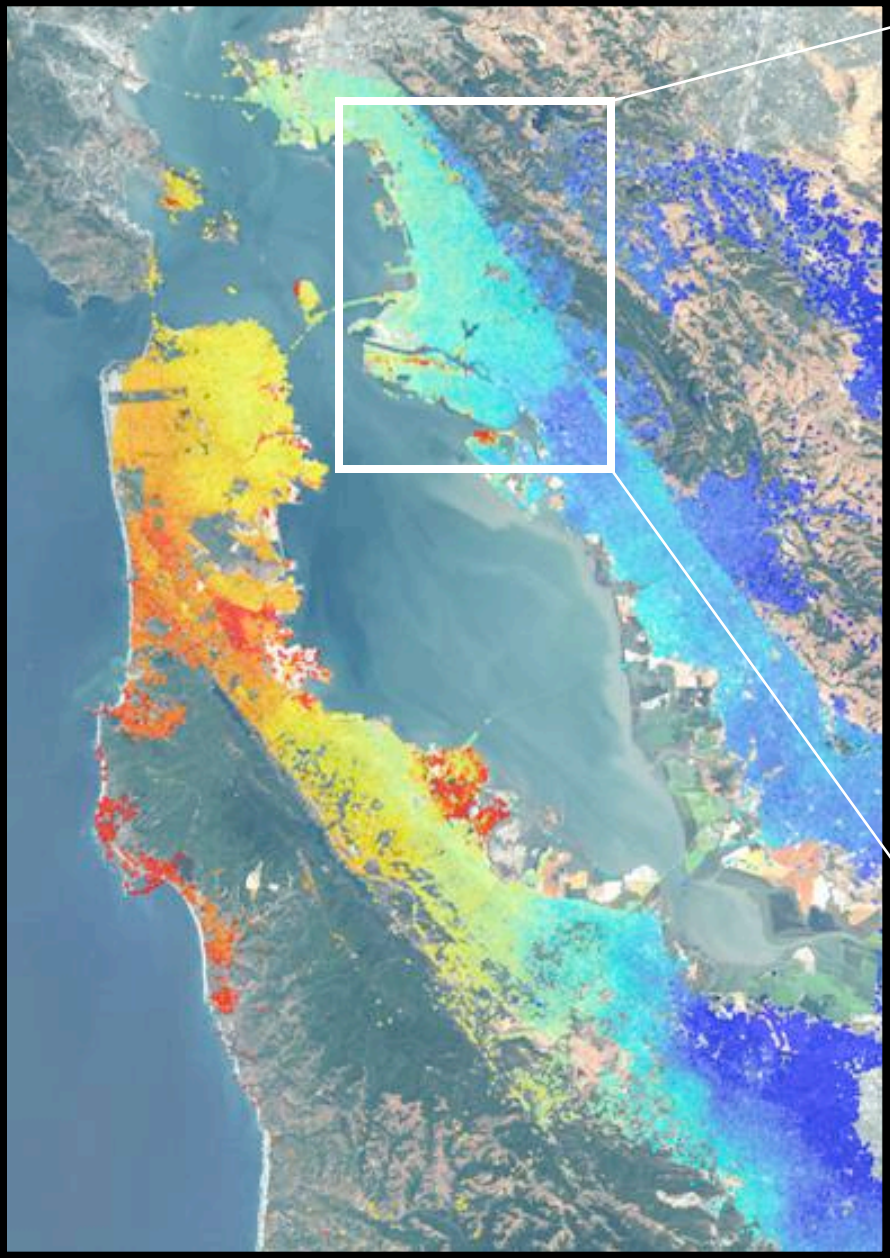
Several 1917-1954 M>7 earthquakes caused viscous flow in the Earth's mantle which is detectable at the Earth's surface.

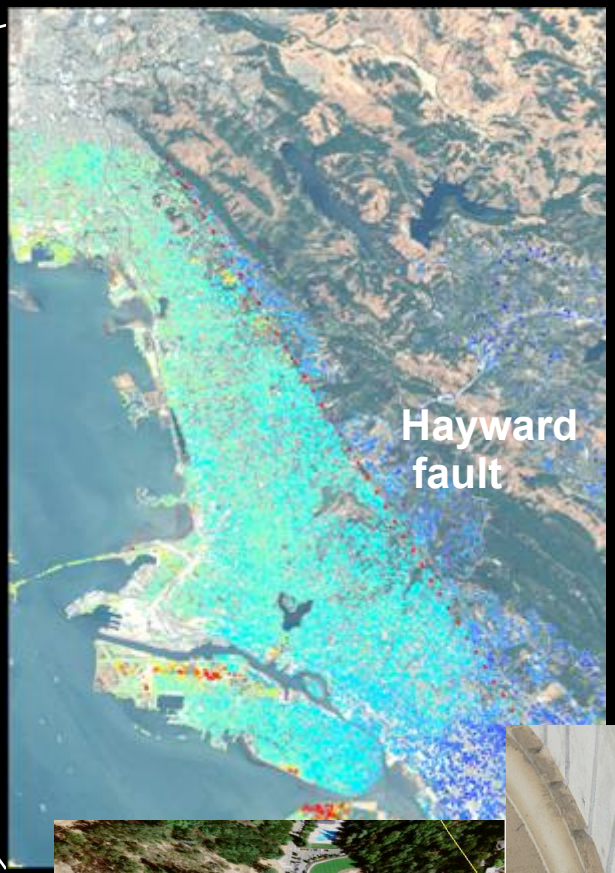


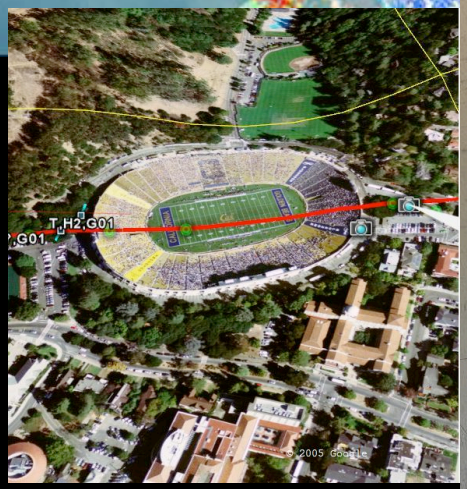
Model prediction of post-seismic deformation field

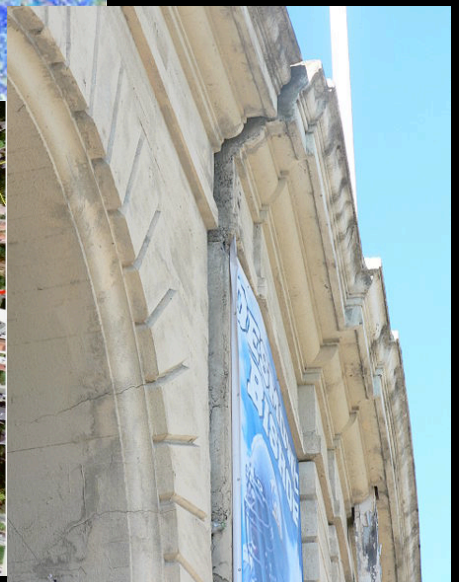
Gourmelen and Amelung, Science, 2005 ERS1,2 SAR data

Science results (4): Creeping faults in San Francisco Bay area



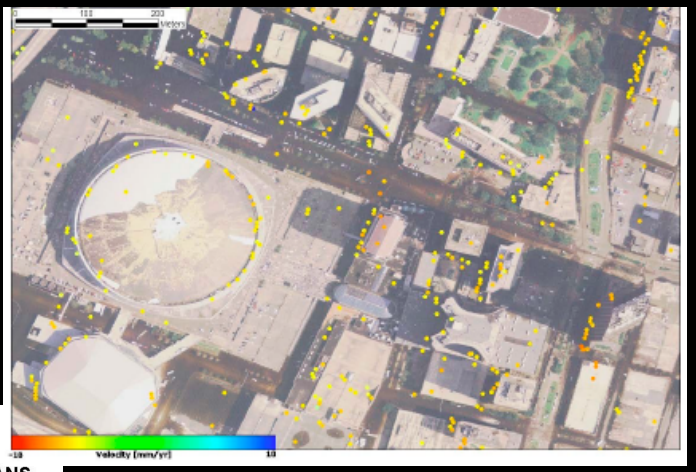


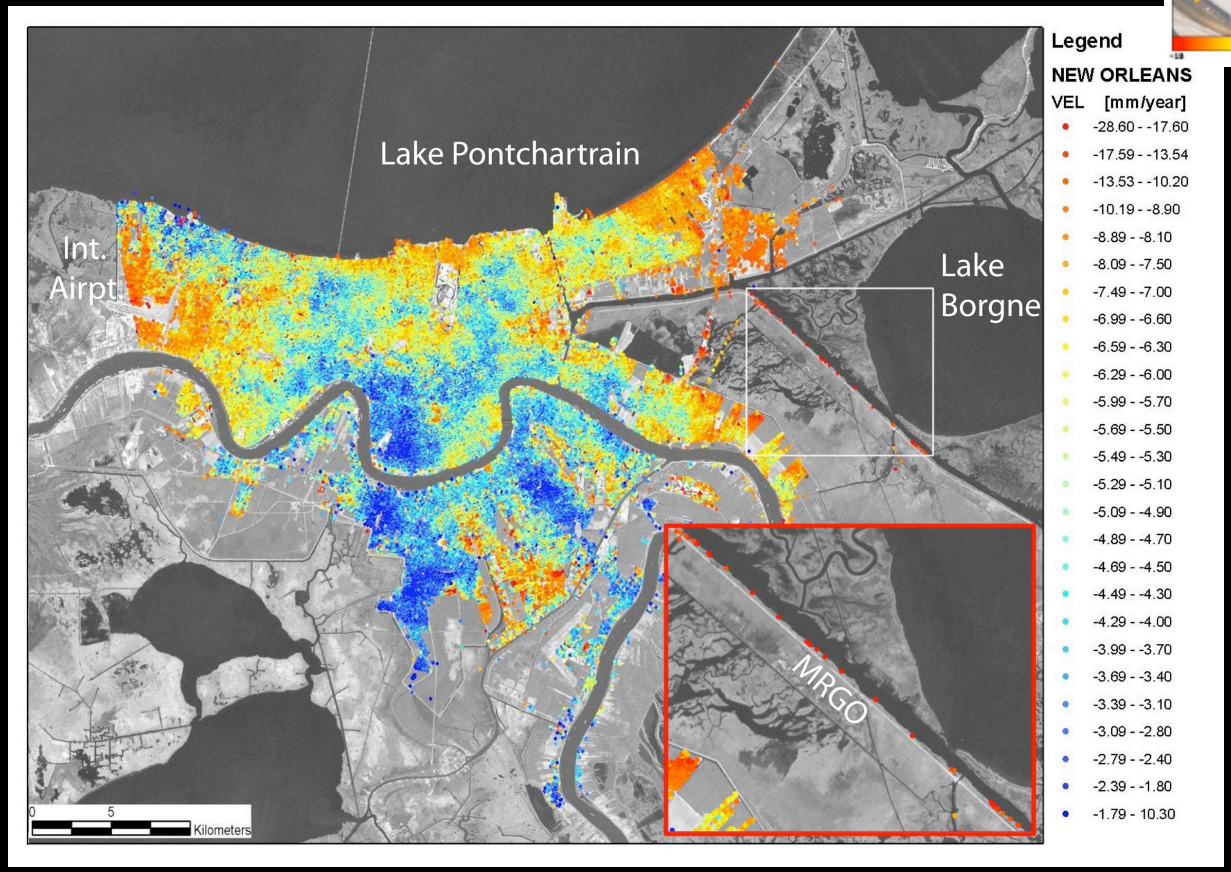




Buergmann et al., Science, 2000, Funning et al., 2007(?)

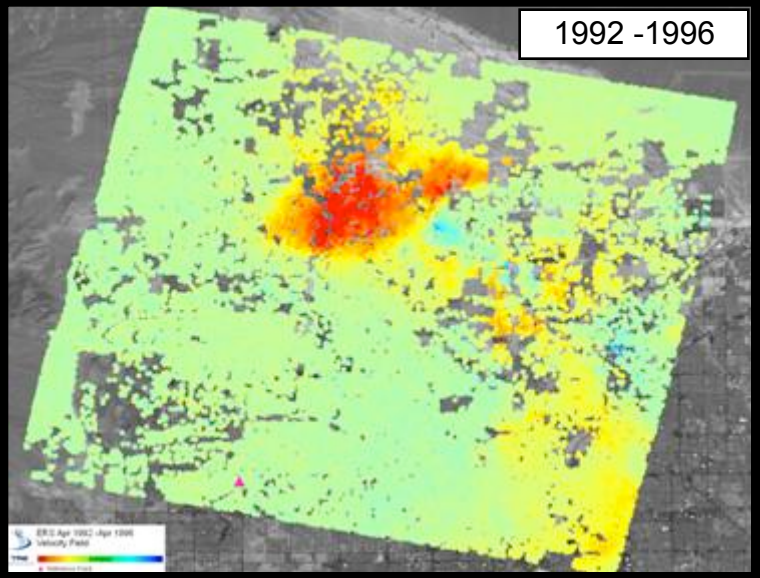
Science results (5): Land subsidence in New Orleans

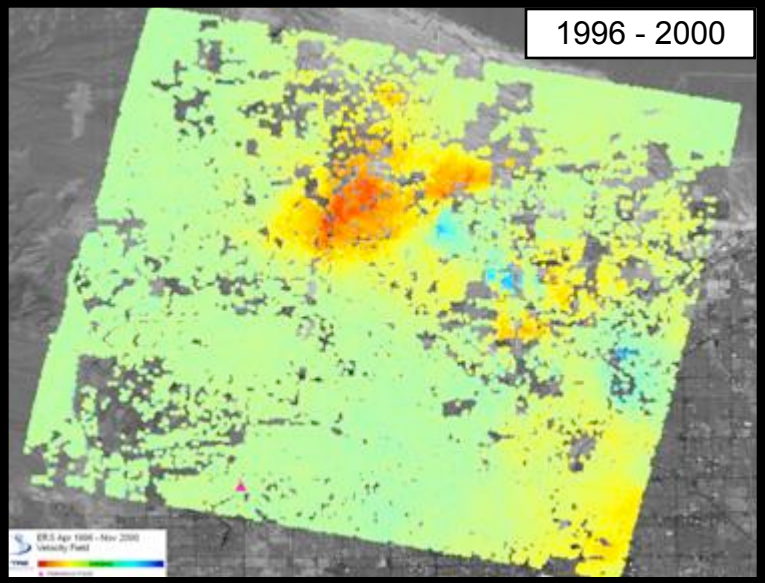


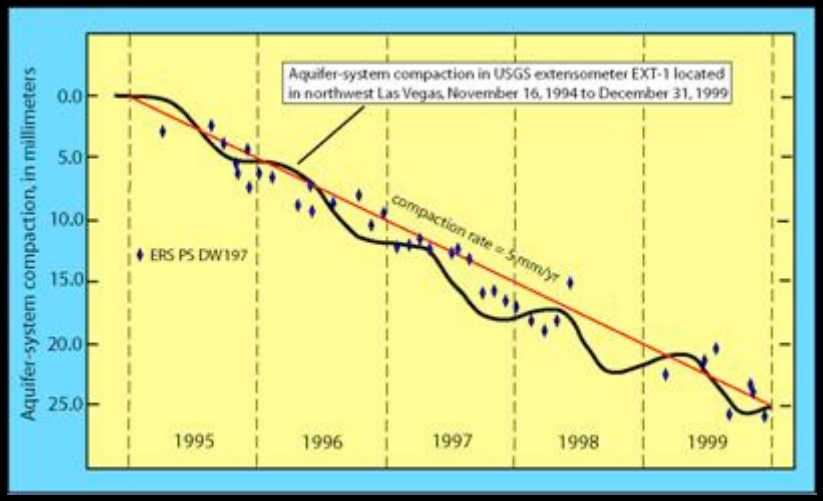


Dixon, Amelung, Ferretti et al., Nature 2006

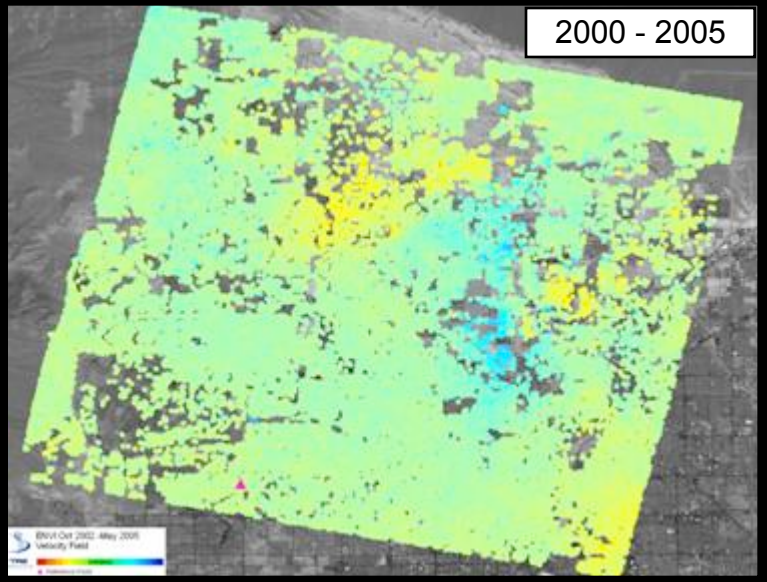
Science results (6): Land subsidence in Las Vegas







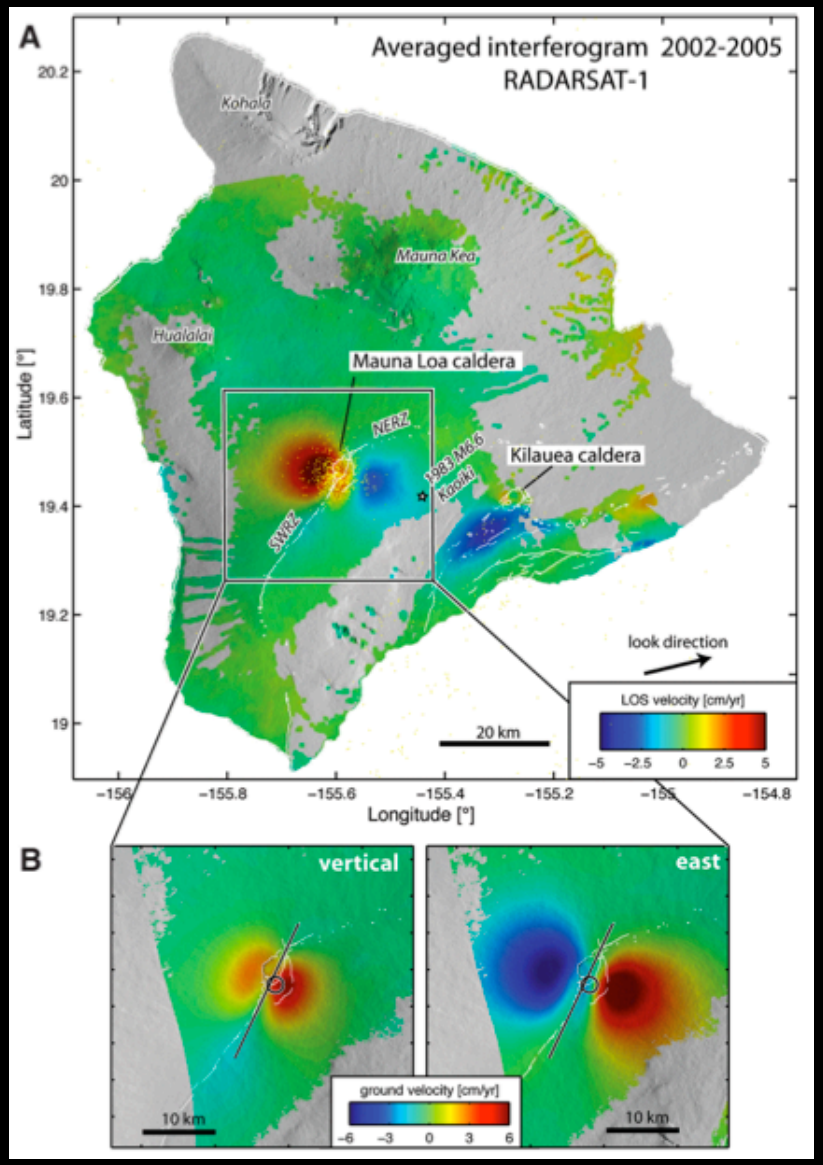
Courtesy of University of Nevada



Bell et al., WWR, in press

Science results (7): Inflation of Mauna Loa volcano, Hawaii

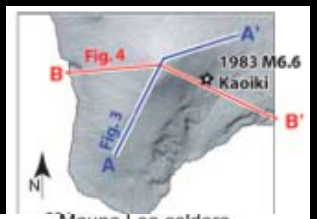
Magma intrusion into riftzone

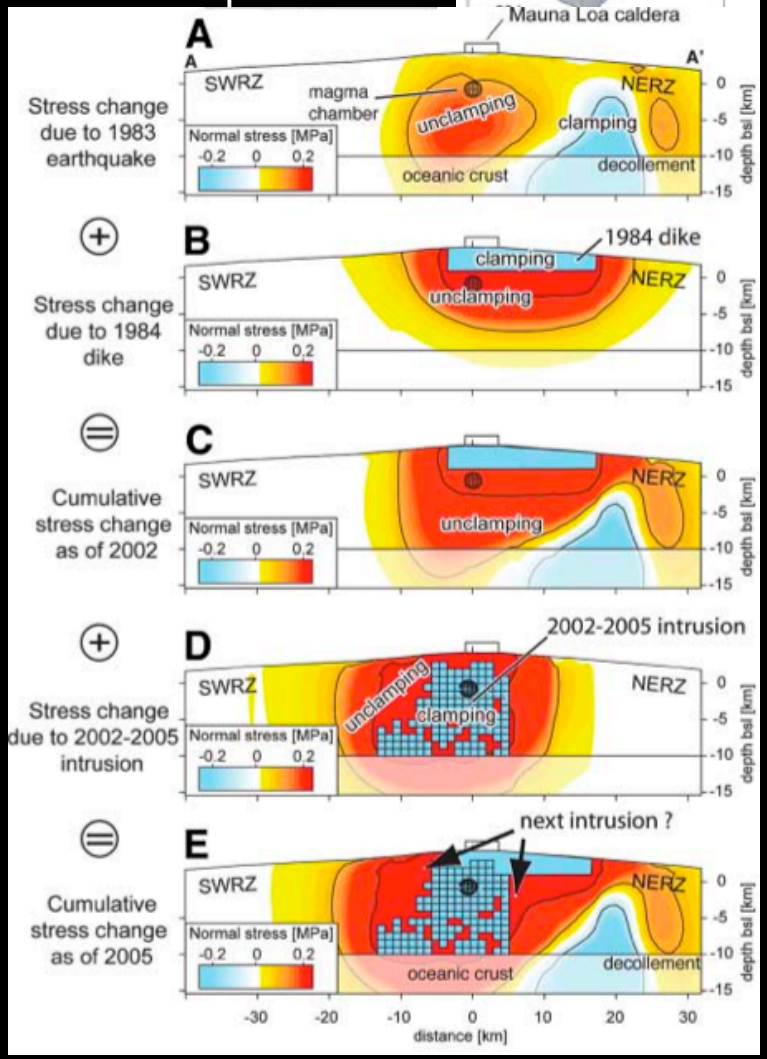


Based on ~100 Radarsat images with different viewing geometry

InSAR helps to predict eruption location !

Magma intruded in section of riftzone that was unclamped by previous earthquakes

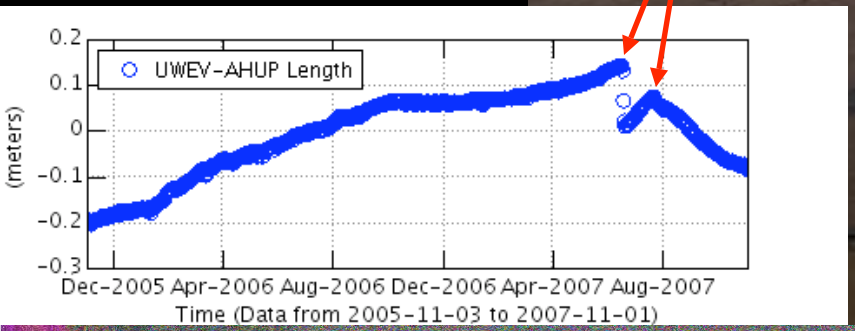




Amelung et al., Science, 2007

Science results (8): June 2007 Kilauea crisis, Hawaii

June-July 2007 events

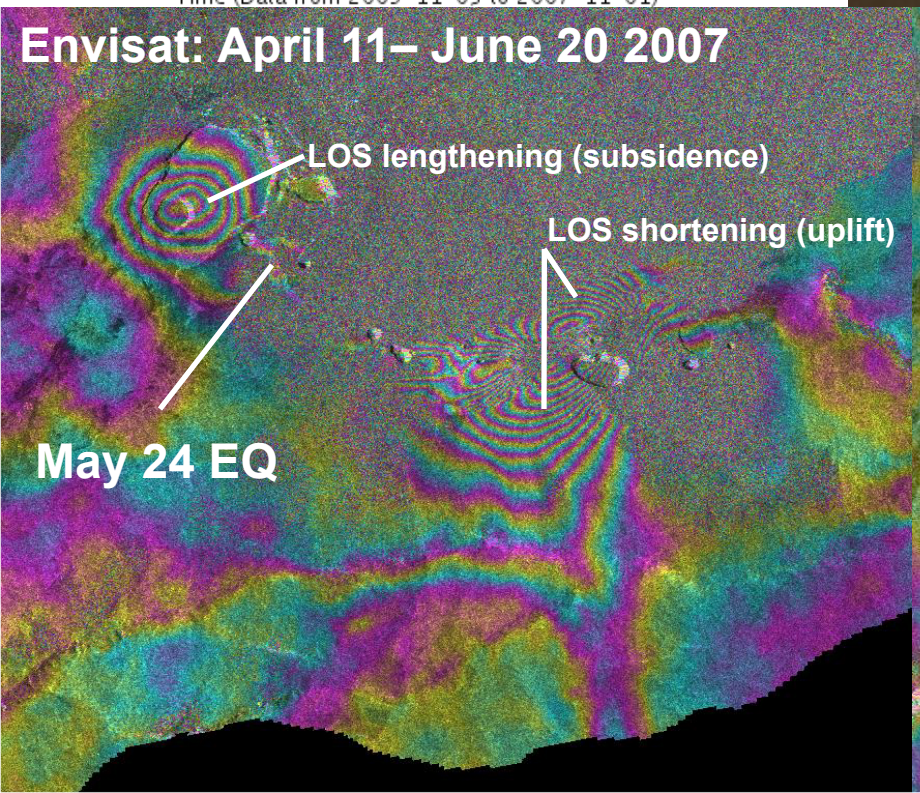


High note: near-real-time monitoring ! contributed in decision making

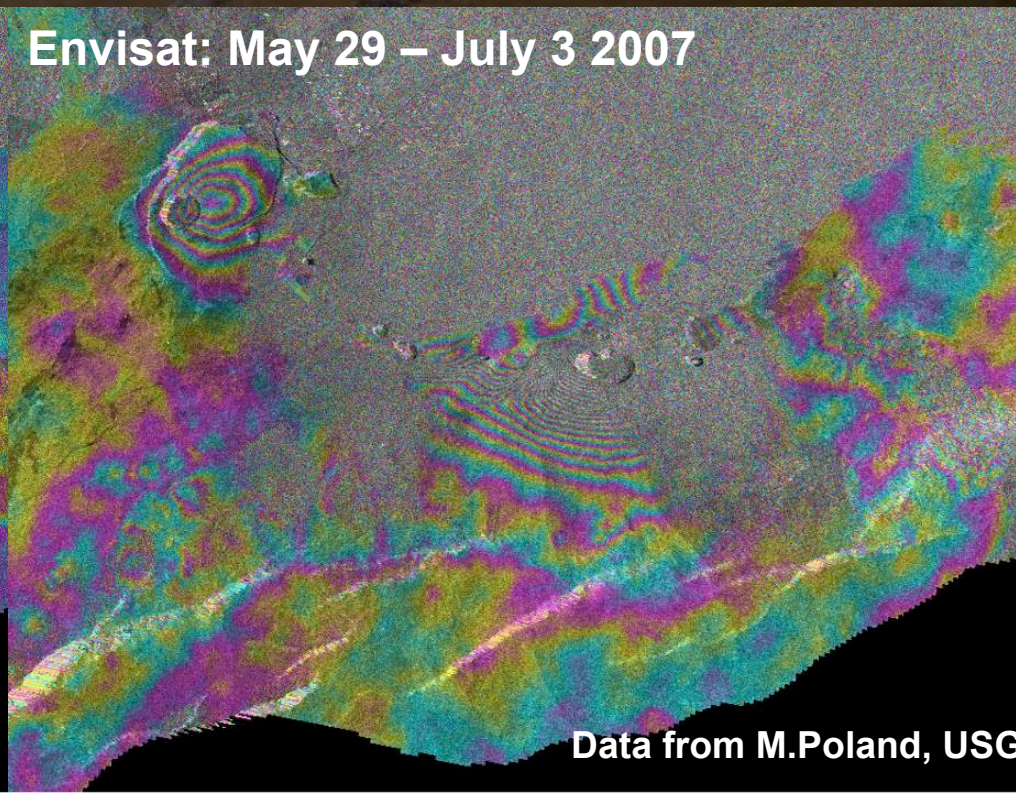
Low note: InSAR work occupied 1 staff member, no time left for geophysical modeling

→ SAR imagery needs to be readily available in near real time

Envisat: April 11– June 20 2007



Envisat: May 29 – July 3 2007



Data from M.Poland, USG

Recent high-impact publications

2004 Hilley, et al., Dynamics of slow-moving landslides from permanents scatterer analysis, *Science*, 304, 1952-1955.

2005 Gourmelen, N. and F. Amelung, Post-seismic mantle relaxation in the Central Nevada Seismic Belt, *Science* 310: 1473-1476.

2006 Fialko, Y., D. Sandwell, M. Simons, and P. Rosen, The origin of shallow earthquake slip deficit , *Nature*, 435.

2006 Fialko, Y., Interseismic strain accumulation and the earthquake potential on the southern San Andreas fault system, *Nature*, 441.

2006 Dixon, T. H., et al., Subsidence and flooding in New Orleans, *Nature*, 441, 587-588.

2006 Wicks, C., W. Thatcher, D. Dzurisin and J. Svarc, Uplift, thermal unrest and magma intrusion at Yellowstone caldera, *Nature*, 440, 72-75.

2007 Amelung, F., S.H. Yun, T. Walter and Paul Segall. Stress control of deep rift intrusion at Mauna Loa volcano, Hawaii. *Science*.

2007 Chang, W.-L., R. B. Smith, C. Wicks, J. M. Farrell, and C. M. Puskas,Accelerated uplift and magmatic intrusion of the Yellowstone Caldera, 2004 to 2006. *Science*.

Publications rely on easy access to SAR imagery through WinSAR !

Recommendation:

Develop Natural Laboratory data facility to make SAR data available in near-real time for scientific research and disaster management!

- ⇨ Prototype facility exists at Unavco.
- ⇨ Uses WinSAR's software.
- ⇨ Can be moved to, or mirrored at, regional centers.
- ⇨ NEEDS SAR DATA

http://naturallabs.unavco.org

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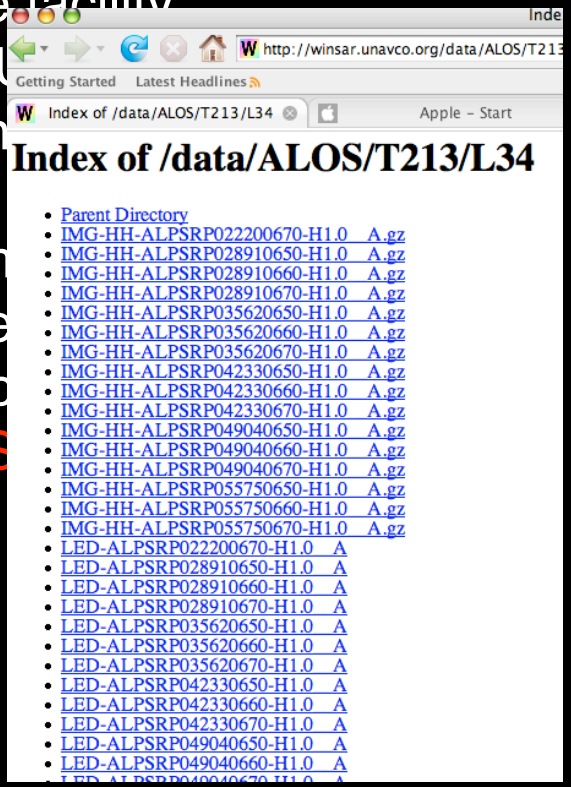

http://naturallabs.unavco.org

Goal:

Obtain open, near-real-time access to ALL SAR data relevant for geophysical research (tectonics, volcanoes, land subsidence).

Why ?

Societal benefits through
- improved earthquake hazard assessment (earthquake forecasting)
- volcano monitoring and eruption forecasting
- assessing water resources
- subsidence monitoring of coastal cities --> forecast effect of sea-level rise

New InSAR studies should include the entire SAR archive. For example, a year-2050 scientist needs access to 1992 imagery.

Status of WinSAR/Geoearthscope:

1. ERS and Envisat:
   - Order and archive procedures in place.
   - Category-1 projects with ESA.
   - Entire archive through Super Cat-1 (Unavco is PI, Co-I's report to Unavco which reports to ESA, Mini Cat-1s).

2. Radarsat:
   - Entire North America archive will be transfered to WinSAR
   - Costs: free for data at ASF. $150/datatake for data archived in Canada (Foreign Ground Station cost, FGS).
   - **No restrictions** from Canadian Space Agency!
   - Ingest software not complete.

3. ALOS:
   - Data obtained from the AADN (ASF) through credits with NASA, NSF.
   - Entire Western US archive expected.
   - Data in L-1 data pool at ASF, ingest software not complete.

4. JERS:
   - ... not yet thought about ...

Supersite/Natural laboratory concept (1)

1. Concept put forward at International Geohazard conferences organized by IGOS Geohazard and GEO (Group or Earth Observation countries)
   - Recommendation of Kuala Lumpur 2006 Southeast Asia Geohazard workshop: "To develop a satellite-based geophysical monitoring capability for SE Asia region".
   - "Frascati declaration" of 2007 International geohazard workshop: "To develop an international effort to monitor and study selected reference sites by establishing open access to relevant datasets"
2. Frascati Declaration endorsed by JAXA, NASA and CSA.
3. Proposed model:
   - WinSAR-type data archive at IGOS Geohazard in Orleans, France.
   - IGOS Geohazard will be Super Cat-1 user for ESA-data (Mini Cat-1s)
   - Data provided by ESA or contributed by WinSAR, INGV (and PIXEL ?).
   (ESA has to charge for reproduction costs. No charges are required for already produced data. Data would be returned to ESA and then given to IGOS Geohazard).
   - JAXA should contribute ALOS/JERS imagery.
4. SAR and ground-based data (GPS, seismic data).

Supersite/Natural laboratory concept (2)

5. Site selection by community consensus: Well-studied sites plus sites to stimulate research.

U.S.: Yellowstone, Hawaii, San Francisco, Los Angeles, Las Vegas.
Canada: Vancouver.
Italy: Etna, Vesuvius.
Africa: Nyiragongo, Mt. Cameroon, Lengai.
Indonesia: Merapi, Mentawai seismic gap.
Japan: ?

6. Summary and next steps.

- ESA very supportive of Supersite/Natural Laboratory concept.
- IGOS Geohazard Joint Committe meeting on Jan 16.
- Space Agencies support data sharing networks as long as they don't have to do too much work.

InSAR community needs to put a international data sharing network in place !

Proposed Model for Data Sharing Network

1. Multiple international nodes with regional responsibilities:
   - WInSAR@Unavco: U.S. and rest of Americas
   - IGOS Geohazard: Supersites
   - PIXEL: Japan and rest of Asia
   - MACRES (Malaysia Center of Remote Sensing): SE Asia Radarsat
   - INGV Italy: Africa, Europe ?
2. Same or similar policies. Members of one node are automatically members of the other nodes.
   - Use WInSAR's archive/ingest system. Software coordination and maintenance by Unavco.
3. NASA is ally. Open data-sharing network is integral part of Desdynl mission. Opportunities if ALOS TDRS data link successful.

Next steps:

1. Coordinate between PIXEL and WinSAR. PIXEL members should become WinSAR members and WinSAR members become PIXEL members.
2. WinSAR strategic planning at UNAVCO Science workshop, Boulder, March 11-13, 2008. Representatives of PIXEL and JAXA are welcome !

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Domo arigato gozaimasu !