Interdisciplinary Science Investigations using Earth Observation Systems

Transatlantic Collaborations

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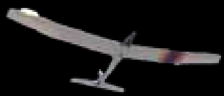
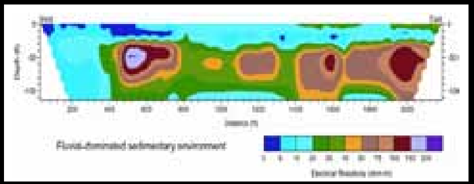
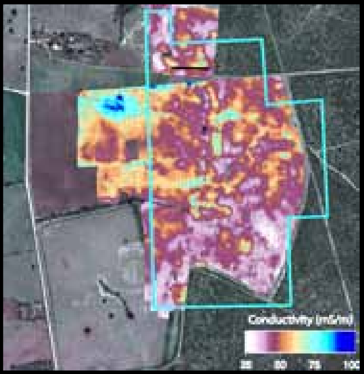
Introduction

- Group on Earth Observations coordinates the construction of a Global Earth Observation System of Systems by the year 2015
- Nine societal benefit areas: Agriculture, Biodiversity, Climate, Disasters, Ecosystems, Energy, Health, Water, and Weather.
- In U.S. government agencies, non-governmental organizations and private sector companies support the Integrated Earth Observation System of Systems
- *Airborne* well as *ground-based* sensor platforms are essential in validating *space* data, and integrating measurements over multiple scales







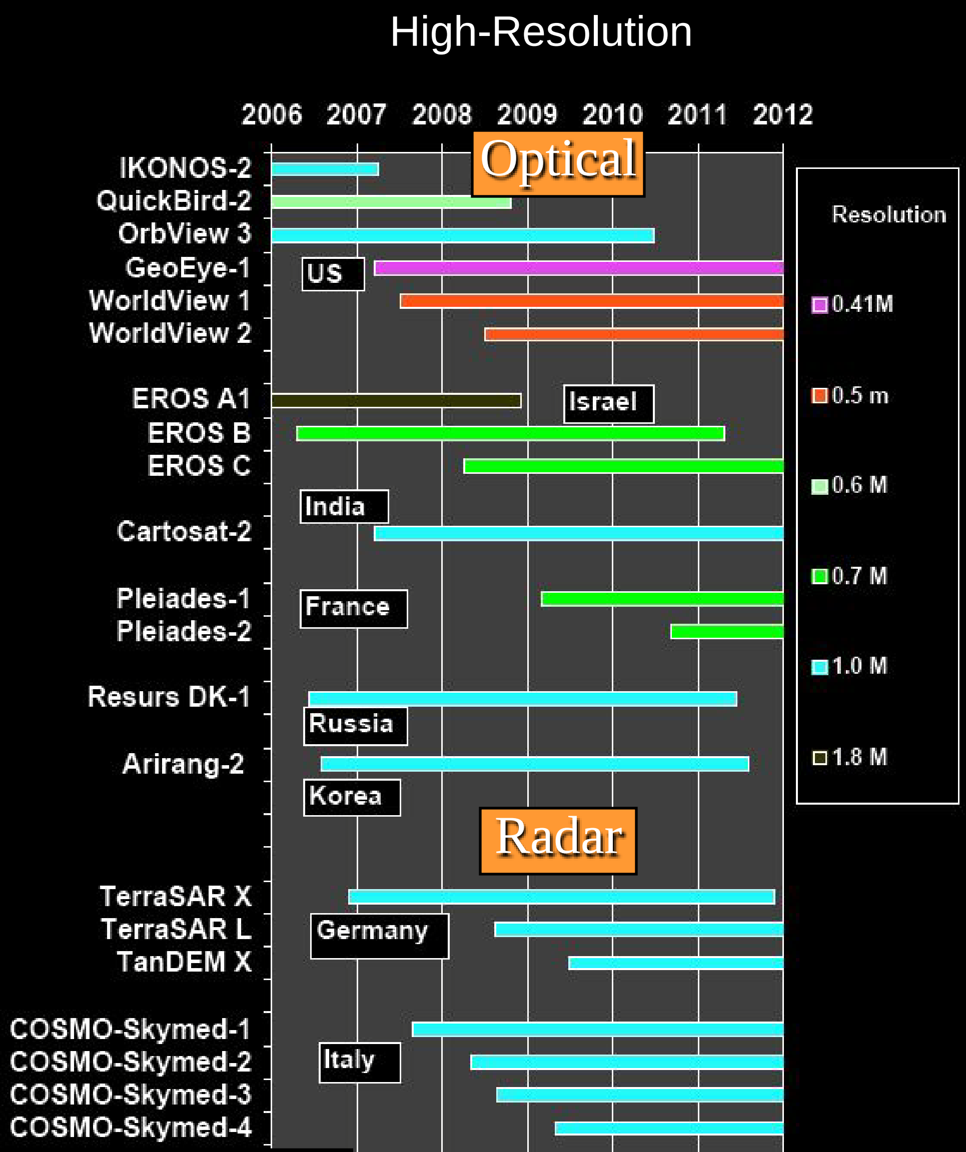
Global Earth Observation System

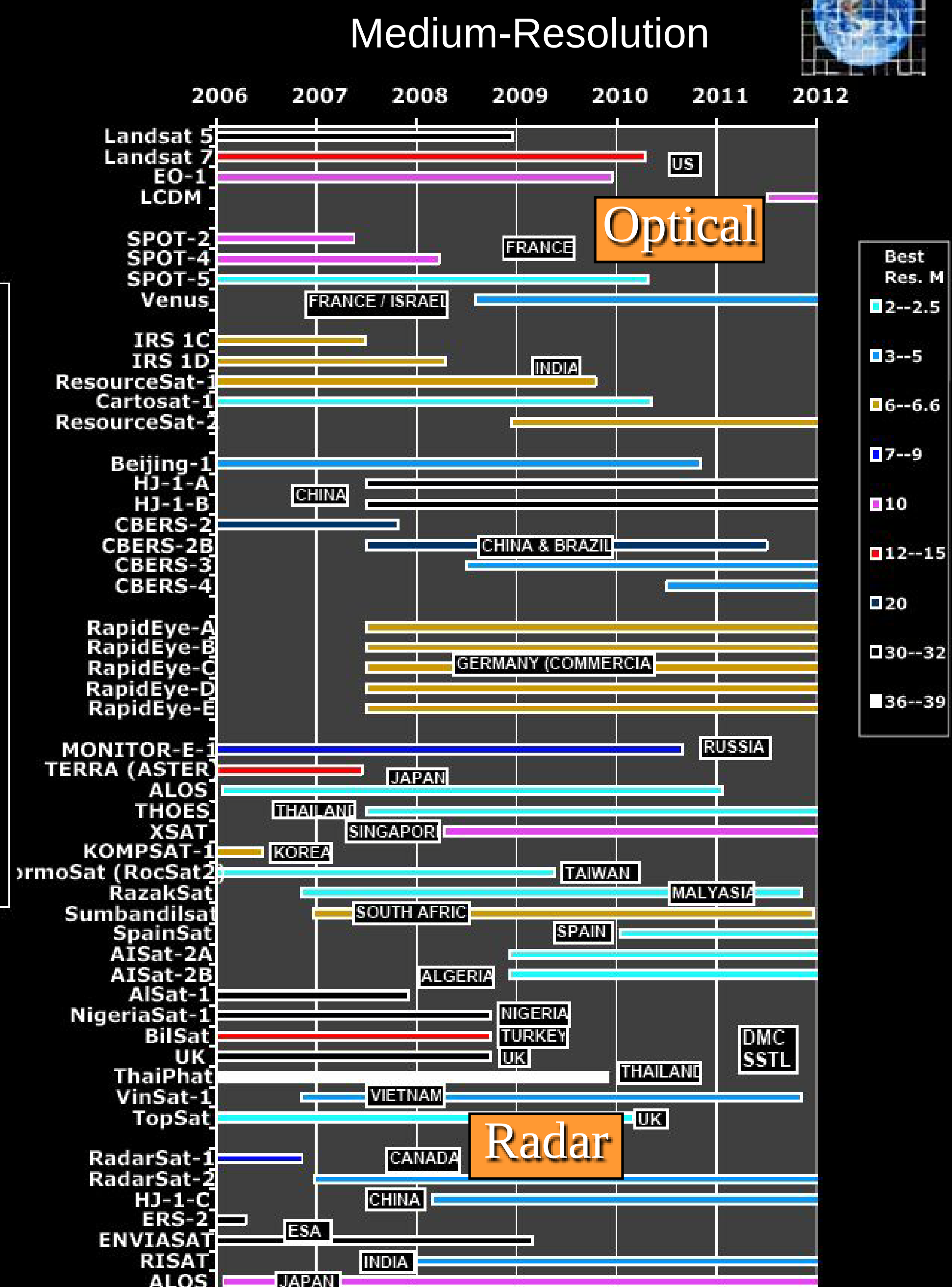
Societal Benefit Areas

- A: Supporting **sustainable agriculture** & combating **desertification**
- B: Understanding, monitoring, & conserving **biodiversity**
- C: Understanding, assessing, predicting, mitigating and adapting to climate change
- D: Reducing loss of life and property from natural & human-induced hazards
- Ec: Managing, monitoring, & conserving terrestrial, **coastal and marine resources**
- En: Improving management of **energy resources**
- H: Understanding environmental factors affecting **human health**
- Wa: Managing **water resources**
- We: Improving **weather** information, forecasting and warning

Source: GEOSS 10-Year Implementation Plan
http://www.earthobservations.org/documents.shtml

Current and Planned Earth Imaging Satellites





(Stoney, 2006)

The Dichotomy

Decision makers and emergency planners may not be aware of:

- Existing or planned sensors
- Potential or relevance of acquired data to hazard related applications

Remote Sensing scientists and engineers may not be aware of:

- Problems that their mission and sensors could help to solve

Southwest Research Institute (SwRI®)

- Nearly 2 Million Square Feet of Offices and Laboratories
- 1200 Acre Industrial Campus
- Nearly 3300 Employees Plus and Extensive Network of Consultants
- Satellite Offices in Boulder, Detroit, Houston, Ogden, and Washington
- Revenues of $564 Million in 2009

Sensors, instruments, and systems
UAV/UAS, balloon, airborne vehicle platforms
Optical and radar remote sensing, data processing, and interpretation
Data acquisition, mining, fusion, analysis, & visualization

Earth and Space Sciences
Earth and Planetary Atmosphere

Earth Sciences Applications

- Natural hazard and risk assessment
- Hydrology, geology, geophysics, geochemistry and geotechnical engineering

Examples of Natural Hazard Related Projects

Deformation of the Earth’s Crust

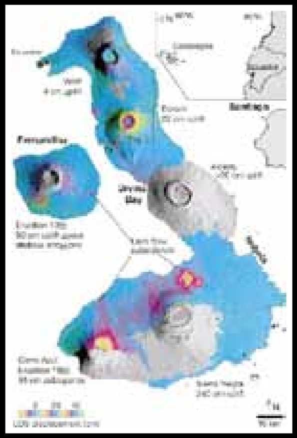
- *Natural causes* due to fault slip, igneous intrusion and volcanic eruption, slope failure and landslides, erosion and compaction
- A*nthropogenic causes* due to groundwater withdrawal, oil field production, and mine-related collapse features

Groundwater Withdrawal

http://ca.water.usgs.gov/groundwater/gwatlas/image/b94.gif

San Joaquin Valley, California
R.L. Ireland, U.S. Geologic Survey

Volcanism



http://www.nature.com/nature/journal/v407/n6807/images/407993aa.2.jpg

Galapagos Archipelago
Amelung (2000)

Fault Slip

http://serc.carleton.edu/images/quantskills/methods/quantlit/calquake.v2.jpg

1992 Landers Earthquake, California

Oil Field Production

http://www.isgs.uiuc.edu/maps-data-pub/publications/geobits

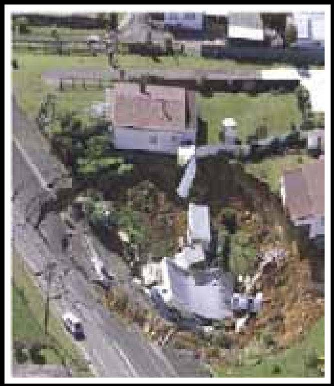
Clark County, Illinois
U.S. Geologic Survey

Landslides

http://pubs.usgs.gov/fs/2004/3072/fs-2004-3072.html

La Conchita, California

Sinkholes and Underground Mining



http://www.hauraki-dc.govt.nz/news/Mining-issues

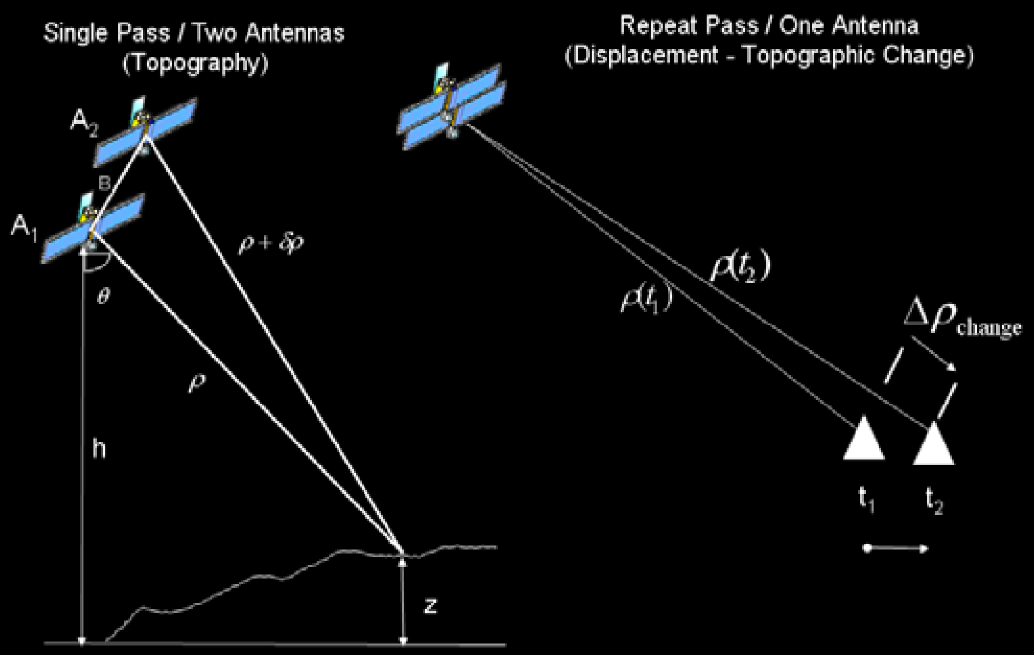
Waihi Underground Mine, New Zeeland

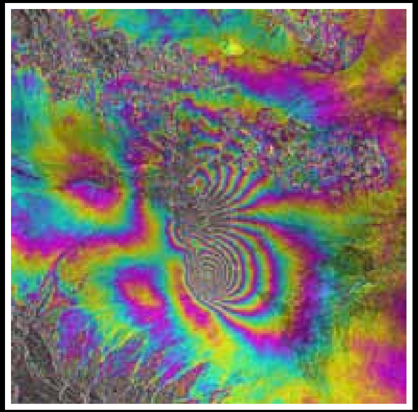
Methods of Measuring Ground Movement

Method	Component displacement	Resolution (millimeters)	Spatial density (samples/survey)	Spatial scale (elements)
Spirit level	vertical	0.1-1	10-100	line-network
Geodimeter	horizontal	1	10-100	line-network
Borehole extensometer	vertical ?	0.01-0.1	1-3	point
Horizontal extensometer:				
Tape	horizontal	0.3	1-10	line-array
Invar wire	horizontal	0.0001	1	line
Quartz tube	horizontal	0.00001	1	line
GPS	vertical horizontal	20 5	10-100	network
Conventional InSAR	range	1-10	100,000-10,000,000	map pixel

(after Galloway et al, 2000)

The Interferometric Synthetic Aperture Radar (InSAR) Technique



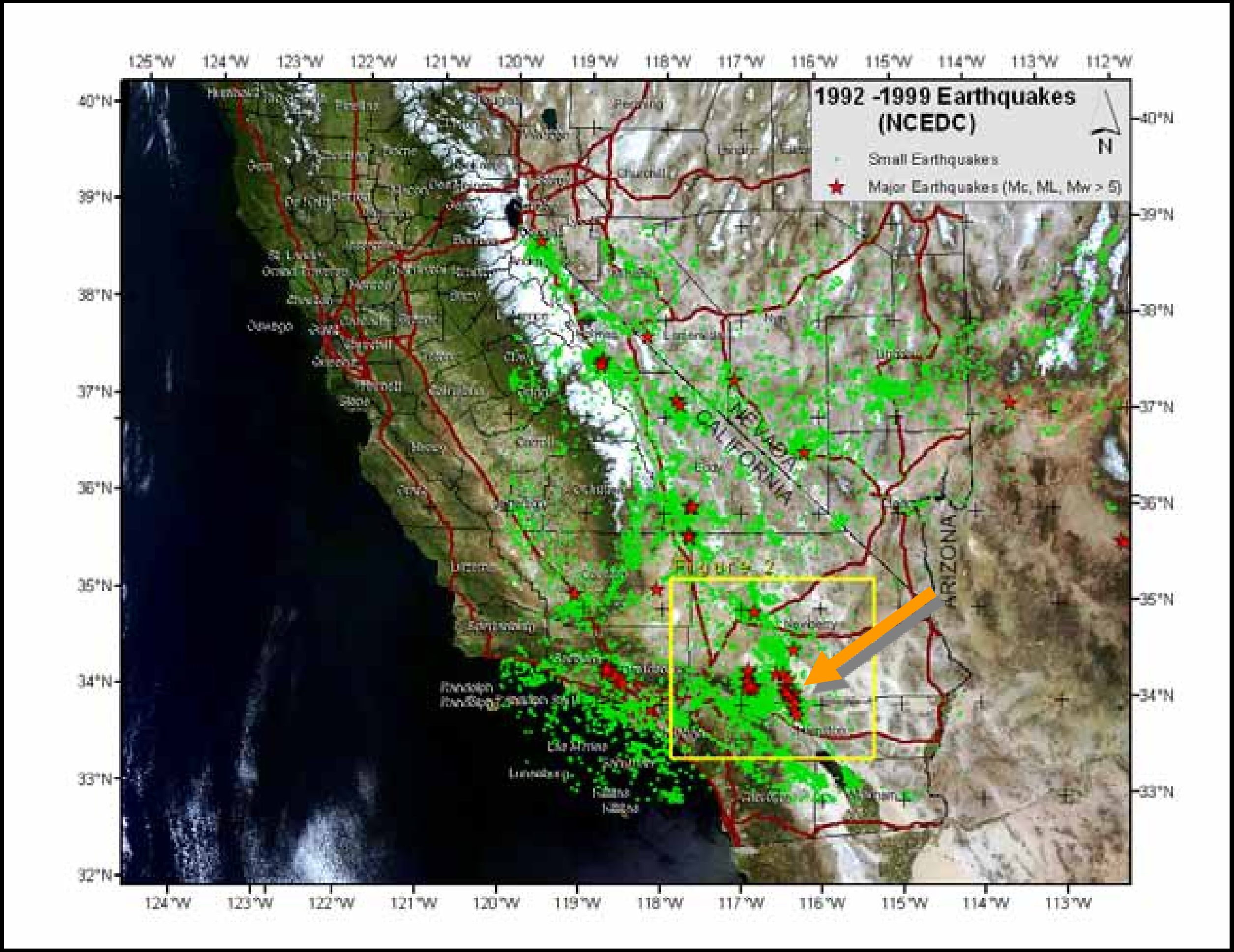


Interferogram of Bam's Earthquake , Iran (Necsoiu, 2009)

- An extremely sensitive airborne or satellite remote sensing technique capable of detecting very small (<=1 cm) elevation changes over very large areas (100 km^2) at a high spatial resolution (<= 30 m)

- A primary tool for measuring coseismic deformation and postseismic transients, provided there is adequate coverage.

InSAR Case Study: The Landers Earthquake, CA



Landers earthquake (Ms 7.6) on 28 June 1992

triggered the nearby

Big Bear Earthquake (Ms 6.7)

and

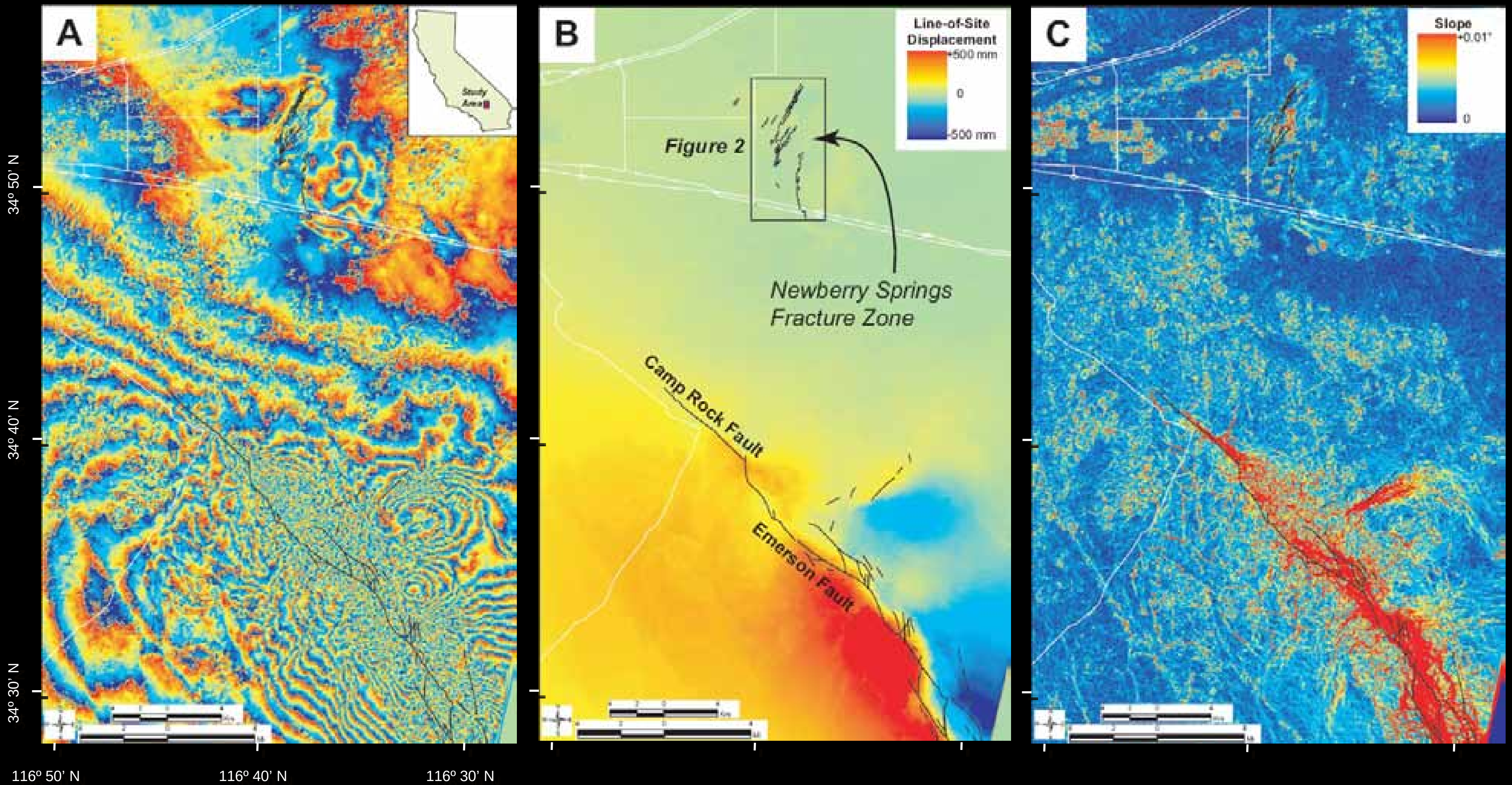
Little Skull Mountain Earthquake (Ms 5.4)

Landers earthquake demonstrated:

- a major earthquake on a segmented fault
- remote triggering of earthquakes
- major activity in a somewhat unexpected area and direction

InSAR Analysis of Earthquake-Related Deformation

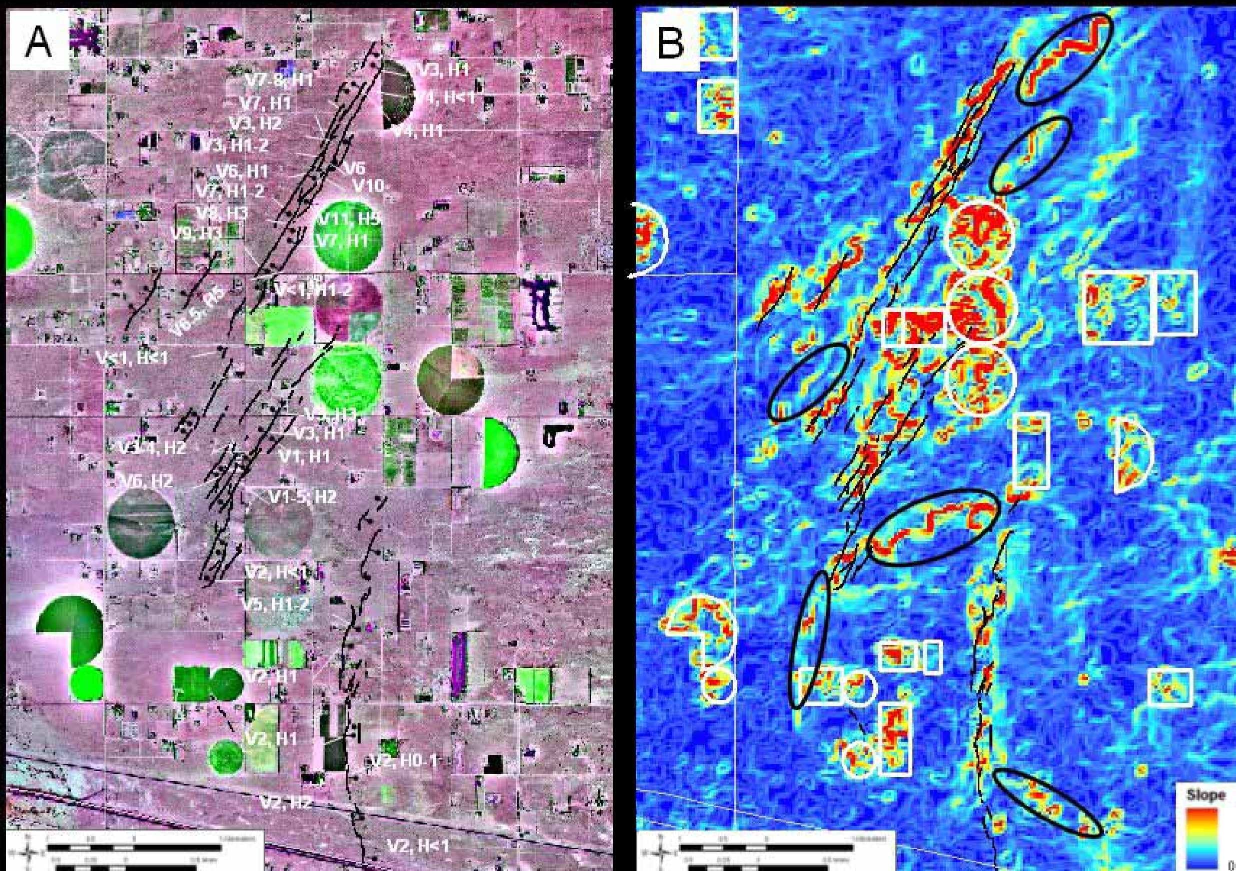
Identification of Fault Ruptures



(Necsoiu et al., 2005; Ferrill et al. 2008)

Displacement Gradiometry

Newberry Springs Fault Zone, California



(Ferrill, Necsoiu and Smart, 2005)

Detailed study area. (A) Landsat 5 TM (RGB 743) image, acquired on May 07, 1990, showing small fault ruptures and measured throw (labeled V) and heave (labeled H) values. The resolution of satellite data was enhanced by fusion with DOQ. (B) Gradiometry map. Cultural and agricultural features (e.g., highway, center pivot irrigation circles, ponds) are outlined in white. Suspected fault ruptures are indicated by black ellipses.

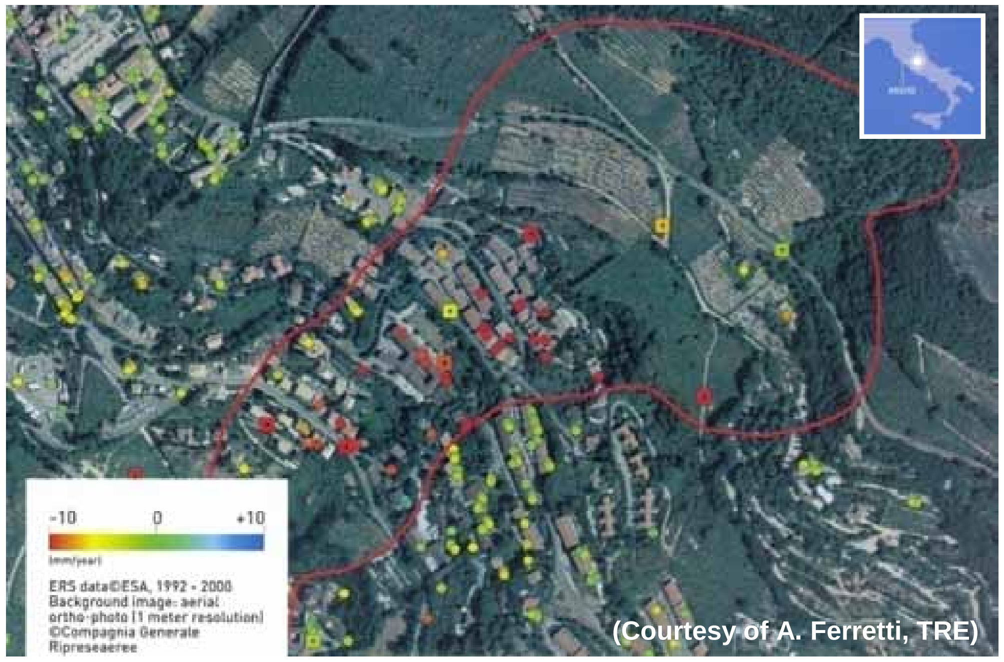
Multi-interferogram InSAR Techniques

PSInSAR™, IPTA, CTM, SPNA: Examples of multi-interferogram InSAR techniques

The Permanent Scatterers (PS): Stable “targets” not affected by radar acquisition, geometry, temporal decorrelation, and displaying reliable phase information

Requirements:
- PS density: > 5 PS / sq. km
    - Minimum 20 radar images (greater for a higher precision of deformation)

Benefits:
- Submillimetric vertical accuracy beyond that of GPS
- Precision: +- 0.1 mm / year
- Suitable for long-term monitoring



(Courtesy of A. Ferretti, TRE)

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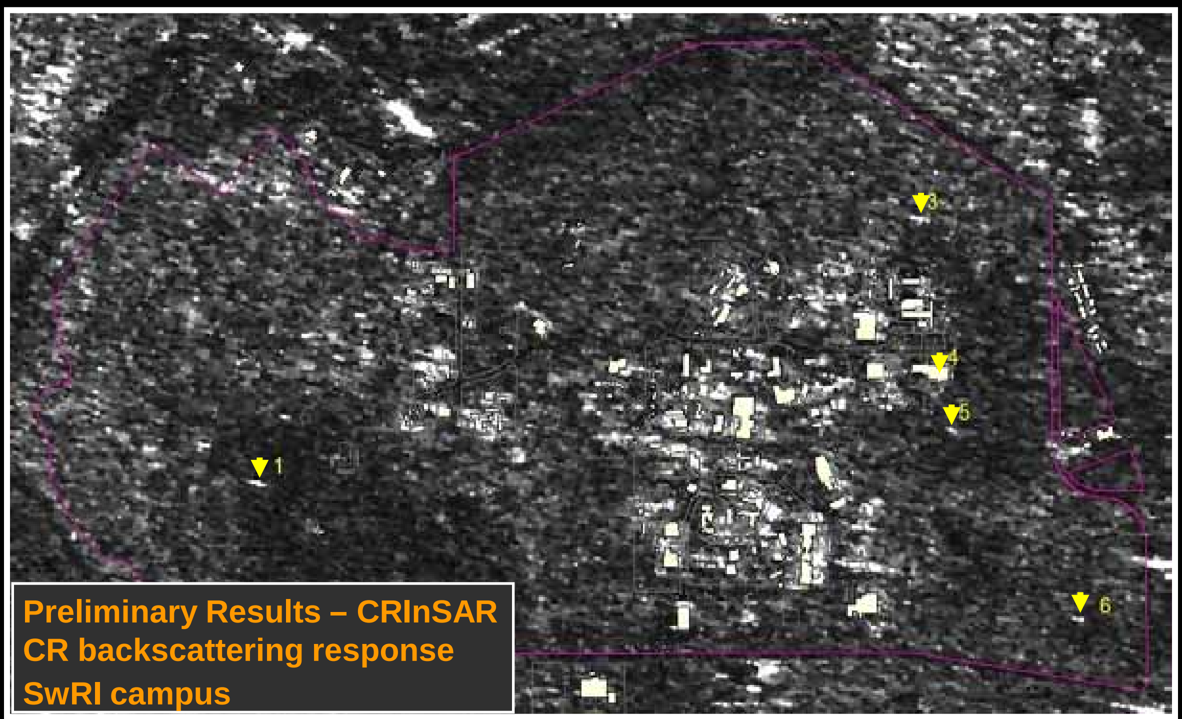
Limitations:
- Problems in vegetated and forested areas, steep topography, low-reflectivity targets (wood structures)
- PS are heterogeneously distributed at unpredictable locations
- Require large radar datasets sometimes unavailable at certain geographic locations

High-resolution Synthetic Aperture Radar Interferometry Validation Using Corner Reflectors

Project Objective:

To develop a radar interferometry method that uses artificial permanent scatterers (e.g., CR) that can measure ground displacement with mm resolution in line of sight.



Preliminary Results – CRInSAR
CR backscattering response
SwRI campus

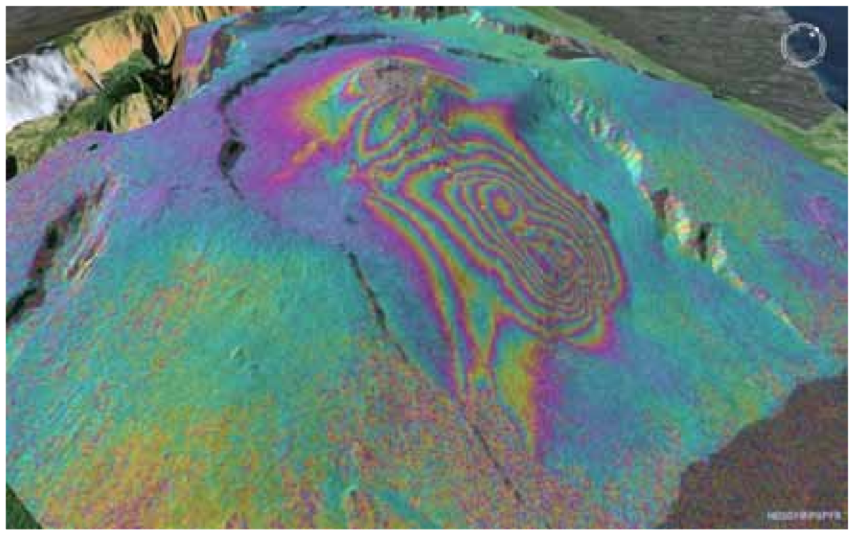
Trihedral Reflector

Dihedral Reflector

Pre-, Syn- and Post- Eruption Volcanic Deformation Using GPS, GIS and Corner Reflector InSAR Technologies

A test case for Guadeloupe, Martinique and Réunion Islands

Objective: To evaluate satellite radar interferometry technologies, identify requirements and develop a methodology for optimal monitoring of geomorphological deformation



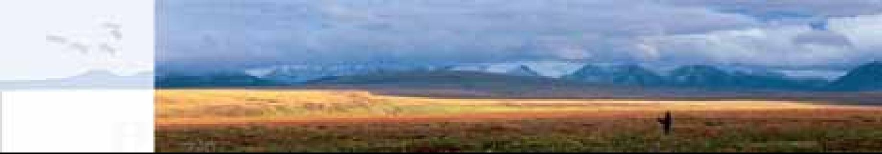
Credits: E. Heggy, Globvolcano Project

The project:

- Uses ground GPS data collected by Volcanological and Seismological Observatories of the Antilles and Reunion Islands in partnership with the local universities and the regional and departmental authorities.

- Builds a GIS database to serve a variety of stakeholders.

Climate Related Projects



Permafrost Degradation

A naturally or artificially-caused decrease in the thickness and/or areal extent of permafrost
(National Research Council of Canada Technical Memorandum No.142.1988)

(U.S. Arctic Research Commission, 2003)

Expressed as:

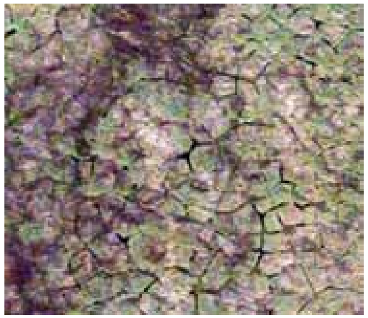
- a thickening of the seasonal active layer
- a lowering of the permafrost table
- a reduction in the areal extent of permafrost
- or the complete disappearance of permafrost.

Has ecological and societal impacts:

- endangers engineered infrastructure
- Impacts vegetation and wildlife
- feeds back into climate change through release of previously sequestered greenhouse gases

Monitoring Land-Cover Changes of Permafrost Landscapes Using Optical and Quad Polarization SAR

Case Study: Kobuk Valley, Alaska



Microwave remote sensing effective for frozen ground mapping due to high difference of permittivity between frozen and unfrozen soil. A recent SwRI study shows that coherence maps derived from pairs of SAR datasets indicates high coherence regions are associated with polygonal soils affected by the presence of massive ice wedges and permafrost.

Support for research:

- Americas ALOS Data Node
- Japan Aerospace Exploration Agency
- National Park Service

Objectives:

- Develop an integrated methodology to monitor changes in permafrost landscapes
- Perform remote soil characterization in thawed state using semi-empirical polarimetric backscattering models
- Estimate the residual liquid water content in frozen background
- Investigate the relationships between SAR coherence and polygonal soils.

Antarctic Sea Ice Thickness from Airborne LiDAR and Ultra-wideband Radar

Objectives:

Obtain concurrent and co-located measurements of sea ice surface topography and snow depth to use in calibration/validation of airborne instruments.

Assess and refine snow and ice thickness algorithms for improved accuracy and potential application to ICESat-2 and/or CryoSat2 satellites

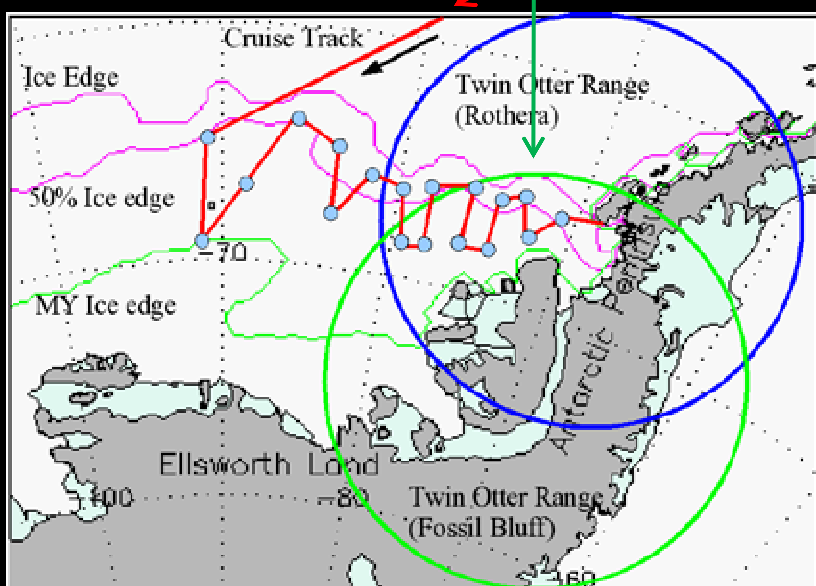
Support for research:
The British Antarctic Survey (BAS) ICE Bell Program
European Space Agency
Extension of existing NSF and NASA funded Antarctic Program

BAS ICE Bell Program

INTERNATIONAL TEAM OF COLLABORATORS

- British Antarctic Survey (primary) - Cambridge, UK
- Scottish Association of Marine Science (SAMS) - Dunbeg, UK
- Woods Hole Oceanographic Institute – Woods Hole, Mass, USA
- University of Manitoba -Winnipeg, Manitoba, Canada
- Desert Research Institute- Reno, Nevada, USA
- Danish Meteorological Institute- Copenhagen, Denmark
- Danish Technical University- Lyngby, Denmark
- University of Texas at San Antonio- San Antonio, TX, USA

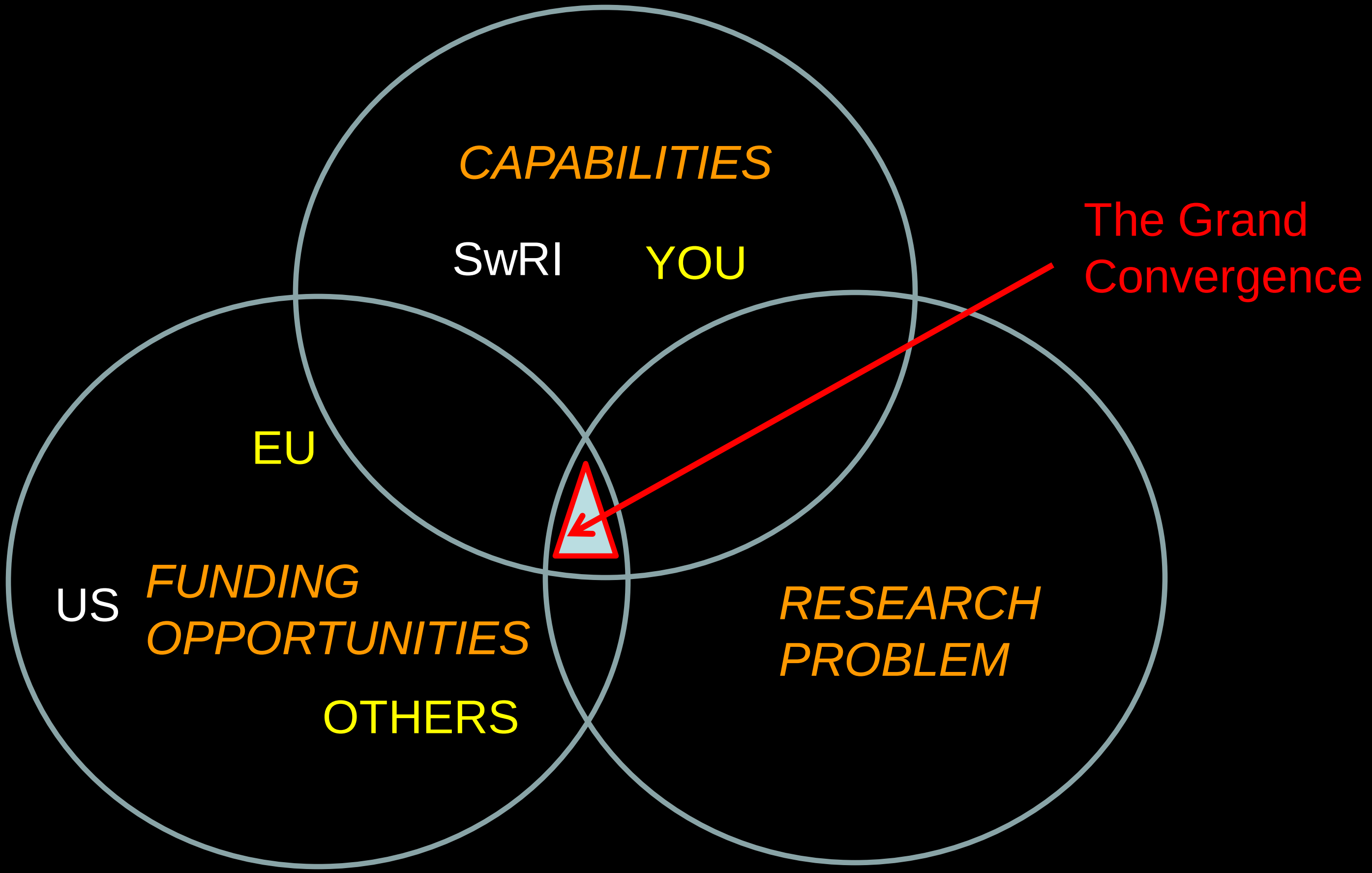
BAS ICE Bell Program



- 3-D mapping of snow surface by airborne LiDAR, surface LiDAR, and gridded survey
- 3-D mapping of under-ice surface by Autonomous Underwater Vehicle (AUV) with upward looking swath bathymetry, Electromagnetic Induction (EMI), and borehole measurements
- Snow properties from snow pits
- Ice Mass-Balance (IMB) buoys installed

Toward Successful Transatlantic Collaborations

The Business Development Triad



Open FP7 Calls addressing cooperation between the EU and the U.S.

The 7th Framework Programme

Current - 16 calls currently open

Food, Agriculture & Fisheries, and Biotechnology (5)

Space (4)

Transport including Aeronautics (3)

Energy (1)

International Cooperation (1)

Socio-economic Sciences and Humanities (2)

Near Future - end of September 2010

Information & Communication Technologies (5)

Conclusions

• There is a new spirit of transatlantic collaboration stemming from the need to open new research frontiers.

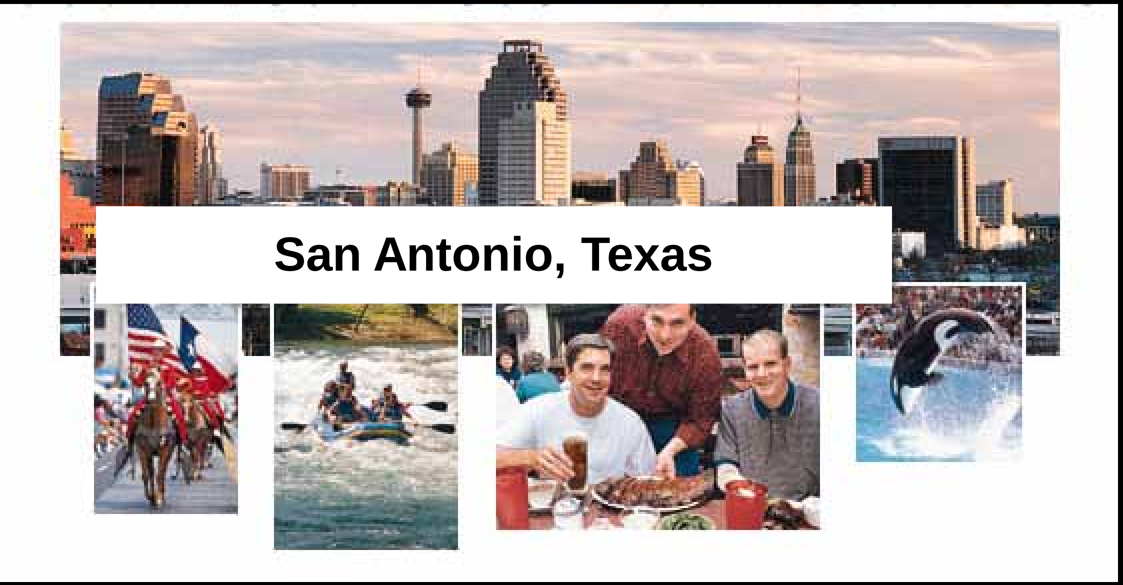
• Genuine interest in solving complex Earth Science problems and developing fruitful collaborations with scientists and engineers around the world.

• Technologies presented here could be applied in a variety of applications related to climate change and hazard risk reduction.

• SwRI actively involved in a variety of Earth Observation Systems research – an excellent avenue to develop exciting transatlantic collaborations.

Acknowledgements

• Mike Lewis, Don Hooper, Gary Walter, and David Ferrill
• Debbie Shaffer and Mike Ladika



Thank You!