DESDynI – Deformation, Ecosystem Structure and Dynamics of Ice

Mission Concept, Possible Roles in US Hazard Monitoring and Mitigation, and Status

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Briefing to the NSTC Subcommittee on Disaster Reduction

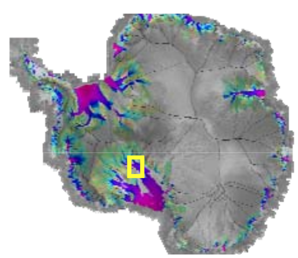
Washington, DC

September 1, 2011

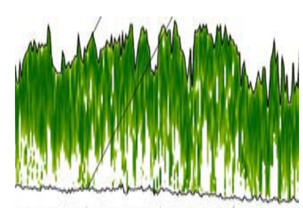
DESDynI Science

- Recommended by the NRC Decadal Survey for near-term launch to address important scientific questions of high societal impact:
  - *What drives the changes in ice masses and how does it relate to the climate?*
  - *How are Earth's carbon cycle and ecosystems changing, and what are the consequences?*
  - *How do we manage the changing landscape caused by the massive release of energy of earthquakes and volcanoes?*
- Planned by NASA as one of the following 4 Decadal Survey TIER 1 Missions
  - *SMAP*
  - *ICESat-II*
  - *DESDynI*
  - *CLARREO*

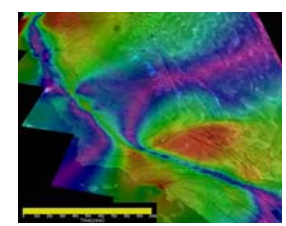
- **Ice sheets and sea level**
  - *Will there be catastrophic collapse of the major ice sheets, including Greenland and West Antarctic and, if so, how rapidly will this occur?*
  - *What will be the time patterns of sea level rise as a result?*
- **Changes in ecosystem structure and biomass**
  - *How does climate change affect the carbon cycle?*
  - *How does land use affect the carbon cycle and biodiversity?*
  - *What are the effects of disturbance on productivity, carbon, and other ecosystem functions and services?*
  - *What are the management opportunities for minimizing disruption in the carbon cycle?*
- **Extreme events, including earthquakes and volcanic eruptions**
  - *Are major fault systems nearing release of stress via strong earthquakes?*
  - *Can we predict the future eruptions of volcanoes?*



Ice Dynamics



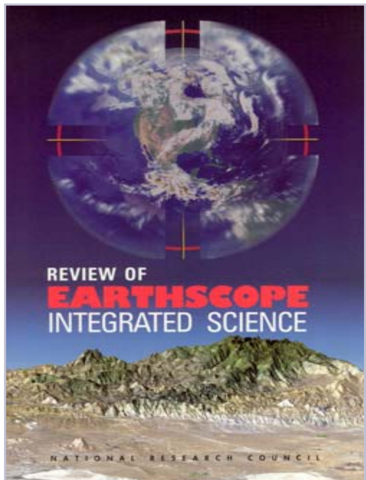
Biomass



Deformation

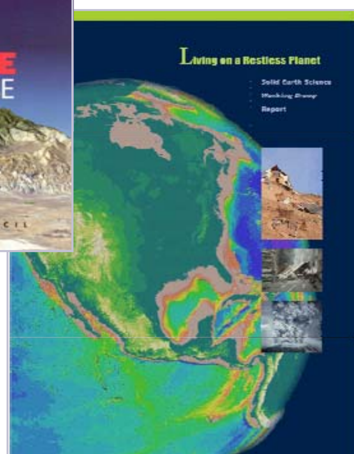
Sources for Science Objectives

…as captured in the NASA Science Plan



Fourth component of EarthScope

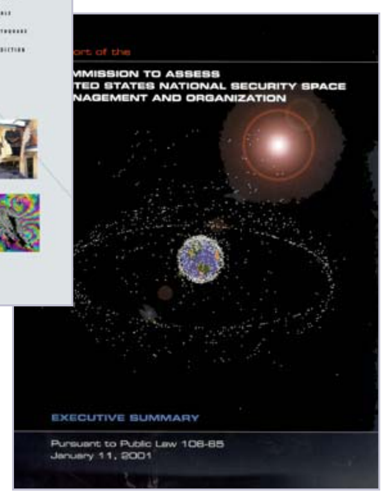
Involvement:
NSF, NASA, USGS,
Universities



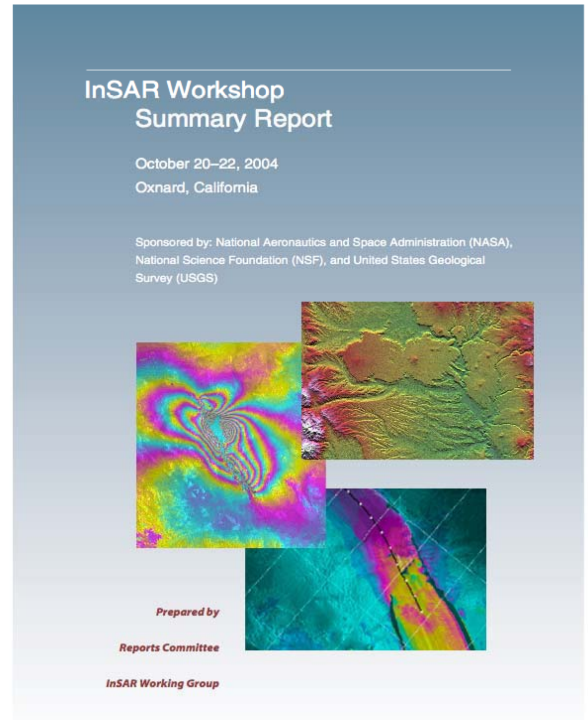
Highest priority of NASA's Solid Earth Science Working Group

Supported in NRC Review

Recommended for the Global Earthquake Satellite System



Department of Defense Applications



Howard Zebker (Chair) Stanford
Involvement:
NASA, NSF, USGS, Universities (63)

Engaging hundreds of scientists and user communities in multiple disciplines

A Call for Hazards Monitoring

Surface deformation and change are recognized as key measurements for hazard monitoring and mitigation in numerous reports beyond the NRC Decadal Survey

- In "*Achieving and Sustaining Earth Observations: A Preliminary Plan Based on a Strategic Assessment by the US Group on Earth Observations"* (September 2010):

  NASA should launch the radar portion of the NRC Decadal Survey mission Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynI) mission…

  The L-Band Interferometric Synthetic Aperture Radar (InSAR) will provide surface deformation measurements.

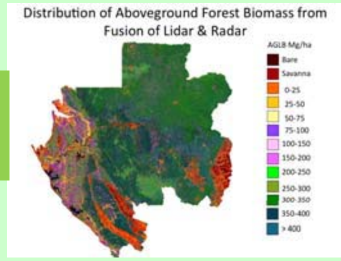
- Similar recommendations have been made for over 15 years
  - Open letter to NASA Earth Science Administrator from Solid Earth Community (1994)
  - Solid Earth Science Working Group Report (2002)
  - IGOS Geohazards Report (2004)
  - IEOS Reducing loss of life and property… report (2007)
  - Subcommittee on Disaster Reduction Working Group Reports (2008)

The US cannot continue to rely on foreign or overtaxed intelligence assets to meet the needs of the science and hazard response communities

DESDynI Science to Implementation

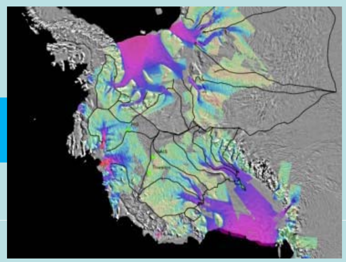
January 2011 Concept

Ecosystem Structure



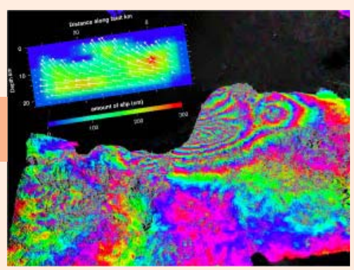
Biomass, Vegetation Structure, Effects of changing climate on habitats and CO_2, disturbance

Cryosphere



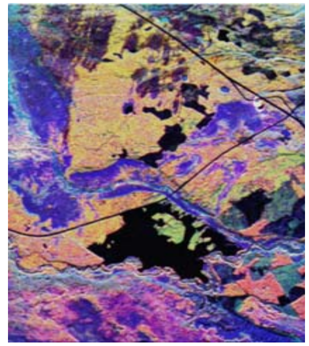
Ice velocity, thickness
Response of ice sheets to climate change & sea level rise

Solid Earth

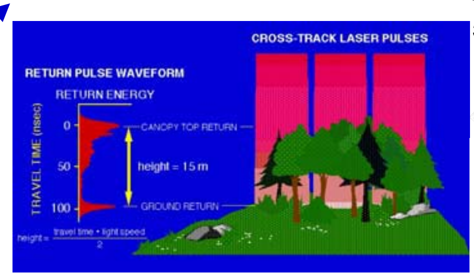


Surface Deformation
Geo-Hazards
Water Resource Management

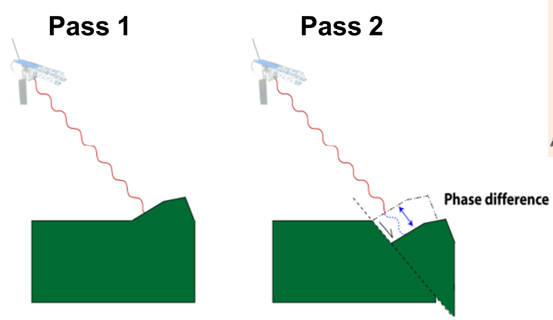
L-band Polarimetric SAR

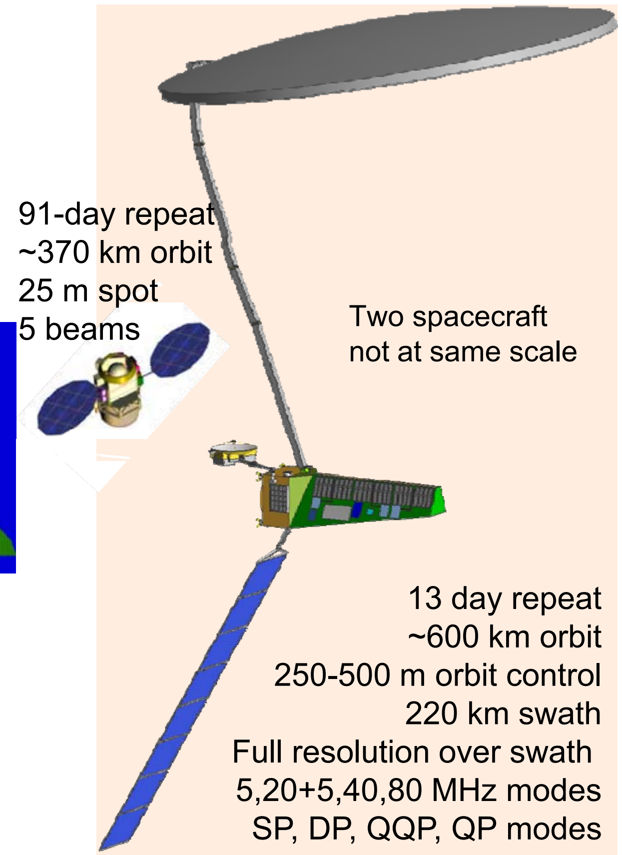


Multibeam Profiling LIDAR

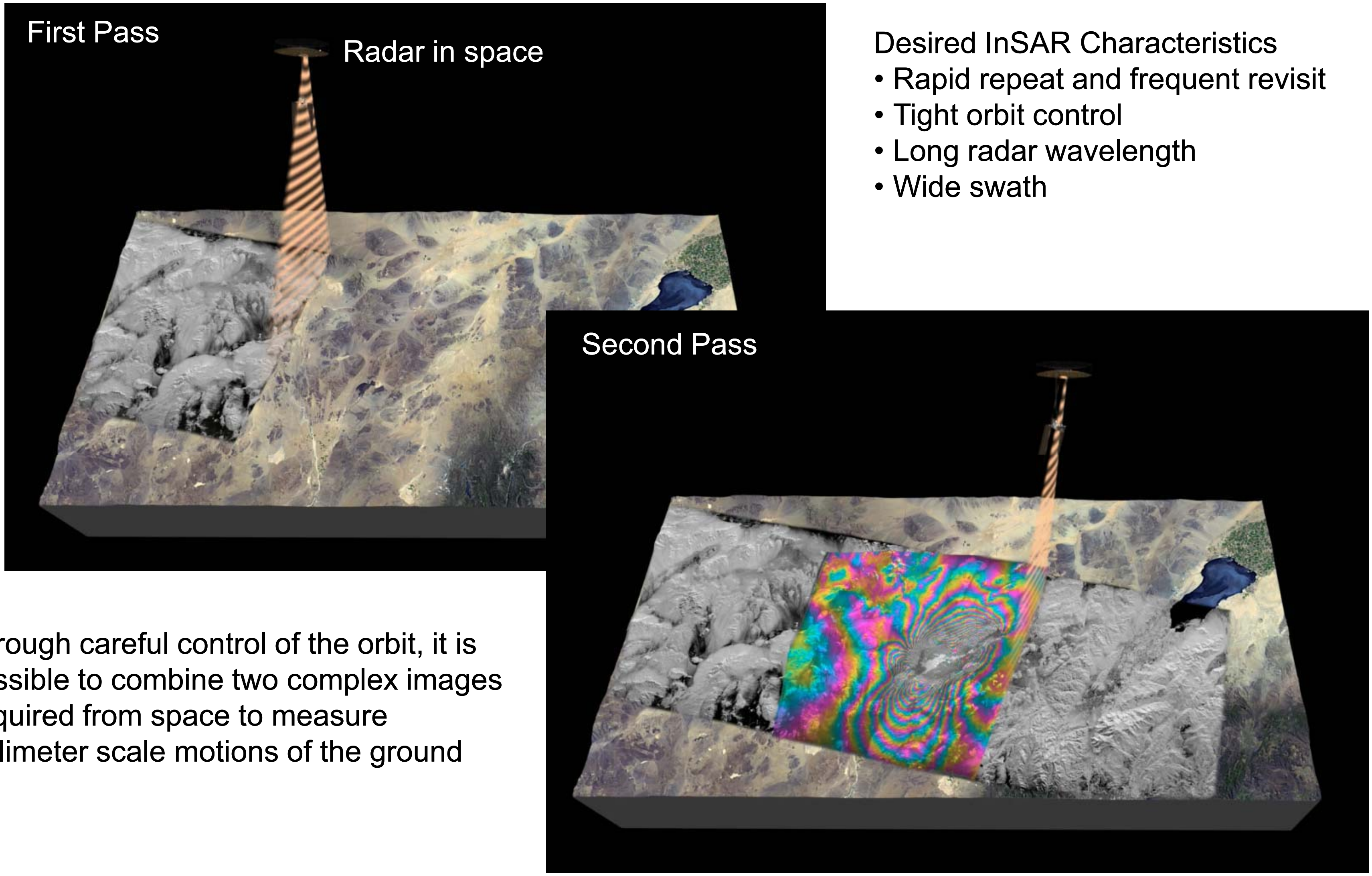


L-band Repeat Pass InSAR





Interferometric SAR Technique

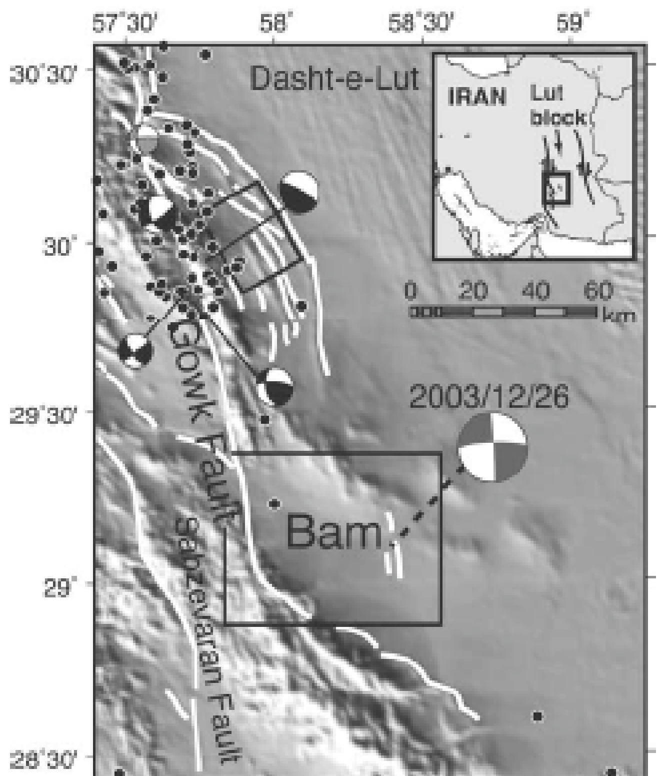


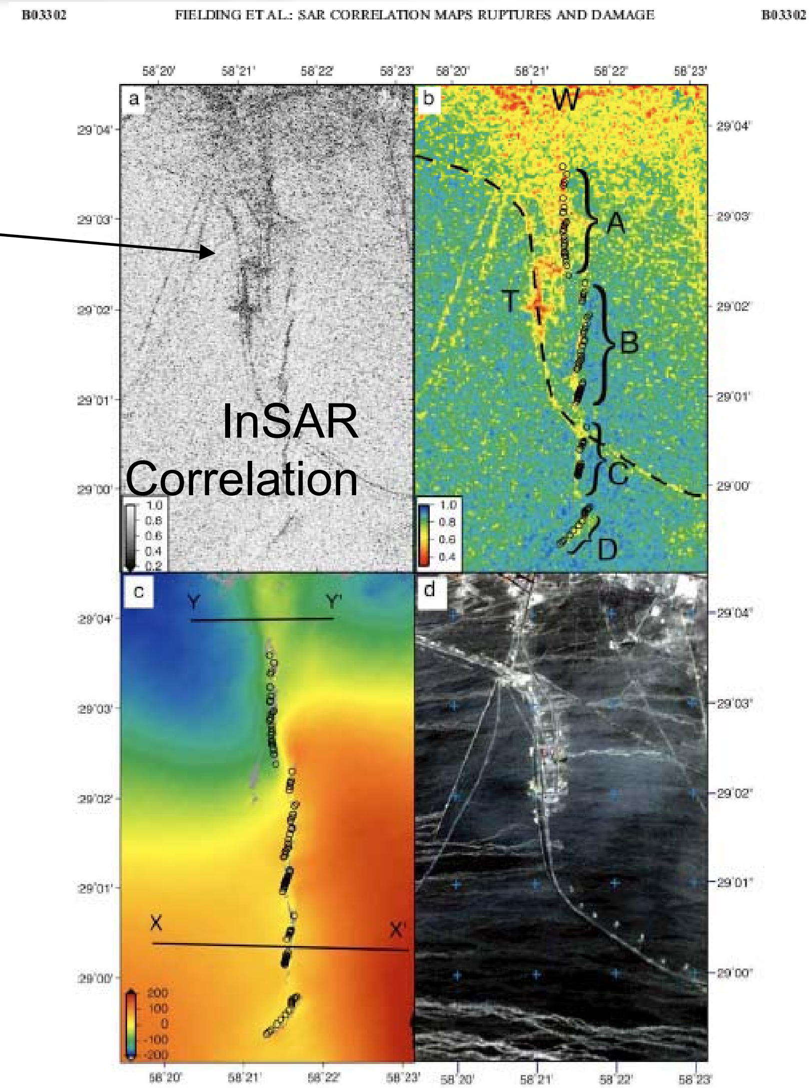
Desired InSAR Characteristics
- Rapid repeat and frequent revisit
- Tight orbit control
- Long radar wavelength
- Wide swath

Through careful control of the orbit, it is possible to combine two complex images acquired from space to measure millimeter scale motions of the ground

2003 Mw=6.6 Bam Earthquake view with InSAR

Surface Rupture from EnviSAT InSAR

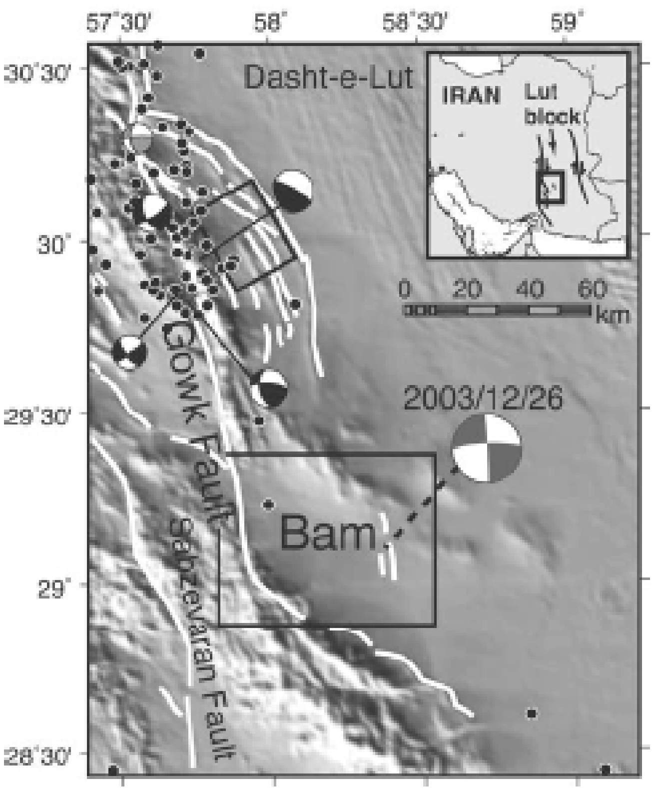




Model Deformation

Optical Data (no evidence of change)

2003 Mw=6.6 Bam Earthquake view with InSAR



Surface Motion from EnviSAT InSAR (Fialko et al., 2005)

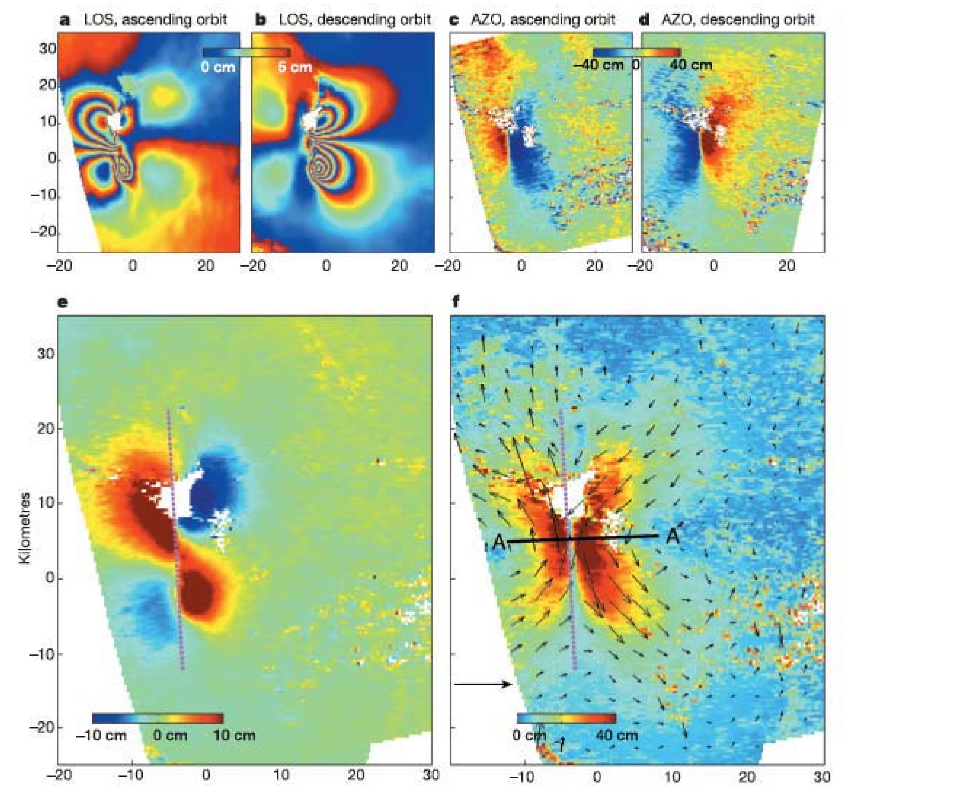


Figure 1 Coseismic deformation caused by the Bam earthquake as imaged by the Envisat ASAR data. The coordinate axes are in kilometres, with the origin at 58.4° E, 29° N. Colours denote displacements in centimetres. **a**, Interferogram for the time period 16 November 2003 to 25 January 2004, ascending orbit. **b**, Interferogram for the time period 3 December 2003 to 11 February 2004, descending orbit. **c**, Azimuthal offsets, ascending orbit. **d**, Azimuthal offsets, descending orbit. **e**, **f**, Vertical (**e**) and horizontal (**f**) components of the surface displacement field derived from the ASAR data. (**a**–**d**). Arrows show the subsampled horizontal displacements. Dashed line shows the surface projection of the fault plane inferred from the inverse modelling of the ASAR data.

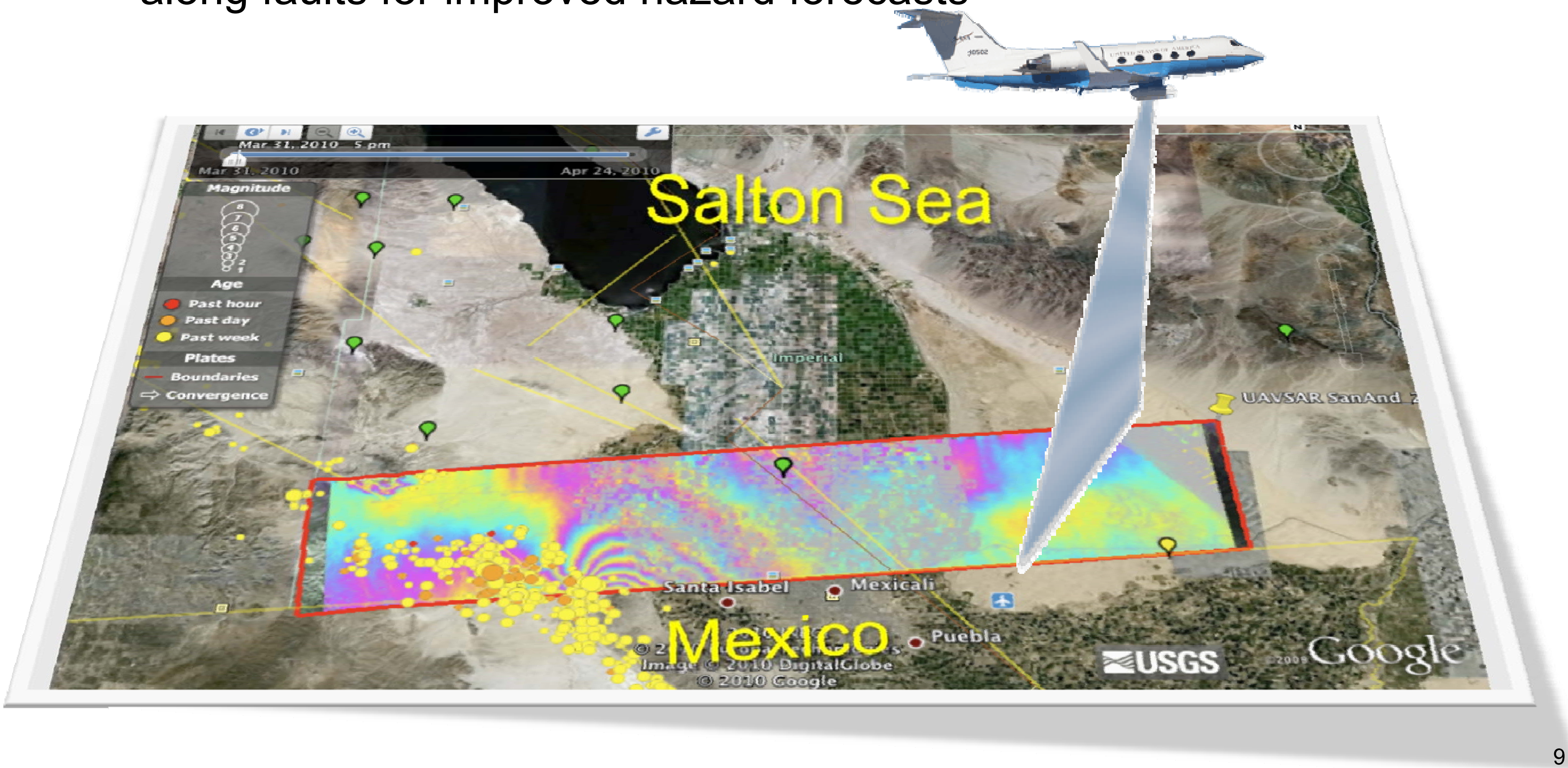
2

NATURE| doi:10.1038/nature03425 | www.nature.com/nature

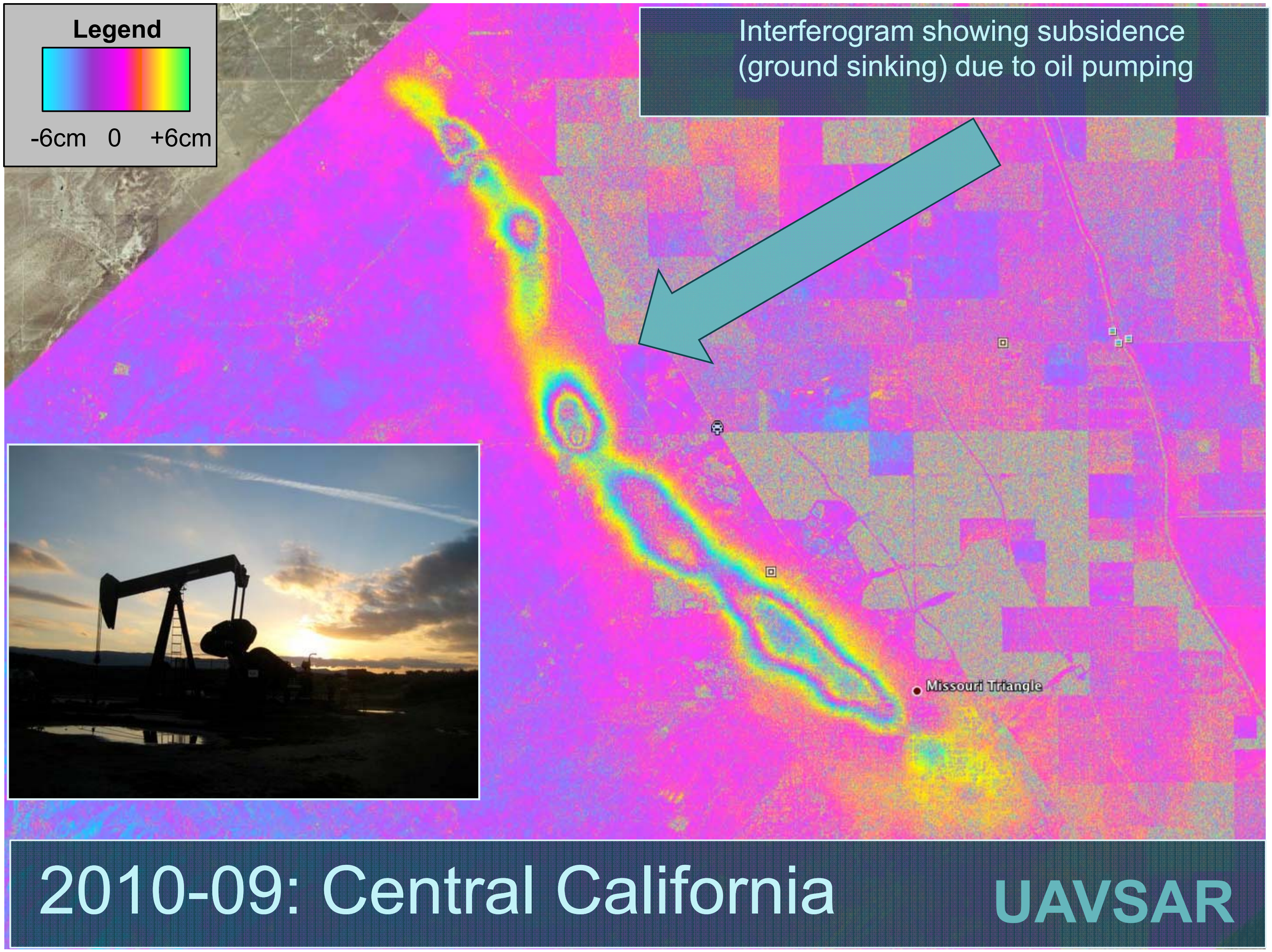
Vector deformation images from space show limited surface disruption, indicating low stress in upper crust

NASA's UAVSAR
First Airborne Measurement of an Earthquake

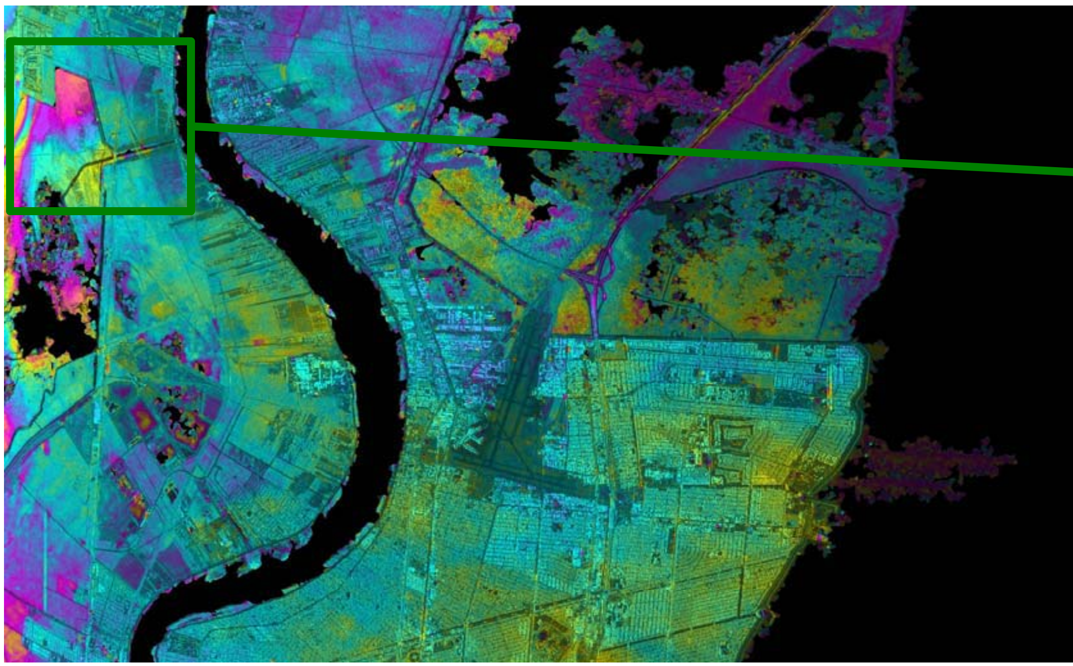
- **Response:** Maps regions of ground disturbance & destruction for use in earthquake response
- **Forecasting:** Determines regions of strain build-up near and along faults for improved hazard forecasts

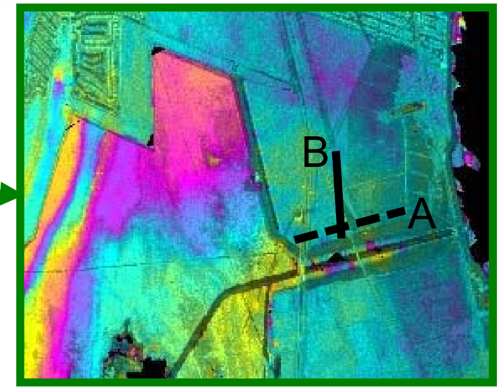


UAVSAR Central California Subsidence

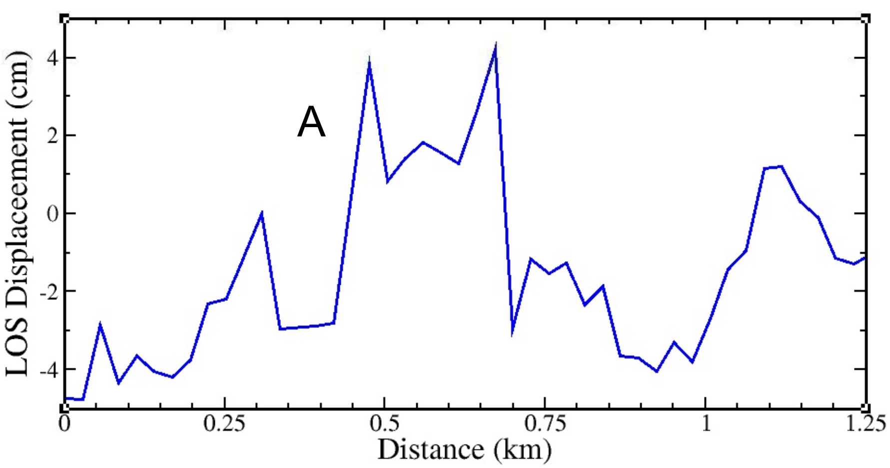


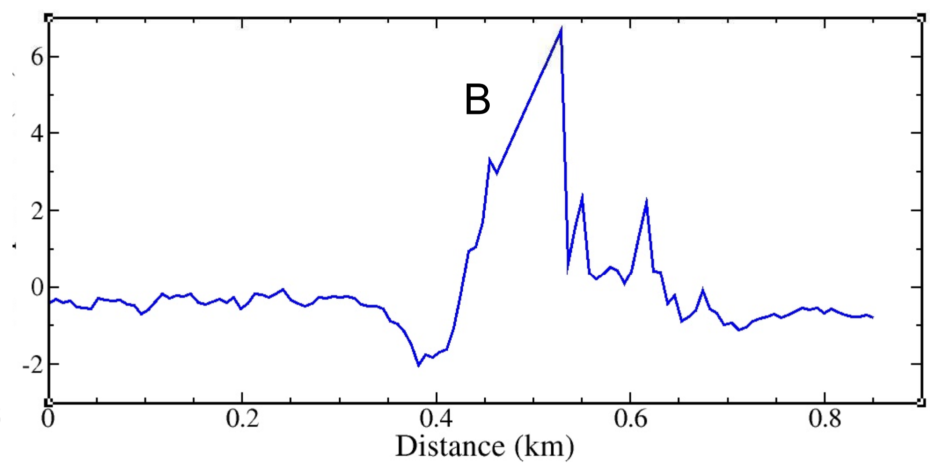
UAVSAR
Deformation Along Levee in New Orleans





- Localized deformation along levee could be indicative of some structural weakness
- Displacements measured from June 16 to September 9, 2009

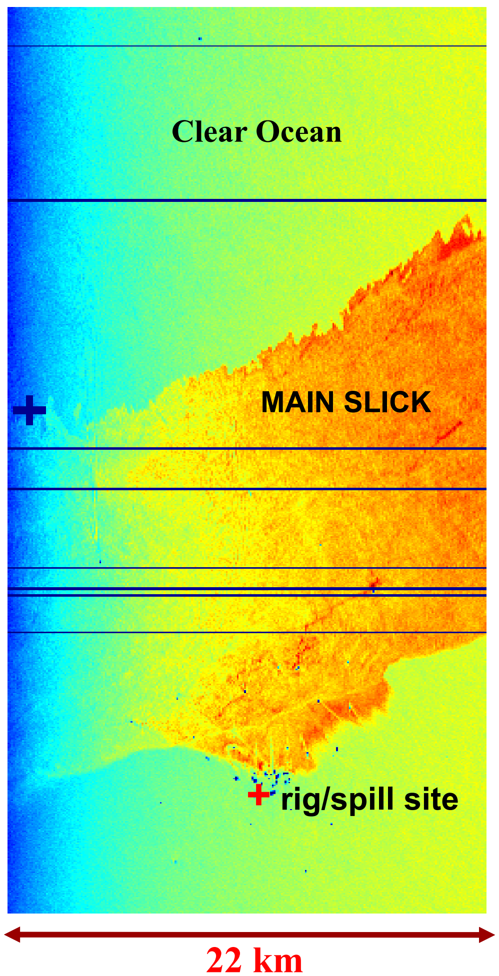




Oil Detection and Characterization

In Both Open Water and Coastal Wetlands

Radar images the surface in all light-weather conditions – through clouds, day or night. UAVSAR is able to detect oil in the main slick on open water and coastal waterways, and detect impacted vegetation in the coastal marshlands.



Gulf of Mexico:

The oil stands out clearly in the UAVSAR PolSAR radar image, showing variations in the main slick depending upon varying oil characteristics.

This capability could be used for targeting response operations to highly oiled areas.

Reference: B. Minchew, C.E. Jones, B. Holt (Caltech/JPL)

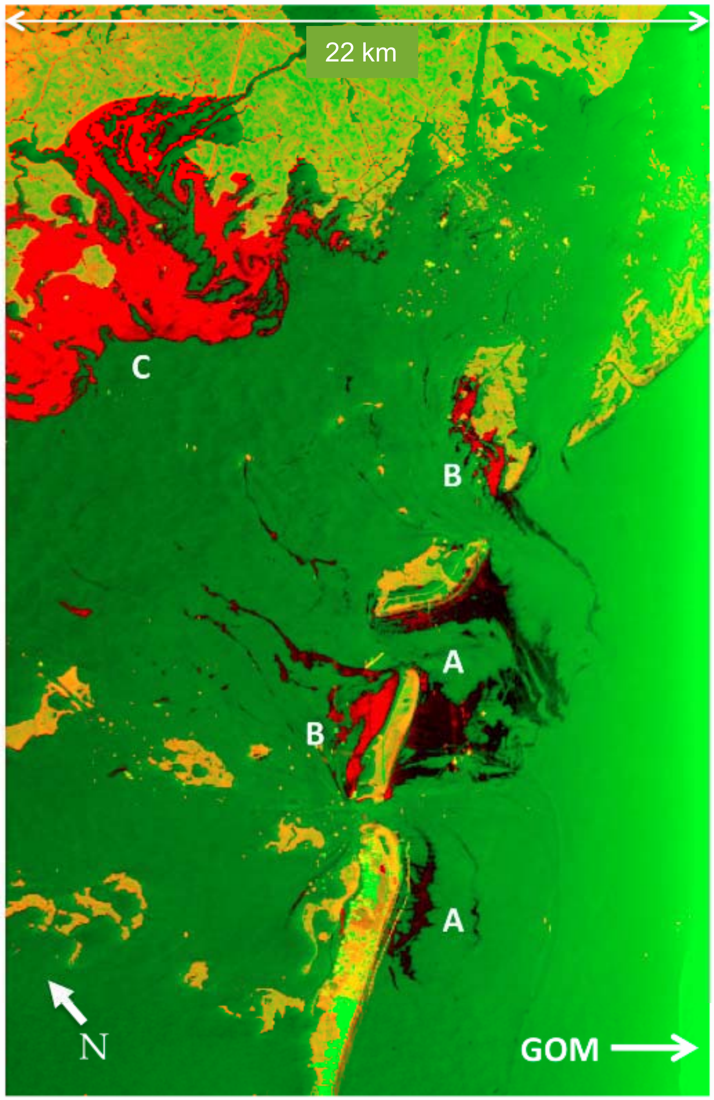
Barataria Bay, Louisiana:

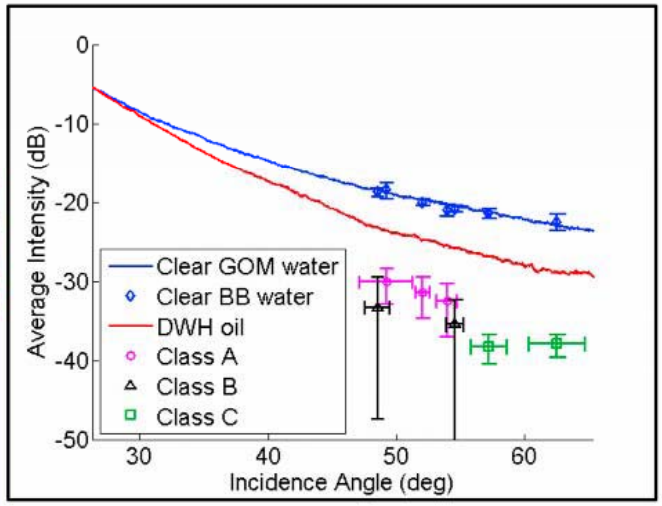
Studies of oiled vegetation in this area showed that UAVSAR can detect oil on water and on vegetation in coastal marshlands.

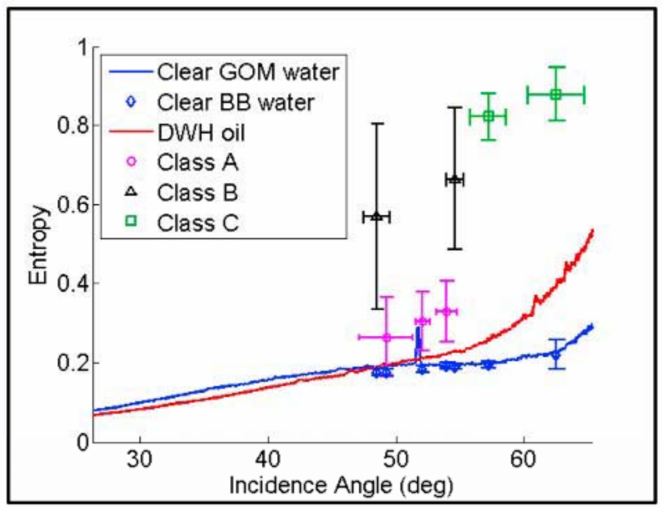
Reference: E. Ramsey, A. Rangoonwala, Y. Suzuoki (USGS), C.E. Jones (Caltech/JPL)

UAVSAR – Cloude-Pottier Decomposition

Comparisons of Fresh Oil at DWH Site and Weathered Oil in Barataria Bay







Large amounts of oil moved far into Barataria Bay in SE Louisiana on 16-17 June 2010, with oil remaining in the area until after the UAVSAR over-flight.

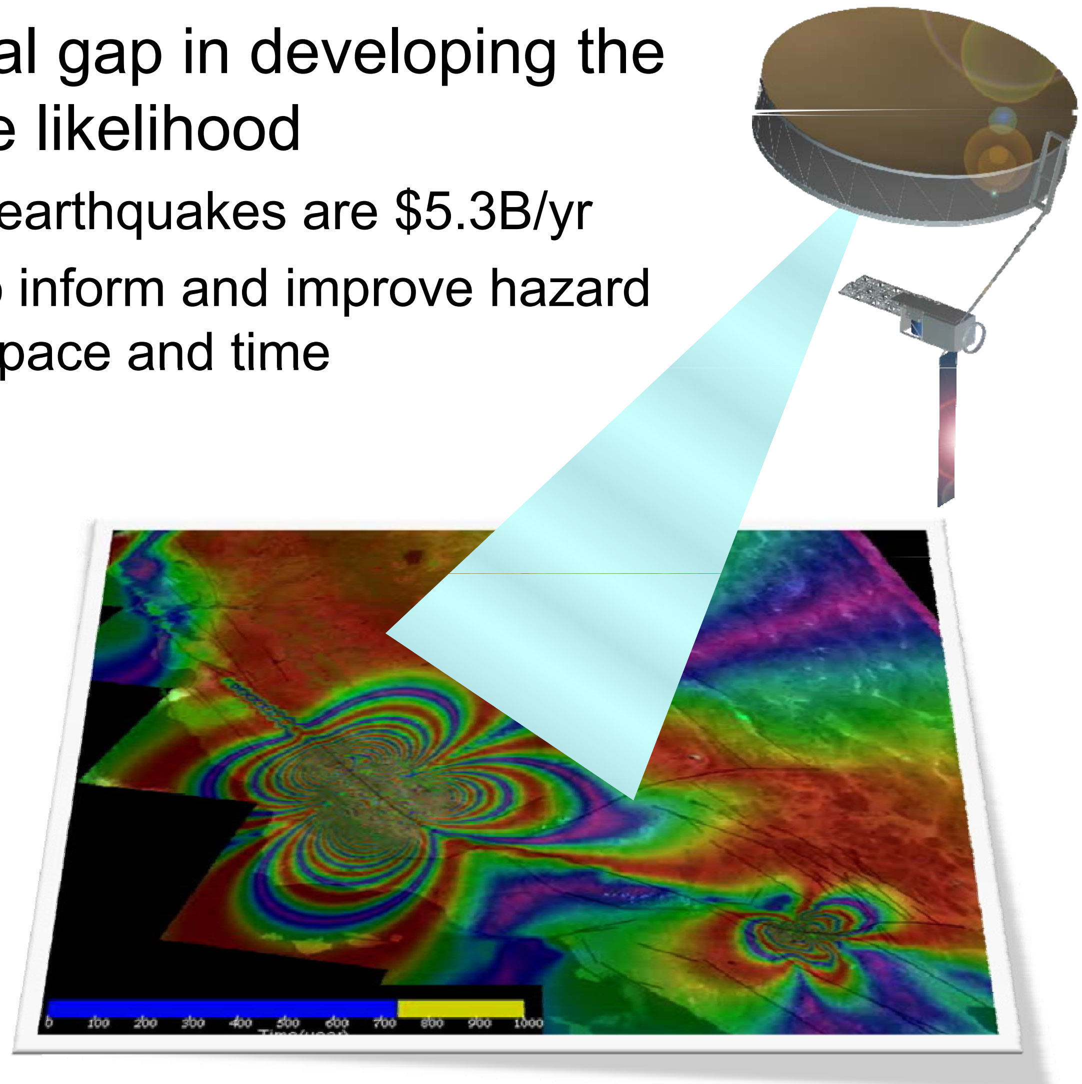
Weathered oil in the interior of Barataria Bay shows a significantly higher entropy than oil around the rig site or in the Gulf of Mexico approaching the Louisiana shoreline.

C. Jones, B. Holt, S. Hensley (JPL/Caltech), B. Minchew (Caltech), Studies of the Deepwater Horizon Oil Spill with the UAVSAR Radar, Accepted to AGU monograph 2011

DESDynI Mission

A source of global data for earthquake research and response

- Fills a major observational gap in developing the big picture on earthquake likelihood
  - US annualized losses from earthquakes are \$5.3B/yr
  - DESDynI will deliver data to inform and improve hazard maps to finer resolution in space and time

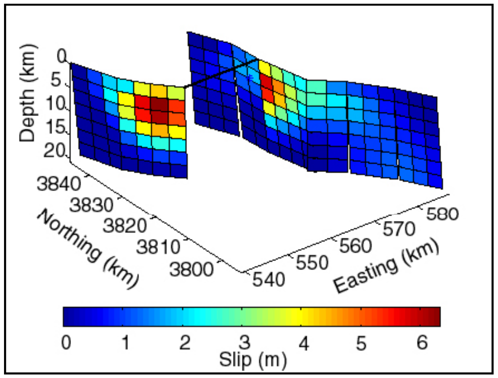


Average 4-day response for earthquakes indicating location and likelihood of M>5.5 aftershocks.

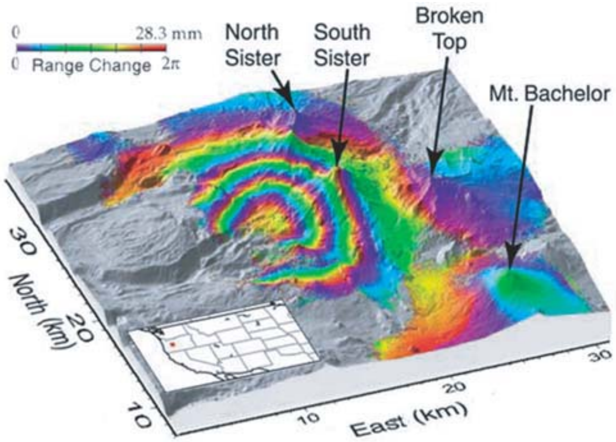
Needed inputs to modeling, forecasting and response.

SAR Provides Scientific Insight That Will Save Lives and Property

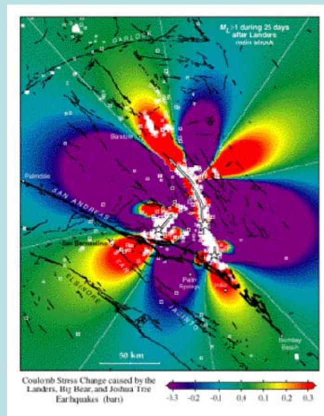
InSAR Data and Analysis



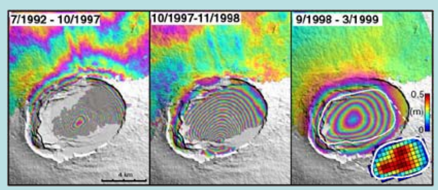
Fundamental Physics and Discovery of Earth Surface Change



Modeling and Application



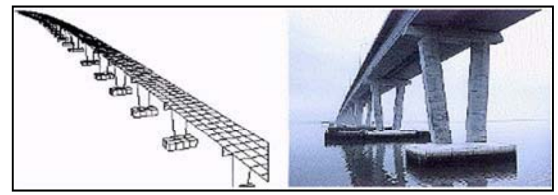
High Resolution Earthquake Hazard Information (Stress Map)



Systematic Volcano Monitoring

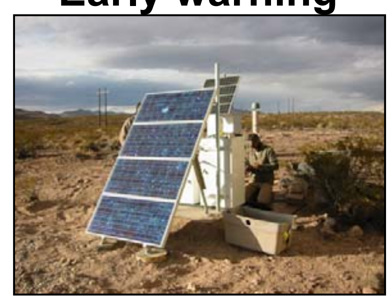
Planning and Preparation

Targeted retrofitting in high-risk areas



Rapid response and recovery

Early warning

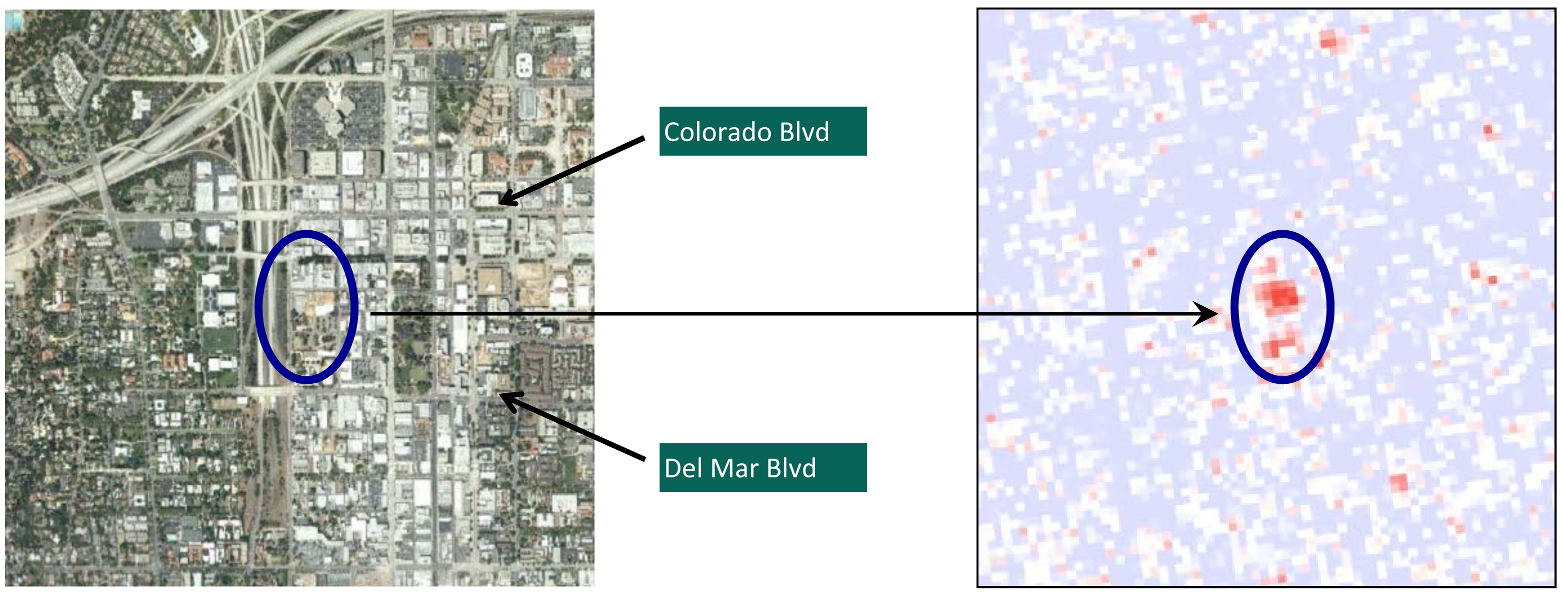


ARIA-EQ:
Using DESDynI for Rapid Response

Rapid Response Proof-of-Concept
A controlled experiment to map building damage with satellite radar

From space we can now detect building damage anywhere, anytime of day, regardless of clouds.

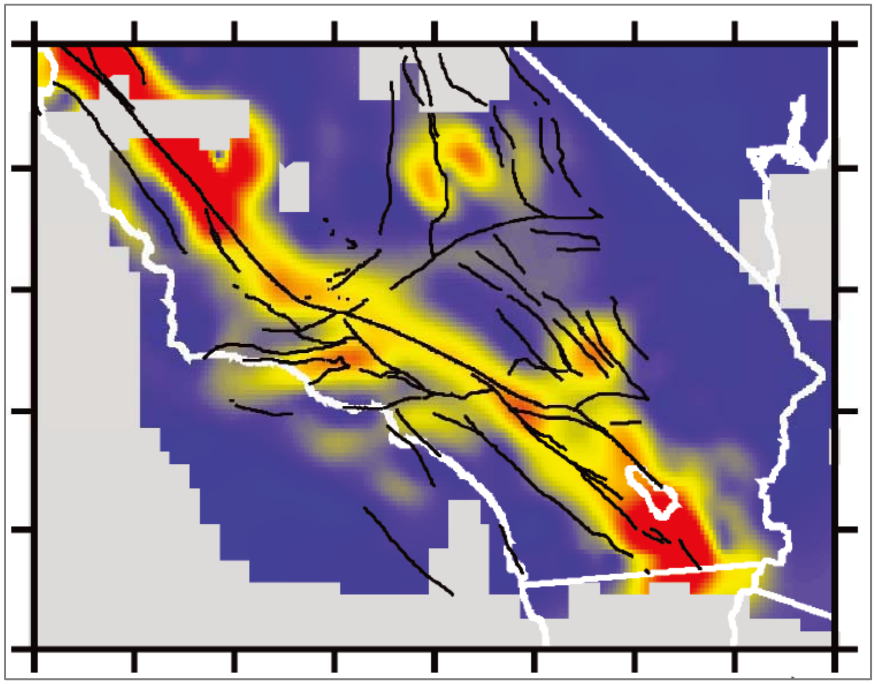
Google Earth image of Pasadena study area



ARIA-EQ: Advanced Rapid Imaging and Analysis for Earthquakes

Research and Response

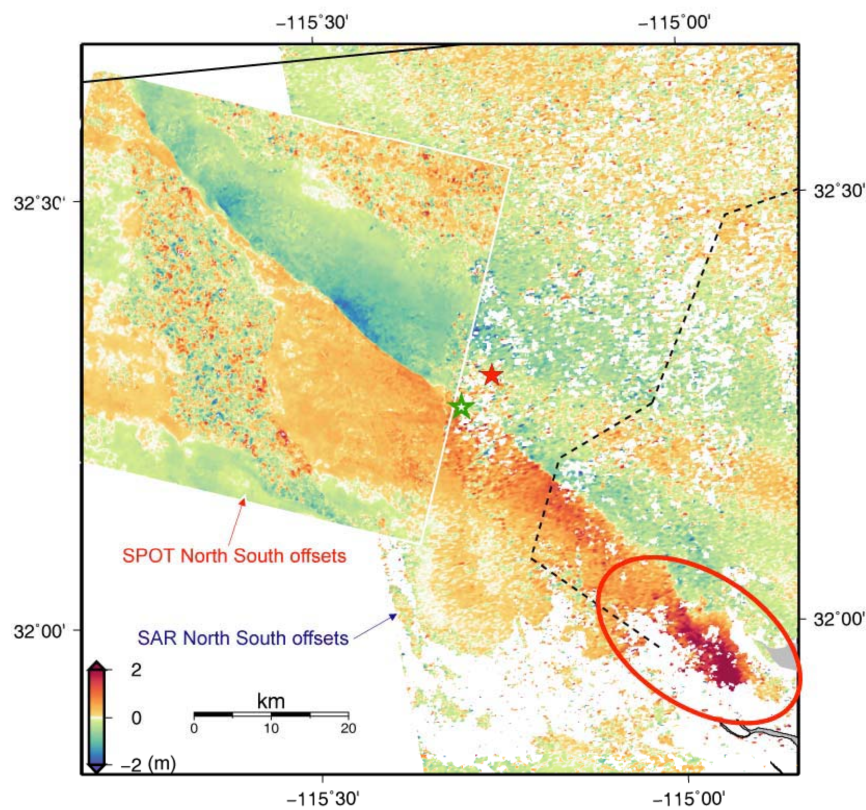
Understanding Earthquakes



- Detecting and interpreting tectonic strain
- Understanding California's system of faults

Rapid Assessment

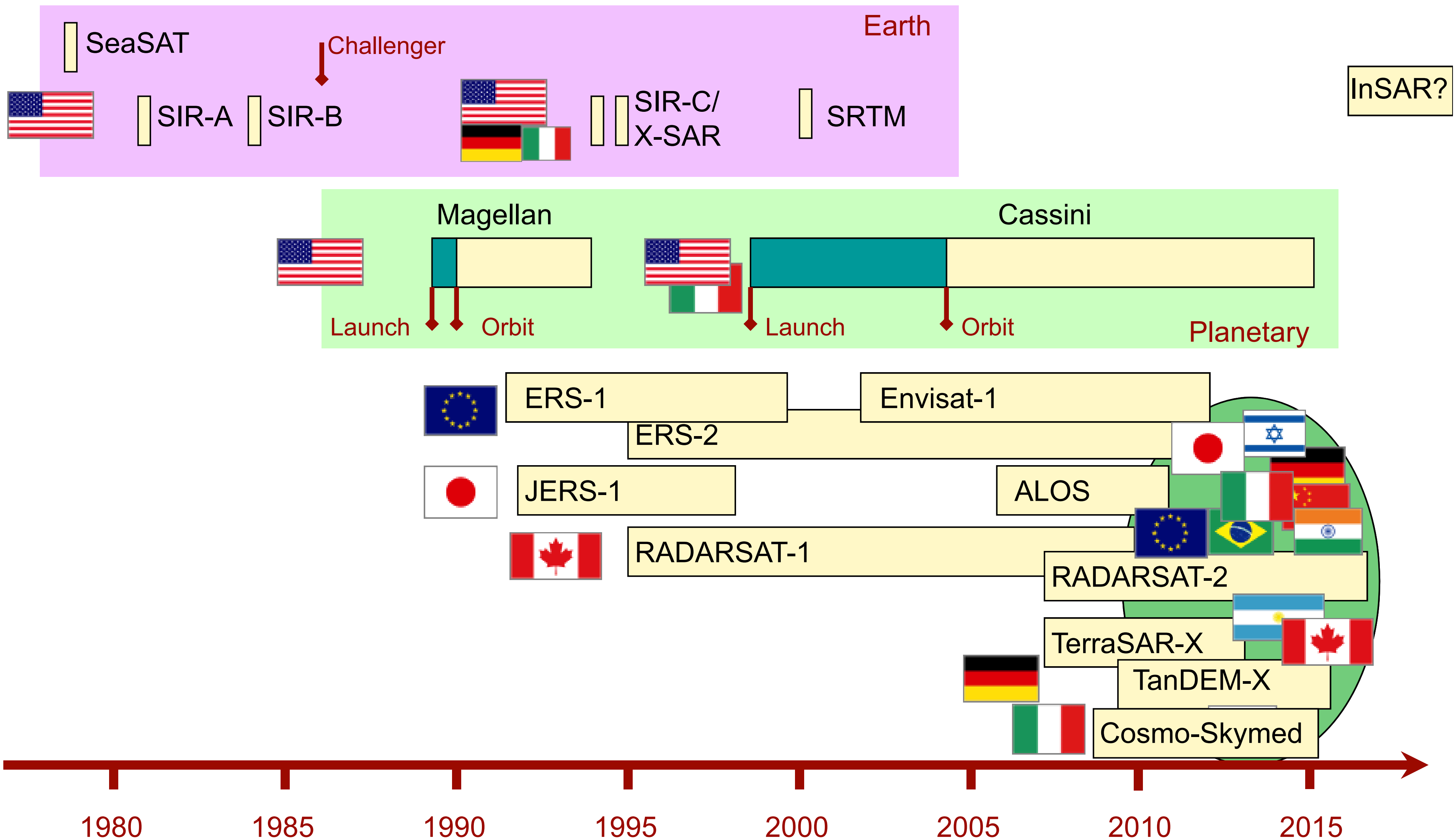
Mw 7.2 El Mayor-Cucapah Earthquake
Baja California - April 4, 2010



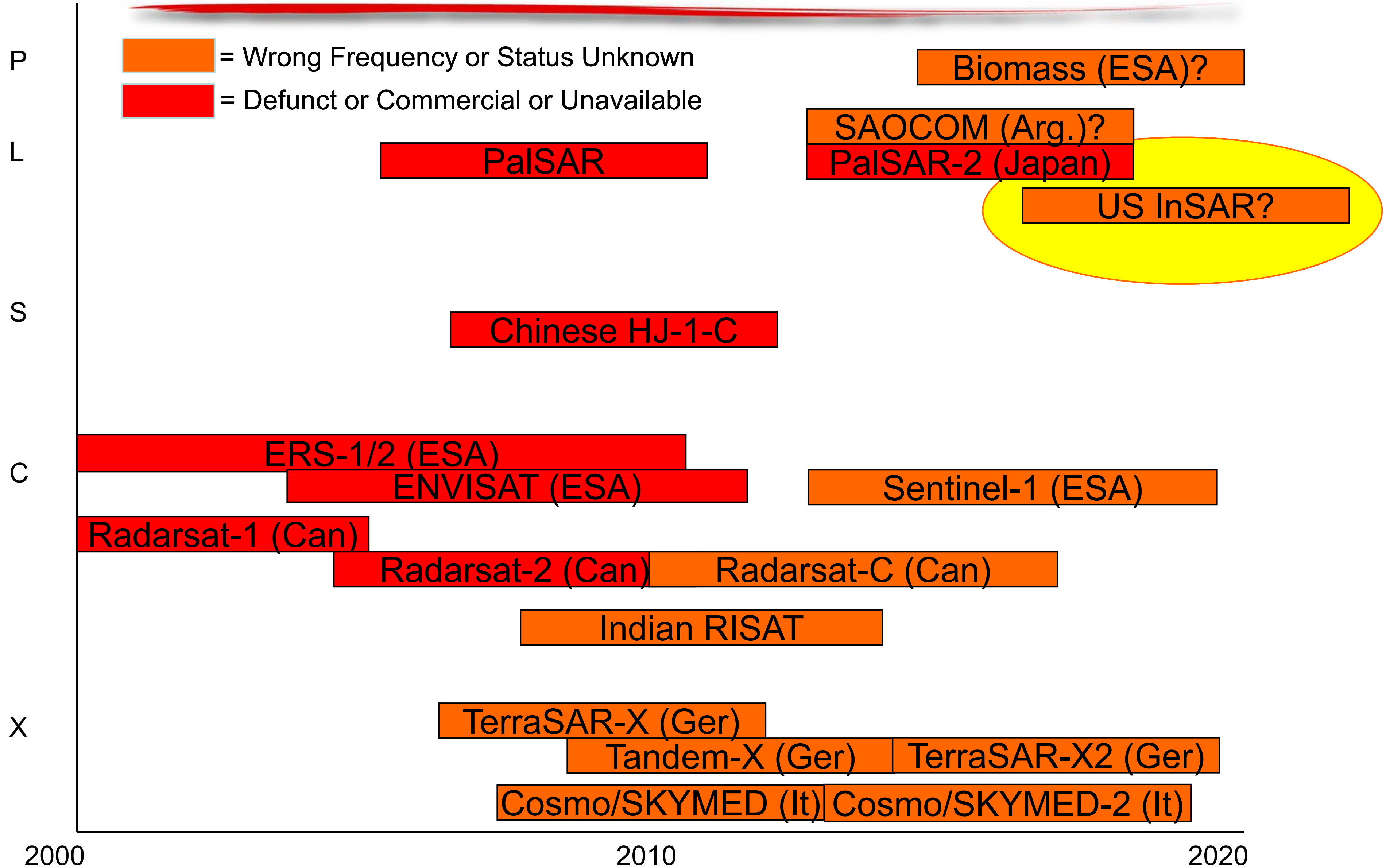
DESDynI Requirement Summary from MCR

Science Objectives	Measurement Requirements	Stressing Instrument Capabilities
Ecosystem Structure • Global biomass/carbon • Biomass disturbance • Biomass loss due to land use change • Habitat and biodiversity	• Canopy height and structure metrics accurate to 1 m (low slope) at 1000 m resolution in 2 yrs • Biomass at 100-200 m resolution in low biomass • High fidelity forest change maps, annually	• 5-beam profiling lidar operated at near nadir incidence, 25 m profile resolution • Lidar 91-day repeat orbit • Quad-pol L-band radar operating in 30-44° incidence angles at 10 m res, seasonally
Dynamics of Ice • Ice sheet dynamics • Glacier dynamics • Sea ice dynamics	• 2-D velocity accurate to 1 m/yr at 100 -500 m res over ice sheets and glaciers, 3 yrs • DEM topography accurate to 1 m at 1 km res over ice sheets and glaciers • dh/dt to 1 m/yr at 2500 m res • Elevation precise to 3 cm at 25 m profile res over sea ice • Sea-ice velocity to 100-m/day at 5 km res, Arctic and Antarctic	• 5-beam profiling lidar operated near nadir, 25 m profile res • Lidar 91-day repeat orbit • L-band co-pol radar operating in 13 day repeat period orbit, global accessibility, at 10 m res, continuously over mission, over all interesting science targets
Deformation • Tectonic processes • Magmatic processes • Sequestration, land-slides, aquifer change	• 2-D velocity time series accurate to 1-5 mm/yr at 10-1000 m res over all active areas, 3 yrs • Weekly or shorter target sampling	• L-band co-pol radar, 13 day repeat period, global accessibility • Weekly target sampling at equator, better at higher latitudes • 10 m resolution • All continuously over mission, over all interesting science targets

International SAR Missions



SAR Frequency Bands/Missions



Community Starved for Data

- Volume of international SAR data is highly limited
- US/NASA was world's largest consumer of L-band SAR/InSAR data from ALOS
- NASA instituted use of TDRSS in April 2010 to double capacity of mission, with over 100,000 scenes per year ingested for scientific use
- DESDynI class mission would provide on order of 1 million scenes per year to satisfy known global science requirements.
- International SARs except Envisat are all fully or quasi-commercial
  - Cost per scene of $3-6K
  - Low-cost science data is limited to 50 scenes per investigator through proposal process
  - Not possible to buy DESDynI science from international providers at these costs, even if the data were available and suitable
- DESDynI class mission could help satisfy the need for observations over a broad range of hazards: geohazards, flooding, oil spills, damage assessment, environmental monitoring, monitoring of infrastructure/lifelines, and others

Outlook for DESDynI

- Successful Mission Concept Review in January 2011
- President's FY12 budget proposal reset the go-forward plan for DESDynI
  - Lidar mission to be contributed, not funded by NASA
  - Radar mission to be implemented more affordably
- NASA is currently exploring options for reducing cost
  - Reducing number and scope of science requirements levied on DESDynI
    - + Combine DESDynI with other satellites to approach DESDynI requirements
  - Find international partners interested in the science and technology
  - Find domestic partners that would increase utility and value of DESDynI data

Summary

- DESDynI would provide exciting scientific returns in three distinct science disciplines
  - Final scope of mission still to be defined
  - Depends on strength of community advocacy and partnership contributions
- DESDynI would provide direct benefits to society as its measurements are used to help forecast sea level rise and the likelihood of earthquakes or volcanic eruptions and to improve forest inventories and carbon monitoring
  - Benefits of regular repeated measurements also apply to hazard monitoring and mitigation
- DESDynI measurements would be unique and available to the world for scientific and other uses
  - L-band full-resolution, full-swath, fast repeat capability would revolutionize our ability to characterize natural hazards, quantify ice dynamics, and monitor Earth's changing terrestrial carbon stocks
  - Accuracy/resolution/coverage would be major improvement for US scientists
- Science community and technology are ready to go