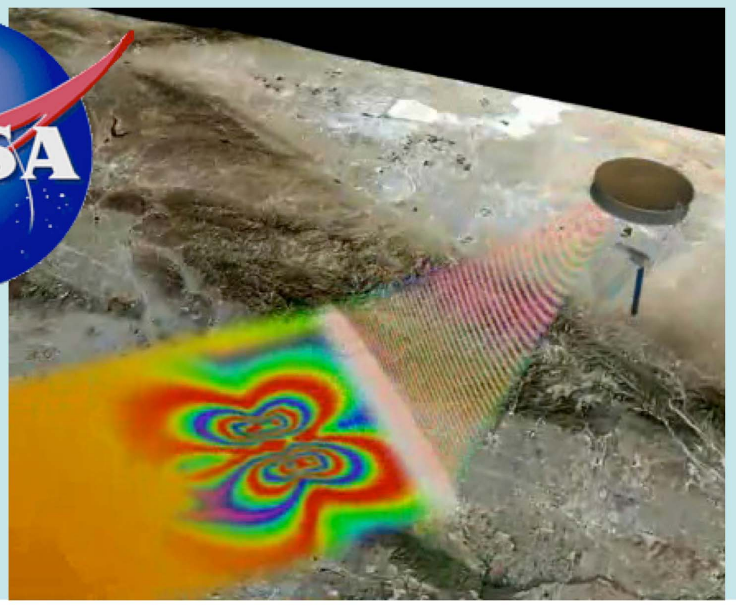
National Aeronautics and Space Administration

Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI) Mission



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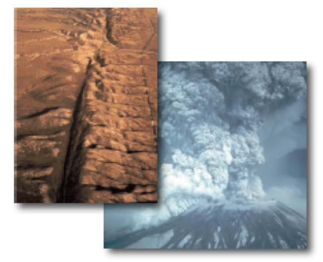
Abstract: The National Research Council Earth Science Decadal Survey, Earth Science Applications from Space, recommends that DESDynI (Deformation, Ecosystem Structure, and Dynamics of Ice), an integrated L-band InSAR and multibeam Lidar mission, launch in the 2010-2013 timeframe. The mission will measure surface deformation for solid Earth and cryosphere objectives and vegetation structure for understanding the carbon cycle. InSAR has been used to study surface deformation of the solid Earth and cryosphere and more recently vegetation structure for estimates of biomass and ecosystem function. Lidar directly measures topography and vegetation structure and is used to estimate biomass and detect changes in surface elevation. The goal of DESDynI is to take advantage of the spatial continuity of InSAR and precision and directness of Lidar. There are several issues related to the design of the DESDynI mission, including combining the two instruments into a single platform, optimizing the coverage and orbit for the two techniques, and carrying out the science modeling to define and maximize the scientific output of the mission.

Requirements: The mission objectives require that surface deformation be measured globally at the level of 1–2 mm/yr to study geophysical processes and ice sheet mass balance. The mission also needs to develop globally consistent and spatially resolved estimates of aboveground biomass and carbon stocks to 10 Mg/ha or to within 20% and changes and trends to 2–4 Mg/ha.

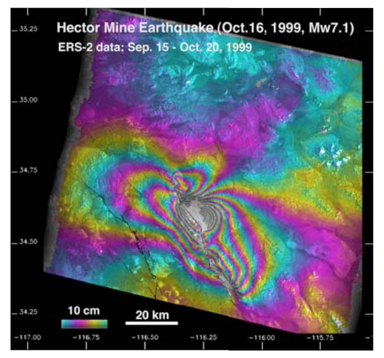
Mission Objectives Derived from the Decadal Survey

Application



Determine the likelihood of earthquakes, volcanic eruptions, and landslides

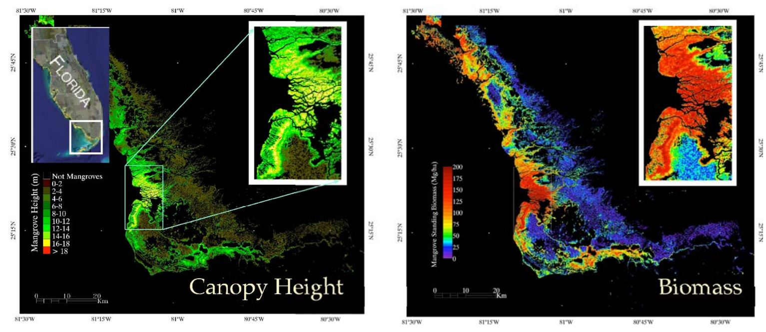
US annualized losses from earthquakes are $4.4B/yr yet current hazard maps have an outlook of 30–50 years over hundreds of square kilometers.



Surface deformation map of the 1999 Hector Mine earthquake, derived from ERS radar data. Each color fringe represents 10 cm of ground displacement from the earthquake.

Characterize the effects of changing climate and land use on species habitats and carbon budget

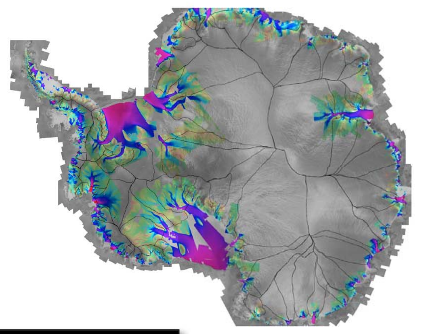
The rate of increase [of atmospheric CO_2] over the past century is unprecedented, at least during the past 20,000 years. The structure of ecosystems is a key feature that enables quantification of carbon storage.



Mangrove forest height and inferred biomass density from SRTM calibrated with Lidar (ICESat/GLAS and airborne) and field data. Mangroves contribute 11% of global total carbon export to the ocean. Mangrove forests are in danger of being lost entirely due to economic development and sea level rise. 35% of mangrove forests have disappeared and 60% could be lost by 2030. (Courtesy Marc Simard)

Predict the response of ice sheets to climate change and impact on sea level

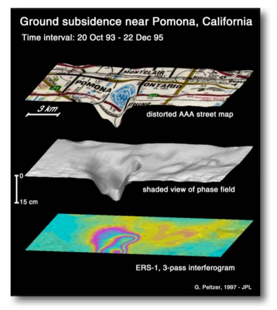
[Ice sheets and glaciers] are exhibiting dramatic changes that are of significant concern for science and international policy. These indicators of climate remain one of the most under-sampled domains in the system.



Mosaic of ice velocities determined from 10 years of ERS 1/2 data in Antarctic overlaid on a radar map. (Courtesy Eric Rigno)

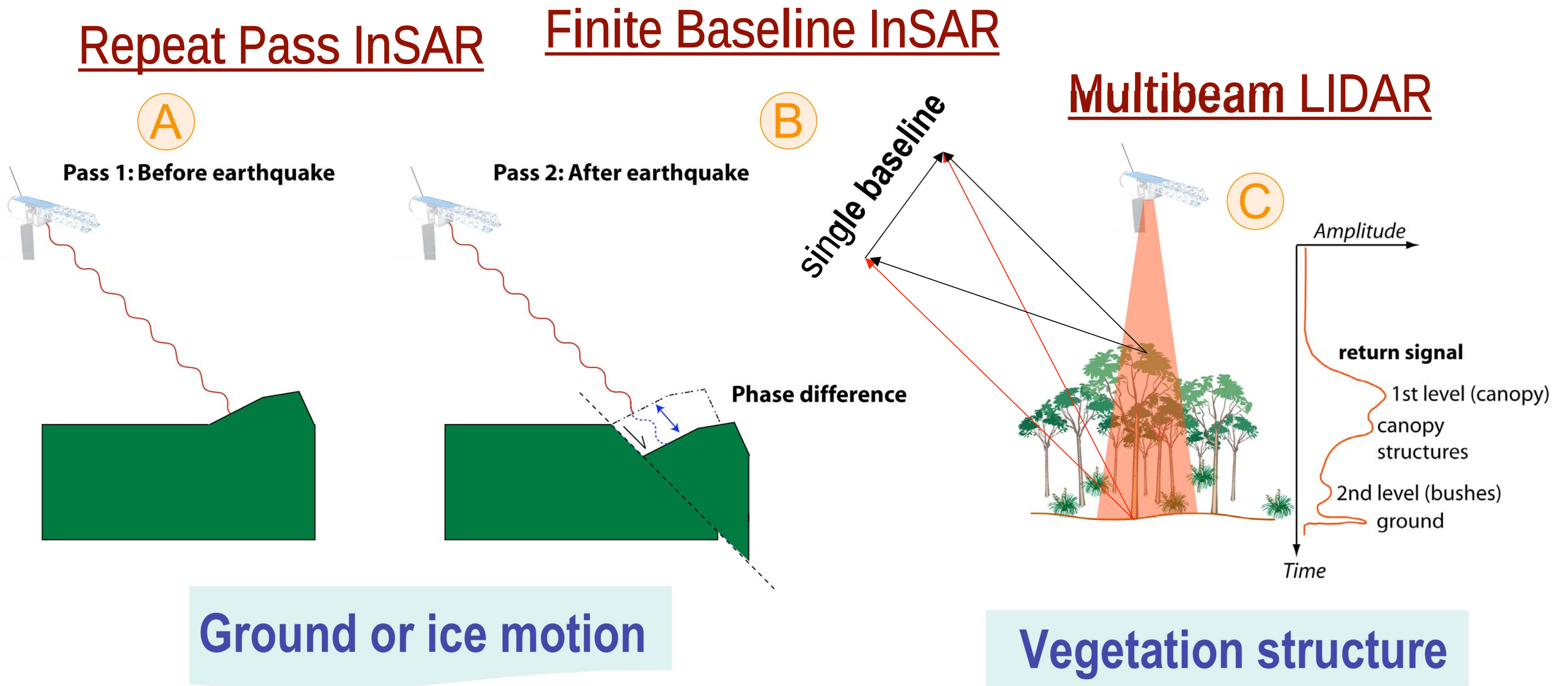
Monitor the migration of fluids associated with hydrocarbon production and groundwater resources

Management of our hydrological resources is applicable to every state in the union.



Ground subsidence from water withdrawal imaged with ERS-1 data. Understanding water discharge and recharge is important for managing our hydrological resources. (Courtesy Gilles Peltzer)

Approach



- (A) Phase of radar wave changes between passes creating a map of movement of over time
- (B) Radar is used to estimate biomass and vegetation structure
- (C) LIDAR return signal contains information on height and structure of forest canopy

DESDynI takes advantage of the precision and directness of the Lidar with the global spatial coverage of the radar. The radar and Lidar measurements for ecosystem studies need to be made in close proximity in time enabling cross calibration and validation. Forest growth, budding, and dropping of leave occur on fairly short timescales, thus each of the measurements must be made within a few weeks of the other. InSAR and Lidar measurements have similar mission requirements. For example, a sun-synchronous dawn-dusk orbit is required for the radar measurements to minimize effects of the ionosphere and for the Lidar to reduce effects of reflected solar radiation, especially in the tropics. The ionosphere is most quiet and the minimum cloud cover is at dawn. However, combining science and measurement objectives in addition to two instruments onto a single spacecraft results in competing design trades. Compromises are possible, however, to accommodate both instruments and the associated science.

- 600 km orbit: Lidar requires 400–600 km orbit due to increased power and aperture with altitude. InSAR requires 600–800 km orbit for swath coverage and to reduce atmospheric drag.
- 12-day repeat with off-nadir pointing of the Lidar instrument increases Lidar coverage without severely impacting temporal coverage for InSAR.
- Flying the instruments on different platforms would ensure maximum data acquisition to meet discipline science requirements and opportunities for cross calibration activities.

Radar operating modes for DESDynI

Mode	Application
Strip Map (single- or dual-pol)	Volcanic, earthquake, ice sheet deformation
ScanSAR (single- or dual-pol)	Tectonic deformation
Full-polarimetry (strip map)	Ecosystems and carbon stocks
Zero baseline	Surface deformation
Finite baseline	Vegetation structure and biomass

Key Needs for Each Discipline

- Deformation (solid Earth and ice sheets)
  - Coverage of global actively deforming zones
  - Long observing span to determine subtle rates
  - Frequent sampling for determining time dependent behavior
- Ecosystem Structure
  - Global vegetated cover
  - Accurate biomass density derived from tree height and structure
  - Monthly to seasonally
- Dynamics of Ice
  - Topography for ice sheet change and freeboard thickness of sea ice
  - Daily to seasonal timescales

Resulting Instrument Needs

- Deformation (solid Earth and ice sheets)
  - **L-band InSAR** for penetrating vegetation
  - Exact repeat pass for forming interferometric pairs
  - Rapid repeat
- Ecosystem Structure
  - **L-band InSAR** for vegetation structure to provide the spatial coverage
  - **Polarimetric SAR/InSAR** to increase contrast and sensitivity
  - **Multibeam LIDAR** for the precision and directness of the measurement
- Dynamics of Ice
  - **SAR** for kinematics (feature tracking)
  - **LIDAR** for topography and freeboard thickness

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