ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

@NASAARSET

Introduction to Remote Sensing for Disaster Management

Instructors:

- Tim Stough (ARSET, stough@jpl.nasa.gov)
- Maggi Glasscoe (Guest Speaker, margaret.t.glasscoe@jpl.nasa.gov)

Week 1

Course Structure

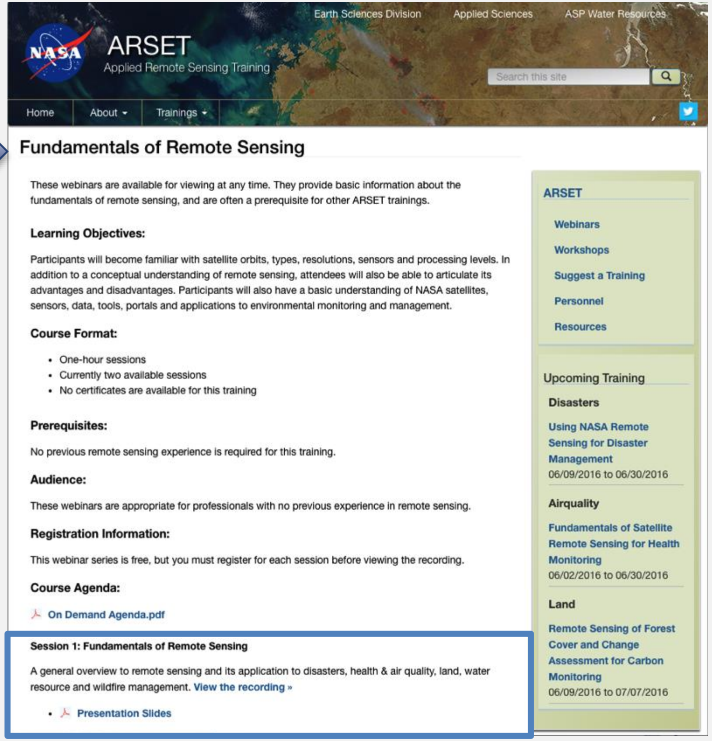
- **One session per week on June 9, 16, 23, and 30, 2016**
  - 11 a.m. – 12 p.m. EDT (UTC-4)
  - 6 p.m. – 7 p.m. EDT (UTC-4)
- **Each session may include**
  - Presentation
  - A homework assignment
- **Q&A following each session or by email to Tim Stough** (stough@jpl.nasa.gov) **or Amita Mehta** (amita.v.mehta@nasa.gov)

Prerequisite

Fundamentals of Remote Sensing: Session 1

http://arset.gsfc.nasa.gov/webinars/fundamentals-remote-sensing

- Session 1: Fundamentals of Remote Sensing
  - A general overview of remote sensing and its application to disasters, health & air quality, land, water resource, and wildfire management

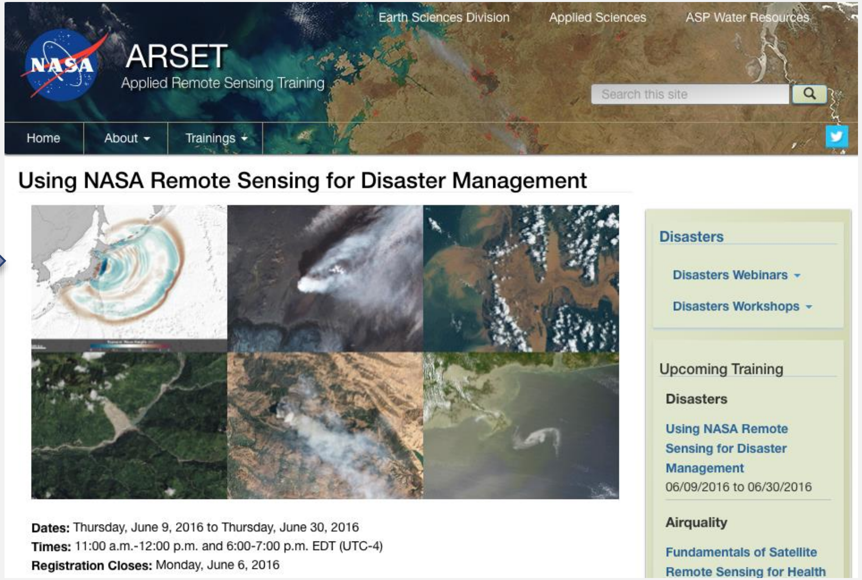


Course Material

http://arset.gsfc.nasa.gov/disasters/webinars/disaster-overview-2016

Webinar presentations, exercises, homework assignments, and recordings

Links will be available on the ARSET course page

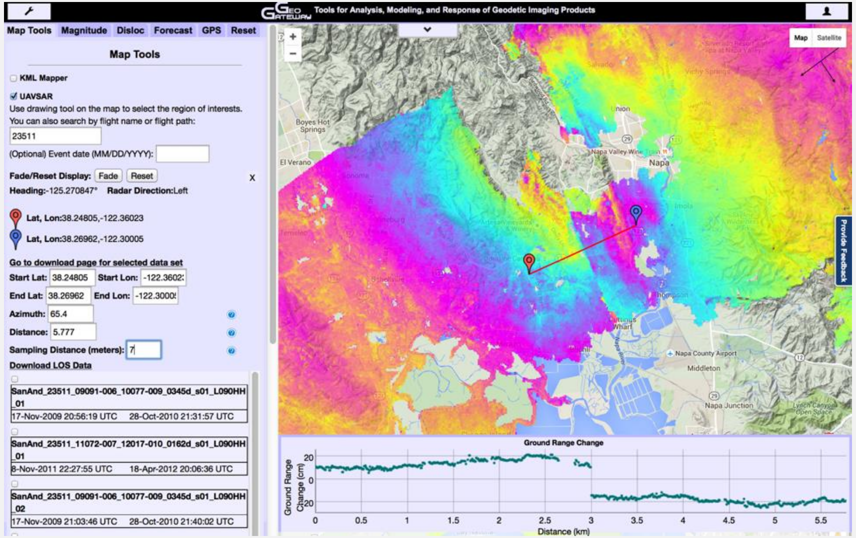


Homework and Certificate

- **Homework**
  - Hands-on exercises
  - Answers to homework questions via Google form
  - Available at https://arset.gsfc.nasa.gov/disasters/webinars/disaster-overview-2016
- **Certificate of Completion**
  - Attend all 4 webinar sessions
  - Complete all homework assignments
  - Certificates will be emailed approximately 2 months after the course finishes by Marines Martins (marines.martins@ssaihq.com)

Course Objectives

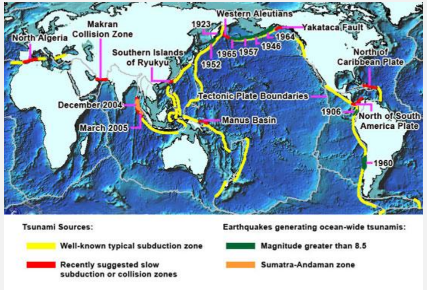
- Participants will become aware of available NASA resources for disaster management
- Participants will learn to access remote sensing observations for local disaster events



GeoGateway interface showing Napa earthquake interferogram with Line of Sight profile across the main rupture.

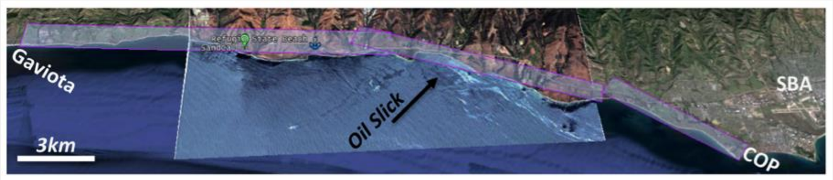
Course Outline

Week 1: Monitoring Earthquakes, and Tsunamis Using NASA Remote Sensing and Models

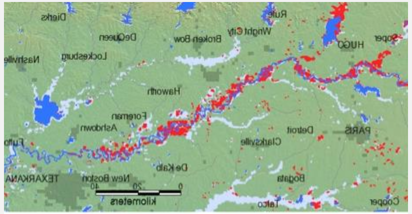


Week 2: Overview of Remote Sensing for Wildfire Applications

Week 3: Observation of Oil Spills Using Remote Sensing Measurements



Week 4: Monitoring Storms, Flooding, and Landslides Using Remote Sensing Observations



Agenda: Week 1

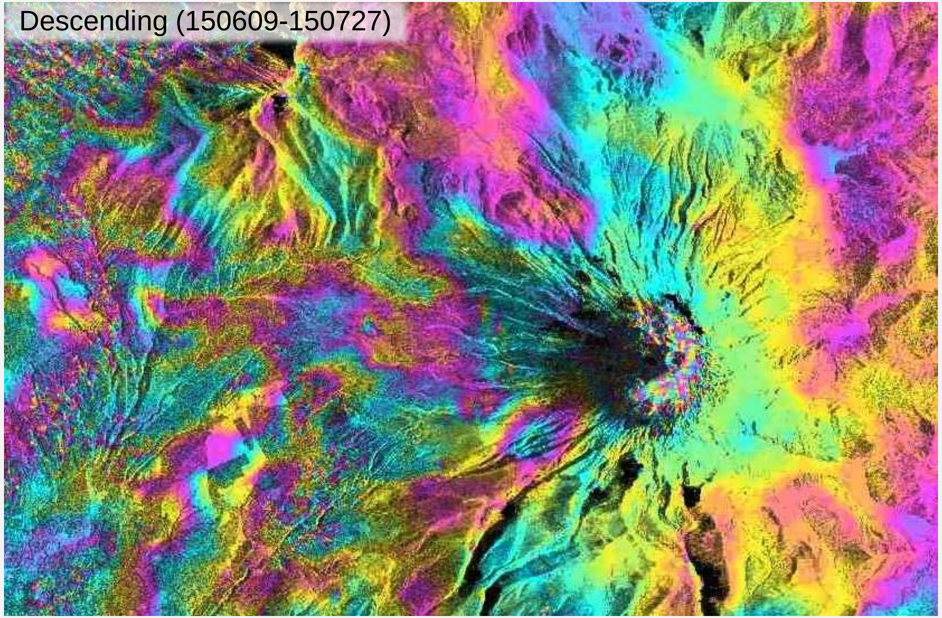
- Monitoring Volcanoes and Volcanic Ash
  - Pre-Eruption Monitoring
  - SAR-VIEWS
  - Volcanic Ash
  - Remote Sensing Resources
- Monitoring Earthquakes, and Tsunamis
  - How do we respond to earthquakes?
  - Remote Sensing Techniques to Monitor Earthquakes
  - Remote Sensing Techniques to Monitor Tsunamis

Part 1: Monitoring Volcanoes and Volcanic Ash using NASA Remote Sensing

Pre-Eruption Monitoring

- Deformation
  - Interferometric Synthetic Aperture Radar (InSAR)
  - Global Navigation Satellite System stations (GNSS, GPS, GLONASS)
  - Tilt meters
- Seismic Activity

Cotopaxi Volcano 2015

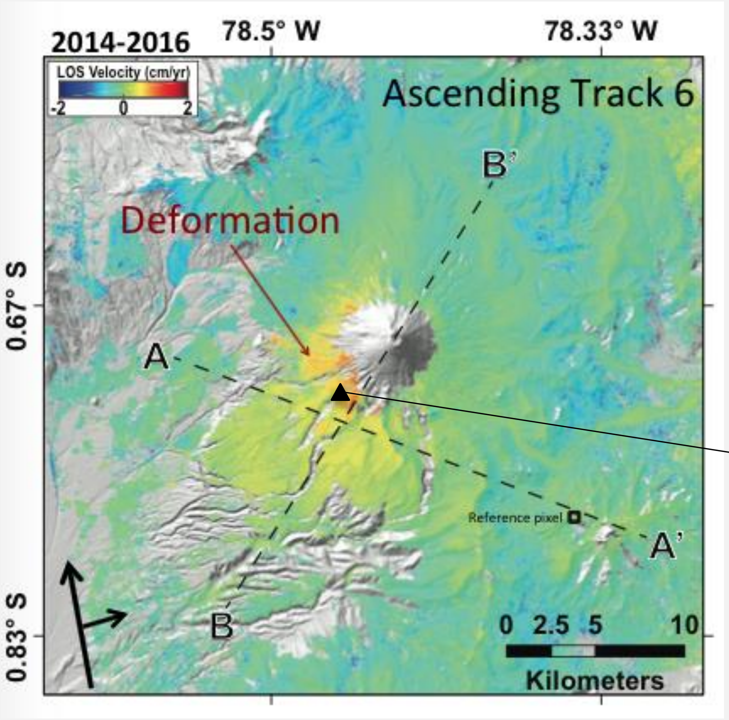


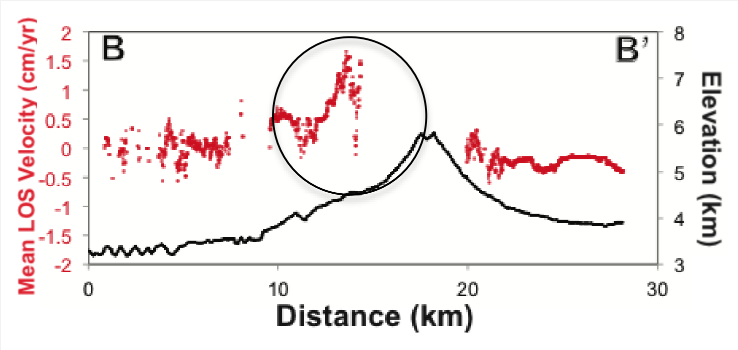
Cosmo-SkyMed InSAR – processed by Dr. Falk Amelung, University of Miami

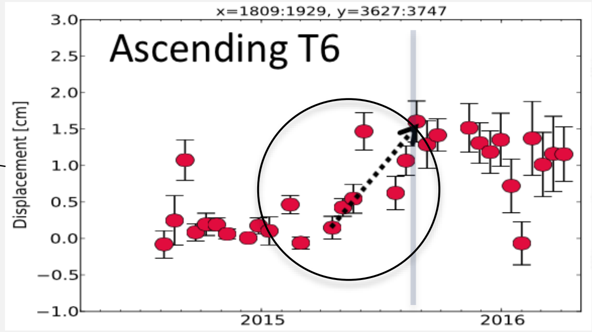
Cotopaxi Unrest and Steam Eruption, August, 2015

Analysis by Dr. Falk Amelung, University of Miami

InSAR based analysis allows inflation to be monitored without ground based sensors



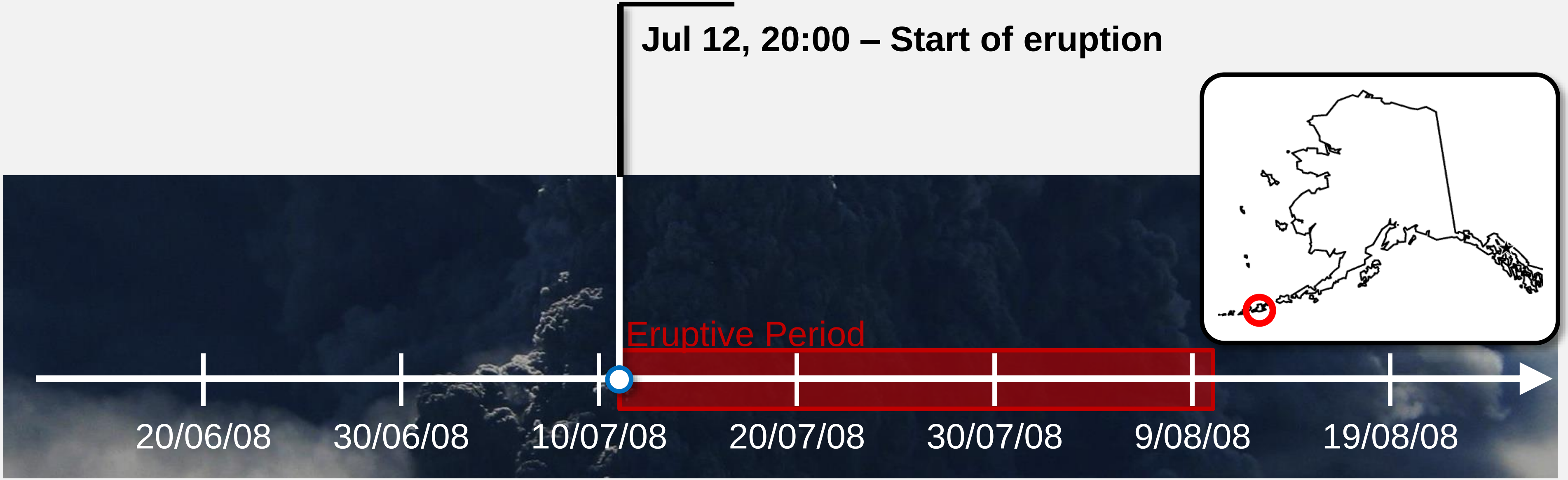




SAR-VIEWS: SAR Volcano Integrated Early Warning System

University of Alaska Fairbanks, Dr. Franz Meyer

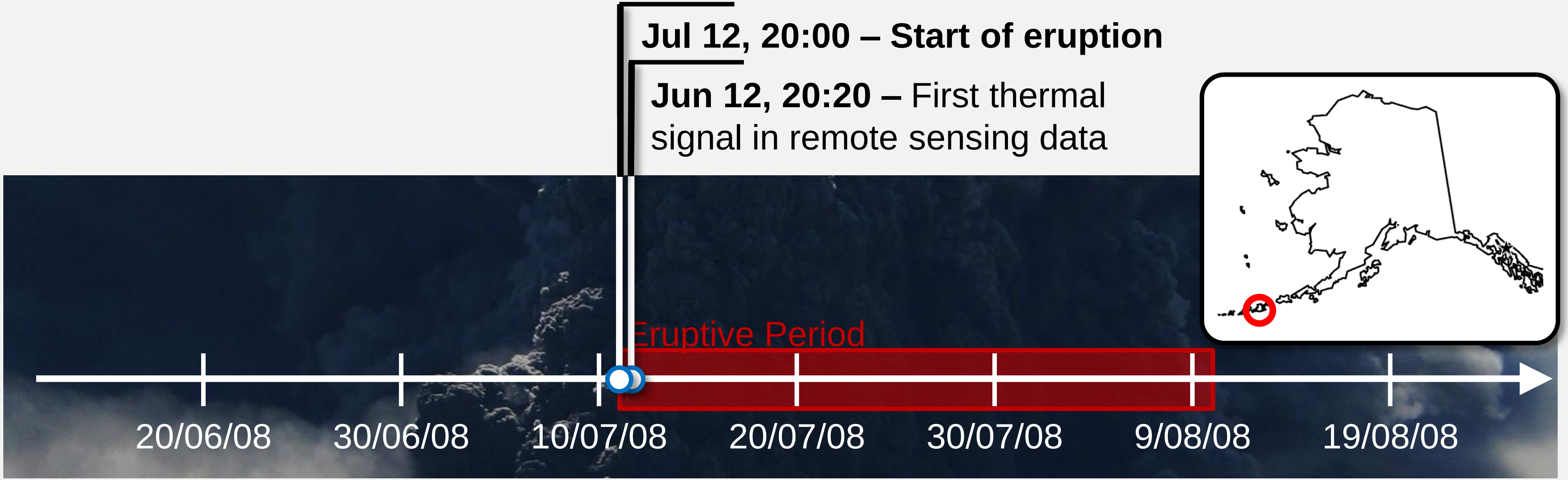
Okmok Eruption, July, 2008



SAR-Views: SAR Volcano Integrated Early Warning System

University of Alaska Fairbanks, Dr. Franz Meyer

Okmok Eruption, July, 2008



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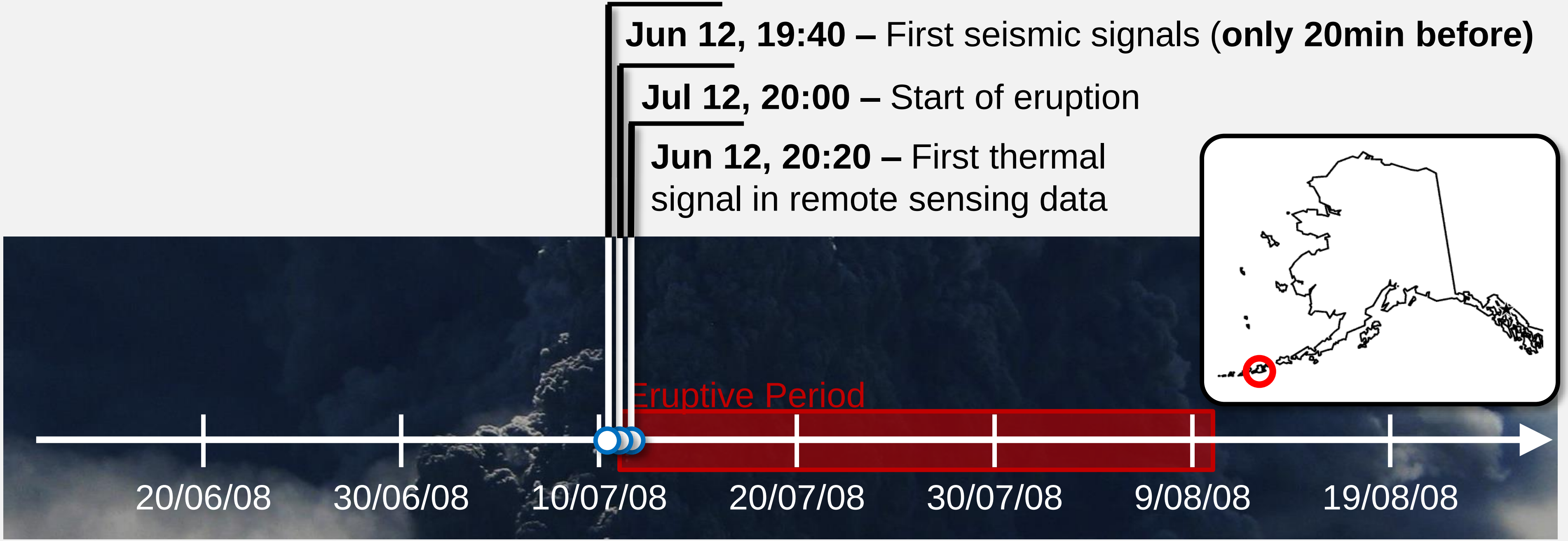

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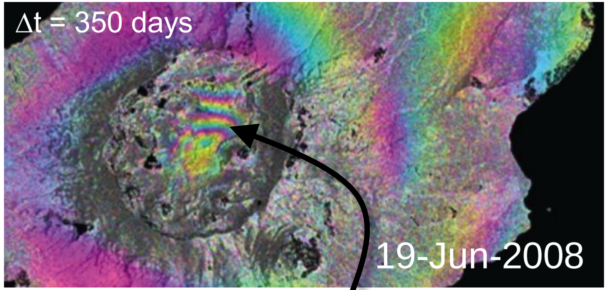
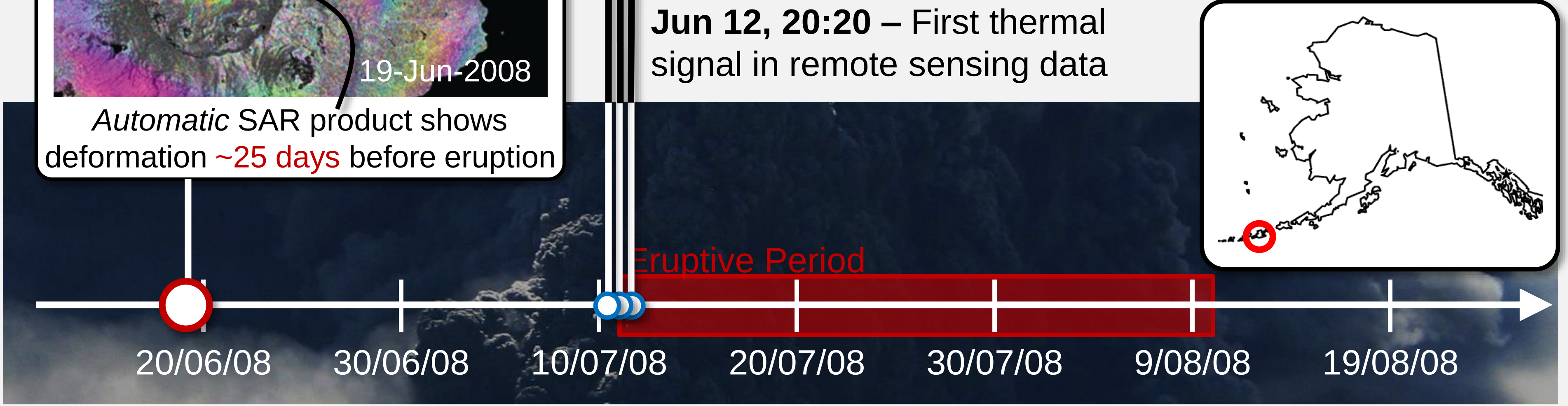


Automatic SAR product shows deformation ~25 days before eruption

Jun 12, 19:40 – First seismic signals (**only 20min before)**

Jul 12, 20:00 – Start of erruption

Jun 12, 20:20 – First thermal signal in remote sensing data



The Volcanic Ash Problem for Aviation

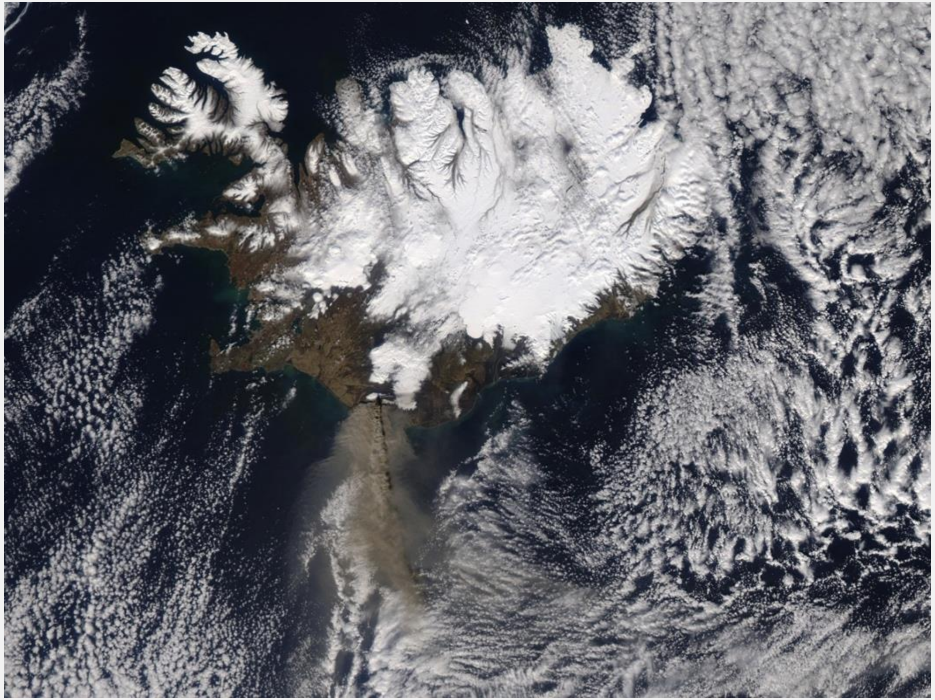
- Air traffic is periodically faced with the threat of a volcanic ash encounter
  - Ash immediately after eruption is most threatening
  - Even over many hours, ash may still cause serious problems for aircraft
  - No aircraft have crashed from an ash encounter, but there have been several close calls

Sicily's Mt. Etna, October 2002; MODIS

Detecting Volcanic Ash with Remote Sensing

Eyjafjallajökull Volcano, April 17, 2010

- Satellite imagers typically provide the best source of information about ash location
- This visible light image is the sort that typically comes to mind



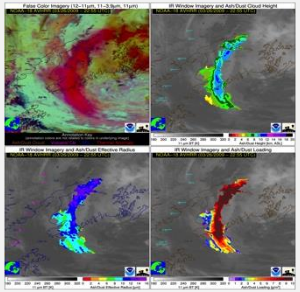
Eyjafjallajökull, April 2010; MODIS

Multi-Spectral Imaging

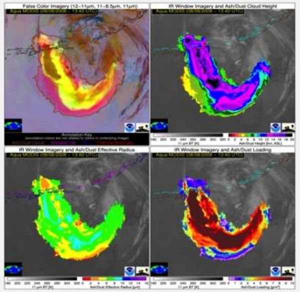
Making Full Use of Space-Based Imagers for Volcanic Cloud Monitoring

LEO

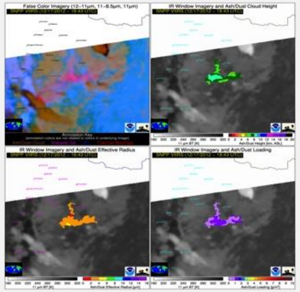
NOAA and MetOp AVHRR



Terra and Aqua MODIS

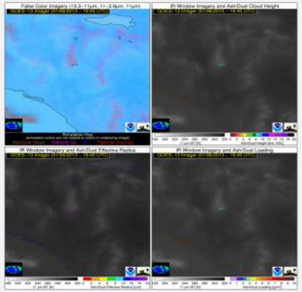


SNPP-VIIRS

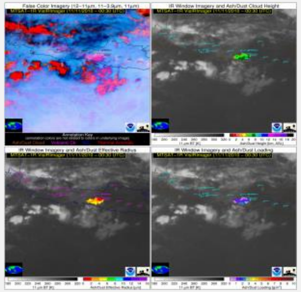


GEO

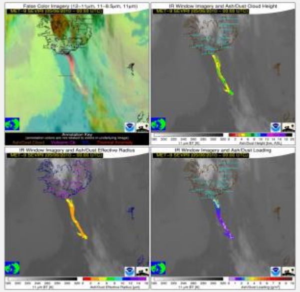
GOES-13-15



MTSAT-(1r and 2)



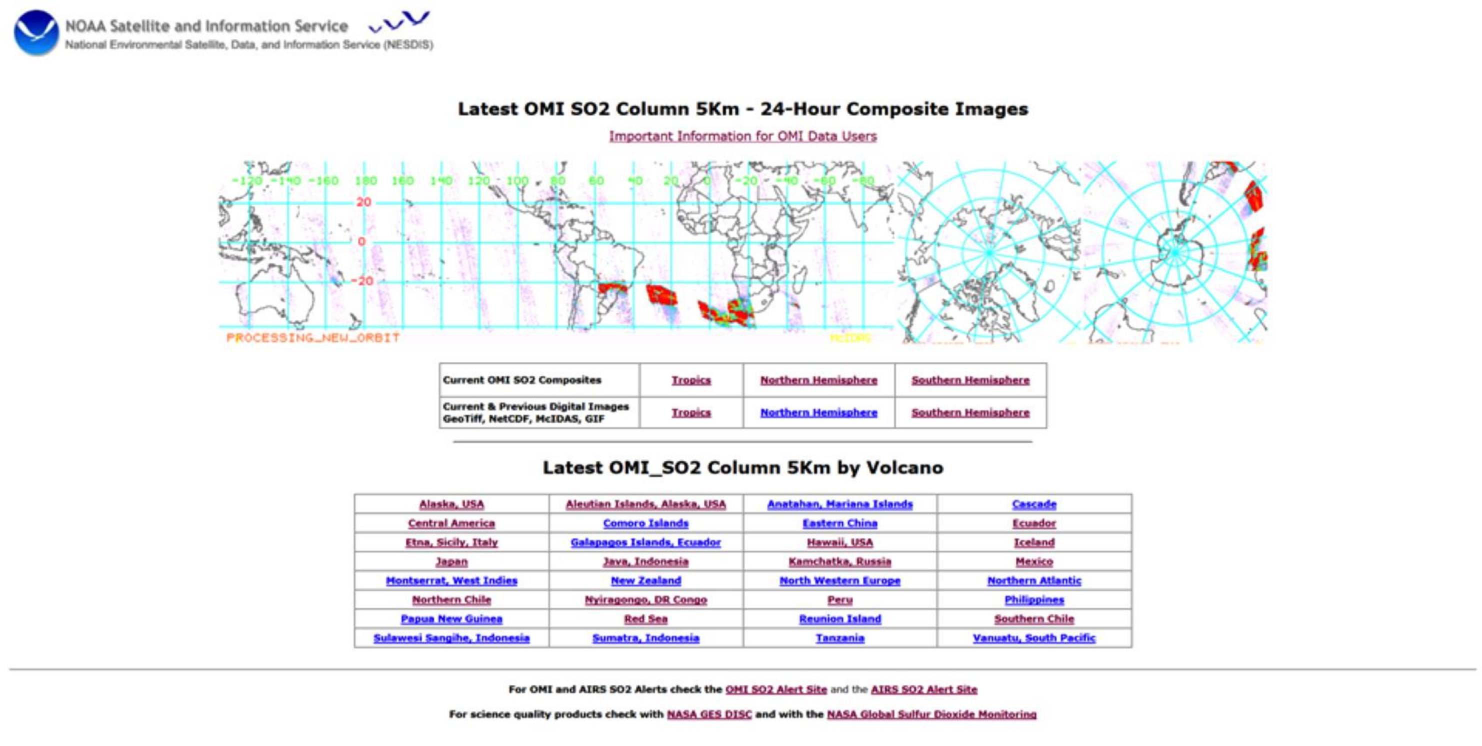
Met-(8,9,10) SEVIRI



Courtesy UW NOAA CIMSS, Madison WI

Aura/OMI SO_2 Data

NOAA/NESDIS Volcanic Alert System: www.ospo.noaa.gov/Products/atmosphere/vaac/



NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS)

Latest OMI SO2 Column 5Km - 24-Hour Composite Images

Important Information for OMI Data Users

Current OMI SO2 Composites	Tropics	Northern Hemisphere	Southern Hemisphere
Current & Previous Digital Images GeoTiff, NetCDF, McIDAS, GIF	Tropics	Northern Hemisphere	Southern Hemisphere

Latest OMI_SO2 Column 5Km by Volcano

Alaska, USA	Aleutian Islands, Alaska, USA	Anatahan, Mariana Islands	Cascade
Central America	Comoro Islands	Eastern China	Ecuador
Etna, Sicily, Italy	Galapagos Islands, Ecuador	Hawaii, USA	Iceland
Japan	Java, Indonesia	Kamchatka, Russia	Mexico
Montserrat, West Indies	New Zealand	North Western Europe	Northern Atlantic
Northern Chile	Nyiragongo, DR Congo	Peru	Philippines
Papua New Guinea	Red Sea	Reunion Island	Southern Chile
Sulawesi Sangihe, Indonesia	Sumatra, Indonesia	Tanzania	Vanuatu, South Pacific

For OMI and AIRS SO2 Alerts check the OMI SO2 Alert Site and the AIRS SO2 Alert Site

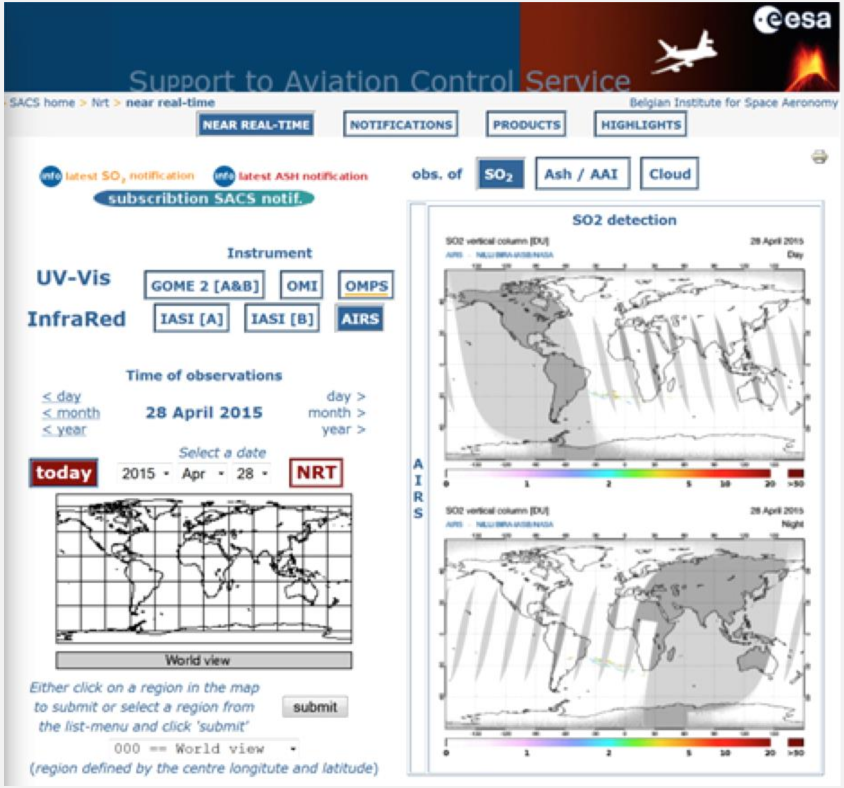
For science quality products check with NASA GES DISC and with the NASA Global Sulfur Dioxide Monitoring

AIRS, OMI, OMPS SO_2 Data

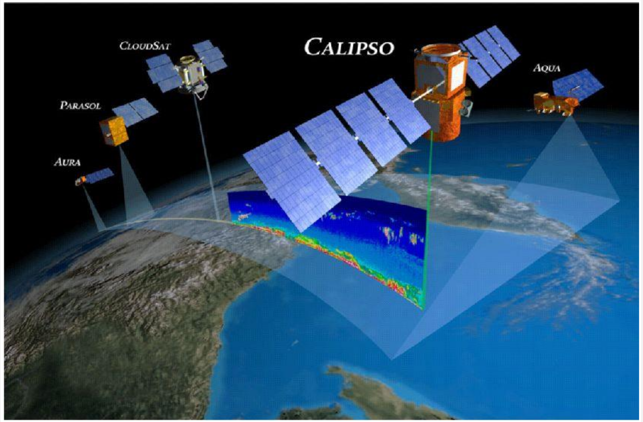
European SACS Volcanic Alert System: http://sacs.aeronomie.be/

The European Support Aviation Control Service (SACS) uses operational volcanic SO_2 column and Ash Index data from

- Aura/OMI
- SNPP/OMPS
- Aqua/AIRS



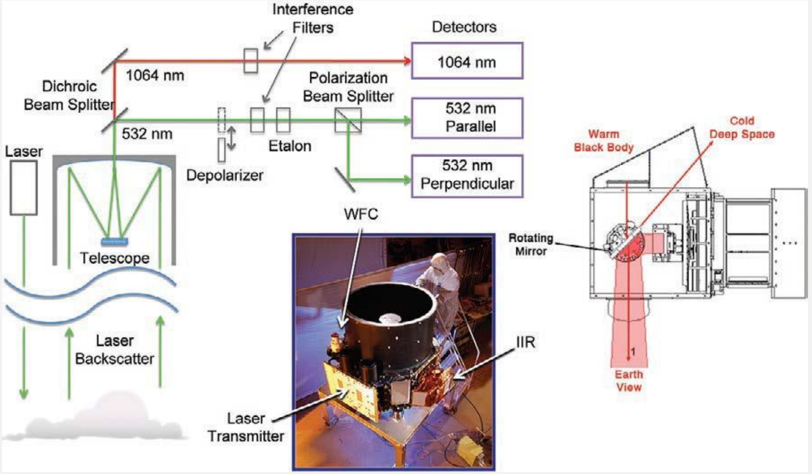
CALIOP – the CALIPSO Lidar



NASA

- High vertical resolution (60m) of backscatter profiles
- Optical parameters provide unique capability to detect volcanic ash and its vertical structure

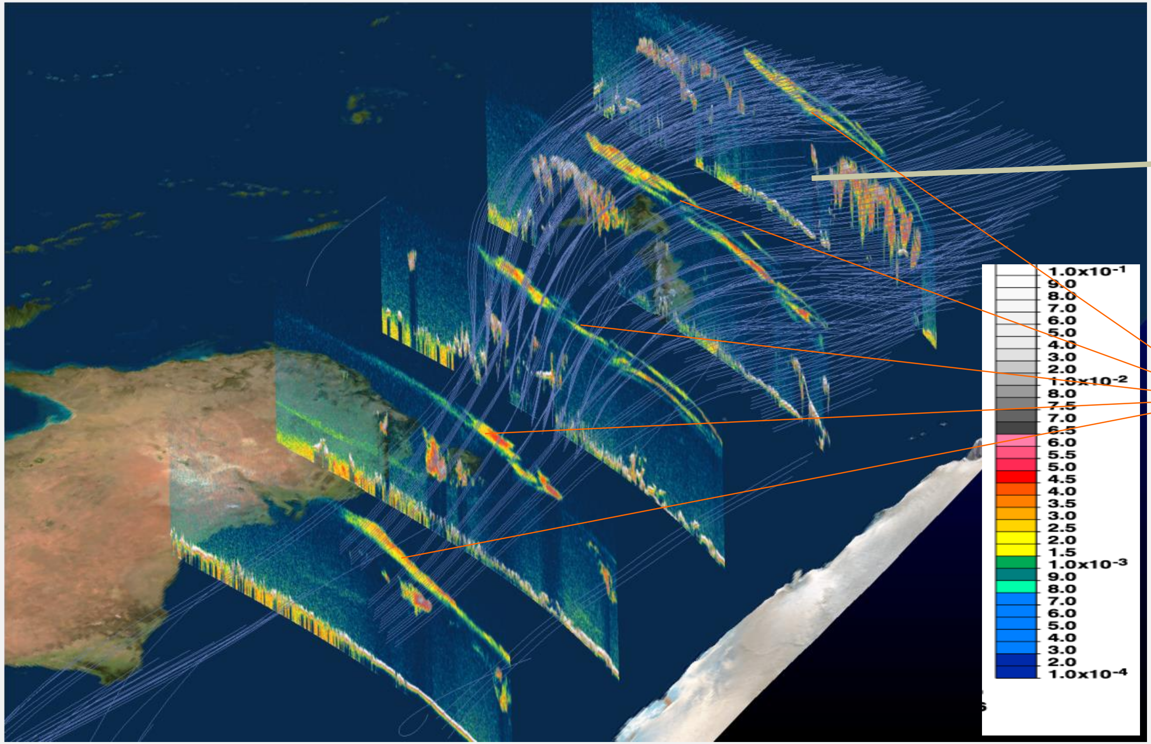
- Operating since 2006 in a polar orbit
- Equatorial crossing-time at 0130 and 1330 LET
- Repeat cycle of 16 days



NASA/LaRC, BATC; eoPortal

Enhanced Characterization

Assimilating Series of CALIPSO Curtains Into Dispersion Forecast Models



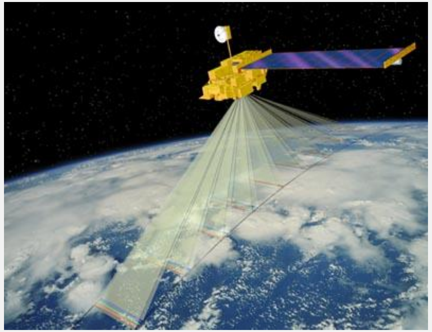
Ensemble of trajectories

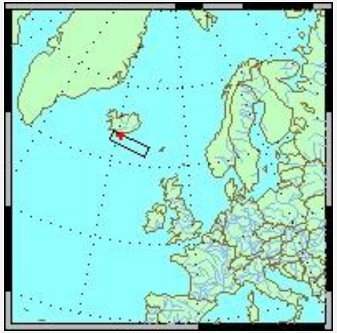
Volcanic ash cloud

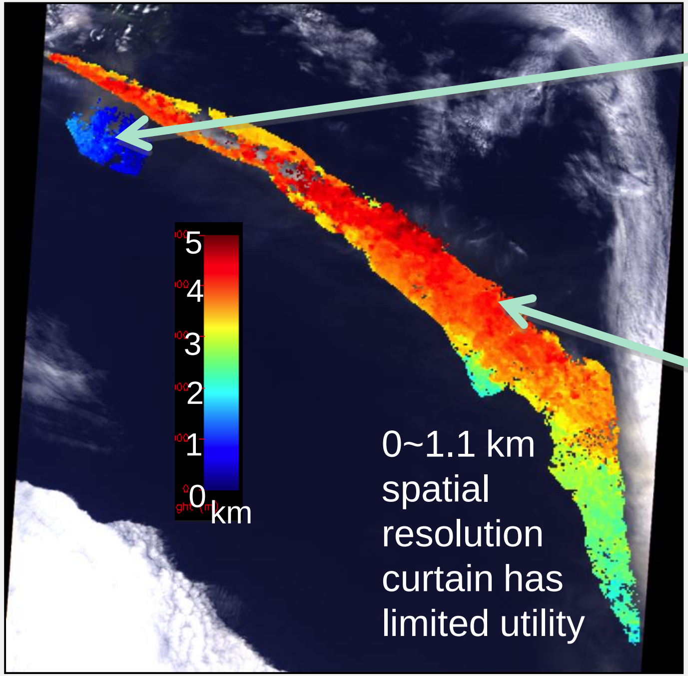
NASA

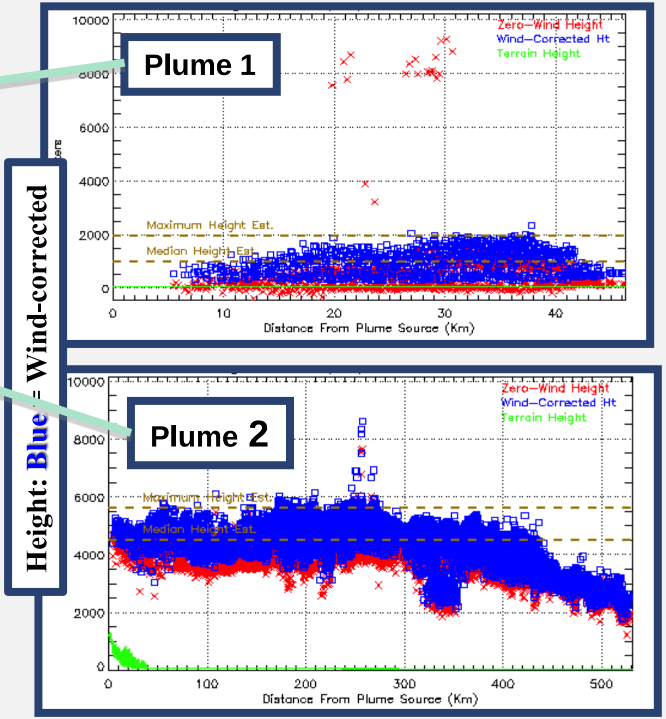
Multi-angle Imaging SpectroRadiometer (MISR)

Adding Stereo-Derived Plume Heights









R. Kahn, D. Nelson, and the MISR Team, NASA JPL and GSFC

NASA Remote Sensing for Volcanic Ash Resources

- MODIS
  - Near Real-Time Data: https://worldview.earthdata.nasa.gov
- ASTER
  - Land Processes DAAC: https://lpdaac.usgs.gov/data_access
  - Using ASTER for Volcano Monitoring: https://www.youtube.com/watch?v=A39FnHdSoNk
- CALIPSO Lidar Curtains
  - https://eosweb.larc.nasa.gov/project/calipso/calipso_table
- MISR Plume Height Project 2
  - https://www-misr.jpl.nasa.gov/getData/accessData/MisrMinxPlumes2/
- Aura, OMI, OMPS SO_2 Data
  - NOAA/NESDIS volcanic alert system website: http://satepsanone.nesdis.noaa.gov/pub/OMI/OMISO2/
  - Global Sulfur Dioxide Monitoring Home Page – NASA Goddard: http://so2.gsfc.nasa.gov
- The European Support Aviation Control Service (SACS)
  - http://sacs.aeronomie.be

Part 2: Monitoring Earthquakes, and Tsunamis Using NASA Remote Sensing and Models

Monitoring Earthquakes and Tsunamis

Maggi Glasscoe

Talk Outline

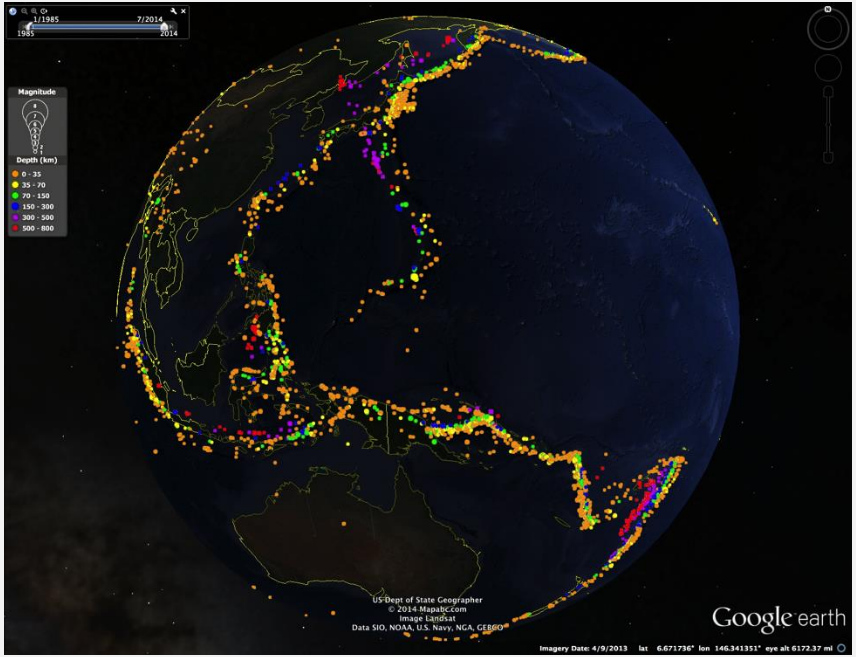
- Introduction
- How do we respond to earthquakes?
- Remote Sensing Techniques to Monitor Earthquakes
  - 2014 Napa, CA
  - 2015 Gorkha, Nepal
- Remote Sensing Techniques to Monitor Tsunamis
  - 2011 Northeast Japan Earthquake
- Conclusions

Introduction

Introduction

Earthquake and tsunami risk

- Annualized losses from earthquakes in the United States are $5.3B (FEMA, 2008)
- From 2000 – 2009, earthquakes killed more people globally than other natural disasters (OFDA/CRED 2009)
- From 1980 – 2009 6 of the 7 natural disasters with the largest economic impact were earthquakes (OFDA/CRED, 2009)
- In the 21st century earthquakes are expected to kill 1.9 – 3.2 million people globally (Holzer and Savage, 2013)



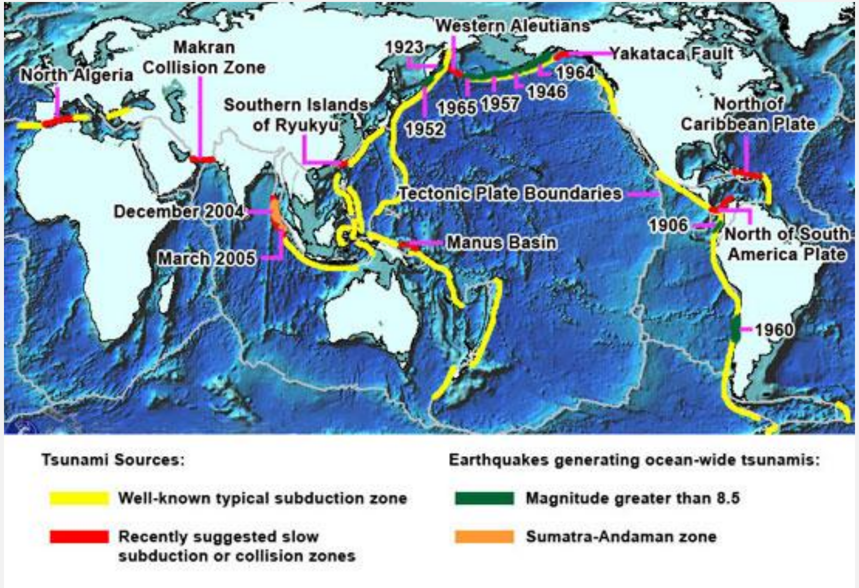
Damaging earthquakes are concentrated near coastal areas. Here two decades of potentially damaging earthquakes are displayed over East Asia and the Pacific, colored by depth. (Data are from the Advanced National Seismic System, Glasscoe, et al. 2016, Decadal Survey White Paper #2).

Introduction

Earthquake and tsunami risk

- 2004 Indian Ocean Tsunami
  - Reached heights of 65-100 ft in Sumatra
  - Caused 200,000+ deaths across 11 countries
  - Registered on tide gauges globally
- 1964 Alaska Tsunami
  - Resulted in 110 deaths
- 1918 Earthquake & Tsunami
  - Killed 118 people in Puerto Rico alone
- 1700 Pacific Tsunami
  - Overran Native American fishing camps
  - Caused damage in Japan

(USGS fact sheet, 2006-3023)

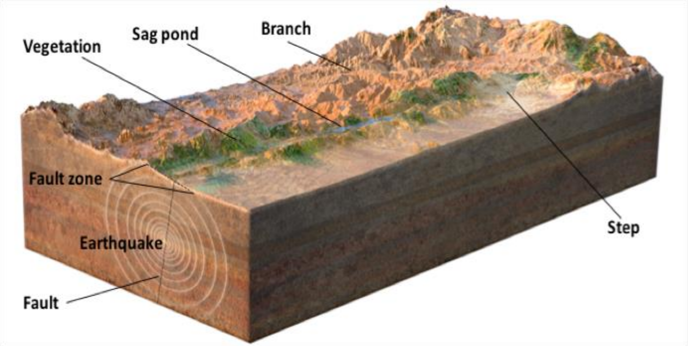


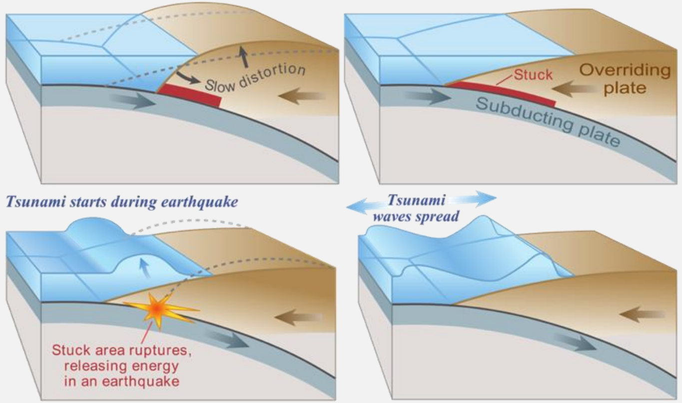
Global tsunami source zones highlighted by color.
Source: ITIC, http://itic.ioc-unesco.org/index.php?option=com_content&view=category&id=1166&Itemid=1166

Introduction

Earthquake and tsunami mechanism

- Faults are made up of a central core surrounded by a damage zone
- Earthquakes occur when stress builds on the fault lines and then it falls
- Ground shaking and displacement
  - lead to injury & loss of life
  - cause damage to infrastructure, homes, and injury
- Tsunamis occur when the seafloor is displaced by an underwater earthquake or landslide
  - generates waves that grow when they reach shore





(Top): Artwork Chuck Carter, JPL; Donnellan, et al., Decadal Survey White Paper #2. (Bottom) Surviving a Tsunami – Lessons from Chile, Hawaii, and Japan, USGS

How do we respond to earthquakes/tsunamis?

When an earthquake/tsunami occurs

How do we respond?

- Researchers gather information from various sources, including satellites
- The International Charter may be invoked in order to target space-borne assets for disaster response

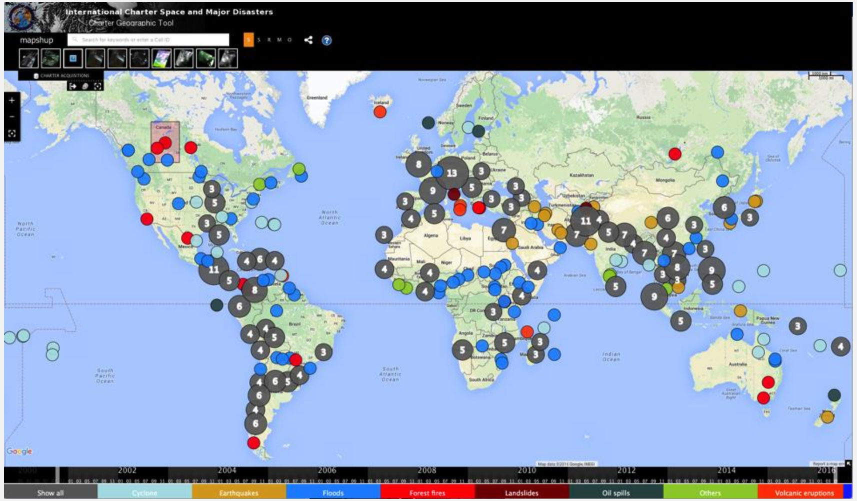
Scenes from Banda Aceh, nearly 3 km from the coast, following a tsunami. Dec 26, 2004. Credit: *Where the first wave arrives in minutes*, UNESCO, 2010.

The International Charter Space and Major Disasters

http://www.disasterscharter.org

The International Charter

- Provides a unified system of space data acquisition and delivery to those affected by disasters
- Mitigate the effects of disasters on human life and property through member agency resources



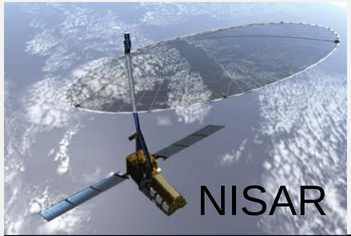
International Charter tool illustrating activations and disaster types.
http://cgt.prod.esaportal.eu/

Remote Sensing Observations for Monitoring Earthquakes

Synthetic Aperture Radar (SAR)

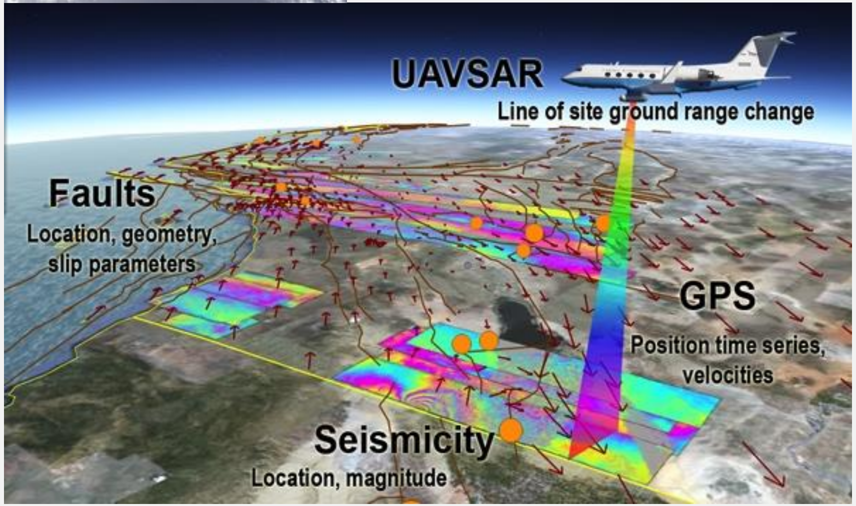
http://uavsar.jpl.nasa.gov; http://nisar.jpl.nasa.gov

- Radar is very useful for studying Earth processes
- Repeat visit allows creation of a landscape *change* image
- High definition:
  - 7m pixel size (UAVSAR)
  - 10m pixel size (Satellite)
- Sensitive: sees 1cm surface fault slip
- NASA instruments:
  - UAVSAR airborne
  - Planned NISAR satellite



Left: satellite for the NASA-ISRO SAR Mission (NISAR)

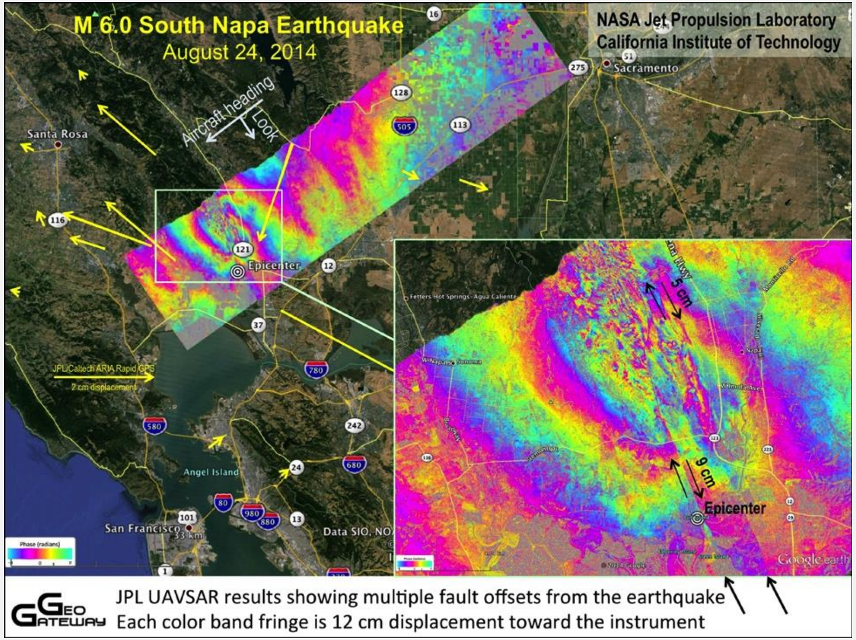
Below: Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR)

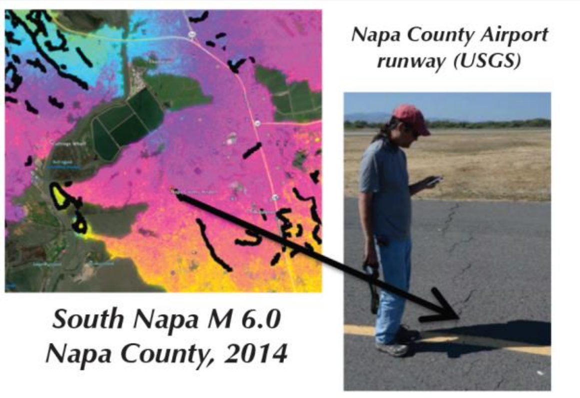


Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR)

2014 Napa Earthquake Response

- Magnitude 6.0 earthquake: Aug 25, 2014
- Strongest to occur in San Francisco Bay Area since 1989
- NASA data aided in response & analysis
- UAVSAR instrument flew a week before and in subsequent months





Above: A comparison of UAVSAR data collected May 29, 2014 and Aug 29, 2014, revealing that multiple strands of the fault slipped near the quake's center. Credit: NASA/JPL-Caltech/ASI/Google Earth; Left: Automated image processing identifying fractures in UAVSAR images to be validated in the field.

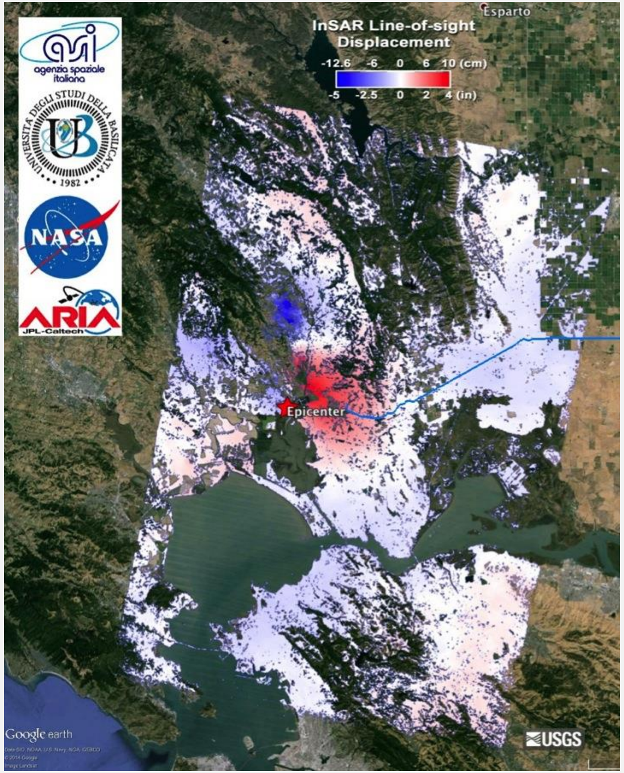
Advanced Rapid Imaging and Analysis (ARIA)

http://aria.jpl.nasa.gov

- Produced an Interferometric Synthetic Aperture Radar (InSAR) map of coseismic displacement
- Derived from COSMO-SkyMed data
- Produced a Damage Proxy Map (DPM)
- Technique uses a prototype algorithm for detecting surface changes

Right: InSAR image of ground deformation resulting from the Napa earthquake. Credit: NASA/JPL-Caltech/ASI/Google Earth

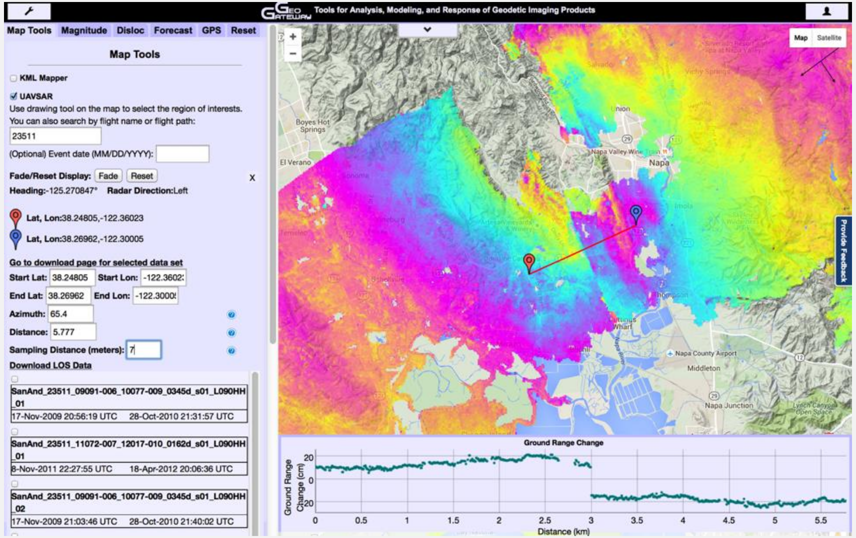
Left: DPM showing potential earthquake damage. Credit: NASA/JPL-Caltech/ASI/Google Earth



Geodetic Data Exploration (GEOGateway)

http://geo-gateway.org

- Allows users to find and use NASA geodetic imaging data products for analysis of deformation pre- and post-event
- Users can access and analyze UAVSAR repeat pass interferometry (RPI) products
- California faults can be displayed over UAVSAR RPI products
- Can extract line of site profiles
- Convention shows “ground range change”

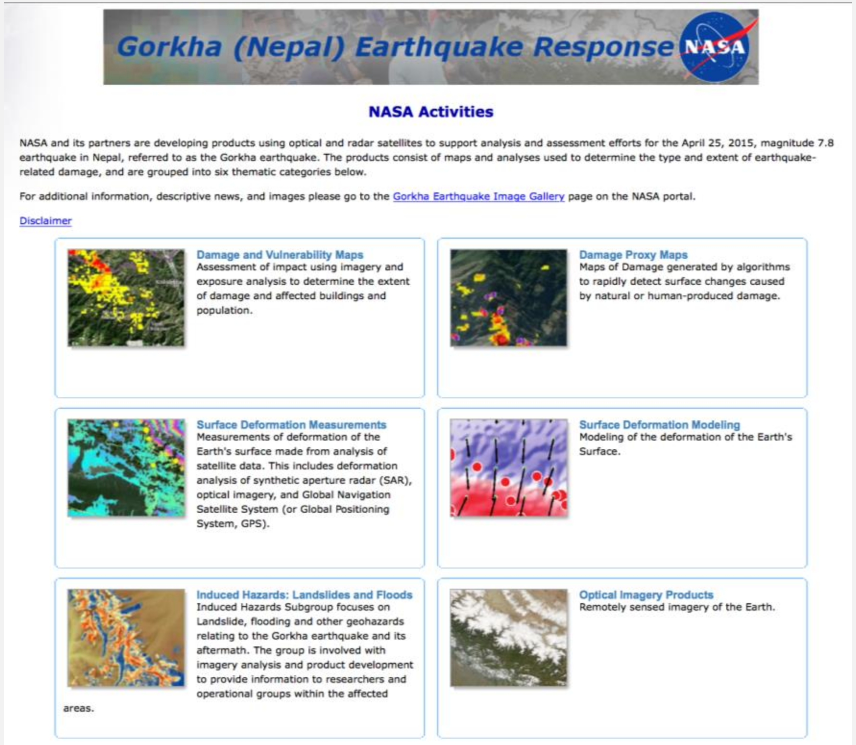


GeoGateway interface showing Napa earthquake interferogram with Line of Sight profile across the main rupture.

2015 M7.8 Gorkha, Nepal, Earthquake Response

http://weather.msfc.nasa.gov/sport/disasters/nepal/

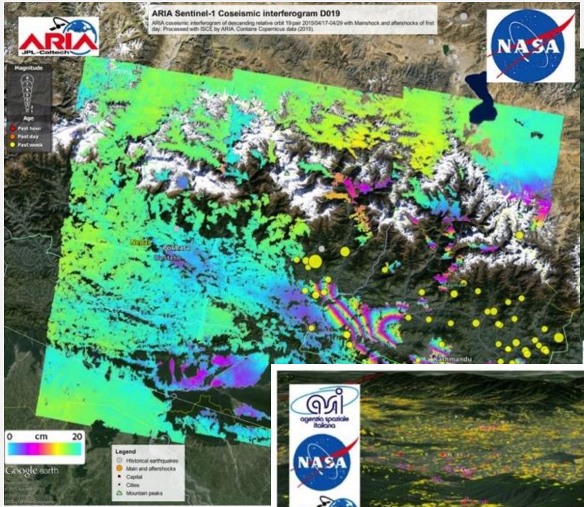
- April 25, 2015, aftershock May 12
- 8 million people affected
- 8,700 deaths
  - Including ~150 in May 12 aftershock
- 22,000 people injured
- 505,000+ homes destroyed
  - 279,000+ homes damaged
- Estimated 40% of Nepal affected
  - 39/75 districts reporting damage
- NASA and partners developed products using optical & radar satellites to support analysis and assessment efforts

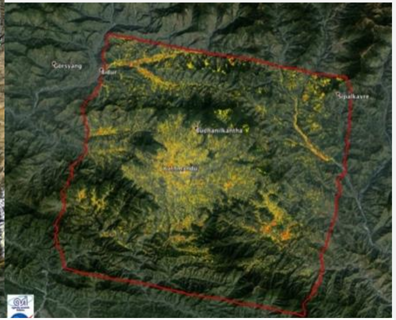


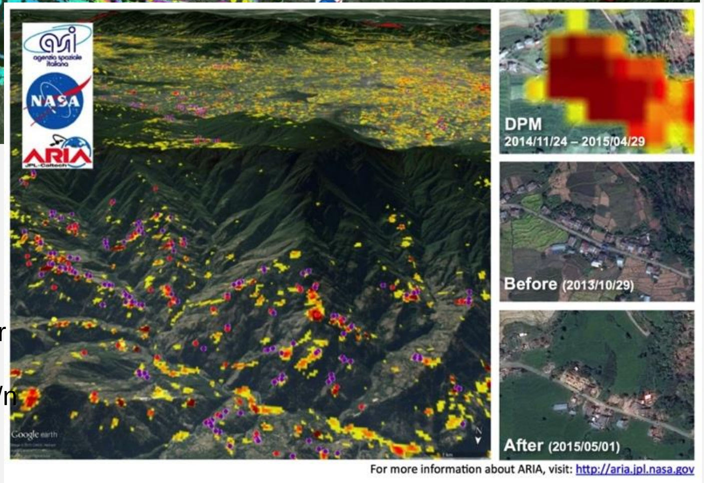
2015 Nepal Earthquake Response (ARIA)

http://aria.jpl.nasa.gov

- Analyzed interferometric SAR images from Copernicus Sentinel-1A
- False-color map shows permanent surface movement
- Produced a Damage Proxy Map
  - Uses X-band interferometric SAR data from ASI's COSMO-SkyMed
- Uses a prototype algorithm to detect surface changes
- Color variations (yellow-red) indicate significant ground surface change
- DPMs can be field verified







Clockwise (top left): InSAR deformation map, Damage Proxy Map, Perspective Damage Proxy Map with field validation (for more information see http://aria.jpl.nasa.gov/node/43)

Short-Term Prediction Research and Transition (SPoRT)

http://weather.msfc.nasa.gov/sport

- Transition unique observations and research capabilities to operational weather community
- Produced as an experimental image showing a decrease in emitted light
- Derived from comparing pre- and post-earthquake imagery
- Warm colors indicate largest reduced light emissions; purple indicates clouds
- This can help relief operations determine areas that may be affected by electrical outages

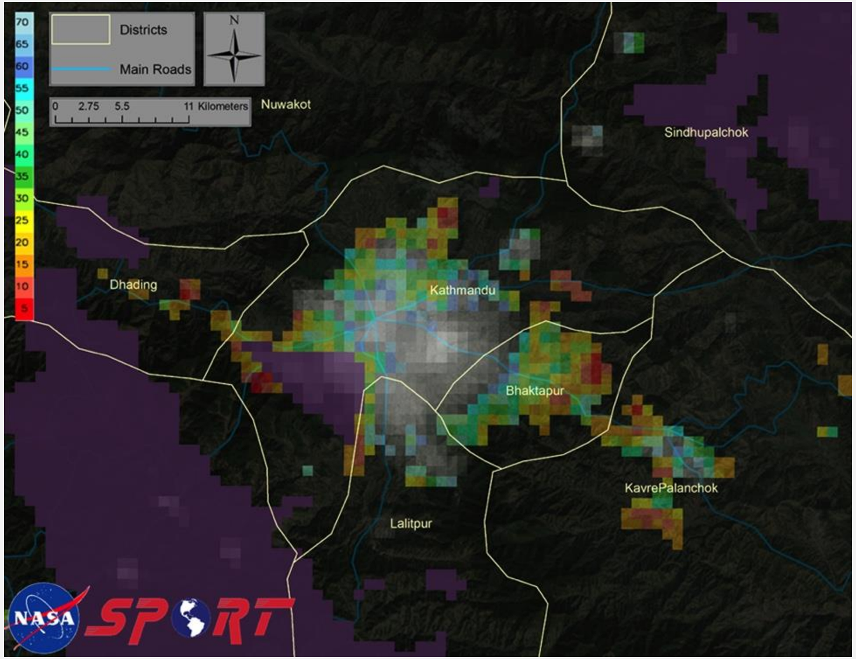


Image Credit: NASA SPoRT, MSFC

Landsat 8 Images of Earthquake-induced Ground Failure

http://landsat.gsfc.nasa.gov

- First obtained April 30
- Acquired first (mostly) cloud-free image of Langtang Valley
- Scientists analyzed imagery and compared with pre-earthquake imagery
- Part of Langtang village was completely buried
  - Eastern part appears to have been destroyed by pressure wave from related avalanche
- Large landslides or avalanches affected other villages
- Extend of damage will require further investigation using higher-res imagery

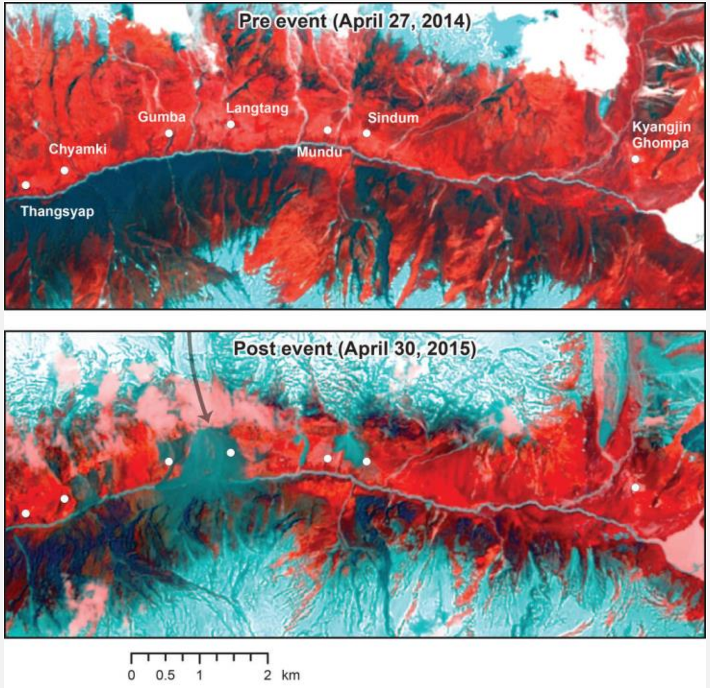


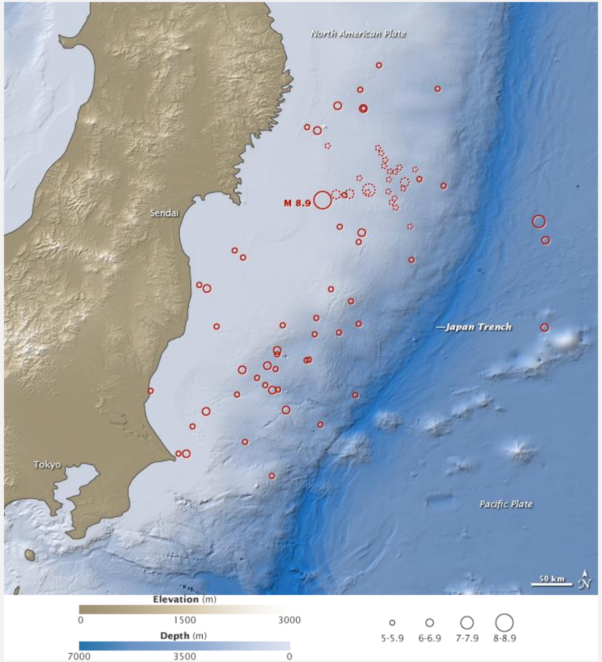
Image Credit: USGS/NASA

Remote Sensing Observations for Monitoring Tsunamis

M9 Northeast Japan Earthquake and Tsunami

March 11, 2011

- Largest earthquake in Japan's modern history
  - 4th largest recorded in the world
- Japan Meteorological Agency and NOAA reported max tsunami heights:
  - Iwate Prefecture: 38.9m
  - Kamaishi: 4.1m
  - Soma: 7.3 m
  - Oarai: 4.2 m
- Max tsunami inundation distance of 7.9 km inland
- 15,800+ deaths
  - 6,000+ injured
  - 228,000+ displaced
- 127,000+ buildings collapsed
  - 272,000+ 'half collapsed'
  - 747,000+ buildings partially damaged

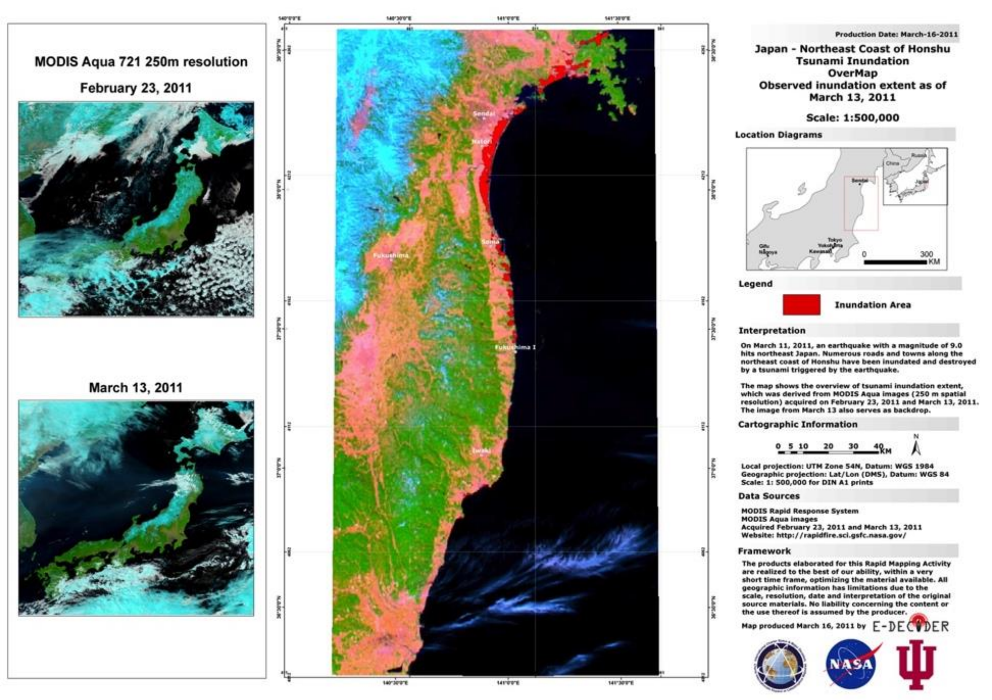


NASA Earth Observatory with data from USGS and ORNL

Tsunami Inundation

http://e-decider.org

- Emergency Data Enhanced Cyber Infrastructure for Disaster Evaluation (E-DECIDER)
- Provides decision support for disaster management and response
- Provided map data response products as part of the International Charter activation

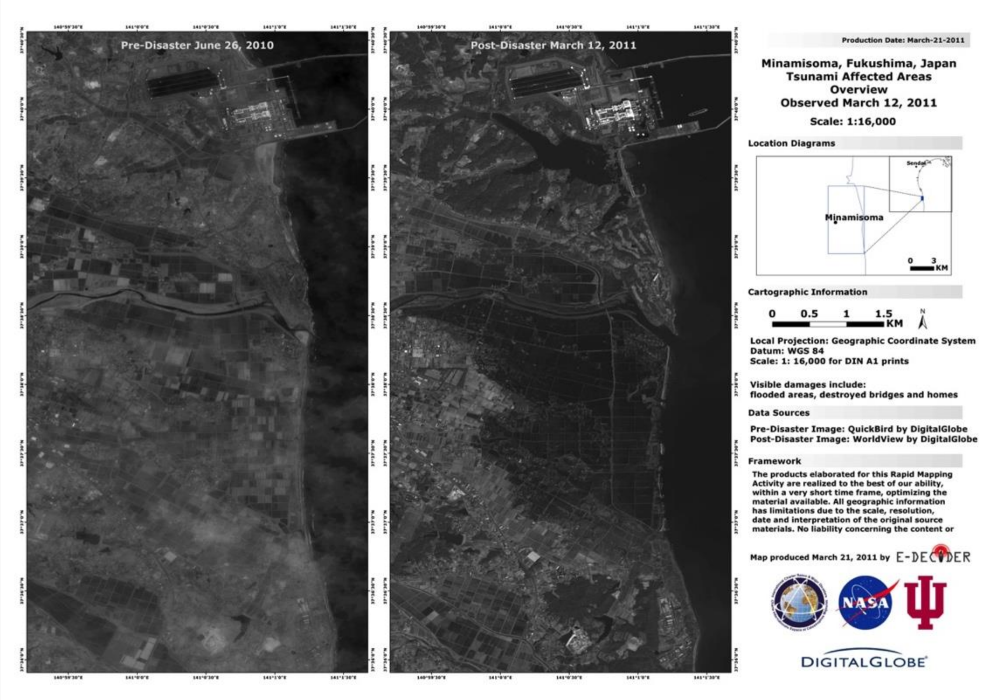


Change detection product using two MODIS images to estimate tsunami inundation extent. Credit: JPL/Indiana University

Tsunami Inundation

http://e-decider.org

- International Charter also provides access to high resolution commercial satellite imagery for disaster response purposes
- E-DECIDER provided the map on the right to the Charter and Japanese government to assess tsunami damage

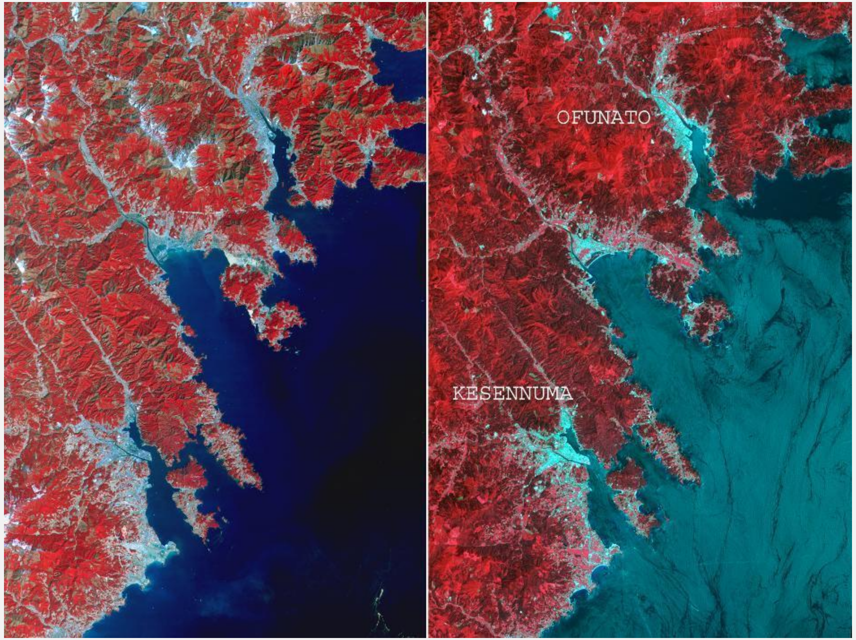


Extent of inundation, and high resolution allows identification of damaged buildings and bridges. Credit: Digital Globe/JPL/Indiana University.

ASTER Images Showing Effects

http://asterweb.jpl.nasa.gov/

- Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)
- Obtains hi-res (15-90 sq m per pixel)
  - 14 different wavelengths
- Areas covered by vegetation are shown in red
- Cities (and unvegetated areas) shown in blue-gray
- In after image, many areas are no longer vegetated

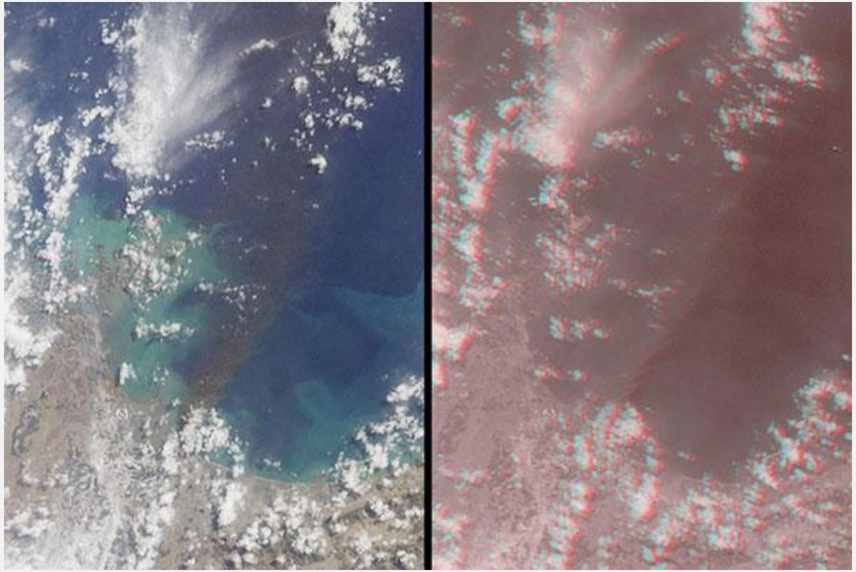


Two ASTER images (left: March 14, 2011, right: August 2008) compare Northeastern coastal cities of Ofunato and Kesennuma. Image Credit: NASA/GSFC/METI/ERSDAC/JAROS

MISR Images of Tsunami Damage

http://www-misr.jpl.nasa.gov/

- Multi-angle Imaging Spectroradiometer
- Views Earth simultaneously at 9 widely spaced angles
- Provides ongoing global coverage with accurate measures of brightness, contrast, and color of reflected sunlight
- Provides stereoscopic images
  - Allows viewers to distinguish and measure height of plumes of smoke and aerosols
- During Toshoku earthquake, MISR identified oil refineries and industrial complexes on fire



MISR images show a large smoke plume that appears to be associated either with Shiogama incident or Sendal port fires. Right image is an anaglyph, showing the plume as an airborne feature. Image Credit: NASA/GSFC/LaRC/JPL, MISR Team

GPS Modeling of Tsunami Wave Heights

http://www.gdgps.net/; http://cddis.gsfc.nasa.gov/Techniques/GNSS/GNSS_Overview.html

- GPS – using Global Navigation System Satellites (GNSS) – can estimate tsunami potential
- Can be used to:
  - detect severity and direction after an earthquake
  - estimate tsunami wave heights within minutes
- Figure on right uses 3 historic earthquakes to predict resulting tsunamis
- Pink arrows are GPS displacement measurements

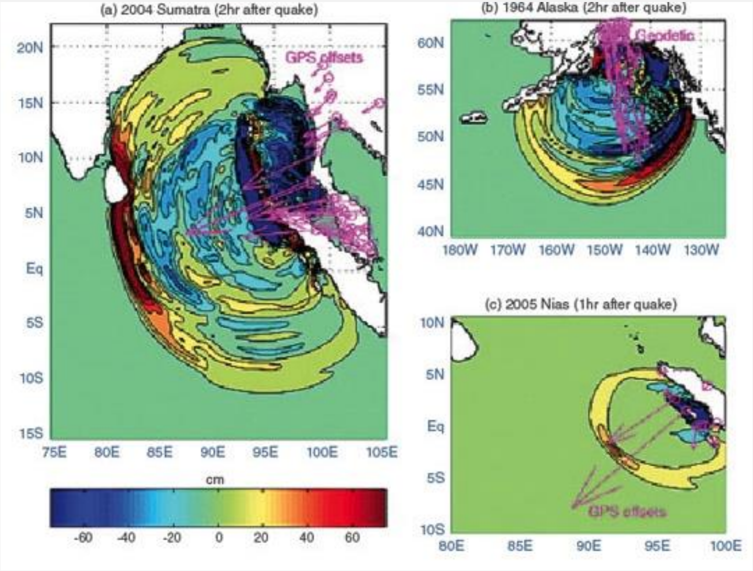


Image courtesy of T. Song, 2007, *Geophysical Research Letters*

Conclusions

Part 2: Monitoring Earthquakes & Tsunamis

Conclusions

- Earthquakes and tsunamis pose substantial risk globally
- Remote sensing techniques can be used to effectively assess the effects of earthquakes and tsunamis
- A number of NASA and other remote sensing platforms, including UAVSAR, satellite InSAR, MODIS, ASTER, MISR, Landsat, SPoRT, GPS and commercial optical imagery can be used to assess and monitor effects of the disaster
- In large natural or man-made disasters, the International Charter may be invoked in order to target space-borne assets for disaster response