AIAA Space 2011 Conference

Delta Forum: Averting Disaster on Earth Using Space Technology

Remote Sensing Technologies for Disaster Mitigation and Response

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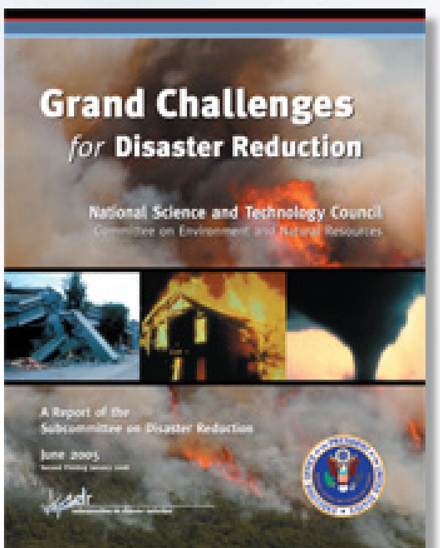
Long Beach, California

NASA's Disasters Focus

Supports the White House Office of Science and Technology Policy (OSTP) Committee on Environment and Natural Resources (CENR) **Subcommittee on Disaster Reduction** (SDR)

- **Six Grand Challenges:**



1. **Provide hazard and disaster information where and when it is needed**
2. **Understand the natural processes that produce hazards**
3. **Develop hazard mitigation strategies and technologies**
4. **Recognize and reduce vulnerability of interdependent critical infrastructure**
5. Assess disaster resilience using standard methods
6. Promote risk-wise behavior

NASA

Other Agencies

Objective and Contributions

To bring NASA capabilities in the area of spaceborne and airborne platforms and observations, higher level data products, and modeling and analysis to improve forecasting, mitigation, and response to natural disasters

- As an agency with spaceborne, airborne, and modeling and analysis capabilities NASA can specifically contribute the SDR Grand Challenges:
  1. **Provide hazard and disaster information where and when it is needed**
- As a research agency NASA can specifically contribute to the SDR Grand Challenges:
  2. **Understand the natural processes that produce hazards**
  3. **Develop hazard mitigation** strategies and **technologies**
  4. **Recognize** and reduce **vulnerability of interdependent critical infrastructure**

Natural Disaster Area Challenges

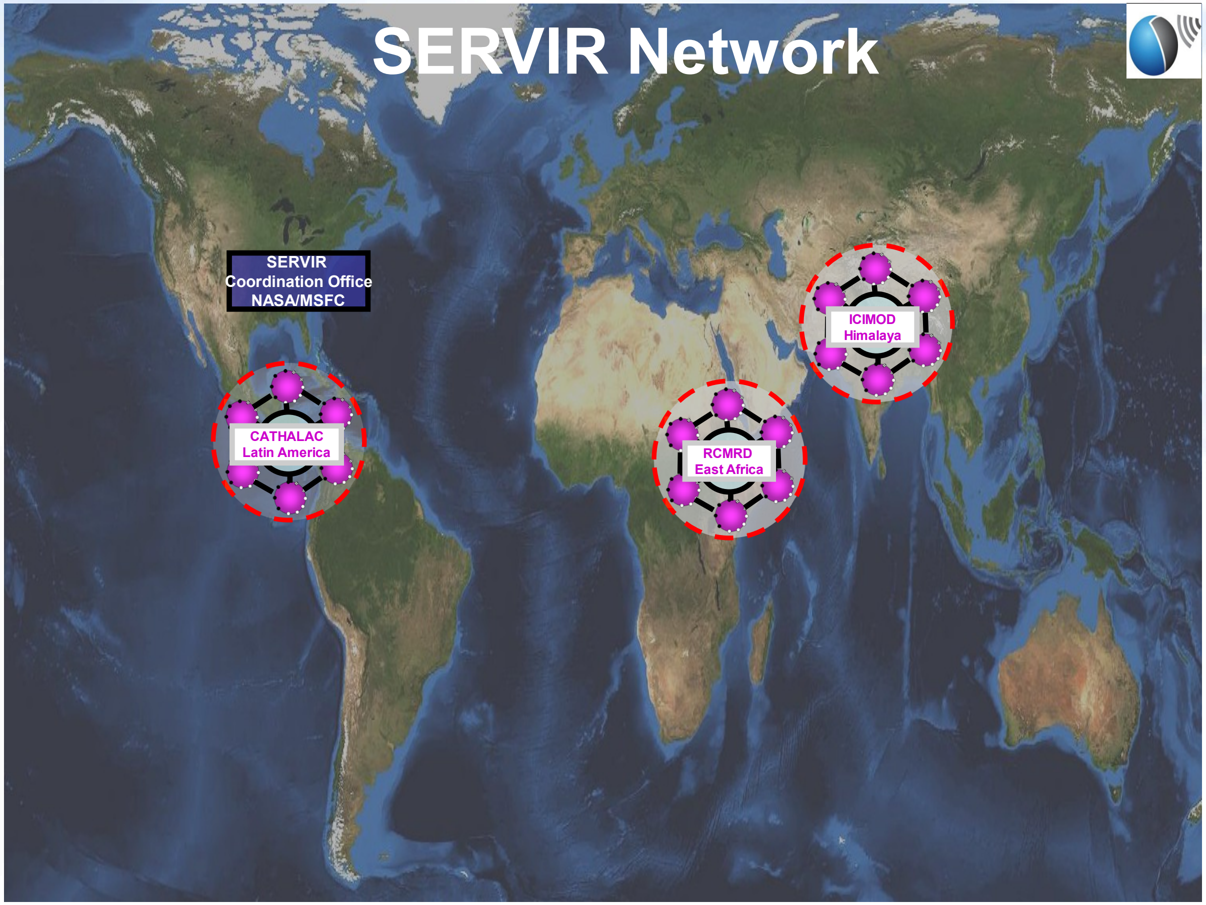
- NASA is a research agency
  - In the event of a disaster NASA applies available assets
- Some overlap between disaster response and science research and analysis
  - Immediate need for information greater for disaster response than for science
- Transferring application research results to end-users
  - Requires existing partnerships and collaborations
  - Is facilitated by joint projects and simulations
    - Develop communication and identify existing gaps
- Existing disaster projects
  - floods, earthquakes, tsunamis, hurricanes, wildfires, landslide, human health, technological, tornadoes

SERVIR

Integrates satellite observations, ground-based data and forecast models to monitor and forecast environmental changes and improve response to natural disasters in Central America, the Caribbean, Africa, and the Himalayas

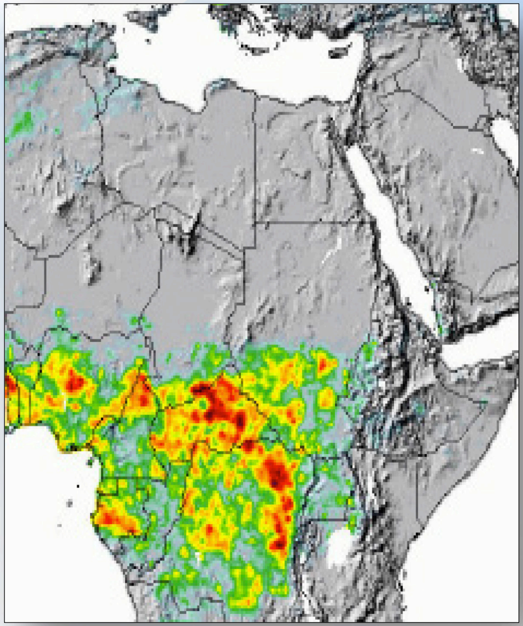
- Data and Models
- Online Maps
- Visualizations
- Decision Support
- Training
- Partnerships

Training and Capacity Building



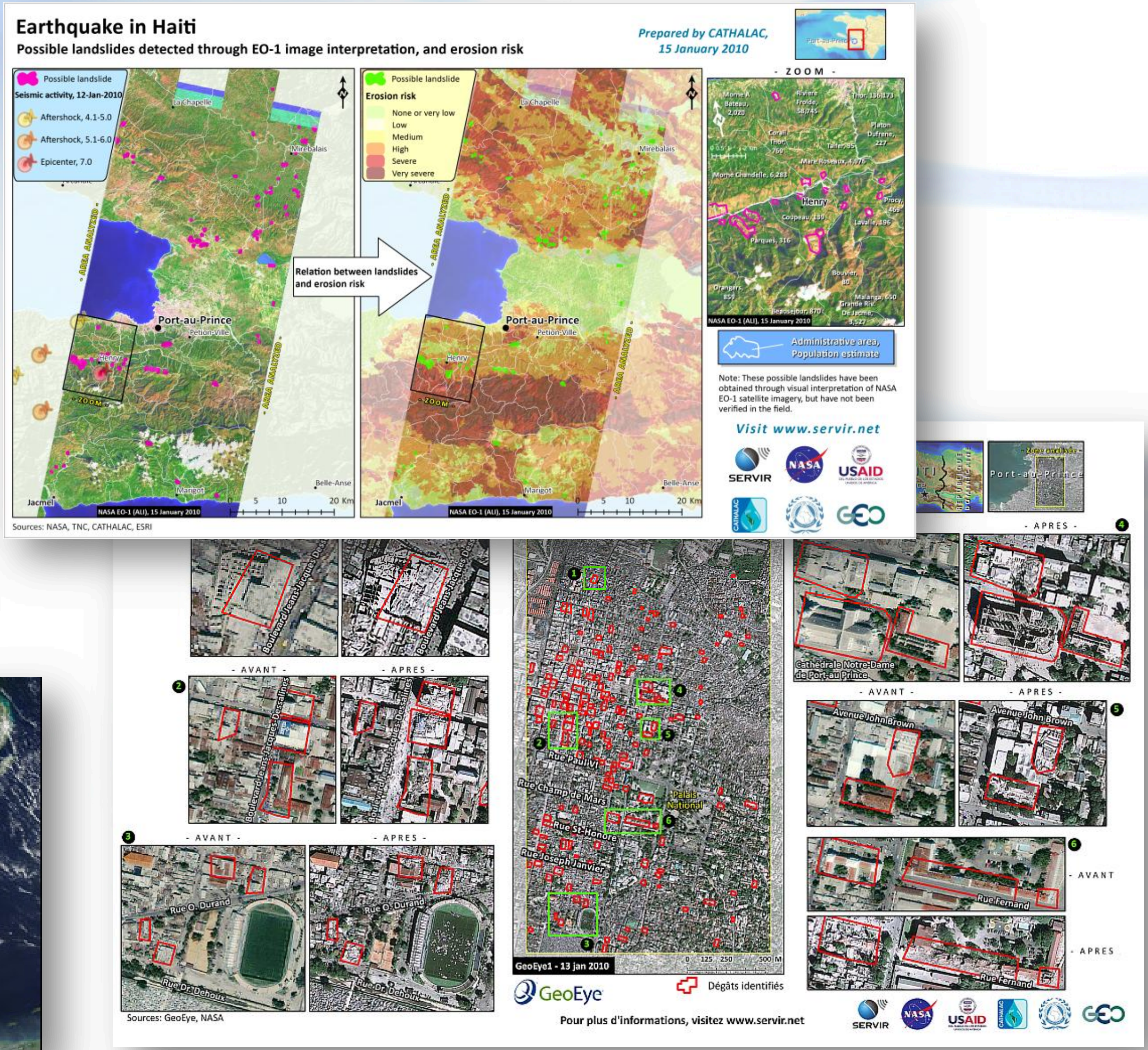
Strengthen capacity of governments and other key stakeholders to integrate earth observation information and geospatial technologies into development decision-making

SERVIR



Flood Forecasting in Africa

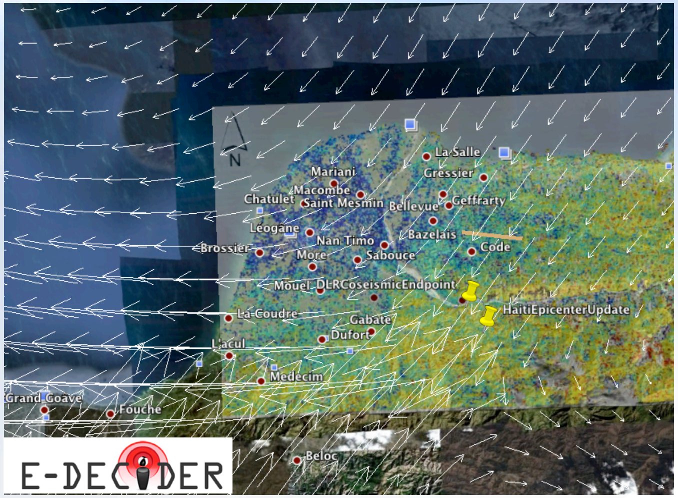
Mapping Fires in Guatemala Mexico



Earthquake in Haiti

Haiti Earthquake

Surface Displacement & Fault Mapping

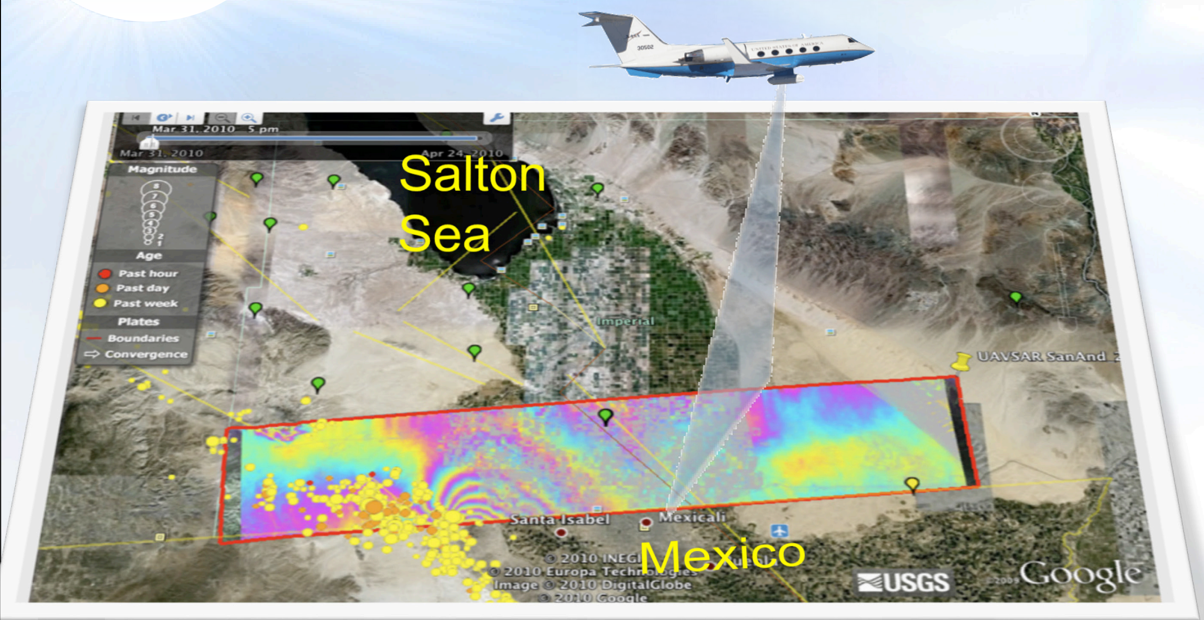


- SPOT5 dual-image displacement (east component, color image)
- Modeled surface displacement from E-DECIDER dislocation model, in the region of the 2010 Haiti earthquake epicenter (west of Port- au-Prince)
- Map overlay of image layers is carried out in Google Earth
- Correlation of SPOT images processed by CEA, images courtesy of CNES and International Charter on Space and Major Disasters

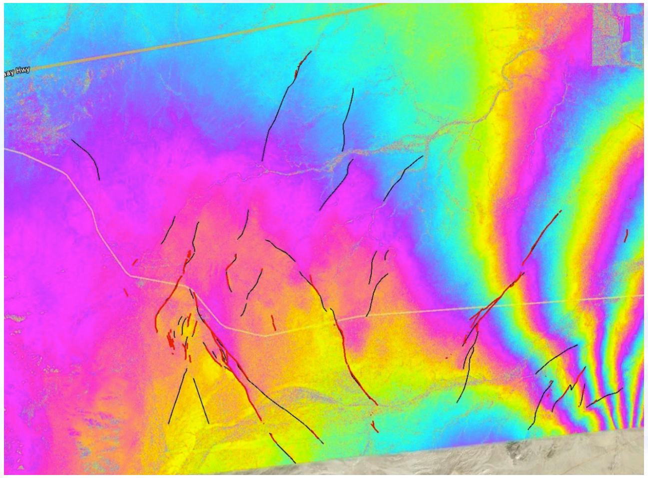
NASA added a series of UAVSAR science over flights of earthquake faults in Haiti and the Dominican Republic on the island of Hispaniola to a previously scheduled three-week airborne radar campaign in the area

First UAVSAR Measurement of an Earthquake

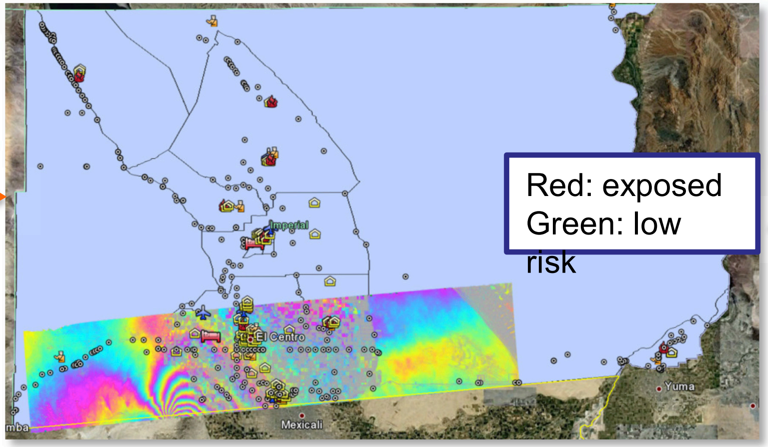
El Mayor – Cucupah M 7.2 on April 10, 2010



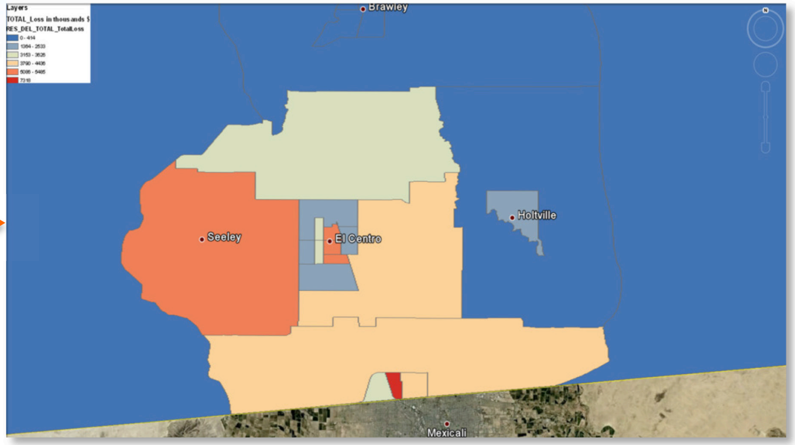
UAVSAR aids mapping faults



Critical infrastructure exposure



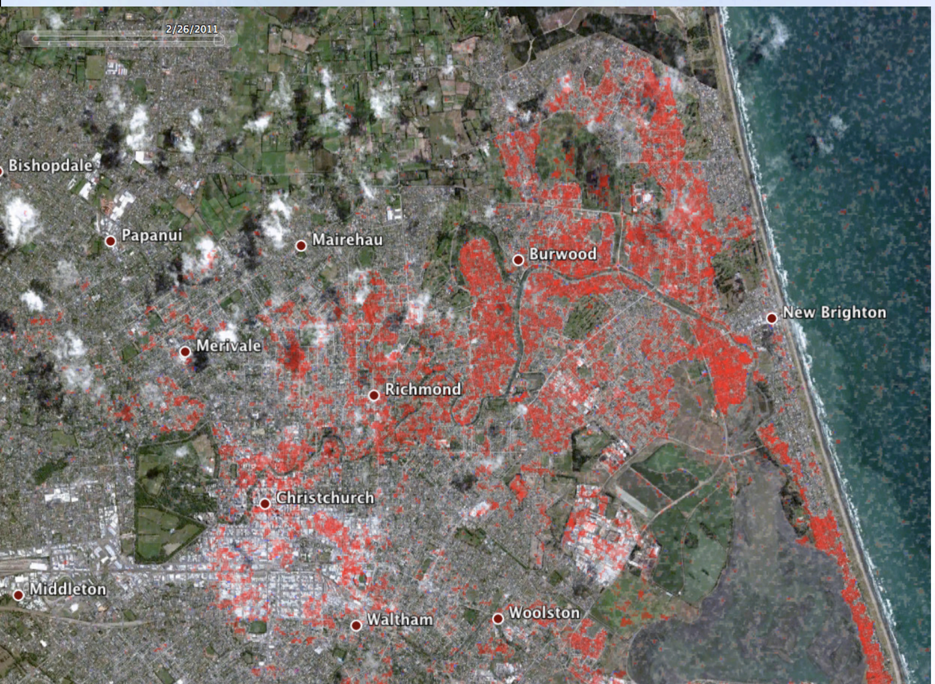
Total loss estimation Hazus output



M6.3 Christchurch Earthquake

February 2011

Damage Proxy Map



Damage mapped in three weeks versus three months on ground
Field verified

InSAR coherence change (ALOS PALSAR A335):
2010/10/10 – 2011/01/10 – 2011/02/25
Google Earth (GeoEye) Image: 2011/02/26

ARIA – JPL/Caltech

The movement dislodged 30 million tons of ice from the Tasman Glacier on the opposite side of the South Island of New Zealand

Pre-Earthquake, 2009

February 17, 2009 22:38 UTC

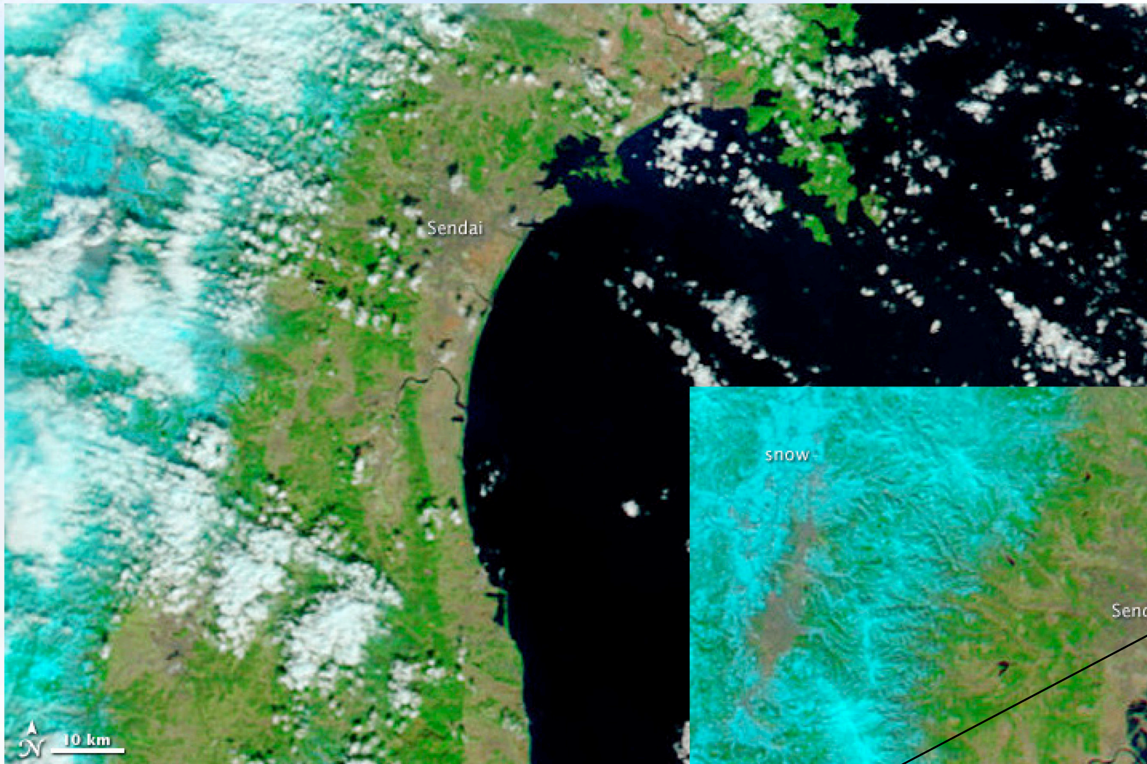
Post-Earthquake, 2011

March 2, 2011 22:43 UTC

Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) simulated natural color views using visible and near-infrared (VNIR) wavelengths at 15m ground resolution

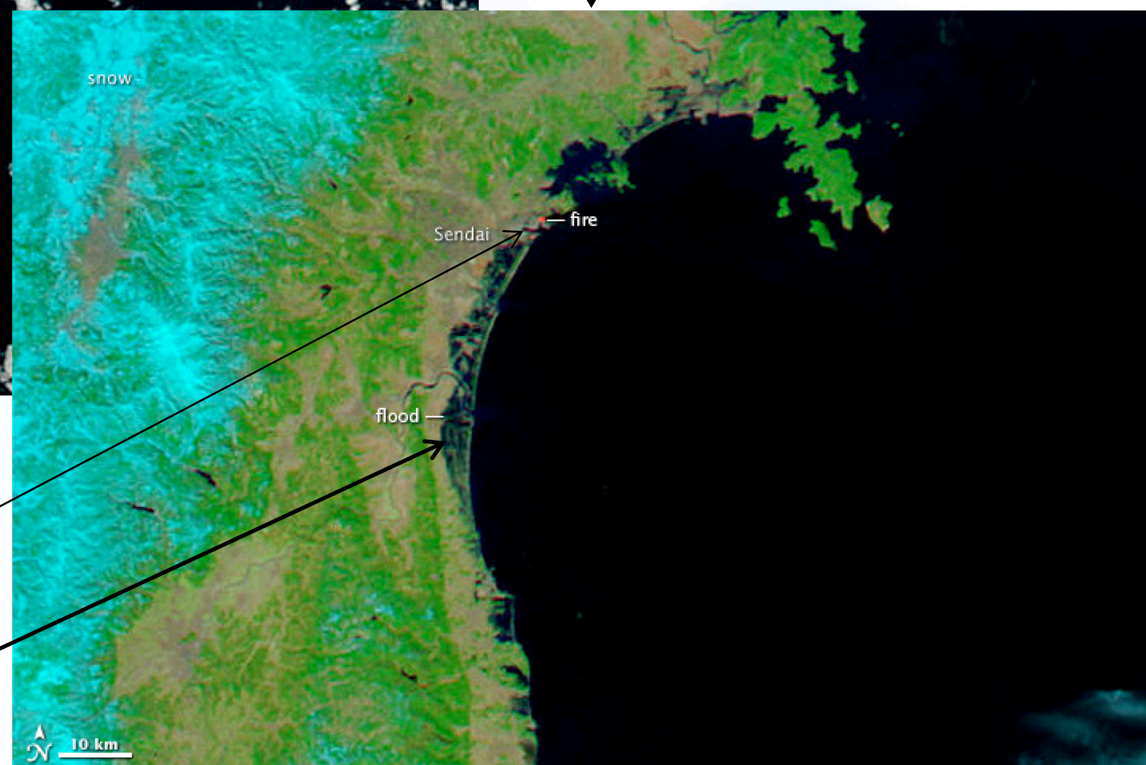
Ken Duda / NASA EOS Sr. Scientist / USGS

Sendai Coast: MODIS Before & After



Before: 26 Feb, 2011

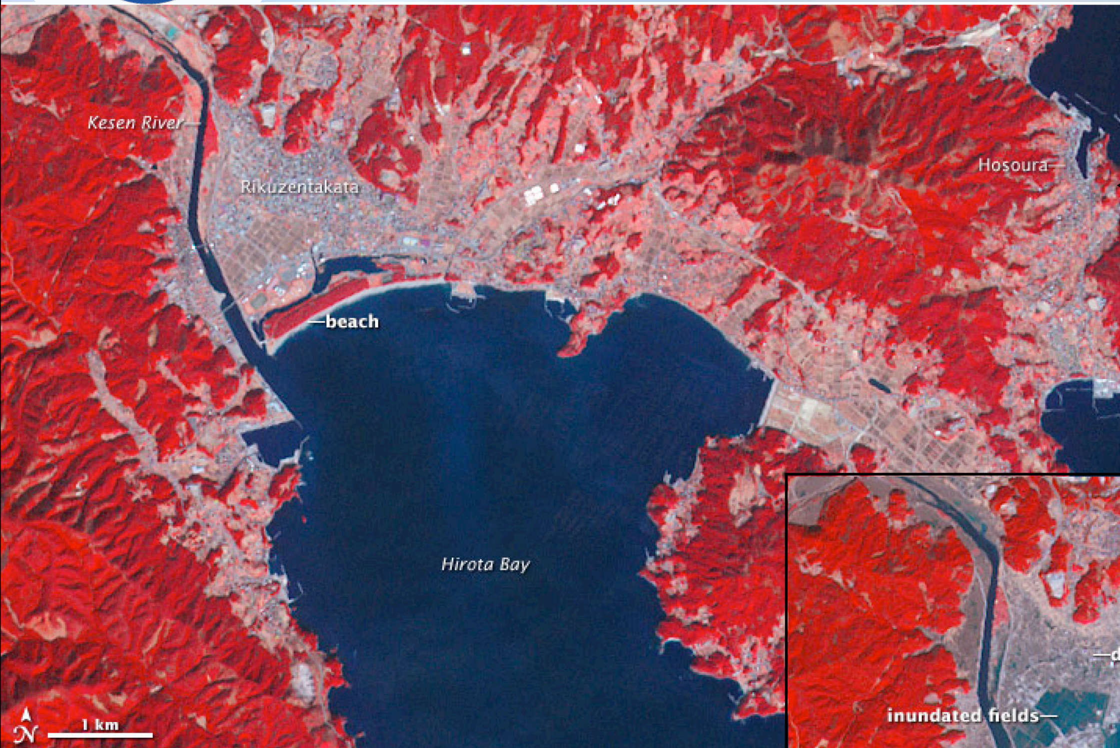
After: 13 Mar 2011



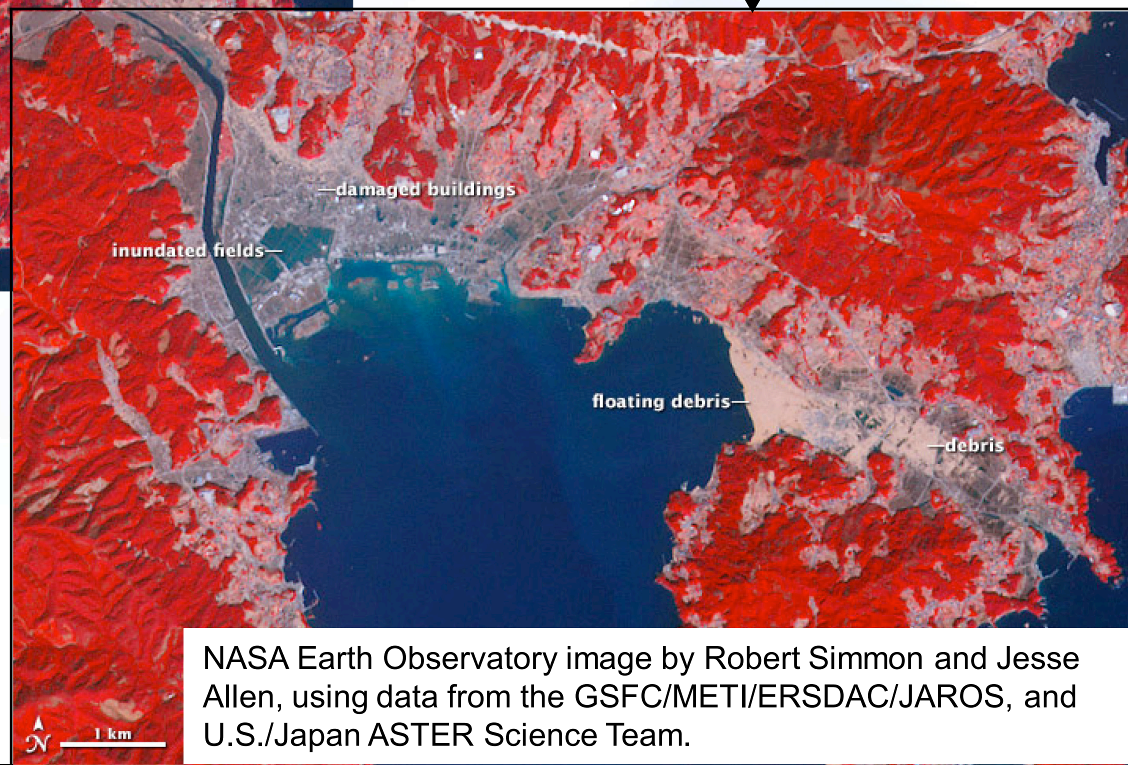
A bright orange-red spot near the city of Sendai is the thermal signature from a fire. Flooding along the coastline is the most obvious sign

Rikuzentakata: ASTER Before & After

Before: 1 March 2007

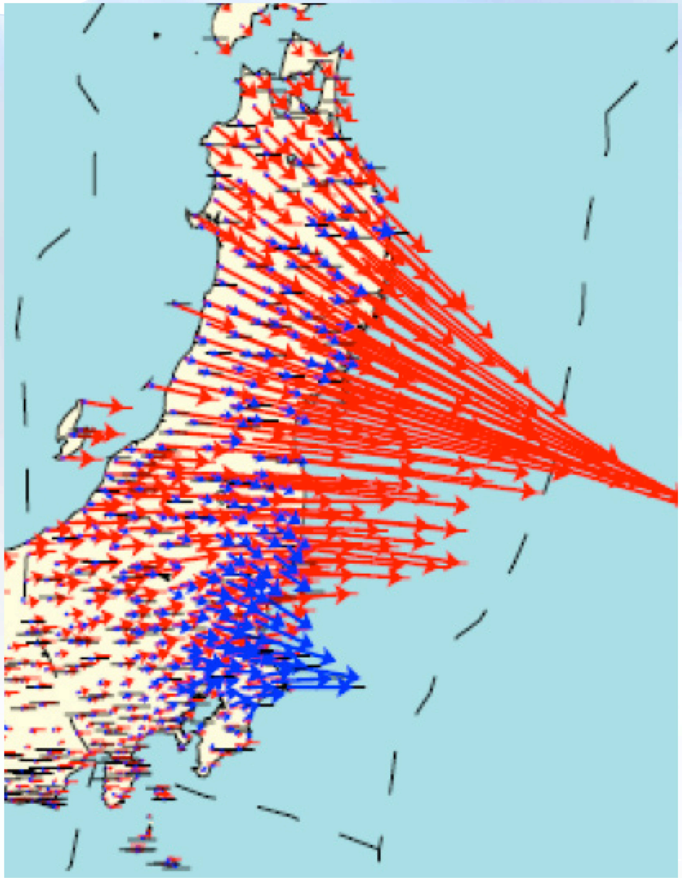


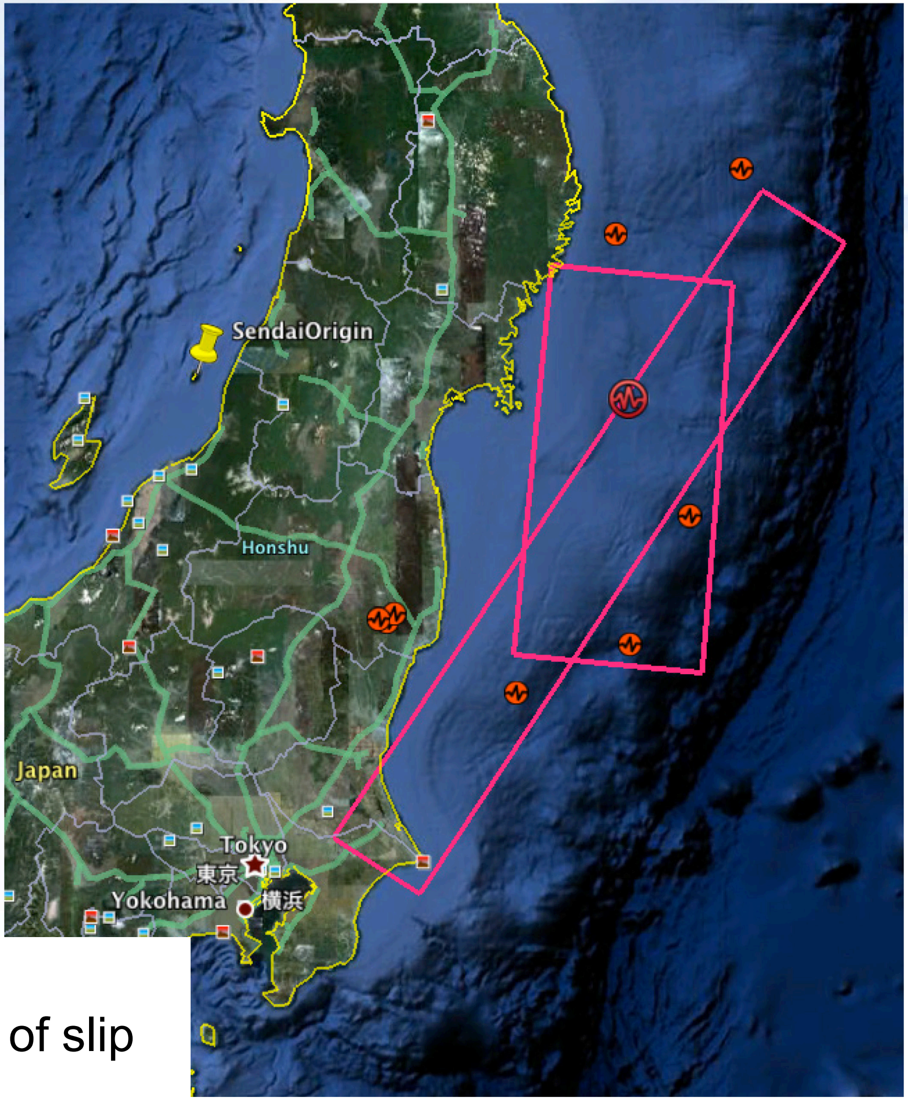
After: 14 March 2011



NASA Earth Observatory image by Robert Simmon and Jesse Allen, using data from the GSFC/METI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team.

M 9.0 Tohoku Earthquake Slip Inversions

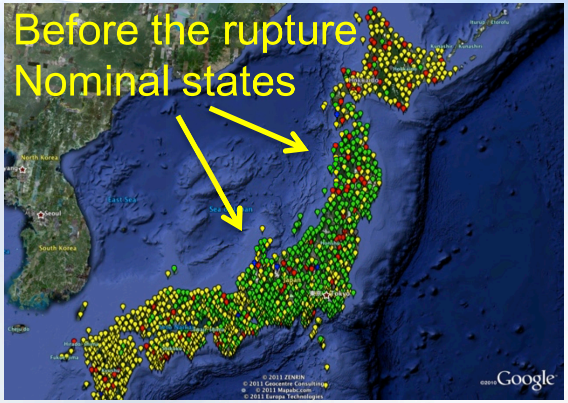




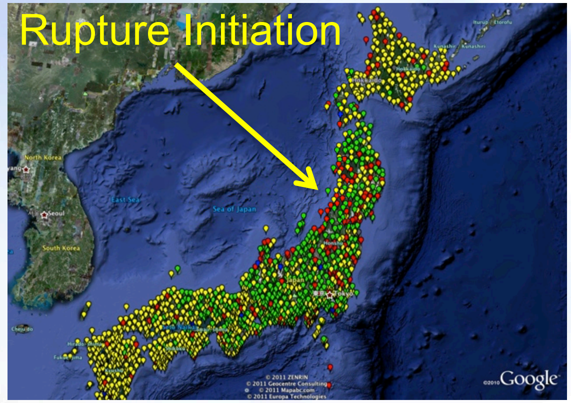
Coseismic model
120 by 249 km fault patch; Nearly 23 m of slip
Postseismic model
65 by 494 km fault patch; 1.3 m of slip

M 9.0 Tohoku-Oki Earthquake

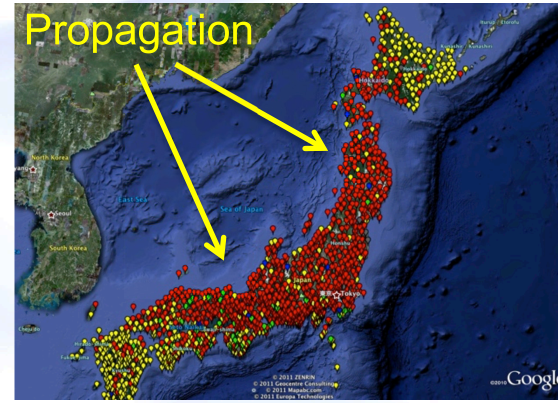
March 11, 2011 0500 UTC



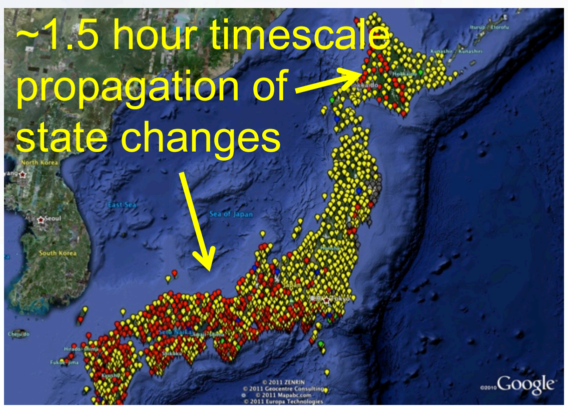
March 11, 2011 0530 UTC



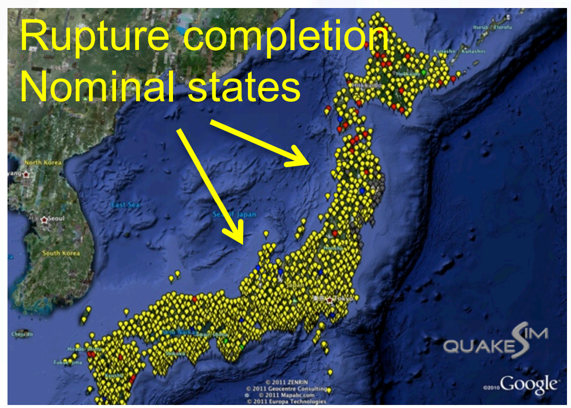
March 11, 2011 0600 UTC



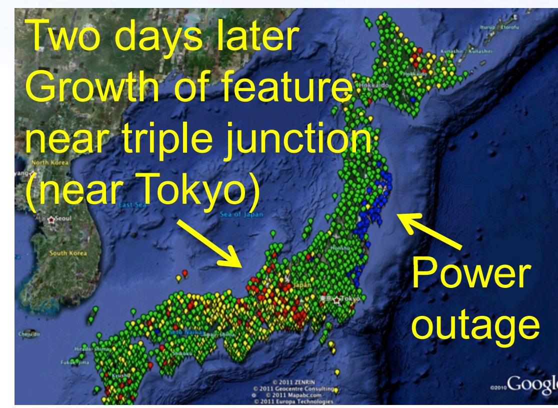
March 11, 2011 0630 UTC



March 11, 2011 0700 UTC



March 13, 2011 1300 UTC



Green – no state change
Red – state changes in last hour
Yellow– state changes in last day
Blue – no data

Automated pattern analysis focuses attention on interesting geophysics

Eyjafjallajökull Volcano Eruption

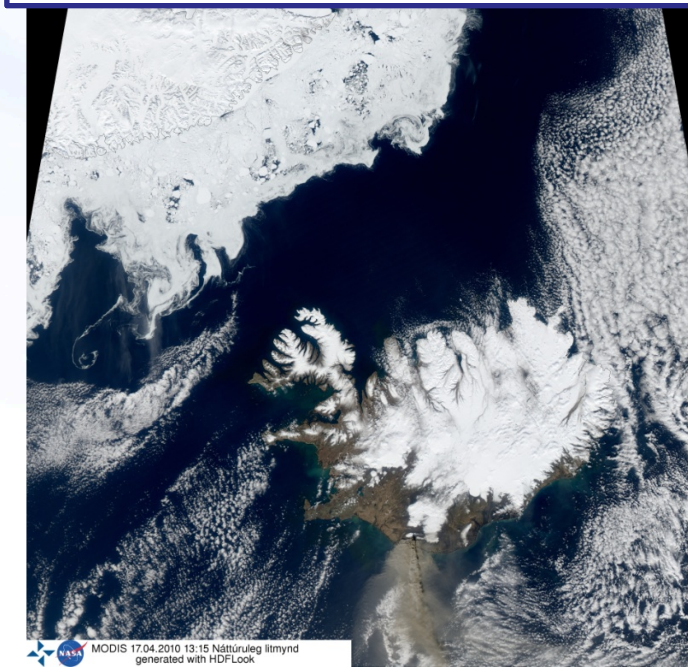
Ash Plume

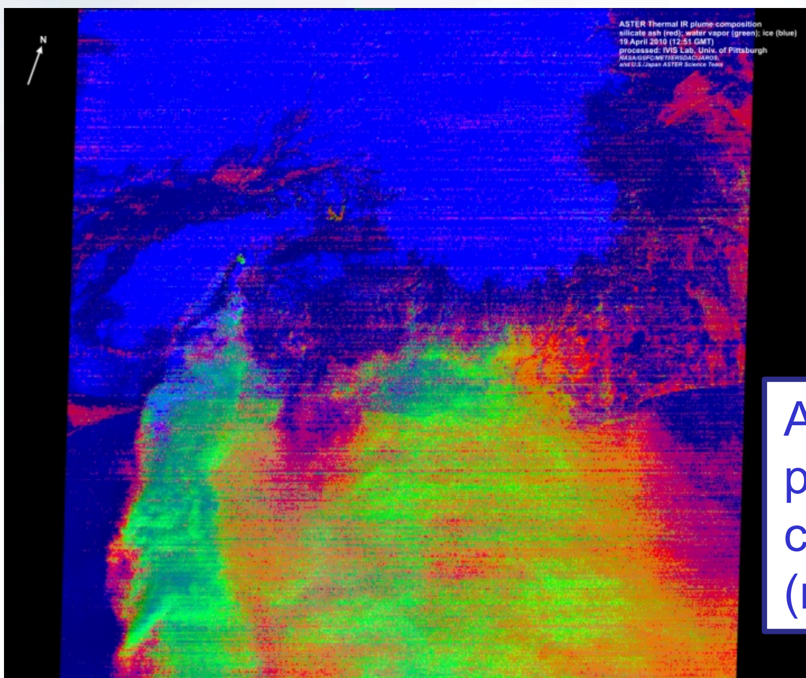
Iceland's Eyjafjallajökull Volcano burst into life on March 20, 2010

In mid-April, a huge plume of ash erupted and spread across the North Atlantic, shutting down air traffic in Europe

By April 21st, the eruption had quieted, but some ash emissions continued

MODIS (Terra) visible imagery of the plume monitoring posted on the Iceland Met Office April 17, 2010

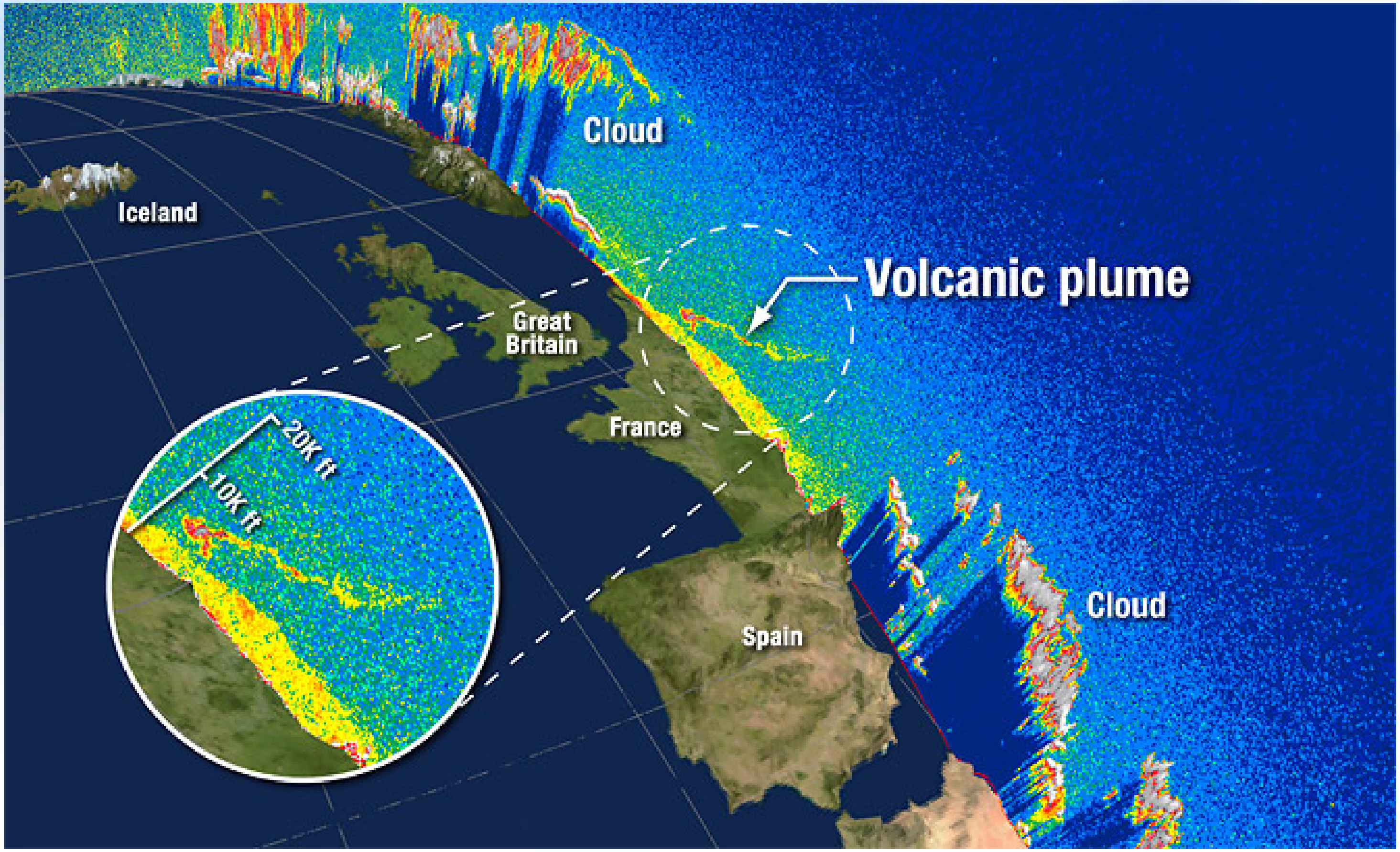




ASTER (Terra) data were used in this processed image showing the composition of the plume – silicate ash (red), water vapor (green) and Ice (blue)

Eyjafjallajökull Volcano Eruption

Tracking of the Ash Plume

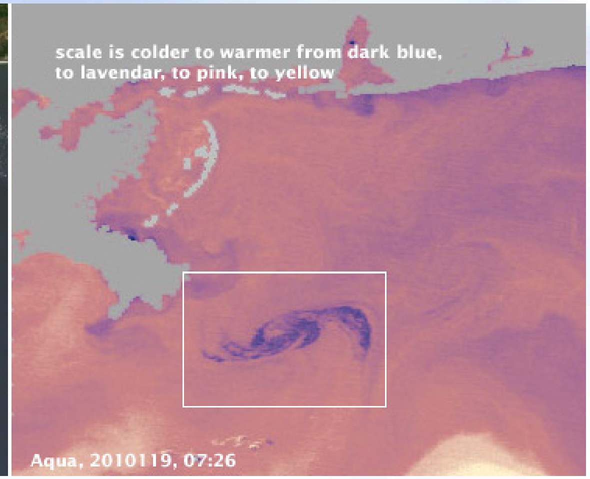


- CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations) satellite provided a bird's-eye view of the ash cloud's horizontal spread
- Ash cloud is seen as a thin, wispy layer of particles ranging in altitude from about 5,000 to 22,000 feet

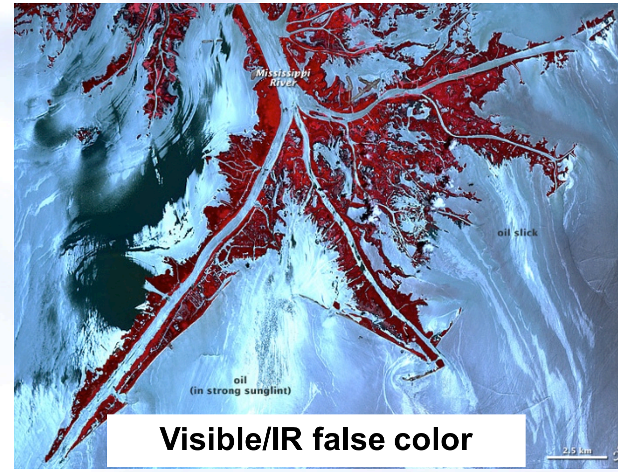
NASA Response to Gulf of Mexico Oil Spill

MODIS Visible 29 April 2010

MODIS Infrared 29 April 2010



ASTER 24 May 2010



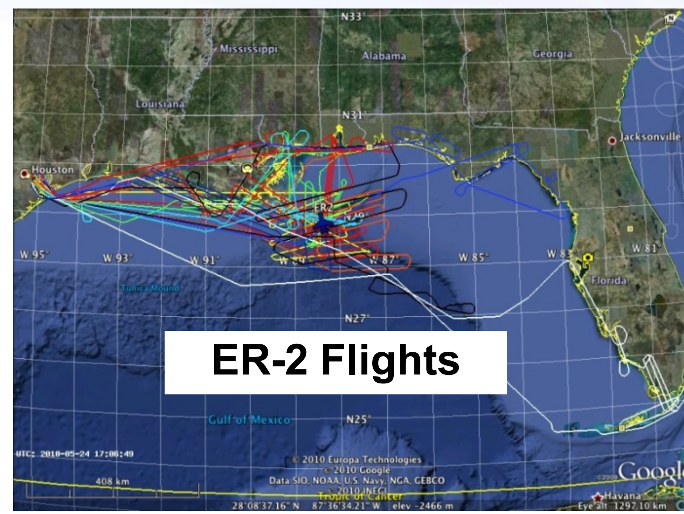
Satellites: Continually monitored the "extent" of the spill

- Terra & Aqua / MODIS – visible and infrared daily synoptic
- Terra / ASTER – visible, near IR and thermal IR high res
- EO-1 / Advanced Land Imager and Hyperion – highest res
- Terra / MISR •CALIPSO / CALIOP

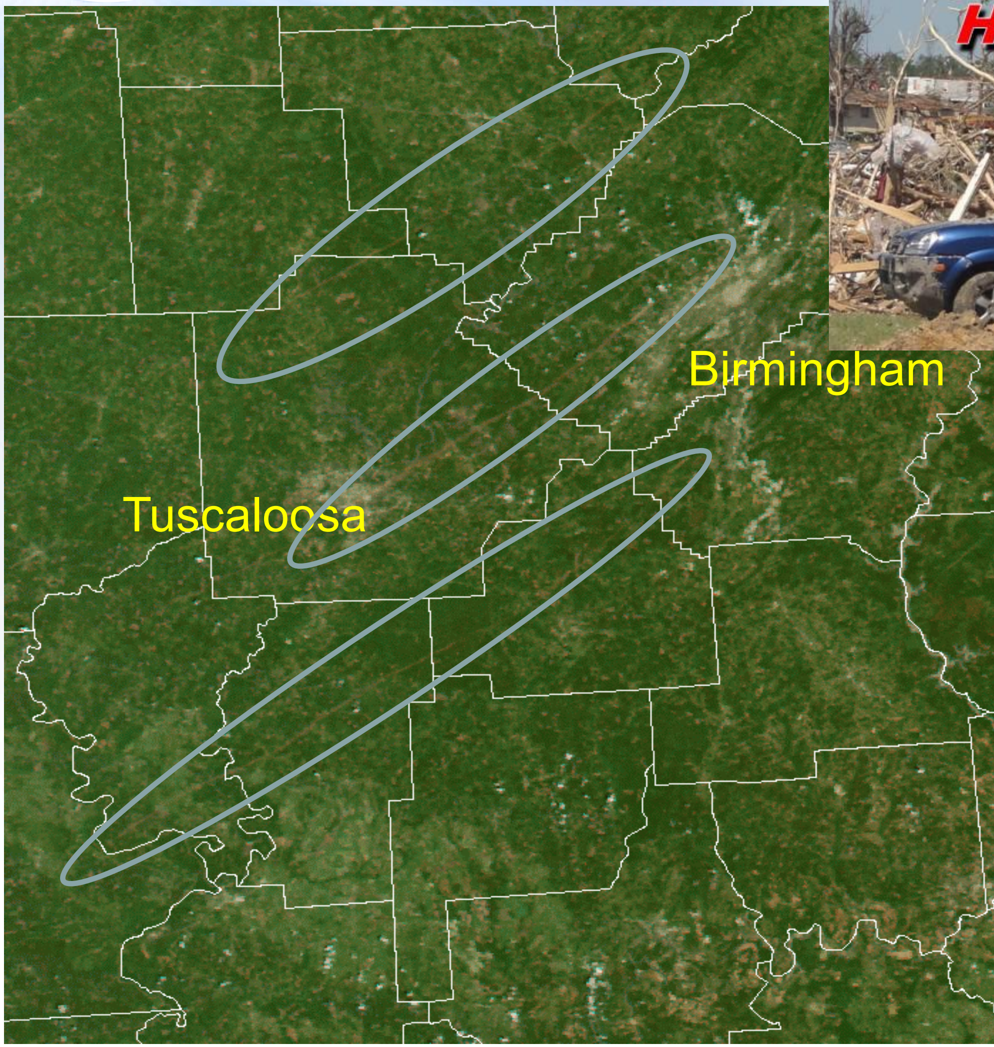
Airborne sensors: Measured spill extent and oil volume

- ER2 / AVIRIS and DCS: **18 sorties, >120 flight hours**
- Twin Otter / AVIRIS: **32 sorties, 107 flight hours**
- B200 / HSRL: **5 sorties, 16 flight hours**
- UAVSAR: 22-24 June, **4 sorties, 21 flight hours**

Data provided for use by first responders;
NOAA used radiances to initialize trajectory model;
USGS used data to detect oil concentrations



MODIS: Tuscaloosa – Birmingham
Tornadoes 5 May 2011



One of the most notable tornado outbreaks in history

Based on techniques of Jedlovec et al. (2006), NWS forecasters use MODIS color composites to evaluate tornado damage tracks

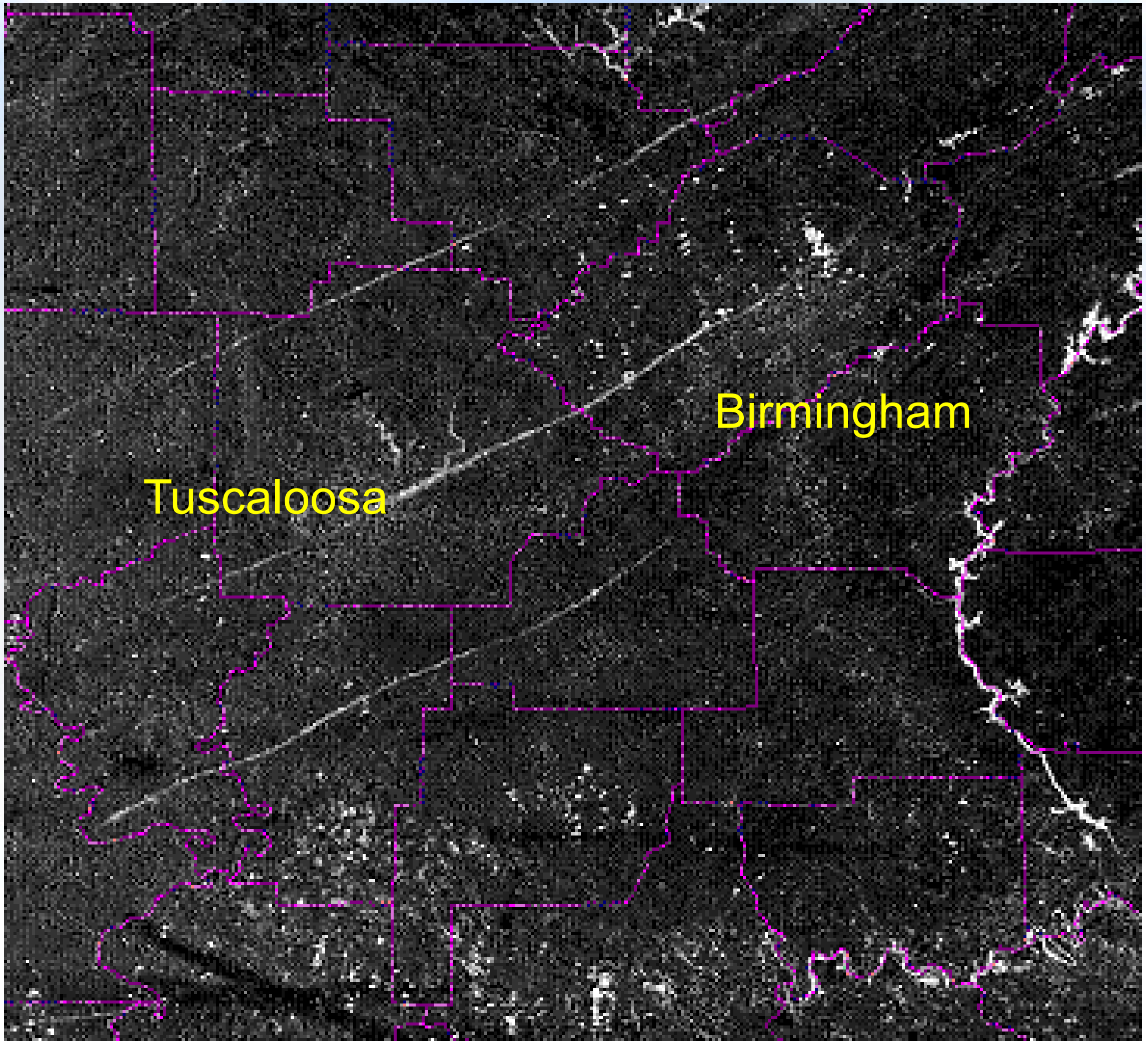
- Guide NWS forecasters to remote locations to conduct post-tornado surveys and analysis
- Correlate damage locations with Doppler radar rotational signatures

Used with high resolution 15m ASTER data for better assessment

Jedlovec, Gary J., Udaysankar Nair, Stephanie L. Haines, 2006: Detection of Storm Damage Tracks with EOS Data. *Wea. Forecasting*, **21**, 249–267. doi: 10.1175/WAF923.1

MODIS Difference: Tornado Tracks

17 April - 4 May 2011



All damage tracks from EF3 and stronger tornados for the southeastern US outbreak are identifiable in the MODIS difference images.

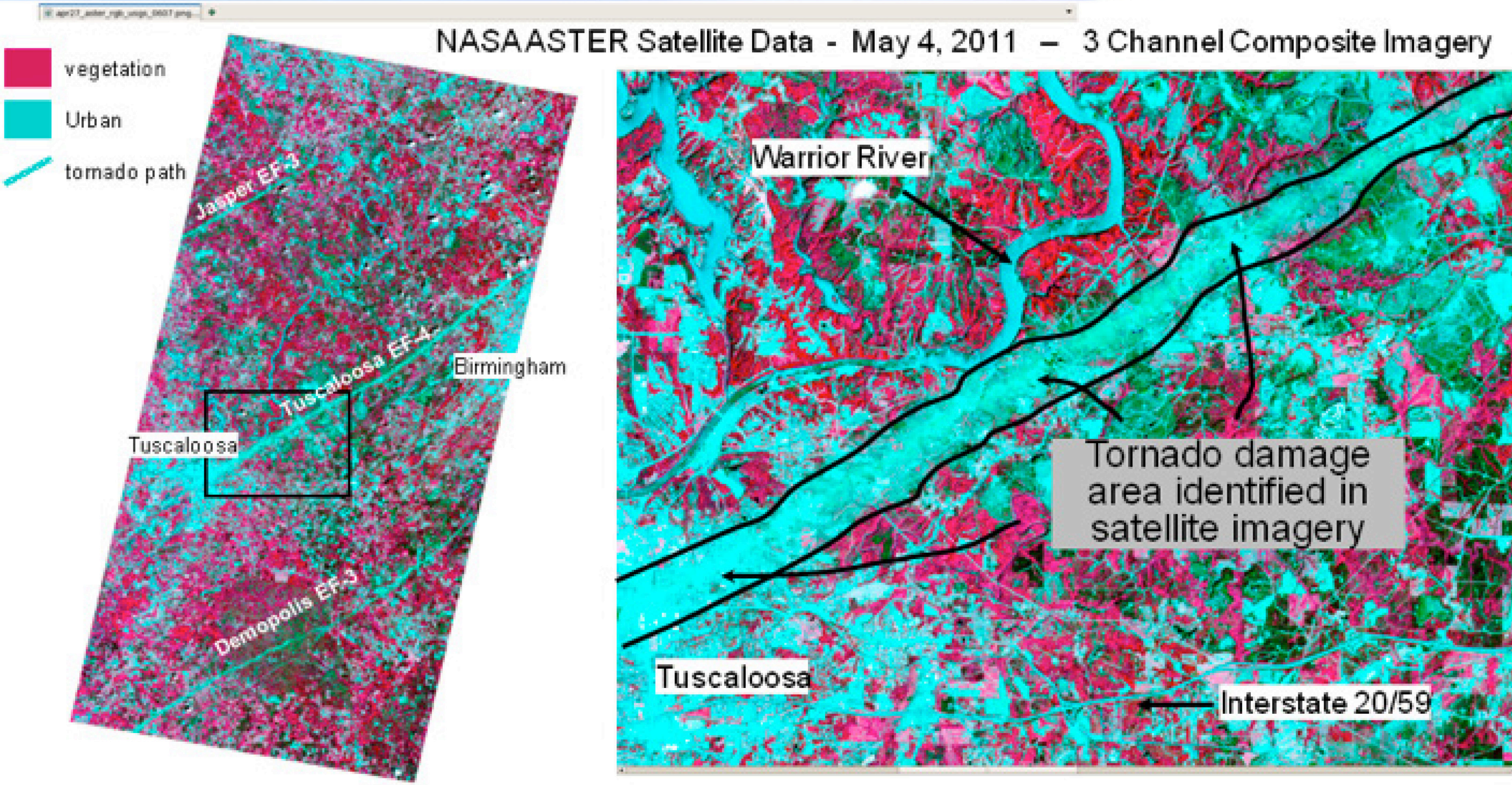
The MSFC SPoRT project applied advanced processing techniques to “before” and “after” images to enhance visibility of tornado damage tracks.

250m visible channel data from MODIS passes on April 17 (Aqua) and May 4 (Terra) were differenced and processed to produce image on left (corresponding to coverage of RGB image in previous slide).

This imagery is currently being used by the NWS in Google Earth to assist in in damage assessment.

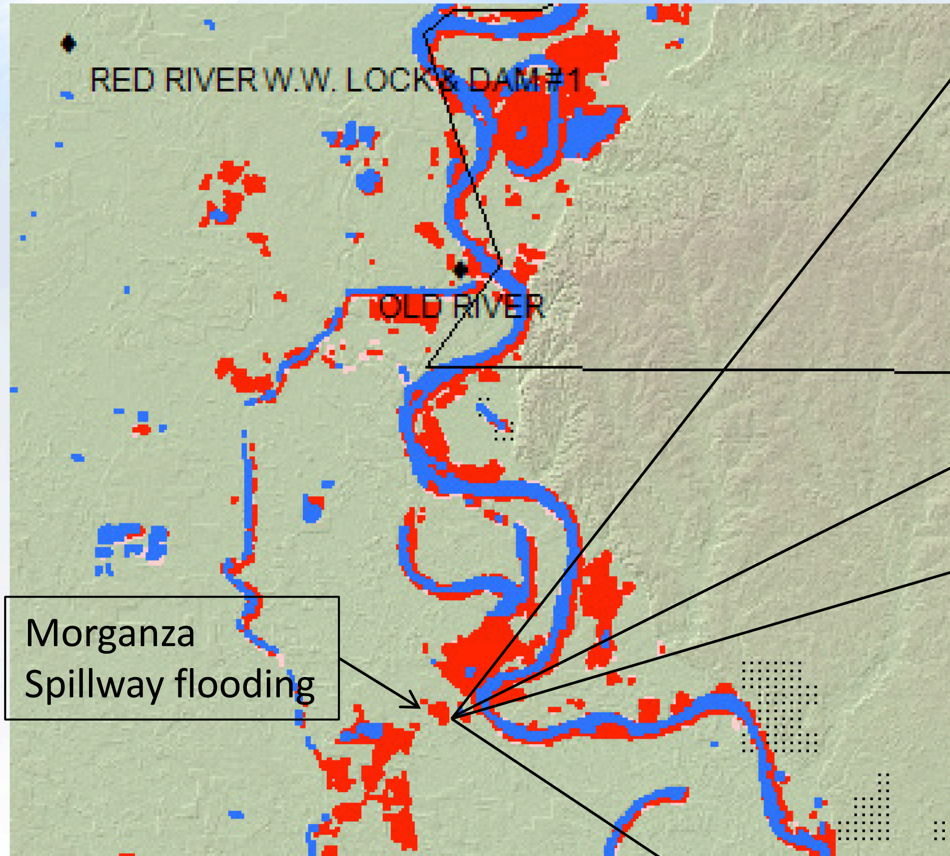
ASTER: Tuscaloosa AL Tornado

4 May 2011



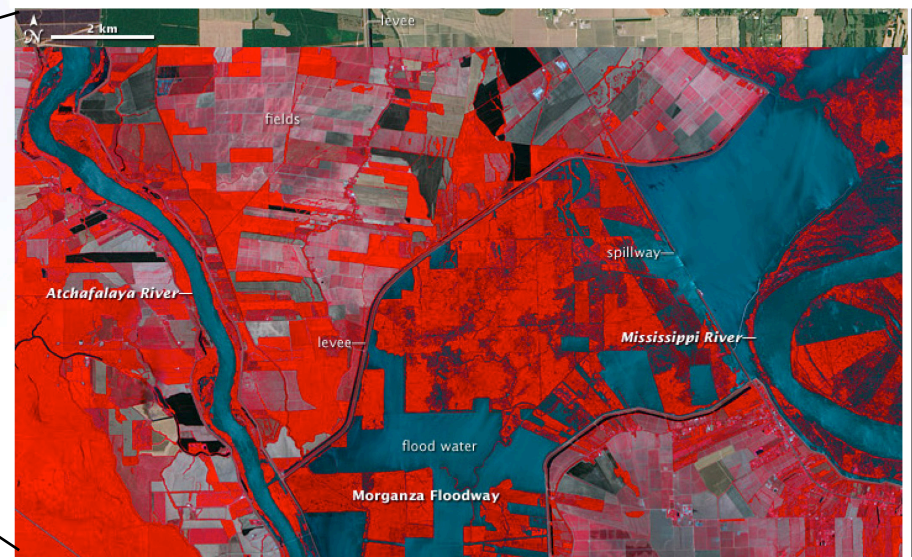
Imagery created by MSFC Short-term Prediction Research and Transition (SPoRT), using data courtesy of NASA GSFC /METI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team.

Mississippi River Flooding at Morganza LA



The red shading above shows the extent of flooding as imaged on May 13-17, 2011 by the two MODIS sensors. Dark blue illustrates "normal" surface water as imaged by MODIS prior to the flooding. The MODIS flooding analysis used by FEMA and state EMA (e.g., AR, MS, LA) for response planning. Image analysis created by the Dartmouth Flood Observatory at the Univ. of Colorado (Brakenridge & Policelli)

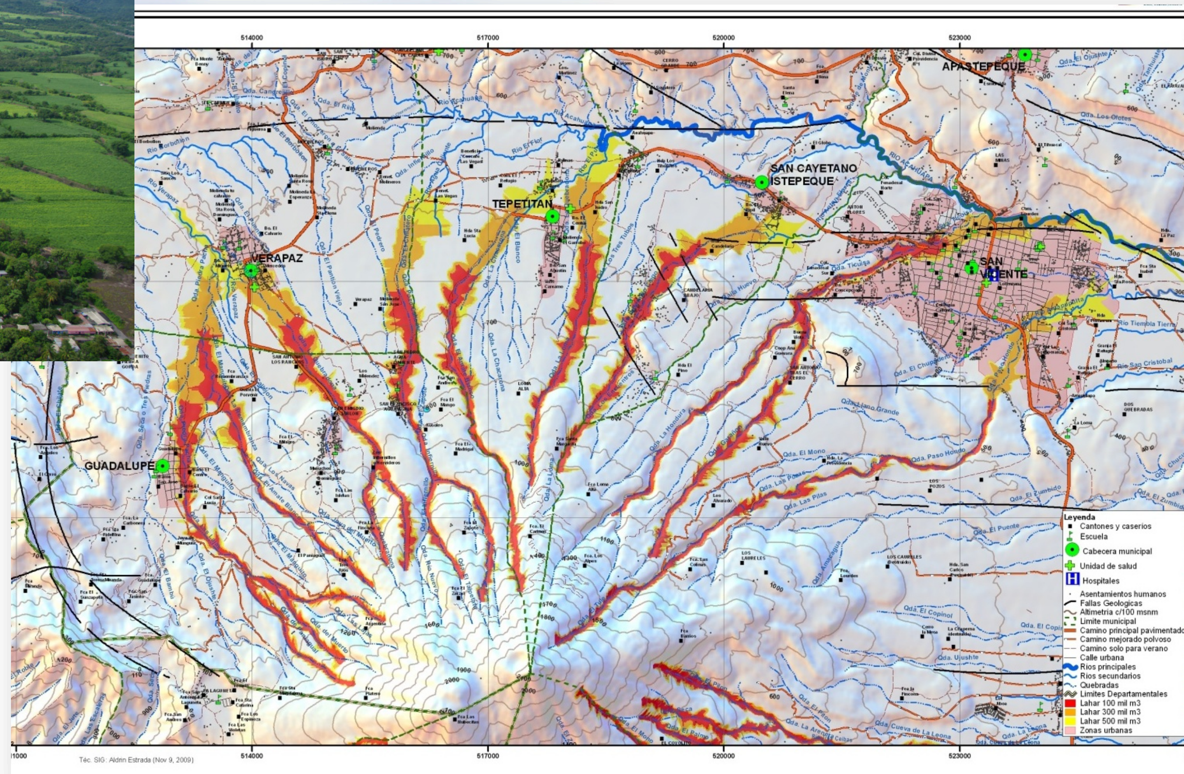
EO-1 ALI image 1day after USACE opened the Morganza spillway – water begins to fill Morganza flood plain



ASTER image 5 days after USACE opened the Morganza spillway – water spread 15–20 miles southward.

El Salvador Flooding and Debris Flow

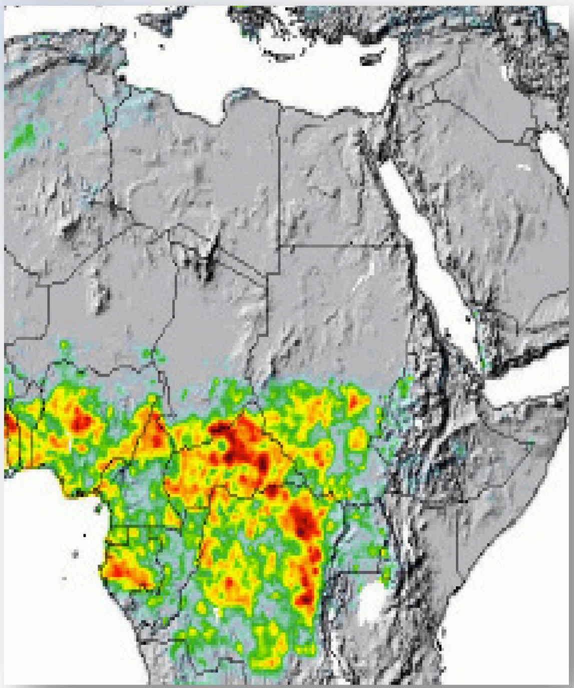
November 2009



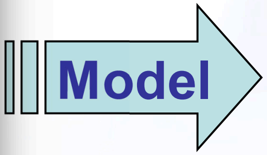
FORMOSAT
E0-1
ASTER
IKONOS

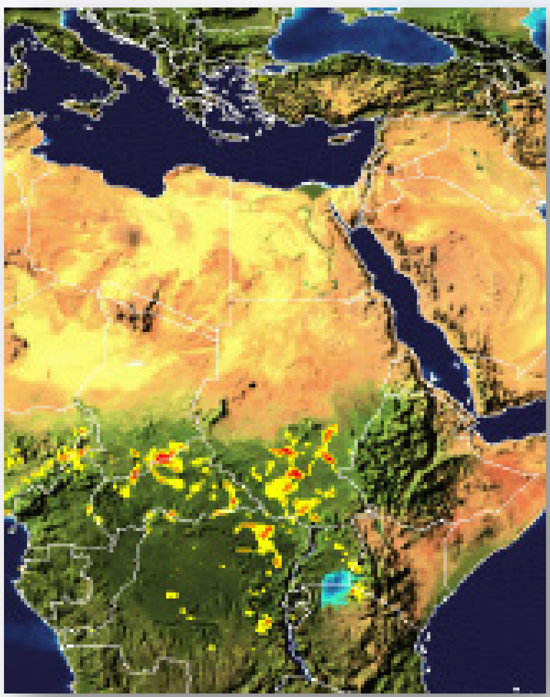
Mapping Flood Potential in Africa

- Using a regional version of the hydrologic model with near-real time precipitation from the 3B42 TRMM rainfall to derive flood potential over a much larger area
- Provides an estimate of expected depth of flood inundation at a 0.25 degree resolution
- Precipitation forecast data can be used with the model to provide longer lead time forecasts



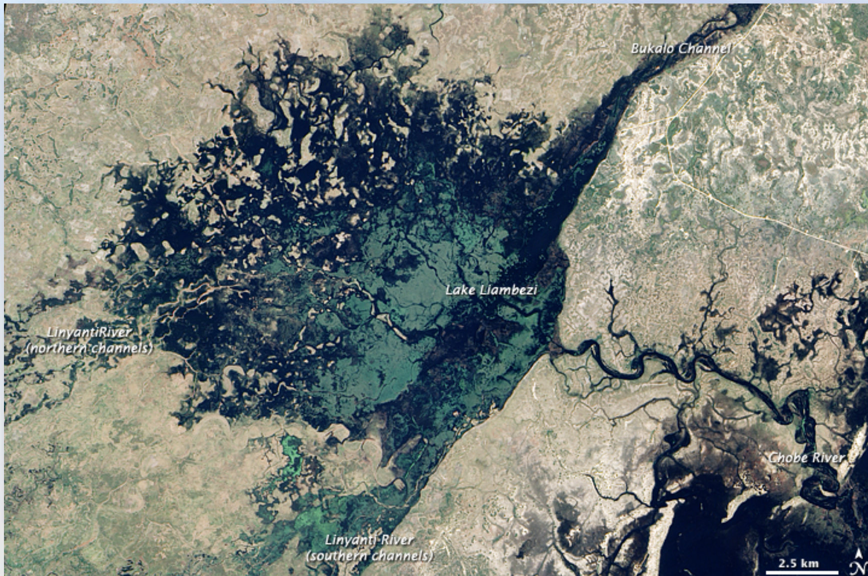
TRMM 3B42 Precipitation

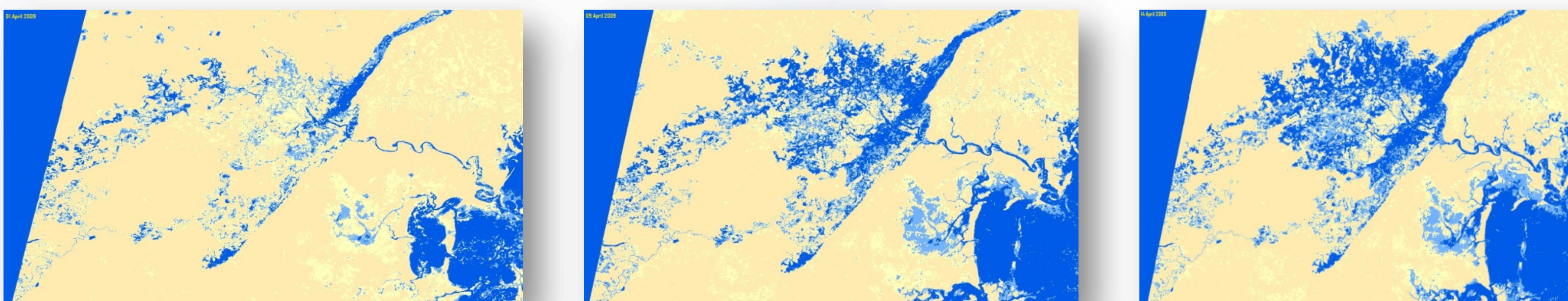




Flood Potential

Mapping Floods in Africa
Lake Liambezi Area

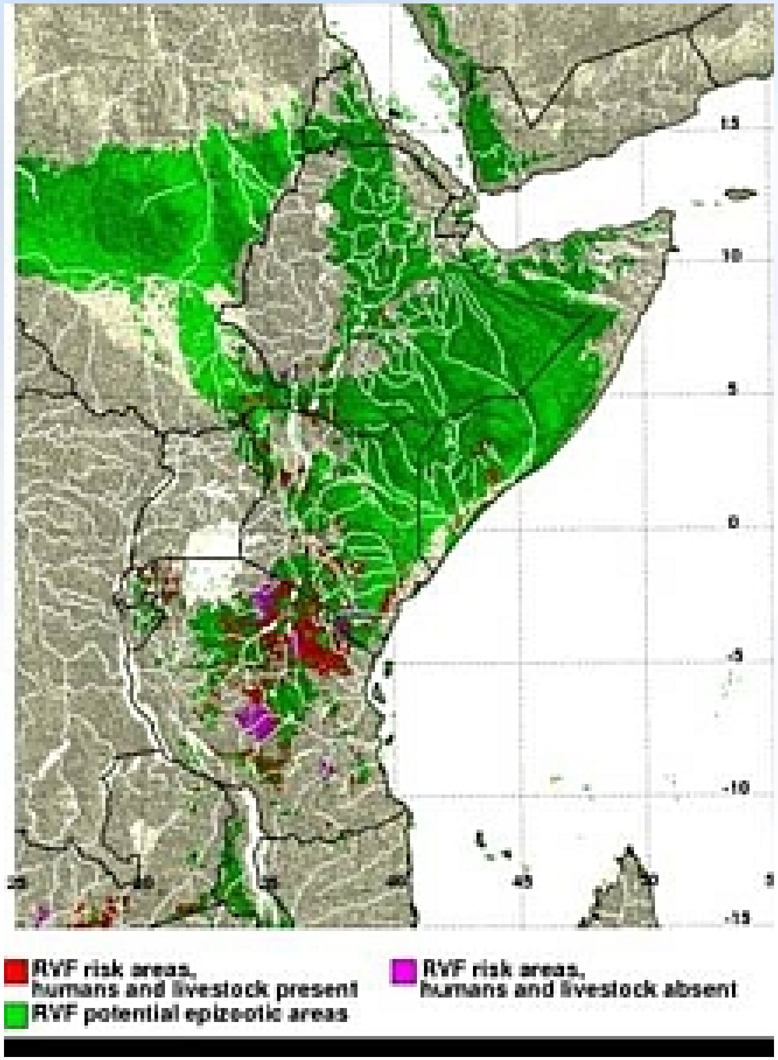




LAKE LIAMBEZI AREA – NASA EO1 BAND 6 SCENES FOR 01, 09 and 14 APRIL 2009

(false colours based on preliminary classification without ground verification)

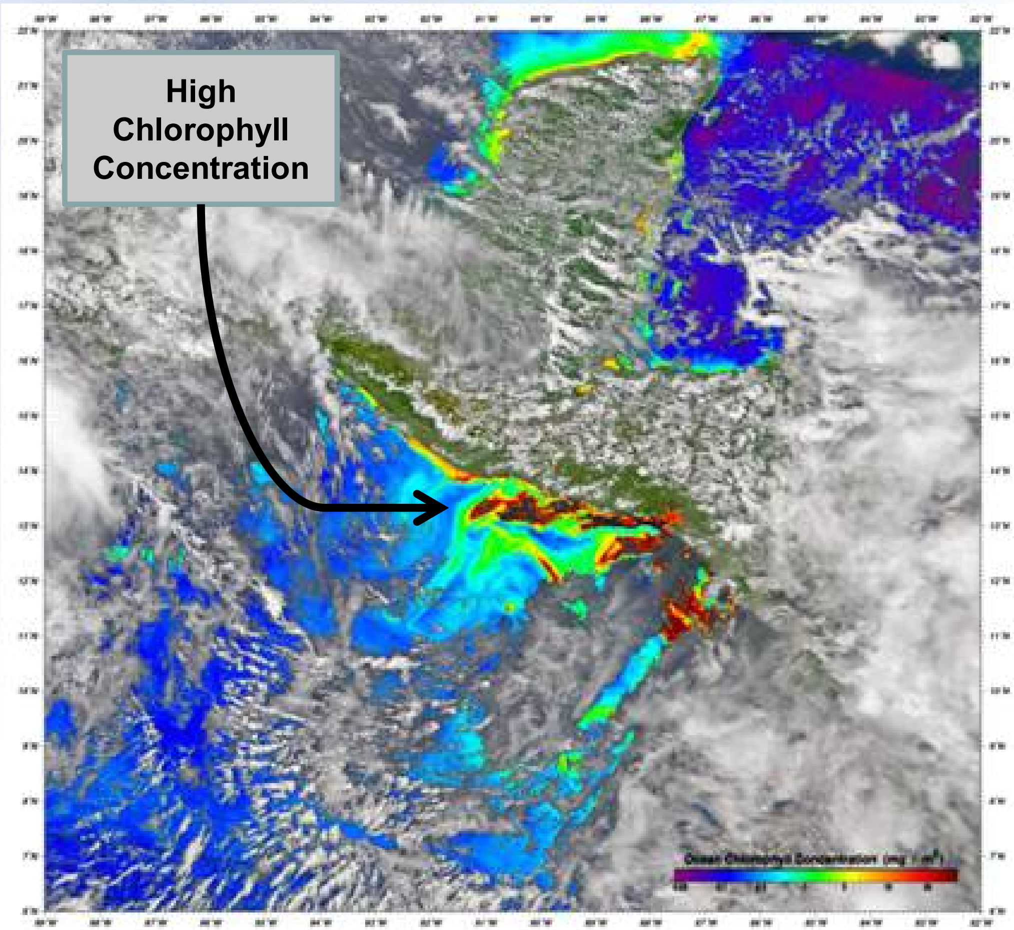
Rift Valley Fever in Africa



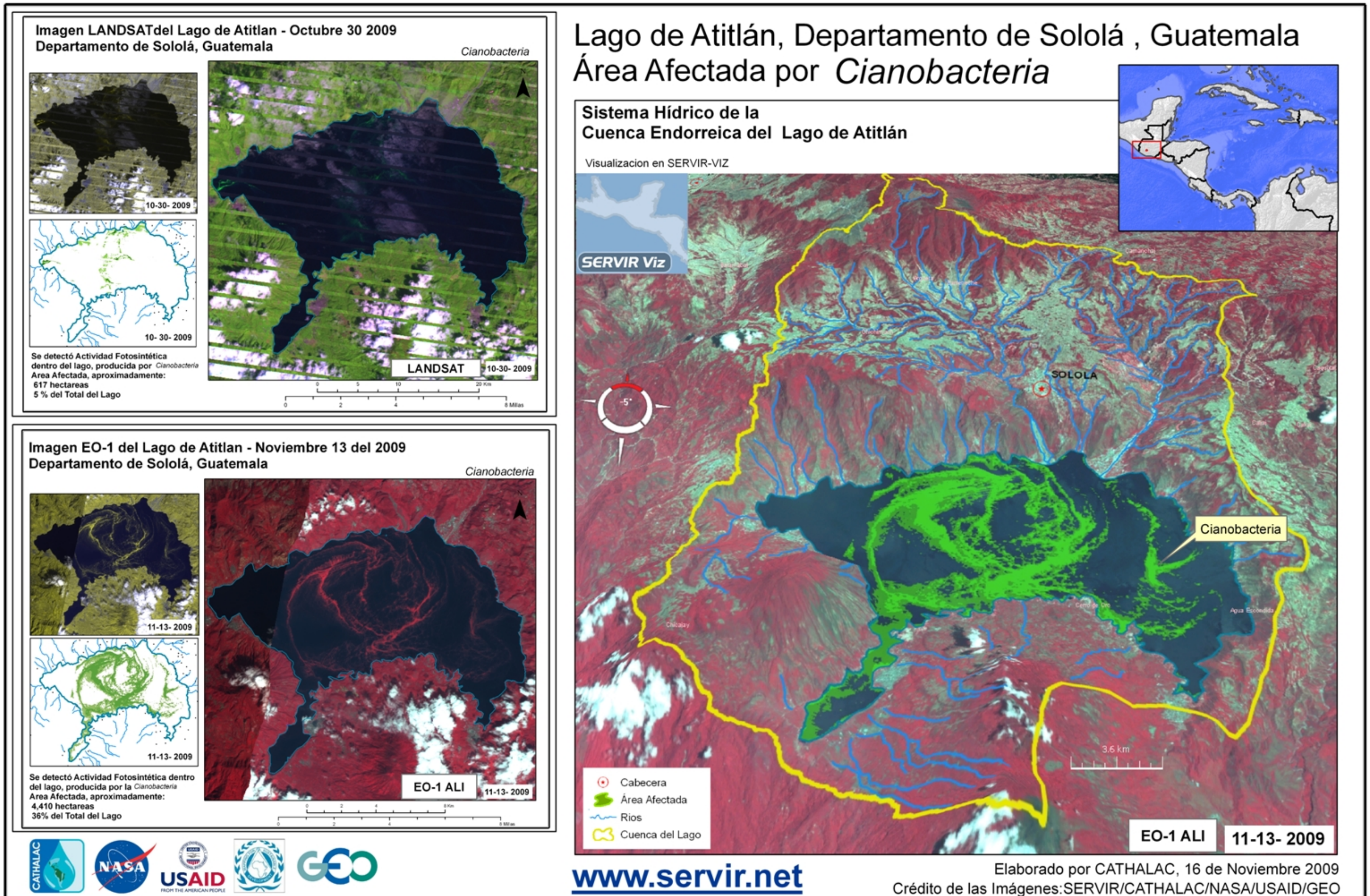
Rift Valley Fever Risk Mapping using AVHRR data and flooding potential maps

Harmful Algal Blooms

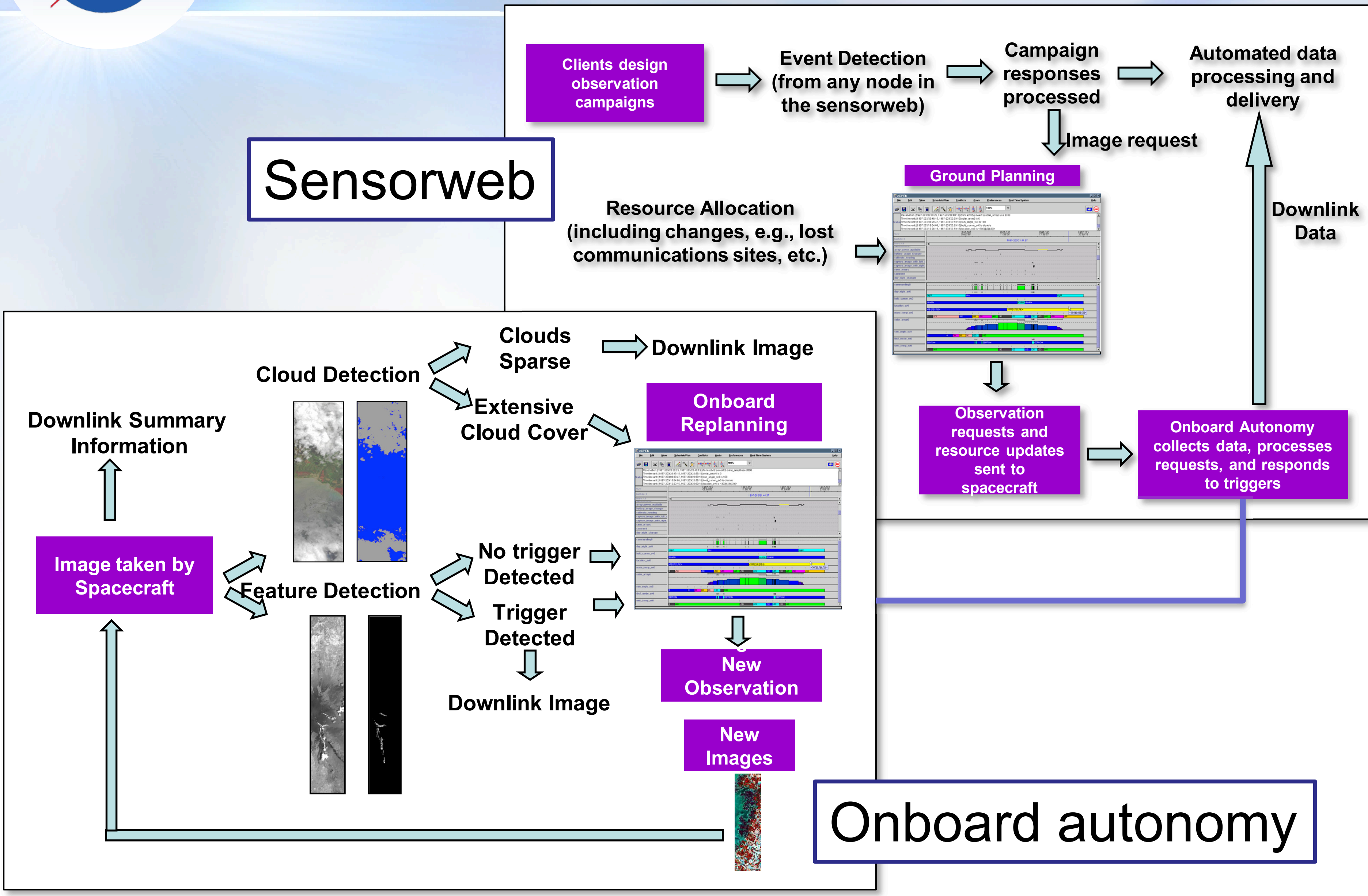
Real time monitoring of Harmful Algal Blooms (HAB) using remotely sensed data products



Lake Water Quality
Cyanobacteria Growth

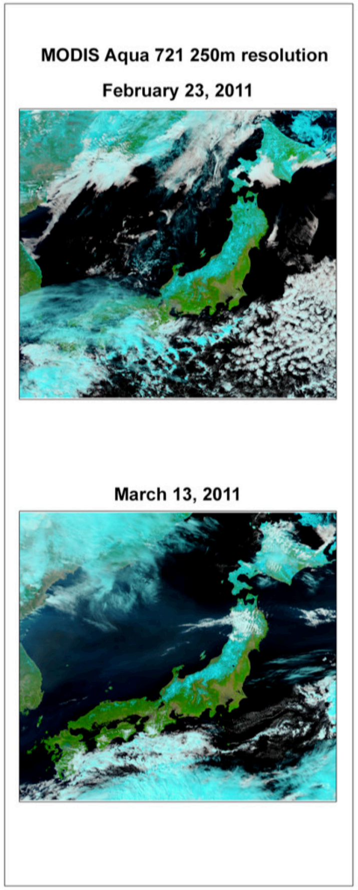


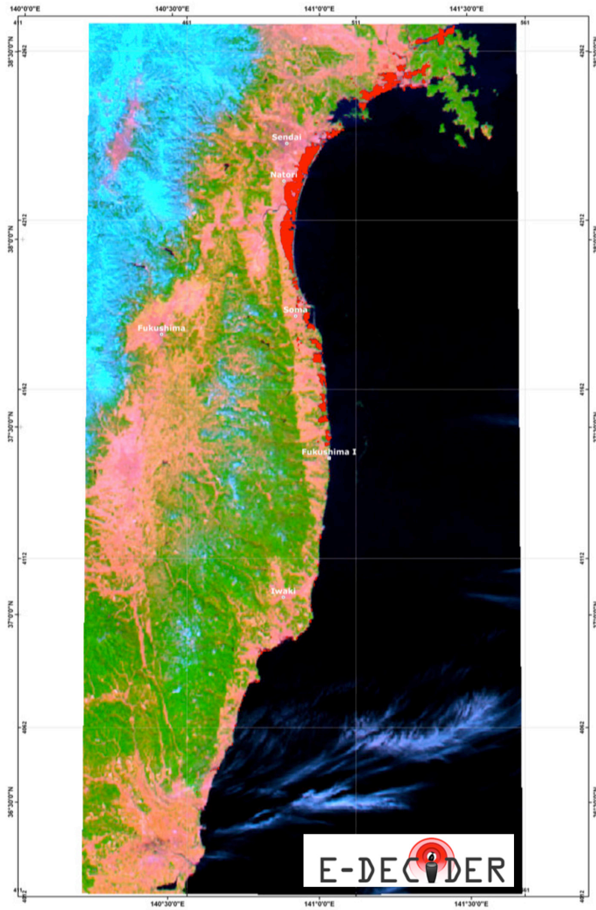
Concept of Operations



Managing the Data Deluge

- Rapidly increasing data sizes
- Data storage
  - PB/year for InSAR
  - TB-PB/year for model runs
  - 1000s of solutions for 1000s of stations
- Focus on geospatial, environmental data sets
  - Data from computation and observation
- Data, data processing, and modeling pipelines are inseparable





Key Recommendations

1. **Strategic**
   a) Accelerate use of NASA data for applications and societal benefit
   b) Develop and maximize government, private, and academic partnerships
   c) Organize around grand challenges in areas to be determined
   d) Leverage Existing activities
2. **Organizational**
   a) Integrate applications users into mission teams as early as possible
   b) Conduct periodic user meetings and encourage more frequent interactions of subgroups and agency partners
   c) Train the next generation

3. **Data**
   a) Ensure data continuity
   b) Improve infrastructure to provide access to high level data products
   c) Improve infrastructure to provide rapid access to data