Remote Sensing Technologies
for Disaster Mitigation and Response

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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

Applied Sciences Disasters Program

Other Agencies
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
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 Himalayans.

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

Strengthen capacity of governments and other key stakeholders to integrate earth observation information and geospatial technologies into development decision-making.
Mapping Fires in Guatemala Mexico

Flood Forecasting in Africa

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

Critical infrastructure exposure
Total loss estimation Hazus output

Red: exposed
Green: low risk

UAVSAR aids mapping faults
The movement dislodged 30 million tons of ice from the Tasman Glacier on the opposite side of the South Island of New Zealand.

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

Pre-Earthquake, 2009
February 17, 2009 22:38 UTC
Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) simulated natural color views using visible and near-infrared (VNIR) wavelengths at 15m ground resolution

Post-Earthquake, 2011
March 2, 2011 22:43 UTC

Ken Duda / NASA EOS Sr. Scientist / USGS
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

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

Before the rupture: Nominal states

Rupture Initiation

Propagation

Propagation of state changes

Rupture completion: Nominal states

~1.5 hour timescale

Two days later:
Growth of feature near triple junction (near Tokyo)

Power outage

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
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).
• 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.
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
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

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 damage assessment.

All damage tracks from EF3 and stronger tornados for the southeastern US outbreak are identifiable in the MODIS difference images.
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.
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 1 day 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.
• 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
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 Risk Mapping using AVHRR data and flooding potential maps
Real time monitoring of Harmful Algal Blooms (HAB) using remotely sensed data products.
Lago de Atitlán, Departamento de Sololá, Guatemala
Área Afectada por Cyanobacteria

Imágenes LANDSAT del Lago de Atitlán - Octubre 30 de 2009
Departamento de Sololá, Guatemala

Imágenes EO-1 del Lago de Atitlán - Noviembre 13 de 2009
Departamento de Sololá, Guatemala

Sistema Hídrico de la Cuenca Endorreica del Lago de Atitlán
Visualización en SERVIR-VIZ

www.servir.net
Elaborado por CATHALAC, 16 de Noviembre 2009
Crédito de las imágenes: SERVIR/CATHALAC/NASA/USAID/GEO
Concept of Operations

Sensorweb

Clients design observation campaigns

Event Detection (from any node in the sensorweb)

Resource Allocation (including changes, e.g., lost communications sites, etc.)

Campaign responses processed

Image request

Automated data processing and delivery

Ground Planning

Downlink Data

Onboard Autonomy collects data, processes requests, and responds to triggers

Image request

Onboard Replanning

Observation requests and resource updates sent to spacecraft

Cloud Detection

Extensive Cloud Cover

No trigger detected

Trigger detected

New Observation

Downlink Image

New Images

Clouds

Sparse

Downlink Summary Information

Image taken by Spacecraft

Feature Detection

Downlink Image

Onboard autonomy
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
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