SensorWeb as an Enabling Step for Holistic Remote Sensing

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Steve Ungar

IS&T Colloquium
May 22, 2013
“Integrating Sensors to Manage Earth Resources”
Remote Sensing Has Consequences

• Gallileo Galilei used the telescope to discover the four Jovian moons and the phases of Venus.
• Championed heliocentric view of solar system
• In 1615 put under permanent house arrest for his views
Early remote sensing

Published in *Le Boulevard*, 25 May 1862.

Gaspard-Félix Tournachon (6 April 1820 – 23 March 1910) known as Nadar, became the first person to take aerial photographs in 1858 at 1200 feet in a balloon over Paris.
Cameras were set to take pictures every 30 seconds while pigeons flew.
Why Are SensorWebs Important?

• Provides flexibility to user to customize data products rapidly

• Automatically cross triggers sensors using predictive models or automatically detected events

• Provides societal benefits for disaster management via early warning, rapid situational awareness and post disaster assessment

• Provides world wide access to sensor data, data visualization and data manipulation over the Internet

• Dramatically lowers cost for data access via the use of open standards

• Can be used to build lower cost remote sensing missions of the future missions
Definition

A **SensorWeb** is a distributed system of sensing nodes (space, air or ground) that are interconnected by a communications fabric and functions as a single, highly coordinated, virtual instrument. It detects and dynamically reacts to events autonomously or semi-autonomously for scientific investigation, disaster management, resource management and environmental intelligence.
Difference From Constellations

• SensorWebs differ from terminology such as formation flying, virtual missions, ad-hoc constellations etc. in that the focus is primarily on the organization and flow of data via information technology for acquisition of sensor data; the processing of the data into data products and the distribution of the data products.

• SensorWebs can live on top of constellations or across a heterogeneous set of sensors from different constellations to create an ad hoc SensorWeb relationship.
Holistic Sensing (Dan’s view from SensorWeb Perspective)

- Holistic ---need to consider observer and observation as a whole to optimize system
- Need to consider the breadth of factors affecting data acquisition and data product production
  - Access/control (open versus closed) and ease of access to sensors
  - Rapid customization
  - Do-it-yourself data product production and data fusion
  - Discovery
  - Complexity and managing complexity
  - Speed (e.g. turn around time)
  - Data volume – handling “Big Data” and data navigation and rapid product production (onboard multicore processors and cloud computing)
  - Composability (abstraction) – Levels of Interoperability
  - Learning and evolving SensorWebs (Model driven SensorWebs)

(Note: for this presentation, will go over selected examples in above list)
10 Years of NASA SensorWeb Experiments (as of Aug 2013)

- Radarsat 2
- Terra and Aqua
- Alaska Ground Station
- Berkeley Ground Station
- Cosmic Hot Interstellar Plasma Spectrometer (CHIPS)
- Elastic Compute Cloud (Matsu)
- Dryden igloo
- Naval Academy Ground Station
- NASA/AMES Predator Ikhana
- Midshipman Space Technology Application Research (MidSTAR)
- WCPS
- IPM/cFE
- SCL/A
- Earth Observing 1 (EO-1)
- HyspIRI (testbed)
- cFE/SWA
- M
- Midshipman Space Technology Application Research (MidSTAR)
- GMSEC
- ST-5 FlatSat
- Users
- I N T E R N E T
MidSTAR-1 Satellite

- Midshipman Space Technology Applications Research
  - US Naval Academy Small Satellite Program effort launched in March 2007
  - General-purpose satellite bus with Linux operating system
  - IP-in-space communication system
  - Operators (Keith Hogie (CSC) and Ed Criscuolo(CSC)) maintain satellite from Goddard Space Flight Center
  - Low-cost program launched through the DoD Space Test Program – Zero budget at this point (running as a ‘pet project’ by Keith and Ed)
  - MidSTAR is a single spacecraft under the command and control of a single satellite ground station at the US Naval Academy
  - US Naval Academy retains responsibility for S/C
SWAMO is a Sensor Web enabling technology. It provides an intelligent infrastructure to support the dynamic planning for utilization of nodes within a Sensor Web.

Intelligent agents within the system encapsulate the models and interact with the planning system. Agents predict the effect of changes to the plan, and provide confidence as to feasibility and impact.
A Goal is presented to a Sensor Web system. The system breaks the Goal down, as necessary, into more atomic, discrete sub-goals that are achievable by sub-systems known to the system. This break-down happens according to predefined, and well known rules, so that the inputs to the subsystems are appropriately provided.

This process happens recursively within subsystems and sub-subsystems, until the atomic sub-goal is directly resolvable.

Sub-Goal Solutions are then repeatedly combined until the original Goal has a Solution.

Key factors are: *Autonomic planning, defined and discoverable interfaces*, and *Web Services*.
Delay Tolerant Network/SWAMO/MidSTAR-1

The goal of this Use Case from the SWAMO point of view is to demonstrate the SWAMO capability to dynamically load an agents on-board a flight asset via a request from a SWAMO agent on the ground. Even though not demonstrated on a science platform, it is a valuable function for science data processing (dynamically configure classifier models in real-time).
SensorWeb Images

Worldwide coverage with many science disciplines
flooding, oceanography, volcanology, forestry,…
Nearly 10,000 SensorWeb Images as of 5/20/11
## Multiple Software Technologies for SensorWebs Documented in NASA Technology Reports

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SensorWeb Reference Architecture GSC-5025286

*Total of seventeen (17) NTRs recorded for SensorWeb technologies*
SensorWeb for Health Related Issues
Cyanobacteria Outbreak on Lake Atitlan

“The EO-1 data provided through SensorWeb for a cyanobacteria outbreak affecting Lake Atitlan even made it to the front page of Guatemala’s widely read Prensa Libre newspaper in November 2009. The data provided was and is still being used to advise the Guatemalan Ministry of Environment on actions that should be taken with regards to the Lake’s contamination, as approximately two hundred thousand Guatemalans use the Lake for both drinking water and recreation.”

– Emil A. Cherrington
Manager, Division of Applied Research and Development, CATHALAC

Water quality in Lake Atitlan is of such importance that the Guatemalan Government is implementing a $350M USD program to mitigate the problem. (Time Magazine 11/29/2009)

“The spatial analysis and studies through the satellite imagery (ASTER, EO-1 and Landsat) provided by CATHALAC through SERVIR have been led by MARN to address these types of alerts and extreme events.

– Luis Armando Zurita Tablada
Vice Minister of the Environment, Guatemala
From 2003 to 2009, SensorWeb team conducted a variety of experiments to identify how best to inject SensorWeb technology into assisting Forest Service to manage large wildfires and assist decision makers. This involved interoperating satellite sensors and an Unmanned Aerial System sensors to produce useful data products to assist U.S Forest Service emergency managers.

**Detect:** National Fire Interagency Center (NIFC) large fire map and MODIS daily hot pixel maps acted as triggers

**Respond:** Trigger EO-1 and Unmanned Aerial System (UAS) images automatically to take a detailed look

**Product Generation:** Active fire maps, burn scar maps

**Delivery:** Experimented with various web based delivery such as mash up displays and RSS feeds

“An exciting aspect of the SensorWeb capability is the ability to automatically image, process and deliver higher resolution satellite imagery products online with little effort.”

-Everett Hinkley, Forest Service Remote Sensing Program Manager
Namibia Flood Early Warning SensorWeb

In 2009, 2010 and 2011, record floods hit Namibia with as much as ¼ of the population of 2 million affected by the floods, along with hundreds of deaths and millions in property damage. SensorWeb technology is being integrated to help Department of Hydrology implement a Flood Early Warning system to save lives and property.

**Detect:** TRMM rainfall estimate monitored upstream, AMSR-E based
Riverwatch used to monitor river widths, daily MODIS flood extent maps

**Respond:** Trigger EO-1 and Radarsat imagery based on detection of triggers

**Product Generation:** MODIS daily flood extent overlays, EO-1 flood extent overlays, river gauge plots

**Delivery:** Aggregated data layers on Flood Dashboard

“This is to reiterate and stress support and enthusiasm for ongoing efforts during the past two years to integrate SensorWeb components for use by us and other flood disaster response workers and institutions.”

— Guido Van Langenhove, Head of Namibia Department of Hydrology
Caribbean Satellite Disaster Pilot

The 2010 hurricane season in the Caribbean was an active year and had more than 20 named storms. High resolution observations from NASA and CSA satellites were triggered to provide images for near real time assessment to regional centers. This provided national authorities with situational awareness. SensorWeb technology is becoming an integral part of disaster and emergency management and is being evaluated for incorporation into regional protocols for response and recovery.

**Detect:** Hurricane landfall and precipitation predictions from the Caribbean Institute of Meteorology and Hydrology, Flood model 1 day forecast using TRMM, AMSR-E, and other satellite inputs, daily MODIS flood detection maps, web inputs from national partners

**Respond:** Trigger EO-1 and Radarsat imagery and generate flood maps for local and regional collaborators

**Product Generation:** Daily flood extent overlays from MODIS, EO-1, and Radarsat that cover 3 hurricanes (Earl, Nicole, Tomas) for Haiti, Jamaica, St Lucia, and Virgin Islands

**Delivery:** Aggregated and custom processed data layers on open cloud platform accessible on the internet

“I applaud the SensorWeb Toolbox development team because they have created a real-world capability that has connected satellite earth observation data to the local users …which leads to saving lives and property in the developing world.”

– Daniel E. Irwin, Director of NASA’s SERVIR Program
EO-1 Hyperion SWIR image of destructive lava flows at Nyamuragira, DR Congo, 4 Dec 2006.

This vital data acquisition allowed pinpointing of the vent and enabled accurate modeling of likely lava flow direction.

"This was a stunning demonstration of the capability of an autonomous system to obtain and provide vital information during a volcanic emergency."
- Gari Mayberry, Geoscience Advisor, USAid

Alert: Uses alerts from multiple sources (in situ sensors, MODIS, AFWA, VAAC, et al.)
Response: Alerts are used in a prioritized fashion to trigger follow up targeted satellite observations.
Product Generation & Delivery: Rapid data processing, thermal maps, modeling of eruption parameters, and posting to end users.

SensorWeb now includes in-situ sensor monitoring of Icelandic volcanoes:
http://en.vedur.is/earthquakes-and-volcanism

A. G. Davies / JPL
Thailand Flood SensorWeb

- **Detect:** Pull 2x daily RAPIDFire subsetted MODIS data, support Vector Machine Learning (SVM) & band ratio methods of classifying gauging reaches against baseline dry scores
- **Respond:** Earth Observing 1 autonomously responds to acquire more detailed imagery
- **Product Generation & Delivery:** Data and flood products electronically delivered to Thailand Hydro Agro Informatics Institute ([http://www.haii.or.th](http://www.haii.or.th))

MODIS 28 Nov 2010 Imagery of Thailand Flooding (band 7-2-1)
**Est. damage over $1.67B USD [CNN], Oct–Nov 2010**

“The Thailand Flood SensorWeb provides a unique capability to detection, monitoring, response, and mitigation of flooding in Thailand”
Dr. Royol Chitadron, Director, HAll Thailand

S. Chien / JPL

**NASA • GSFC • JPL/Caltech • Ames**

A276_SensorWeb.ppt

Respond ➔ Generate ➔ Deliver
(L) MODIS imagery of Bang Pla Ma from 20 Jan 2011
(R) Classified surface water extent from MODIS image

(L) ALI imagery of Bang Pla Ma from 21 Jan 2011
(R) Classified surface water extent from ALI image
Thailand Fire Sensorweb

Detect: Uses FIRMS MODIS-based fire detection system to monitor National Heritage Areas and Wildlife Sanctuaries

Respond: Alerts are used in a prioritized fashion to trigger follow-up targeted satellite observations by EO-1.

Product Generation & Delivery: Imagery & burn severity products electronically delivered to National Park, Wildlife and Plant Conservation Department of Thailand (NPWPCD; http://www.dnp.go.th)

“We are currently using the system to monitor fire activity in six critical areas of Thailand.”

– Director General, National Park, Wildlife and Plant Conservation Department of Thailand

S. Chien / JPL
Significance to Technology/Applications

Detection, Response, Workflow automation technologies have been documented in 70 publications and presentations (including 20 peer reviewed publications)

- Detection
  - Advances the state of the art and state of the practice in automated interpretation of satellite imagery and in use for automated workflow chaining services for data processing and interpretation. See Doubleday et al. 2011 AI/Space, Chien et al. 2011 IGARSS.

- Response
  - Advances the state of the art in routine use of automated re-tasking of assets. See Chien et al. 2010 SpaceOps, i-SAIRAS.
  - Advances the state of the art and state of the practice in semi-automated and automated integrated control of space, air, marine, and fixed sensor assets. See Schofield et al. EOS 2010, Chien et al. i-SAIRAS 2008.

- Data product generation and delivery
  - Advances the state of the art and state of the practice in use of workflow services for automated product generation and delivery
Significance to Science/Applications

- **Hydrology**—SensorWeb brings together more data sources (4+ satellites, in-situ, models) more rapidly (within hours from acquisition) to enable more precise modeling

- **Forestry**—SensorWeb integrates more data sources & automates product generation & delivery to lower barrier for use

- **Volcanology**—SensorWeb allows rapid response to acquire more satellite data (> 500 in FY10, total of 1000’s of scenes)

- **Oceanography**—SensorWeb enables synergistic combination of space with in-situ data from gliders, floaters, ships, and autonomous underwater vehicles
Steve’s Presentation Here

• Add Science perspective
Need Right Tool for the Job

• Use SensorWeb software to get right tool for the job
Original HyspIRI Low Latency Data Flow Operations Concept (Intelligent Payload Module)

- **TIR**: 130.2 Mbps
- **VSWIR**: 804 Mbps
- **Intelligent Payload Module (IPM)**
  - **Command & Data Handling Solid State Recorder**
  - **Direct Broadcast Module**
    - 20 Mbps
  - **S-band command**
  - **Housekeeping data**
  - **X-band 800 Mbps Science data**

**To/From Alaska and Norway Ground Stations**

**Direct Broadcast Antennas**
SensorWeb High Level Architecture

Sensors, Algorithms and Models Wrapped in Web Services Provide Easy Access to Sensor Data and Sensor Data Products

floods, fires, volcanoes etc

Data Processing Web Services Node
Level 0 and Level 1 processing
Geolocation, Orthorec, Coregistration, atmospheric correction
Level 2 algorithms (e.g., flood extent)

SWE Node

SOS
SAS
SOS
SAS
Web Notification Service (WNS)
EO-1 Satellite
In-situ Sensor Data Node
Sensor Planning Service (SPS)
Sensor Observation Service (SOS)
Satellite Data Node

RSS Feeds
Get satellite images

Internet

OpenID 2.0

Sensor Data Products

GeoBPMS
Workflows

Task satellites to provide images

Web Coverage Processing Service (WCPS)

Design new algorithms and load into cloud
Matsu Cloud
- Eucalyptus/Open Stack-based Elastic Cloud SW
- 300+ core processors
- 500+ Tbytes of storage
- 10 Gbps connection to GSFC
  - being upgraded to 100 Gbps (Part of OCC)
- Hadoop Tiling/MapReduce/Accumulo
- Supplied by Open Cloud Consortium
- Open Science Data Cloud Virtual Machines & HTTP server to VM's

Starlight 100 Gigabit Ethernet Exchange

Hyperion and ALI Level 0 Processed data from GSFC, building 3 server

EO-1 GeoBPMS

Joyent Cloud
- Ruby on Rails
- 3 processors
- 3 Tbytes of storage
Experimental Intelligent Payload Module  Quick Load/Quick Look Ops Con

Web Coverage Processing Service (WCPS)-Client
Uploads to Various Environments

- Create Custom Algorithm
- Quick algorithm upload
- GlobalHawk, Ikhana, ER-2 ...
- Lua Scripts
- NASA Cloud Infrastructure As A Service
- WCPS-Runtime Executes Algorithm Against Selected Sensor Data
- Refined Offline Notification to user
- Quick look data products
- Custom Data Product (KMZ, PNG...)

SCIENCE USER

Machine Learning Supervised Classifier (Regression Tree)

Cloud

WEBKA The University of Waikato
Use GeoSocial API on Facebook to Task IPM

IPM Tasking

Request A New WCPS Imaging Task

Place Name: Greenbelt Imaging
Description: First Image Testing
Theme: Disasters
Category: Wildfires
Algorithm: vis_composite

Submit Task Request
Top Level IPM Ops Concept

SCIENCE USER

High speed instrument data source

Create algorithm

Cloud

WCPS Algorithm Builder Service

Select algorithm to run

IPM Flight Testbed

SpaceCube FPGA Co-Processor

Run

Onboard Algorithm Buffer

WCPS Runtime Service

Objectives for HyspIRI
Roadmap for IPM Flight Opportunities

2013-2014

- Ikhana
- Global Hawk

2013-2014

- HyspIRI/HSI+
- Thermal

2013-2014

- Mini UAV Helicopter

2013

- Ikhana
- Global Hawk
- 2020+
- HyspIRI/HSI+

Instrument and IPM Configuration TBS

2013 HyspIRI Airborne Campaign

- ER-2
- eMAS
- SpaceCube
- TileraPro

2012/2013

- Bussmann Helicopter
- SpaceCube
- TileraPro
- AMS

2008

- Chai 640

2013

- Citation Jet USFS

NASA • GSFC • JPL/Caltech • Ames
Flight & Ground Architecture Using Operational SW Components

CASPER – Continuous Activity Scheduling Planning Execution and Replanning system

WCPS – Web Coverage Processing Service

CmdIn – Command Ingest

TlmOut – Telemetry Output

CFDP - CCSDS File Delivery Protocol

ASIST - Advanced Spacecraft Integration and System Test Software
First Calibration Test with Chai V640 Imaging Spectrometer Instrument (5/16/13)

Visible image constructed from test data
Intelligent Payload Module Assembly with Chai640

Brandywine Optics Chai640 instrument

IPM
Beginning Integration Process on Helicopter
Sample Operational Scenario: Detection of Harmful Algal Blooms with Rapid Map Downlinked to Validation Team on Ground

Realtime map with following processing steps:
- Radiance to reflectance conversion
- Atmospheric Correction
- Geocorrection/Co-registration
- Classification

Validation team in boat being directed to location by rapid map product
Intelligent Payload Module (IPM) Prototype without Box

Joshua Bronston/581 coop
Tim Creech/NSTRF
Vuong Ly/583
Power supply
SpaceCube board
Neil Shah/581 summer intern
Matt Handy/583
Freewave Radio Transceiver & Antenna
Tilera board
Dream plug (processor)
Solid state disk
Testing Freewave Radio

Chris Flatley/581 summer intern

Neil Shah/581 summer intern

Tim Creech/NSTRF/581

Vuong Ly/583
IPM Testbed with Tilera Acting as Proxy for Maestro & Maestro-lite Board (building 23)

Above: Vuong Ly/583 (Ground System SW Branch) standing front of IPM testbed holding a SpaceCube board. Right: Tawanda Jacobs/582 (Flight SW Branch) working on integration of cFE onto IPM testbed.
Designed Box with Pro-E to House IPM Components

Mike Flick/SES

Mike Mandl/UMCP Student
Mike Flick
Neil Shah/Summer Intern
Chris Flatley/Summer Intern
Plan to Mount IPM to Helicopter for Tests Under AIST ESTO Research Grant

Vibration isolation mount for helicopter

Mike Flick talking to Bussmann Aviation technician

Joshua Bronston/581

Mike Mandl/UMCP student

Chris Flatley/581 Summer intern

Steve Bussmann/Bussmann Aviation
Unmanned Aerial System Jellyfish Monitoring Mission with IPM (Univ. of Catalunya)

Area of interest: Delta del Ebre south of Barcelona. Multiple Australian jellyfish being increasingly detected.

First test mission: Late summer 2012
Initial low-altitude mid-altitude images successfully acquired.

http://www.youtube.com/watch?v=Uam7-thvM80
Namibia Flood Dashboard

SensorWeb enabled for early flood warning

Daily Bulletin:

HYDROLOGICAL SERVICES NAMIBIA – DAILY FLOOD BULLETIN 30 JANUARY 2013

Rains returned to central northern Namibia. NMS reported 25.4 mm for Okahao and 15.4 mm for Oshikango, and Ms Nancy Robson gave 7 mm for Otjikoto. Satellite images showed also good rains in the headwater of Kavango and Kunene rivers, and higher flows may be building up to reach Namibia next week. The Zambezi River is further rising at Katima Mulilo, but more slowly now. The forecast is still for 5.50 m by 10 February, which would be the normal seasonal flood level that is usually reached by the beginning of April.

View Complete Current Bulletin
View Bulletin Records
Search Bulletin Records
New Bulletin
Namibia Flood Dashboard - Geospatial Display (The Big Map)

Legend:

<table>
<thead>
<tr>
<th>ALI Flood Classification</th>
<th>Class 1 - Background</th>
<th>Class 2 - Opaque Clouds</th>
<th>Class 3 - Cloud Shadow</th>
<th>Class 4 - Haze and Thin Clouds</th>
<th>Class 5 - Clear Water</th>
<th>Class 6 - Turbid Water</th>
<th>Class 7 - Dry Land</th>
</tr>
</thead>
</table>
TRMM Rainfall
Cell-to-Cell Flow Routing

Storage = (Precip. — ET) + (Inflow – Outflow) - Infiltration

Step I: Rainfall-infiltration Partitioning (Distributed and Time-variant)

Step 2: Flow Routing using Macro-scale Cell-to-Cell Algorithm

Step 3: Flood Inundation Mapping
Segmented Library of Inundation Extents (SLIE)

Kansas Applied Remote Sensing Program (KARS) - The University of Kansas

SLIE for 400 km Stretch of the Kavango

Application Example

Sources: Earth, DigitalGlobe, GeoEye, Itek, USDA, USGS, ABA, GoogleEarth, Astogrid, IGN, IRS, and the SLIE User Community

More info: kevindobbs@ku.edu
Segmented Library of Inundation Extents (SLIE)

Use Best Available DEM

Produce **SLIE** for **Full Range** of Flood Levels (in advance)

Example: May 2000 Flooding Kavango - (Landsat)

SLIE Selectors: GPS, Image Point Extraction, Stream Gauge, GFDS

Select Corresponding Library Elements to Produce Flood Map

Approximately 6 x 15 km Lower Kavango

Automated Parallel Processing Over Large Areas to Produce Library

Example of Image Point Extraction (or Simulated GPS Points)

Actual Extent Layer Produced from Points – Rapid Turnaround Time

More info: kevindobbs@ku.edu
End Goal!

• Use historical Moderate Resolution Imaging Spectroradiometer (MODIS), Radarsat, and Earth Observing-1 (EO-1) Water Level Maps to relate Hydrologic Model Streamflow to Spatial Extent of Flooding.
Timeline of Initial Activities Related to Namibia Early Warning Flood Project
Coordination Meetings at UN in Bonn Germany 2009
Flood SensorWeb Workshop Held in Windhoek, Namibia in January 2010

The following agencies contributed to establish an international expert team and sent representatives to this field mission:
European Commission, Joint Research Center (JRC), Italy; German Aerospace Center (DLR), Germany; German Technical Cooperation (GTZ), Windhoek, Namibia; International Institute for Geo-Information Science and Earth Observation (ITC), University of Twente, The Netherlands; National Aeronautics and Space Administration (NASA), US; NOAA / National Environmental Satellite Data and Information Service (NESDIS), US; Ukraine Space Research Institute (USRI), Ukraine; UNESCO; United Nations Resident Coordinator, Namibia; United Nations Office for Outer Space Affairs (UNOOSA), Austria/Germany; and World Meteorological Organisation (WMO).
2010 Initial Experiment to Correlate Remotely Sensed Rain Upstream with Flood Wave Downstream

Note blue bars (TRMM data) indicating a surge of rainfall upstream.

Then a flood wave appears downstream at Rundu river gauge days later (gauge data).

Early CREST Model trying to predict flood wave (Green).

Riverwatch Model trying to predict flood wave (Orange). Better than CREST based on AMSR-E.

Zambezi basin consisting of upper, middle and lower catchments.
Early Look at Inundation Extent Related to River Height

- Zambia water lines from old database
- Lower Zambezi catchment
- Multiyear river gauge measurements

Envisat swath

EO-1 Data March 2009
Radarsat Data March 25, 2009

Envisat Data March 2009

NORMAL, 2009 AND 2010 WATER LEVELS AT KATIMA MULILO - UPDATE 23 FEBRUARY 2010

- blue line: normal
- red line: 2009
- black line: 2010

Graph showing water levels from January 1 to April 11.
Unosat Flood Time Sequence In March 2009 in Caprivi when Katima Mulilo River Gauge Above 7.5 M

Vision is to generate similar product automatically when floods predicted and pair them with river gauge measurements.
Repeat Process with Namibia Data Gathered January 2012 Radarsat, EO-1 and Ground GPS

McCloud Katjizeu (orange) Dept. of Hydrology compares GPS readings of control point with Univ. of Namibia students for mapping exercise.

Georeferenced photos enable Rob Sohlberg/Univ. of Maryland to train classifier algorithm to detect presence of water in grassy marsh lands from satellite data.
Explored Socioeconomic Assessment

Left to Right: Matt Handy (NASA), Reinhold Kambuli (NDH), Village Resident, Dr. Julie Silva (UMD), John Moyo (Local Guide)

Preliminary visits to flood prone villages to gauge community interest in participating in socioeconomic surveys and assess familiarity and perceptions of radio flood forecasts.
Flooding and Impacts on Local Livelihoods

Villager shows flood damage and impact during team site assessment
Conducted field exercises around Kavango river in 2012 and 2013 to train in country hydrologist and research methods to use in Namibia.
Integrated Water Edge Detection Display with Boat GPS Measurements, GPS located photos, Radarsat/EO-1 water edge detections

- **RadarSat Water Edge Detection (yellow polygon)**
- **BOAT TEAM 1 track**: Walking bank to collect GPS points (purple track)
- **EO-1 Water Edge Detection**
- **BOAT TEAM 2 track**: Walking bank to collect GPS points (orange track with numbered waypoints)
GPS photos Overlaid on Boat Track

Boat Team 1 track with overlaid GPS photos (green track)
GPS Photo Shows Terrain Type Overlaid on Boat Track (geotagged elephants!)

Boat Team 1 track with overlaid GPS photos (green track) with photo overlay showing land terrain.
GPS Photo Shows Terrain Type Overlaid on Boat Track and Radarsat/EO-1 Water Detection
Backup
**Phase 1 Standard Ops Architecture**

- **Level 1 & higher processed science data products**
  - **Science Validation Team targets**
  - **Technology Validation Team activities**
  - **USGS target requests**
  - **Ops engineering requests**

**Planning Committee**
- Deputy Mission Scientist
- Mission Sys Engineer
- Mission Planner
- USGS Representative

**Level 0 processed science data**

- JPL
- USGS
- GSFC
- Flight Ops

**Level 0 Processing at GSFC**

- **White Sands Scheduling group**
  - contact times

- **Flight Dynamics Support Sys**
  - station in-views times

- **Mission Planner**
  - Daily plan

- **Mission Ops Planning & Sched Sys**
  - Daily activity plan

- **ASIST Telemetry & Command Sys**
  - tracking data
  - commands
  - telemetry

**RF Link cmd/telemetry**

- Alaska, Norway, Wallops Ground Stations

**User interface**
Detail of Phase 3 – User Services

Scheduling and Notification of EO-1 Image Acquisitions

Note: This follows the path of information only, not image data.

New image request

Note: Each facility currently has its own user notification method.

Self serve users

New image request

You’ve got data

Your image has been scheduled (not in place yet)

Dash lines indicate future development of scheduling feedback so users know if their images have been scheduled.

New: Installed at GSFC in 2011

Active list of images to be taken (not in place yet)

Collated list of images to take

Collated list of images to take

GSFC

Mission
Science
Office

JPL

Users

USGS EDC

GSFC

GeoBPMS
(Secure Web Interface)

GSFC

L1R, L1G Cloud Pipeline

GSFC Automated L0

Onboard EO-1

Science Processing

CASPERS Onboard Planner

SCL-Meta-command controller

science data

cmds

activities

Notification of completed images

Request for new or replacement image

Request for new or replacement image

Request for new or replacement image

GSFC OpenID Provider (OP)

Server

Aspen Ground Planner

with Web Interface

at JPL (now)

Note: This follows the path of information only, not image data.
Phase 4 Add Cloud Computing

Matsu Cloud
- Eucalyptus/Open Stack-based Elastic Cloud SW
- 300+ core processors
- 500+ Tbytes of storage
- 10 Gbps connection to GSFC
  - being upgraded to 100 Gbps (Part of OCC)
- Hadoop Tiling/MapReduce/Accumulo
- Supplied by Open Cloud Consortium
- Open Science Data Cloud Virtual Machines & HTTP server to VM’s

Level 1R and Level 1G Processing for ALI & Hyperion

Co-registration with Landsat GLS

Web Coverage Processing Service (WCPS) to enable users to customize Level 2 products

Starlight 100 Gigabit Ethernet Exchange

Hyperion and ALI Level 0 Processed data from GSFC, building 3 server

Atmospheric Correction for ALI & Hyperion

Namibia Flood Dashboard

Multi year data product archive

Joyent Cloud
- Ruby on Rails
- 3 processors
- 3 Tbytes of storage

EO-1 GeoBPM's

EO-1 GeoBliki
Original vision for access was to provide Web Coverage Service (WCS) as mashup to visualize available satellite data and possible future satellite data in an area of interest on Google Earth.

Satellite imagery available on Myanmar flooding as a result of Nargis cyclone May 2008.