Matsu: An Elastic Cloud Connected to a SensorWeb for Disaster Response

Matt Handy - NASA/GSFC 4/13/11
SensorWeb High Level Architecture

Data Processing Node
- Web Coordinate Transformation Service (WCTS)
- Web Processing Service (WPS)
- Web Coverage Service (WCS)
- SensorML Capabilities Documents
- SensorML

SensorML

Internet
- RSS Feeds
- OpenID 2.0
- Web Coverage Processing Service (WCPS)
- GeoBPMS

In-situ Sensor Data Node
- Web Feature Service (WFS)
- Sensor Planning Service (SPS)
- Sensor Alert Service (SAS)
- Sensor Observation Service (SOS)

Satellite Data Node
- Web Feature Service (WFS)
- Sensor Planning Service (SPS)
- Sensor Alert Service (SAS)
- Sensor Observation Service (SOS)

EO-1 Satellite

Data Processing Node
- Satellite Data Product
- Internet
- Web Coverage Processing Service (WCPS)
- GeoBPMS

Floods, fires, volcanoes etc

Satellite Data Products

GeoBPMS

Workflows
Cloud Integration for EO-1 - Overview

- Hyperion and ALI Level 0 Processed data from GSFC, building 3 server
- External users, especially international (e.g. disaster workers)
- NASA Investigators
- Technologists

Eucalyptus-based Elastic Cloud SW
- 300+ core processors
- 40 x 2 Tbytes of storage
- 10 Gbps connection to GSFC
  - being upgraded to 80 Gbps (Part of OCC)

At Univ of Illinois at Chicago
- 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
Atmospheric Correction for ALI & Hyperion
Web Coverage Processing Service (WCPS) to enable users to customize Level 2 products

Nambia Flood Dashboard
2 year data product archive

OCC = Open Cloud Consortium
Phase 3 Add Elastic Cloud Ongoing April 2011
Transformation to On-Demand Product Cloud Part 1

EO-1 Data Product Pipeline

- EO-1 Level 0 Processor Server
- EO-1 Level 1 Processor Service
- EO-1 Hyperion Atmospheric Correction – FLAASH Service
- EO-1 Hyperion Atmospheric Correction – ATREM Service
- Storage – 1 year Hyperion & ALI Level 1R
- Storage – 1 year Hyperion Level 1R & ALI Level 1R
- Storage – 1 year Hyperion Level 1G & ALI Level 1G
- Storage – Available Algorithms
- WCPS Algorithm Generation Service
- WCPS Runtime Service
- Storage – Available Algorithms
- Select algorithms & run against
- Generate a new product with this new algorithm
- User Defined L2 Products
- Storage – 1 year User Defined L2 Products
- Storage – 1 year Hyperion & ALI Level 1R and Level 1G AC
- Storage – 1 year Hyperion & ALI Level 1G
- Storage – Available Algorithms
- Select algorithm & data to run against

Phase 3 Add Elastic Cloud Ongoing April 2011
On-Demand Product Cloud Part 2
Flood Dashboard (Matsu)

- CREST Hydrological Model
- TRMM based Global Rainfall Estimates
- Radarsat Images
- MODIS Daily Flood Extent Map
- Global Disaster and Alert and Coordination System (GDACS)

Storage – 1 year Hyperion & ALI Level 1R
Storage – 1 year Hyperion & ALI Level 1G
Storage – 1 years Hyperion & ALI Level 1R and Level 1G AC
Storage – 1 year User Defined L2 Products e.g. EO-1 Flood Mask

Flood Dashboard Display Service
- Mashup
- Google Maps Inset
- Plot Package

http server

5 Namibian River Gauge Stations - Daily Measurements
Namibia River Gauge Database

Phase 3 Add Elastic Cloud Ongoing April 2011
Detail of Processing Image Data in OCC
Open Science Data Cloud

- Hadoop / HBase
- Partition into Cloud Cache
- Suitable for Google Earth / Open Layers
- Web map Service (WMS)
- HBase storage of multiple missions over multiple days
- Phase 3 Add Elastic Cloud Ongoing April 2011

Storage – 1 year
Hyperion & ALI Level 1R

Storage – 1 year
Hyperion & ALI Level 1G

Storage – 1 years
Hyperion & ALI Level 1R and Level 1G AC

Storage – 1 year
User Defined L2 Products e.g. EO-1 Flood Mask

Storage – 1 year
Hyperion & ALI Level 1G

Storage – 1 year
Hyperion & ALI Level 1R

Storage – 1 year
User Defined L2 Products e.g. EO-1 Flood Mask
GeoBPMS – Web-based satellite tasking tool

Improved flood prediction model

Customized plan of needed satellite images

Manual or automated triggered requests for satellite imagery in area of interest

Flood alerts to users

Ground flood measurements to validate model

Flood conditions

Compare to history

Improved flood prediction model

*SPS = Sensor Planning Service
Shanalumono River Gauge Station

Portion of 2011 Namibian Flood SensorWeb Early Warning Pilot

Water flow from North through basin

Oshakati

Ongwediva

Namibia

Angola
Shanalumono River Gauge Station

TRMM based rain estimates: Monitor rains upper basin

Early user alert

Global Disaster and Coordination System - (Based on AMSR-E)

MODIS Daily Flood Mask
Follow flood wave down basin

GeoBPMS

Auto-trigger Hi-res Satellite images

High resolution satellite imagery (e.g. EO-1)

Flood Dashboard (mashup)

Daily flood gauge levels & predicted river levels plots

Auto triggers

Portion of 2011 Namibia Flood SensorWeb Early Warning Pilot:

Auto triggers

Oshakati

Ongwediva
Experimental Namibian Flood SensorWeb

Flood Dashboard

Namibia Short Term Pilot for 2010

- Colored areas represent catchments where rainfall collects and drains to river basins
- River gauges displayed as small circles
- Detailed measurements are available on the display by clicking on the river gauge stations.
- This display can be viewed and manipulated at:
  - [http://geobpms.geobliki.com/namibia](http://geobpms.geobliki.com/namibia)
  - [http://geobpms.geobliki.com/namibia2](http://geobpms.geobliki.com/namibia2)

Note blue bars indicating a surge of rainfall upstream

Then a flood wave appears downstream at Rundu river gauge days later

Zambezi basin consisting of upper, middle and lower catchments
Shanalumono River Gauge Station and Community
Prone to Flooding
Experimental Namibian Flood SensorWeb
Test View of Envisat & EO-1 Overlay Images

Flood Dashboard
Namibia Flood SensorWeb

- River Stations
- Flood Potential Forecast

Daily Report
25 Apr

- 1-Day Flood Potential Forecast
- 5-Day Flood Potential Forecast
- Severe Flood Report

SensorWeb Layers
- Catchments
- River Gauges
- GDACS
- Current/Past Floods
- Water Lines and Areas
- Angola
- Namibia
- Zambia
- Dwelling Density
- Northern Namibia
- Satellite Overlays
  - EO1 ALI
  - SAR (SRI Ukraine)

2010-01-30 Flood Water Area
Flood/water mask derived from SAR imagery
Image credit: Copyright ESA 2009, 2010
Image processing, map created by:
Space Research Institute,
National Academy of Sciences of Ukraine,
National Space Agency of Ukraine.

2010-03-28 (07:58 UTC)
Download KML file

Envisat SAR and EO-1 Optical Image Overlays

Experimental TRMM-based Flood Forecast Products
## Status as of 3-24-11

<table>
<thead>
<tr>
<th>Item</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port Flood Dashboard to Single Virtual Machine in Full Environment Upgrade</td>
<td>Complete</td>
</tr>
<tr>
<td>Integrate MODIS Daily Flood Extent Overlay</td>
<td>April 2011</td>
</tr>
<tr>
<td>Display Joint Research Center River Watch AMSR-E based 2 sigma River Flood Trigger (triggers will be used later to auto-trigger EO-1)</td>
<td>April 2011 (display portion</td>
</tr>
<tr>
<td>Integrate Radarsat Flood Extent Overlay</td>
<td>May 2011</td>
</tr>
<tr>
<td>Integrate TRMM based Rainfall Estimate Overlay</td>
<td>June 2011</td>
</tr>
<tr>
<td>Rework River Gauge Plot Widget</td>
<td>Sometimes between April-June 2011</td>
</tr>
<tr>
<td>Multi-Virtual Machine Load Balancing</td>
<td>Summer/Fall 2011</td>
</tr>
<tr>
<td>EO-1 Flood Extent Overlays</td>
<td>TBS</td>
</tr>
</tbody>
</table>
Experimented with various hydrometeorological information for flood forecasting models
- remote sensing
- rainfall estimates
- 24 February 2010
- NASA Servir Africa
- red is > 35 mm
Experimental Global TRMM Based Flood Forecast
Experimental Flood Extent Data Product Derived from MODIS

First product out of automated MODIS flood extent map pipeline prototype. Used data from March 2009 when large floods occurred to test.
Recent MODIS Daily Flood Extent

Area toured on January 2011 trip

Recent flooded area

http://oas.gsfc.nasa.gov/SERVIR_Africa/calendar.html?latlong=010E010S
Sample of Planned Addition of Higher Resolution Flood Product Overlay Using EO-1

- **March 12, 2009 True-Color Image EO-1 ALI Image**
  - In this true-color image, note how the water color is so muddy that it makes discerning the extent of the flooding difficult.

- **March 12, 2009 False-Color Image EO-1 ALI Flood Product**
  - This false-color image combines infrared and visible light, which makes the extent of the flooding far more obvious. Water is dark blue, while plant-covered land is green, and bare earth is rosy tan.

- **March 25, 2009 False-Color Image EO-1 ALI Flood Product**
  - Two weeks later, the flood waters have receded even more, which the EO-1 Flood Product makes evident.

Images are from NASA's Earth Observatory website (http://earthobservatory.nasa.gov/).
Rainfall prediction
From GEOS-5

TRMM based daily rainfall estimates

Various flood models such as CREST model (Univ. of Oklahoma)
Sample Display of Multi-year Satellite Measurements (in month of March) of Katima Mulilo Linked to JRC Via Namibia Flood Mashup Based on Terra AMSR-E Microwave Instrument
Sample Alert During Pilot

Namibia daily flood bulletin 03 March 2010:
There have again been heavy rains in parts of the Zambezi catchment. See attached NASA map. The waterlevels at Chavuma started rising again. See attached graph. Our forecast remains that the Katima Mulilo waterlevels are heading for 7 m by mid-March 2010. For perspective, the flood would be:
- similar to 2007
- higher than 2008
- lower than 2009
But much will depend on the rains and the catchment response in the coming weeks.
Sample Time Sequence Flood Map Generated by Unosat, Derived from Multiple Satellite Data Sets

Vision is to generate similar product automatically when floods predicted and pair them with river gauge measurements
Conclusion

• Combining SensorWebs with an elastic computation cloud enables surge capacity for disasters by enabling parallel processing of various algorithms and other processes within the cloud
• Elastic cloud provides work space for user to customize their experience instead of preset outputs
• Elastic cloud allows capacity to expand and contract server capacity to fit current user load