A Namibia Early Flood Warning System – A CEOS Pilot Project

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Where is Namibia

Namibia Use Case: 2009 Flood Disaster

- *In February and March 2009, torrential rains increased water levels in Zambezi, Okavango, Cunene and Chobe Rivers*
- *This led to a 40-year flood in Caprivi, Kavango and Cuvelai basins, affecting some 750,000 people (37.5% of population of Namibia)*
- *Whole villages were cut off and had to be relocated into camps. Some 50,000 people were displaced*
- *Livestock were stranded and died of hunger*
- *102 people died*

Flood Related Impacts

- Health
  - Malaria
  - Cholera
  - Schistosomiasis
- Infrastructure damage
  - Roads
  - Schools
  - Clinics
- Food security
  - Crop and wildlife loss
- Human wildlife conflict
  - Encroachment of wildlife on human settlements

Stakeholders

- Namibia Department of Hydrology
- University of Namibia, Department of Geography
- National Aeronautics and Space Agency (NASA)/ Goddard Space Flight Center (GSFC)
- Canadian Space Agency (CSA)
- United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER)
- Deutsches Zentrum fur Luft- und Raumfahrt *(DLR)* German Aerospace Center
- Ukraine Space Research Institute (USRI)
- European Commission, Joint Research Center
- University of Maryland, Department of Geography
- University of Oklahoma
- University of Chicago
- Open Cloud Consortium
- Committee on Earth Observing Satellites (CEOS)
  - ✓ Disaster Societal Benefit Area
  - ✓ Working Group on Information Systems and Services (WGISS)

Partner Contributions

- Namibia Department of Hydrology, Namibia Ministry of Health
  - ✓ In-country equipment, personnel and other resources
  - ✓ Logistics support
  - ✓ Direct technology development of other stakeholders
  - ✓ Local conditions expertise
  - ✓ Capacity building
- NASA, CSA, Univ. of Maryland, Univ. of Chicago, Univ. of Oklahoma, Open Cloud Consortium, DLR, USRI, JRC
  - ✓ Satellite imagery
  - ✓ Training on how to process the imagery to extract salient flood information
  - ✓ Preliminary flood models
  - ✓ Training on further refinement of flood models
  - ✓ Computation cloud and web interface to host data, models and displays
- Univ. of Namibia and Univ. of Maryland
  - ✓ Ground survey of water
  - ✓ Development and design

Project Objectives

- Support disaster architecture definition and the building of an open, extensible disaster decision support enterprise model for satellite data under the auspices of CEOS (task DI-01-C1_2, C5_1 & C5_2) WGISS task GA.4.D, and the GEO Architecture Implementation Pilot AIP-5
- Identify compelling disaster decision support scenarios that will help to focus effort
- Select one or more scenarios and develop demonstrations that will help to coalesce specific disaster architecture recommendations to CEOS/WGISS and GEO
- Leverage SensorWeb components and Open Geospatial Consortium (OGC) Sensor Web Enablement (SWE) standards to the degree possible
- Expected Impact:
  - Reduce the time to acquire and improve utility of relevant satellite data
  - Simplify and augment access of International Charter and other remote sensing resources for risk management and disaster response

Approach

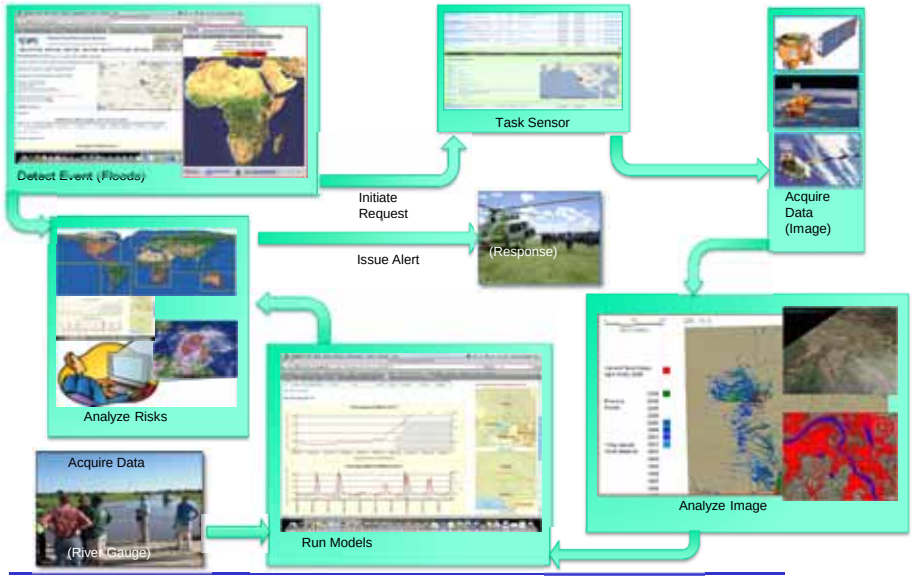
- Phase 1 (2009 – 2011):
  - ✓ Prototype an automated data processing chain to deliver flood related satellite data to Namibia Department of Hydrology,
  - ✓ Leverage SensorWeb components which use standard web services to wrap key processes such as tasking satellites
  - ✓ Exercise process of monitoring flood waves traveling from northern basins that result in flooding of towns in Northern Namibia and experiment with various hydrological models as prediction tools
  - ✓ Begin to build some initial capacity to allow users in Namibia to obtain flood related products via a compute cloud and the Internet
- Phase 2 (2011 – present)
  - ✓ Develop capacity for user to task (or at least automatically request task of) radar satellite
  - ✓ Enable user to run algorithm on compute cloud to adjust algorithm based on ground data to make it more accurate

Approach

- Phase 2 (2011 – present)
  - ✓ Develop method to store, edit and display water contours in common format
  - ✓ Demonstrate the use of crowd sourcing as a method to calibrate and validate water extent displays via GPS ground measurements of water locations
  - ✓ Develop architecture framework to manage changing water contours
  - ✓ Use SensorWeb automation and improved identification of water contours to automatically create time series of water locations (including the use of multiple satellite) to show flood water movements
  - ✓ Use improved knowledge of water locations to develop better hydrological models relating rainfall to upcoming floods

Phase 1
Prototype General Components to Automate Data Products Production

NASA Flood SensorWeb Concept



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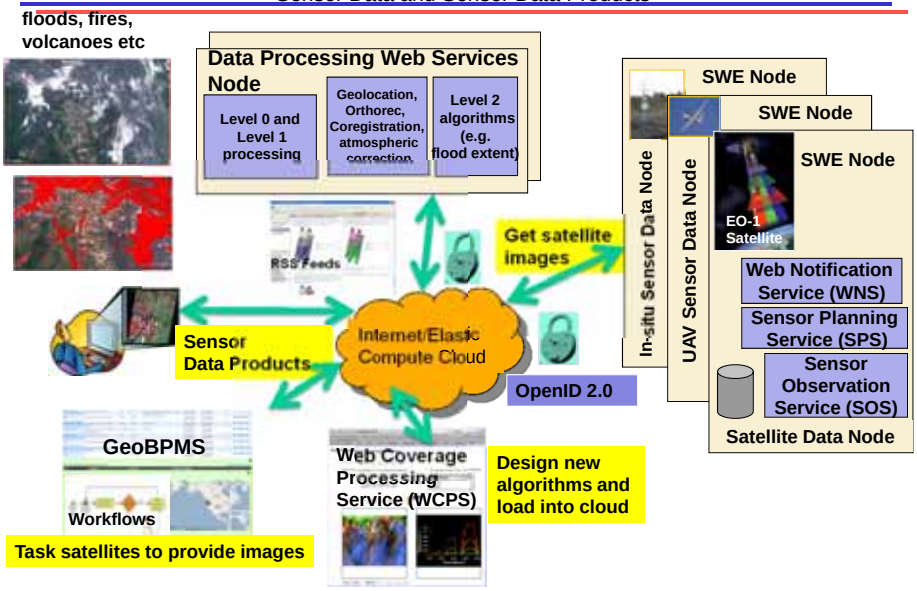
SensorWeb High Level Architecture

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



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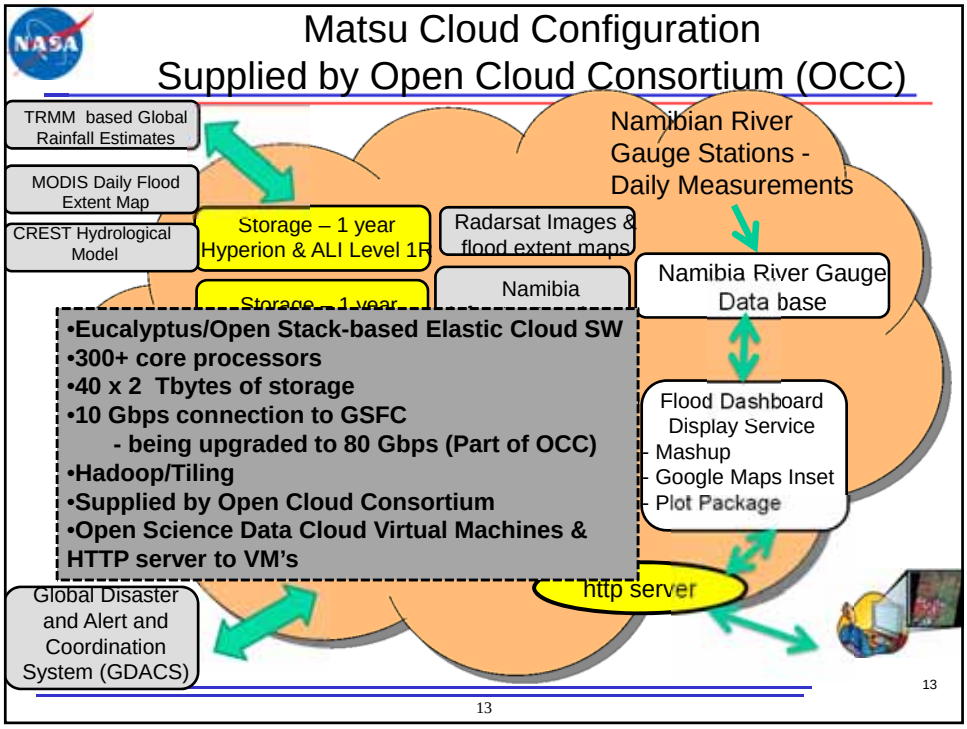
Matsu Cloud Configuration
Supplied by Open Cloud Consortium (OCC)
TRMM based Global Rainfall Estimates
MODIS Daily Flood Extent Map
CREST Hydrological Model
Storage – 1 year Hyperion & ALI Level 1R
Radarsat Images & flood extent maps
Namibia
Namibian River Gauge Stations - Daily Measurements
Namibia River Gauge Data base
•Eucalyptus/Open Stack-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)
•Hadoop/Tiling
•Supplied by Open Cloud Consortium
•Open Science Data Cloud Virtual Machines & HTTP server to VM's
Flood Dashboard Display Service
- Mashup
- Google Maps Inset
- Plot Package
http server
Global Disaster and Alert and Coordination System (GDACS)
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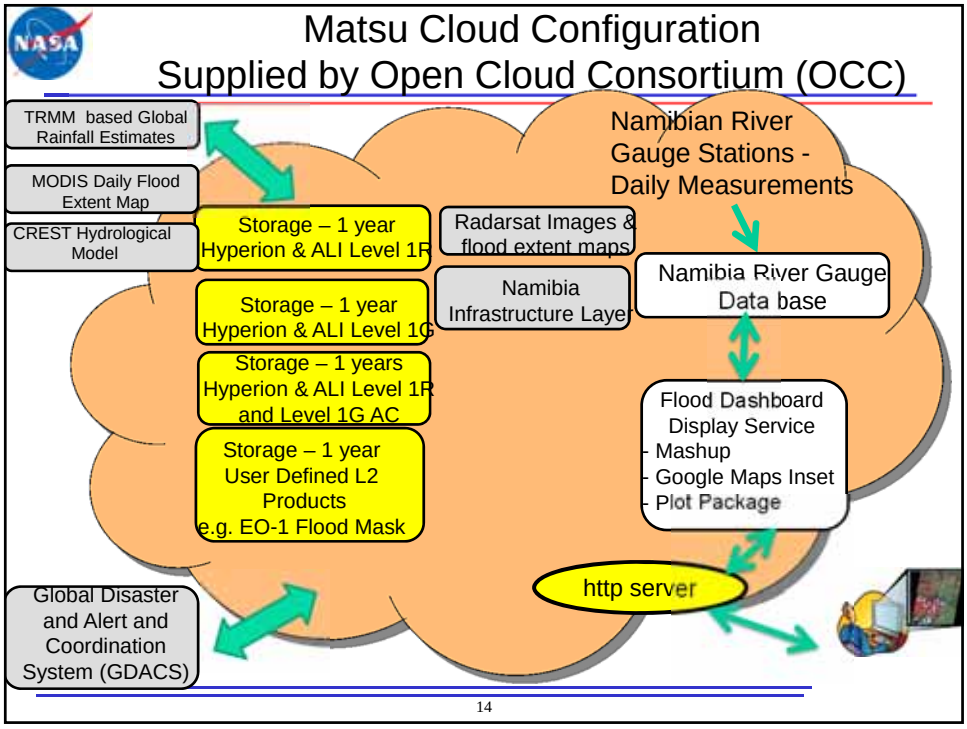
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Radarsat Images & flood extent maps
Namibia Infrastructure Laye
Storage – 1 year Hyperion & ALI Level 1G
Storage – 1 years Hyperion & ALI Level 1R and Level 1G AC
Storage – 1 year User Defined L2 Products e.g. EO-1 Flood Mask
Namibian River Gauge Stations - Daily Measurements
Namibia River Gauge Data base
Flood Dashboard Display Service
- Mashup
- Google Maps Inset
- Plot Package
http server
Global Disaster and Alert and Coordination System (GDACS)
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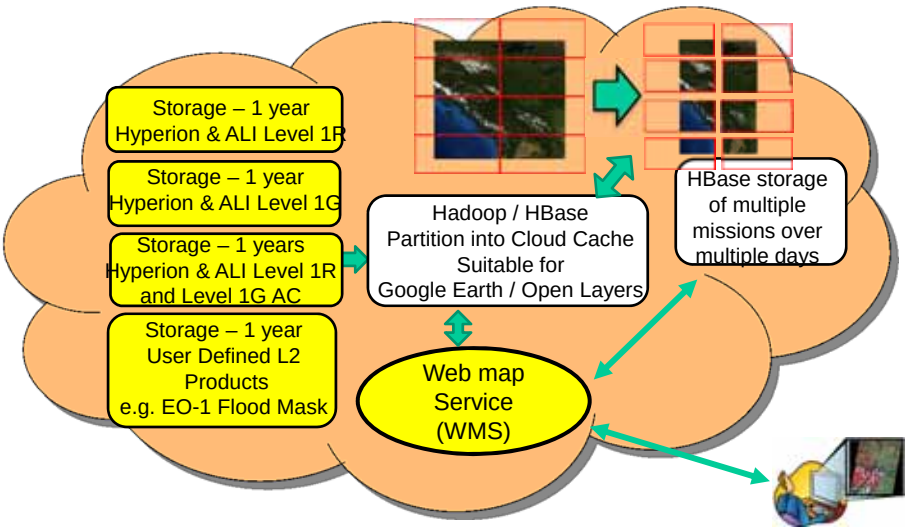
Matsu Cloud (In process)
Hadoop and Tiling Handles Large Dataset Displays



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Connected to Global Lambda Integrated Facility (GLIF)
OCC Collaboration with Starlight (part of GLIF)

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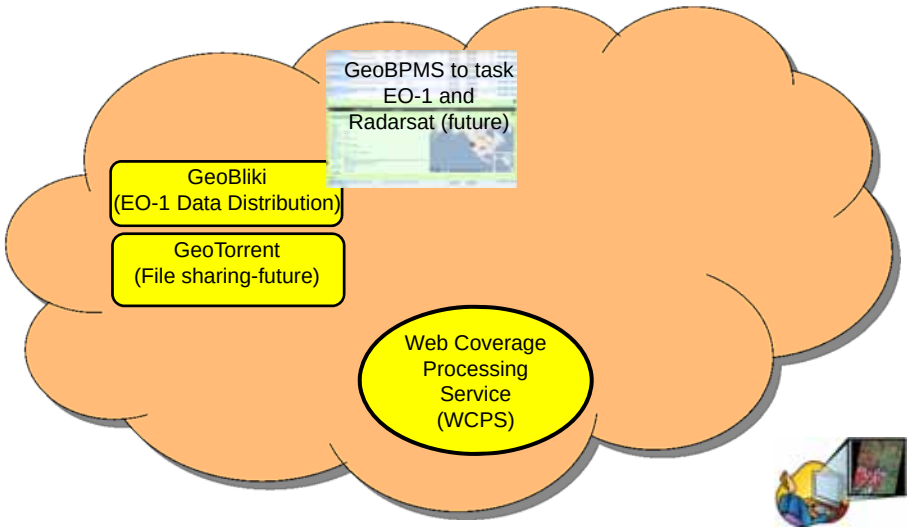
Joyent Cloud Hosting Some Different and Overlapping Operational Functionality



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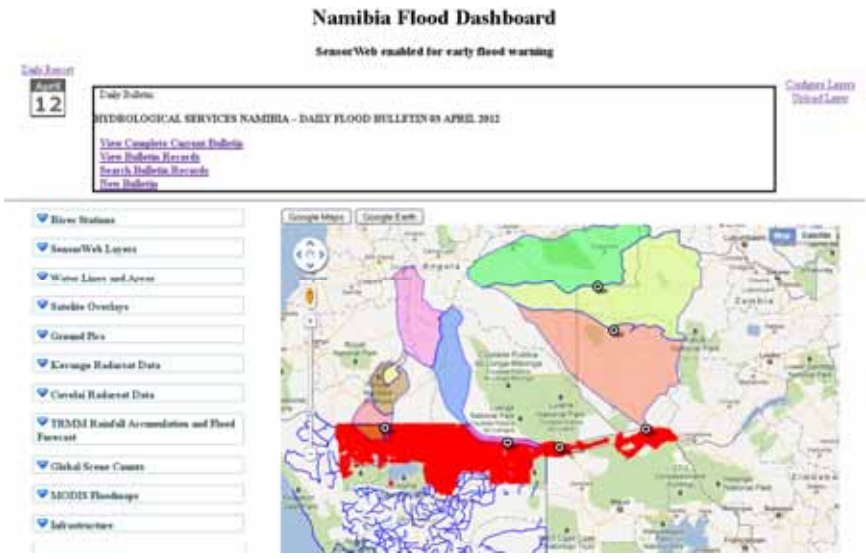
Flood Dashboard on Matsu Cloud



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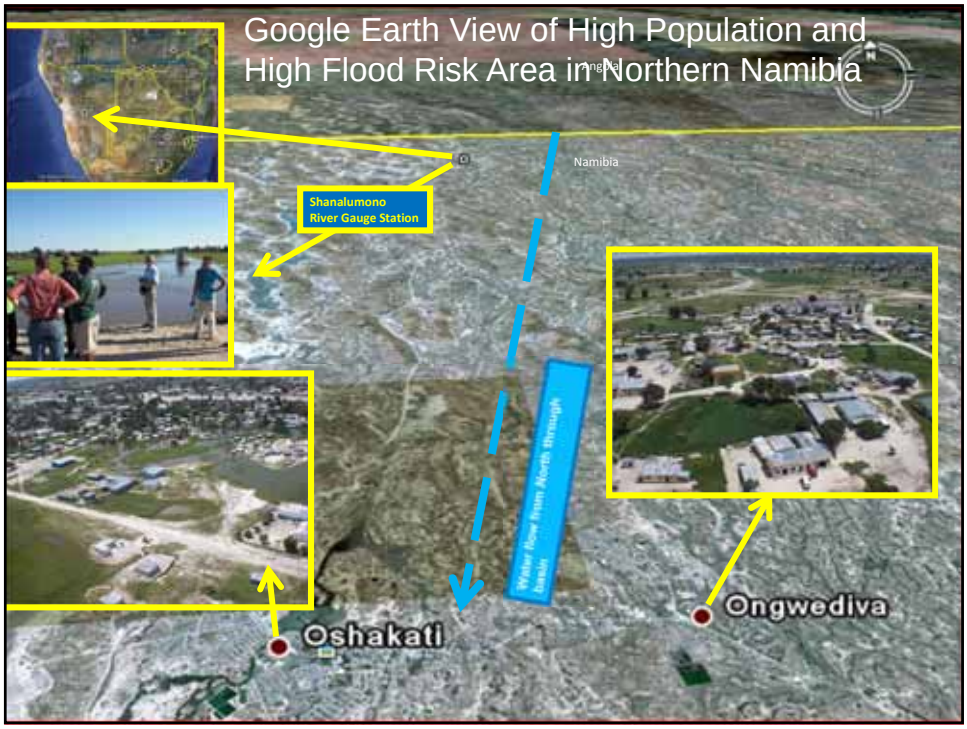
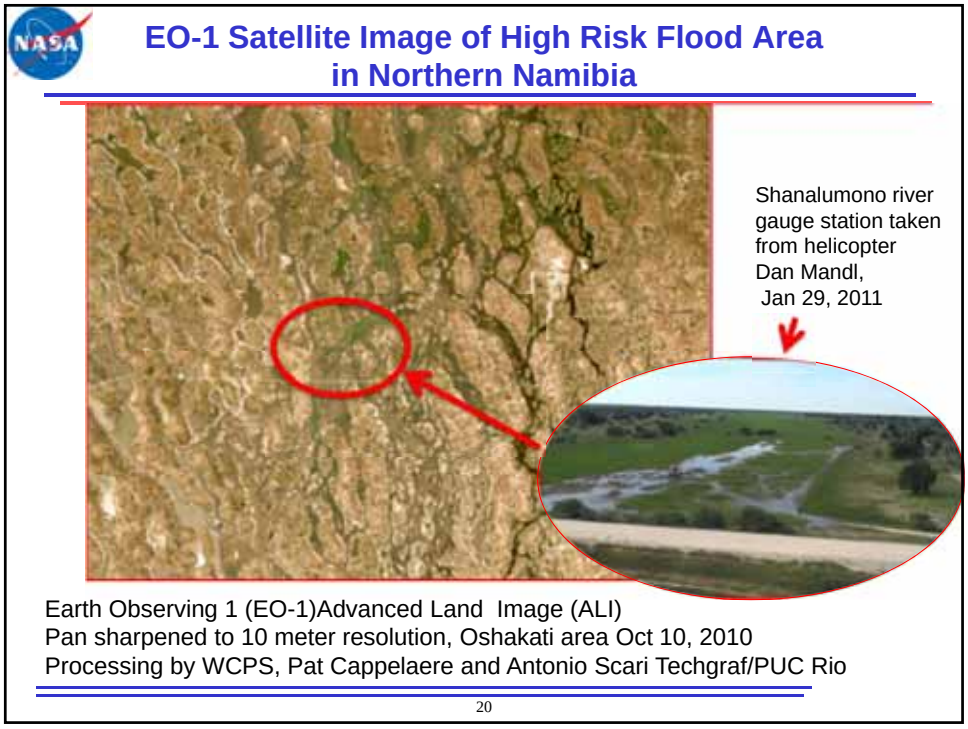

Google Earth View of High Population and High Flood Risk Area in Northern Namibia
Angola
Namibia
Shanalumono River Gauge Station
Water flow from North through basin
Ongwediva
Oshakati


EO-1 Satellite Image of High Risk Flood Area in Northern Namibia
Shanalumono river gauge station taken from helicopter Dan Mandl, Jan 29, 2011
Earth Observing 1 (EO-1)Advanced Land Image (ALI)
Pan sharpened to 10 meter resolution, Oshakati area Oct 10, 2010
Processing by WCPS, Pat Cappelaere and Antonio Scari Techgraf/PUC Rio
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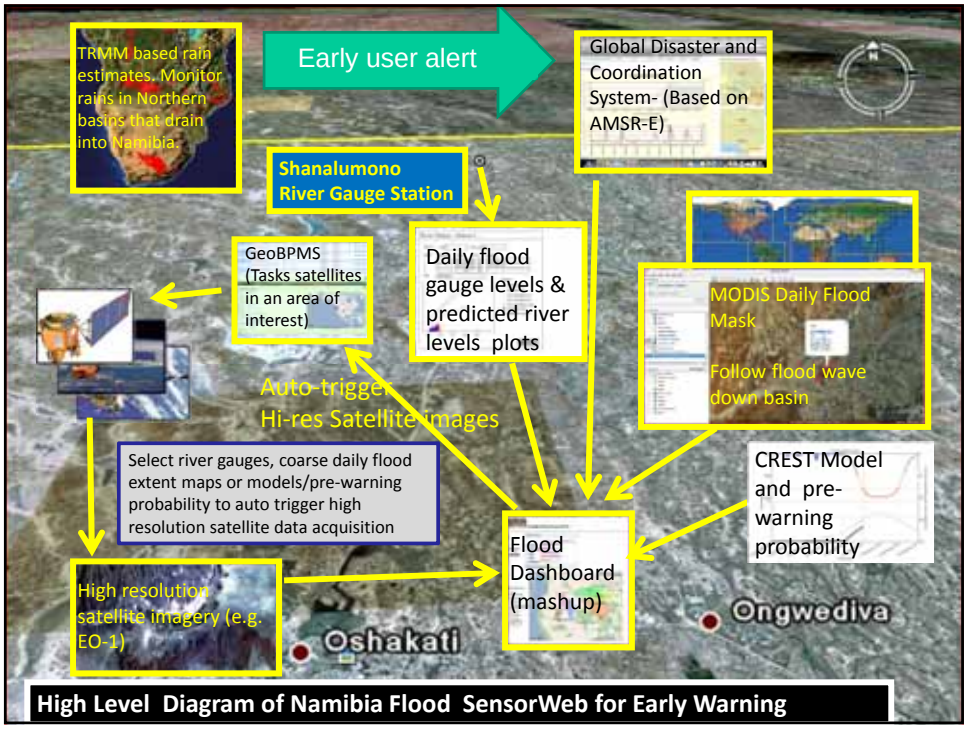


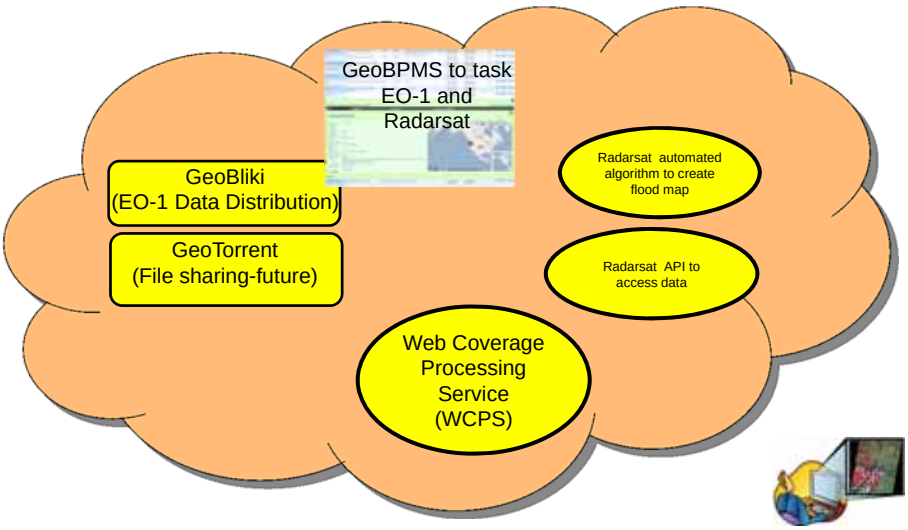
High Level Diagram of Namibia Flood SensorWeb for Early Warning

Phase 2
Add Automated Radarsat Water Extent Data Products, Tiled Display Output and Methods to Calibrate

User Needed Capabilities for Namibia

- Application Program Interface (API) to submit Radarsat task request
- API to query what Radarsat data and data products are available in an area of interest
- Common storage of water contours so that multiple satellite images, data from multiple satellites and/or ground data can be combined
- Hierarchical tile management of data for large displays
- Automated Radarsat flood extent processing
  - ✓ Training on algorithm and how to adjust algorithm based on ground data
- Architecture to handle measurements of changing water contours

Updated Joyent Cloud Functionality After Phase 2



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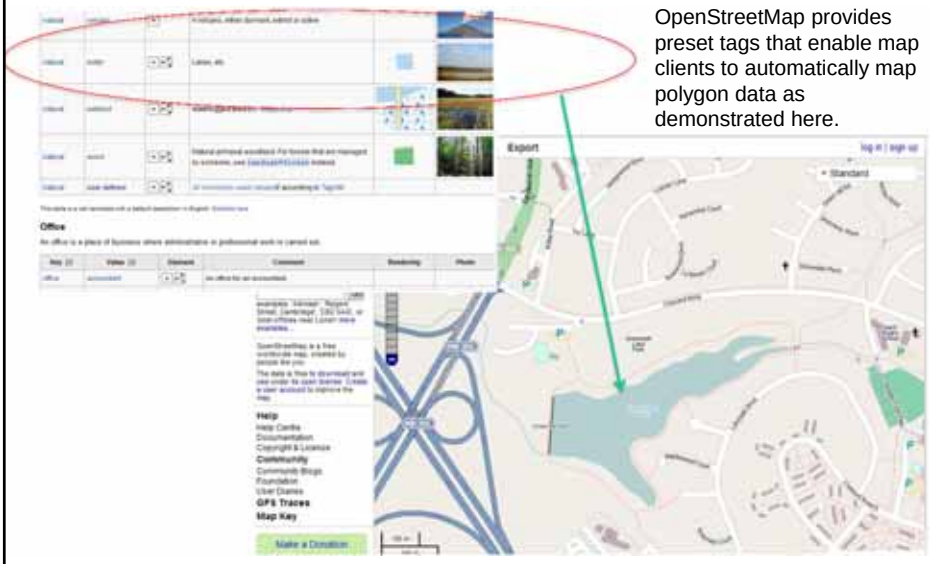
Use OpenStreetMap



OpenStreetMap provides preset tags that enable map clients to automatically map polygon data as demonstrated here.

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Use OpenStreetMap

1. Use Planet.osm to store and ever improving base water mask with contributions from many sources
   - Use commonly used tags to maximize interoperability
   - Use standard tags to enable use of standard map clients
2. Use combination of standard and augmented tags to enable calibration and validation of satellite images
   - Define tags and terms needed for use by hydrologists (e.g. error locations of water)
   - Query database and customize output display
3. Use heterogeneous data base of water contours to query data base and create customized time series of water progression of floods from multiple sources

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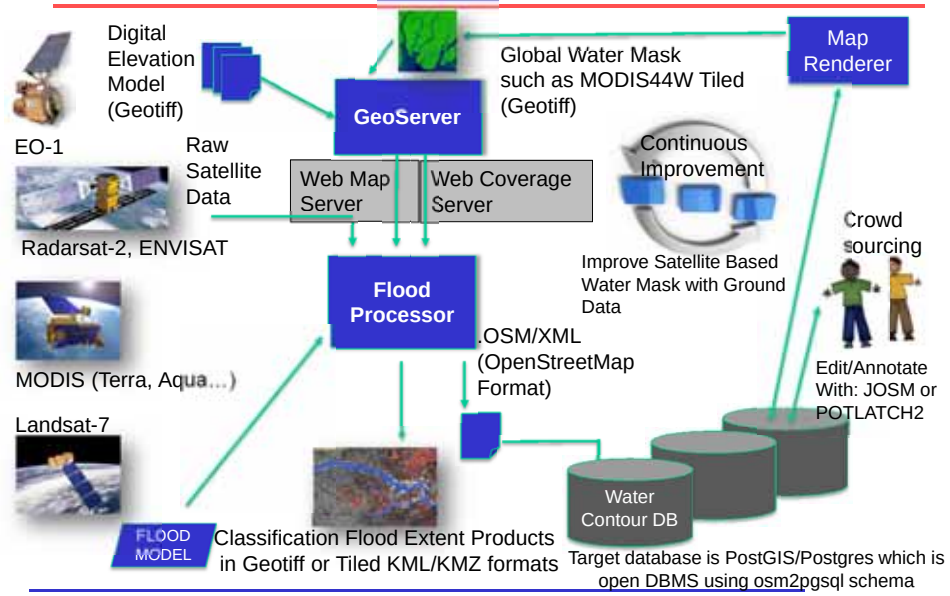
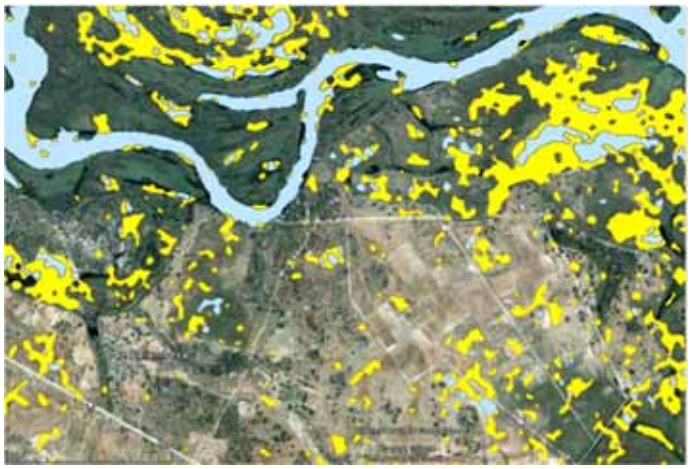
Vision of Generalized Water/Flood Architecture with Parallel OpenStreetMap (OSM) Format Output



Radarsat Processing Into Flood Extent



Kavango River in Namibia. Radarsat image processed manually by MacDonald Detweiller and Associates (MDA) as a PDF shape file (blue: open water; yellow: inundated), derived from the image processing applied to the Feb. 17, 2012 RADARSAT-2 image, converted into KML format and displayed in Google Earth.

Prototype Automated Radarsat Water Extent (without Inundation Differentiation) in Tiled Geotiff Format

Same Kavango image, Feb 17, 2012 in Namibia but processed with our automatic Radarsat processor algorithm with tiled output running on laptop. Goal is to run on Matsu and Joyent clouds to make it a "do-it-yourself" process.

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Next Step; Convert Geotiffs to Polygons with OpenStreetmap Tags

- Original Geotiff file was 1.2 Gbytes
- Converted OpenStreetmap file was 2.4 Gbytes
- Took 24 hours to process
- Need streamlined methods to make this happen
- Also need to identify tags to use when this conversion is done to make it useful for hydrologists

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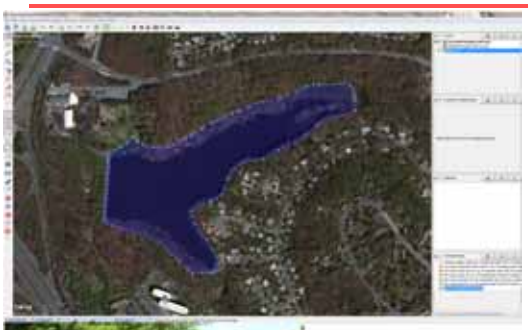
Student Work – Java OpenStreetMap Editor Familiarization – GSFC Lake & Greenbelt Lake – Taking GPS Points to Lay Track on Map



Left: Neil Shah, Summer Intern, Univ. of Md College Park, major Aerospace Engineering, Middle: Chris Flatley, summer intern, Virginia Tech, major Computer Engineering

Joshua Bronston, Navajo Tech College GSFC Coop student – Pursuing Masters in Computer Engineering

Left: Michael Mandl, Univ. of Md College Park, engineering student with Neil Shah and Chris Flatley

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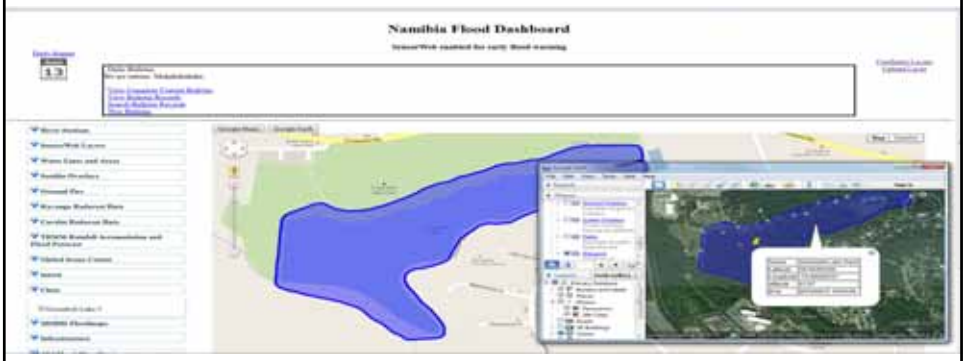
Transfer OSM track to Flood Dashboard



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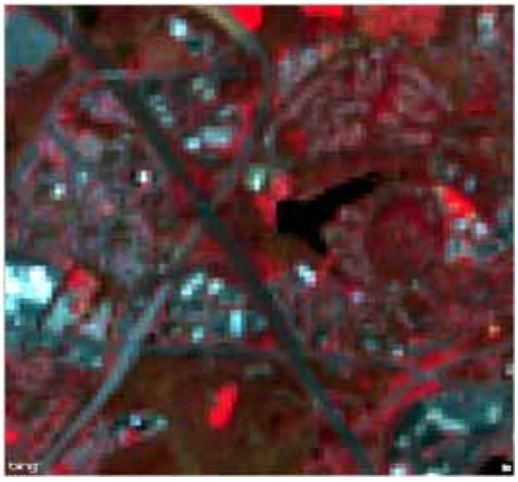
Practice Process of Adjusting Water Contour with EO-1 Hyperion Image (April 2008) with Greenbelt Lake Identified via Water Classification Algorithm



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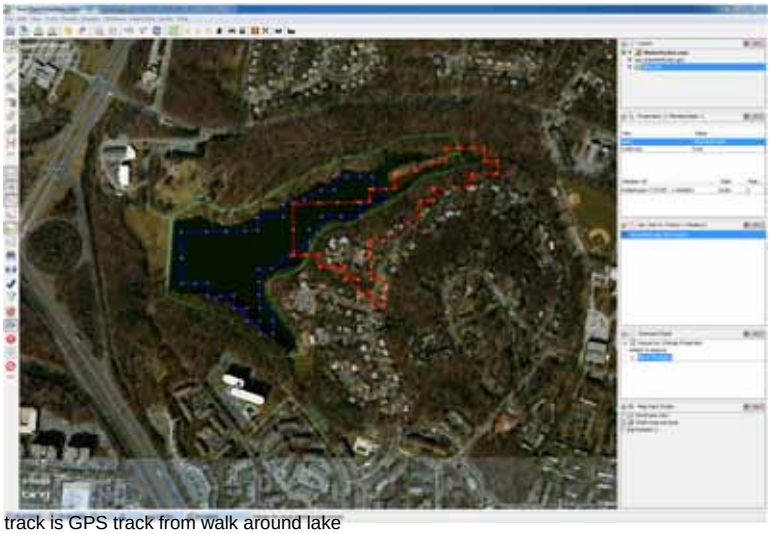
Experiment to Add Ground GPS Points, Add EO-1 ALI Water Detection Converted to Polygons and Begin to Edit in OSM



Green track is GPS track from walk around lake
Red track is converted polygon representing water contour from EO-1 ALI (known approx. 300 meter offset)
Blue track is use of JOSM to move satellite derived polygon using JOSM editing capability

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Repeat Process with Namibia Data Gathered January 2012 Radarsat, EO-1 and Ground GPS (late summer 2012)

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

Georeferenced photos enable Rob Sohlberg/UMD to train classifier algorithm to detect presence of water in grassy marsh lands from satellite data.

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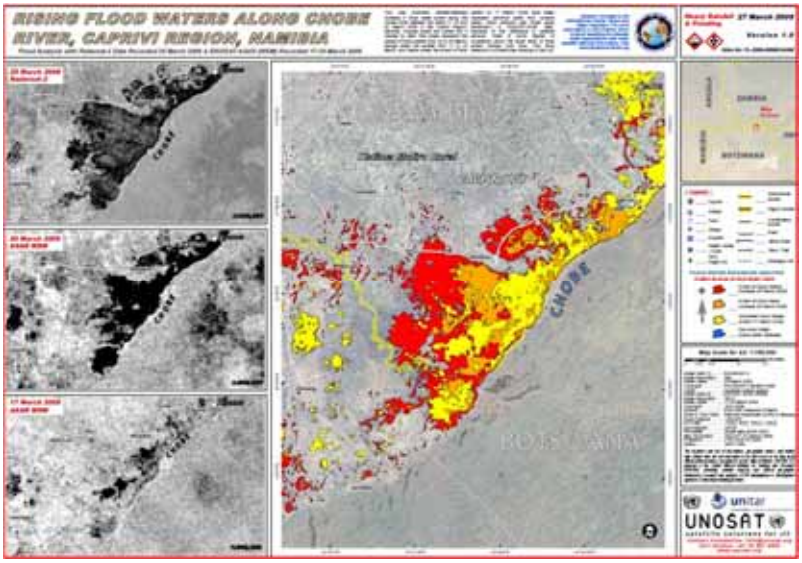
Future Goal is to Automate Creation of Time Series Differential Map, Below is Example Manually Created in 2009 by Unosat



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Conclusion

- Phase 1 of Namibia Early Flood Warning was mostly about experimenting with rapid satellite data access
- Phase 2 of Namibia Early Flood Warning is more about beginning to build capacity that actually can be used for real decision support
  - Calibration of Radarsat data
  - Training on how to process Radarsat data by in country hydrologist
- Developing architecture that can store a common format for water contours which allows monitoring of changing base water and inundation water contours via compute clouds and data base software
- Developed API to query what Radarsat data and data products are available in an area of interest

• Functions added will support disaster architecture definition and the building of an open, extensible disaster decision support enterprise model for satellite data under the auspices of CEOS (task DI-01-C1_2, C5_1 & C5_2) WGISS task GA.4.D, and the GEO Architecture Implementation Pilot AIP-5