Towards A Sensor Web Architecture For Disaster Management: Insights From The Namibia Flood Pilot

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Overview

- GEOSS Architecture for Disaster Management and Risk Assessment (GA.4.Disasters)
  - Project of the CEOS Working Group on Information Systems and Services (WGISS)
  - Goal: a structured understanding, shared among CEOS and GEO members, of satellite data support to Disaster Reduction activities
- Namibia SensorWeb Flood & Health Pilot
  - Ongoing collaboration between NASA and Govt. of Namibia
  - Improve flood detection from satellite imagery
  - Produce flood data products rapidly for decision support
  - Facilitate user access, and user feedback
- Findings and Recommendations

GEOSS Architecture for Disaster Management and Risk Assessment

(GA.4.Disasters)

Problem Statement

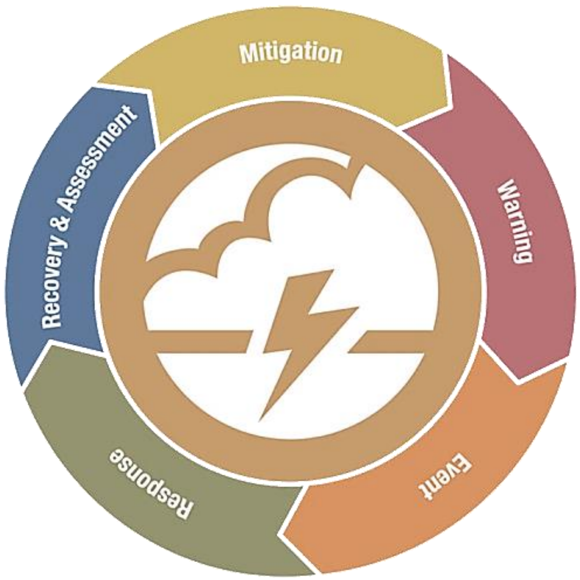
- Supporting disaster management with satellite observation often involves ad hoc arrangements among many players

  => Limited effectiveness, efficiency
- New suppliers: unclear how to contribute data & services
- New users: unclear how to tap into these data & services
  - Challenges in accessing data using current service standards
- Planners: Unclear what resources are
  - Shared
  - Missing
  - Interdependent
  - Isolated
- Need to establish partnerships, standards, shared vocabulary, etc., in advance of disaster events
- Need a precise, common understanding of processes, information & computing resources, and user needs

Scope, purpose, structure

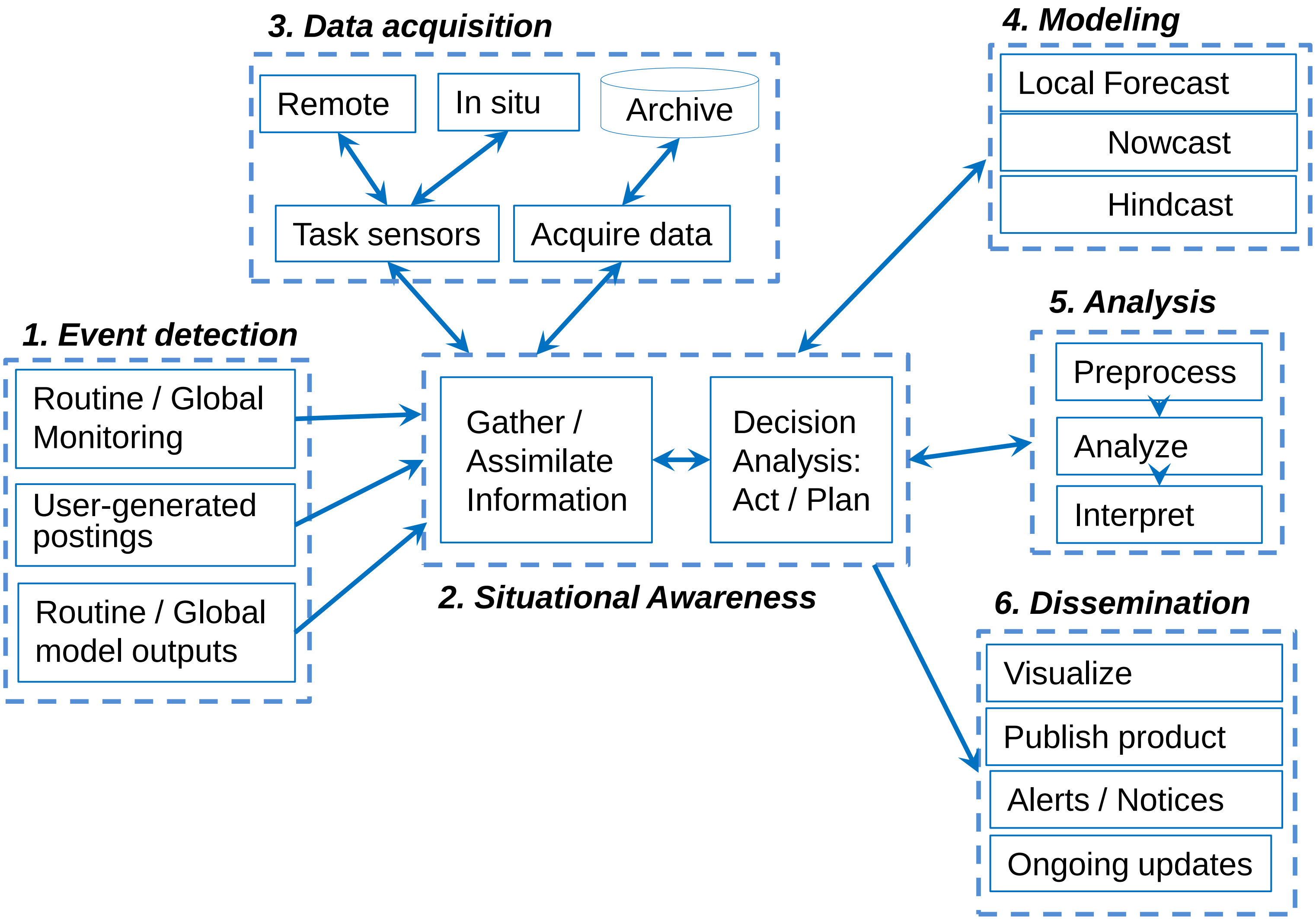
Enterprise Viewpoint

- Scope & purpose based on
  - GEO Task DI-01
  - GEOSS Strategic Targets
  - CEOS WGISS charter
- Consistent with GEOSS principles
  - System of Systems
  - Data Sharing Principles
  - Interoperability Arrangements
- Lifecycle phases
  - Mitigation
  - Warning
  - Response
  - Recovery
- Disaster types
  - Flooding
  - Earthquakes
  - Volcanoes
  - Drought
  - Windstorms
  - Landslides
  - Wildfires
  - Tsunamis



Activities involved in Satellite Data Support to Disaster Management

Enterprise Viewpoint



Stages of Disaster Management Capability

Enterprise Viewpoint

- System initiation vs. steady-state operations
- Initiation stage:
  - Identify inputs for event detection; event triggers
  - Choose indicators for situational awareness (e.g., flood extent)
  - Define modeling elements (e.g., regional flood model)
  - Develop workflows and data flows (for processing and delivery)
  - Define automation goals (e.g., subscriptions, custom products)
  - Validate observations, models
- Steady state / operational stage:
  - Monitor data streams, detect events & trigger workflows
  - Track key indicators
  - Task sensors; Acquire data
  - Run models (hindcast, nowcast, forecast)
  - Analyze and disseminate products

Information content & semantics

Information Viewpoint

- Basis in GEOSS AIP Architecture:
  - Spatial referencing • Feature Model
  - Data Quality / Provenance • Data Policies / Licensing (etc.)
- Priority observations by disaster type & phase
  - based on prior CEOS / GEO studies
- Metadata
  - provenance, quality, fitness for use – esp. based on
    - sensor type • revisit frequency • spatial resolution
    - wavelength • timeliness of product availability
  - Semantic definitions and relationships
    - Terminology: UNISDR; GCMD/IDN keywords; Unidata CF conventions
    - Ontologies, e.g., NASA-JPL SWEET
    - Semantic languages, e.g., RDF, SPARQL

Computation and Services

Computation Viewpoint

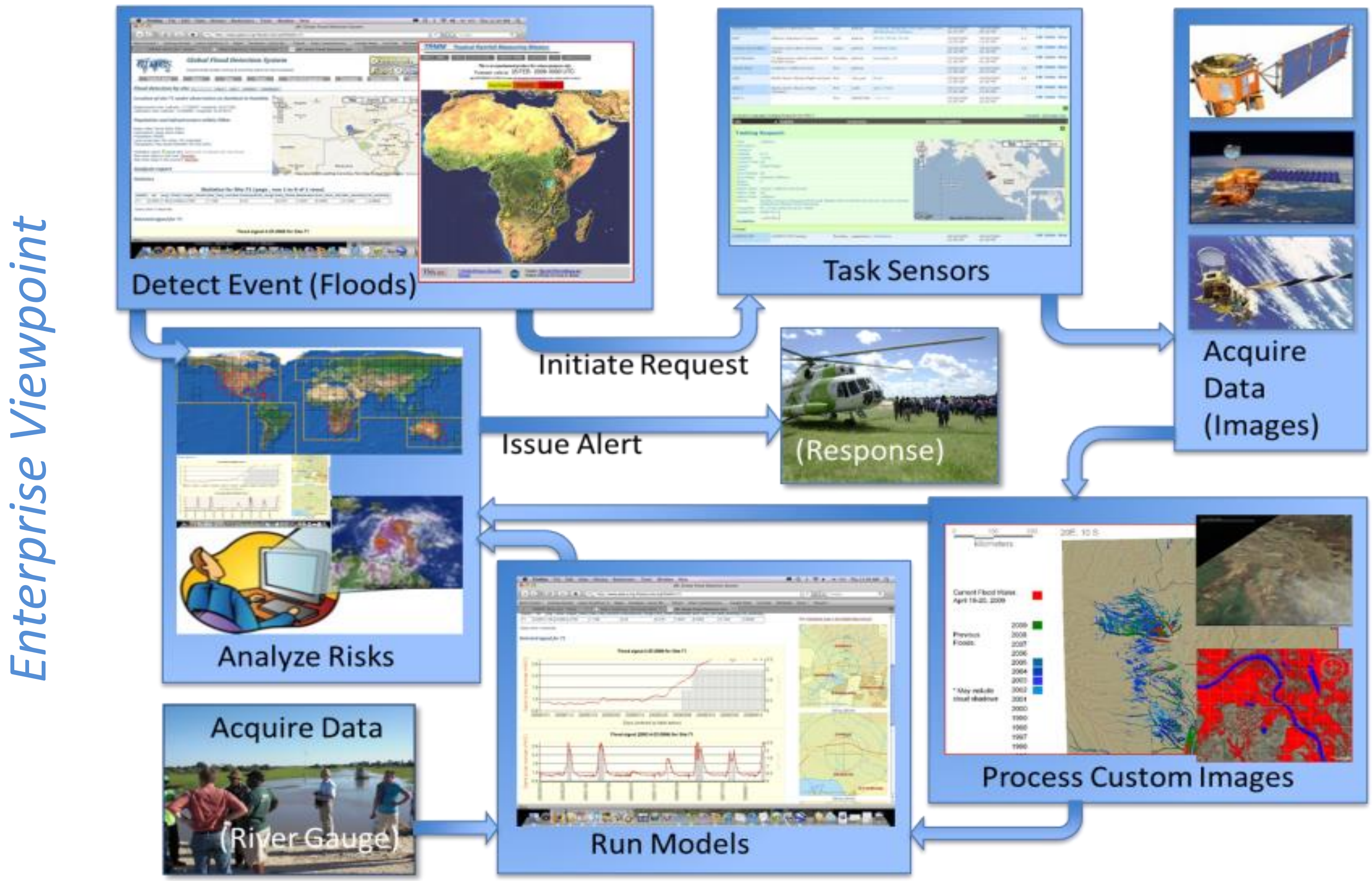
- Generic service types (from AIP-5 architecture):
  - Catalog Registration & Search
  - Portrayal / Display / Styling
  - Data Access & Ordering
  - Processing algorithms
  - Sensor access & control
  - User management
- Disaster-specific service types:
  - Event detection
  - Sensor tasking
  - Data Analysis & Interpretation
  - Modeling & Prediction

Namibia Sensor Web Flood / Health Pilot

Overview

- Ongoing collaboration between NASA and Namibian govt.
  - Incl. local and regional governmental officials, universities, and local communities most affected by annual flooding events
  - Part of the CEOS and GEO workplans
- Supporting disaster warning, response, and recovery with
  - Satellite data: EO-1, Radarsat, MODIS, TRMM, ASTER, Landsat 8
  - Hydrological models – esp. CREST Flood model (Oklahoma Univ.)
  - Geospatial and I.T. resources:
    - OpenStreetMap tools and standards => facilitate sharing data
    - Web Coverage Processing Service (WCPS) => create new products in real time
    - Single sign on => streamline inter-organizational workflows
    - GeoSocial API => infuse social media into all of the above

Namibia Sensor Web Pilot: Activities (use cases)



GROUP ON EARTH OBSERVATIONS

Working Group on Information Systems and Services

OGC Open Geospatial Consortium, Inc.

Stinger Ghaffarian Technologies

Global Science & Technology, Inc.

Namibia Flood Pilot: Obtaining and Handling Data

Information Viewpoint

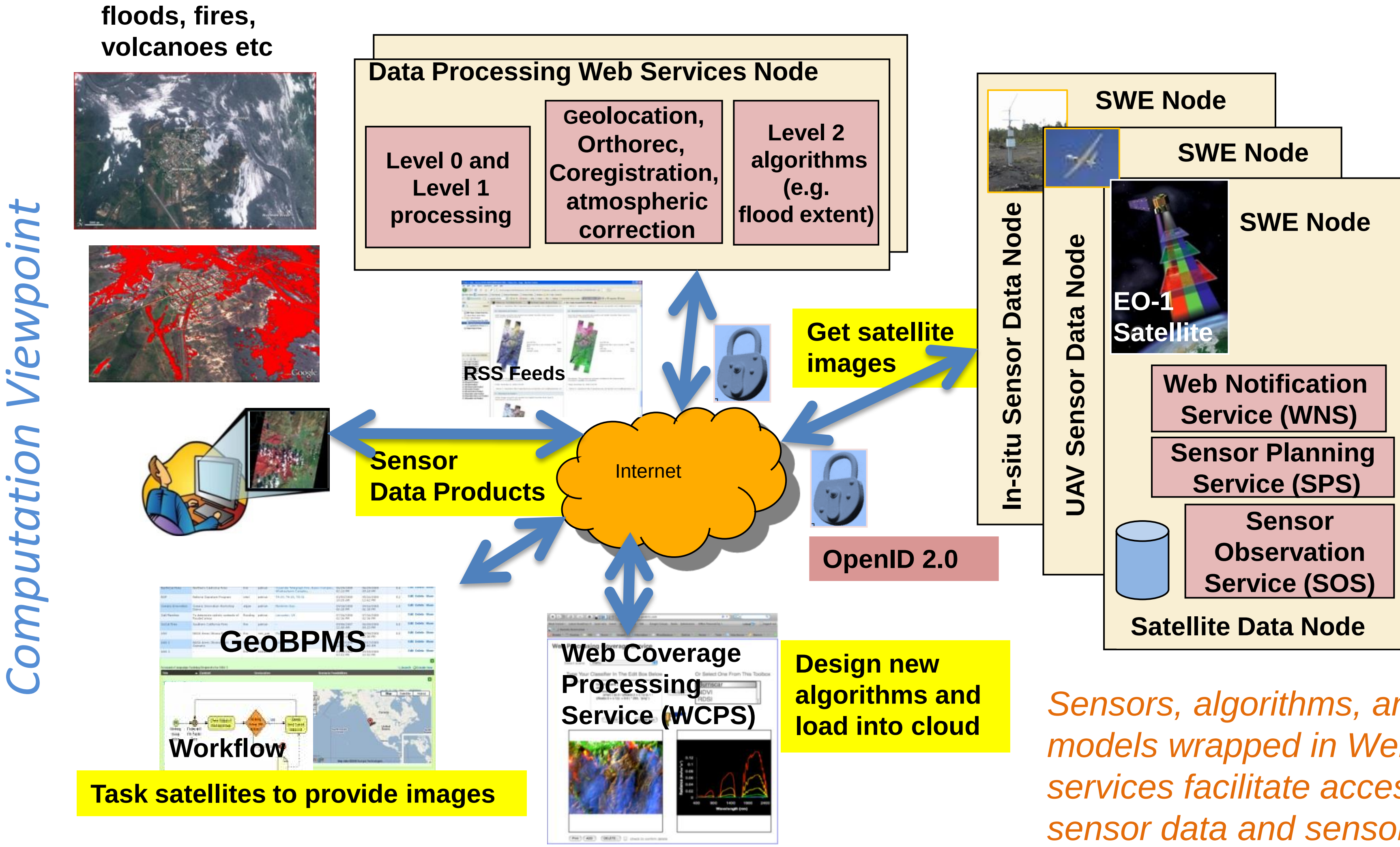
- Typical process:
  - Acquire data from multiple satellite such as EO-1, RADARSAT
  - Harvest products from global monitoring platforms (MODIS, Landsat)
  - Process data: Decoding & Calibration (L0->L1), Orthorectification, Co-registration, Atmospheric Correction
  - Interpret / classify data: Flood extent *vs.* “normal” water boundaries
- Technical challenge: detecting water reliably via remote sensing
  - Especially water in areas with reeds growing
  - Experimenting with calibration and validation methods based on in situ observations, managed via OpenStreetMap tools and a PostGIS database
  - Refining the process via yearly visits
- Technical challenge: satellite image co-registration, georectification
  - Using Digital Elevation Models (DEMs) to cross-correlate water locations (and to discard spurious water detections from EO-1 or RADARSAT)

Namibia Flood Pilot: Sensor tasking, Modeling, and Forecasting

Computation Viewpoint

- Using rain gauges to calibrate rainfall estimates and hydrologic models for use in flood prediction
  - Rainfall estimates from TRMM
  - Flow estimates from CREST water balance model
    - (Coupled Routing and Excess STorage – from Oklahoma U. & NASA SERVIR)
- Using add'l models for flood estimation and prediction:
  - RiverWatch (based on AMSR-E and TRMM microwave sounder)
  - Global 15km flood model *(by Robert Adler – U. Maryland)*
  - NASA GEOS-5, NOAA GFS global models => rainfall predictions
- Global monitoring imagers (MODIS, Landsat)
- Automated tasking of EO-1 satellite
  - Future goal: simultaneously task RADARSAT

Namibia Sensor Web Pilot: Services



Sensors, algorithms, and models wrapped in Web services facilitate access to sensor data and sensor data products

Flood Dashboard

Computation Viewpoint

Daily Report

April 12

Configure Layers
Upload Layer

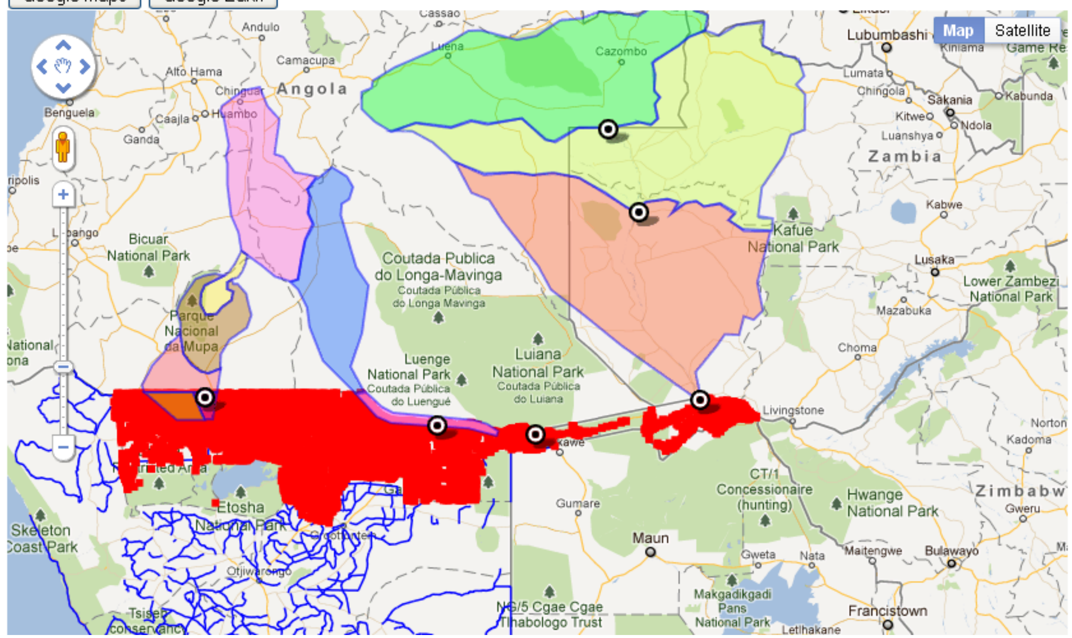
Daily Bulletin:

HYDROLOGICAL SERVICES NAMIBIA – DAILY FLOOD BULLETIN 03 APRIL 2012

View Complete Current Bulletin
View Bulletin Records
Search Bulletin Records
New Bulletin

- River Stations
- SensorWeb Layers
- Water Lines and Areas
- Satelite Overlays
- Ground Pics
- Kavango Radarsat Data
- Cuvelai Radarsat Data
- TRMM Rainfall Accumulation and Flood Forecast
- Global Scene Counts
- MODIS Floodmaps
- Infrastructure

Google Maps | Google Earth



Flood Dashboard enables users to customize view of selected data product layers.
http://matsu.opencloudconsortium.org

Namibia Sensor Web Pilot: Jan. 2013 visit Overview

- Goals:
  - *In situ*, crowdsourced observations to validate RADARSAT-based flood maps and CREST model
  - Explore use of open online tools to manage and share data
  - Experiment with correlation of optical and radar satellite data
- Approach:
  - NASA team worked with Namibia Hydrological Services (NHS) team
  - On foot, in boats, or on 4-wheelers, recorded GPS readings at the water's edge while viewing satellite overlays depicting the water-land boundary
  - Used OpenStreetMap tools developed by the World Bank to handle and tag satellite / shapefile overlays

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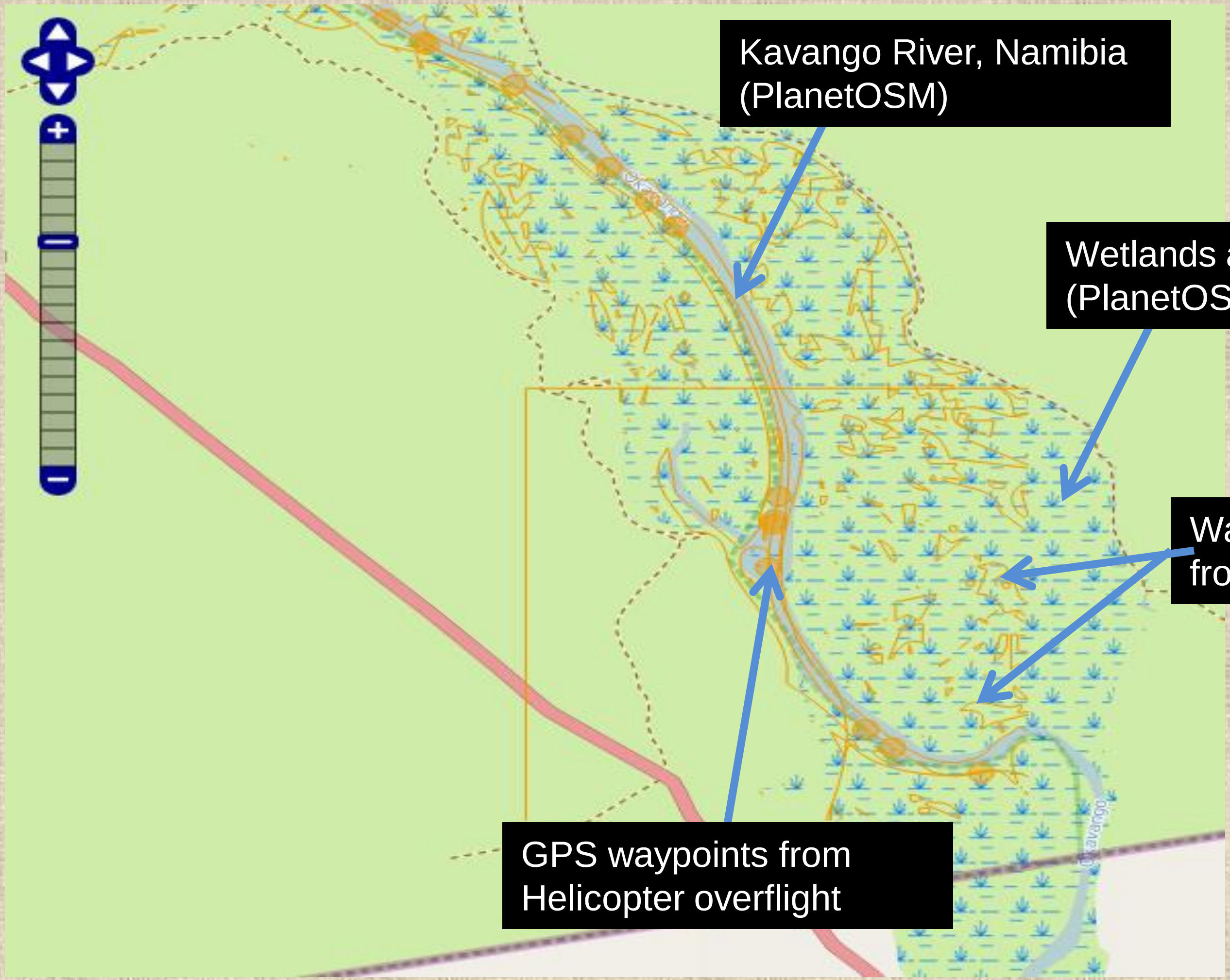
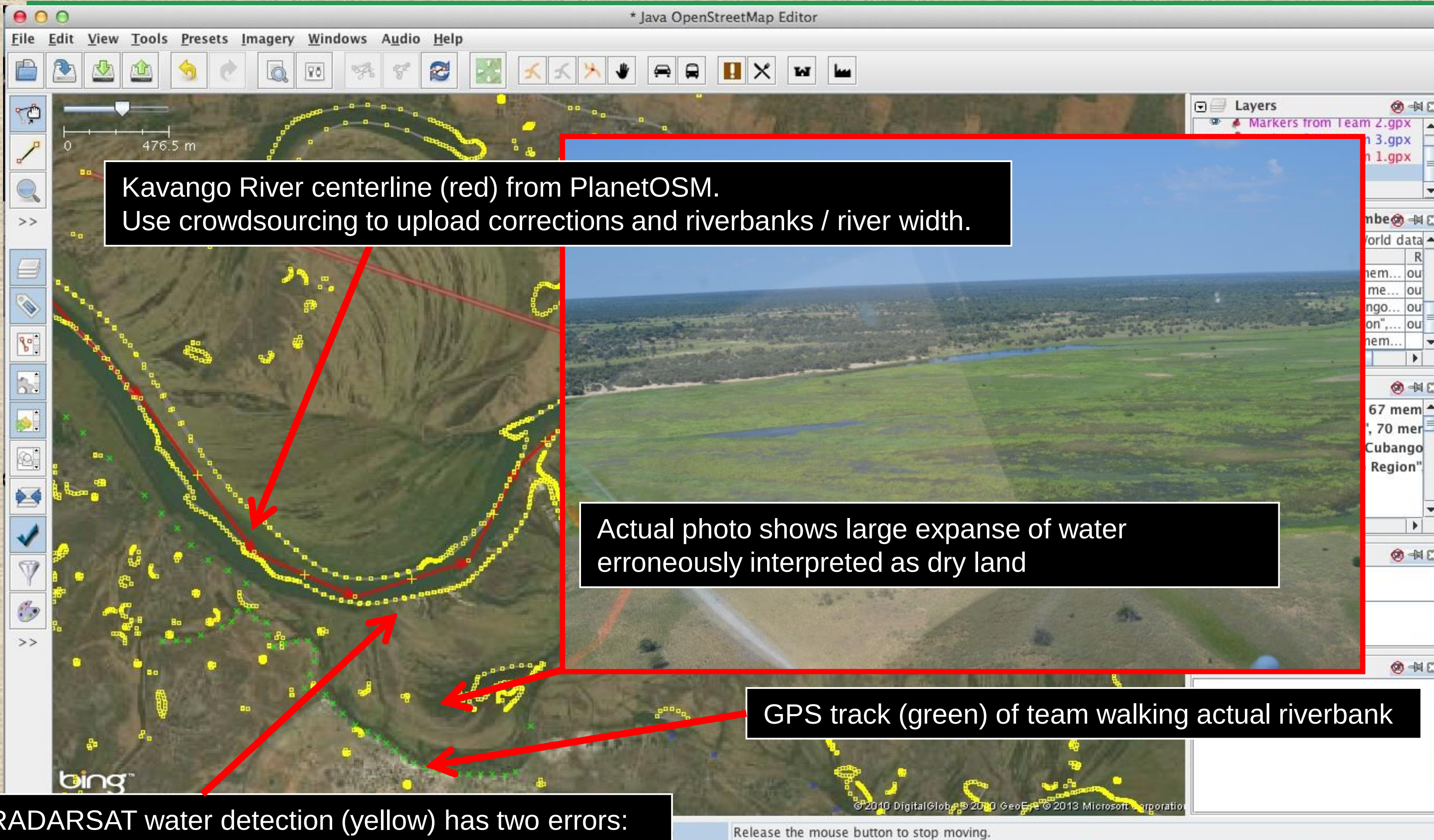
Namibia Sensor Web Pilot: Jan. 2013 visit OpenStreetMap view



Namibia Sensor Web Pilot: Jan. 2013 visit Validation exercise along Kavango River



Kavango River centerline (red) from PlanetOSM.
Use crowdsourcing to upload corrections and riverbanks / river width.

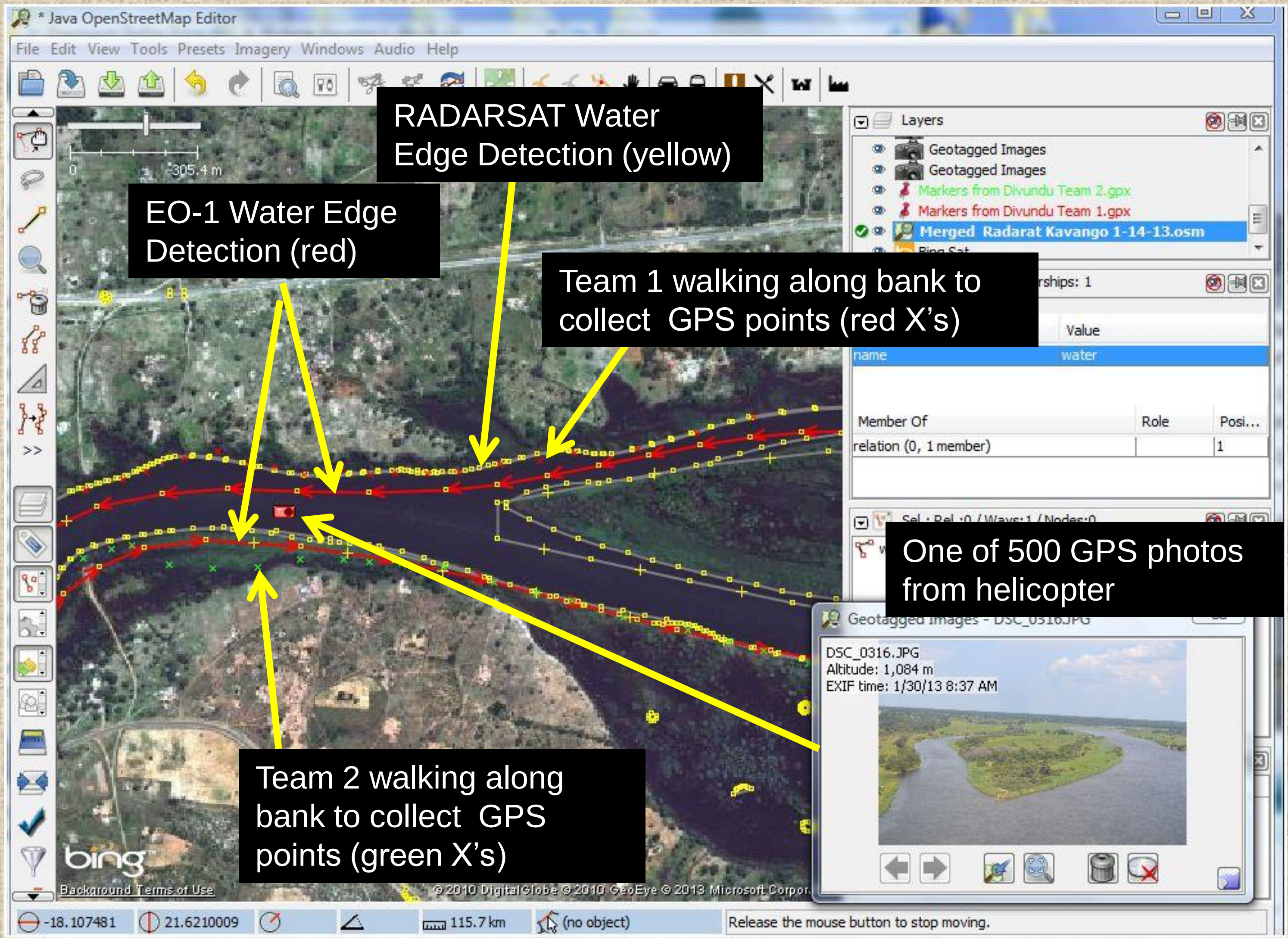
Actual photo shows large expanse of water erroneously interpreted as dry land

GPS track (green) of team walking actual riverbank

RADARSAT water detection (yellow) has two errors:
- offset from actual river location, processing error
- reeds in water detected as dry land detection

Need to tag reed area as wetlands and upload into OSM database

Namibia Sensor Web Pilot: Jan. 2013 visit Validation exercise along Kavango River



Namibia Sensor Web Pilot: Jan. 2013 visit outcomes

- Strengthened local capacity to use satellite data for disaster risk management
- Devised methods & tools to help users provide value to scientists by validating satellite interpretations and models
- Improved techniques for detecting water extent from space
- Useful exercise in integrating remotely sensed with *in situ* observations
    - Decision support in disaster
    - Calibrating and validating new remote data products
    - Augmenting baseline water masks
- Lessons applicable to other regions around the globe
    - E.g. integration of remotely-sensed and in situ observations

Conclusions

- Fieldwork and architecture development were “conjoined” – to mutual benefit
  - Architecture viewpoints (enterprise, information, computation) facilitated learning from diverse experiences like Namibia
  - Namibia experience provided a useful starting point, and ongoing “reality check,” for architecture development
- Outcomes will continue to streamline coordination and collaboration in disaster management – in particular:
  - Suppliers of data or services can focus on a subset of the solution instead of always designing & building end-to-end
  - Integrating in-situ and remote observations is easier and more reliable through improved services, metadata, and semantics.