NASA Support for Disaster Risk Management under the Committee on Earth Observation Satellites

Presented at the IWG-SEM meeting

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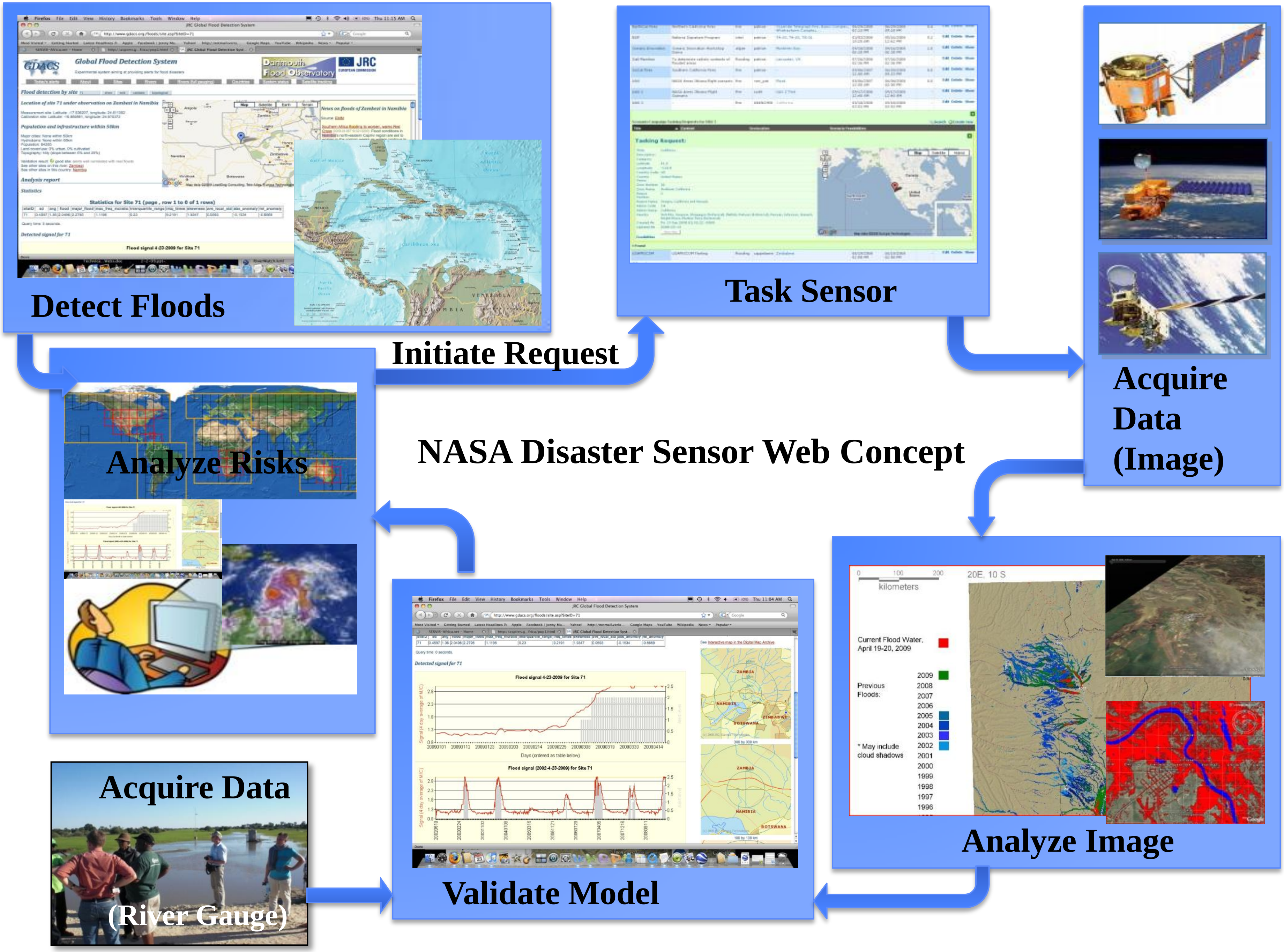
10-11 October 2013

Overview

- National Aeronautics and Space Administration (NASA) satellite tasking, data processing, and distribution for disasters – Sensor Web technology and science research
- NASA collaboration with Canadian Space Agency (CSA) for disaster management
- Committee on Earth Observation Satellites (CEOS) Flood Pilot and Group on Earth Observations (GEO) End-To-End Disaster Systems projects
- Ground validation, crowd sourcing, and hand-held clients



NASA Disaster Sensor Web Concept
Detect Floods
Initiate Request
Task Sensor
Acquire Data (Image)
Analyze Image
Validate Model
Acquire Data (River Gauge)
Analyze Risks

NASA Web Service URLs

- OpenID Provider-Server https://op.geobliki.com/ controls the security (this is where you setup your account)
- Campaign Manager http://geobpms.geobliki.com/home allows tasking requests to be submitted (i.e., targets)
- EO-1 Server http://eo1.geobliki.com/ this is where EO-1 data can be found along with the status of future and past taskings
- Radarsat Server http://radarsat.geobliki.com/radarsat where we provide access to Radar raw data, browse images, metadata, and processed flood products
- MODIS Flood Server http://oas.gsfc.nasa.gov/floodmap/ is where you can point your browser to manually check on daily MODIS flood maps (browser GUI-based only)
- MODIS Flood Server http://modis.geobliki.com/modis is the server that provides and API for accessing the daily MODIS maps

NASA URLs Concluded

- Flood Dashboard Client http://matsu.opencloudconsortium.org/namibiaflood this is an example of a client implementation that runs on a cloud computing platform provided through a collaboration with the University of Illinois/Chicago
- Web Coverage Processing Service (WCPS) http://matsu.opencloudconsortium.org/wcps/session/login is where you go to generate and run algorithms against satellite data
- Pub/Sub Server http://opsb.geobliki.com/session/new is where you setup a subscription for requesting notifications about new data in your area or from a particular instrument or with a particular feature or….The notifications come via Email, SMS, or twitter and contain RSS or Atom feeds for you to follow to find the processed or raw data. Clients can be automated to monitor the feeds and pull the data they are programmed to look for

NASA-CSA Collaboration Objectives

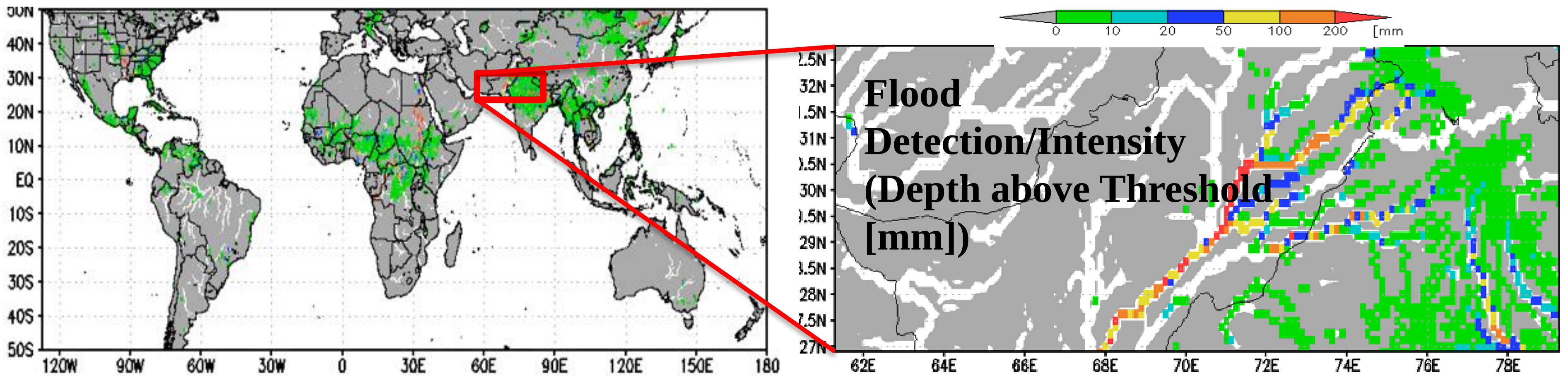
- To demonstrate the effectiveness of satellite imagery to strengthen regional, national and community level capacity for mitigation, management and coordinated response to natural hazards
- To identify specific satellite-based products that can be used for disaster mitigation and response on a regional level
- To identify capacity building activities that will increase the ability of the region to integrate satellite-based information into disaster management initiatives

Collaboration Approach

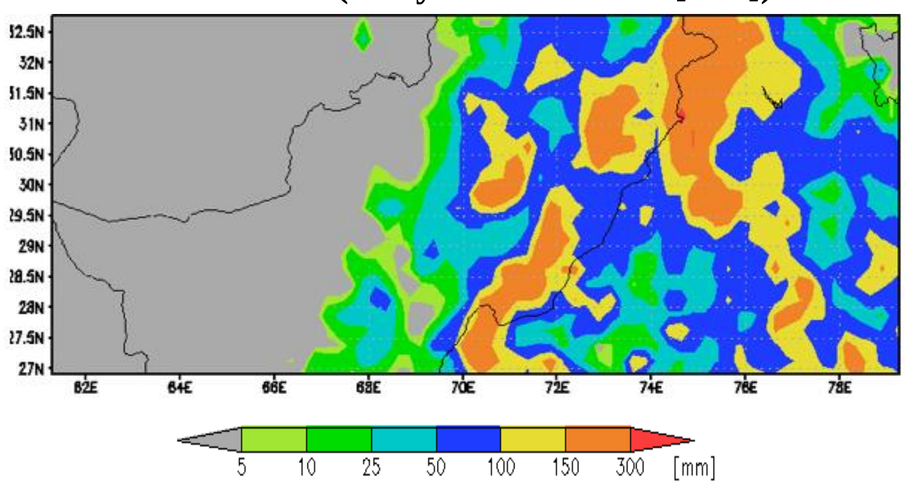
- Focus on areas where Earth Observations from satellites can have most impact (flooding, landslides, volcanoes, wildfires, etc.) and on large-scale disasters
- Select a small number of regional and national partners to validate usefulness of Earth Observations
- National agencies solicited in 3 regions – Caribbean/Central America, Southern Africa, and Southeast Asia (lower Mekong/Indonesia/Java) and partners selected based on:
  - Commitment to make relevant data sets available
  - Agreement to provide direct support (in-kind)
  - Assurance of close collaboration between key national, regional, and international players
  - Representative cross-section of GIS capability development
- Regional Teams created in all three areas with broad participation from concerned Departments
- Global Component setup for low-spatial-resolution, high-temporal-resolution assets

Global Flood Monitoring System (GFMS) Using Satellite Rainfall and Hydrological Model

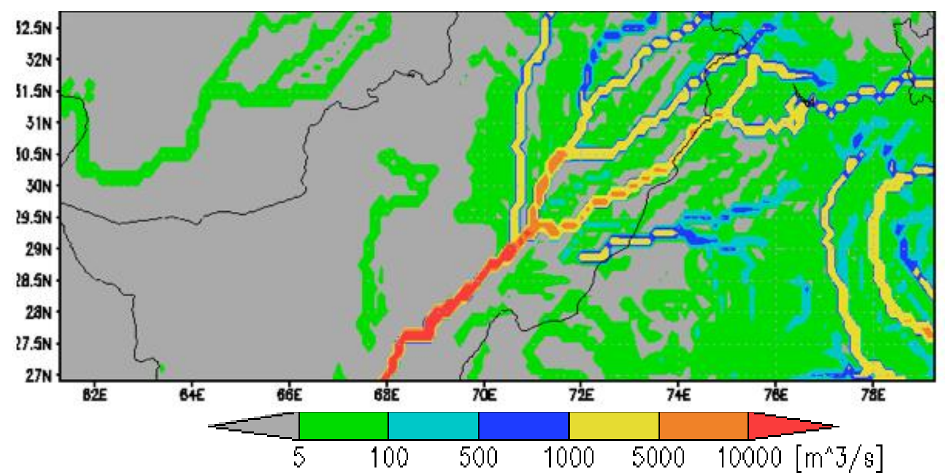
Example: Detection of Recent Flooding in Pakistan 20 August 2013 06 GMT



Rainfall (7 day Accumulation [mm])



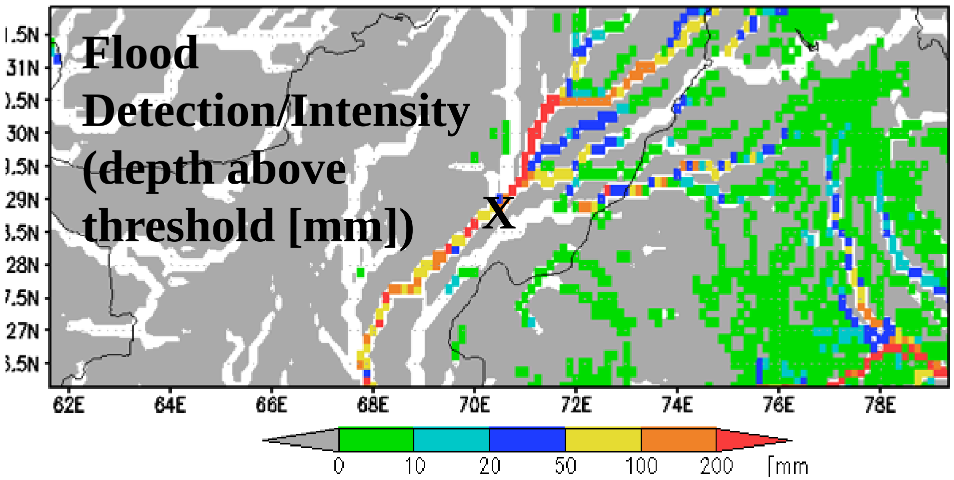
Streamflow [m^3/s]

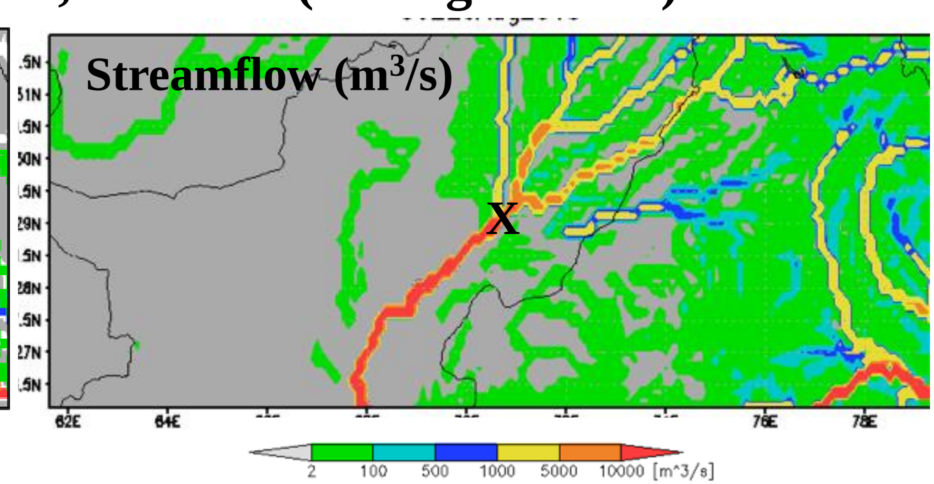


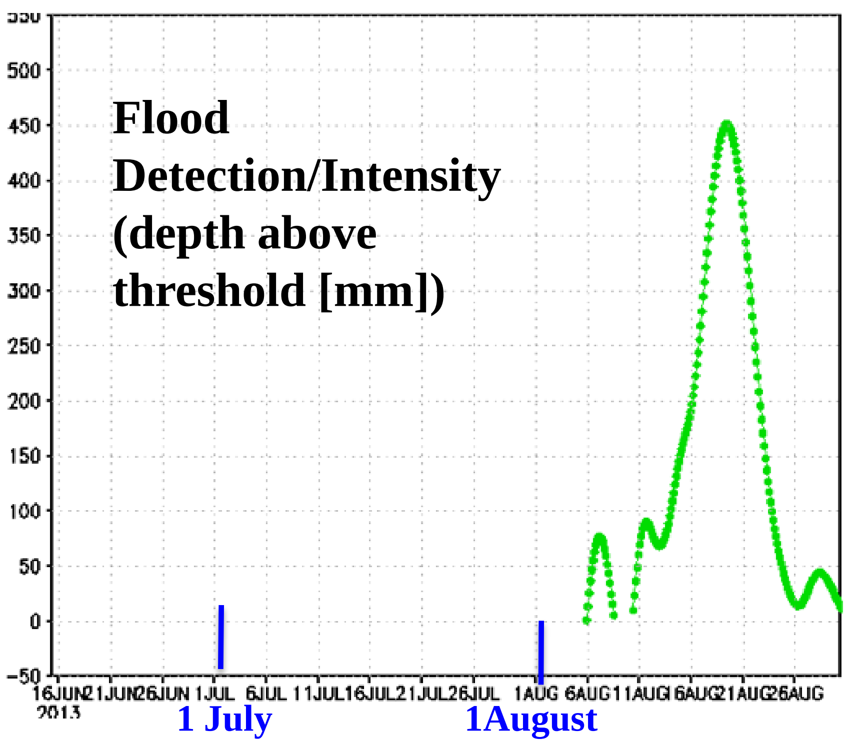
http://flood.umd.edu/

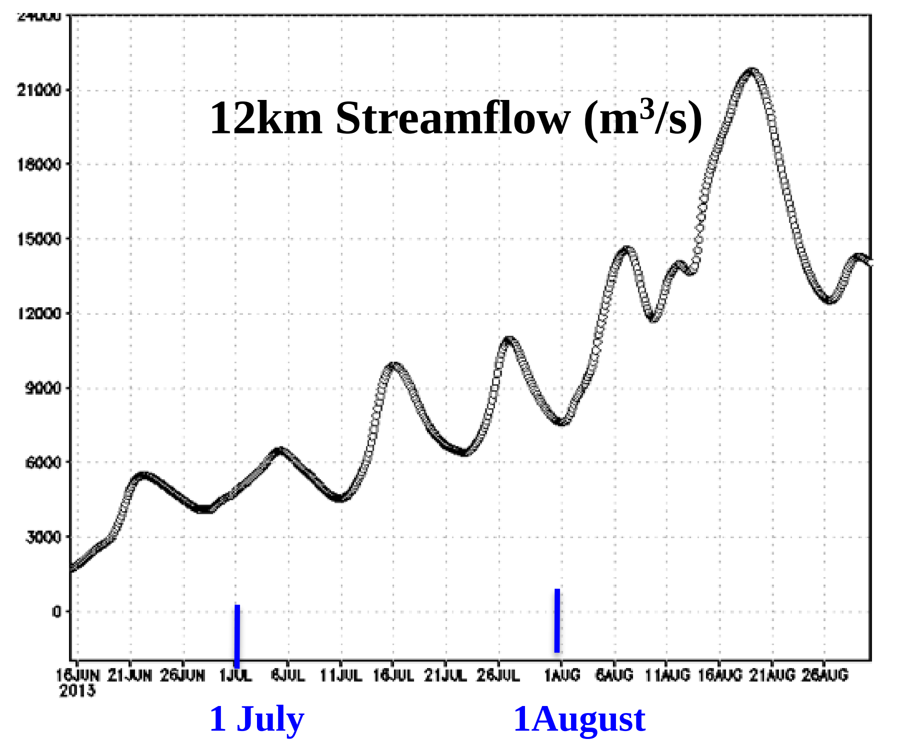
Adler/Wu U. of Maryland

Recent Flooding in Indus River, Pakistan (20 August 2013)





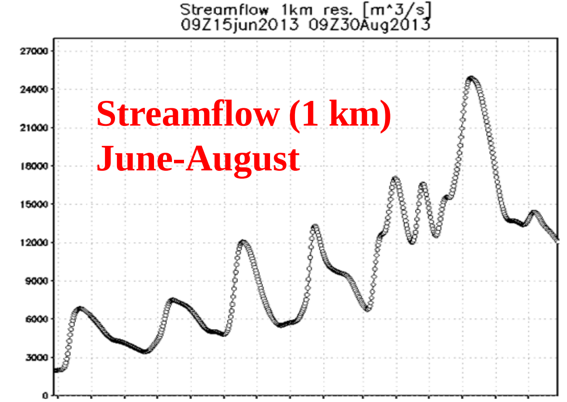


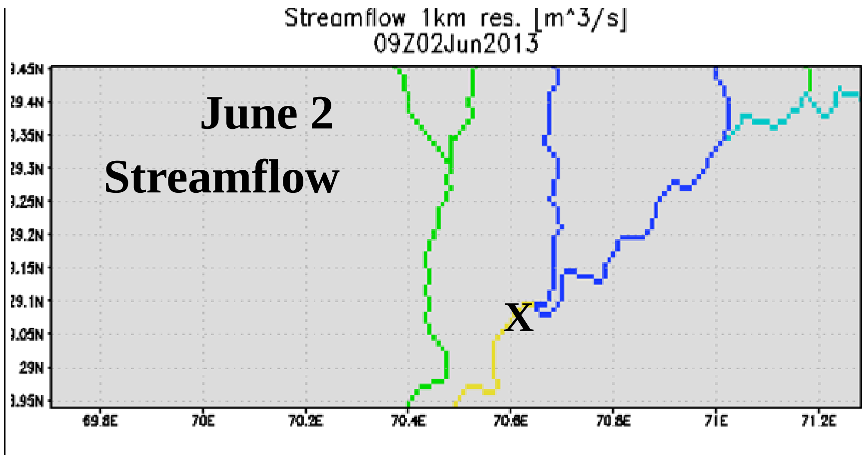


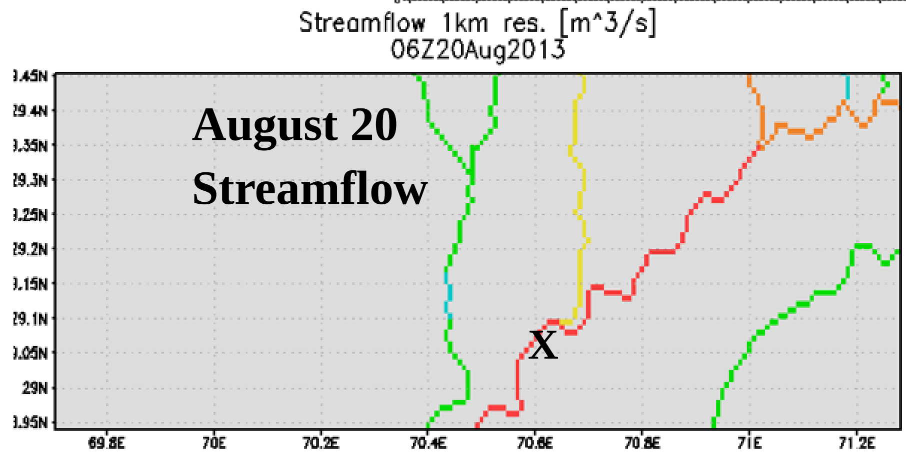
Real-time Calculations at <u>1 km</u>

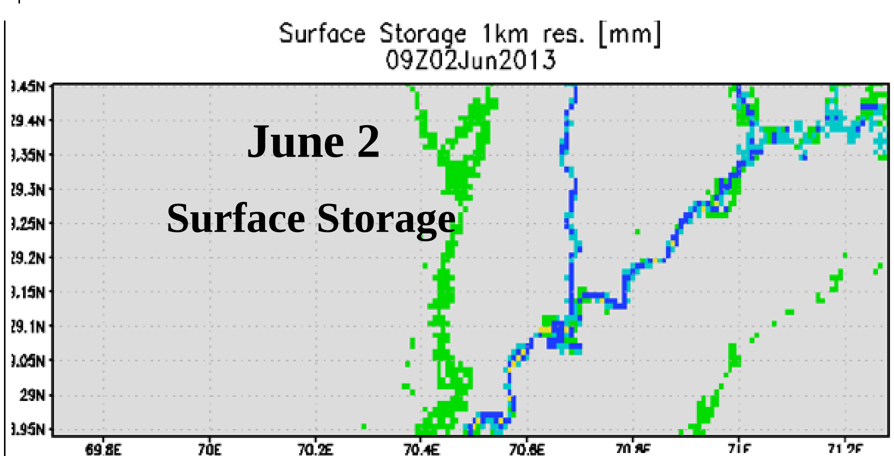
Streamflow and

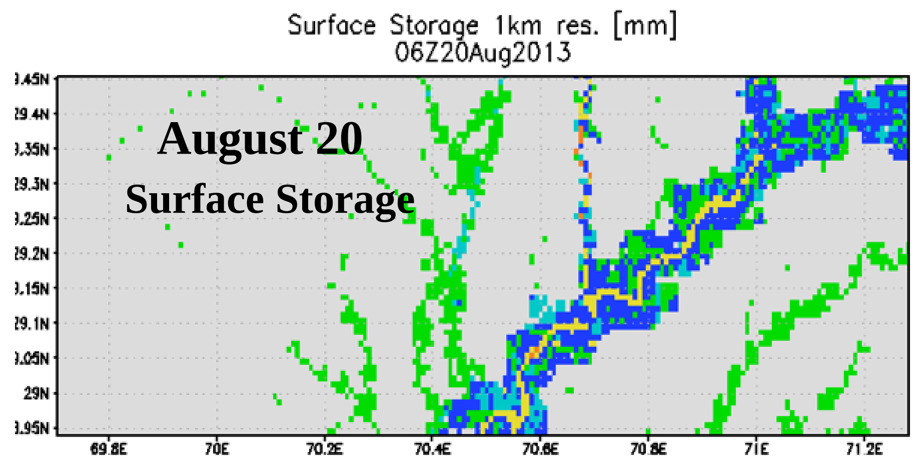
Water Storage (Routed Runoff + Bank Overflow)

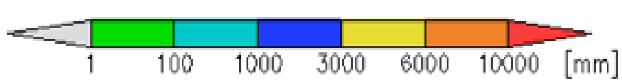












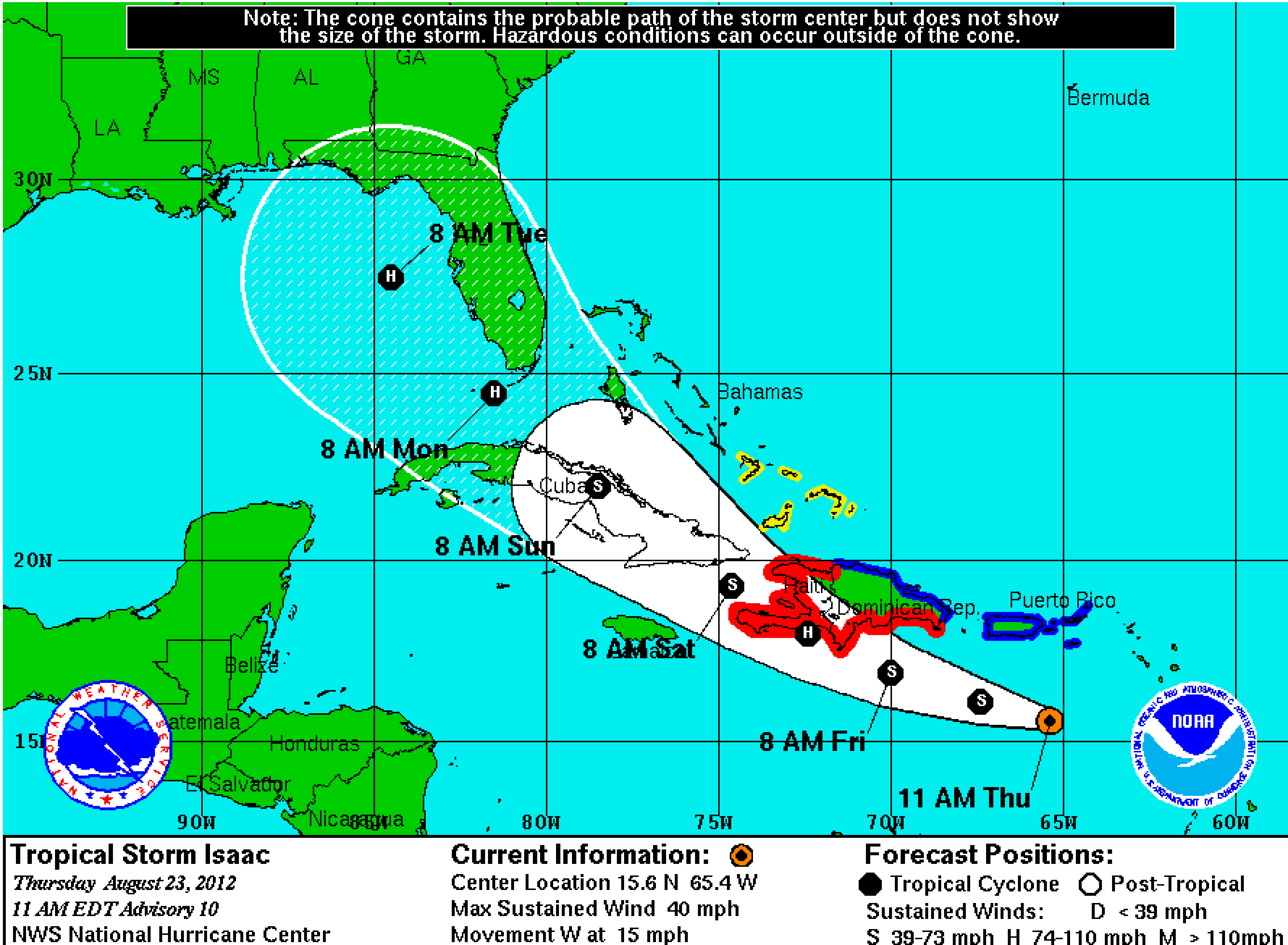
Example of Caribbean Satellite Disaster Pilot (CSDP) Steering Committee

- Guy Aube (CSA)
- Philippe Bally (ESA)
- Emil Cherrington (Cathalac)
- Alessandro Coletta (ASI)
- Lorant Czaran (UN-SPIDER)
- David Farrell (Caribbean Institute for Meteorology and Hydrology)
- Stuart Frye (Chair, NASA/GSFC/SGT) – stuart.frye@nasa.gov
- Francesco Gaetani (GEO Secretariat)
- Bishwa Pandey (World Bank)
- Kenneth Korporal (Environment Canada, GEOSS in the Americas)
- Jennifer Lewis (NOAA)
- Dan Mandl (NASA/SensorWeb)
- Jacob Opadeyi (University of Guyana)
- Bruce Potter (Island Resources)
- Guy Seguin (NASA Consultant/former CSA Engineering Head)

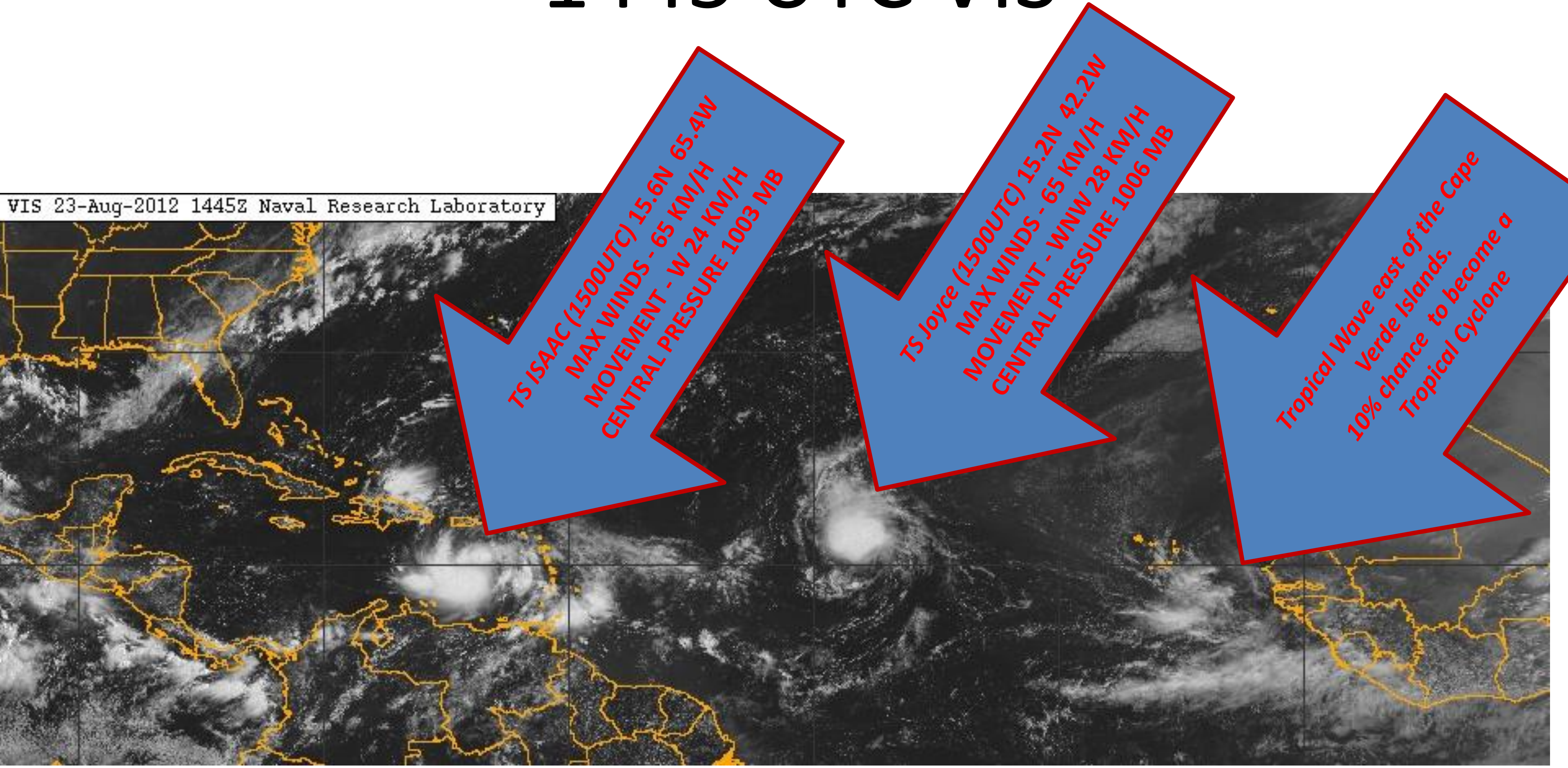
2012 Accomplishments in Caribbean

- MODIS, EO-1, Worldview-2 and Radarsat-2 coverage for hurricanes Ernesto, Isaac, and Sandy for Jamaica, Barbados, St Lucia, British Virgin Islands
- New contacts made in Haiti Risk and Disaster Management for distribution of Hurricane Isaac data products
- Coverage for flooding in Panama, earthquake in Guatemala, algal bloom in El Salvador, wildfires in Belize, landslides in Trinidad
- 34 Radarsat-2, 3 Worldview-2, and 19 EO-1 images targeted and delivered plus daily coverage with MODIS and the Global Flood Monitoring System
- Worked with CSA and MacDonald-Dettwiler to begin development of a REST-ful tasking interface between the Campaign Manager (geobpms.geobliki.com) and the Radarsat-2 image ordering system

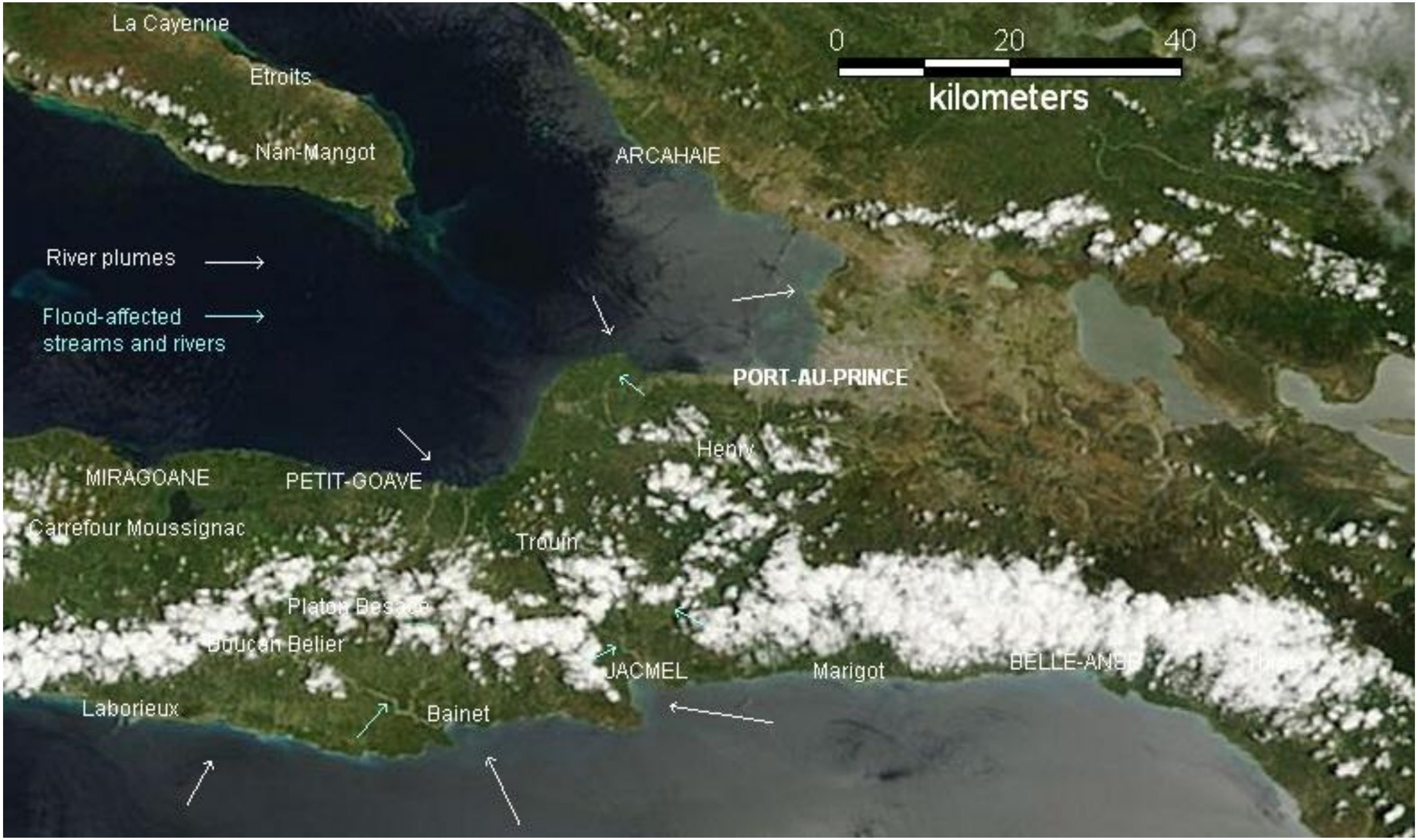
NHC's Potential Track Area for TS Isaac



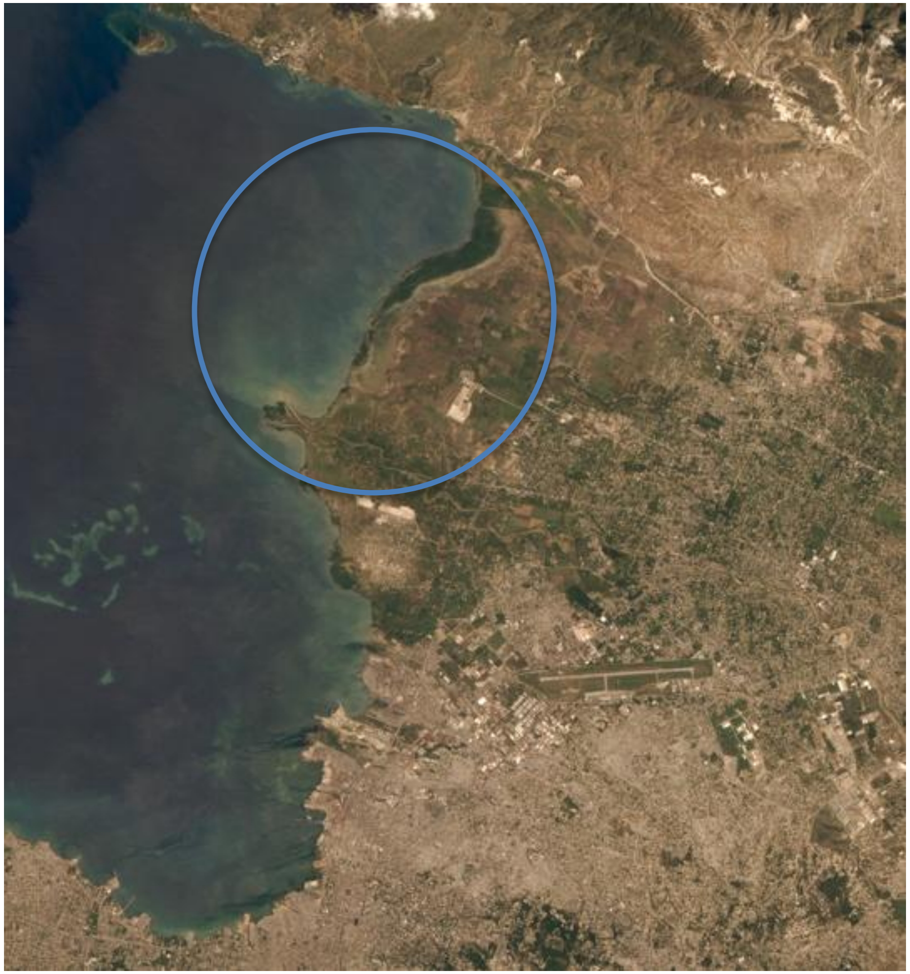
1445 UTC VIS


VIS 23-Aug-2012 1445Z Naval Research Laboratory
TS ISAAC (1500UTC) 15.6N 65.4W
MAX WINDS - 65 KM/H
MOVEMENT - W 24 KM/H
CENTRAL PRESSURE 1003 MB
TS Joyce (1500UTC) 15.2N 42.2W
MAX WINDS - 65 KM/H
MOVEMENT - WNW 28 KM/H
CENTRAL PRESSURE 1006 MB
Tropical Wave east of the Cape Verde Islands.
10% chance to become a Tropical Cyclone

MODIS – ISAAC aftermath



EO-1 Port of Prince, Haiti
Before and After TS Isaac



Haiti, Port of Prince area: August 18, 2012
Pre- TS Isaac
EO-1 ALI scene ID: EO1A0090472012231110P0
Pan-sharpened product

Haiti, Port of Prince area: August 31, 2012
Post- TS Isaac
EO-1 ALI scene ID: EO1A0090472012244110KF
Pan-sharpened product

EO-1 North of Port of Prince, Haiti
Before and After TS Isaac

Haiti, Port of Prince area: August 18, 2012
Pre- TS Isaac
EO-1 ALI scene ID: EO1A0090472012231110P0
Pan-sharpened product

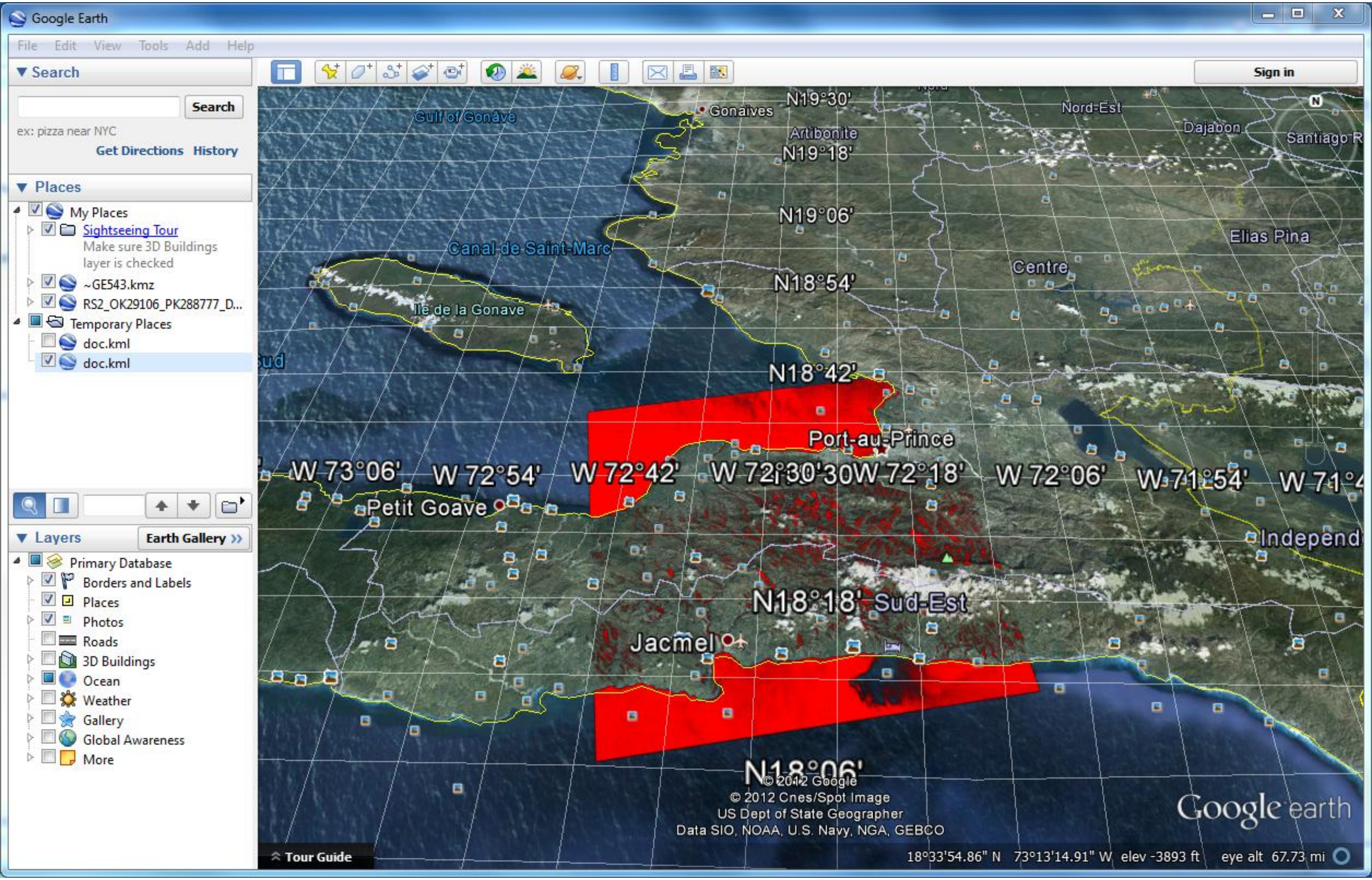
Haiti, Port of Prince area: August 31, 2012
Post- TS Isaac
EO-1 ALI scene ID: EO1A0090472012244110KF
Pan-sharpened product

Radarsat-2 ISAAC aftermath

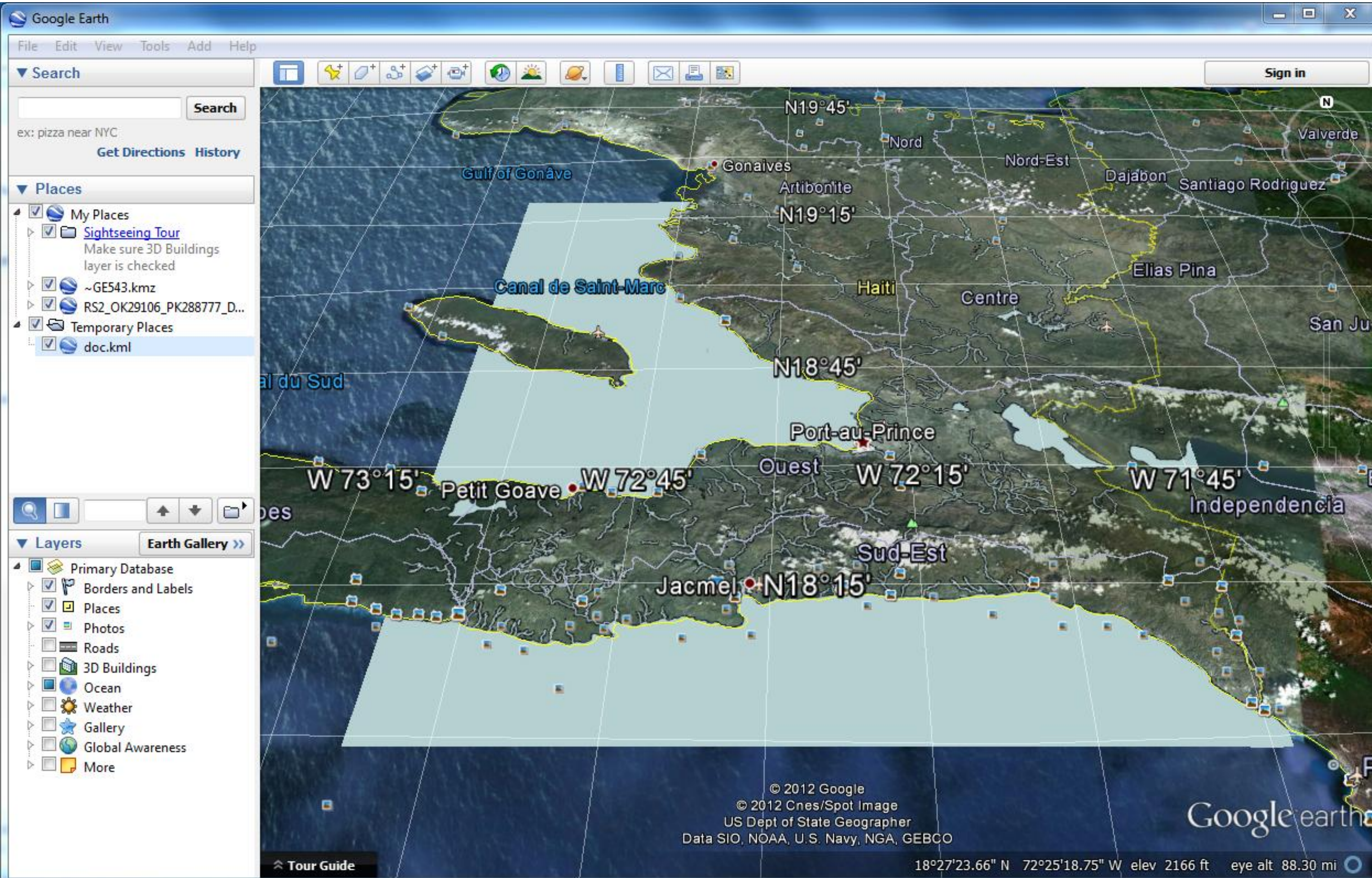
- Developed processing on radarsat.geobliki.com to show water as red layer in Google Earth (next page)
- Extracted Open Street Map baseline water level as light blue layer (second page)
- Served both as tiled doc.kml layers and as Open Street Map polygons (see third page for kml combined overlay)

NASA Web Service URLs and server descriptions available at
http://eo1.gsfc.nasa.gov/new/sensorWebExp/SensorWebReadMore.html

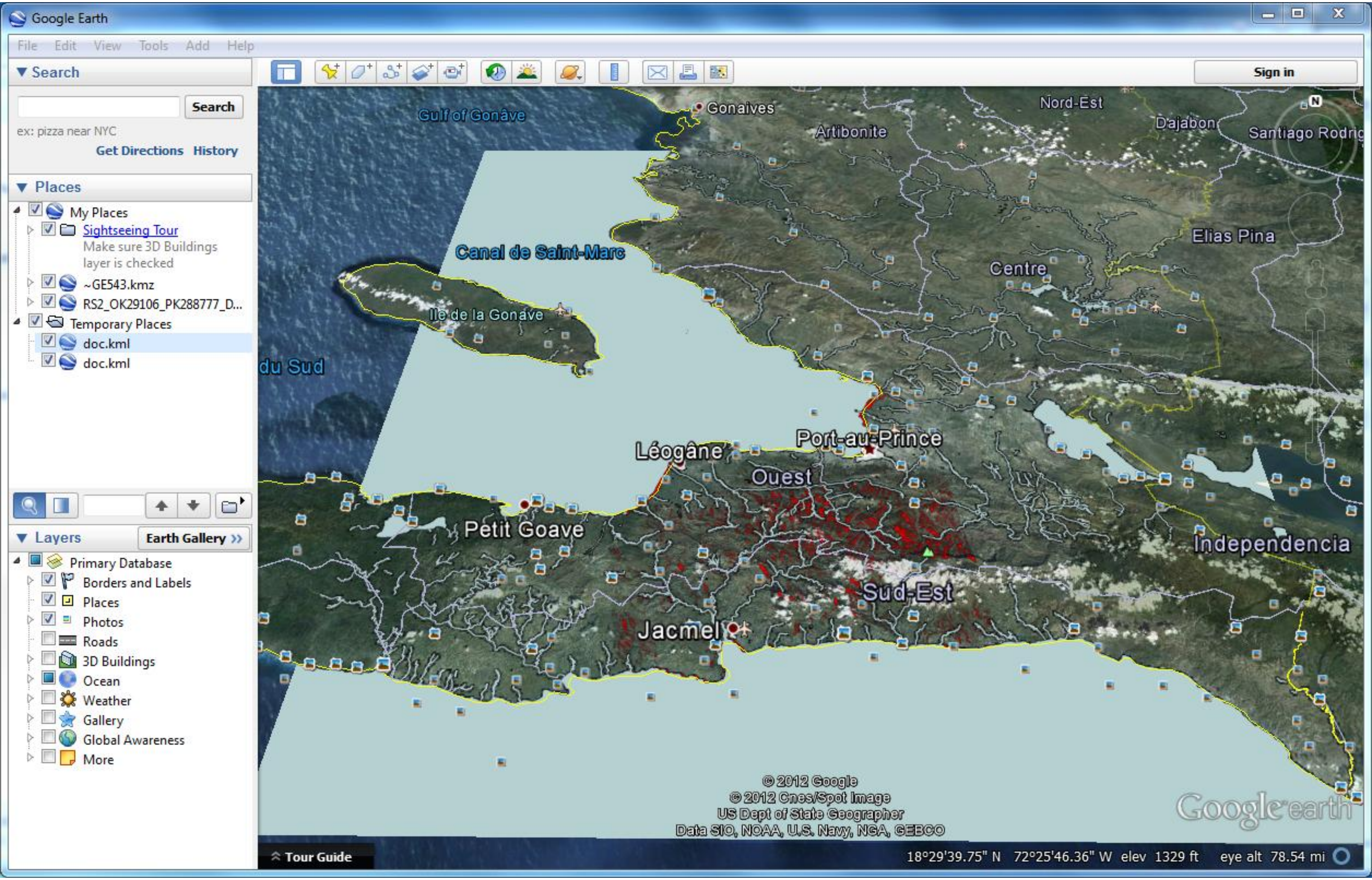
Radarsat-2 flood map (red layer)



OSM Normal Water (blue layer)



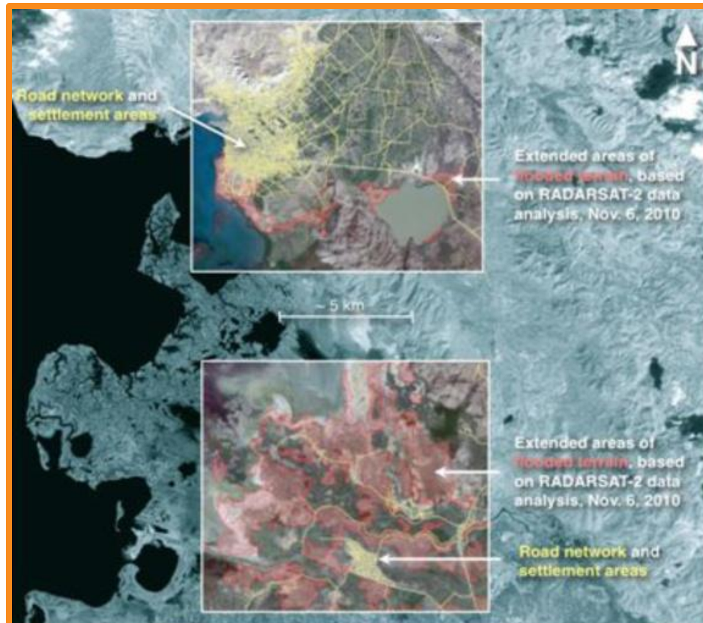
Combined Overlays (blue on red)



Caribbean Combined EO-1 and Radarsat-2 Example

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."

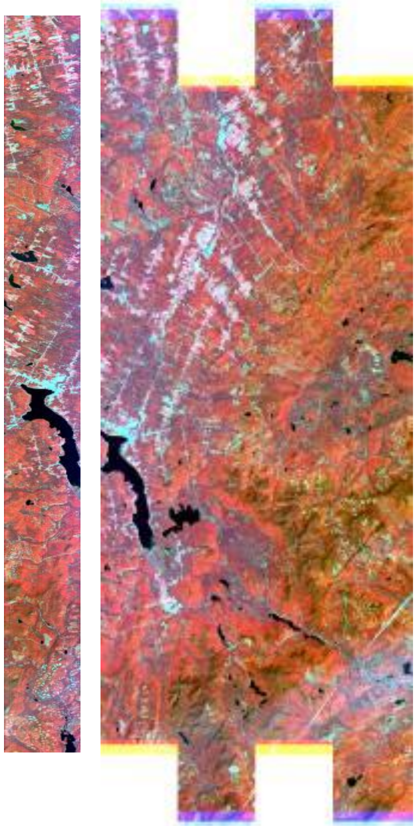
– **Daniel E. Irwin, Director of NASA's SERVIR Program**

EO-1 Observations of Lac Megantic Train Wreck and Oil Spill

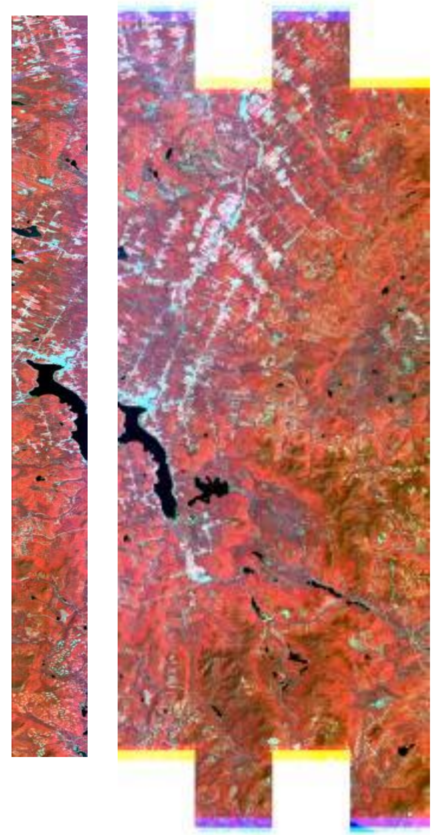
- Images acquired on July 10, 21, 31, August 6, 24, and September 1, 17
  - UTC days 191, 202, 212, 218, 236,249, and 260
- Both ALI (9-30m spectral bands and a 10m panchromatic band) and Hyperion (190- 30m spectral bands in 400-2400 nm range)
- Level 1R (radiometrically corrected) and Level 1G (terrain corrected) delivered plus pan-sharpened products for all ALI scenes

Level 1R Browse Images of Lac Megantic Acquisitions
Hyperion on left, ALI on right

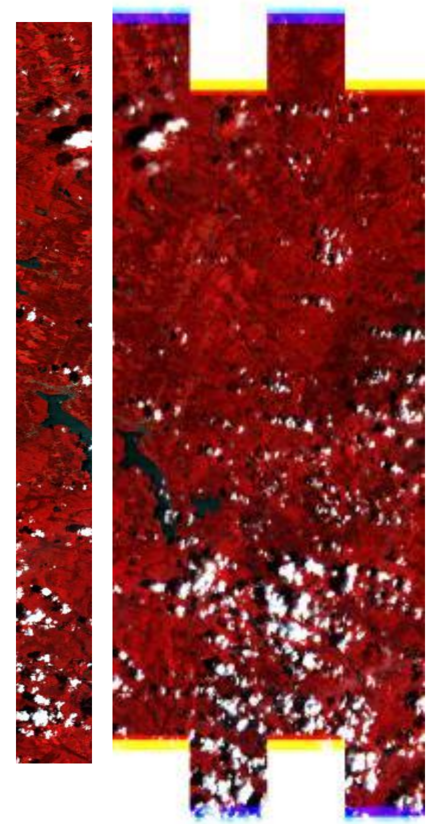
17 Sep



6 Sep

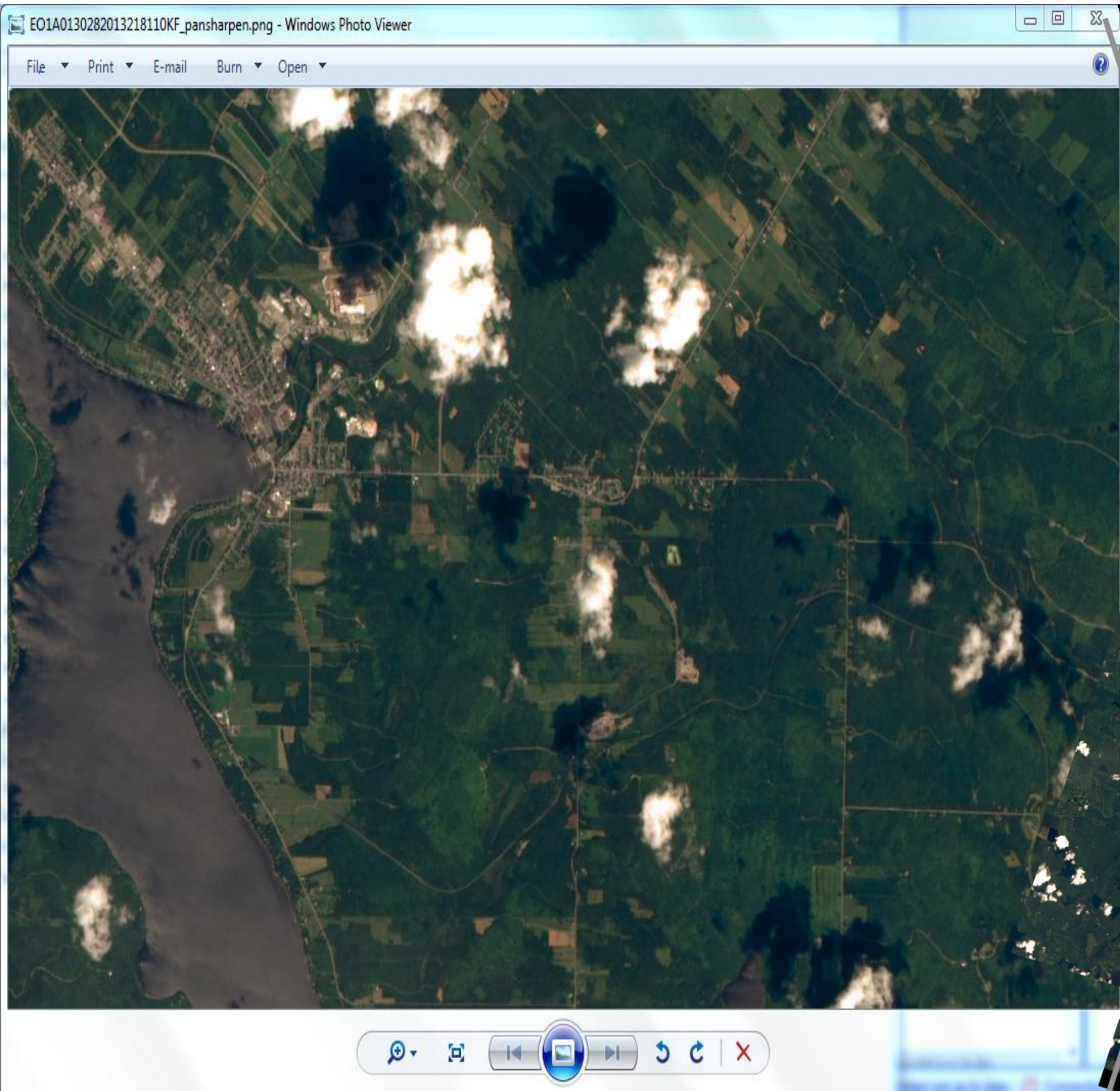


24 Aug



6 Aug

ALI Level 1G with Pan-enhancement



Acquired on 6 August 2013

Full ALI Scene
37X85km

Landsat 8 example in Haiti
LC80090472013117LGN01 vis_composite (5-4-3) (EPSG 4326) TIF Compressed 76.4MB

Using WCPS

Original Data Set 8 OLI Bands TIF 108.7MB each (7461x7281 pixels 30m resolution)

Surface Water Detection Product

Using WCPS

5.9MB TIF LZW Compressed

Note: Particular Algorithm is Not Relevant In this Example

Analysis

- TIF Surface Water Product (5.9MB)
  - Preserves coordinates/projection
  - RGBA (4 bands for a bit mask water/no-water) for visualization
- PNG Product (753KB)
  - But no coordinates/projection information
- After ZIP Compression
  - TIF: 2.2 MB
  - PNG: 638KB (but not useable for cartography)

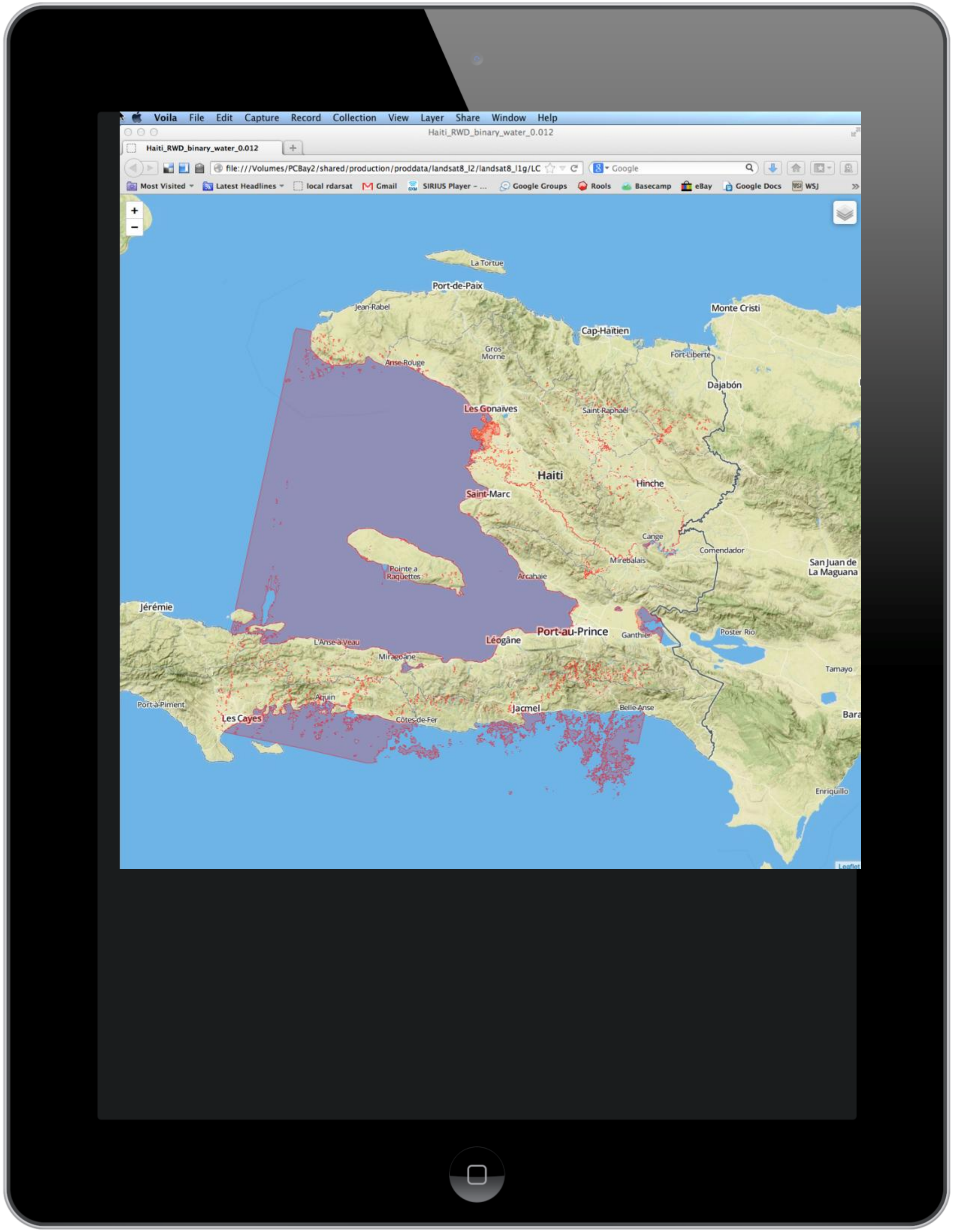
Vectorization

- Autotrace (potrace) and Convert to geojson
  - >10.6MB
- Convert to topojson
  - >3.5MB
- Simplify Lines 0.50 (Visvalingam Algorithm)
  - >2MB
- Compress
  - >350KB

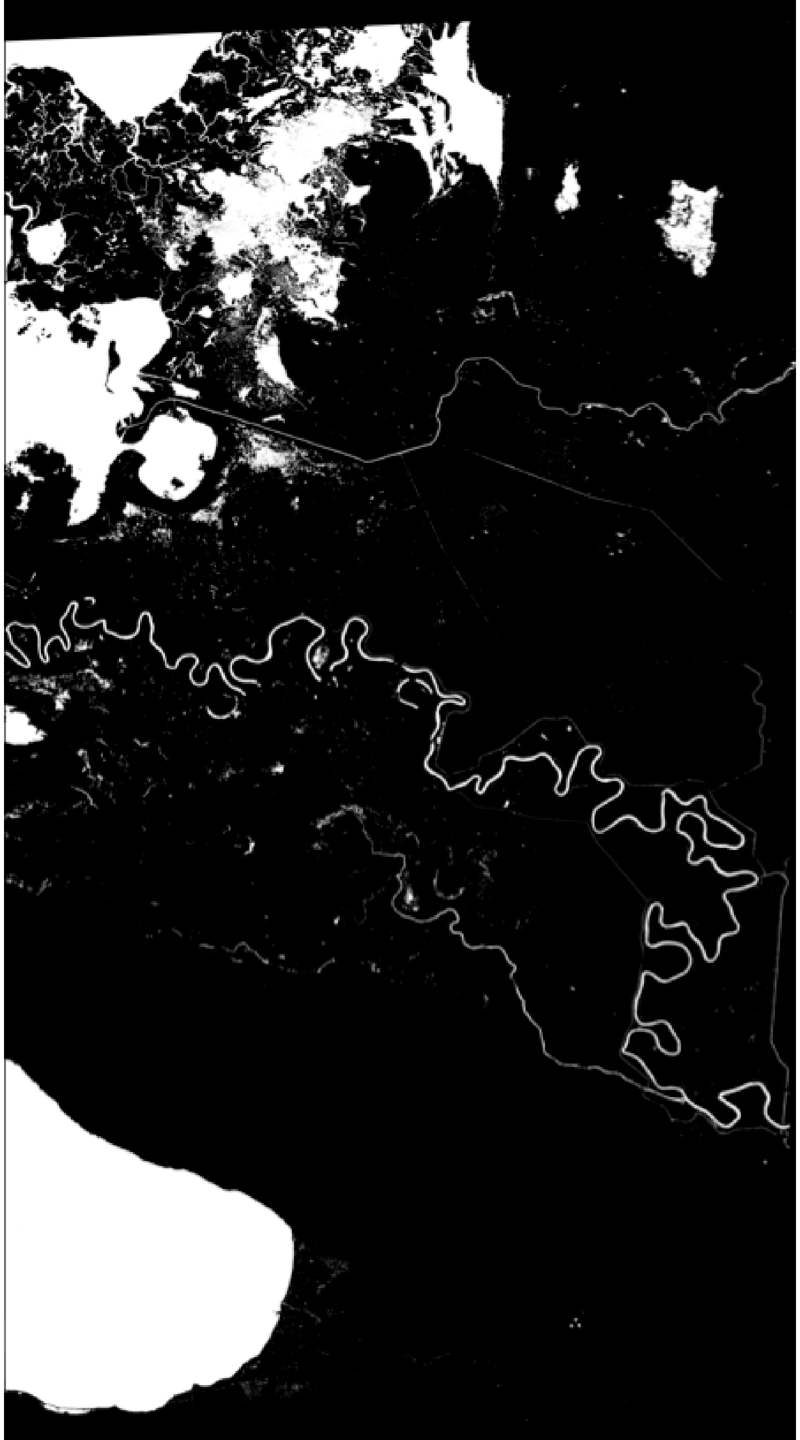
Resulting Product On Mobile Browser

Mapbox.js, MapBox Terrain Layer…

Other Layers Can be Added From OpenStreetMap such as Reference Water…
Or Population Density…



Final Achievement:
Product Compressed Size From:
2.2MB to 350KB



Worldview-2 Processed Data (Binary TIF File)

Surface Water in White

Files: Haiti_RWD_binary_water_0.012.tif
Size is 9419, 17304
Coordinate System is:
```
GEOGCS["WGS 84",
   DATUM["WGS_1984",
      SPHEROID["WGS 84",6378137,298.257223563,
         AUTHORITY["EPSG","7030"]],
      AUTHORITY["EPSG","6326"]],
   PRIMEM["Greenwich",0],
   UNIT["degree",0.0174532925199433],
   AUTHORITY["EPSG","4326"]]
```
Origin = (-72.761256,19.38983)
Pixel Size = (0.000018,-0.000018)

~2m/pixel

Image Structure Metadata:
INTERLEAVE=BAND
Corner Coordinates:
Upper Left (-72.7612560, 19.3898340)
Lower Left (-72.7612560, 19.0783620)
Upper Right (-72.5917140, 19.3898340)
Lower Right (-72.5917140, 19.0783620)
Center (-72.6764850, 19.2340980)
Band 1 Block=9419x1 Type=Byte, ColorInterp=Gray

OpenStreetMap Zoom levels

• Deutsch • **English** • español • français • Nederlands • polski

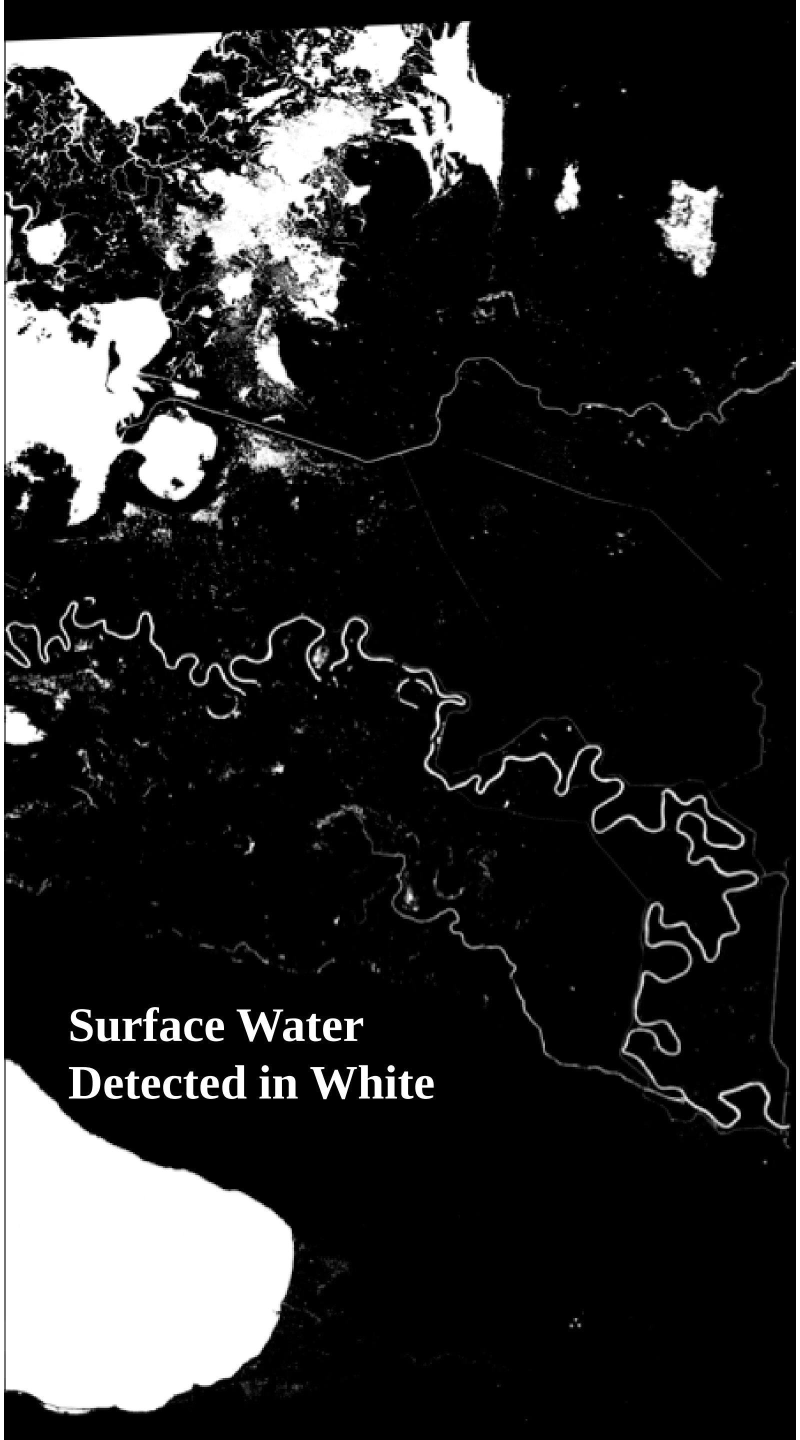
Disaster User Zoom Range 9-18

Image Resolution

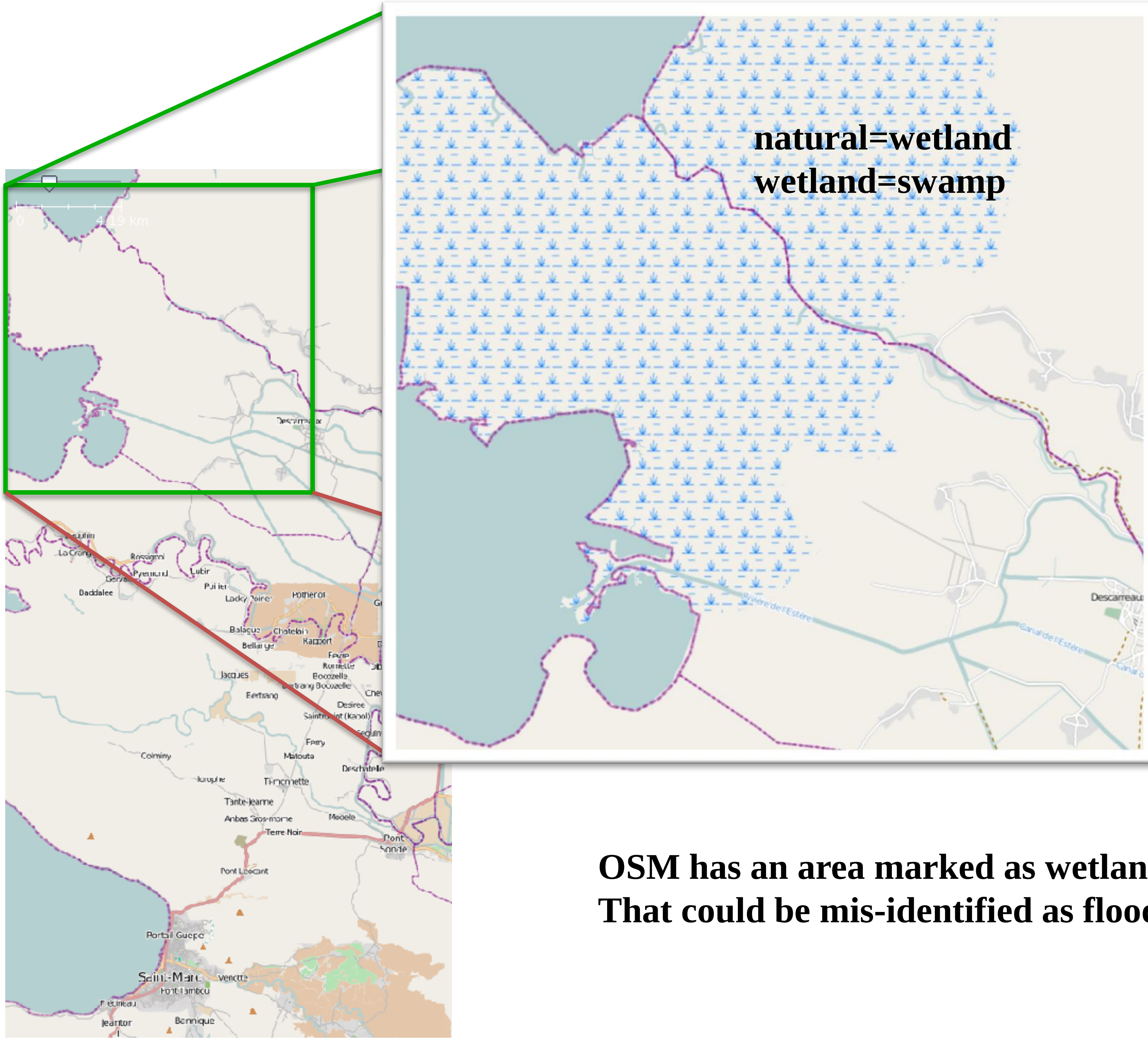
Level	Degree	Area	m / pixel	~Scale
0	360	whole world	156,412	1:500 Mio
1	180		78,206	1:250 Mio
2	90		39,103	1:150 Mio
3	45		19,551	1:70 Mio
4	22.5		9,776	1:35 Mio
5	11.25		4,888	1:15 Mio
6	5.625		2,444	1:10 Mio
7	2.813		1,222	1:4 Mio
8	1.406		610.984	1:2 Mio
9	0.703	wide area	305.492	1:1 Mio
10	0.352		152.746	1:500,000
11	0.176	area	76.373	1:250,000
12	0.088		38.187	1:150,000
13	0.044	village or town	19.093	1:70,000
14	0.022	largest editable area on the applet	9.547	1:35,000
15	0.011		4.773	1:15,000
16	0.005	small road	2.387	1:8,000
17	0.003		1.193	1:4,000
18	0.001		0.596	1:2,000
19	0.0005		0.298	1:1,000

Process

- Generate a binary mask for water detection
- Convert to PNG (Black & White) and then to PNM
- AutoTrace and convert to GeoJSON
- Convert to TopoJSON
- Simplify Lines
- Compress Files for Potential Distribution
- Map viewer in Plain Firefox Browser Using Open Source Libraries


Surface Water
Detected in White


OpenStreetMap
0
4.19 km
RN 1
RN 1
RN 1
L'Estère
Dauphin
La Grange
Rossignol
Gervais
Daddalee
Lubin
Potier
Lucky Poirier
Potherot
Gravé
Balague
Chatelain
Bellange
Rapport
Favre
Romette
Jacques
Boccozelle
Bertrang Boccozelle
Bertrang
Desiree
Duclas
Seguin
Cadeu
Fougère
Ferry
Matouta
Colminy
Deschatelle
Tanfe-Jeanne
Anbas Gros-morne
Terre Noir
Medele
Pont Sondé
Pont Lessant
Portail Guepe
Saint-Marc
Fort Lambeu
Bamnique
Jeantor

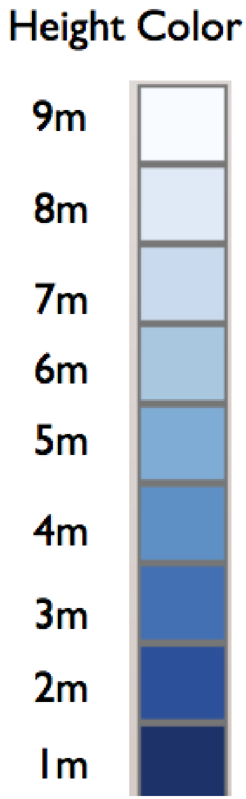


OSM has an area marked as wetland/swamp
That could be mis-identified as flooded area

Height Above Nearest Drainage (OSM)

In Black: Areas to be masked

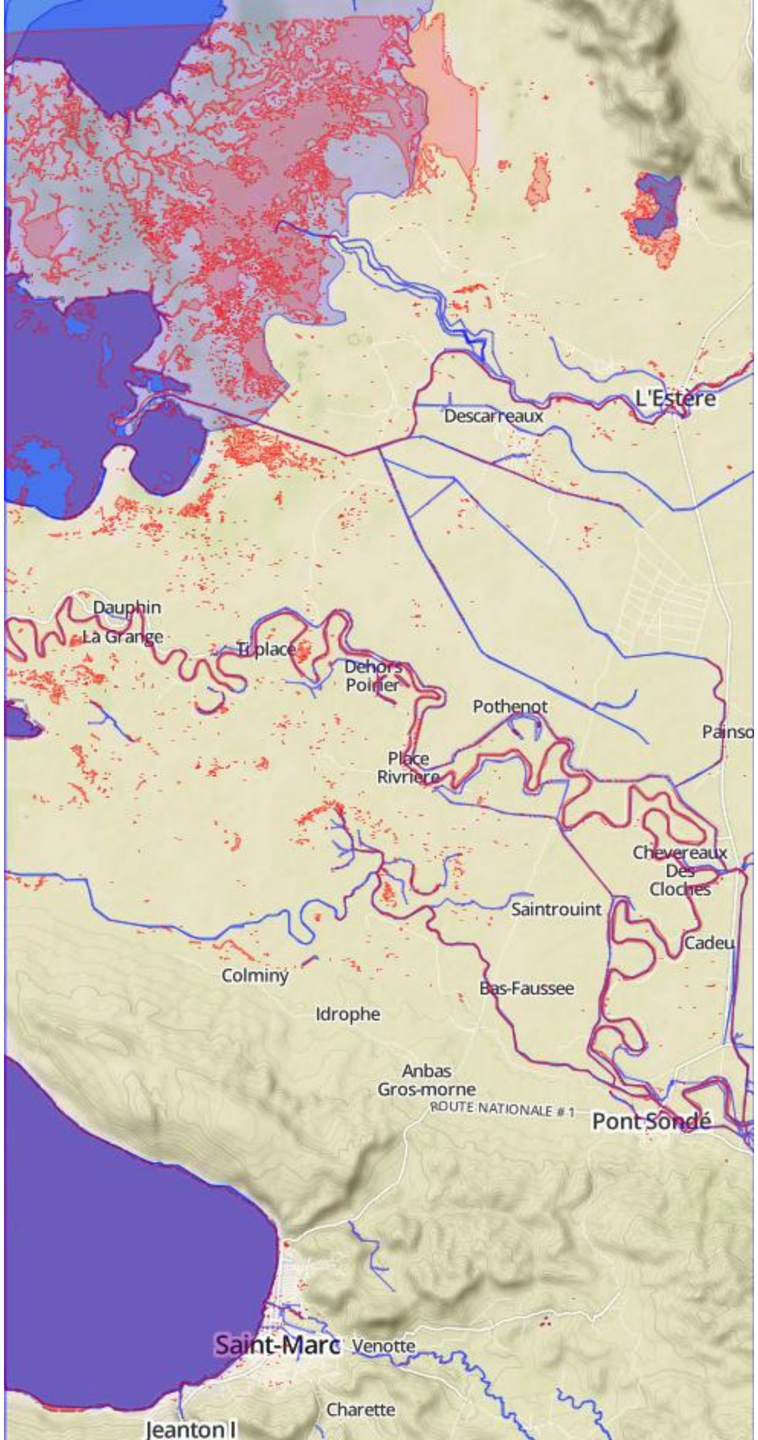
Removed:
46,297 out of 23,659,581

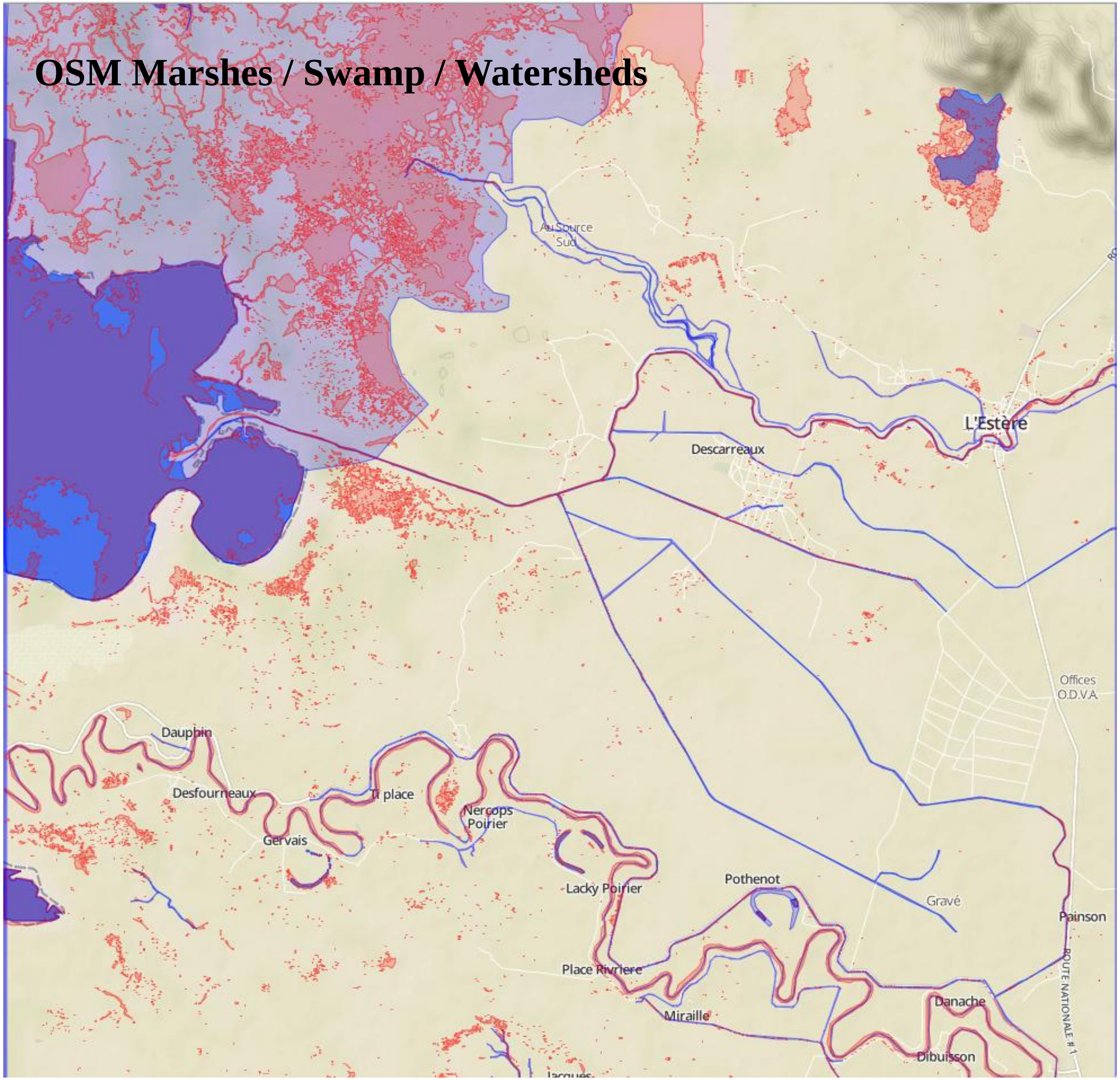


https://maps.google.com
Terrain Map

Resulting Zoomable Flood Map In Browser

Red: Surface Water
Blue: OSM Reference Water
Background: Terrain Map From Mapbox





OSM Marshes/Watershed Tags Are Important

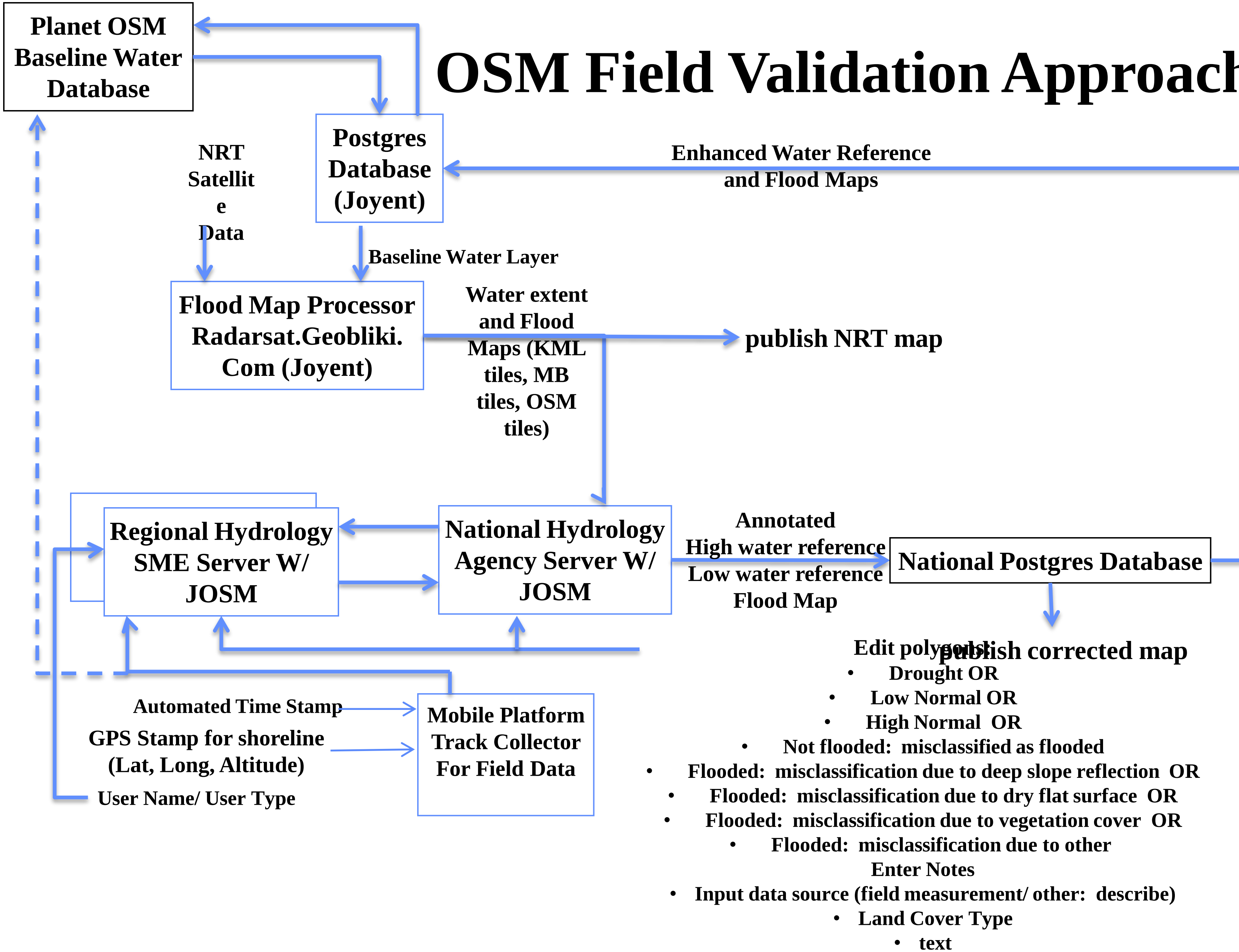
File Statistics

Processed Binary File (tif)	163.1MB
GeoJSON	40MB
GeoJSON.zip	7.2MB
TopoJSON	6.4MB
TopoJSON.zip	689KB
Simplified TopoJSON	< 1MB
Simplified Compressed	210KB

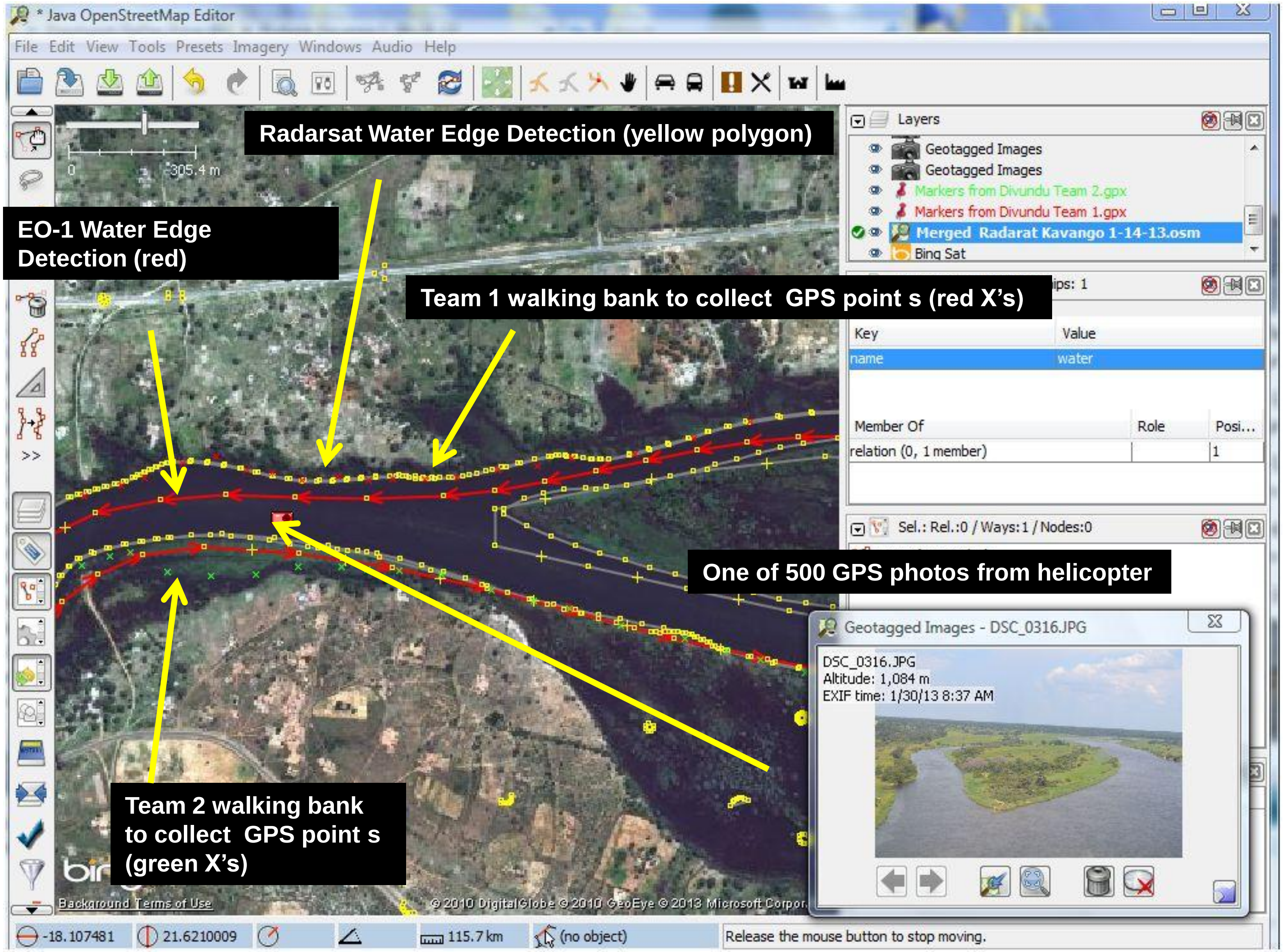
Issues

- **HAND processing needs validation**
- **Map Rendering (Browser)**
  - **A little slow to manage all the vectors (but does work)**
- **Next steps: Vector Tiling (Vector rendering at multiple scales) to speed map rendering for high res imagery [Already implemented in OSM]**

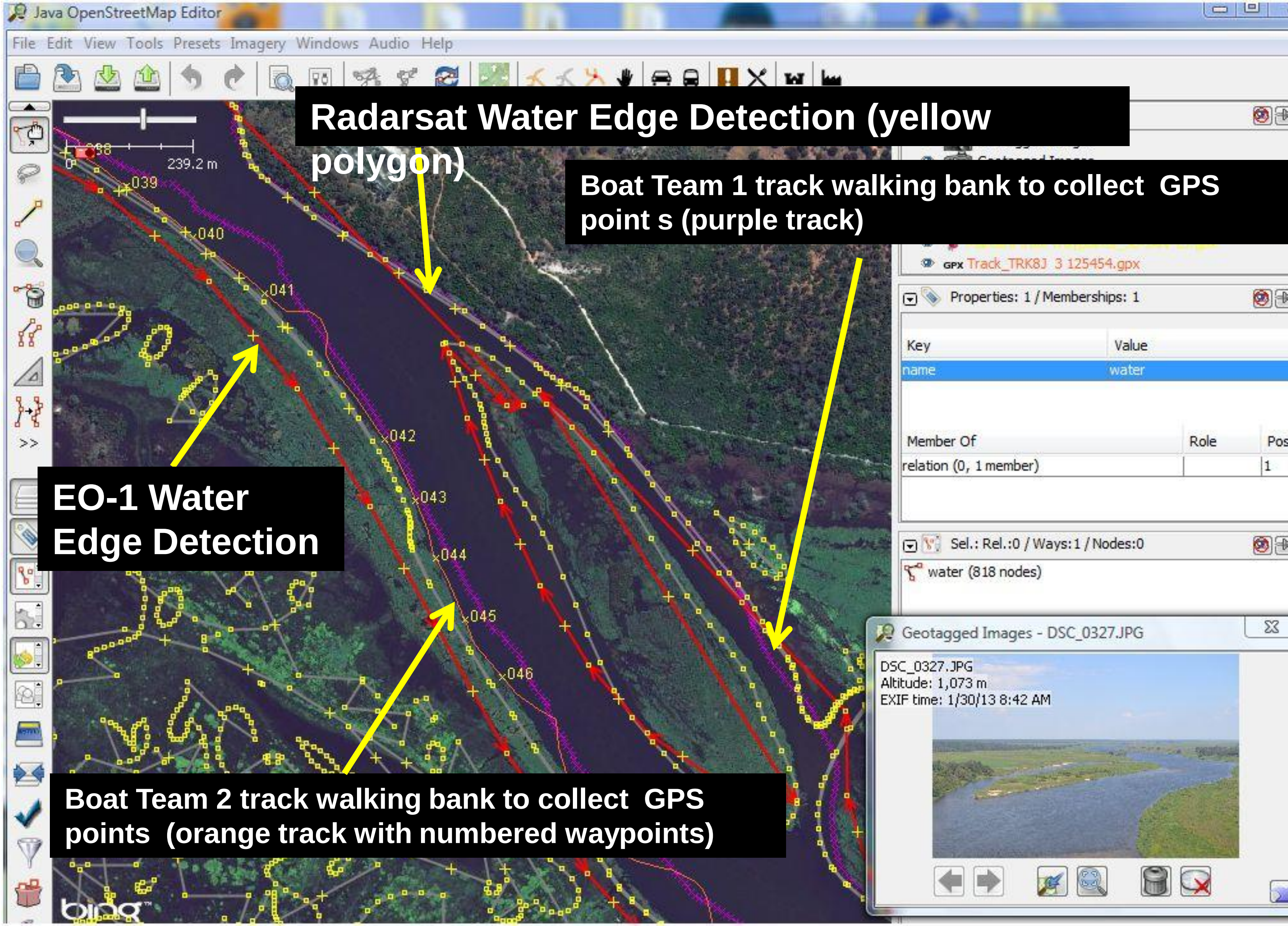
OSM Field Validation Approach



Ground Cal/Val Exercise with Radarsat, EO-1, Ground Team, Helicopter team, OpenStreetMap, Crowd Sourcing on Kavango river in Namibia 1-30-13

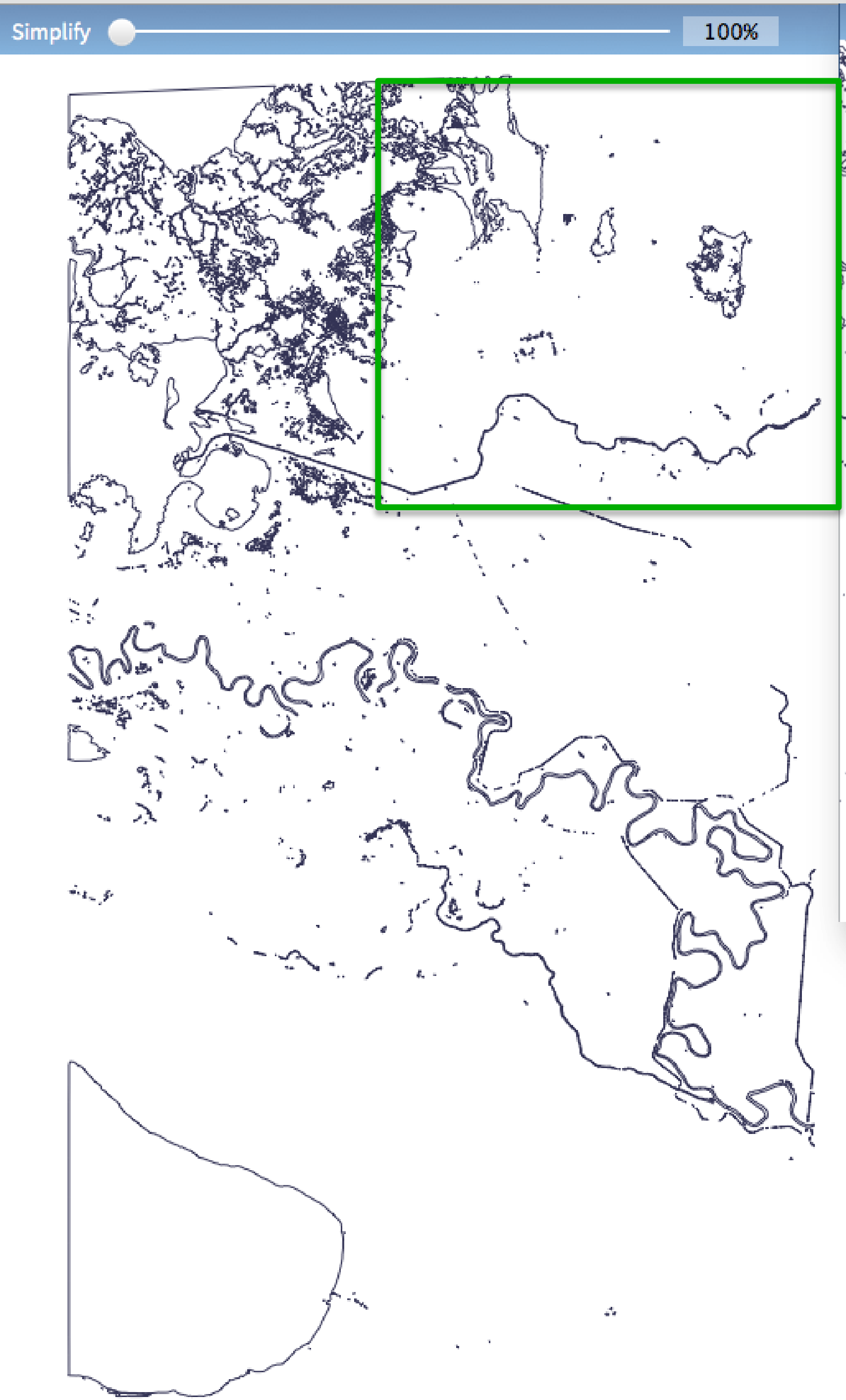


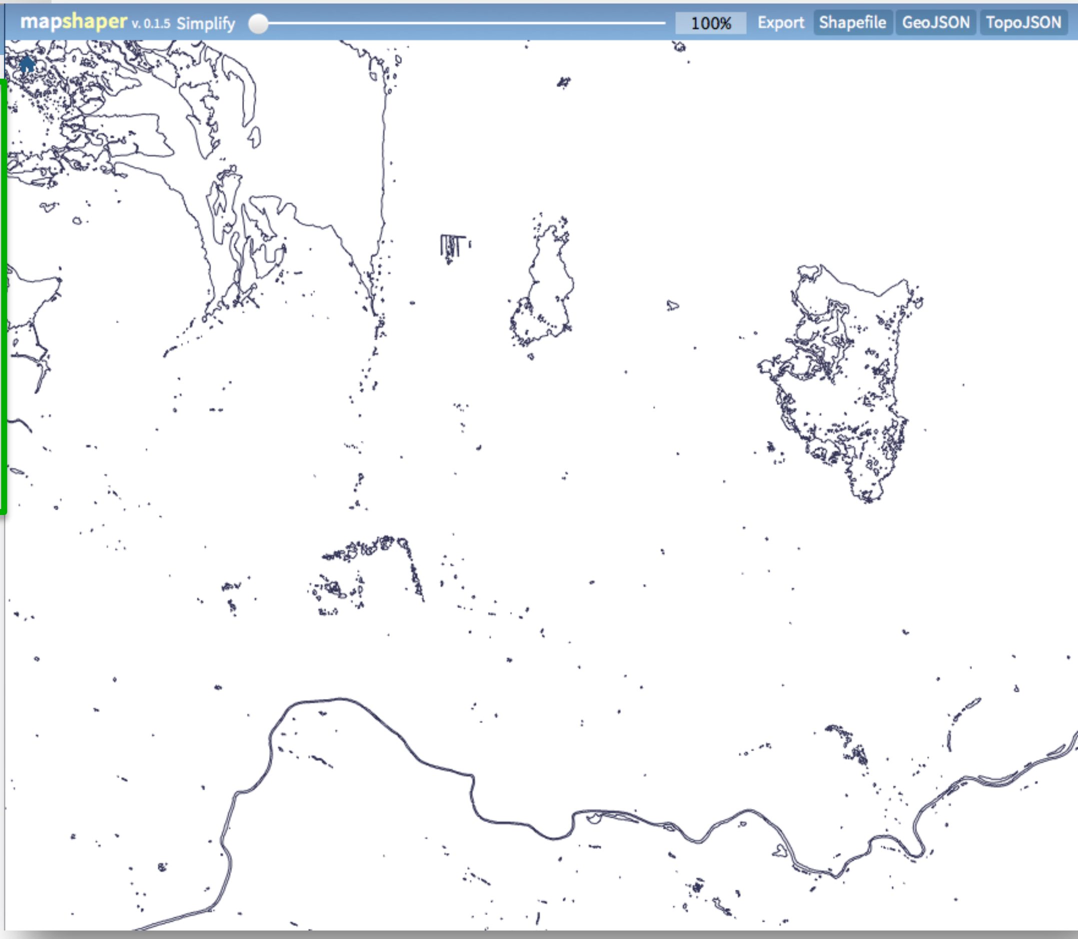
Integrated Water Edge Detection Display with Boat GPS Measurements, GPS located photos, Radarsat/EO-1 water edge detections



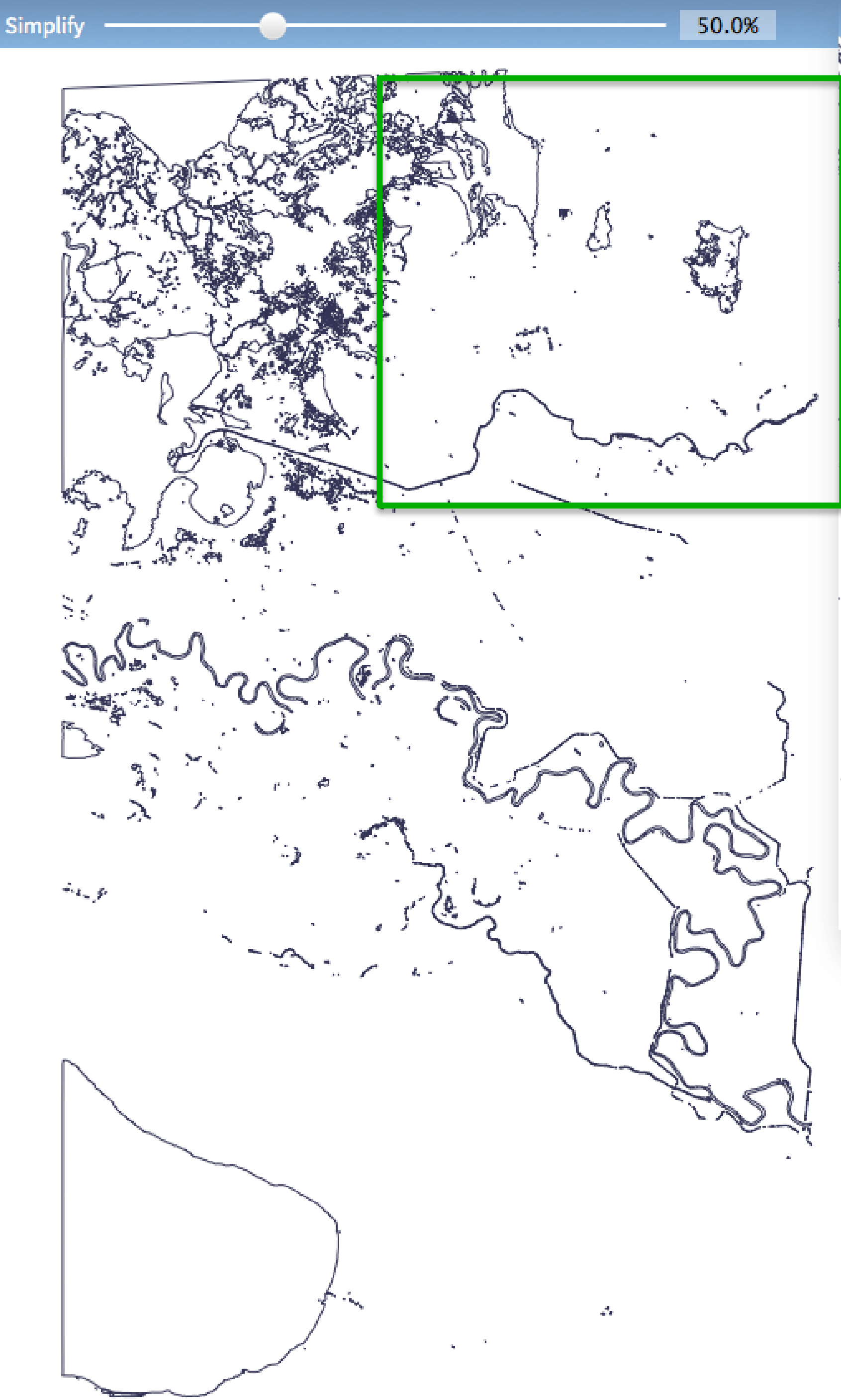
Vector Line Simplification

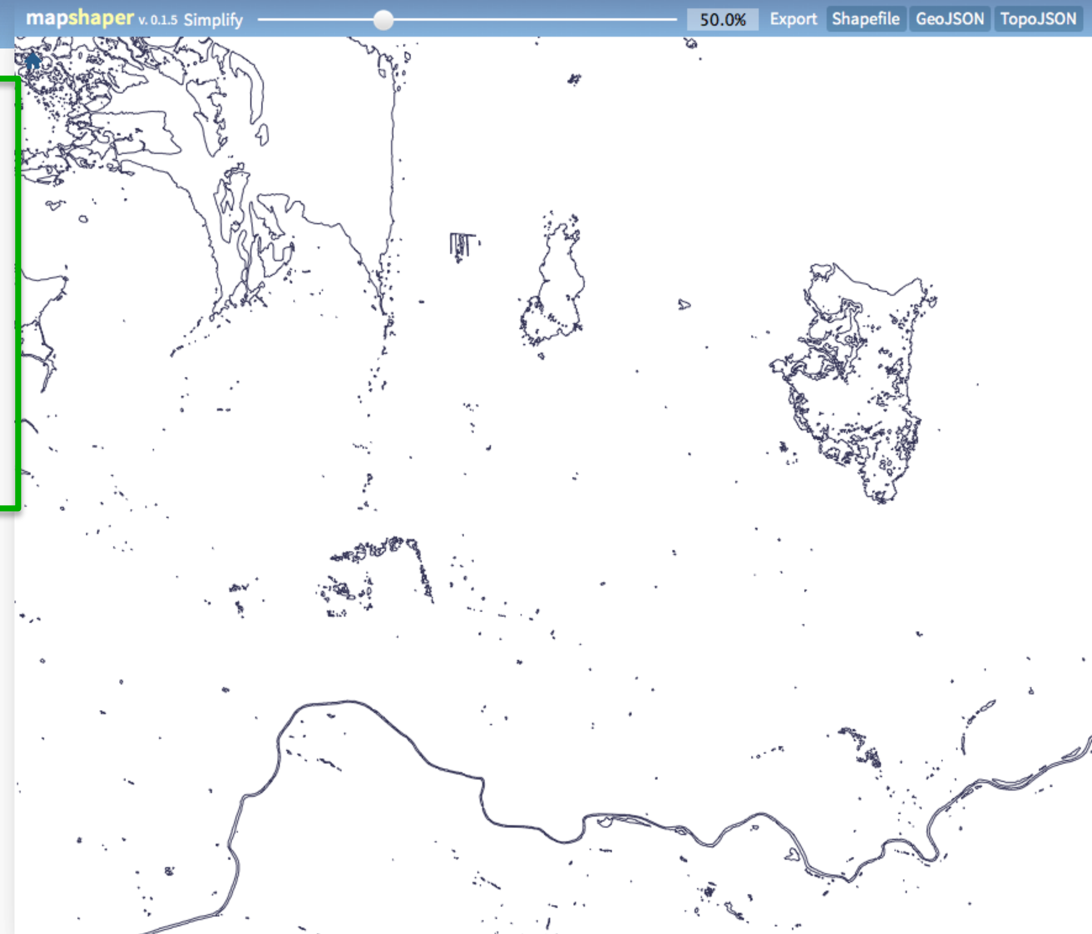
Visvalingam Algorithm





Initial Flood Vectors
-- 100% 6.4MB (zip: 689MB)





Vector Simplification -- 50% 4.3MB (zip: 766KB)