

NASA Global Flood Mapping System

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Bob Brakenridge, University of Colorado

Joe Nigro, SSAI/ GSFC

Alfred Hubbard, SSAI/GSFC

September __, 2017

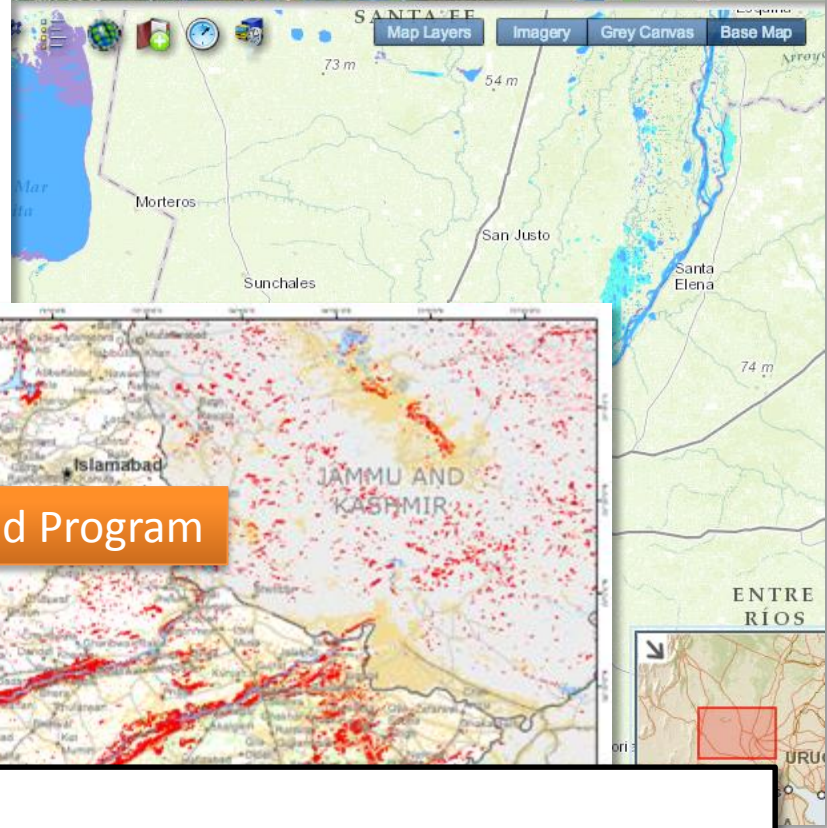


**Goddard Space Flight Center
Hydrological Sciences Lab**



**Dartmouth
Flood Observatory**

Selection of users



United Nations and the European Commission



GDACS

Global Disaster Alert and Coordination System



World Food Program

Map of Paraguay showing flood-affected areas in red. The map includes a scale bar and a north arrow.

El mapa evaluado



Producción por MapAction
www.mapaction.org
paraguay@mapaction.org

MapAction agradece el apoyo de



FEMA

NRCC – National Response Coordination Center

Product utility – key factors

- Near real time, automated production
- Flood spatial extent
- Cloudiness
- Pixel resolution: 250m
- Flood temporal extent
 - Flash floods / short duration on ground?
- Landcover
 - Water under vegetation cover vs open water

A little history

- Bob Brakenridge (Dartmouth Flood Observatory) manually generated flood maps using MODIS rapid response imagery
 - Product distribution via large-format digital maps (tif and pdf)
 - Useful product, but:
 - Generated from rapid response jpegs not meant for analysis
 - Not automated
 - Not easily incorporated into GIS
- NASA funded GSFC to build an automated daily, global, near real-time system



Terra

The MODIS sensor is on both the NASA Terra and Aqua satellites



Aqua

MODIS product distribution system:

<http://oas.gsfc.nasa.gov/floodmap>

NRT Global Flood Mapping

South America

| | | | | | |
|--------------|--------------|--------------|--------------|--------------|--------------|
| 090W 020N | 080W 020N | 070W 020N | | | |
| 090W 010N | 080W 010N | 070W 010N | 060W 010N | | |
| 090W 000S | 080W 000S | 070W 000S | 060W 000S | 050W 000S | 040W 000S |
| | | 080W 010S | 070W 010S | 060W 010S | 050W 010S |
| | | 080W 020S | 070W 020S | 060W 020S | 050W 020S |
| | | 080W 030S | 070W 030S | 060W 030S | |
| | | 080W 040S | 070W 040S | | |
| | | 080W 050S | 070W 050S | | |

For more information, please contact floodmap at lists.nasa.gov

NOTE: THIS IS AN EXPERIMENTAL PRODUCT AND SYSTEM

NASA Official: Frederick Policelli
Page Last Updated: February 13, 2017
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> Contact Us

3 Day Composite | 2 Day Composite | 1 Day Composite | 14 Day Composite

<< August 2017 >>

| S | M | T | W | T | F | S |
|----|----|----|----|----|----|----|
| | 1 | 2 | 3 | 4 | 5 | |
| 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| 27 | 28 | 29 | 30 | 31 | | |

| Products | Available Downloads |
|---------------------|--|
| MODIS Flood Map | MFM png |
| MODIS Flood Water | MFW shapefile (.zip) KMZ |
| MODIS Surface Water | MSW shapefile (.zip) KMZ |
| MODIS Water Product | MWP geotiff |
| README | pdf txt |

NASA EXPERIMENTAL SCIENCE PRODUCT

MODIS Flood Map

9-11 Aug 2017
Title: 060W030S

- Current floodwater
Input: LANCE MODIS
- Cloud
MODIS / MOD35
- Reference water
MOD34/Water
Natural/Earth Waters
- Urban areas

Background:
US NPS World Physical Map

100 km Projection: Plate Carree, WGS-84

NASA GSFC Flood Mapping Project
NASA Goddard Space Flight Center
Greenbelt MD 20771 USA

Product: 30307 / 2017233
Generated: 11 Aug 2017 21:22:43 GMT

Continental tile index

Specific tile

- Date selector
- Available product/format downloads

MODIS Flood Product

Input data: near real-time MODIS imagery from the LANCE system at NASA Goddard Space Flight Center

- Daily calibrated Terra and Aqua MODIS reflectances for bands 1, 2,7
- Corresponding cloud products for cloud and cloud shadow masking
- Delivered in 10 deg. X 10 deg. tiles

Water detection algorithm

Water if: $\frac{(Band2+A)}{(Band1+B)} < C$

AND $Band1 < D$

AND $Band7 < E$

| | |
|---|------|
| A | 13.5 |
| B | 1081 |
| C | 0.7 |
| D | 2027 |
| E | 676 |

- Bands are MOD09 surface reflectance product
- **Developed by Bob Brakenridge, Dartmouth Flood Observatory, U. Colorado**

Additional Processing

- Multi-look compositing: require multiple positive water detections to label a pixel as water – minimizes cloud shadow false-positives
- Terrain shadows masked using DEM and solar geometry
- Flood: water exceeding normal surface water, as defined by static global water map (MOD44W)

Automated MODIS Flood Map Production System

- Fully automated (since Nov 2011)
- 223 10x10° tiles x 3 products (2-day, 3-day, 14-day) = 669 daily product suite generated
- Product suite includes: geotiffs, shapefiles, KML (Google Earth), and graphic maps (png)
- Products typically available within 6 hours of Aqua overpass (~ 8:00 PM local time)
- Delivery via web download

Products: 3 elements

1. Composite period (balance between currency and spatial completeness):
 - Standard products: 2-day, 3-day
 - Short-term: 1-day
 - Extended: 14-day
2. Product name:
 - MWP: MODIS Water Product (core product)
 - MFW: MODIS Flood Water (derived)
 - MSW: MODIS Surface Water (derived)
 - MFM: MODIS Flood Map (derived)
3. Formats:
 - Raster / geotiff (some products)
 - Vector / shapefile & KML (some products)
 - Graphic product/ png

MODIS Flood Map Compositing

- 1-day composite: requires 1 water observation over current day's imagery (potentially 2 observations with Terra and Aqua). **Not normally generated.**
- 2-day: requires 2 water observations over 2 days of imagery (potentially 4 observations).
- 3-day: requires 3 water observations over 3 days of imagery (potentially 6 observations).
- 14-day: second order composite, combining the 14 previous 3-day products. Provides a recent-historical view.

Distribution via NASA website: <http://oas.gsfc.nasa.gov/floodmap>

3 Day Composite | 2 Day Composite | 1 Day Composite | 14 Day Composite

<< August 2017 >>

S M T W T F S
1 2 3 4 5
6 7 8 9 10 11 12
13 14 15 16 17 18 19
20 21 22 23 24 25 26
27 28 29 30 31

| Products | Available Downloads | |
|---------------------|---------------------|--|
| MODIS Flood Map | MFM | png |
| MODIS Flood Water | MFW | shapefile (.zip) KMZ |
| MODIS Surface Water | MSW | shapefile (.zip) KMZ |
| MODIS Water Product | MWP | geotiff |
| README | pdf | txt |

NASA EXPERIMENTAL SCIENCE PRODUCT

MODIS Flood Map
9-11 Aug 2017
Tile: 060W030S

Current floodwater
Input: LANCE MODIS

Cloud
MODIS / MOD35

Reference water
MOD44W lakes
NaturalEarth rivers

Urban areas

Background:
US NPS World Physical Map

100 km Projection: Plate Carree, WGS-84

NASA GSFC Flood Mapping Project
NASA Goddard Space Flight Center
Greenbelt MD 20771 USA

Product: 30307 / 201723
Generated: 11 Aug 2017 21:22:43 GMT

| Products | | Available Downloads | |
|---------------------|-----|----------------------------------|---------------------|
| MODIS Flood Map | MFM | png | |
| MODIS Flood Water | MFW | shapefile (.zip) | KMZ |
| MODIS Surface Water | MSW | shapefile (.zip) | KMZ |
| MODIS Water Product | MWP | geotiff | |
| README | | pdf | txt |

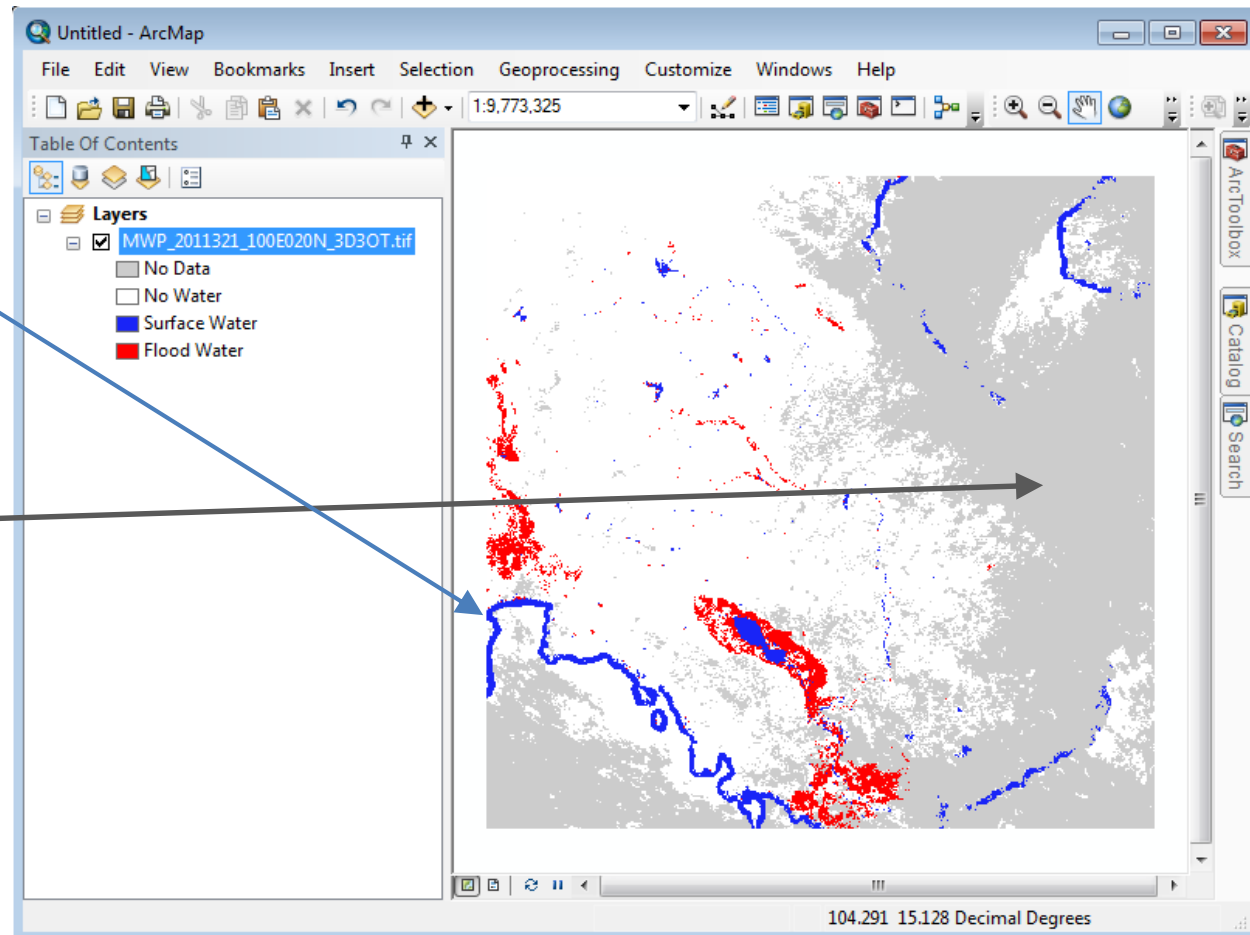
Product downloads table

060W030S

- date selector
- product/format downloads
- navigation tool

Products: MODIS Water Product (MWP)

- Core product
- Geotiff format
- Values:
 - 0: Insufficient data (for composite period)
 - 1: No water detected
 - 2: Surface water (corresponding to Reference water pixels).
 - 3: Flood water (water outside Reference water pixels).
- Coastal strip visible; ocean water removed beyond 10 km
- MOD35 Cloud used only to populate "Insufficient data"; water detected through cloud IS reported



Products: MODIS Flood Map (MFM) 10° tile graphic map (PNG)

**NASA EXPERIMENTAL
SCIENCE PRODUCT**

MODIS Flood Map

1-2 Nov 2011

Tile: 100E020N

Current floodwater
Input: LANCE MODIS



Cloud
MODIS / MOD35



Reference water
MOD44W lakes
NaturalEarth rivers



Urban areas



Background:
US NPS World Physical Map



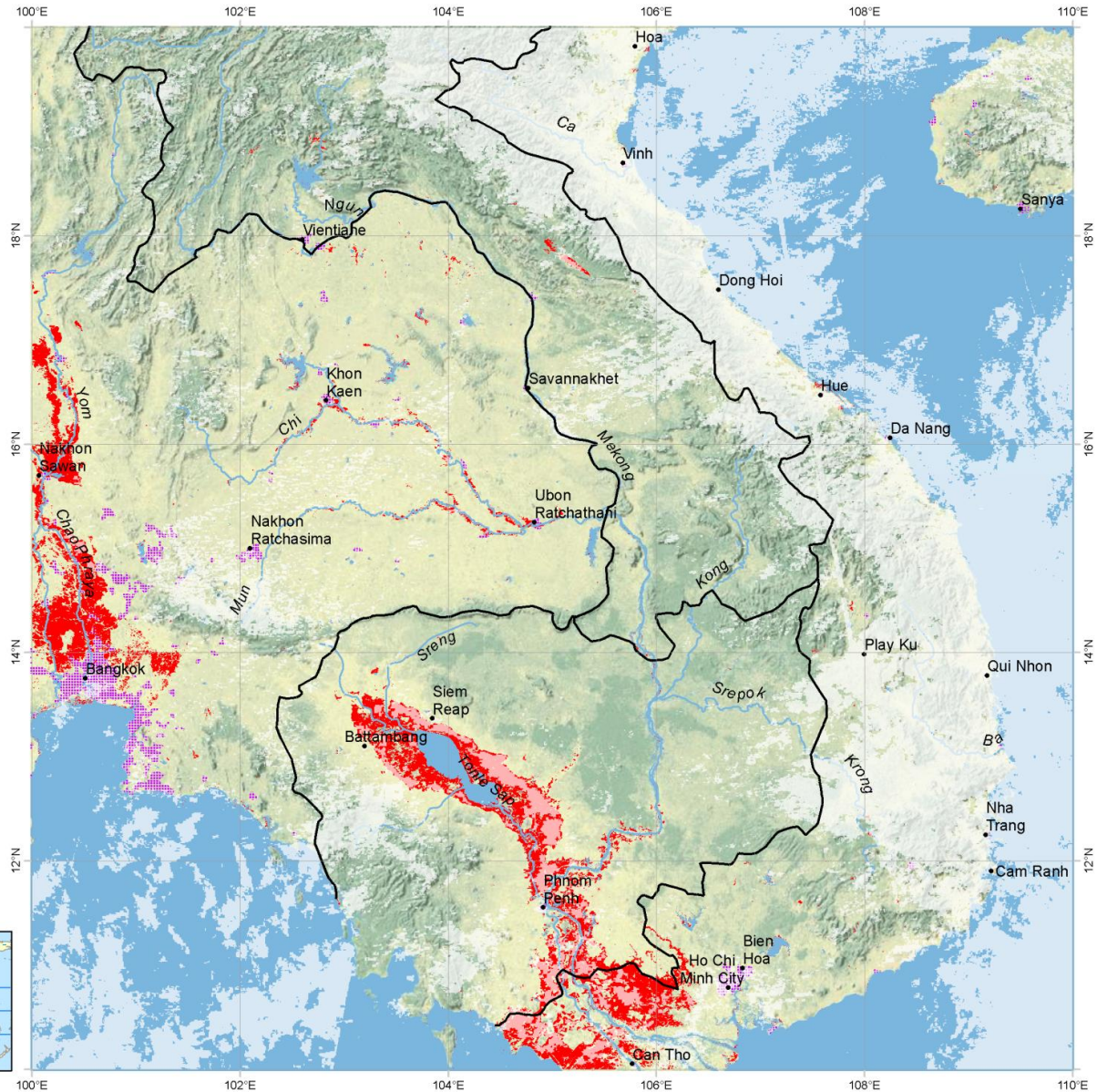
Projection:
Plate Carree, WGS-84



Office of Applied Sciences
NASA Goddard Space Flight Center
Greenbelt MD 20771 USA



Product: 2D20 / 2011306
Generated: 15 Feb 2012 18:50:08 GMT



Products: MODIS Surface & Flood Water (MSW, MFW) shapefiles

- Vectorized from MWP (raster) product
- Does not indicate where insufficient data to determine (value 0 of MWP product)
- Provides area and centroid per polygon
- Production can fail if too many polygons
- KML production skipped if #polygons > 15000

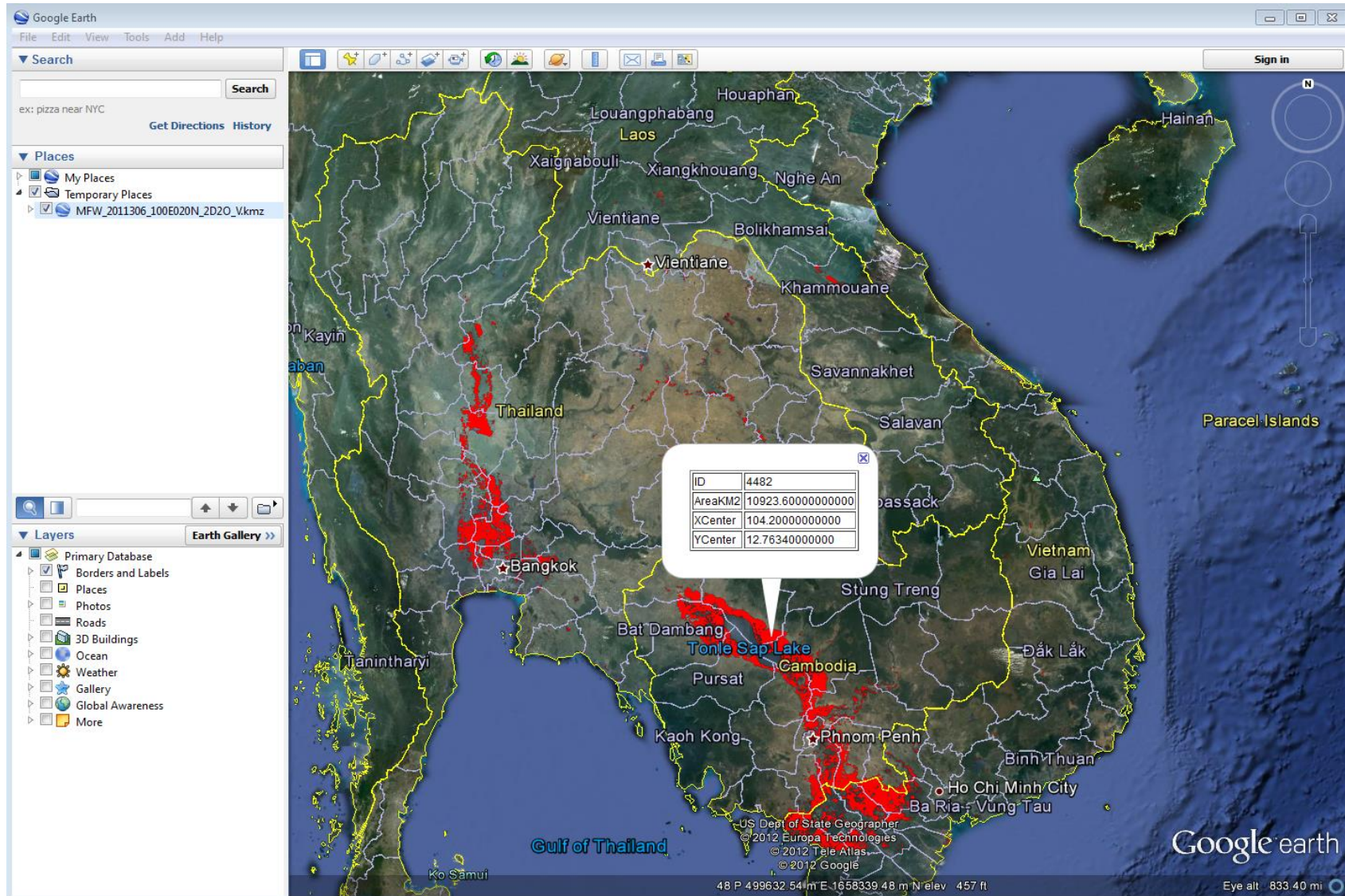
The screenshot shows the ArcMap interface with a map displaying flood water polygons in red and blue. A 'Table' window is open, showing the following data for the selected feature:

| FID | Shape | ID | AreaKM2 | XCenter | YCenter |
|------|---------|------|----------|---------|---------|
| 1448 | Polygon | 1449 | 0.172375 | 100.197 | 16.1918 |
| 1449 | Polygon | 1450 | 0.114848 | 100.42 | 16.1932 |
| 1450 | Polygon | 1451 | 1079.59 | 100.291 | 15.8377 |
| 1451 | Polygon | 1452 | 1.54798 | 101.102 | 16.1823 |
| 1452 | Polygon | 1453 | 0.402077 | 100.347 | 16.1766 |
| 1453 | Polygon | 1454 | 0.114927 | 100.191 | 16.1757 |

The status bar at the bottom indicates '1 features selected' and the coordinates '106.128 13.523 Decimal Degrees'.

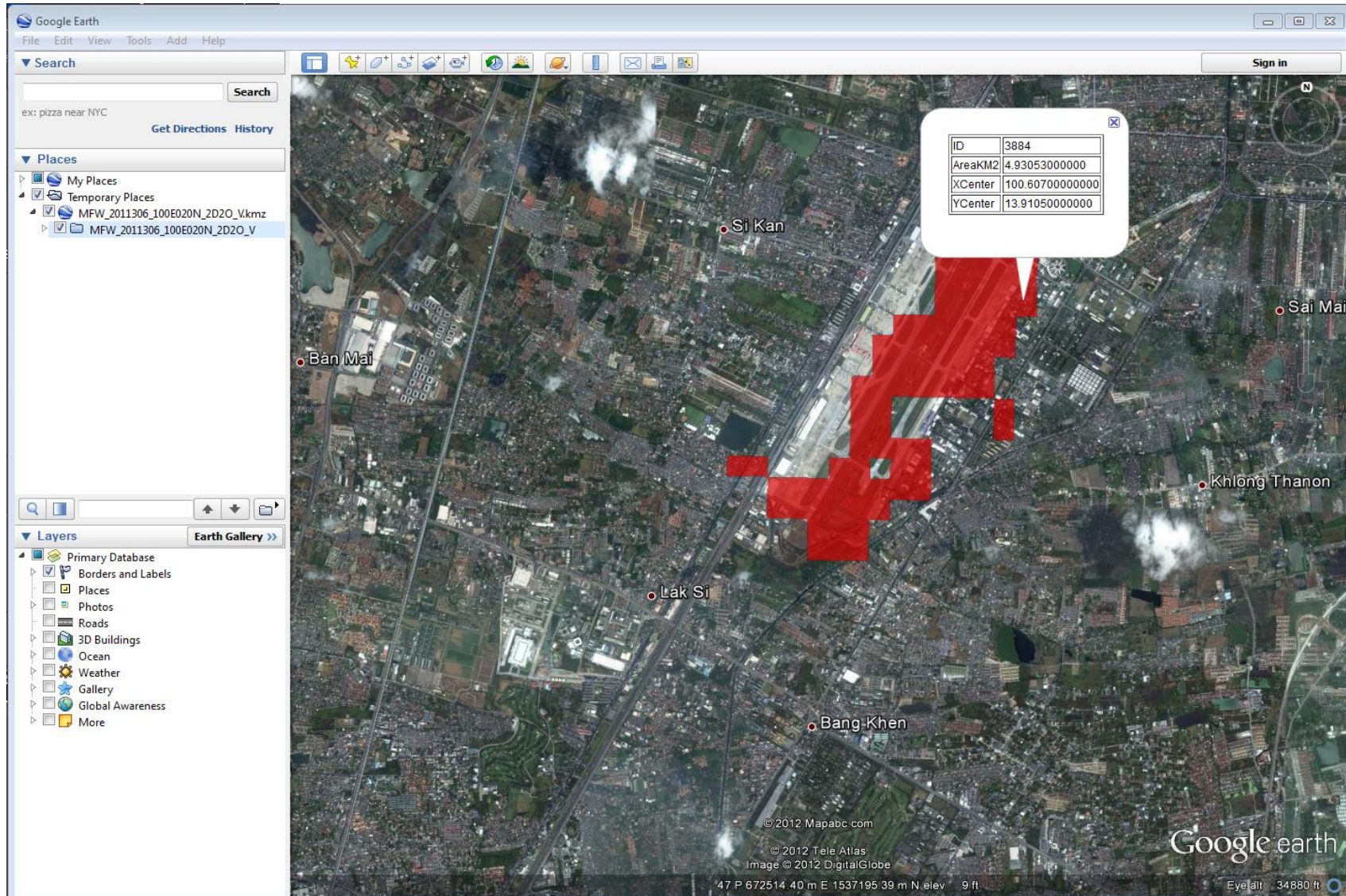
Products: MODIS Surface & Flood Water KML files (Google Earth)

KML files in Google Earth:



Products: MODIS Surface & Flood Water KML files (Google Earth)

Google Earth zoomed in -- Bangkok's Don Muang Airport runways under water:



MODIS Flood Product Evaluation

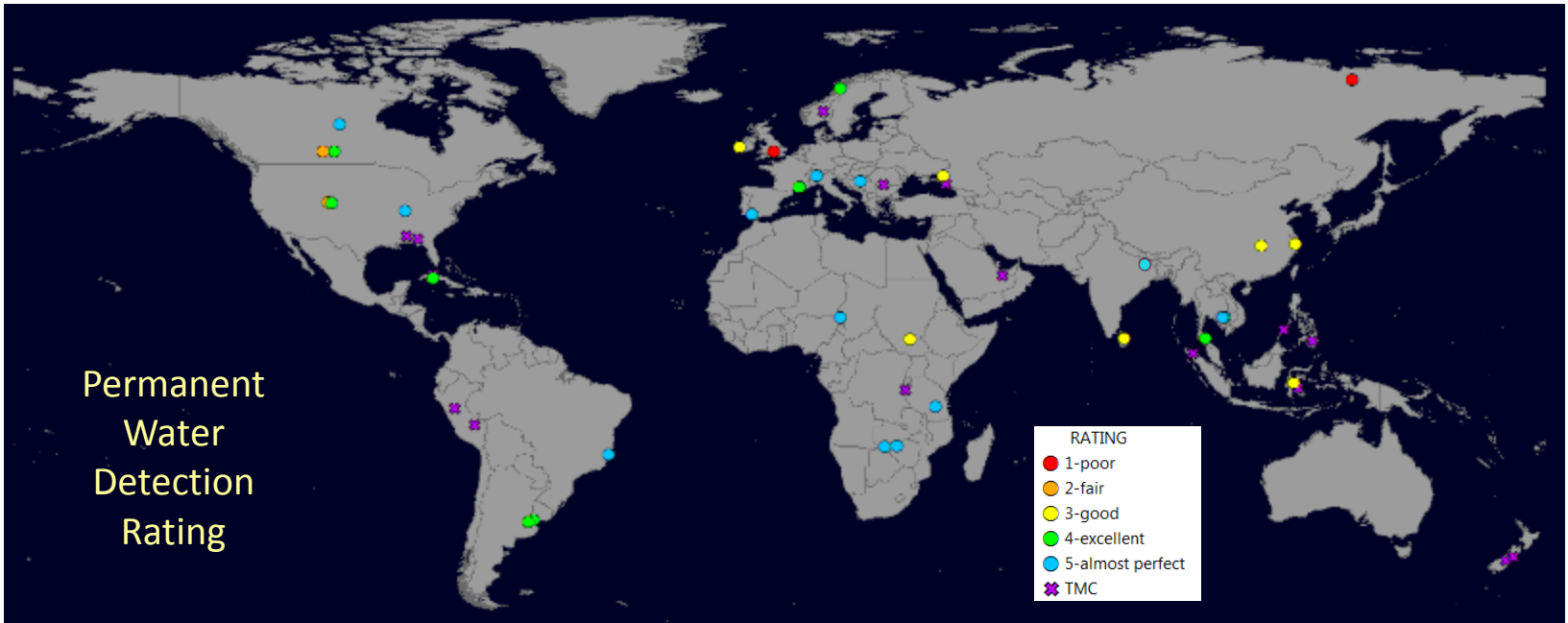
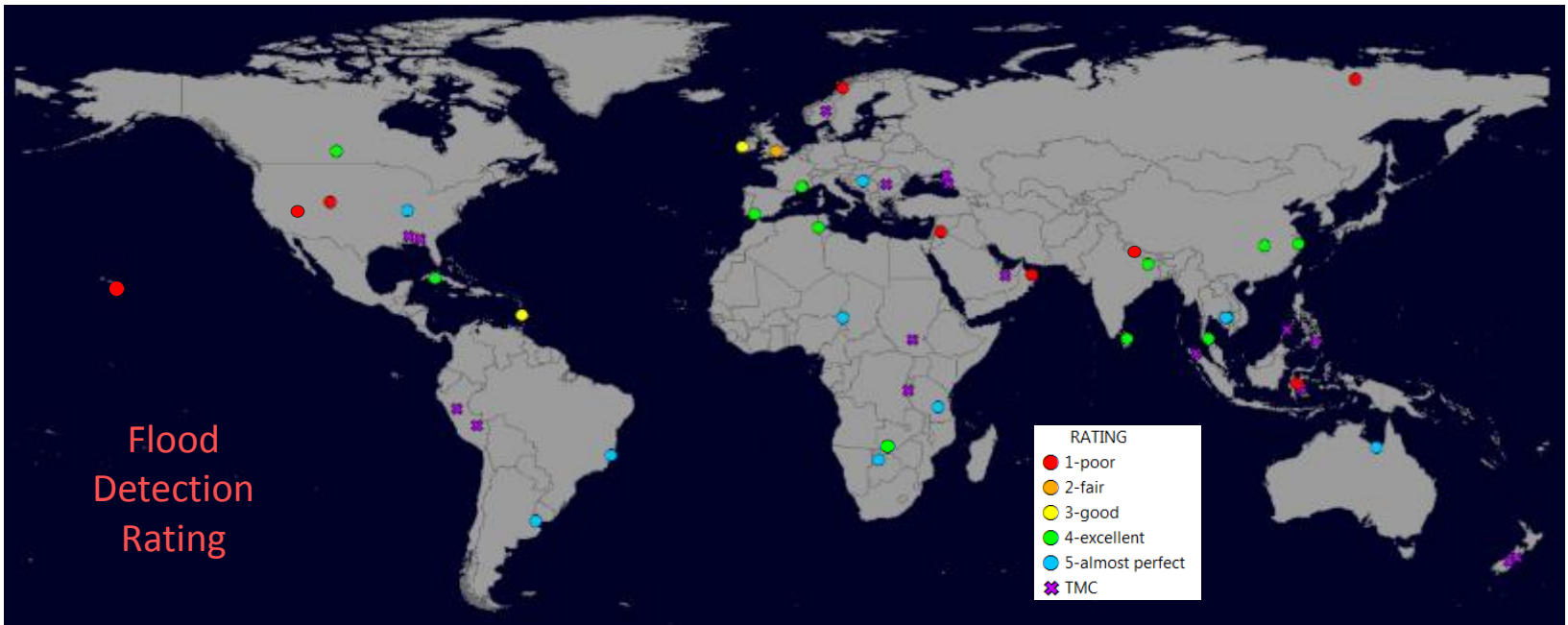
Purpose:

- Is water detection algorithm working
 - correctly detecting visually obvious water?
- Are certain situations problematic?
- Are the multi-day composited products working well?
- Differences between detection of flood water vs normal water

Evaluation method:

- Globally distributed flood and permanent water sites (~50 each)
- Visual and qualitative assessment of performance
 - raw MODIS and Landsat imagery used to help inform assessment

http://oas.gsfc.nasa.gov/floodmap/documents/NASAGlobalNRTEvaluationSummary_v4.pdf



Flood Detection Ratings

| RATING | Count | % |
|-------------------------------|-------|--------------------------|
| 5-almost perfect | 11 | 21 |
| 4-excellent | 10 | 19 |
| 3-good | 2 | 4 |
| 2-fair | 1 | 2 |
| 1-poor | 11 | 21 |
| TMC - too many clouds | 17 | 33 |
| Outside product coverage area | 1 | Eliminated from equation |
| TOTALS | 53 | 100 |

} 66% of clear

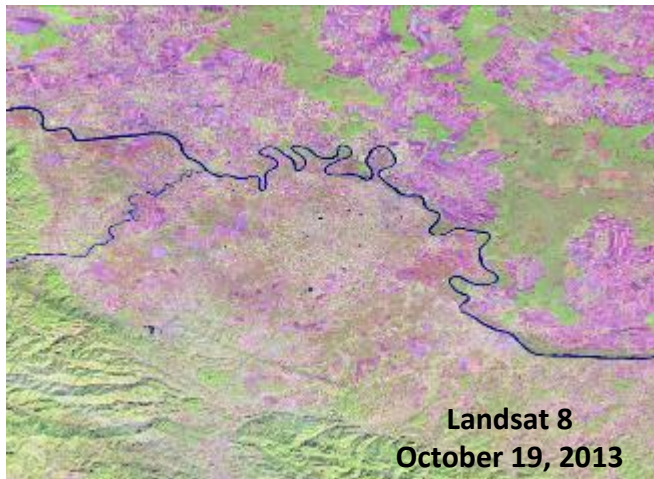
Permanent Water Detection Ratings

| RATING | Count | % |
|-------------------------------|-------|--------------------------|
| 5-almost perfect | 15 | 28 |
| 4-excellent | 9 | 17 |
| 3-good | 7 | 13 |
| 2-fair | 2 | 4 |
| 1-poor | 4 | 8 |
| TMC - too many clouds | 16 | 30 |
| Outside product coverage area | 1 | Eliminated from equation |
| TOTALS | 54 | 100 |

} 84% of clear

Correct flood identification

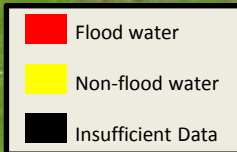
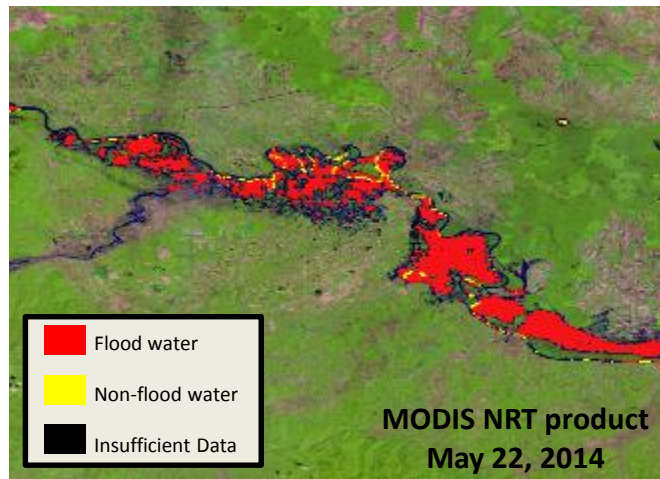
Bosnia and Herzegovina: 22 May 2014



Landsat 8
October 19, 2013



Landsat 8
May 22, 2014



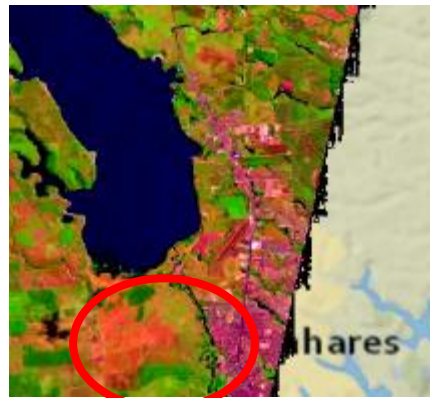
MODIS NRT product
May 22, 2014

Correct flood and permanent water identification

Brazil: 02 January 2014



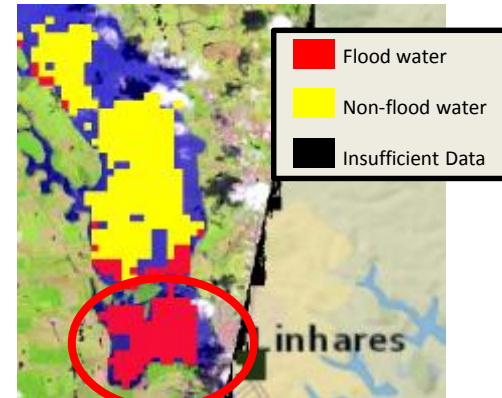
National Geographic
base map



Landsat 8 Pre-flood
Apr 21, 2013



Landsat 8 Flood
Jan 2, 2014



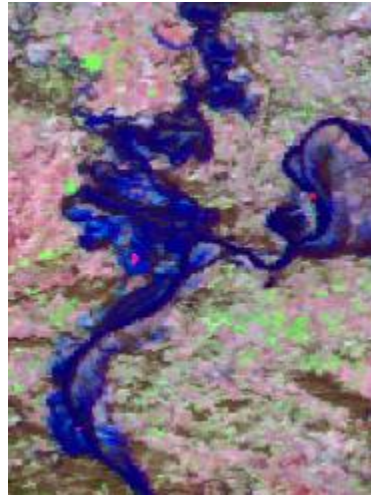
MODIS NRT product
Jan 3, 2014

Example: Correct flood identification

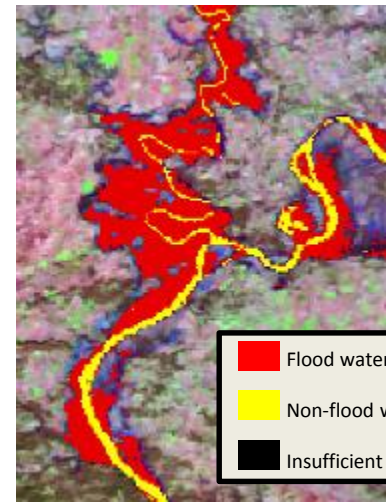
Kentucky: 04 Jan 2014



MODIS (MOD09) Pre-Flood
Oct 12, 2013



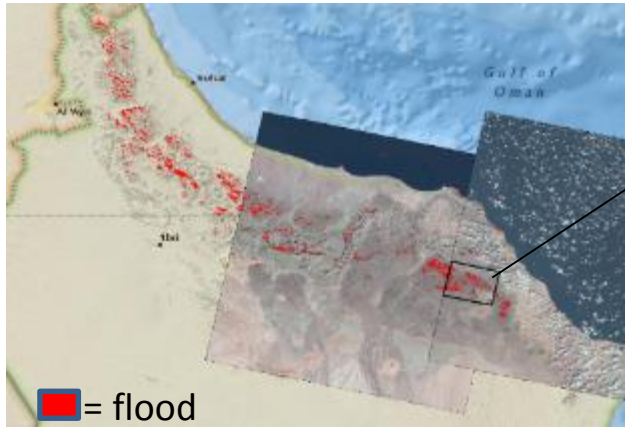
MODIS (MOD09) Flood
Jan 4, 2014



MODIS NRT Product
Jan 4, 2014

Terrain shadow false-positives

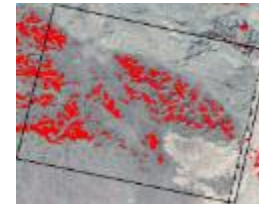
OMAN: mid November 2013 products



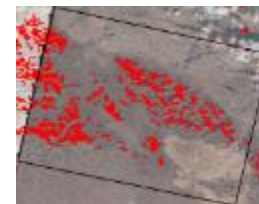
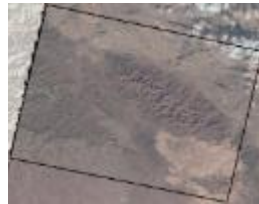
3-day product



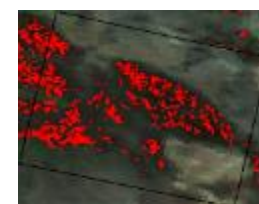
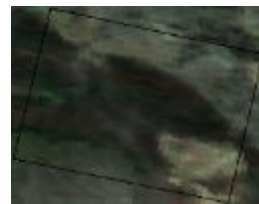
Landsat 8
June 17, 2013
(2013178)



Landsat 8
Nov 9, 2013
(2013313)



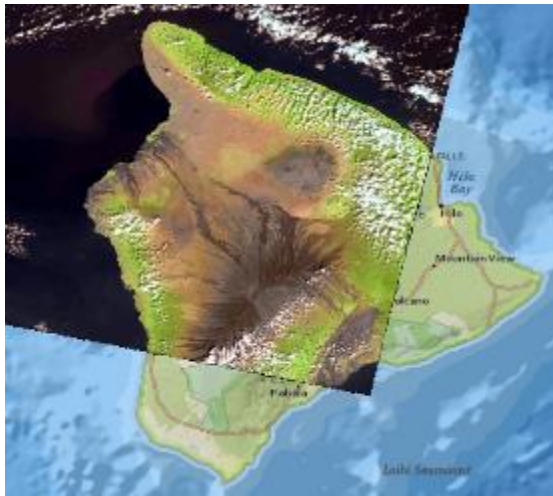
Landsat 8
Nov 18, 2013
(2013322)



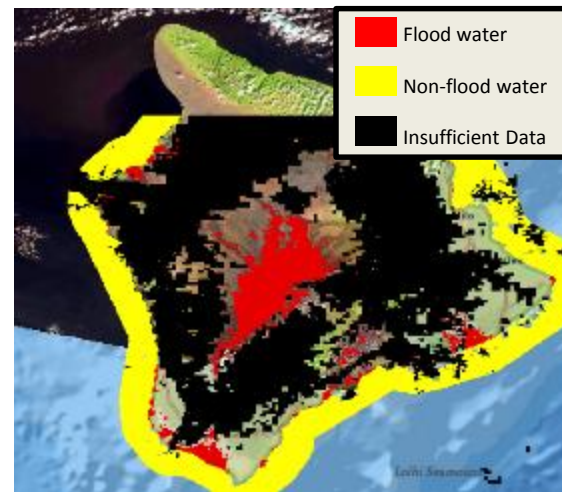
MODIS (MOD09)
Nov 11, 2013
(2013315)

Example: Barren rock / volcanic false positives

Mauna Loa, **Hawaii**: 17 Dec 2013



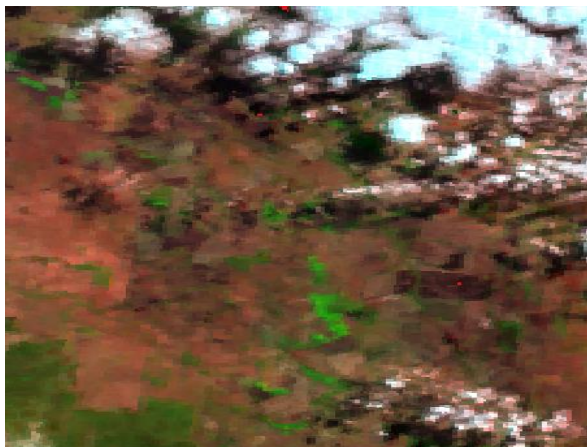
Landsat 8



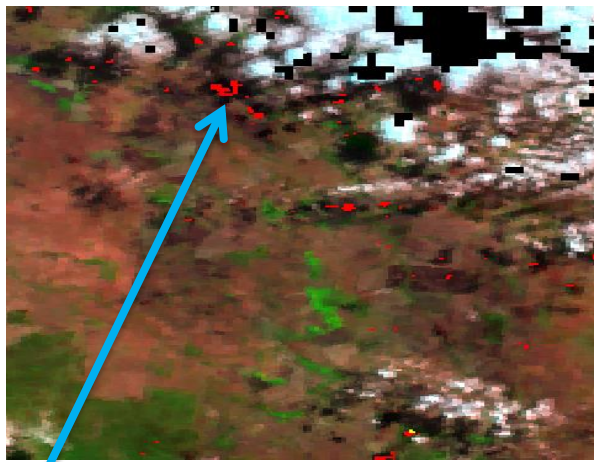
MODIS NRT Product

Example: Cloud shadow false-positives

Australia: 04 July 2014



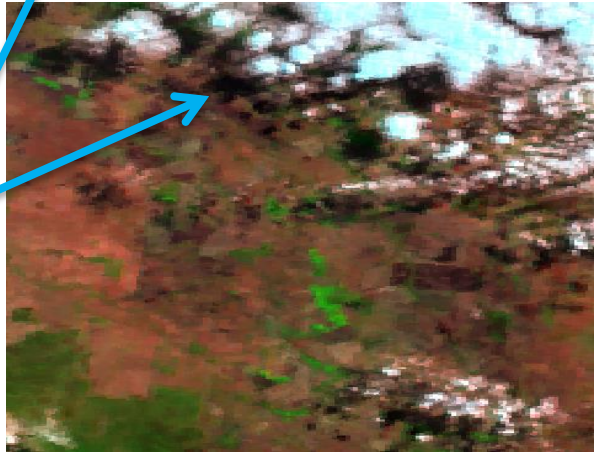
Input data: MOD09, 04 Jul 2014



2-day Product on MOD09

| | |
|--|-------------------|
| | Flood water |
| | Non-flood water |
| | Insufficient Data |

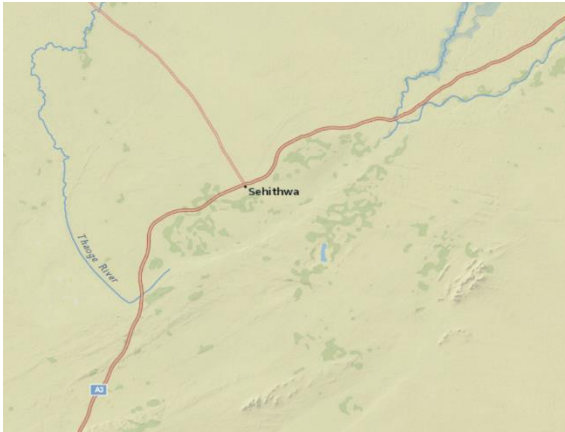
3-day product
removes most
cloud shadow
false positives



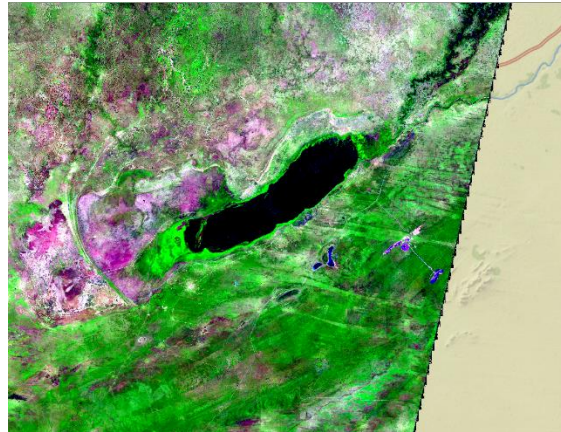
3-day Product

Comparison of different compositing periods: 2-day vs 3-day product

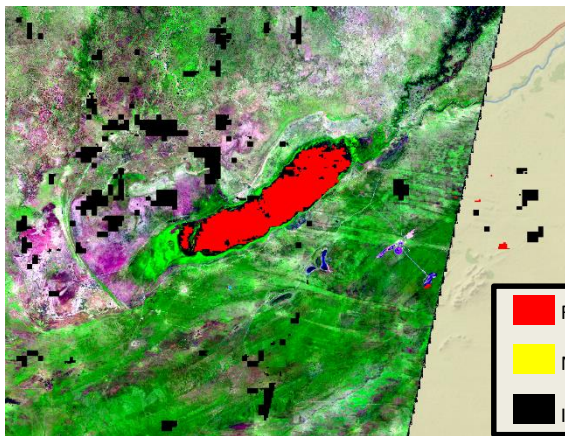
Botswana: 24 Mar 2014



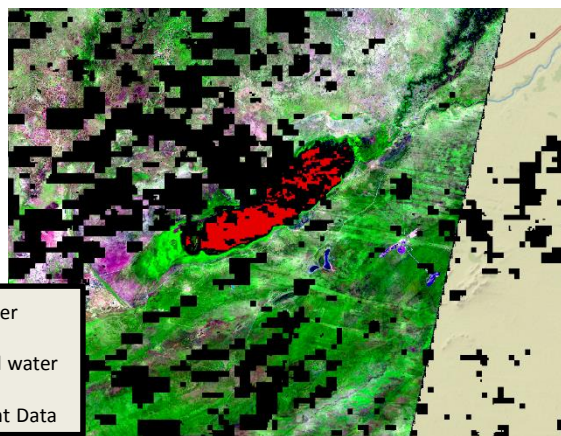
National Geographic base map



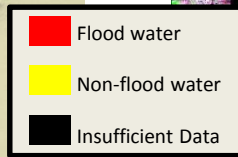
MODIS (MOD09) Mar 24, 2014



2-day product



3-day product



Which compositing period should I use?

Just how cloudy is it?

- It depends....basically on cloud conditions:
 - User tolerance for false positives (and false negatives)
 - User need for only the most up-to-date information
- Clear conditions? Use 2-day or 1-day.
- Very sensitive to false-positives? Use 3-day.
- Very sensitive to false-negatives (cloud)? Use 14-day.
- Need the latest info? Use 1-day.
- Best approach? Look at them all and evaluate for given event and needs.

Current efforts

- Recently transitioned flood map distribution to NASA LANCE
- Working transition of flood map production to NASA LANCE
- Improvements to MODIS product
 - Replace $10^{\circ} \times 10^{\circ}$ Tiles with swath data
 - Decreased latency
 - Improved masking of cloud and terrain shadows
 - Masking of high slope areas (HAND algorithm)
 - Ephemeral water mask (recurring water that is not unusual flooding)

Comments/ Questions ?