NASA Global Flood Mapping System

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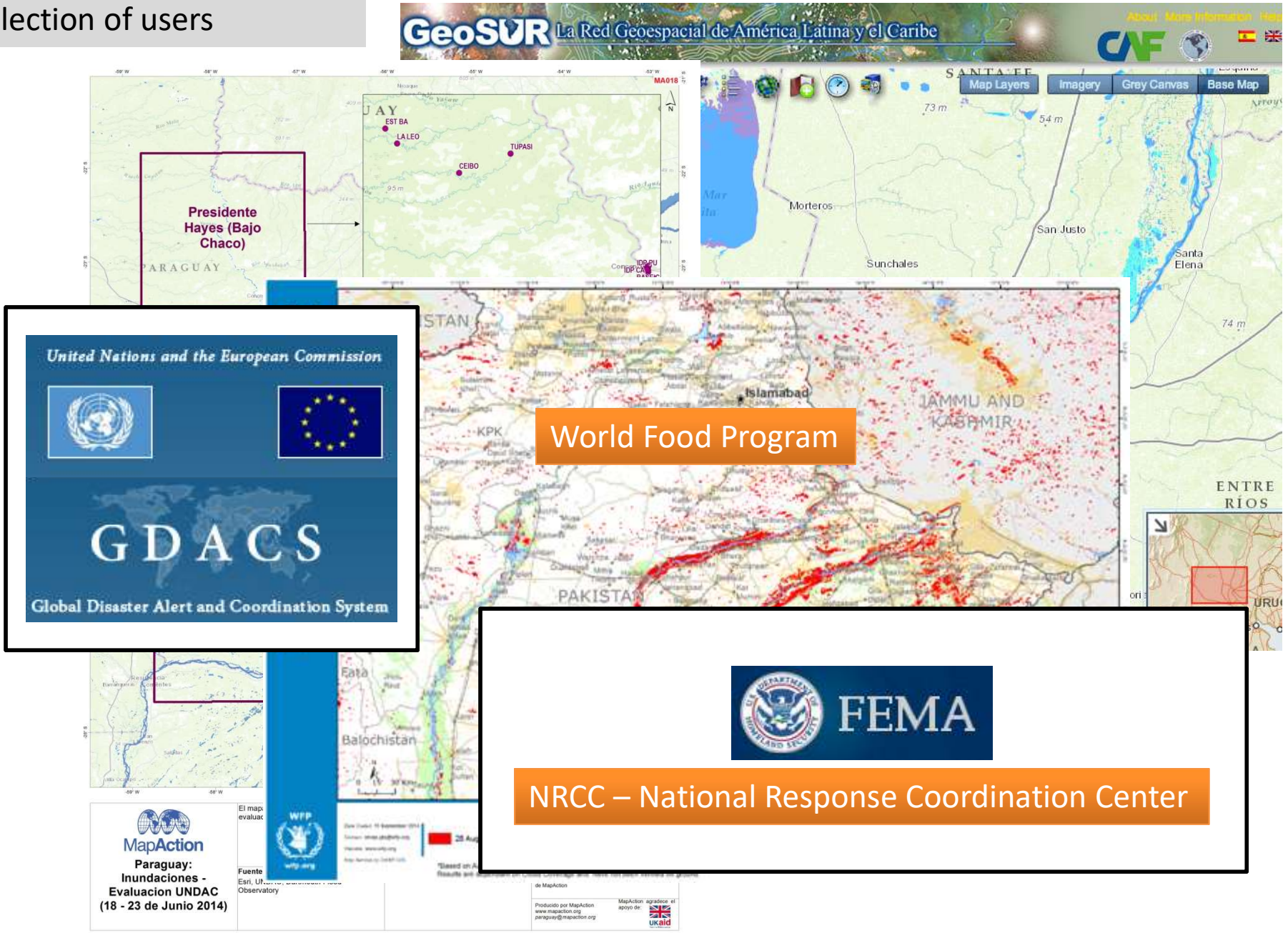
Goddard Space Flight Center
Hydrological Sciences Lab

Dartmouth Flood Observatory

Selection of users



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

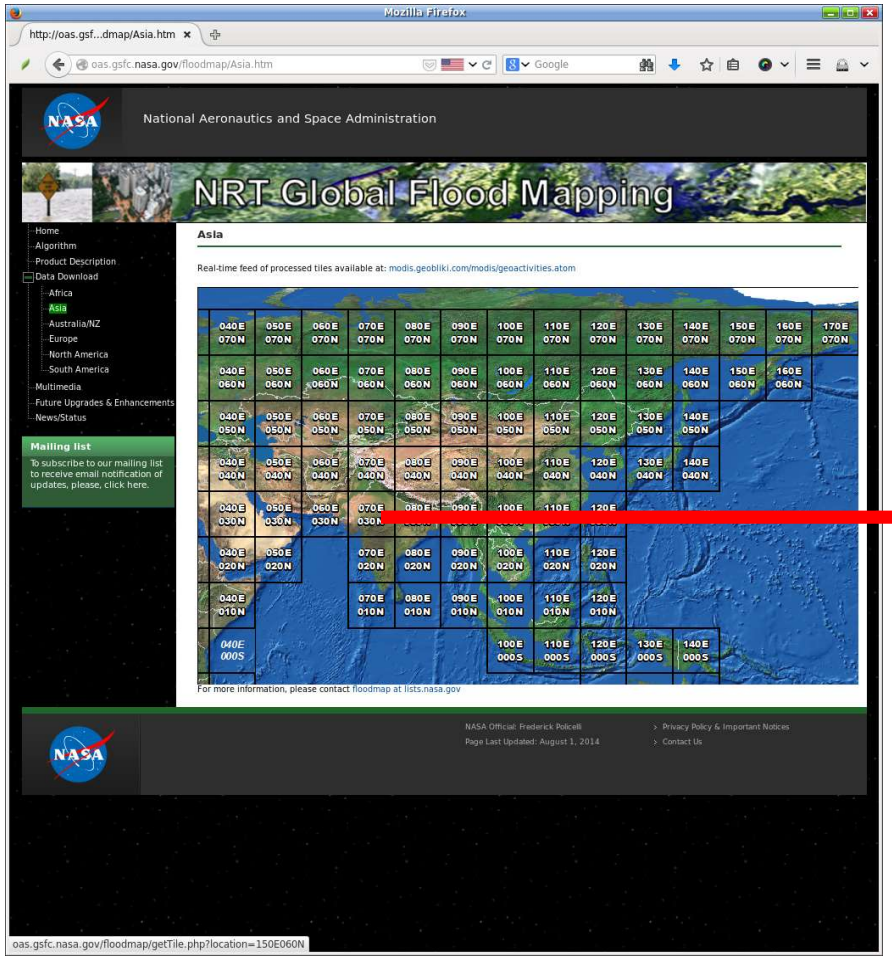
Terra

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

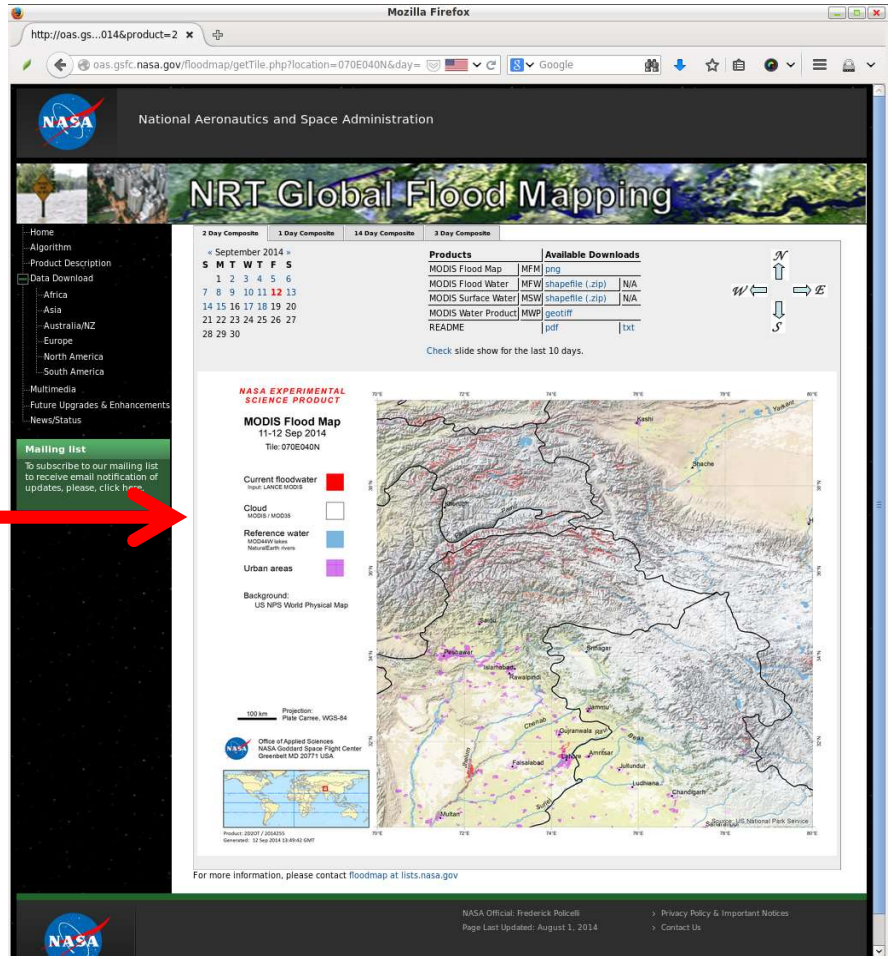
Aqua

MODIS product distribution system:

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



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

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

Flood detection algorithm: Bob Brakenridge / Dartmouth Flood Observatory

- Water detection empirically-derived band ratio (bands 1,2)
- Band 7 radiances exceeding threshold are not labeled water
- 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 suites include: 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

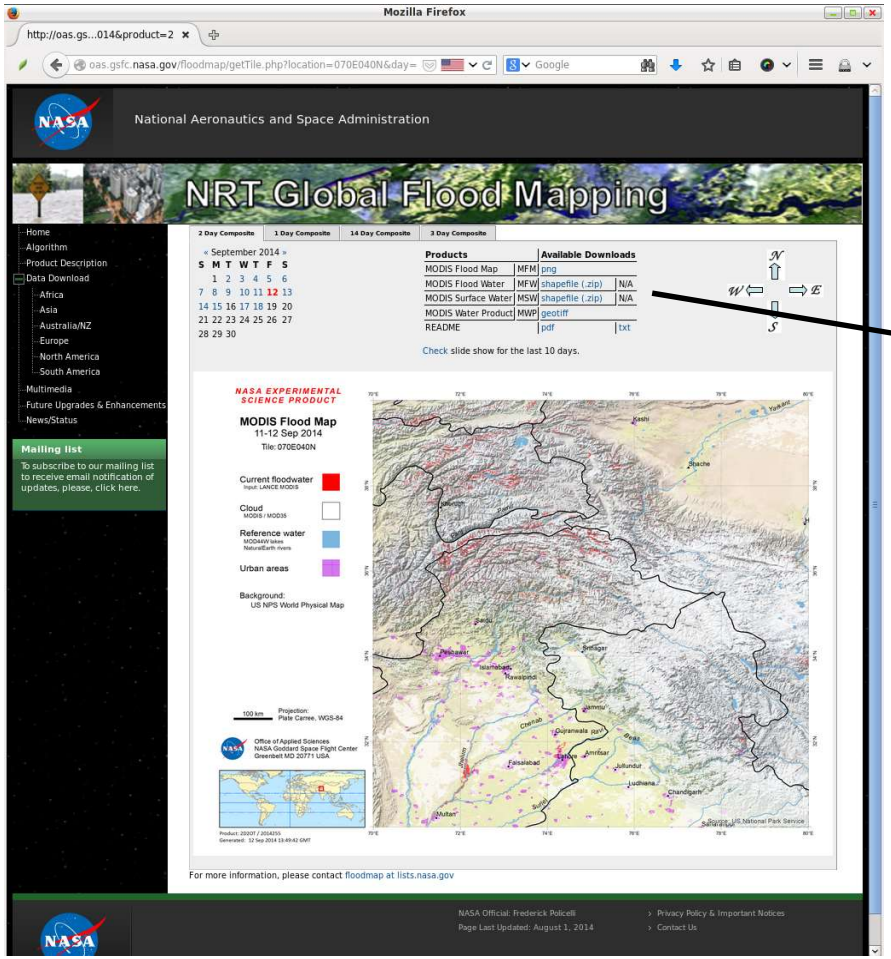
2. Product name:
   - MWP: MODIS Water Product (core product)
   - MFW: MODIS Flood Water (derived)
   - MSW: MODIS Surface Water (derived)
   - MFM: MODIS Flood Map (derived)

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



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

070E040N (NE Pakistan)

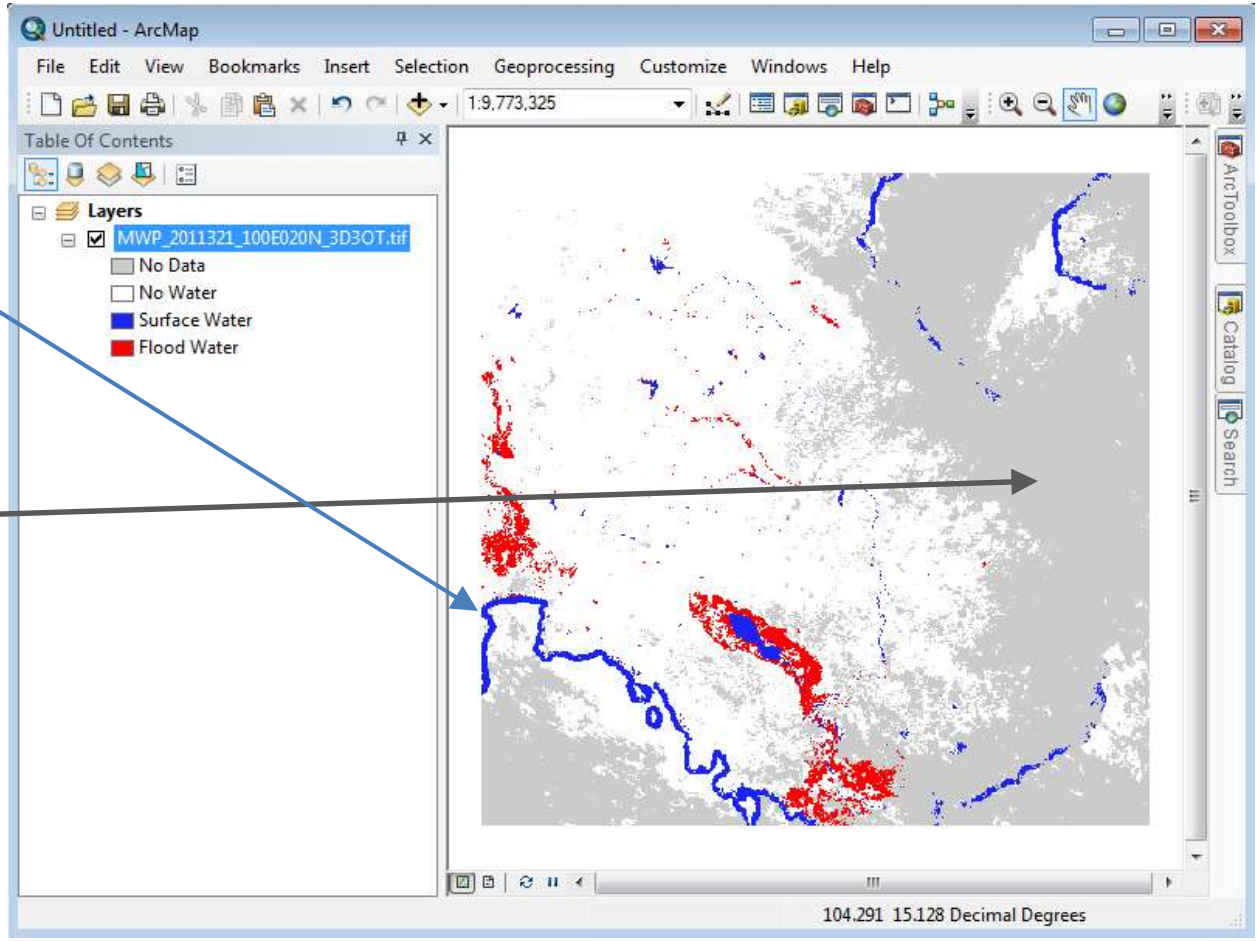
- date selector
- product/format downloads

Products: MODIS Water Product (MWP)

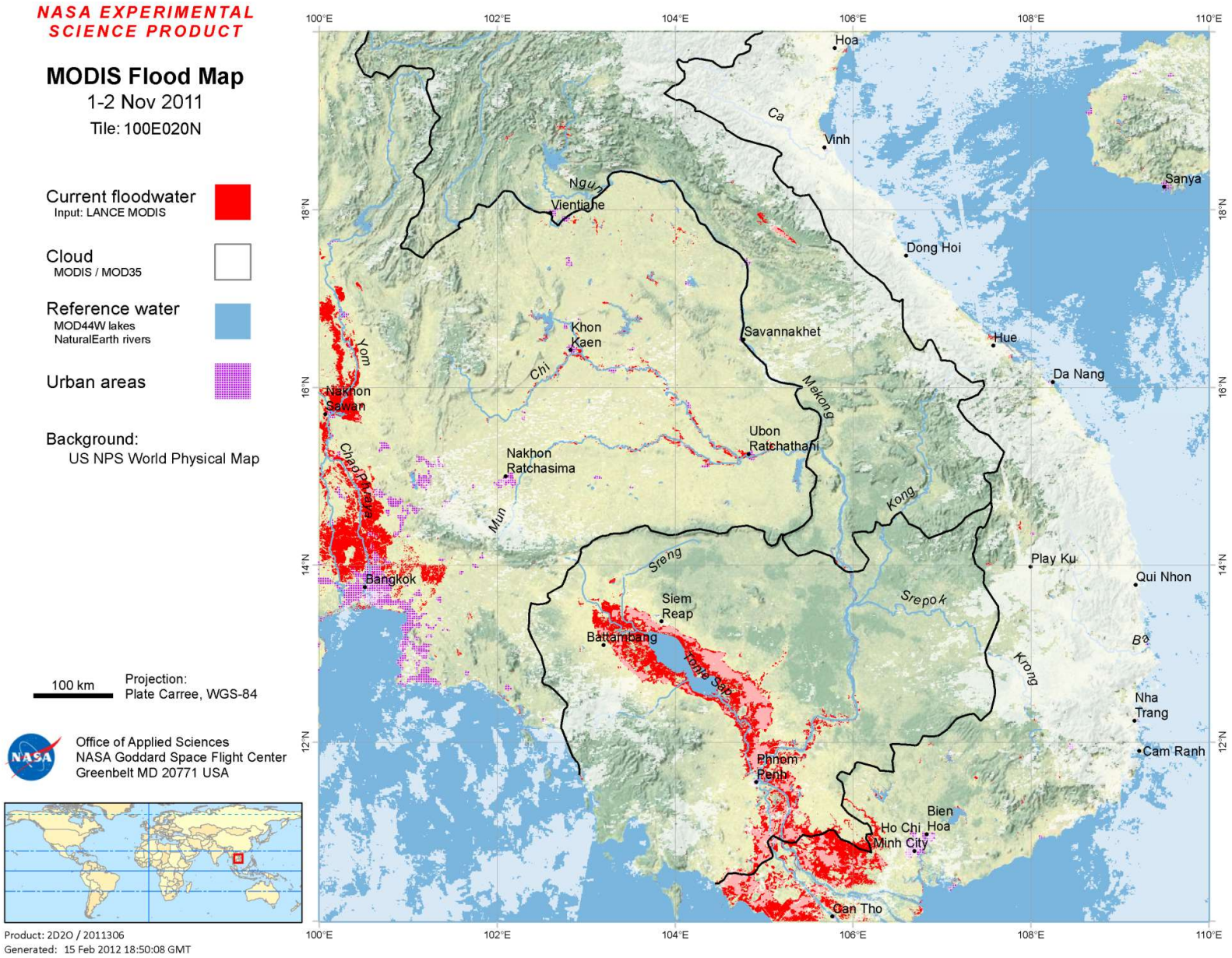
- Core product
- Geotiff format
- Values:
  - 0: Insufficient data (for composite period)
  - 1: No water detected
  - 2: Surface water (corresponding to Reference water pixels).
  - 3: Flood water (water outside Reference water pixels).

- Coastal strip visible; ocean water removed beyond 10 km

- MOD35 Cloud used only to populate "Insufficient data"; water detected through cloud IS reported

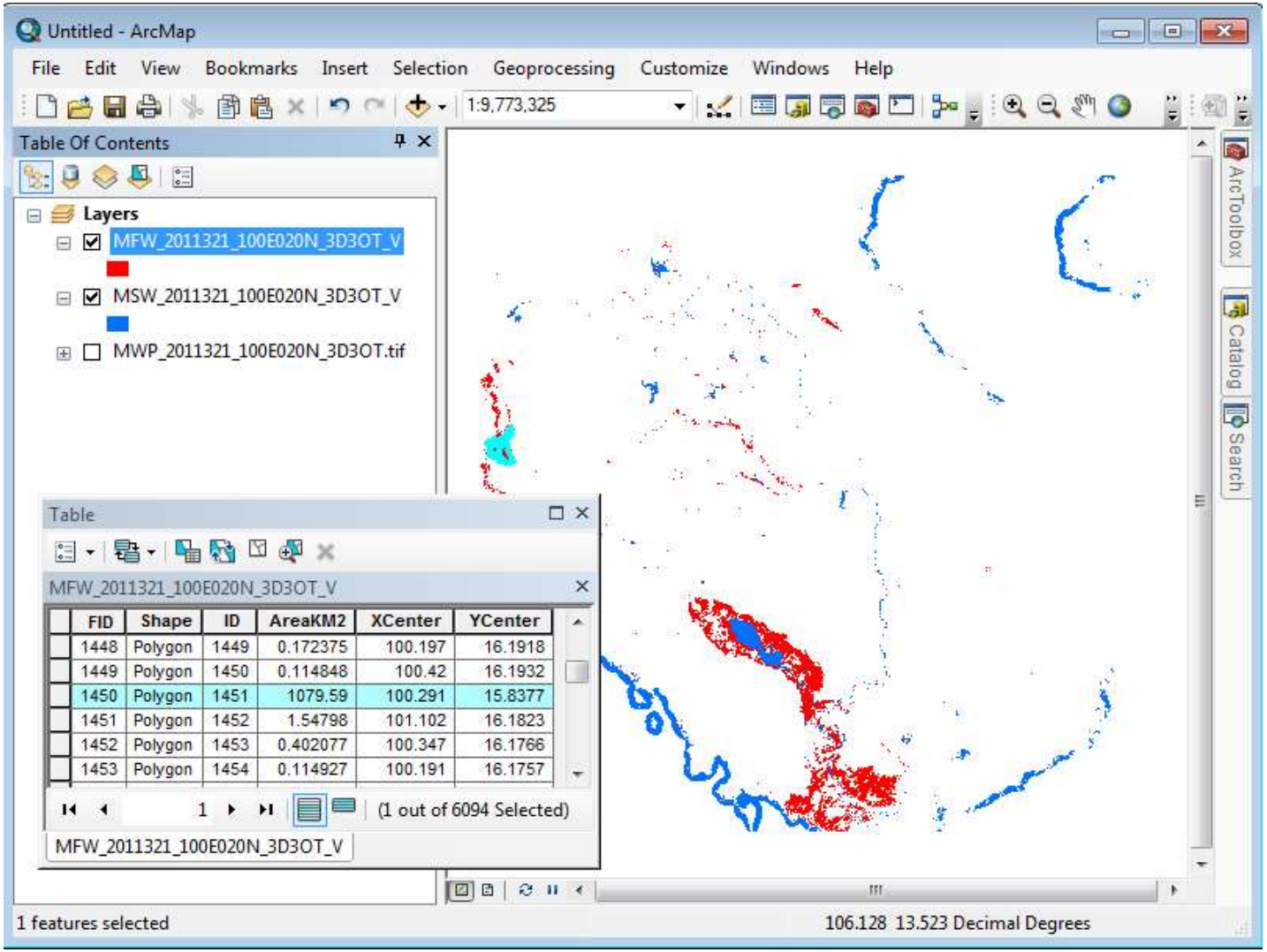


Products: MODIS Flood Map (MFM) 10° tile graphic map (PNG)



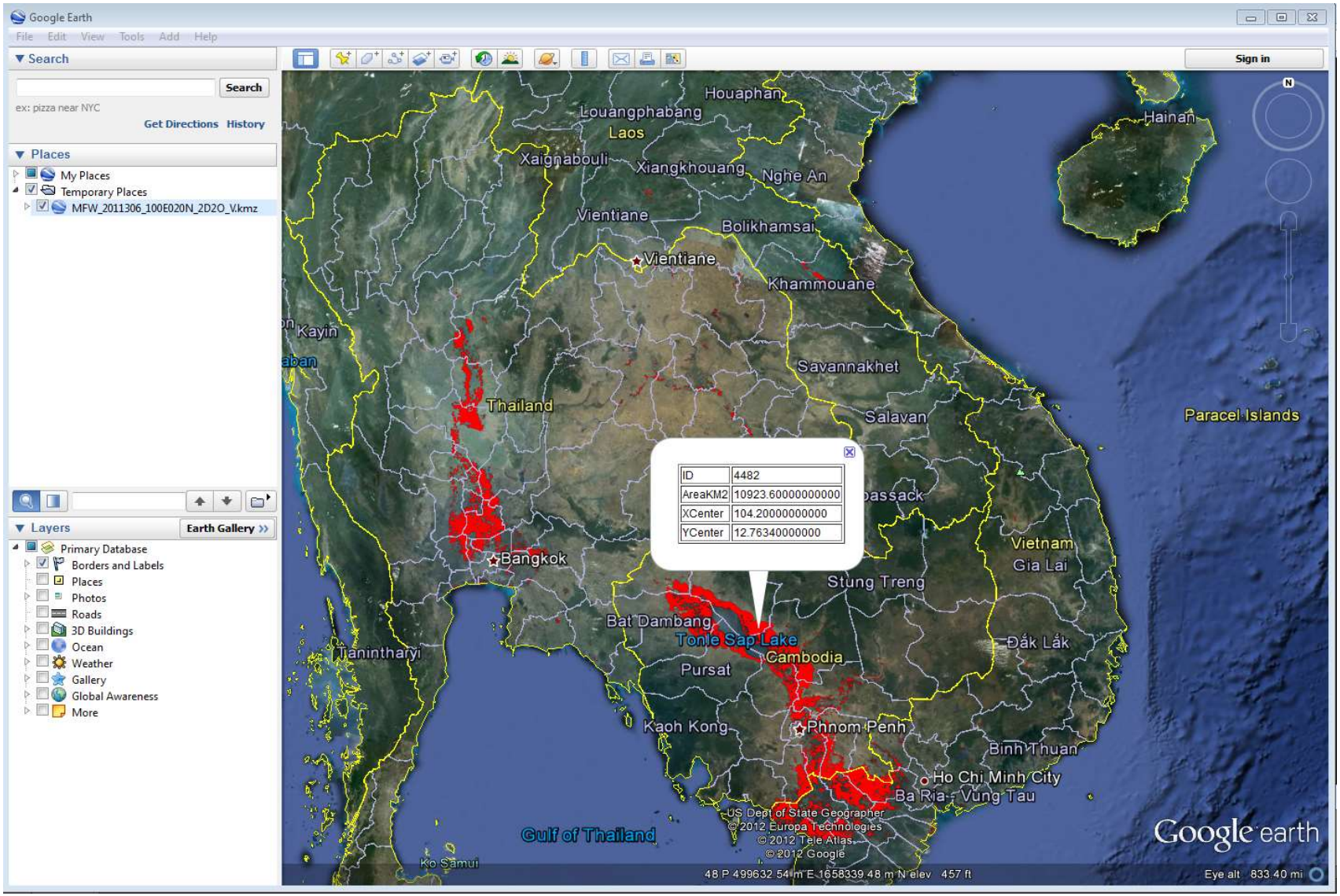
Products: MODIS Surface & Flood Water (MSW, MFW) shapefiles

- 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



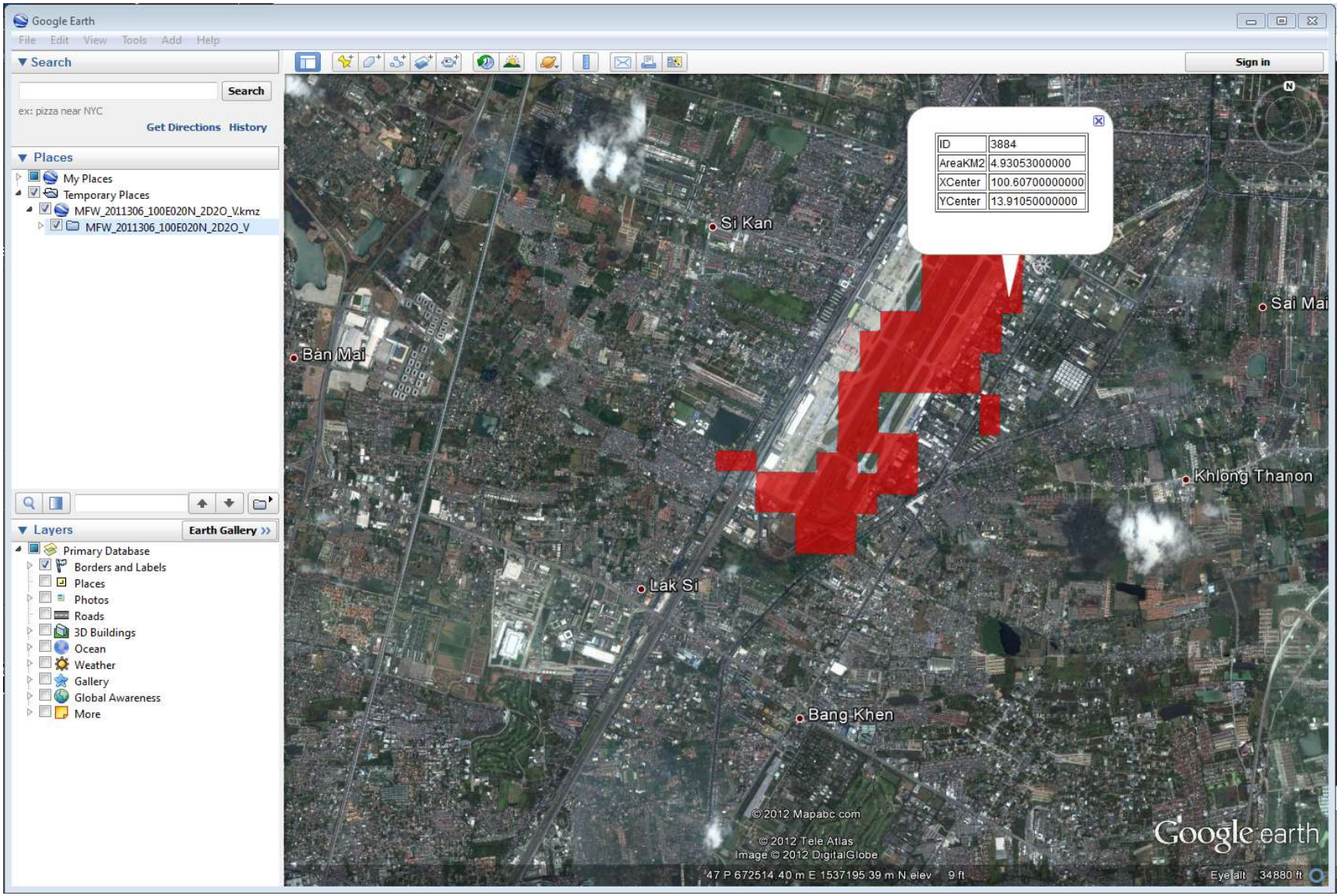
Products: MODIS Surface & Flood Water KML files (Google Earth)

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

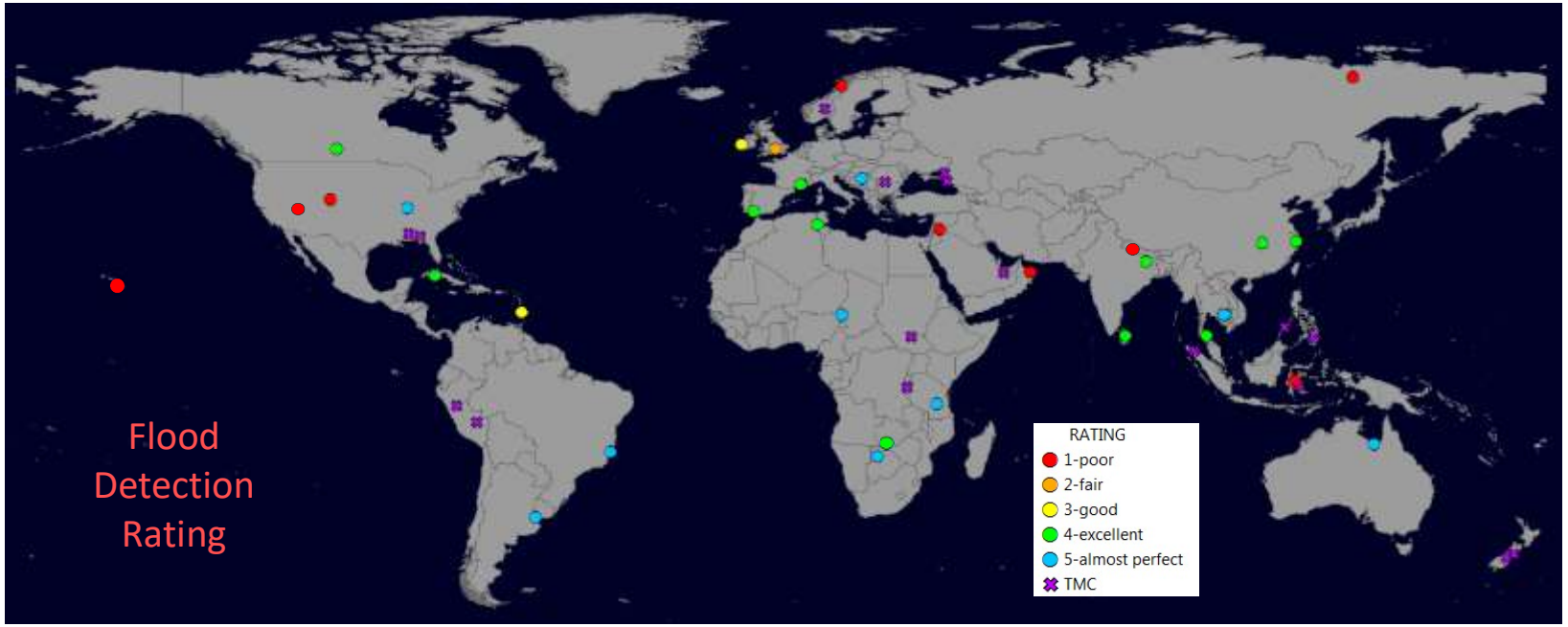
Purpose:

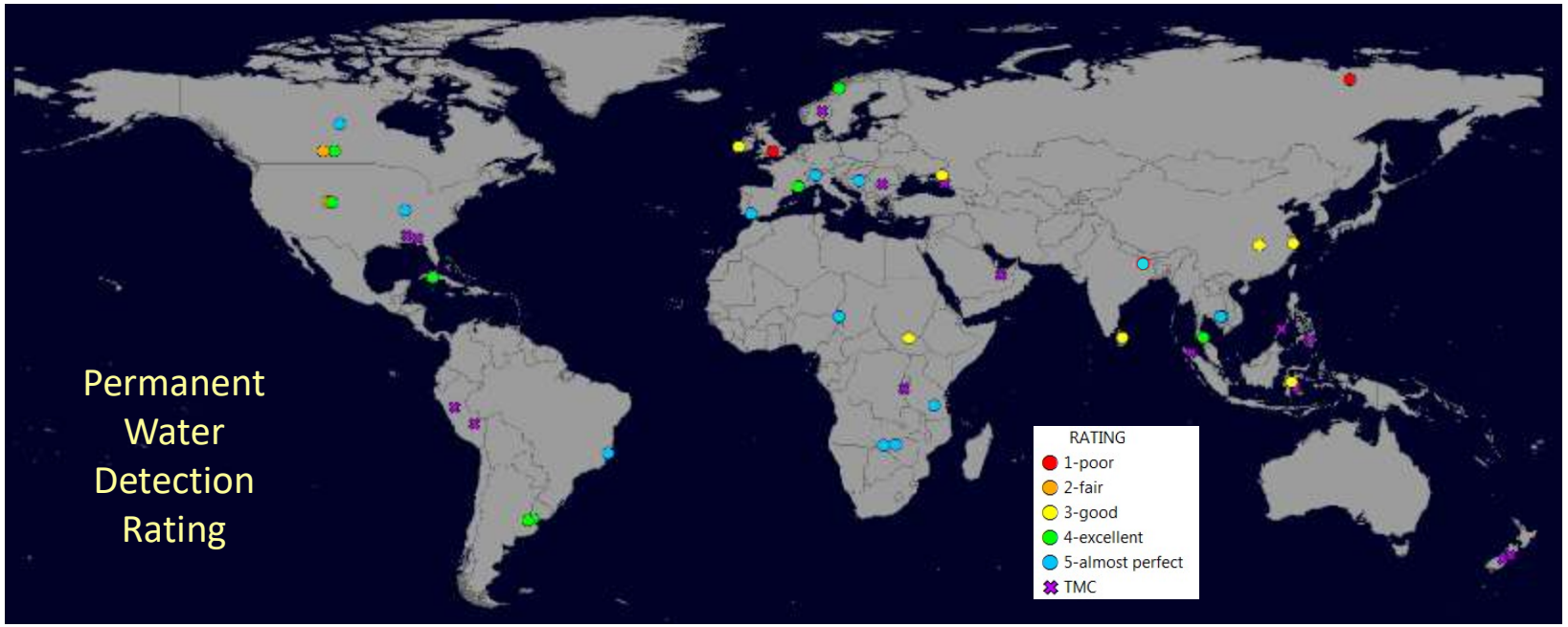
- Is water detection algorithm working
  - correctly detecting visually obvious water?
- Are certain situations problematic?
- Are the multi-day composited products working well?
- Differences between detection of flood water vs normal water

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
Rating
RATING
1-poor
2-fair
3-good
4-excellent
5-almost perfect
TMC


Permanent
Water
Detection
Rating
RATING
1-poor
2-fair
3-good
4-excellent
5-almost perfect
TMC

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

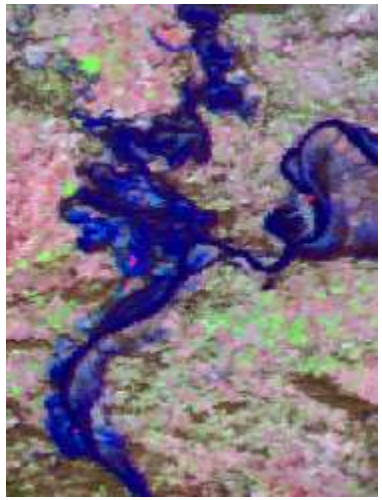
84% of clear

Example: Correct flood identification

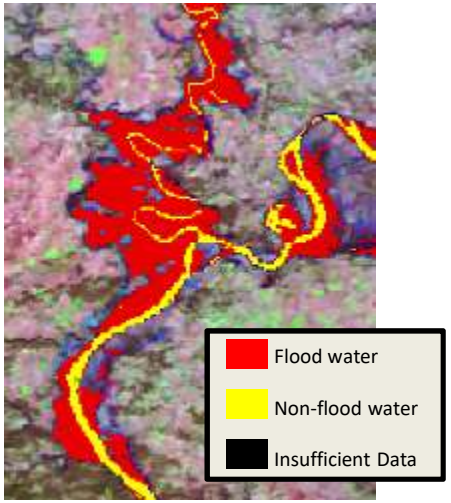
Kentucky: 04 Jan 2014

National Geographic
base map

MODIS (MOD09) Pre-Flood
Oct 12, 2013



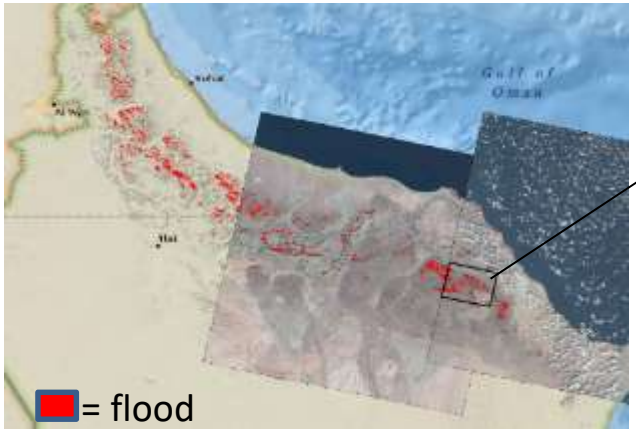
MODIS (MOD09) Flood
Jan 4, 2014



MODIS NRT Product
Jan 4, 2013

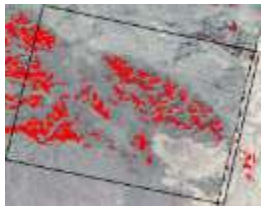
Terrain shadow false-positives

OMAN: mid November 2013 products

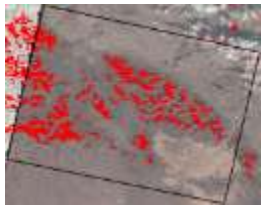


3-day product

Landsat 8
June 17, 2013
(2013178)



Landsat 8
Nov 9, 2013
(2013313)



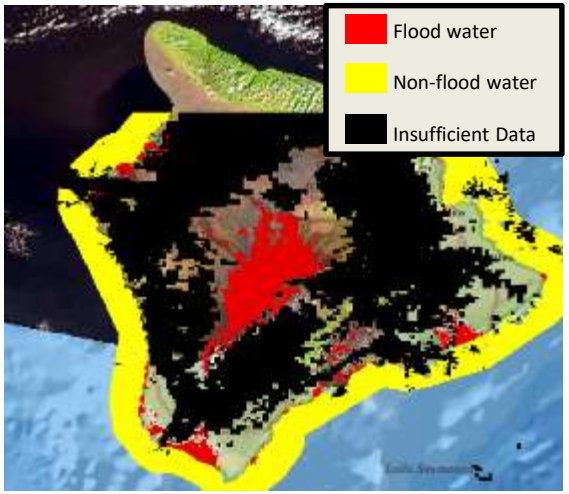
Landsat 8
Nov 18, 2013
(2013322)

MODIS (MOD09)
Nov 11, 2013
(2013315)

Example: Barren rock / volcanic false positives

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

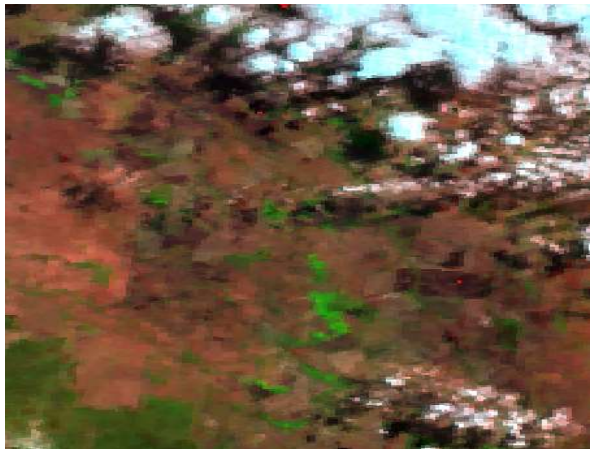
Landsat 8



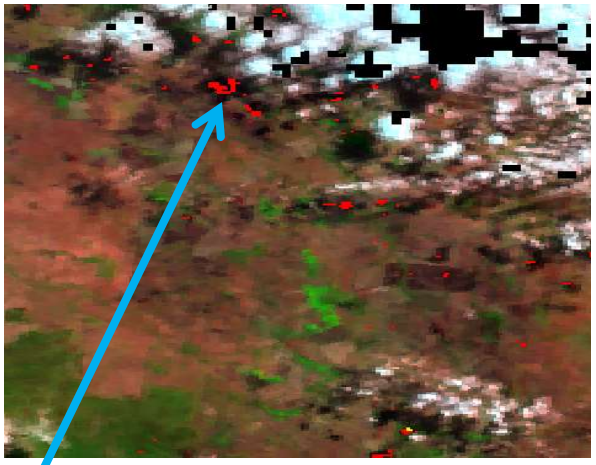
MODIS NRT Product

Example: Cloud shadow false-positives

Australia: 04 July 2014



Input data: MOD09, 04 Jul 2014



2-day Product on MOD09

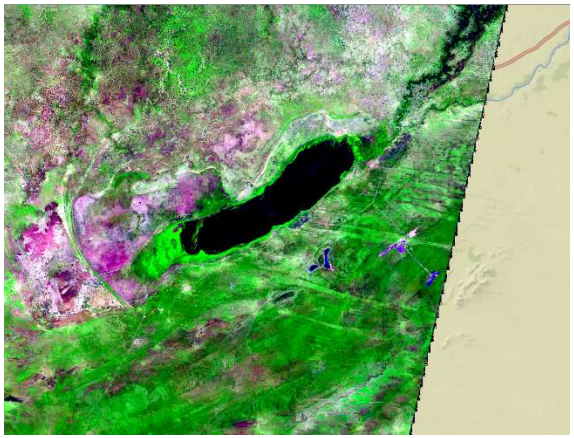
3-day product removes most cloud shadow false positives

3-day Product

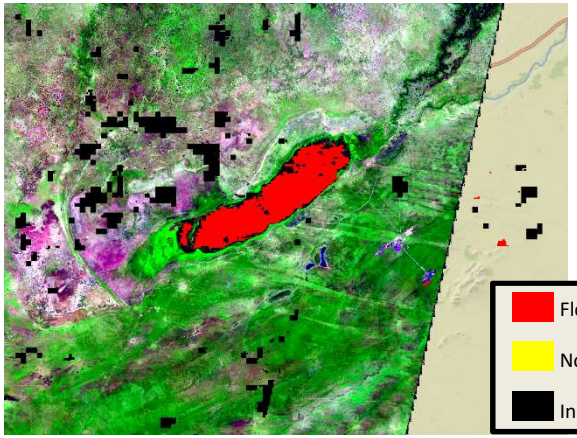
Comparison of different compositing periods: 2-day vs 3-day product

Botswana: 24 Mar 2014

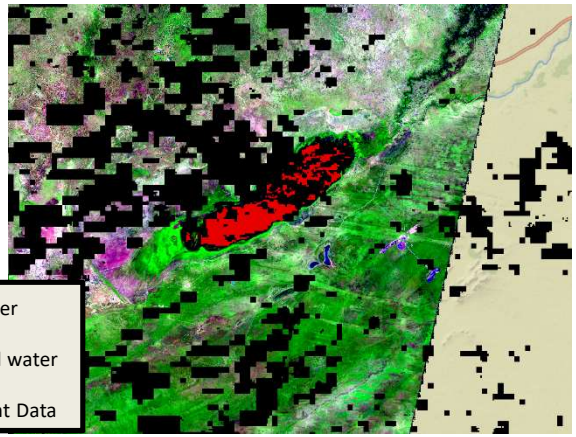
National Geographic base map



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^{o} X 10^{o} 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 ?

Water detection algorithm

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

AND $Band1 < D$

AND $Band7 < E$

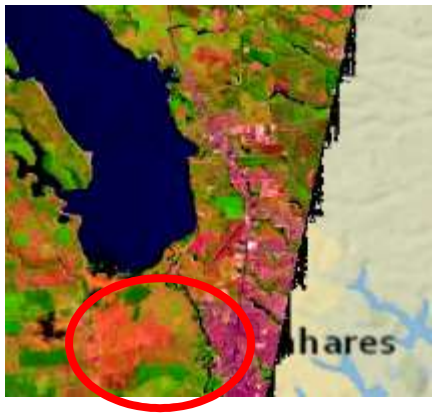
A	13.5
B	1081
C	0.7
D	2027
E	676

Bands are MOD09 surface reflectance product
Thresholds in units of scaled reflectance (0-10000)
Developed by Bob Brakenridge, Dartmouth Flood Observatory

Correct flood and permanent water identification

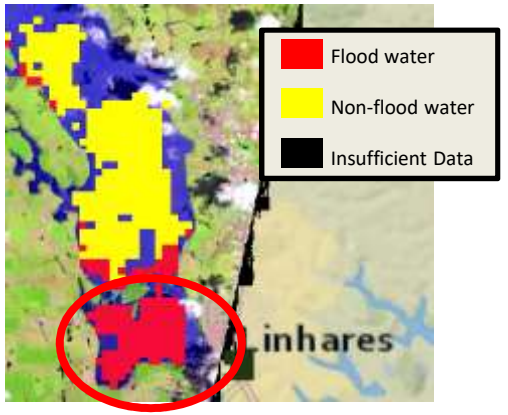
Brazil: 02 January 2014

National Geographic base map



Landsat 8 Pre-flood Apr 21, 2013

Landsat 8 Flood Jan 2, 2014



MODIS NRT product Jan 3, 2014

Correct flood identification

Bosnia and Herzegovina: 23 May 2014