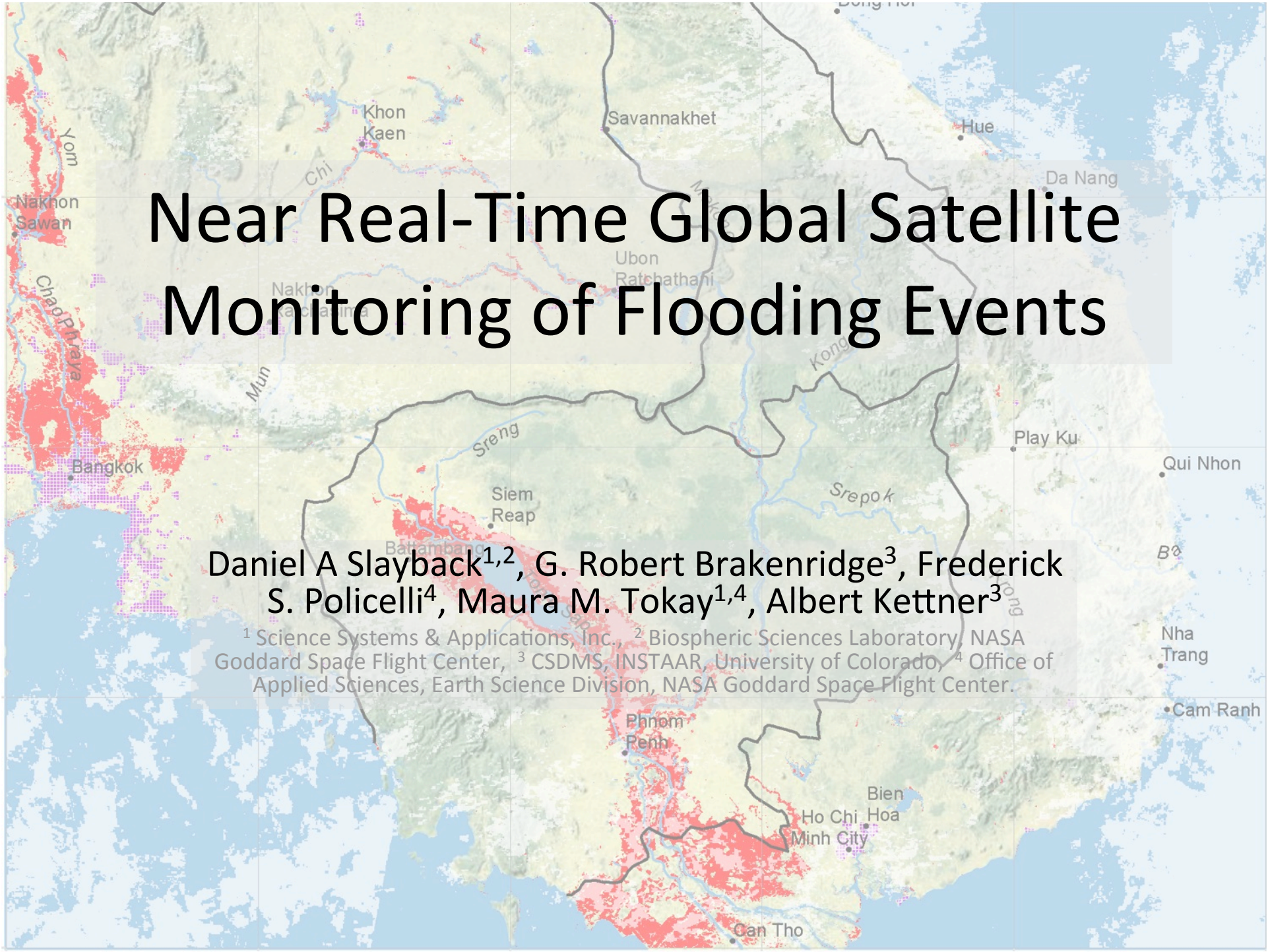

Near Real-Time Global Satellite Monitoring of Flooding Events

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Motivation

2011 Floods:

Flooding constitutes a significant, and often the highest, proportion of disasters worldwide.

Center for Research on the Epidemiology of Disasters (CRED) figures show:

1. Floods are the most common natural disaster: globally 30% of all reported natural disasters.
2. Floods are increasing in number, especially over the last 15 years.
3. Floods are globally widespread.

Fig 1:

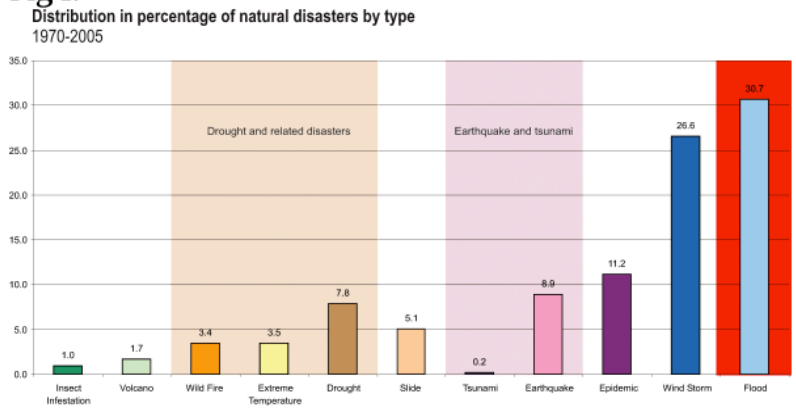


Fig 2:

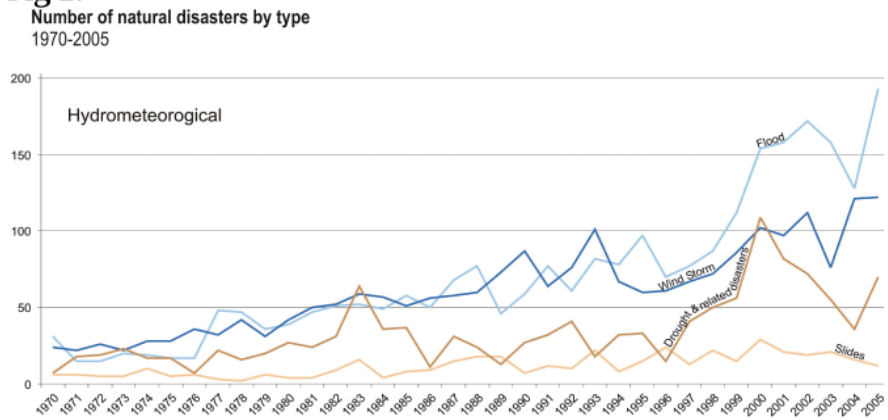
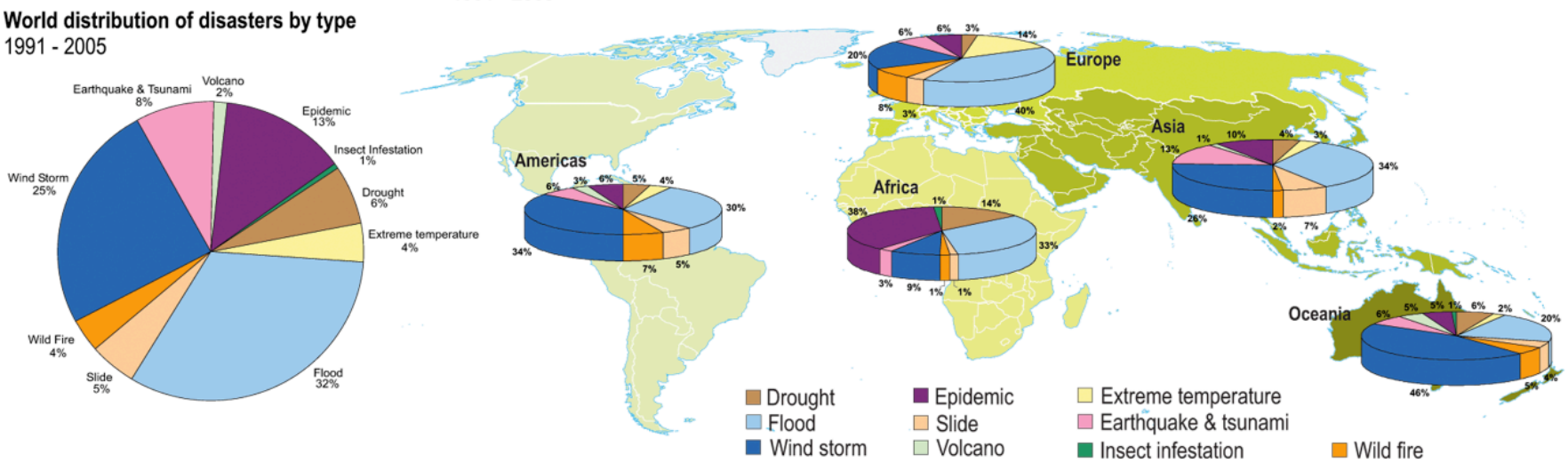


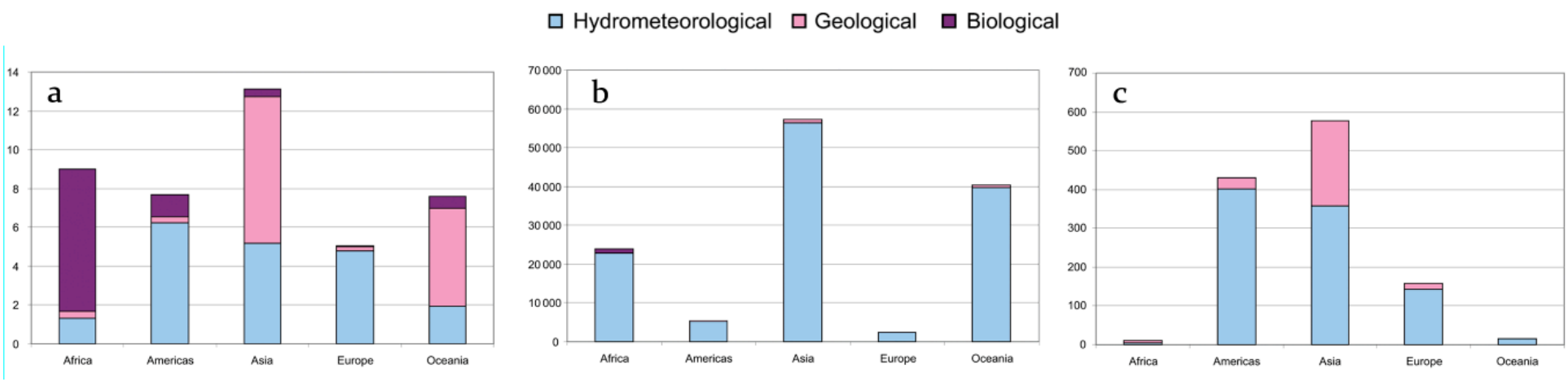
Fig 3:



Human & Economic Impacts

The majority of global disaster impacts, including numbers of people killed and affected, and economic damages, result from flooding.

1991-2005 (CRED): (a) # people killed/million inhabitants, (b) # people affected /million, and (c) reported economic damages, billion US$.



An International Flood Initiative report (ICWHRM 2007) estimates:

- Floods affecting > 520 million people per year worldwide (~10% of global population) via homelessness, disaster-induced disease, crop and livestock damage, famine.
- Annual death toll of ~25,000
- Economic toll of $50-60 billion US$

Motivation

- Disaster management agencies have very limited capabilities to monitor the onset and progress of these events.
- Aid agencies such as the International Federation of Red Cross and Red Crescent Societies (IFRC) and government agencies such as FEMA (Federal Emergency Management Agency) and the Pacific Disaster Center are increasingly seeking better information concerning flooding extent in order to respond to and help mitigate the effects of damaging floods.
- The Dartmouth Flood Observatory (original developed at Dartmouth College, but now housed at the University of Colorado) has developed algorithms for detecting flood water using daily imagery from NASA's MODIS satellite, and has been providing the resulting current floodwater information on freely available maps for the past decade (http://floodobservatory.colorado.edu/Modis.html).
- However, the preparation of these flood maps has been a manual process; they are not always available in the timely manner needed by relief agencies at the start of an event, a particularly important time as the extent of flooding will be least understood.
- To achieve near real-time flood map production, NASA's Applied Sciences Program provided funding to automate this process.
- Our team has now operationalized global near real-time flood mapping from MODIS imagery.

OAS Flood Mapping System

Key Features

1. Custom MODIS input imagery from the near real-time LANCE system at NASA Goddard.

   We engaged NASA's LANCE-MODIS system (Land Atmosphere Near real-time Capability for EOS, http://lance.nasa.gov) to provide custom imagery products, to ease the routine processing burden.

   The LANCE system delivers daily images of calibrated band 1, 2, and 7 reflectances from each satellite, compositing all orbits for the day into 10-degree tiles, along with corresponding cloud and solar angle products.

2. Flood detection algorithm provided by B. Brakenridge/Dartmouth Flood Observatory.

   –Empirically derived band ratio threshold to detect surface water: (Band1+A)/(Band2+B).

   –Combine multiple MODIS images over several days to overcome issues with incomplete coverage (cloud, MODIS swath coverage gaps), and problematic cloud and terrain shadows (which can appear as 'water').

   –Compare detected surface water to expected surface water (lakes, rivers, ocean) to identify flood waters.

3. Near real-time flood map production system developed at NASA Goddard's Office of Applied Sciences.

   –Fully automated system runs 24/7, ingesting new MODIS imagery as available from LANCE, and delivering products ~ 30 minutes later via web and ftp.

   –Daily products typically available within ~6 hours of Aqua overpass (~ 8:00 PM local time).

   –Producing global flood products since November 2011.

Near Real-Time Processing System: Product Types

- MWD: MODIS Water Detection. Shows surface water detected in single MODIS image (Terra or Aqua).

- MSW: MODIS Surface Water. Surface water composited from several MWD products (typically all available Terra & Aqua MWD over several days)

- MFW: MODIS Flood Water. MSW with reference water removed to isolate floods.

Near Real-Time Processing System: Product Indicator: *X*D*Y*O

Y: number of water observations required to tag a pixel as water

X: number of days of imagery to examine

Current default product: 2D2O.

Thus, 2 water observations are required over 2 days of imagery (= 4 possible observations) for a pixel to be tagged as water in the MSW and MFW products.

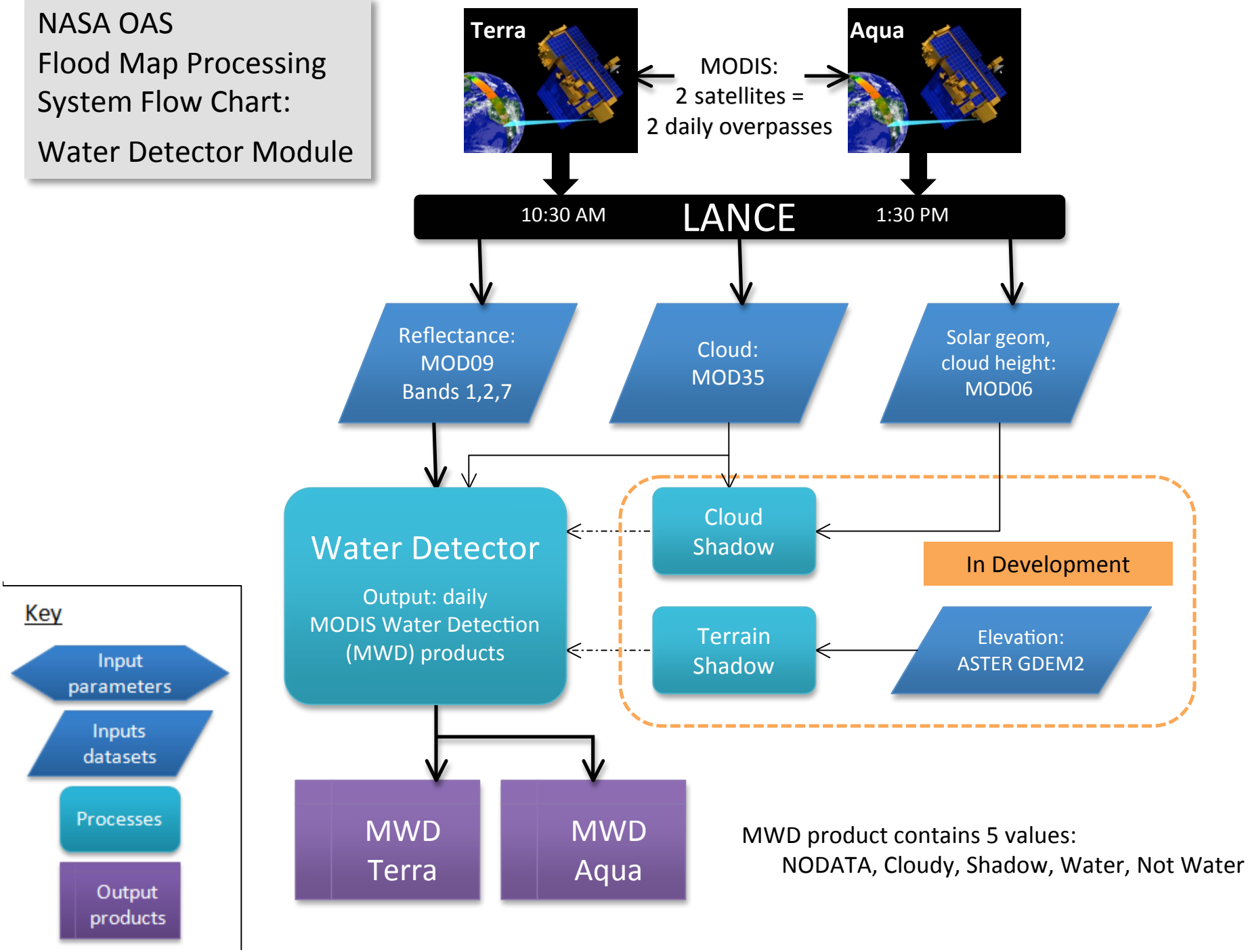
- Requiring multiple days reduces gaps in coverage due to clouds.
- Requiring multiple observations reduces false-detects due to shadows.
- Both increase product latency.

Near Real-Time Processing System: Processing Outline

1. Water Detector module generates MWD base products as LANCE imagery received.
2. Water Compositor module combines MWD files over the product-specified number of days/number of observations, generating the MODIS Surface Water (MSW) product.
3. Reference water (eg., expected normal water levels for rivers/lakes/ocean) is removed from the MSW, to produce flood (MFW) product.
4. Raster MSW and MFW products converted to shapefile and KML vector products.
5. Attributes for the size and centroid of each flood polygon are added to vector products.
6. Graphic map (PNG) display of each 10° map tile is generated.
7. Products posted to web (http://oas.gsfc.nasa.gov/floodmap), ftp'ed to alternate distribution sites (currently DFO), and announced via atom feed (http://modis.geobliki.com/modis/geoactivities.atom).

NASA OAS
Flood Map Processing System Flow Chart:

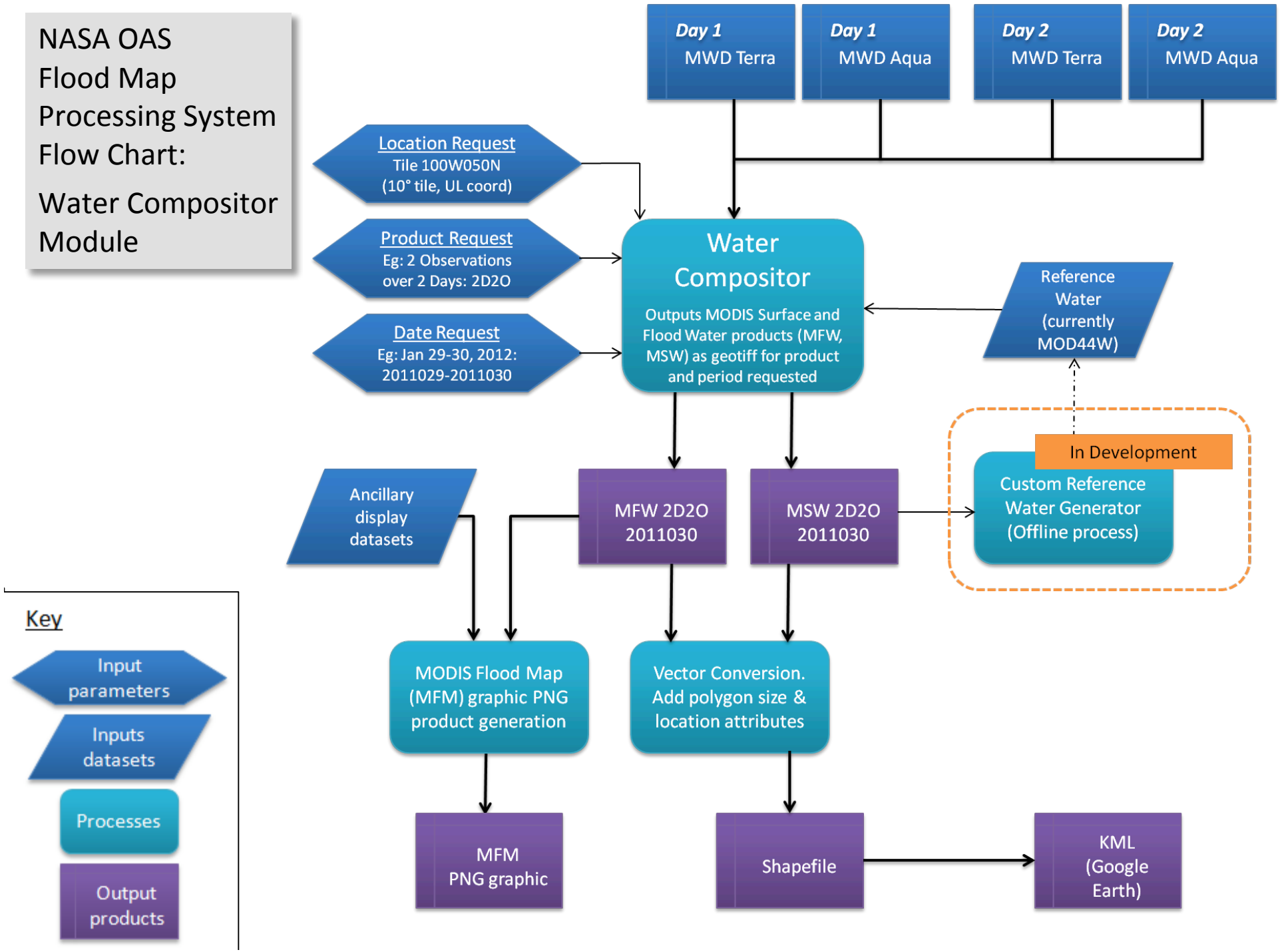
Water Detector Module



MWD product contains 5 values:
NODATA, Cloudy, Shadow, Water, Not Water

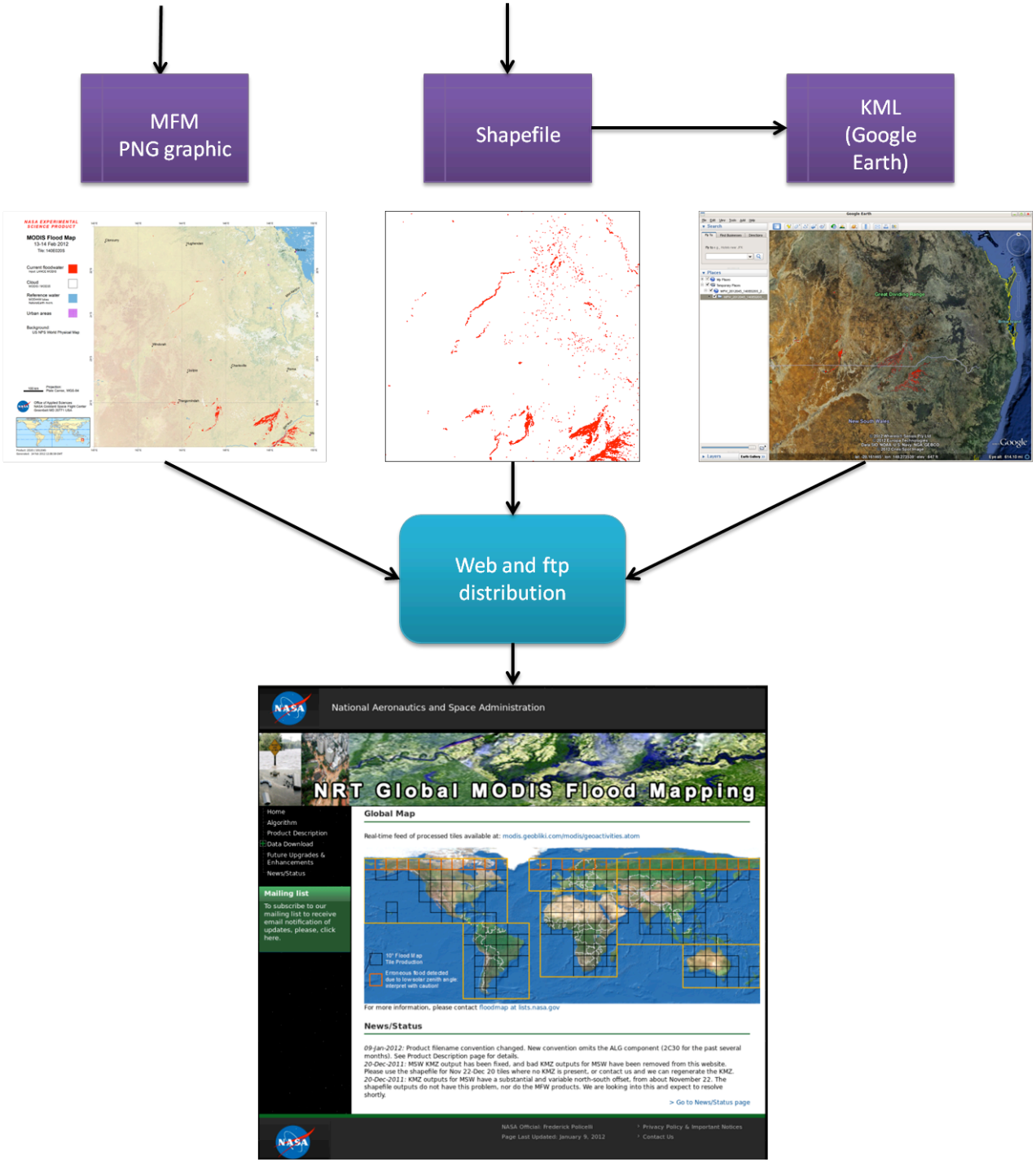
NASA OAS Flood Map Processing System Flow Chart:

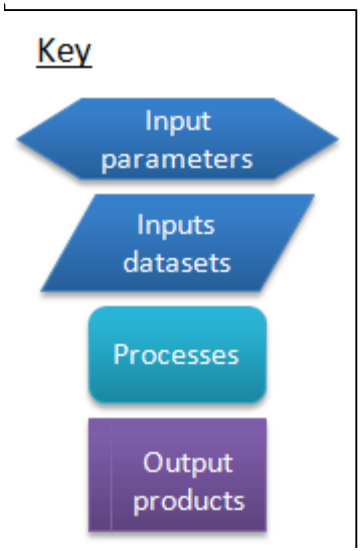
Water Compositor Module



NASA OAS Flood Map Processing System Flow Chart:

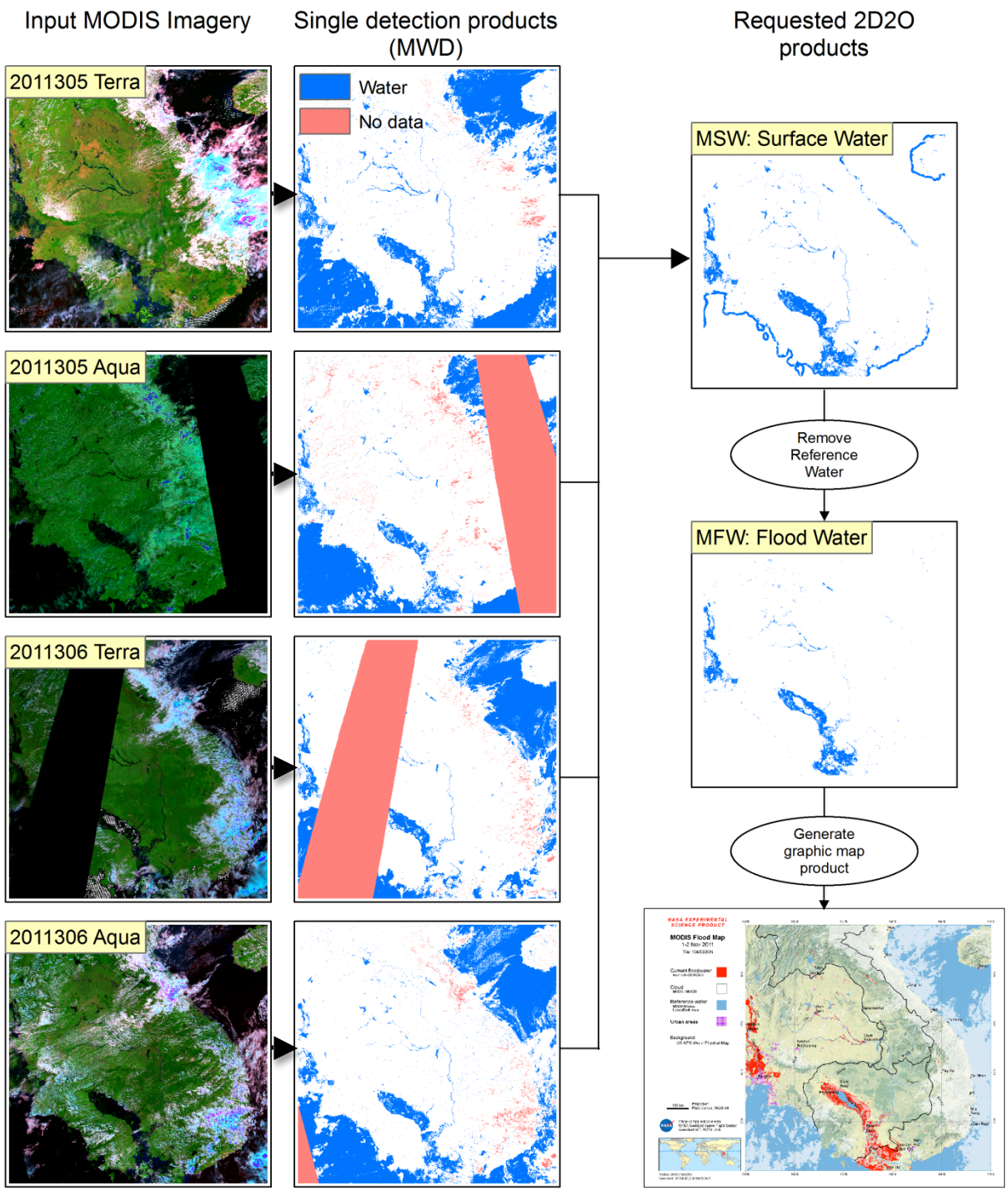
Products & Distribution



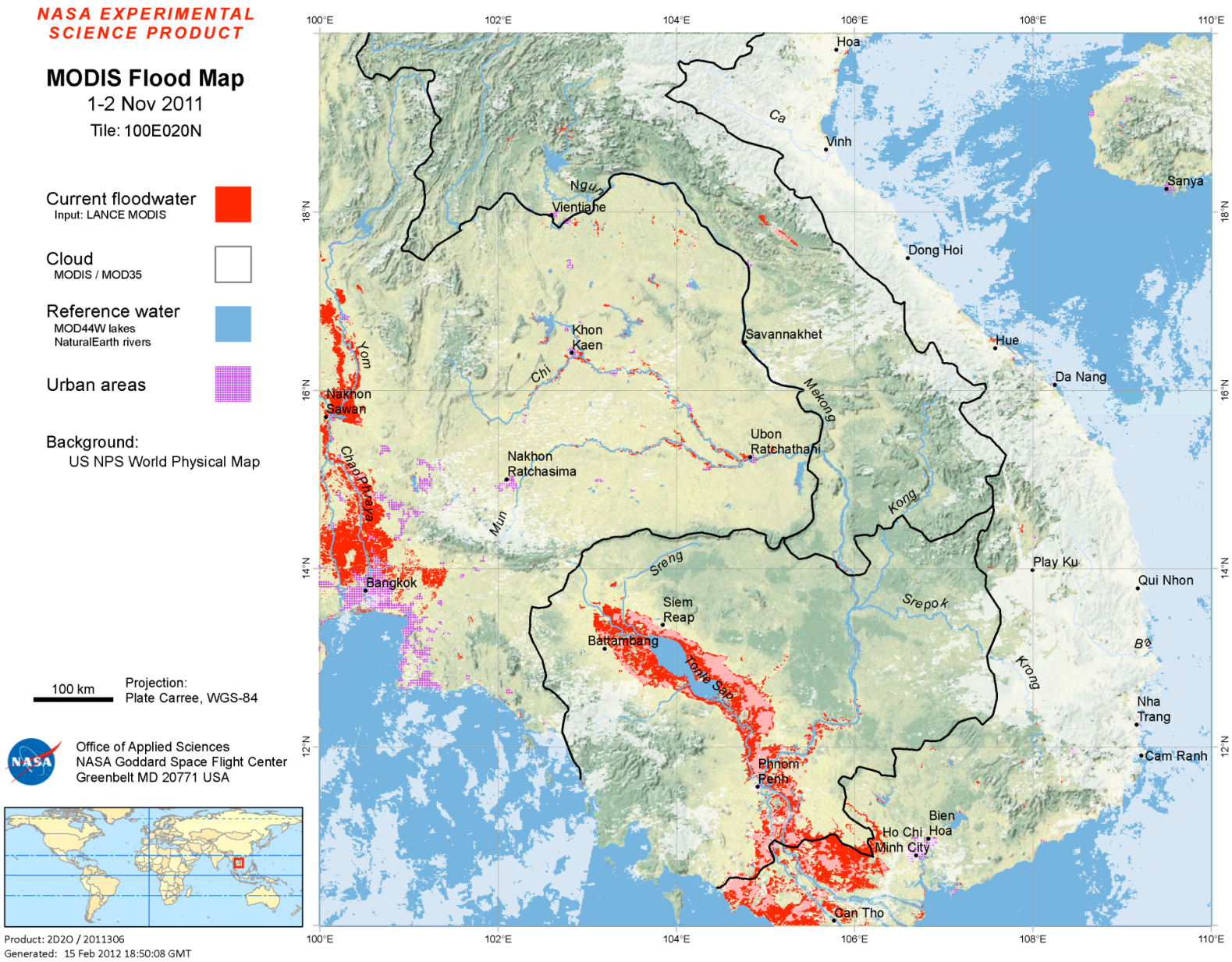


Example:
Thai Floods 2011

Tile: 100E020N
Dates: 1-2 Nov 2011
Product: 2D2O

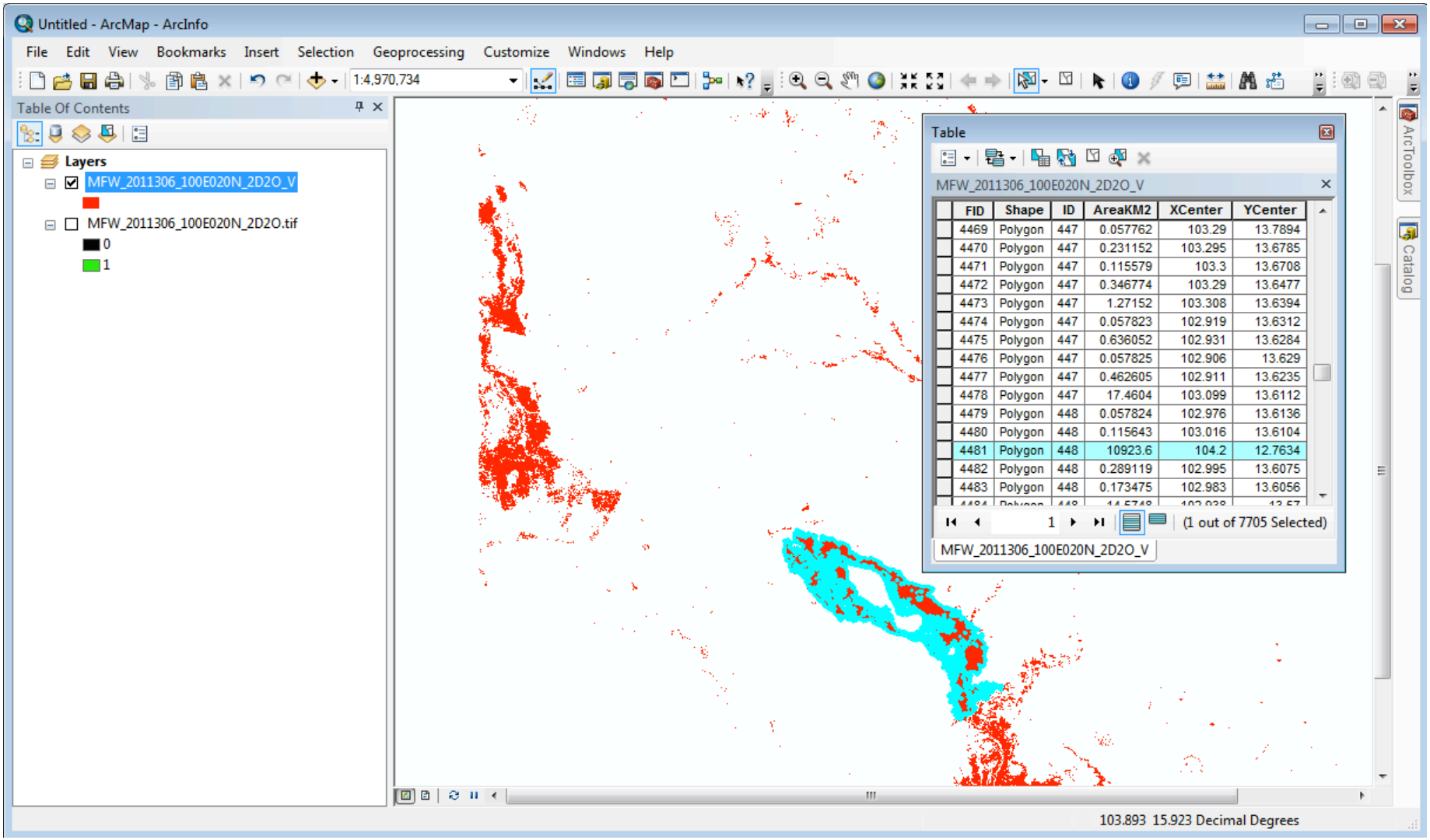


Distribution Products: MODIS Flood Map (MFM) 10° tile png graphic



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

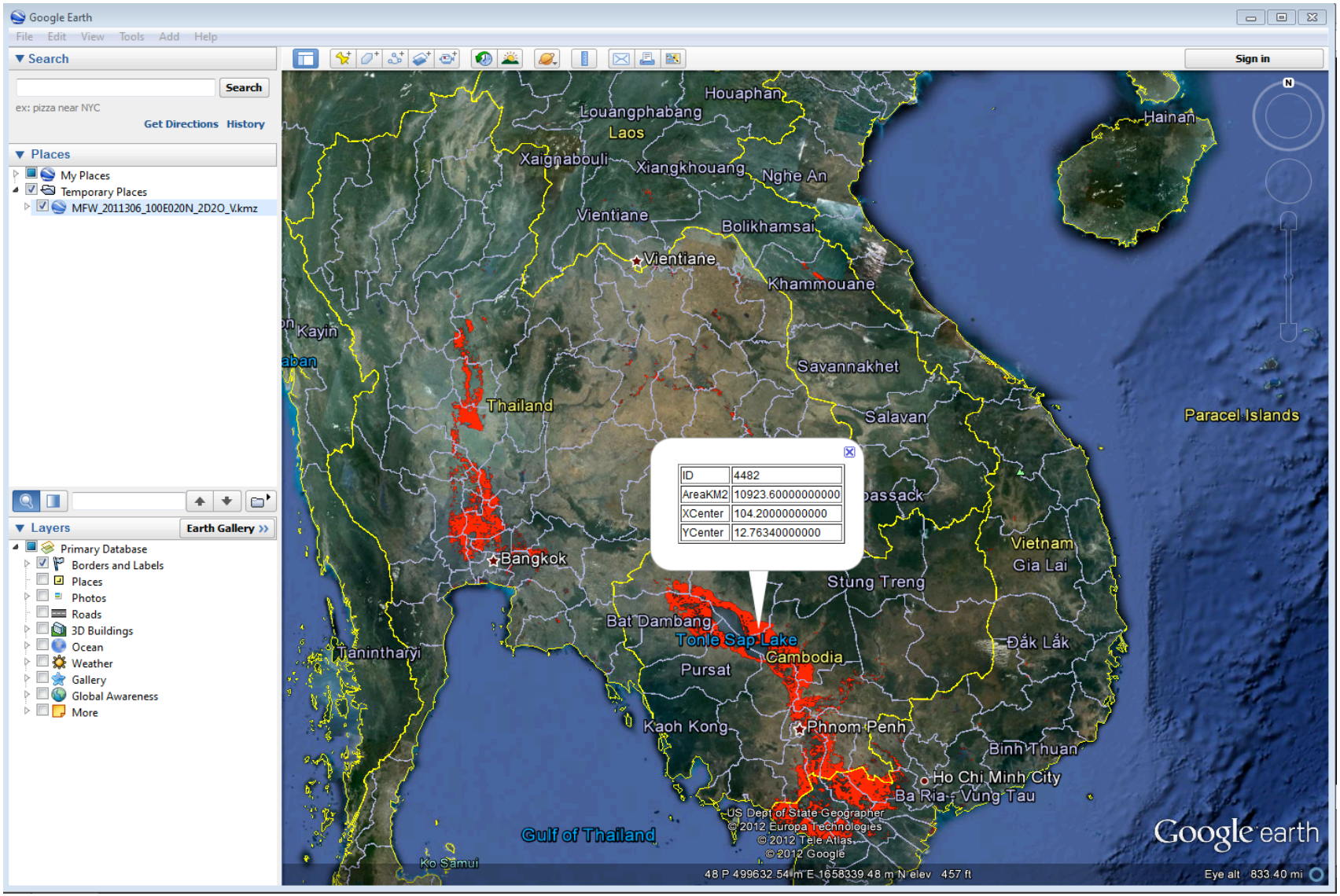
Display / query in ArcMap:



FID	Shape	ID	AreaKM2	XCenter	YCenter
4469	Polygon	447	0.057762	103.29	13.7894
4470	Polygon	447	0.231152	103.295	13.6785
4471	Polygon	447	0.115579	103.3	13.6708
4472	Polygon	447	0.346774	103.29	13.6477
4473	Polygon	447	1.27152	103.308	13.6394
4474	Polygon	447	0.057823	102.919	13.6312
4475	Polygon	447	0.636052	102.931	13.6284
4476	Polygon	447	0.057825	102.906	13.629
4477	Polygon	447	0.462605	102.911	13.6235
4478	Polygon	447	17.4604	103.099	13.6112
4479	Polygon	448	0.057824	102.976	13.6136
4480	Polygon	448	0.115643	103.016	13.6104
4481	Polygon	448	10923.6	104.2	12.7634
4482	Polygon	448	0.289119	102.995	13.6075
4483	Polygon	448	0.173475	102.983	13.6056

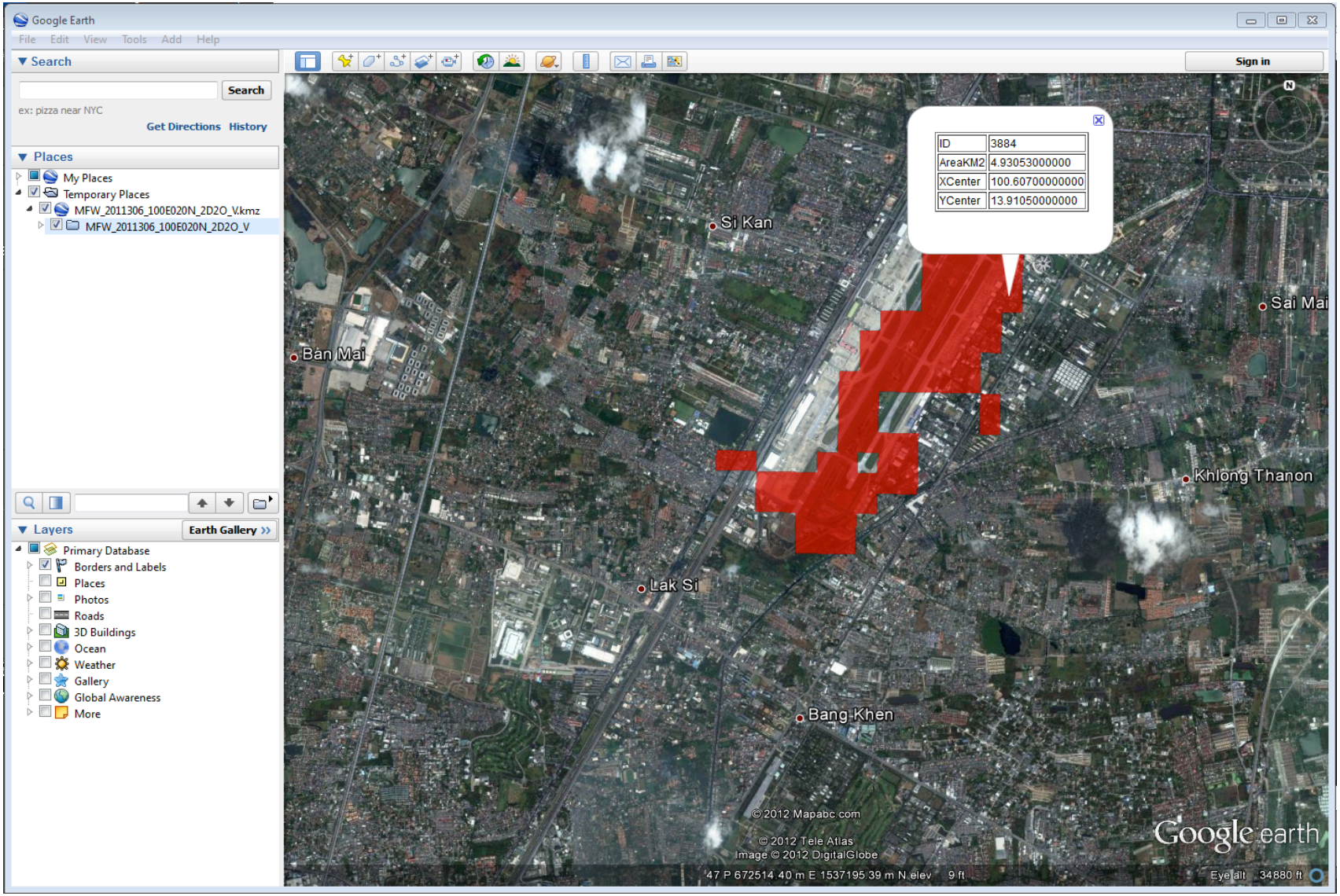
Distribution Products:
MODIS Surface & Flood Water KML files (Google Earth)

Display / query in Google Earth:



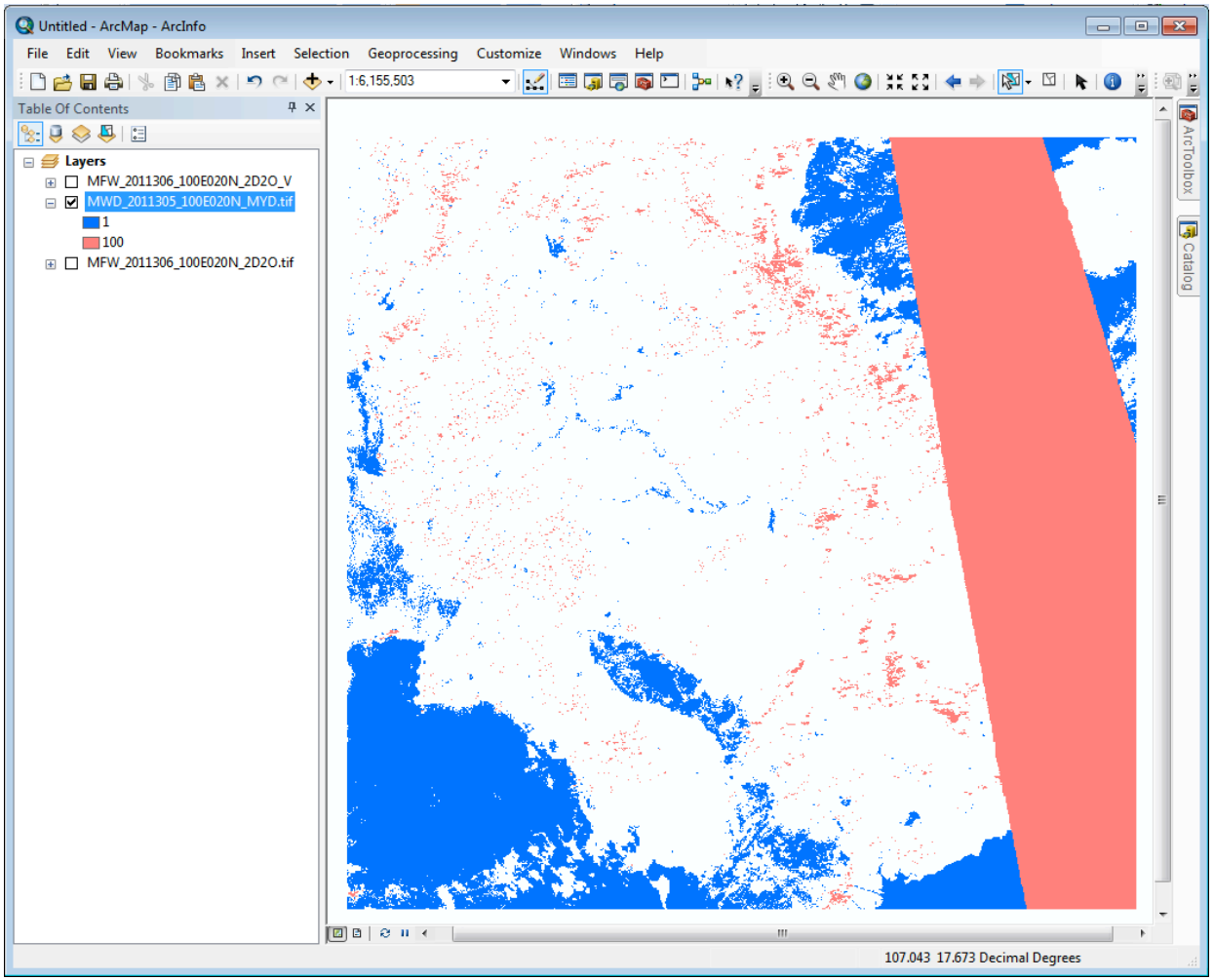
Distribution Products:
MODIS Surface & Flood Water KML files (Google Earth)

Display / query in Google Earth -- Bangkok's Don Muang Airport under ~5 km^2 of water:



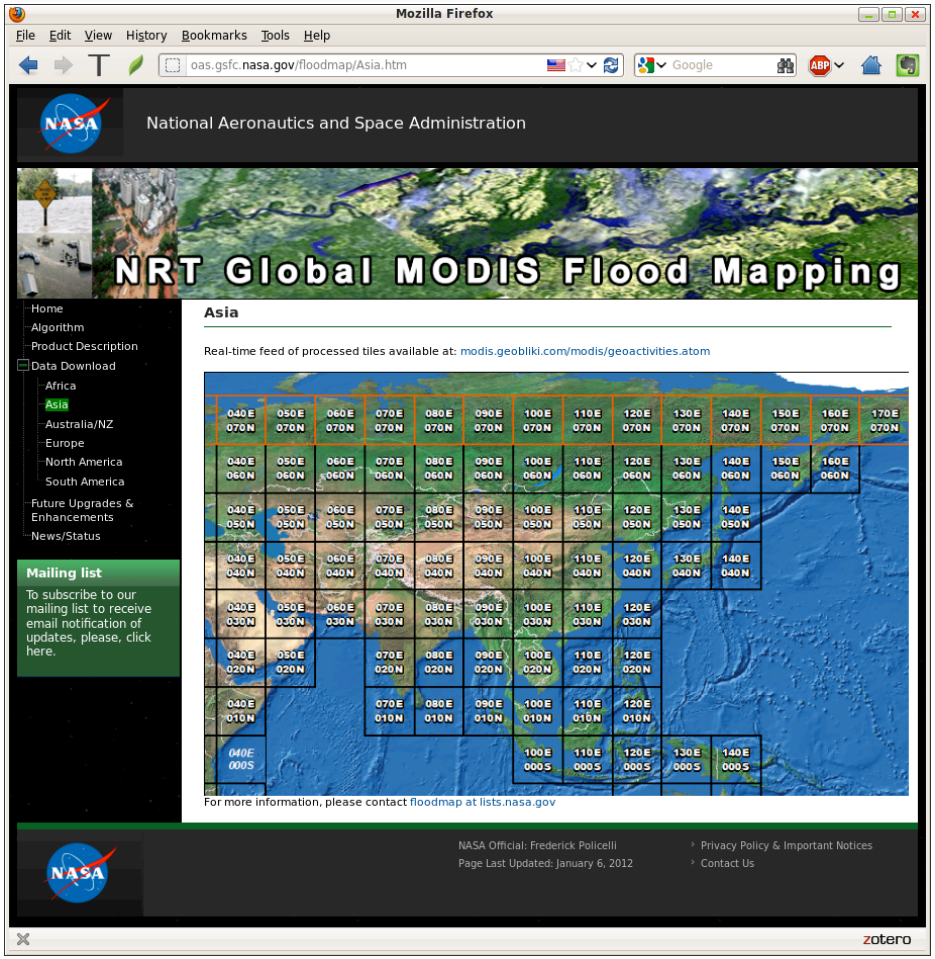
Distribution Products: MODIS Water Detection (MWD) files.

- These single image water detection products are not suitable for public/general distribution as a flood indicator, because this product presents a limited view of flood water extent:
  - Cloud and terrain shadows appear as water.
  - Water under cloud is not detectible; a lack of water indicated in the MWD does not imply no water on the ground at a given point.
- Geotiffs only (at present).
- Values indicate:
  - Water
  - Cloud (not displayed ->)
  - No Data
  - Shadow (TBD)

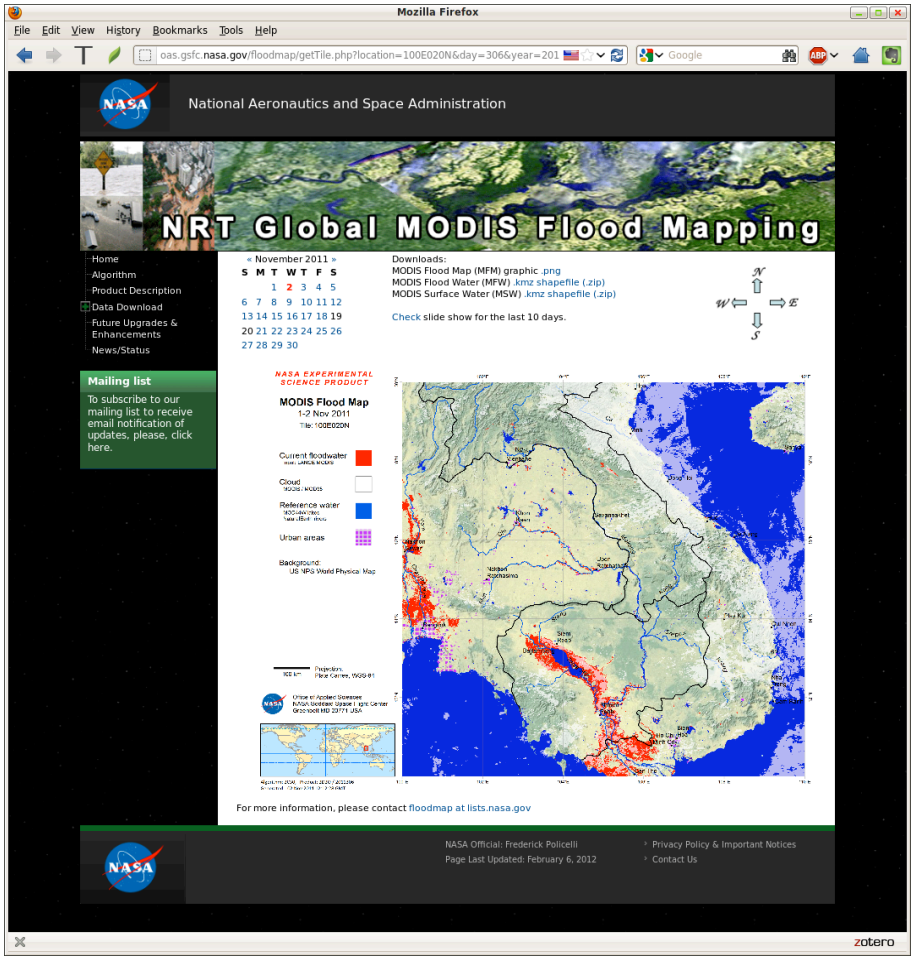


Distribution: OAS website

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



Continental tile overview



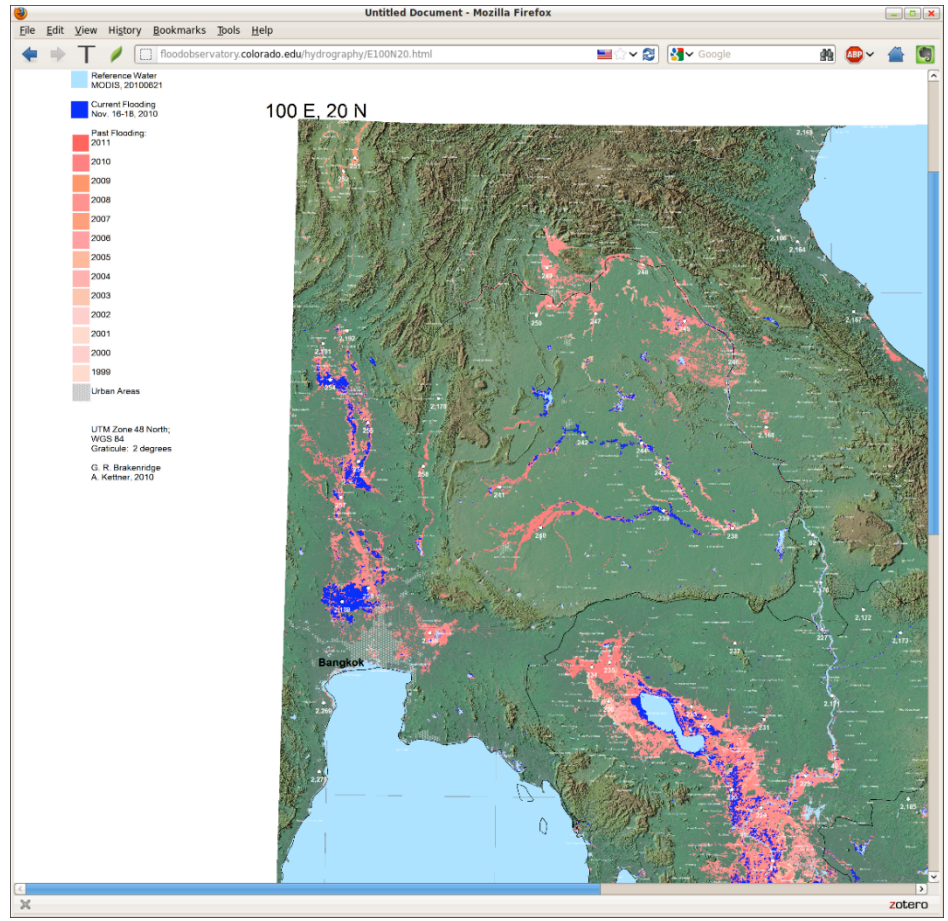
Specific tile:

- date selection
- adjacent tile navigator

Distribution: DFO website

http://floodobservatory.colorado.edu/Modis.html

Global tile overview



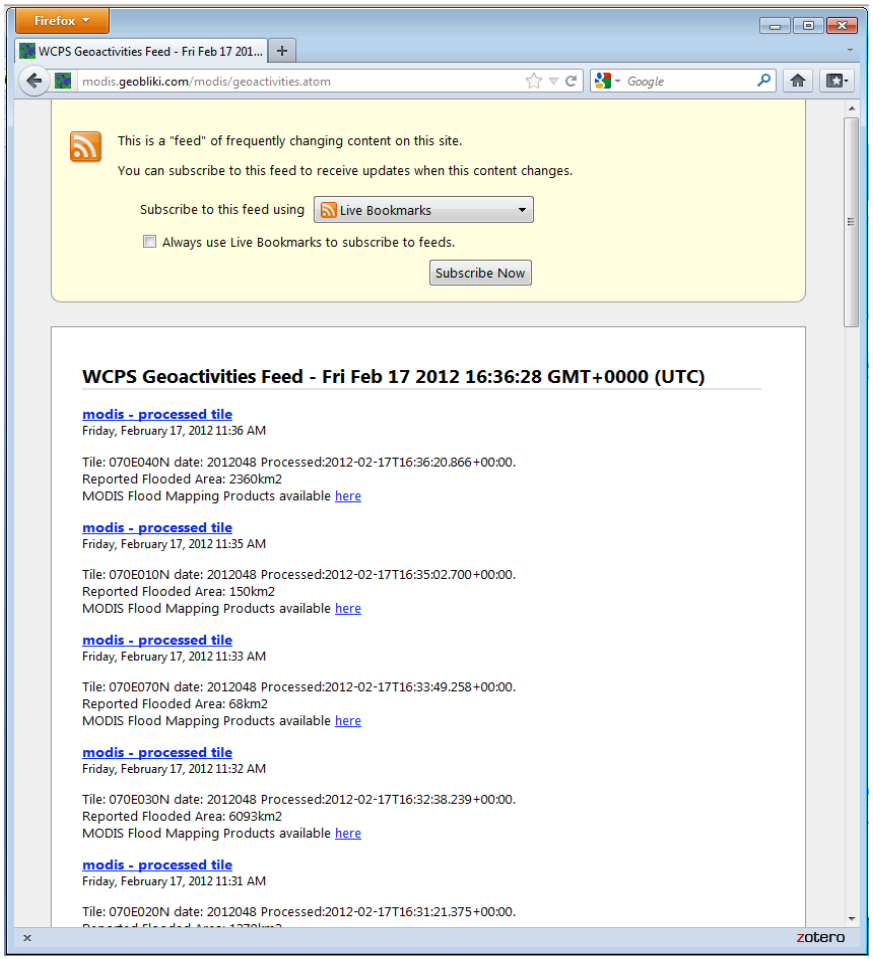
Tile for Thai Flooding, 2011

Distribution: atom feed notifications

http://modis.geobliki.com/modis/geoactivities.atom

Updates posted as product files are delivered to OAS website, including:

- Tile
- Date
- Processing timestamp
- Total reported flood area for tile
- Link to product on OAS website



Next Up

- Geolocation corrections (awaiting LANCE)
- Terrain Shadow Masking
- Cloud Shadow Masking
- Single Day/Sensor Products (1D1O)
- WebGIS interface
- Integration of Landsat, radar, and potentially other sources of water extent
- Validation: problematic. Multiple sensor may be most feasible.