Integrating Global EO and Modeling Systems to support Disaster Relief Agencies

Albert Kettner [1]

Robert Brakenridge[1]

Guy Schumann [1,2]

Bob Adler [3]

Fritz Policelli [4]

Dan Slayback [4]

Patrick Matgen [5]

Michael Souffront [6]

1) DFO - Flood Observatory, CSDMS, INSTAAR, University of Colorado
2) Remote Sensing Solutions (RSS)
3) University of Maryland
4) NASA Goddard Space Flight Center
5) LIST, Luxembourg Institute of Science and Technology
6) Aquaveo, Utah

Dartmouth Flood Observatory

Bob Brakenridge

Paul Bates

Awarded the:
Commander of the British Empire

Recognition for his major contributions towards a better understanding of flood risk management

Integrating Global EO and Modeling Systems to support Disaster Relief Agencies

Albert Kettner [1]

Guy Schumann [1,2]

Bob Adler [3]

Fritz Policelli [4]

Dan Slayback [4]

Robert Brakenridge[1]

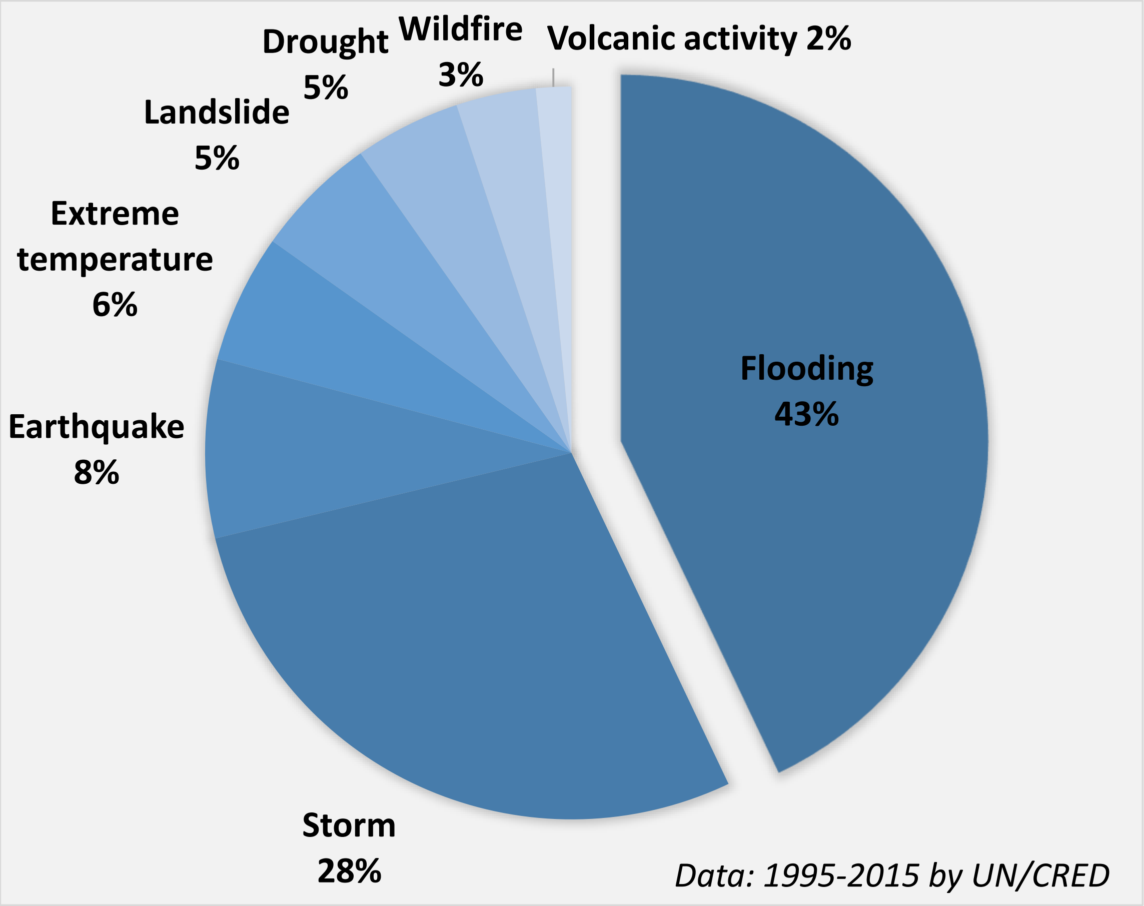
Patrick Matgen [5]

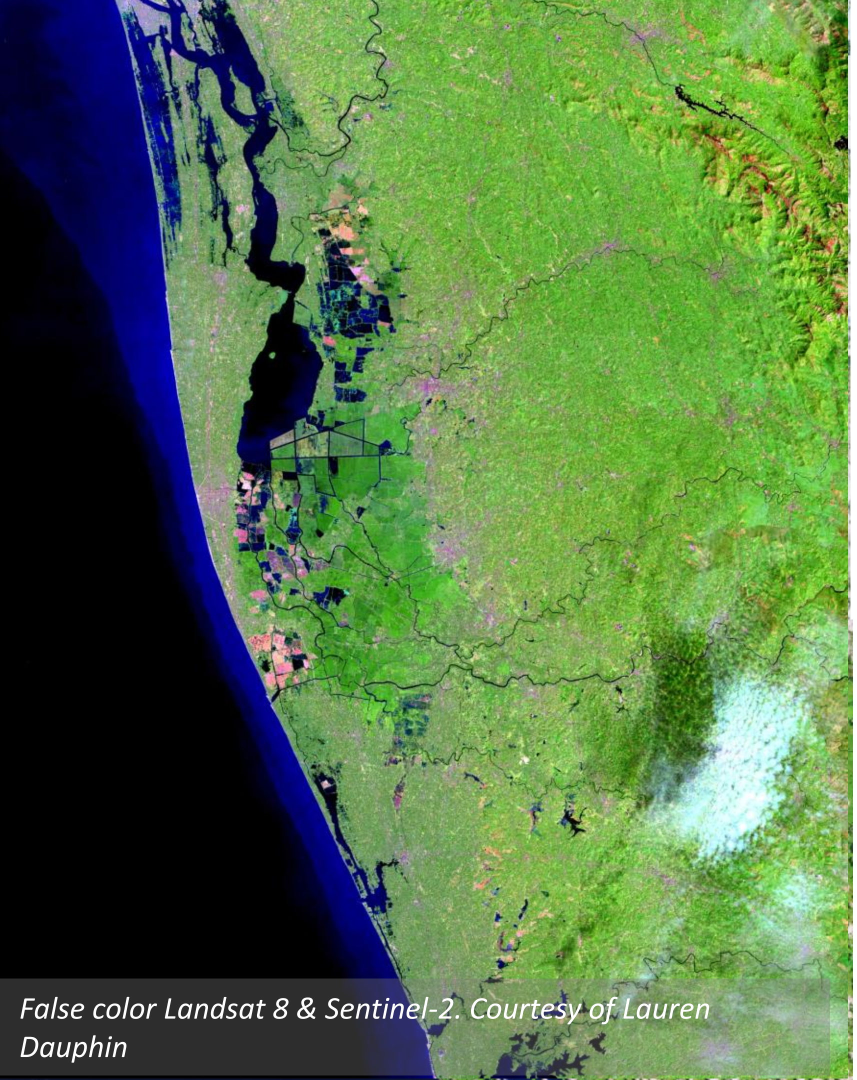
Michael Souffront [6]

1) DFO - Flood Observatory, CSDMS, INSTAAR, University of Colorado
2) Remote Sensing Solutions (RSS)
3) University of Maryland
4) NASA Goddard Space Flight Center
5) LIST, Luxembourg Institute of Science and Technology
6) Aquaveo, Utah

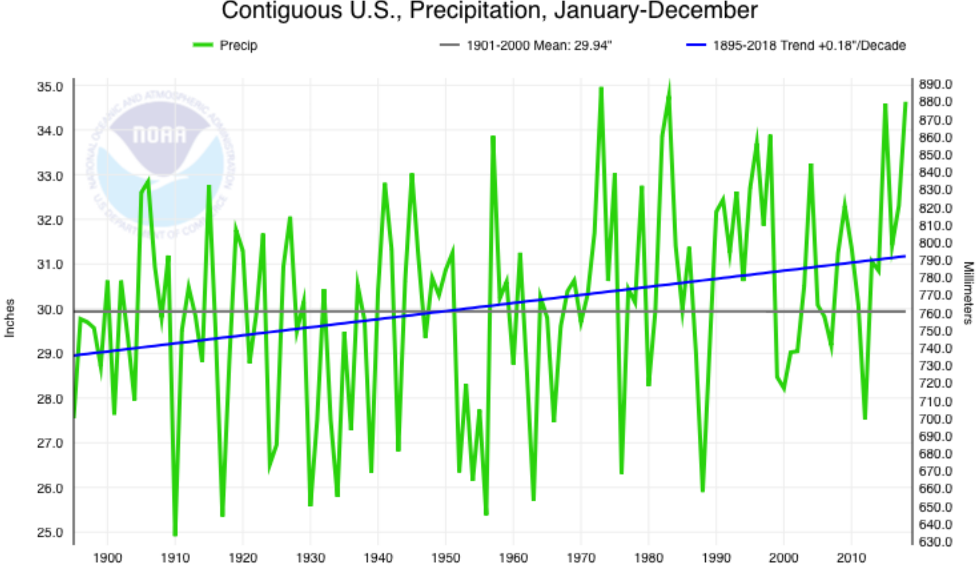
Natural disasters

- Flooding is ***the*** most common natural hazard worldwide & often devastating
- Impacts 21 million people every year
- Affects global GDP by ~$100 billion every year





False color Landsat 8 & Sentinel-2. Courtesy of Lauren Dauphin



By 2030

- 54 million people impacted per year
- > $400 billion

World Resources Institute

By 2050 *for Europe*

- 5 fold increase in economic loss: *a) climate change, b) increasing value of land, c) urban development.*

European Environment Agency

Kerala, India

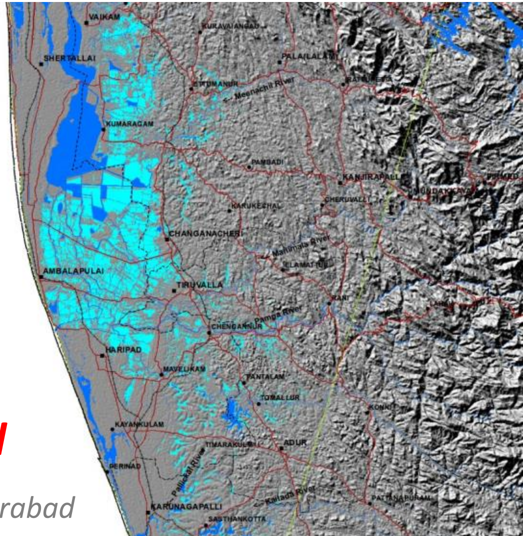

Source: Twitter - non-profit Stand With Kerala

- August 2018 flooding
- Heavy monsoon (75% more rainfall)
- 65% of dams opened to prevent overflowing
- 501,19 km^2 was flooded by 17 August
- 483 fatalities & ~1million affected

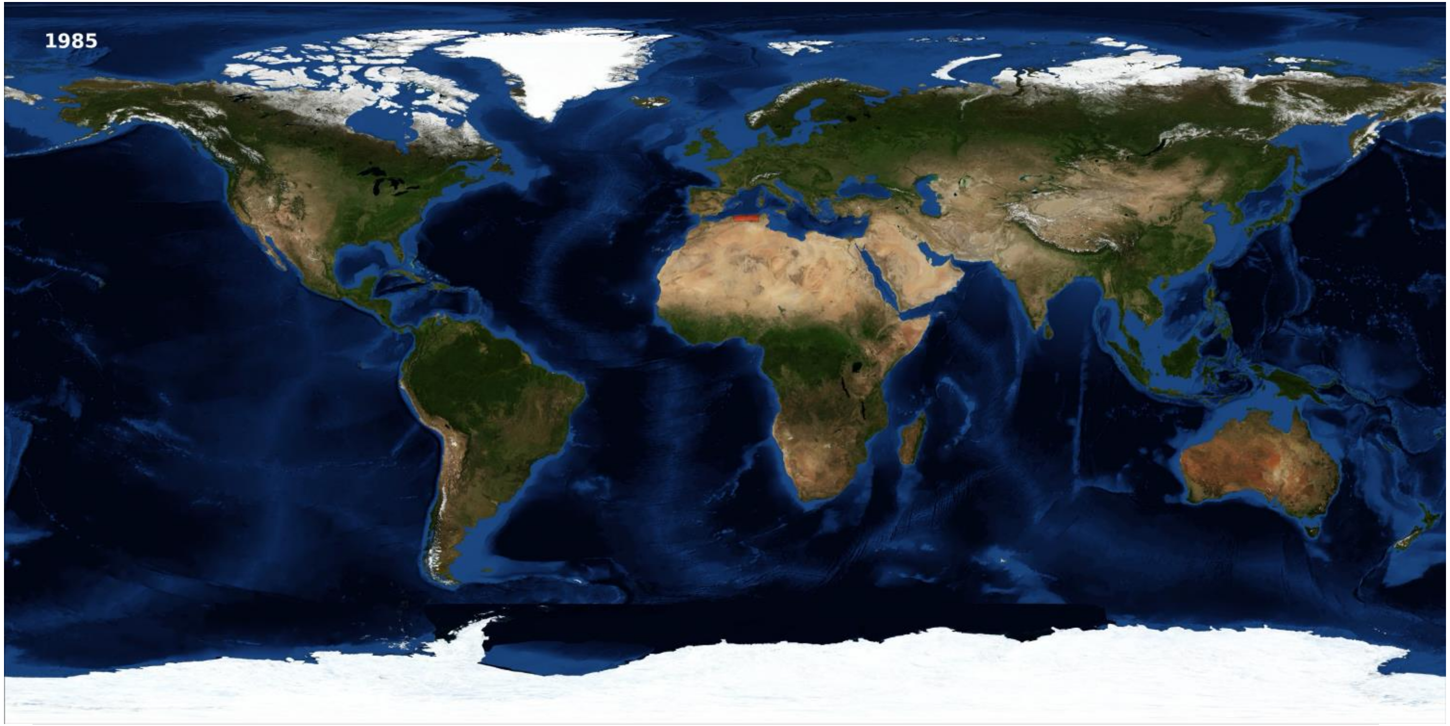
15 countries responsible for 80% of the population exposed to river floods

Winsemius et al., 2013; Ward et al., 2013

8 countries in Southeast Asia; total 14M people exposed


NRSC/ISRO, Hyderabad

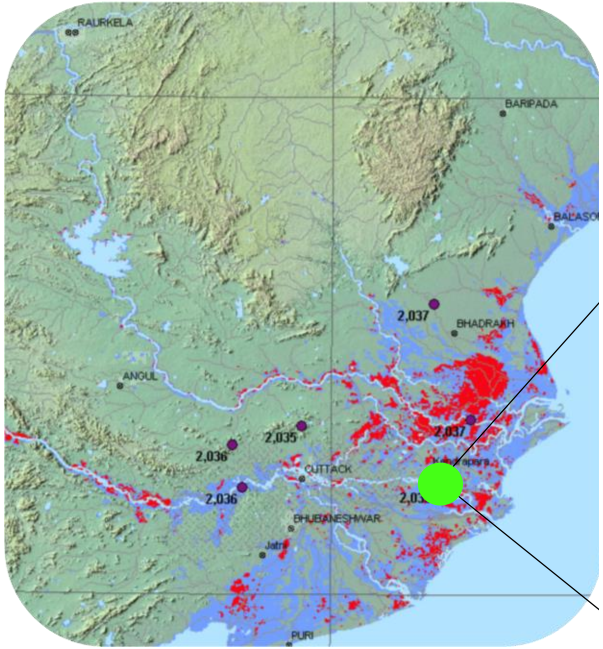
DFO - Flood Observatory: Archive



Register #	Annual DFO # (discontinued)	Glide #	Country	Other	Nations	Affected	Detailed Locations (click on active links to access inundation extents)	Validation (post event #3503)	Began	Ended	Duration in Days	Dead	Displaced	Damage (U:
4410		0	Vietnam	0	#N/A	#N/A	Four central provinces	News	9-Oct-16	16-Oct-16	8	21	100000	
4409		0	Australia	0	#N/A	#N/A	South Australia, north of Adelaide	News	1-Oct-16	16-Oct-16	16	1	0	
		0	Romania	Albania	#N/A	#N/A	Eastern Romania, Albania	News	9-Oct-16	16-Oct-16	8	1	300	

Flood products available in general - Observations

Global initiatives



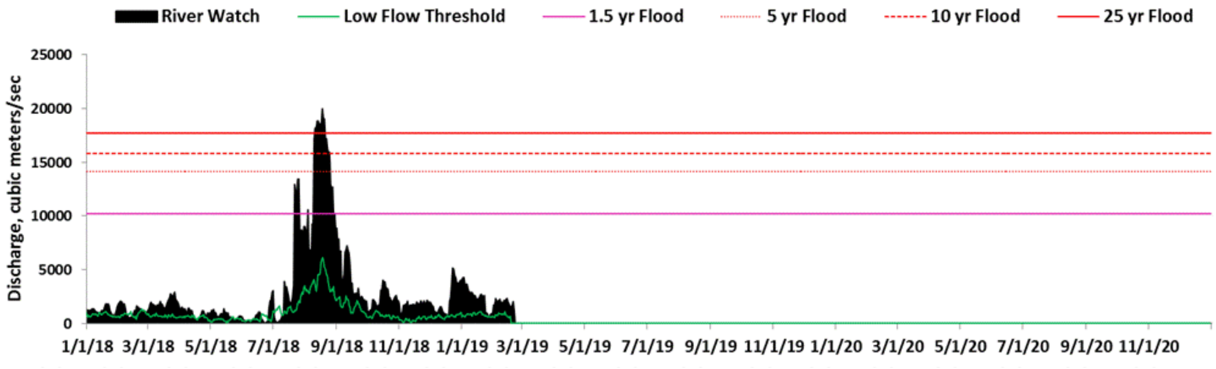
Dartmouth Flood Observatory

GFP global flood partnership

NASA

Predicted Flooded Area

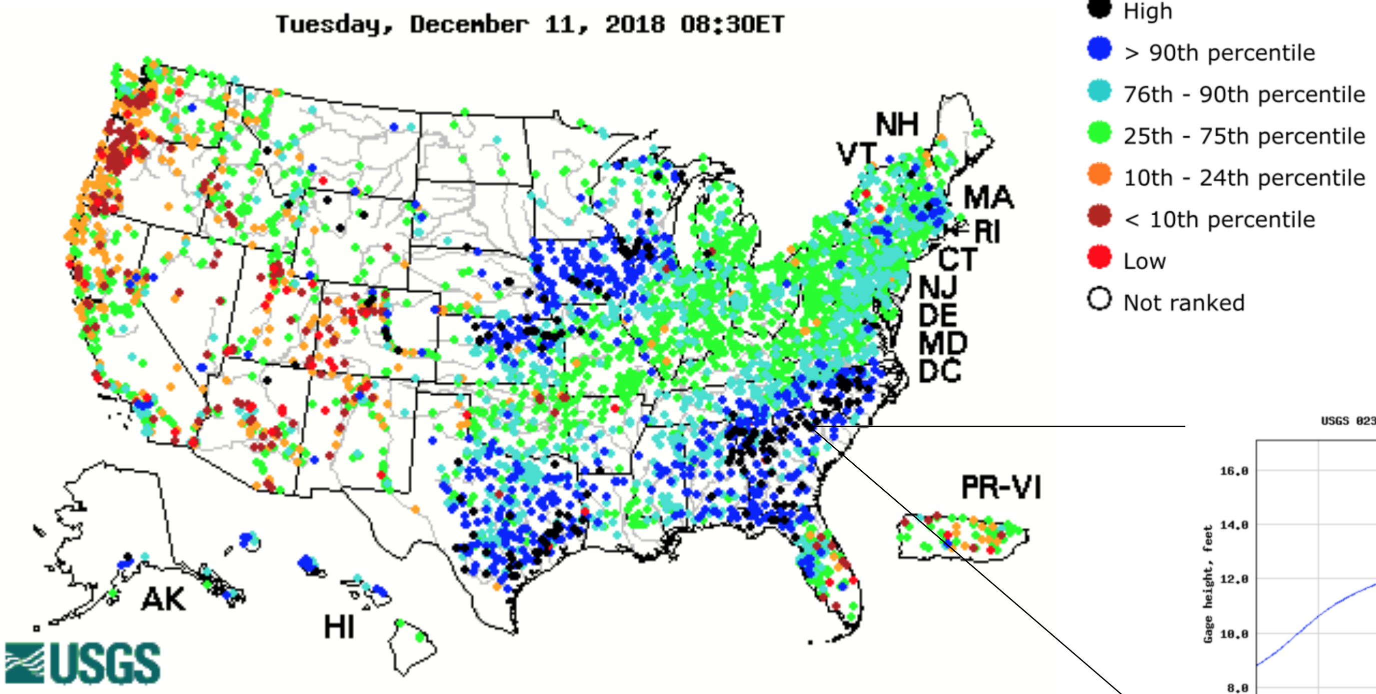
River Watch Gauging site 2029, Mahanadi River

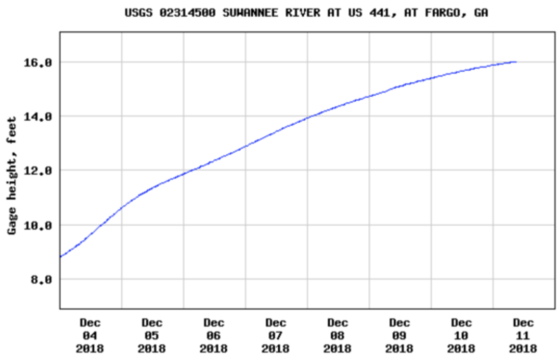


Flood extent: NRT + historical

Flood products available in general - Observations

By country

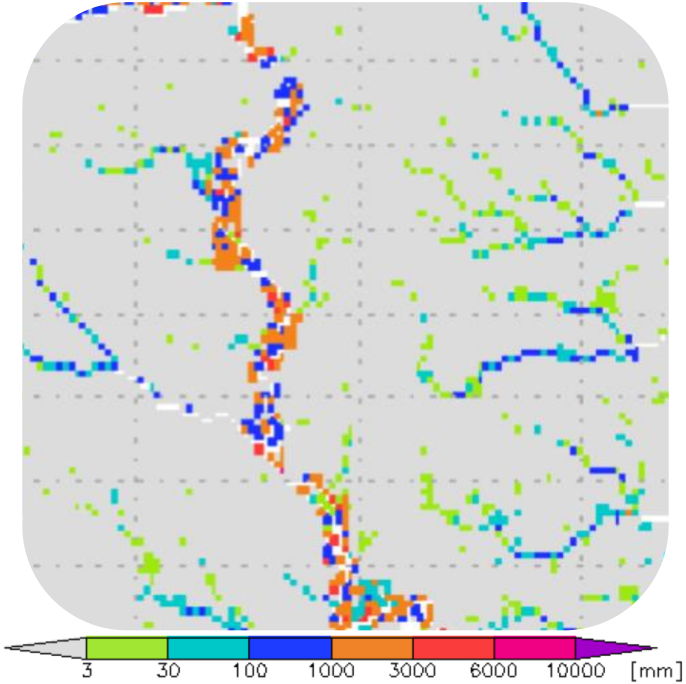




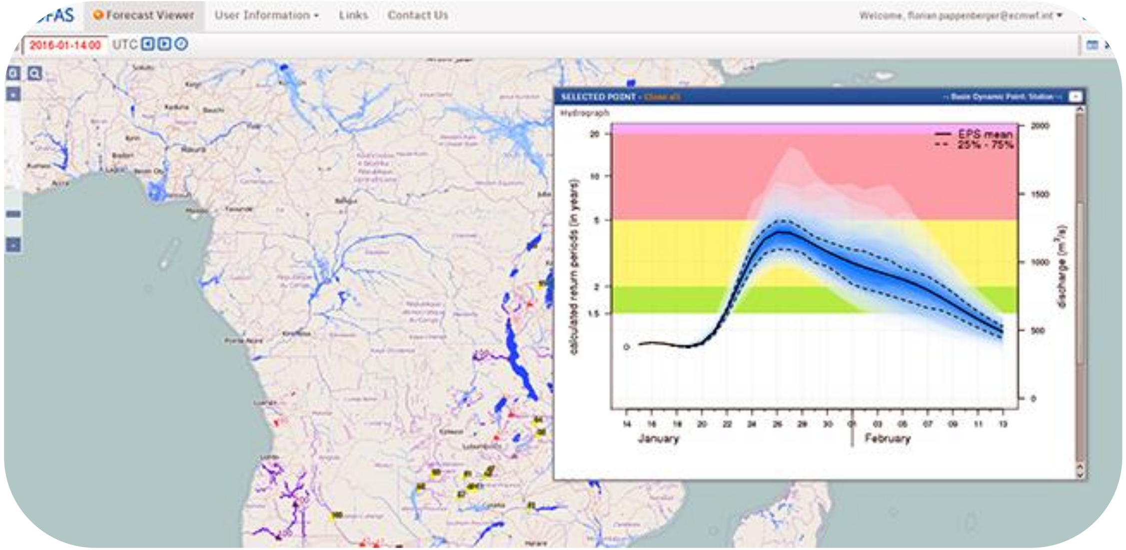
Discharge NRT and status

Flood products available in general - Simulations

Global initiatives



Global Flood Monitoring system (GFMS – UMD; NRT + Forecast)



GLOFAS – Global Flood Awareness System

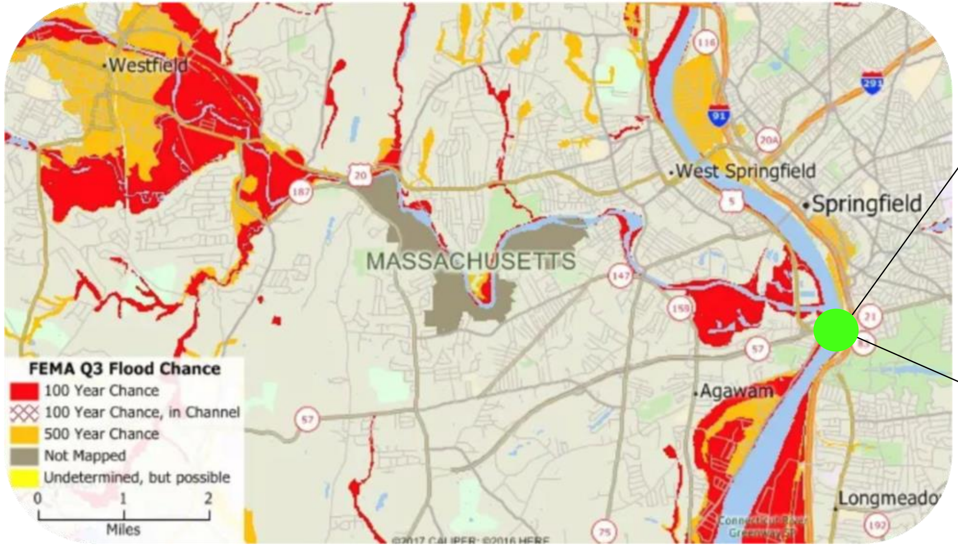
NRT + Long term flood forecast

JRC & ECMWF

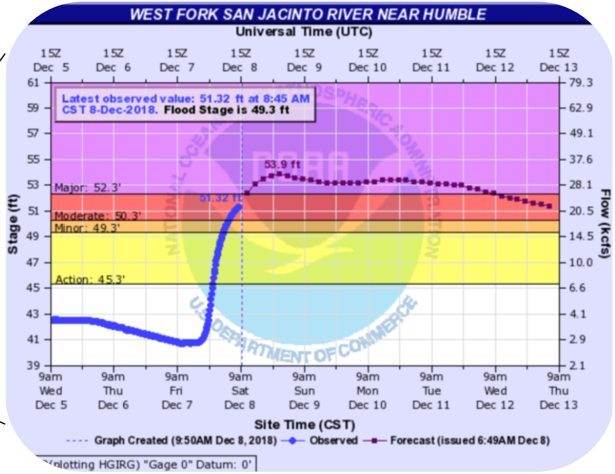
Operational since April 2018 at Copernicus Emergency Management Service

Flood products available in general - Simulations

Per country



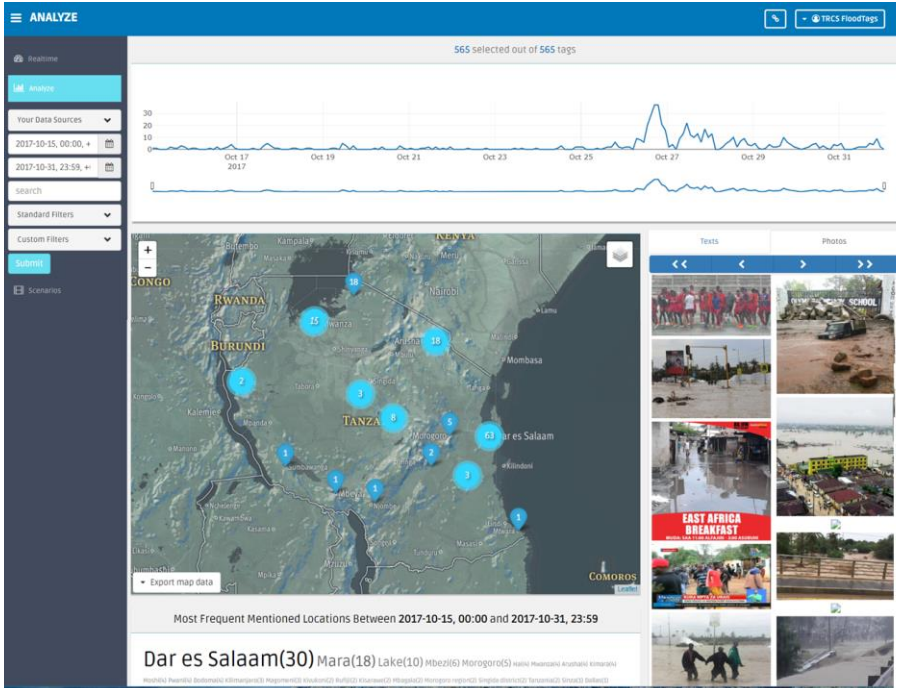
USA - FEMA: 100 – 500yr return periods



Hydrograph forecast NOAA - USGS

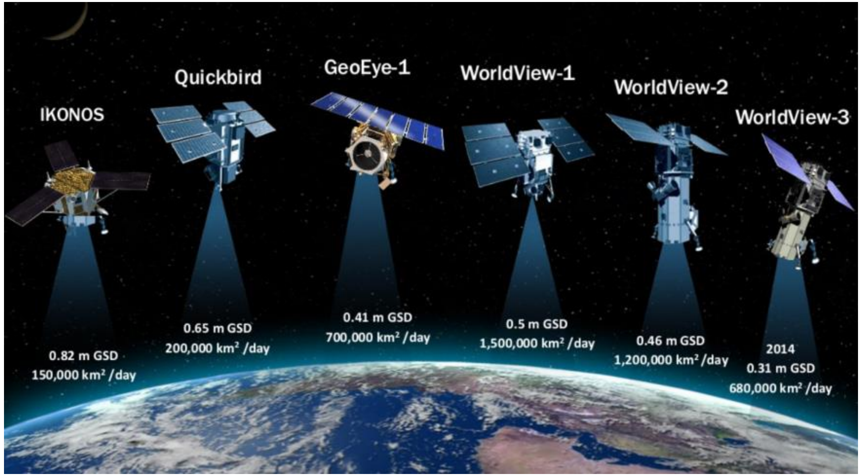
Flood products available in general – New Tech

Social Media



FloodTags

Commercial satellites



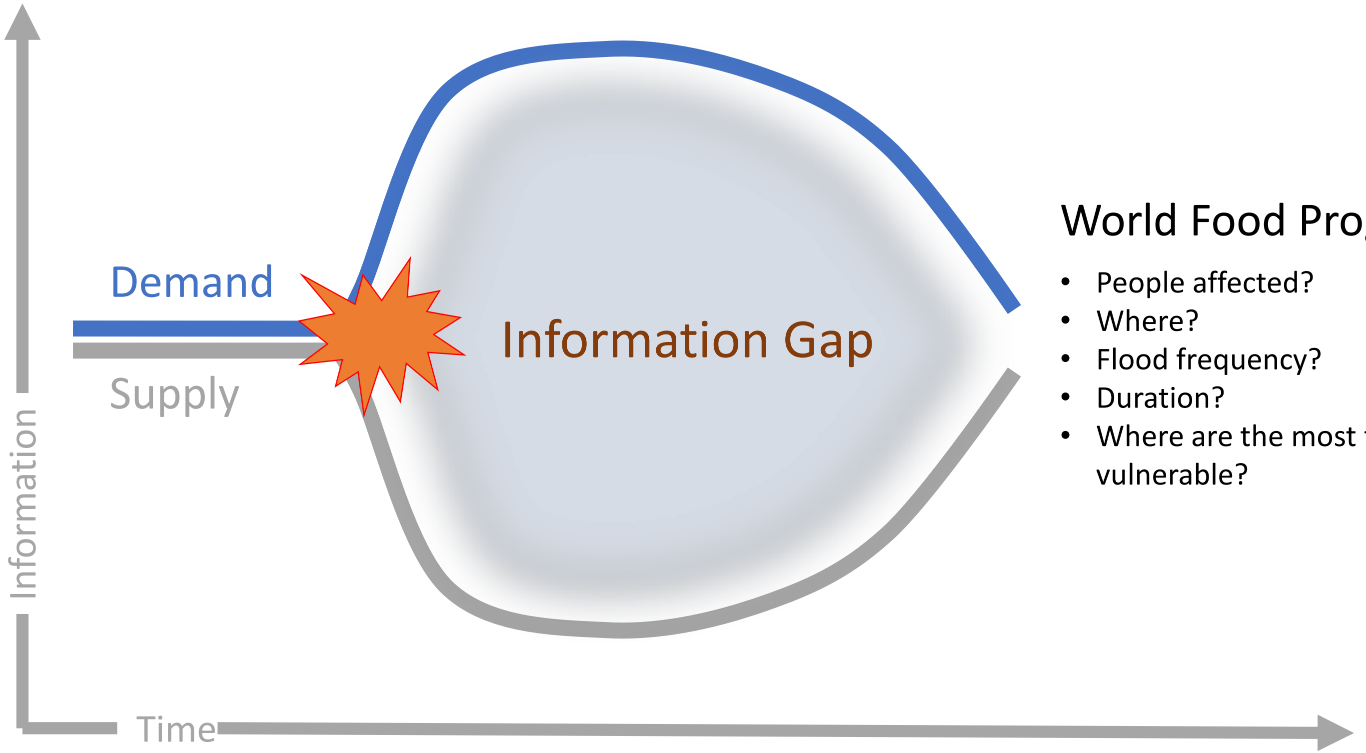
- DigitalGlobe
- SpaceX
- ……

Disaster relief agencies
When to respond?

In the immediate moments following a disaster event, humanitarian actors need to make rapid decisions on how to prioritize affected areas impacted by the event.

What is missing?

Disaster strikes!



World Food Program (WFP)

- People affected?
- Where?
- Flood frequency?
- Duration?
- Where are the most to least vulnerable?

"One Stop Shop" for all flood products

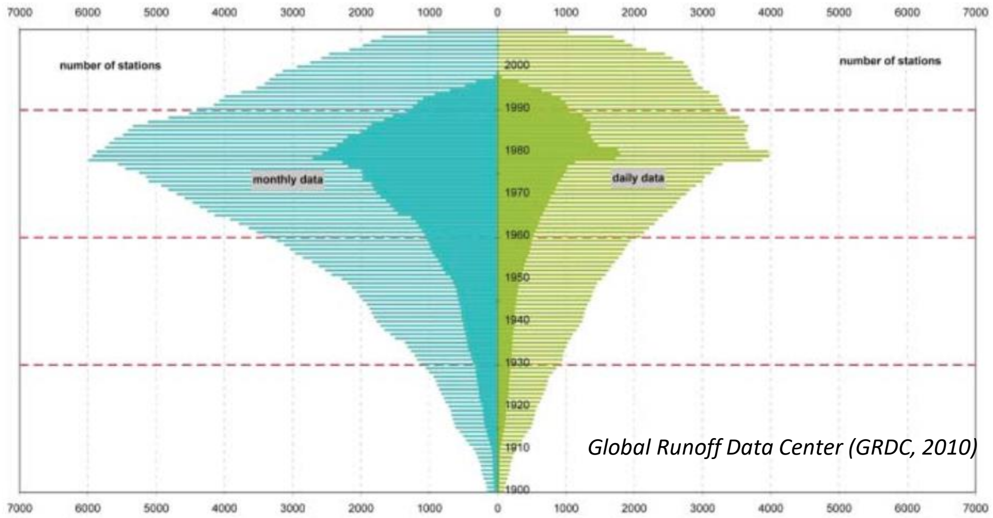
One portal to get to all water related data

- Global coverage
- That includes:
  - Simulations (Forecasts + e.g. per return interval)
  - Observations (Extent as well as water discharge - ground and satellite)
  - Near Real Time + Historical data (max flood extent, flood frequency)
- Keep data at source but connect through API / OGC standards

Ground based observations Water discharge

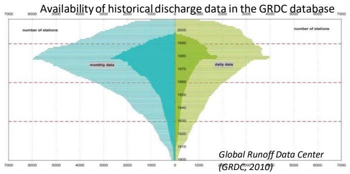
- Countries have only sparse amount of gauging stations and discharge data gets hardly shared although rivers cross boundaries.

Availability of historical discharge data in the GRDC database



Global Runoff Data Center (GRDC, 2010)

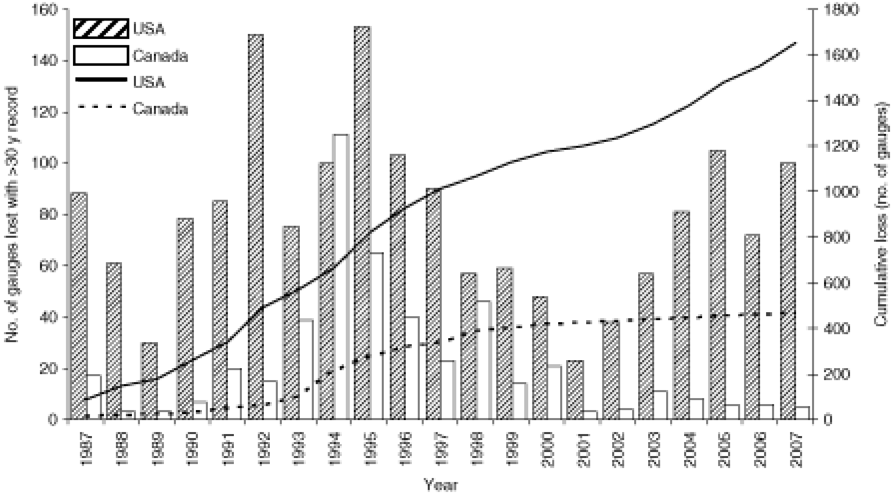
Ground based observations Water discharge



- Countries have only sparse amount of gauging stations and discharge data gets hardly shared although rivers cross boundaries.

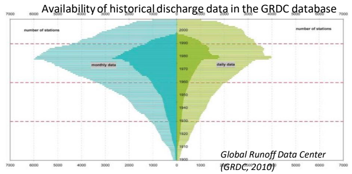
- Worldwide, water observation networks are incomplete to determine water quantity & networks are in jeopardy of further decline.

Hannah et al., 2010



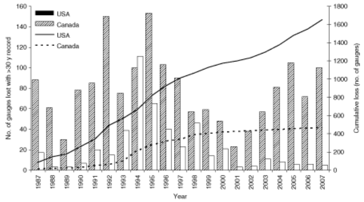
Ground based observations Water discharge

- Countries have only sparse amount of gauging stations and discharge data gets hardly shared although rivers cross boundaries.



- Worldwide, water observation networks are incomplete to determine water quantity & networks are in jeopardy of further decline.

Hannah et al., 2010



So:

Societies recognize that measuring river discharge **is important** from socio-economic or practical view *but* if already taken, discharge measurements are **hardly shared** and countries are **not enough investing** to extend or maintain gauging station networks

Water discharge from Space

Advantages utilizing satellites

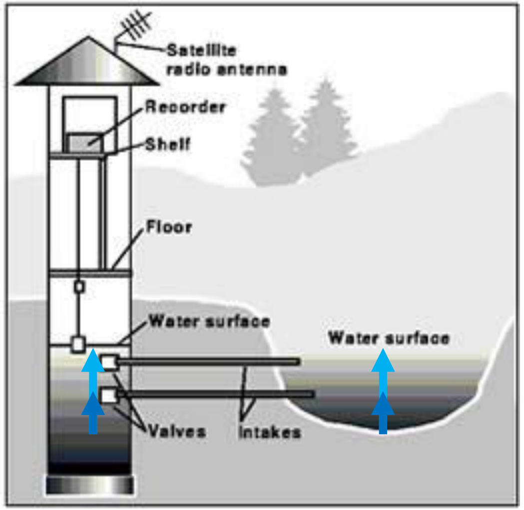
- Continuous record also in the event of a flood; unlikely gauging station which could get destroyed during a large event
- Low maintenance costs
- Back processing of data once preferable gauging location is set
- Crossing borders, is applied globally

Disadvantages utilizing satellites

- Lower temporal resolution (daily not every 5 – 10 minutes)
- Preferable gauging location is not always an option (steep canyons, vegetation cover)

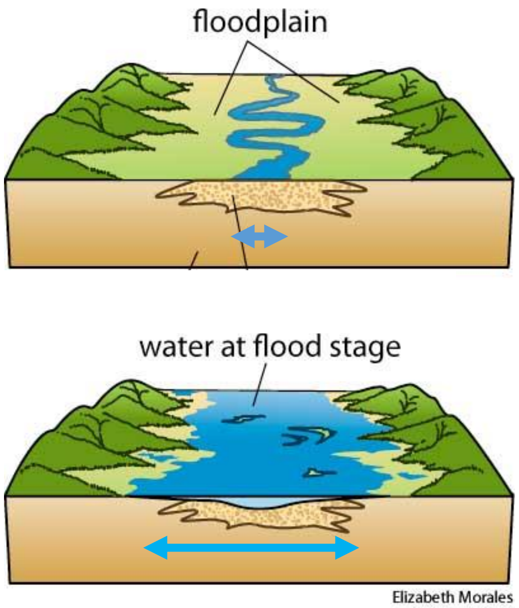
Ground based Gauging station

DEPTH



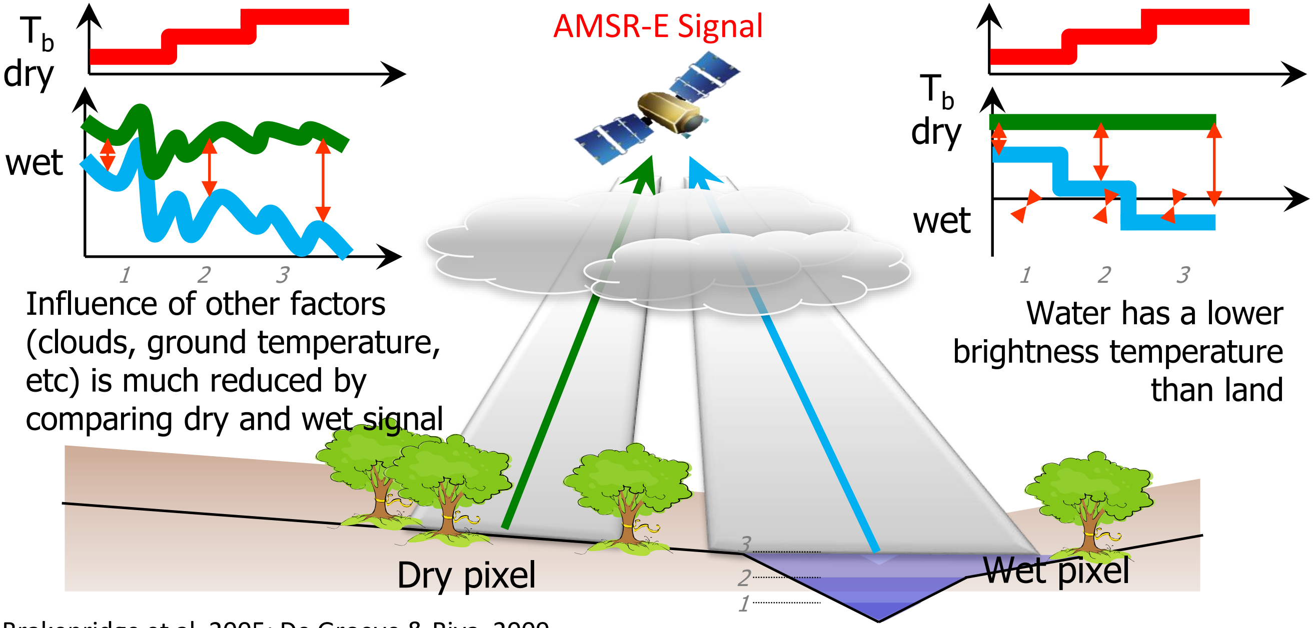
Satellite based Gauging station

WIDTH

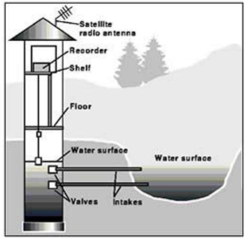


AMSR-E/AMSR-2 River discharge Measurement Method

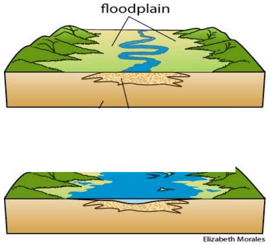
Measuring temperature change by passive microwave signal



Brakenridge et al, 2005; De Groeve & Riva, 2009



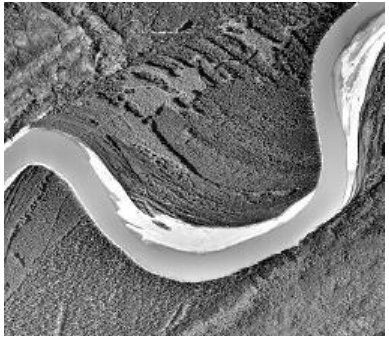
River discharge

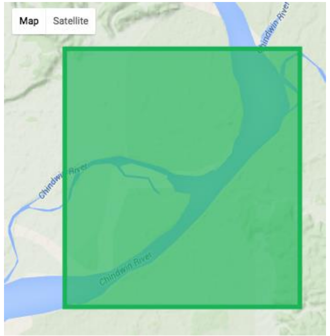


Q = Width x Depth x Velocity

When rivers rise (discharge, Q, m^3/sec, increases), flow width and water surface area also increase.

River Watch sites use satellite passive microwave radiometry to sensitively monitor this in-pixel surface temperature change.

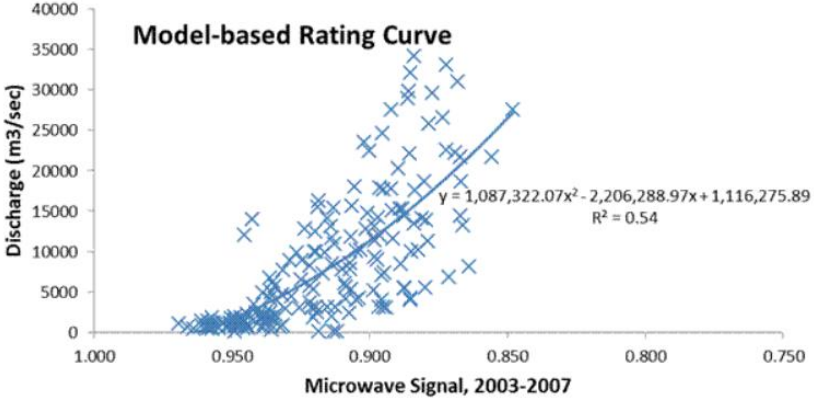


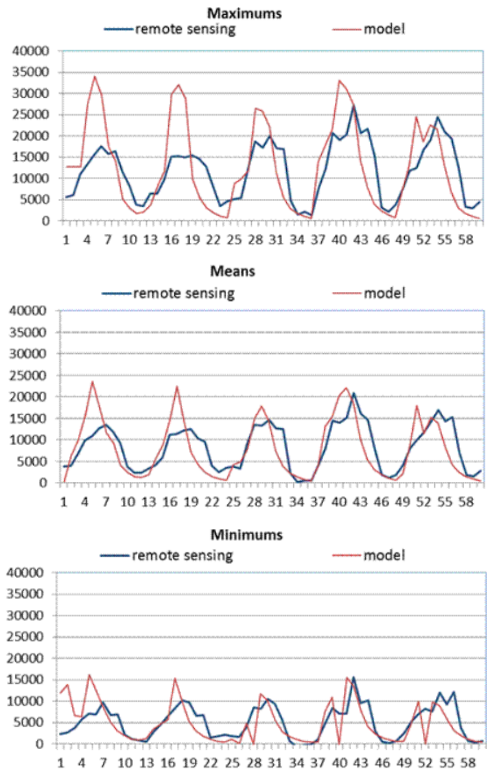


Translate Temperature to Discharge

If possible use **Ground** gauge data otherwise **model**

Model-based rating is comparison of *WBM* modeled monthly mean, maximum, and minimum discharges, 2003-2007, to the satellite-observed, time-equivalent signal

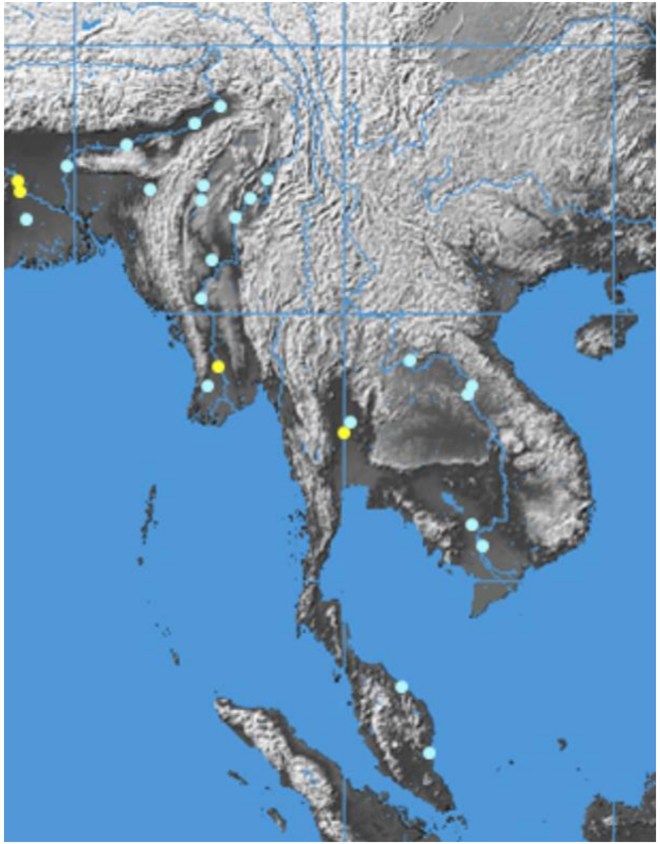




Dartmouth Flood Observatory

GDACS

Cooperative work including EU's **J**oint **R**esearch **C**entre (GDACS, Dr. Tom De Groeve) and DFO has resulted in a ***global*** network of satellite river gauging sites, with records extending on daily basis from 1998 up to today. Online display (click on dots).



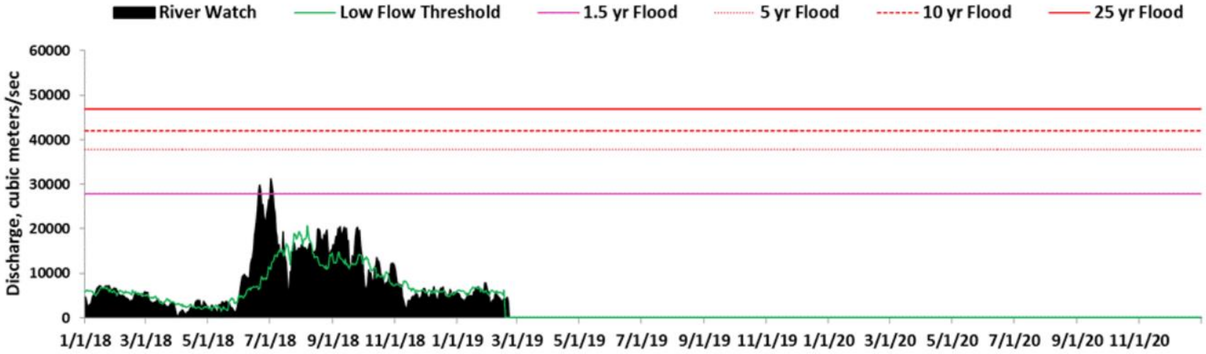
- Low flow
- Normal Flow
- Moderate Flooding, r > 1.33 years
- Major Flooding, r > 5 years

River and Reservoir Watch Version 3.5

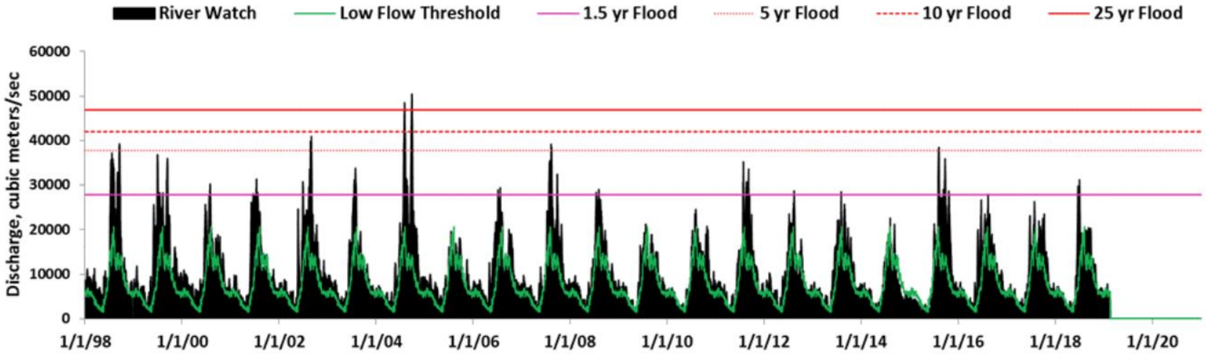
River Discharge and Reservoir Storage Changes Using Satellite Microwave Radiometry

*G. R. Brakenridge**
*A. J. Kettner**
*T. De Groeve, S. Paris***
*S. Cohen****
*S. V. Nghiem*****
**CSDMS/INSTAAR, University of Colorado*
***Joint Research Centre, Ispra, Italy*
****University of Alabama*
****JPL/Caltech*

			Irrawaddy	Center:	95.445	Long.	*Signal/Model agreement:* **Very Good**
GFDS Site Number	30	Modis History	Myanmar	Center:	18.044	Lat.	*S/N rating:* **Very Good**
GEE Time Lapse		Predicted Flooded Area	Learn more about this river		370110	**sq km**	WBM contributing area
Last measured:	16-Feb-19			Obtain Data			
Discharge:	**4317**	m3/sec	Status: **1**	(1, low; 2, normal flow; 3, moderate flood, r >1.5 y; 4, major flood, r >5 y)			
7-day Runoff	**6.9**	mm	**69%**	(7-day runoff compared to 20 y average for this date, 1998-2017)			
Flood Magnitude:	**#N/A**	Scale of 0-10	Flood Magnitude Defined	Technical Summary			



Notes: 5-day forward moving average is applied.
Low flow threshold is 20th percentile discharge for this day, 2003-2013.



Annual Maximum Discharge

1998	39322
1999	36862
2000	30291
2001	31356
2002	40998
2003	33845
2004	50466
2005	19666
2006	29443
2007	39216
2008	29060
2009	21253
2010	24571
2011	35270
2012	28729
2013	28535
2014	22609
2015	38500
2016	27984
2017	26341

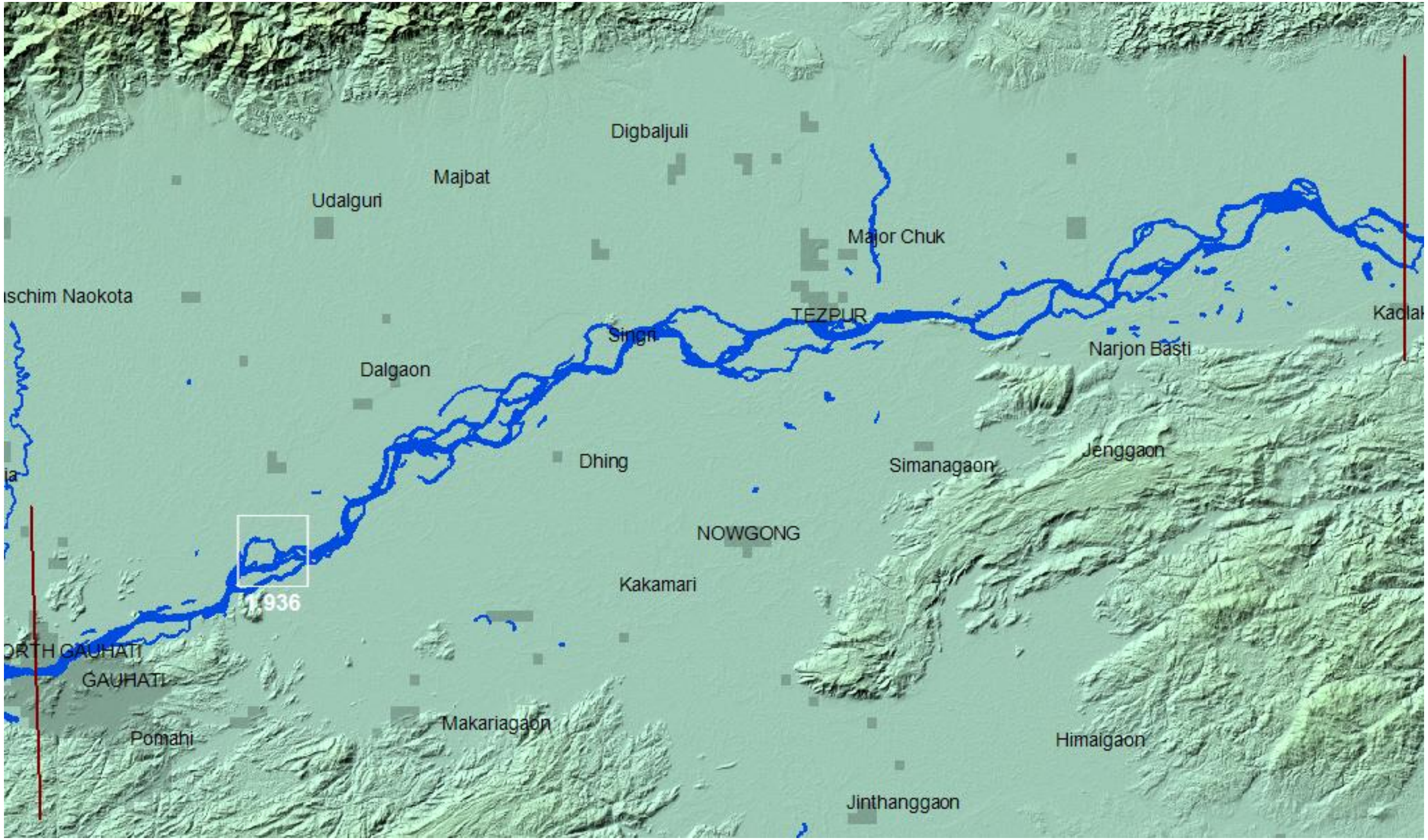
Flood Frequency Analysis, 1998-2017

25 yr*
46897
10 yr*
41939
5 yr, major flood*
37759
1.5 yr, bankfull flood*
27856
Mean Discharge
10485
*From Log Pearson III

Low Flow Threshold: **6150** **m3/sec**
(for this day of the year)

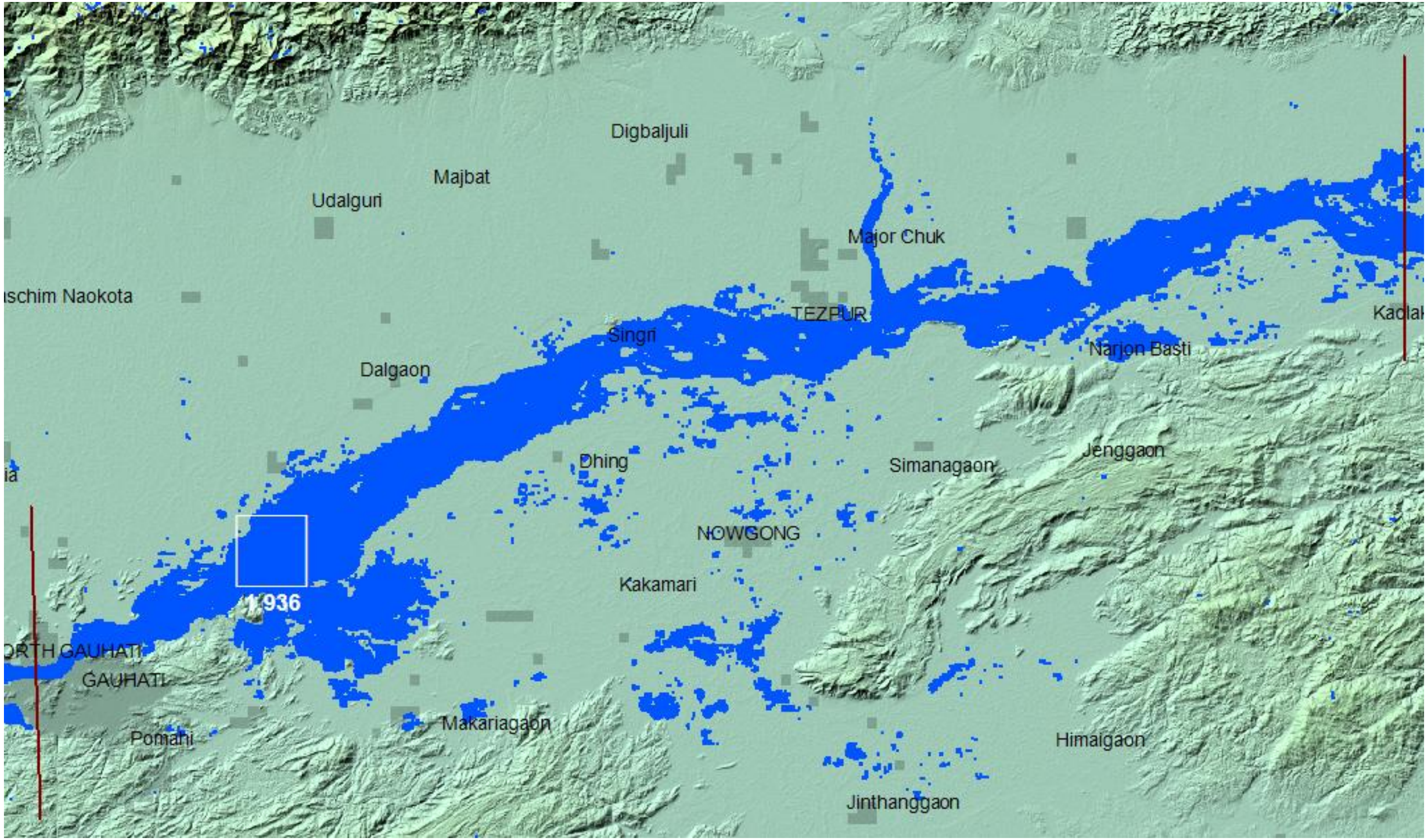
Brahmaputra, India

Flooded area for Normal Flow, Winter (~ 6100 m^3/sec, observed February 11-22, 2000)



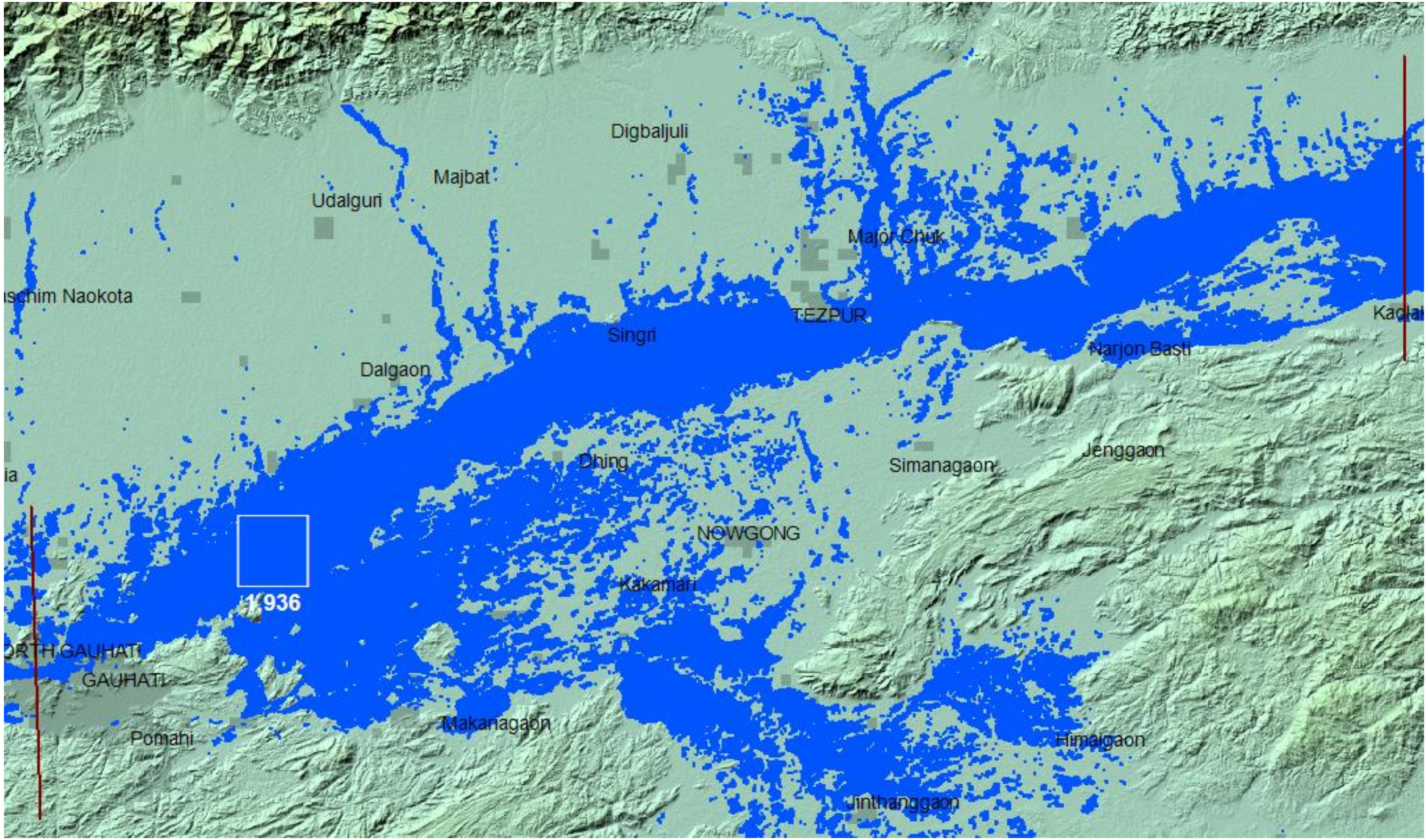
Brahmaputra, India

Flooded area for Moderate Flooding, **r = 1.8 yr** (37,000 m^3/s, observed summer, 2013)



Brahmaputra, India

Flooded area for Moderate Flooding, **r = <u>3 yr</u>** (44,000 m^3/s, observed summer, 2007



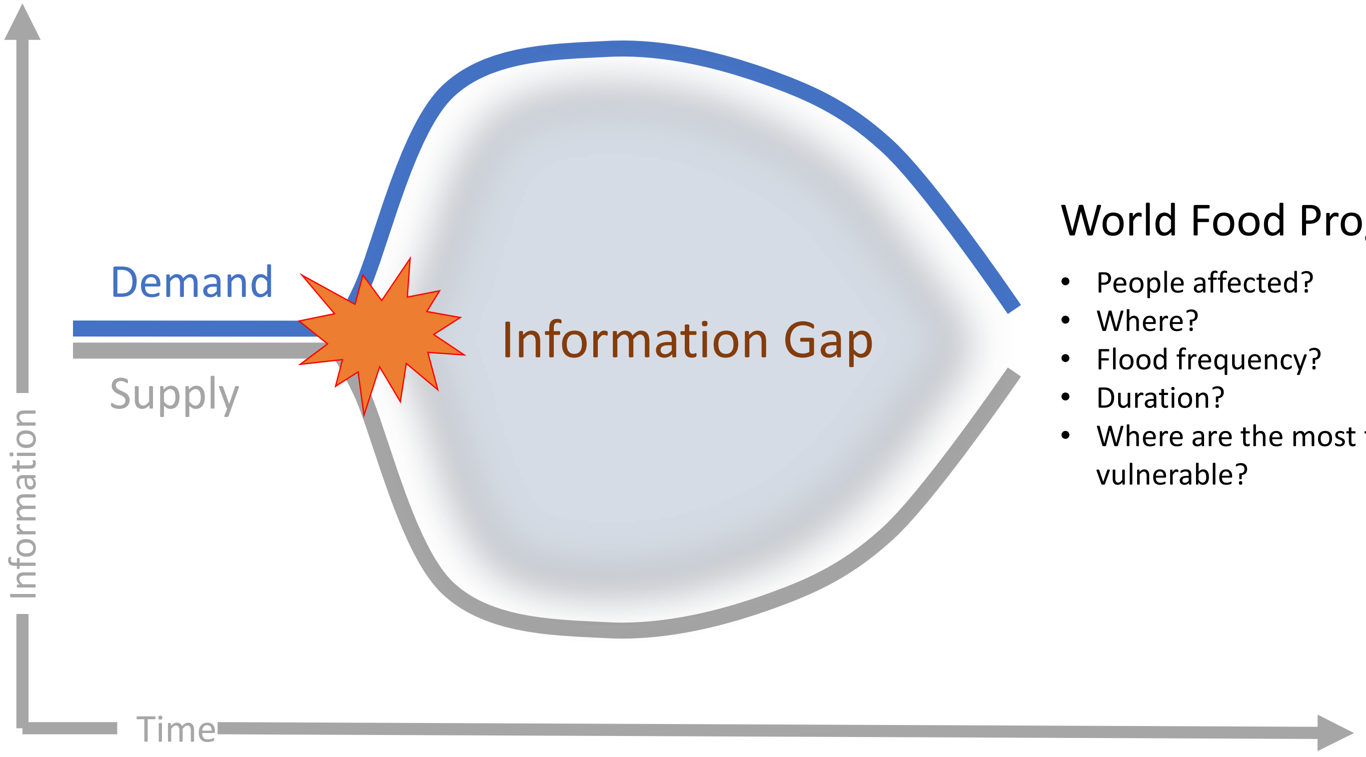
So combining 2 remote sensing techniques, we can overcome Knowledge gap

Floodplain within the alluvial plain of the Waimakariri River, New Zealand.

We **start to have** adequate geospatial information on a *global basis* defining floodplains within the *mean annual* flood limit, or 25 - 50 - 100 year floodplains.

What is missing?

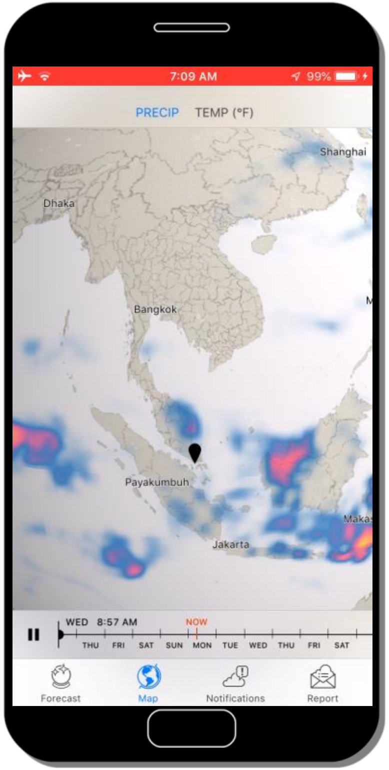
Disaster strikes!



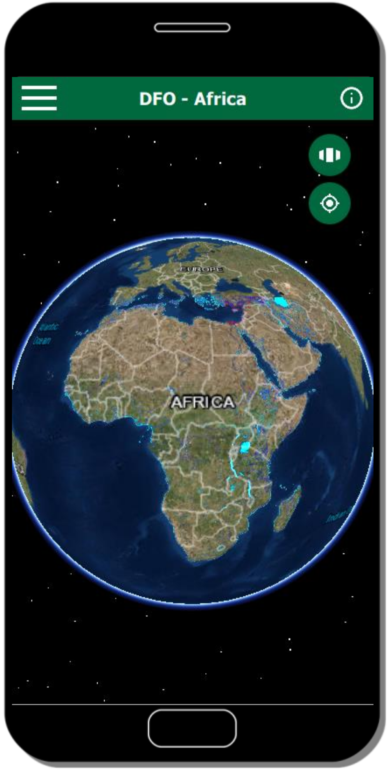
World Food Program (WFP)

- People affected?
- Where?
- Flood frequency?
- Duration?
- Where are the most to least vulnerable?

Vision: One portal, all flood data



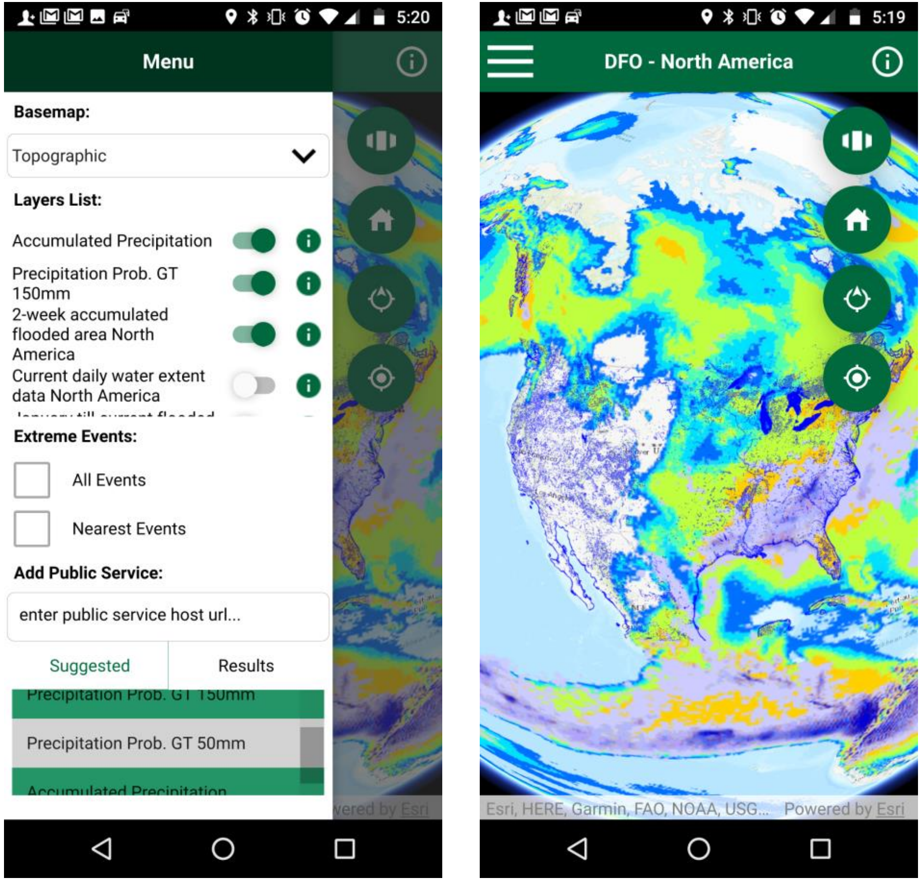
- Recurrence interval layers (1 in 100 – 500yr)
- High + low resolution
- Time machine mode
- Integrate DFO products with ***flood forecasts,*** e.g. GFMS (UMD), and GLOFAS (JRC)



Analog to e.g. DarkSky

http://floodobservatory.colorado.edu

Flood layers



Add layers

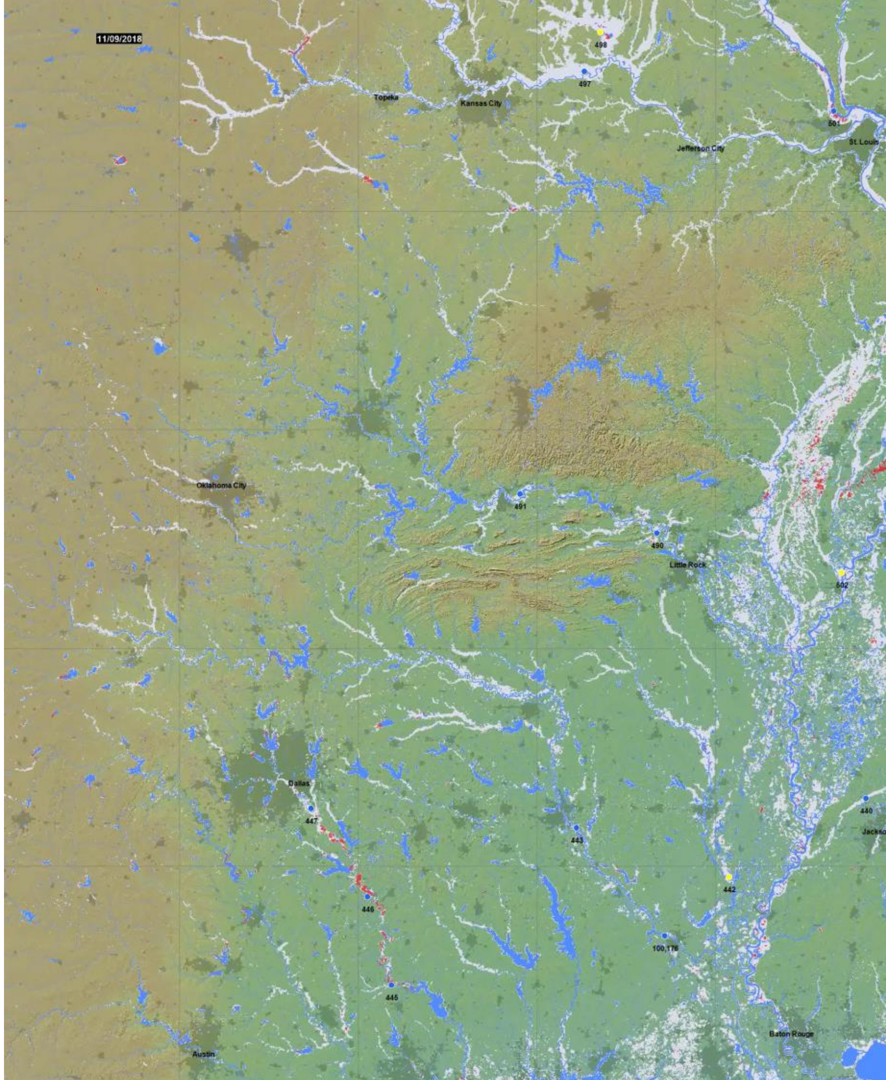
“Time machine mode” 2019 flooding part of USA

Observing flooding using AQUA/Terra Satellites – MODIS optical data

- Mean annual water layer
- Maximum observed flooding (1993 – now)
- Flooding in excess of mean annual water layer

Dots = Satellite based discharge station

- low flow
- Normal flow
- flooding
- major flooding



Challenges to overcome

- Global coverage
- Integrate various temporal + spatial scales
- Amount of different data sources & formats: observations, simulations, historical data, discharge data, ……
- Uncertainties in datasets

Flooding due to Cyclone Idai – Mozambique, Zimbabwe & Malawi

Thank you!

Albert Kettner
kettner@colorado.edu

Dartmouth Flood Observatory

NASA

- SBIR
- Applied sciences

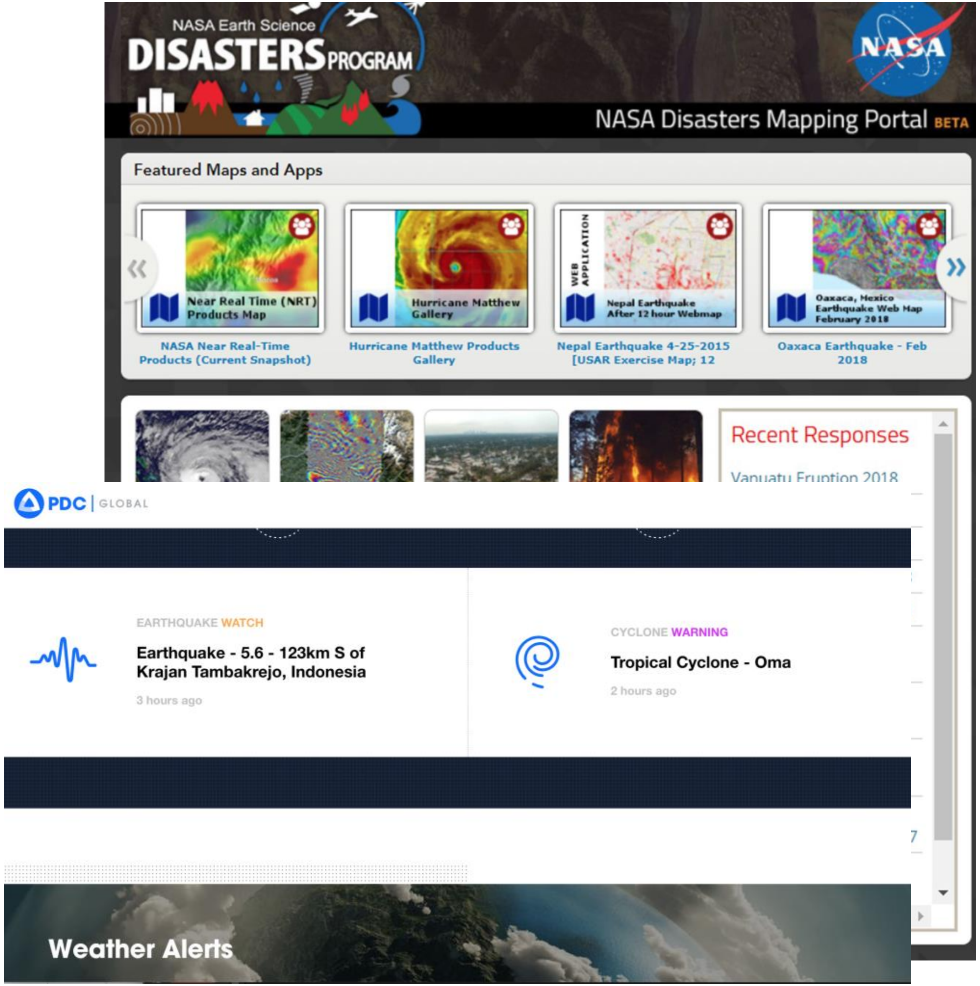
GFDRR
Global Facility for Disaster Reduction and Recovery

http://floodobservatory.Colorado.edu

Similar initiatives

- NASA disaster portal
  - Multiple disasters
  - Monitoring on event base

- Pacific Disaster Center (PDC)
  - Multi hazards
  - NRT + forecast, less so historical events



Flood severity index

Hurricane intensity:

The Saffir-Simpson Scale

(*1971 Herbert Saffir & Robert Simpson*)

Saffir–Simpson hurricane wind scale	
Category	Wind speeds
Five	≥70 m/s, ≥137 knots ≥157 mph, ≥252 km/h
Four	58–70 m/s, 113–136 knots 130–156 mph, 209–251 km/h
Three	50–58 m/s, 96–112 knots 111–129 mph, 178–208 km/h
Two	43–49 m/s, 83–95 knots 96–110 mph, 154–177 km/h
One	33–42 m/s, 64–82 knots 74–95 mph, 119–153 km/h
Additional classifications	
Tropical storm	18–32 m/s, 35–63 knots 39–73 mph, 63–118 km/h
Tropical depression	≤17 m/s, ≤34 knots ≤38 mph, ≤62 km/h

Earthquake intensity:

- The Moment Magnitude Scale succeeded in the 70's Richter scale
- The Modified Mercalli (MM) Intensity Scale (1931 Harry Wood and Frank Neumann) Used in the United States.

INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
Shaking	Not felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Damage	None	None	None	Very slight	Light	Moderate	Moderate/ heavy	Heavy	Very heavy
Peak Acc	<0.17	0.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
Peak Vel	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16 -31	31-60	60-116	>116

Peak Acc = Peak ground acceleration (g), Peak Vel = Peak ground velocity (cm/s)