University of Colorado
Boulder

DFO
Flood Observatory

Remote Sensing

Applying satellite data to support analyzing fluvial processes

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Rockies; Gibson Reservoir, west of Great Falls, Montana

Layout

- Brief intro to remote sensing
- Fluvial Geomorpholgy related Remote sensing
- Monitoring discharge
- Monitoring surface water extend
- Analyzing flood frequency

Remote sensing

Remote sensing is the art, science, and technology of ***observing*** an object, scene, or phenomenon by ***instrument-based*** techniques.

Where **remote** means that the observation by the instrument is done ***at a distance***, without physical contact.

For example using: satellites – airplane – drone – balloons – etc.

Advantages and disadvantages of Remote Sensing

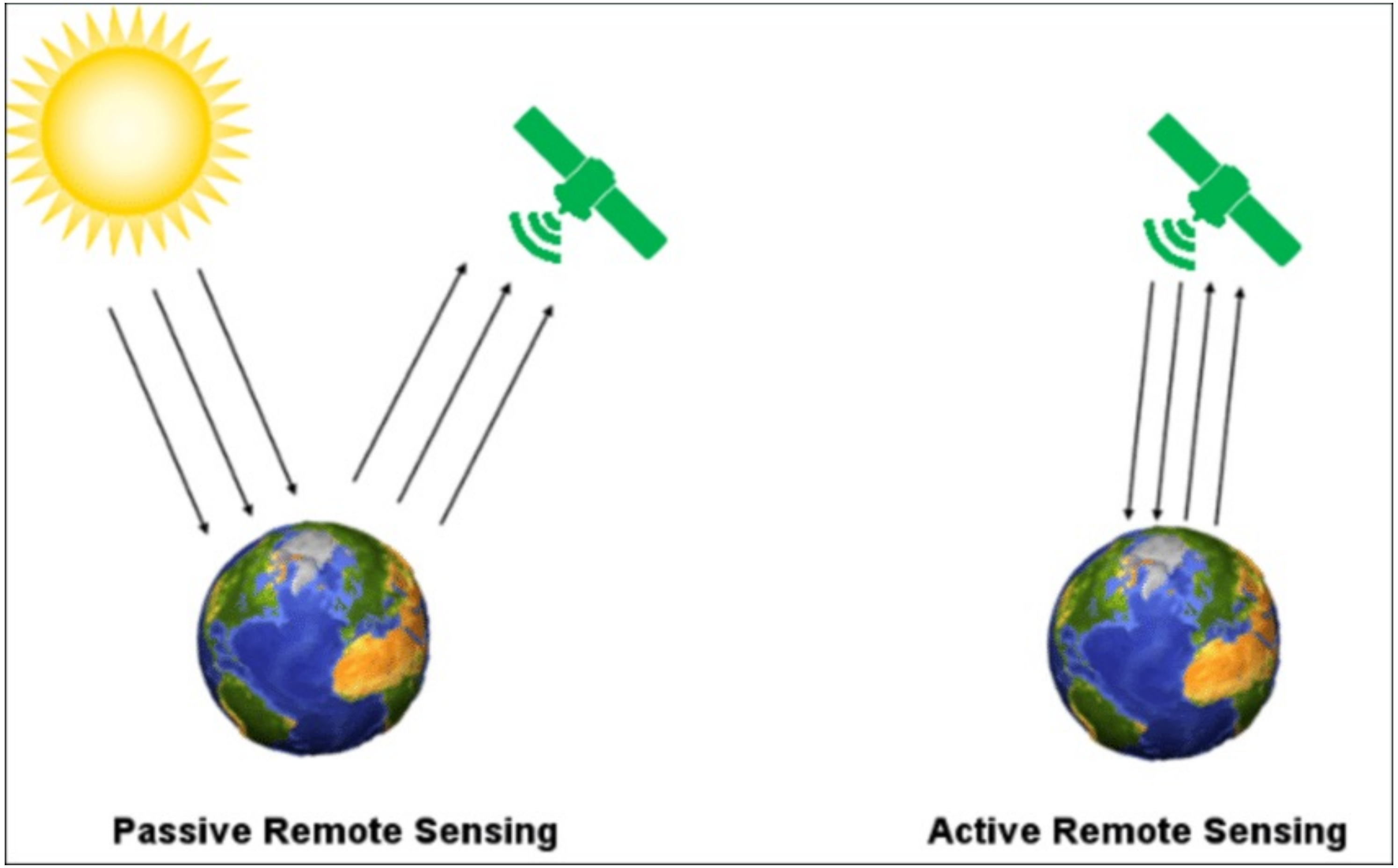
Advantages

- Provides data over large areas
- Provides data of very remote and inaccessible regions
- Able to obtain imagery of any area over a continuous period of time through which the any anthropogenic or natural changes in the landscape can be analyzed
- Relatively inexpensive when compared to employing a team of surveyors
- Easy and rapid collection of data
- Rapid production of maps for interpretation

Disadvantages

- The interpretation of imagery requires a certain skill level
- Needs cross verification with ground (field) survey data
- Data from multiple sources may create confusion
- Objects can be misclassified or confused
- Distortions may occur in an image due to the relative motion of sensor and source

Different types of Remote sensing



Satellites that contain **passive** sensors include:

- LandSat
- MODIS (Aqua/Terra)
- VIIRS
- Sentinel 2

Satellites that contain **active** sensors (e.g. Radar/Lidar):

- Sentinel 1 (a/b)
- ICESat-2
- TRIMM *
- GPM *
- SWOT (Surface water Ocean topo)*

*) only certain sensors

Data from Passive RS is often more intuitive (less complicated) to analyze.

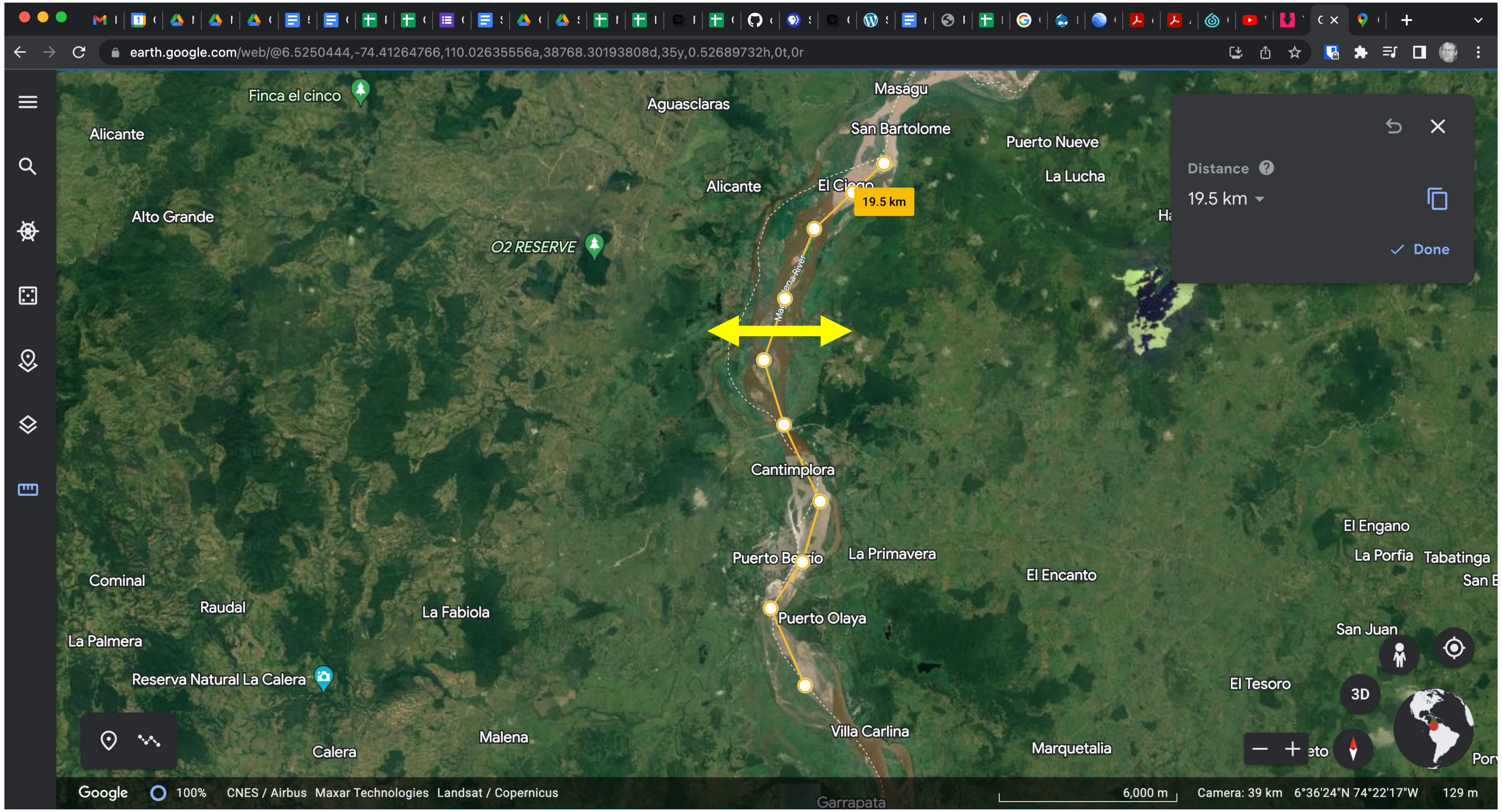
Different temporal – Spatial – Spectral resolutions

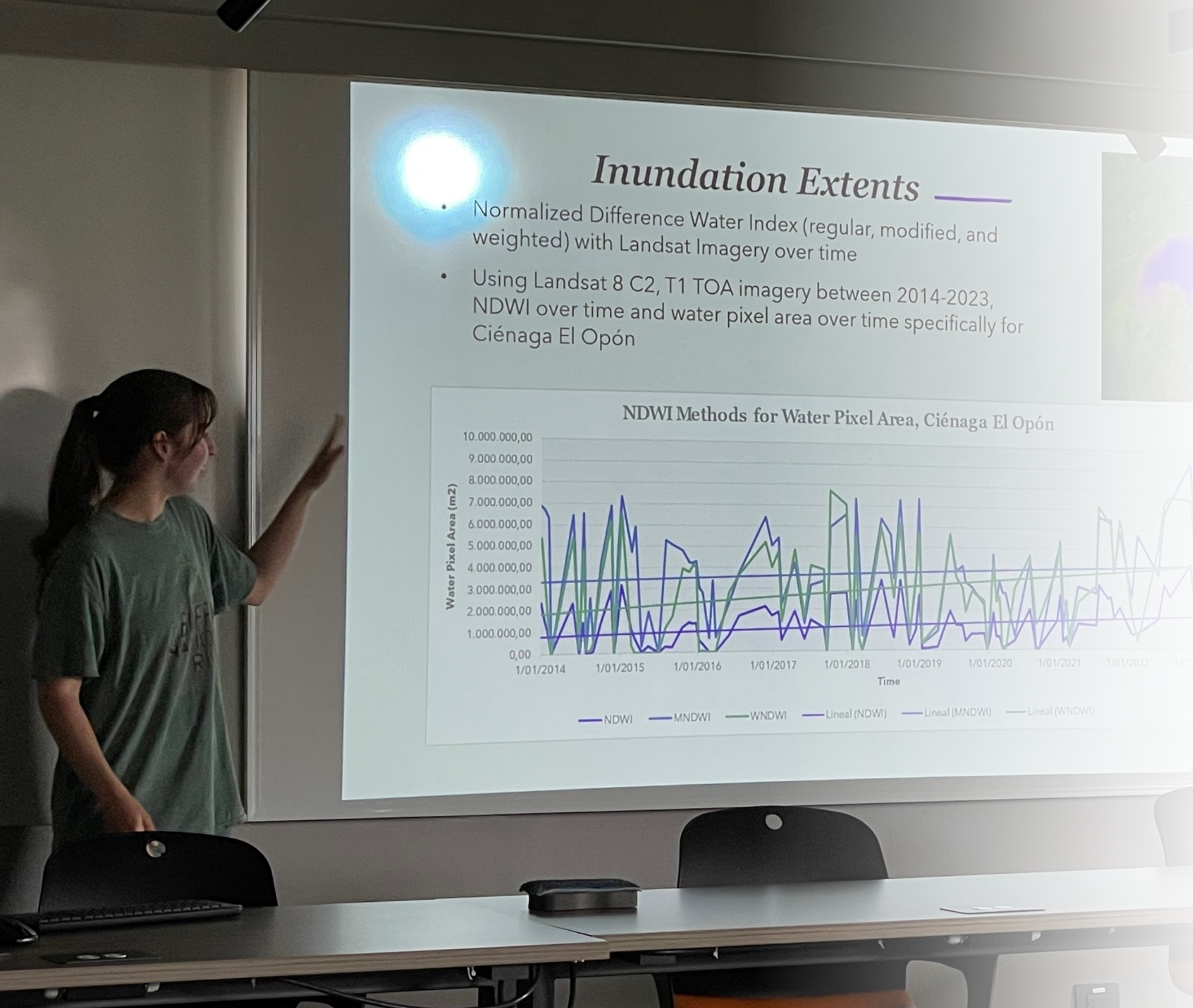
- **Temporal resolution**: the return period (time between images) of taking an observation at the same location
- **Spatial resolution**: the size of the smallest feature that can be detected by a satellite sensor
- **Spectral resolution**: the ability of a satellite sensor to measure specific wavelengths of the electromagnetic spectrum

Sensor	Temporal resolution	Spatial resolution	Launch year
MODIS	2 x Daily	250m	Early 2000s
VIIRS	1 x Daily	325m	2011
LandSat	16-day repeat	30m	1st generation 1984
Sentinel	5-10 day repeat	10 (20-60)m	2015

Fluvial Geomorphology related Remote sensing
Map simple river characteristics from optical imagery

Using imagery for 1 time period, utilizing the R,G,B bands):
- River width, length
- Slope (underlying DEM)





More advanced methods to measure e.g. inundation extents over time

Presentation by Serena Butler

- Utilizing different wavelength bands (spectral resolution, beyond R,G,B) to measure water extent (Normalized Difference Water Index (NDWI)).

- NDWI uses Near-Infrared & short-wave infrared channels

Many indices are available

Different indices for different sensors on specific satellites

New indices are still developed / optimized

https://www.indexdatabase.de
https://www.nv5geospatialsoftware.com/docs/AlphabeticalListSpectralIndices.html

Alphabetical List of Spectral Indices

- Alunite Index (ALUI)
- Anthocyanin Reflectance Index 1 (ARI1)
- Anthocyanin Reflectance Index 2 (ARI2)
- Atmospherically Resistant Vegetation Index (ARVI)
- Burn Area Index (BAI)
- Calcite Index (CALI)
- Carbonate Index (CARI)
- Cellulose Absorption Index (CAI)
- Clay Alteration Index (CLAI)
- Clay Minerals Ratio (Clay)
- Carotenoid Reflectance Index 1 (CRI1)
- Carotenoid Reflectance Index 2 (CRI2)
- Difference Vegetation Index (DVI)
- Disease Water Stress Index (DWSI)
- Dolomite Index (DOLI)
- Enhanced Vegetation Index (EVI)
- Epidote / Chlorite / Amphibole Index (ECAI)
- Ferric Iron Alteration Index (FEAI)
- Ferrous Iron (Fe2+) Index (FEI)
- Ferrous Minerals Ratio (Ferrous)
- Ferrous Silicates Index (FESI)
- Global Environmental Monitoring Index (GEMI)
- Green Atmospherically Resistant Index (GARI)
- Green Chlorophyll Index (GCI)
- Green Difference Vegetation Index (GDVI)
- Green Normalized Difference Vegetation Index (GNDVI)
- Green Optimized Soil Adjusted Vegetation Index (GOSAVI)
- Green Ratio Vegetation Index (GRVI)
- Green Soil Adjusted Vegetation Index (GSAVI)
- Green Vegetation Index (GVI)
- Hydroxyl-Bearing (OH) Altered Minerals Index 1 (OHI1)
- Hydroxyl-Bearing (OH) Altered Minerals Index 2 (OHI2)
- Hydroxyl-Bearing (OH) Altered Minerals Index 3 (OHI3)
- Infrared Percentage Vegetation Index (IPVI)
- Iron Oxide Ratio (Iron Oxide)
- Kaolinite Index 1 (KAI1)
- Kaolinite Index 2 (KAI2)
- Kaolinite Index 3 (KAI3)
- Laterite Index (LATI)
- Leaf Area Index (LAI)
- Leaf Chlorophyll Index (LCI)

Eye-candy
Evolution of Ucayali River, Peru – 1985 - 2011

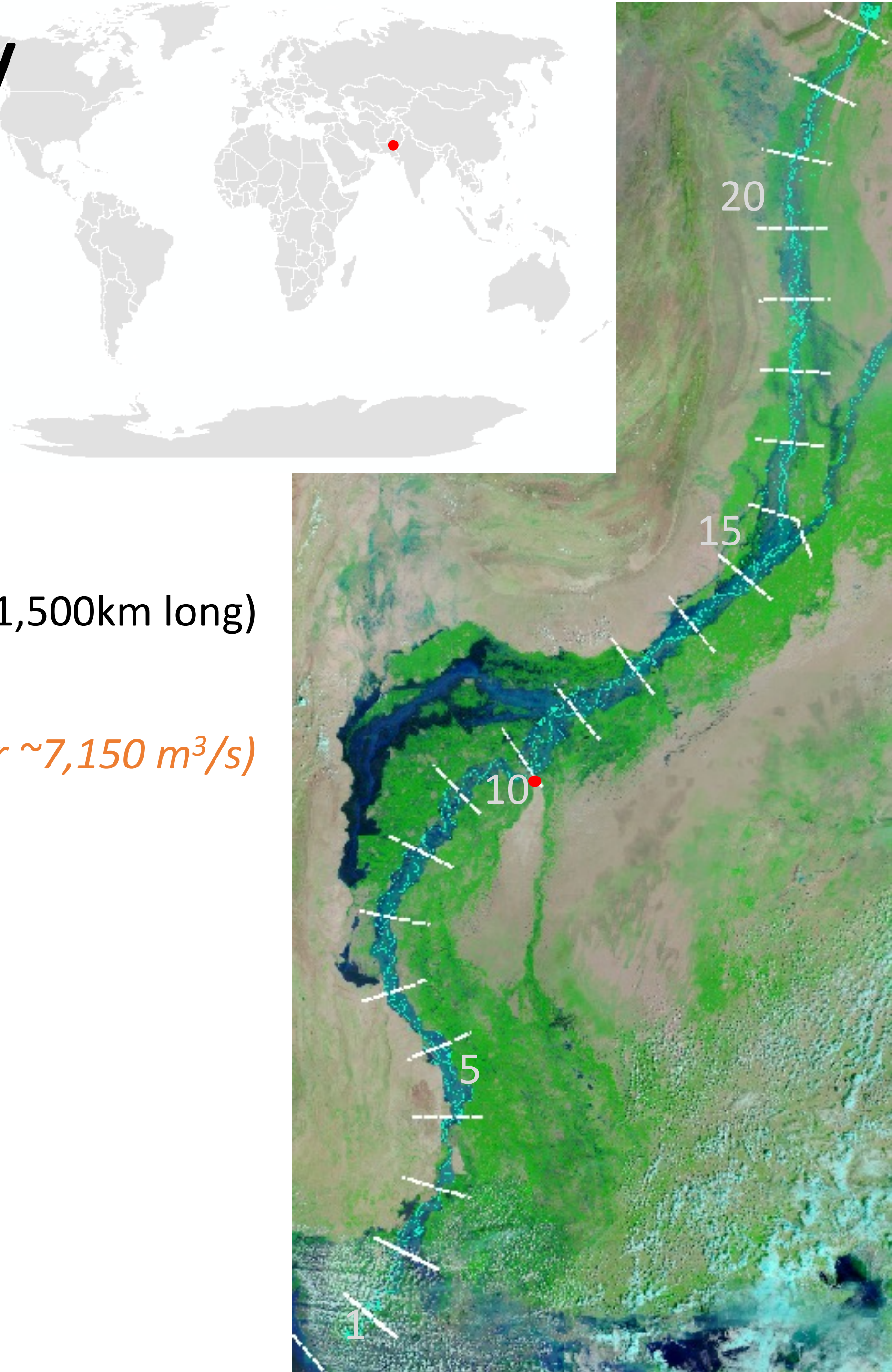
Courtesy of Zoltan Sylvester

Multiple images, long term period

- Changes in water extent
- Changes in sinuosity
- Formation of oxbow lakes
- Connectivity of lakes / wetlands / etc

Fluvial geomorphology case study

Detect storage and remobilization of sediments by analyzing morphological impact at regional scale of a large flood event



Indus River: a regulated fluvial system

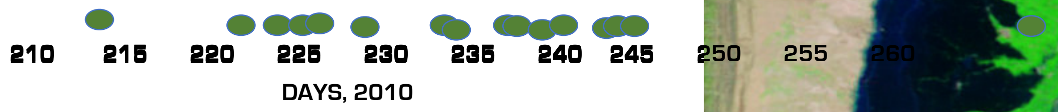
- Heavily engineered system -> levees along most of the main river channel (>1,500km long)
- Largest irrigation network in the world
- Discharge reduced from ~3,000 to ~300-800 m^3/s *(Average Magdalena River ~7,150 m^3/s)*
- Sediment flux to coast reduced to < 10%

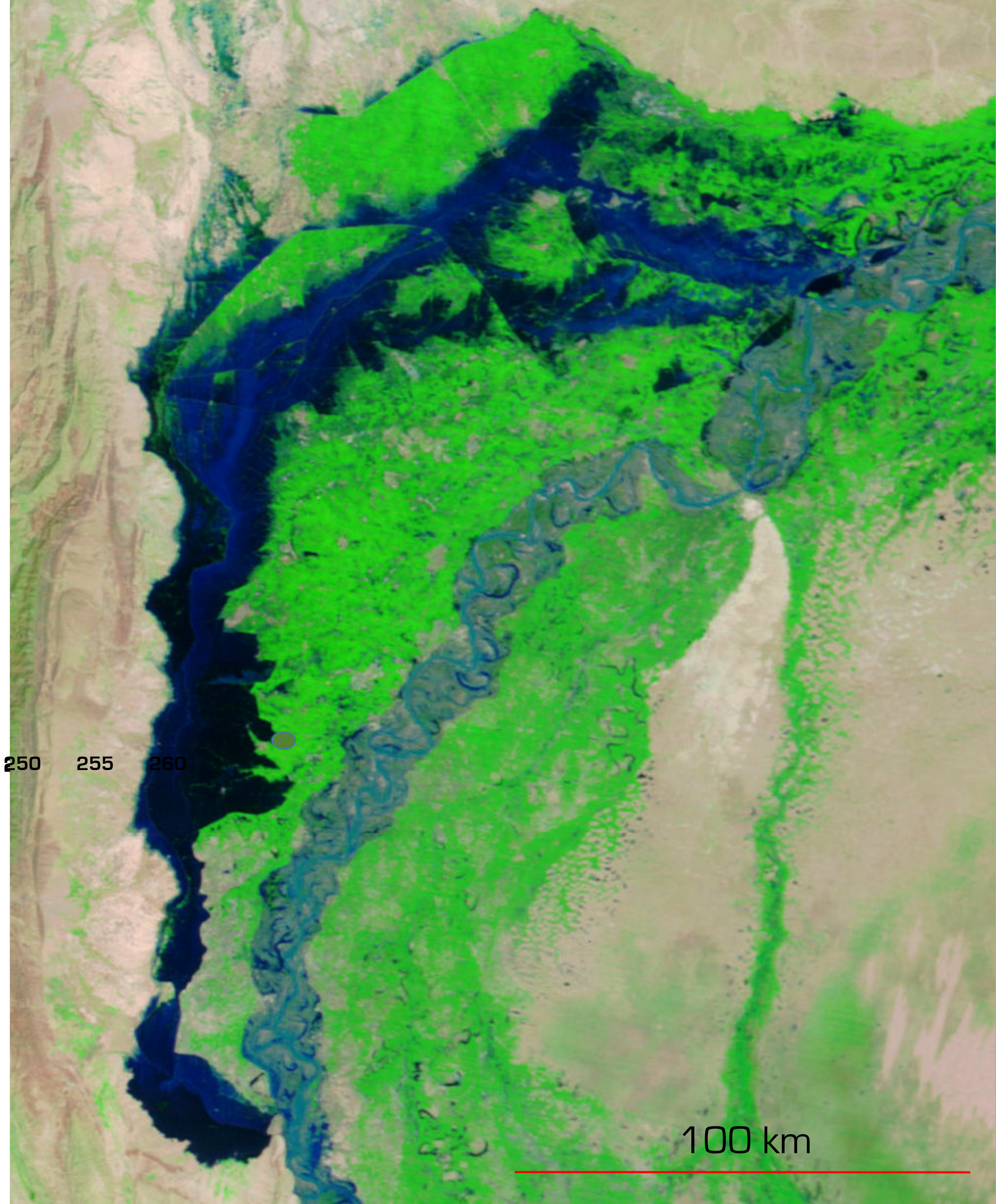
2010 Flood specifics

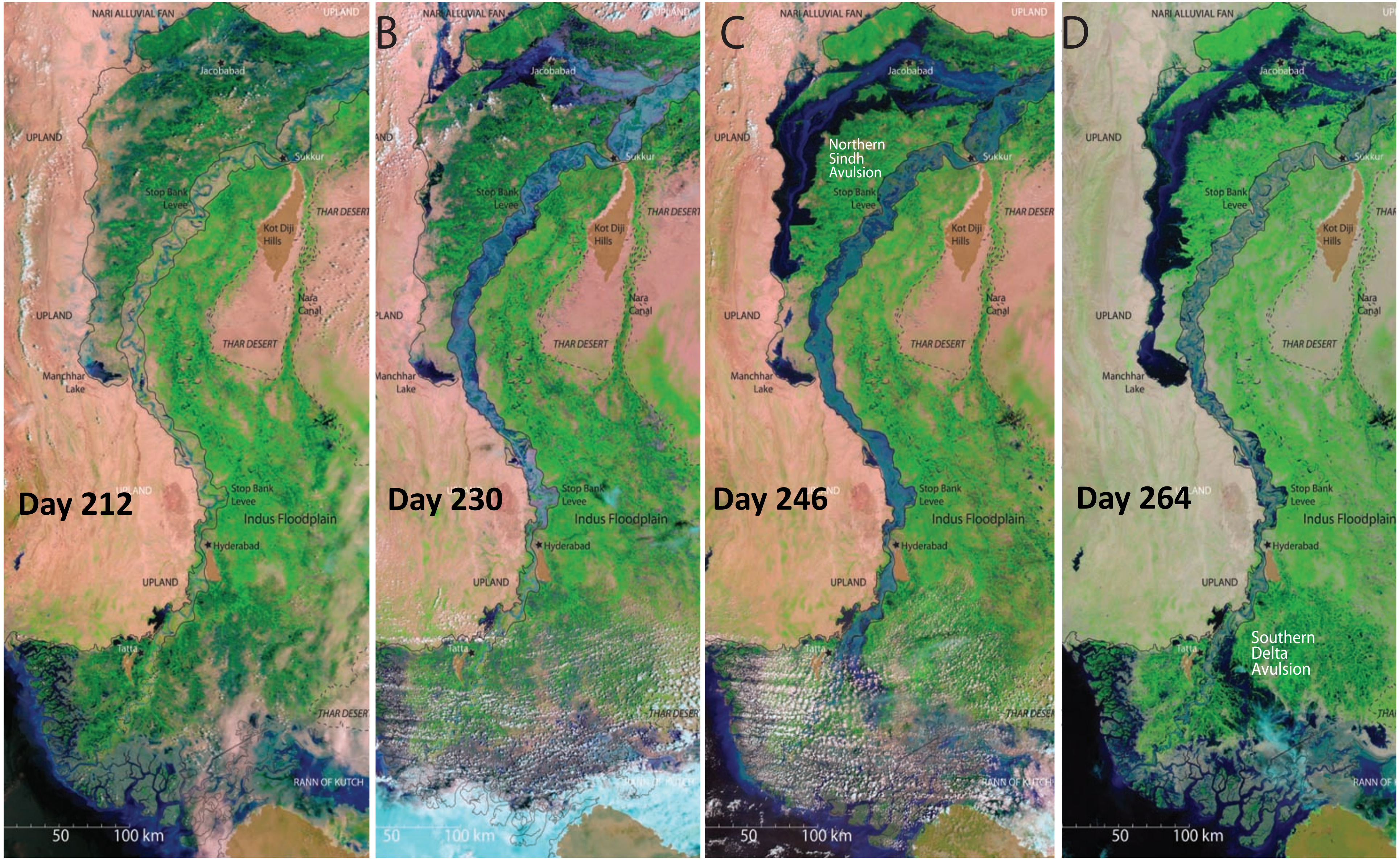
- Flood lasted >2months (August-October 2010)
- 20 million people displaced, 2,000 fatalities
- Peak discharge ~32,000 m^3/s (Sukkur Barrage); similar to 1976, 1986, 1988
- Large avulsion -> inundated ~40,000 km^2

MODIS Terra - Aqua

- Day 210 (Jul 29th): Heavy rain in the upland
- Flood wave travels through the main channel in 10 days, then into the delta in 10 days.
- Flood wave travels through breach and low-lying floodplains in 42 days.

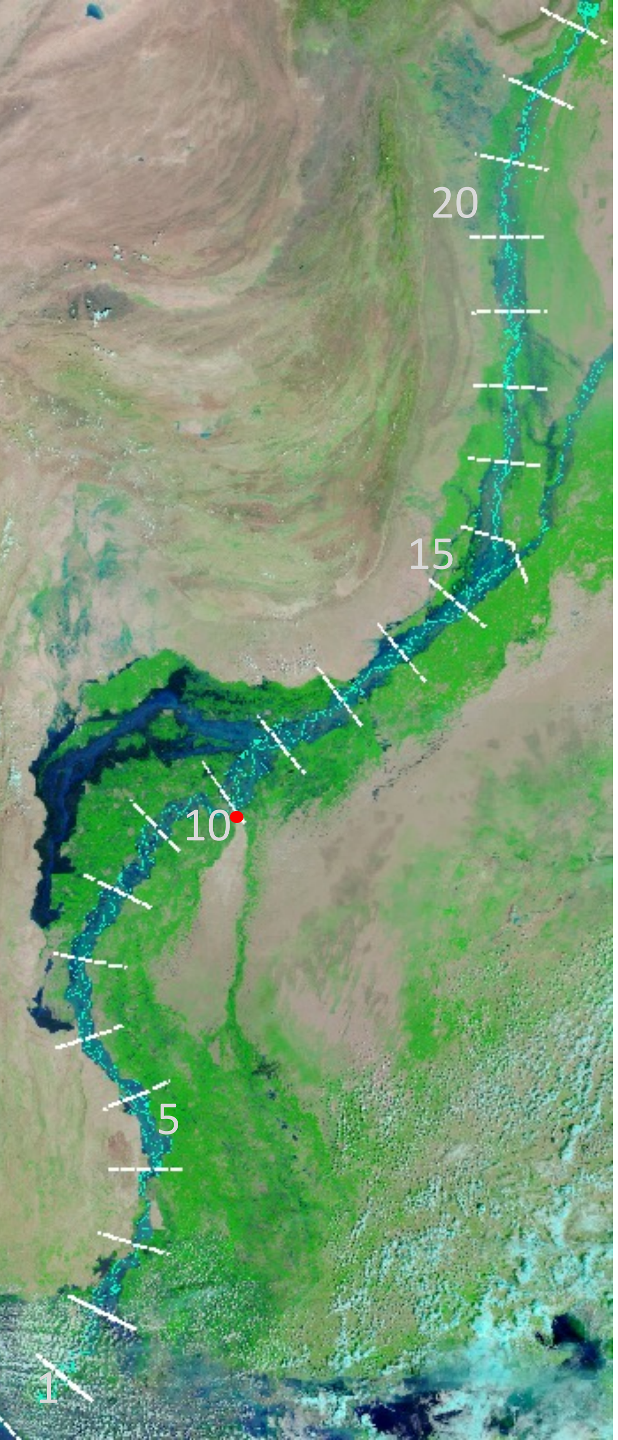






B
C
D
NARI ALLUVIAL FAN
UPLAND
Jacobabad
Sukkur
Stop Bank Levee
Kot Diji Hills
THAR DESERT
Nara Canal
Manchhar Lake
Northern Sindh Avulsion
Day 212
Day 230
Day 246
Day 264
Indus Floodplain
Hyderabad
Tatta
Southern Delta Avulsion
RANN OF KUTCH
50
100 km

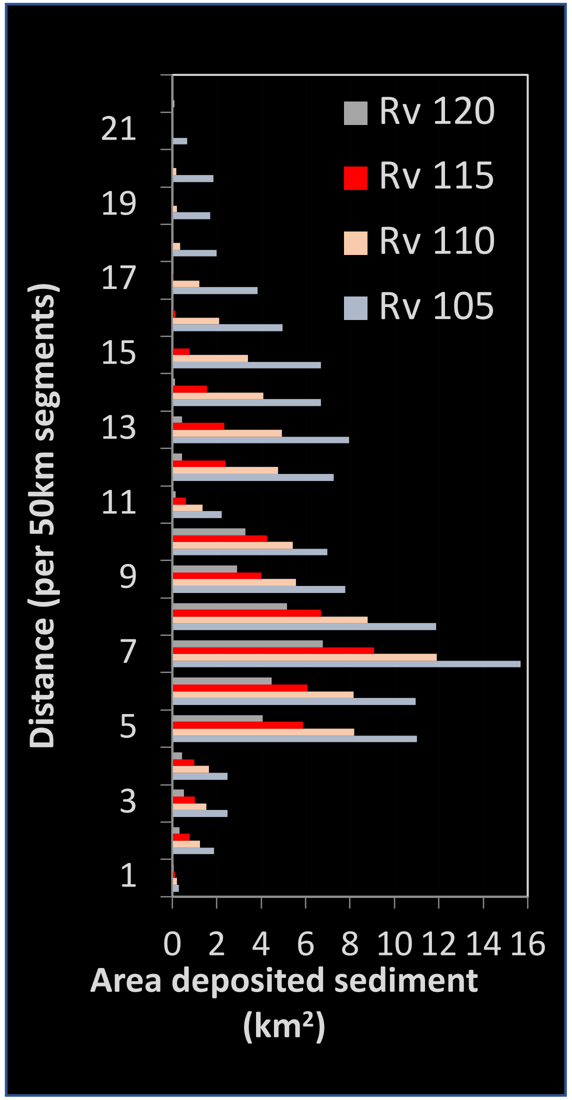
Remote sensing data analyzes techniques

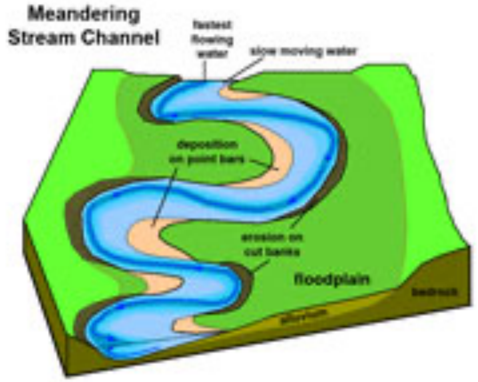


Quantify:

1. Changes in the main channel
2. Spatially sediment deposits

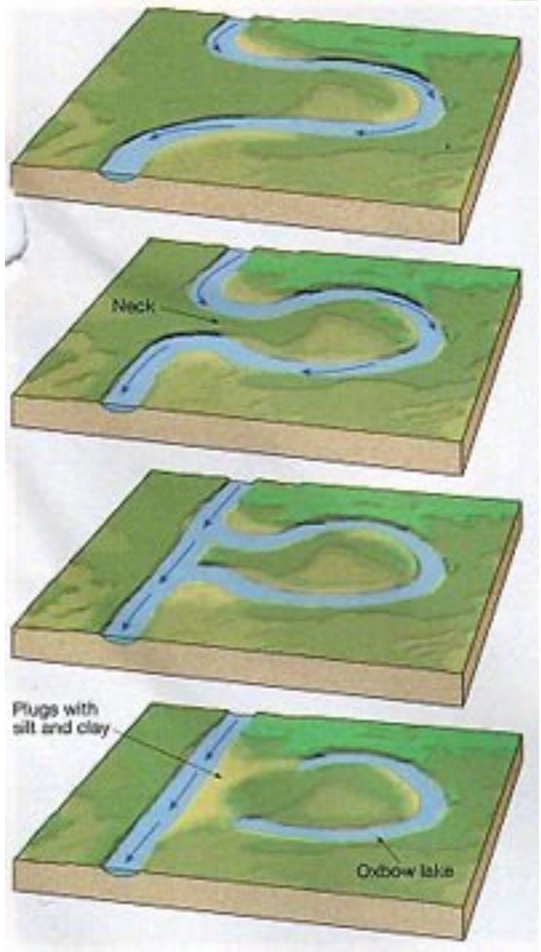
- Determined *outline inundated area* based on water reflectance (*MODIS 7-2-1 band*)
- Established *before & after* *flood* *centerlines* of the main channel (*LandSat, band 1*)
- Set a conservative *sediment reflectance value* (Rv) (LandSat, band 1) by validating (*ASTER-A1 & Maxar imagery*) for whole region
- Defined the *inner and outer* stretch of each *bend* for whole river (>1500km)

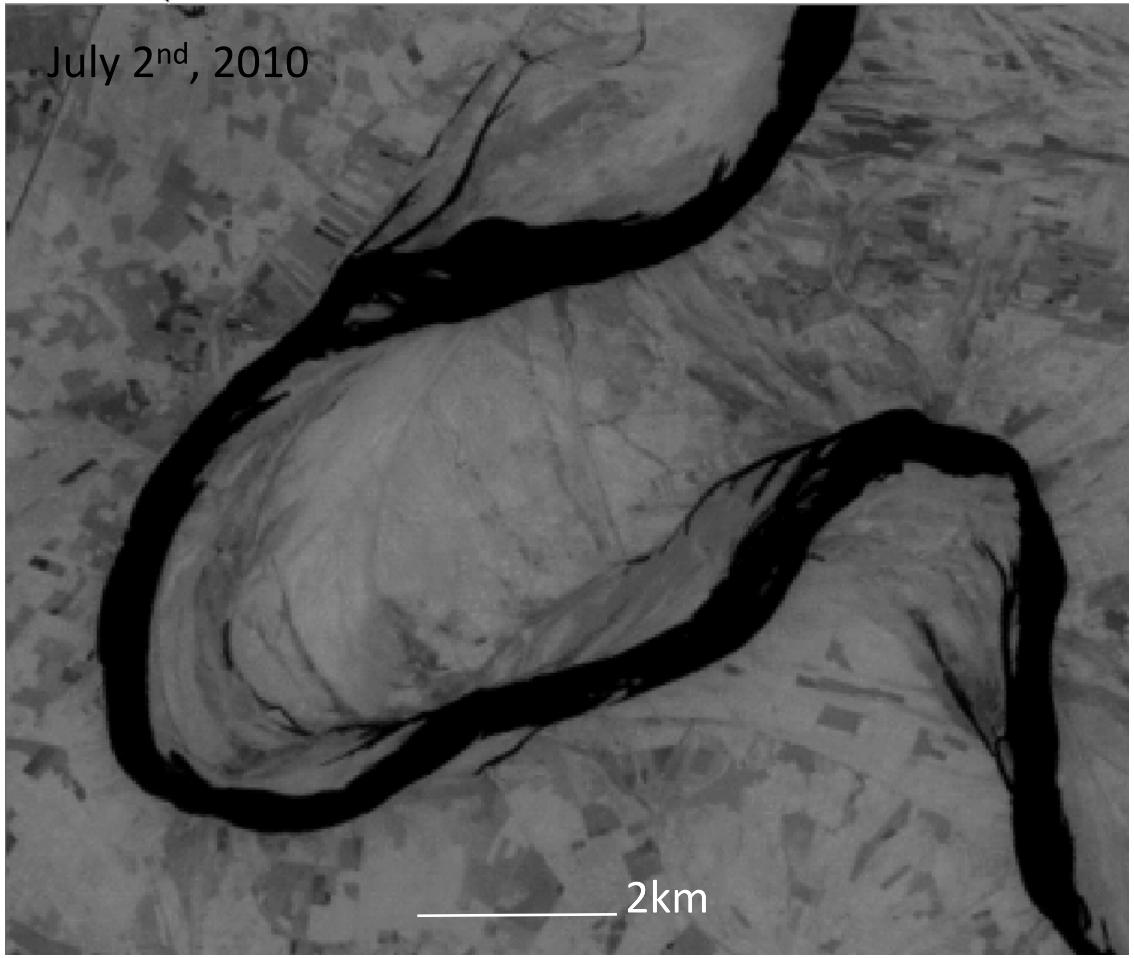


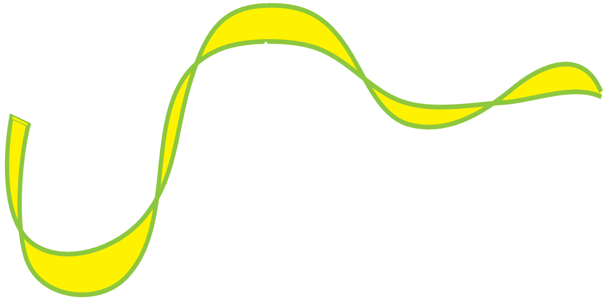


Point bar formation

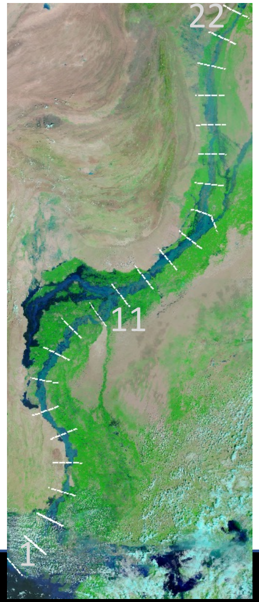
Neck cutoff



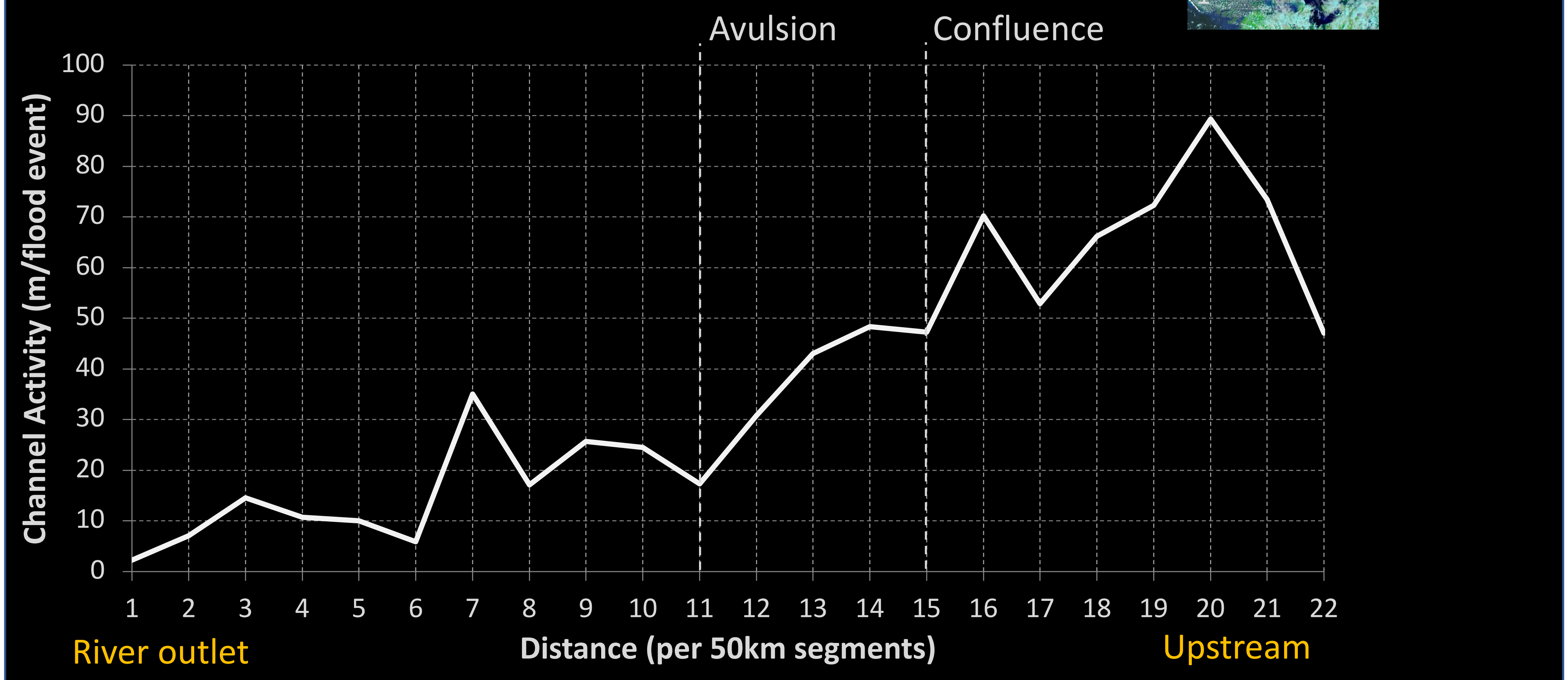


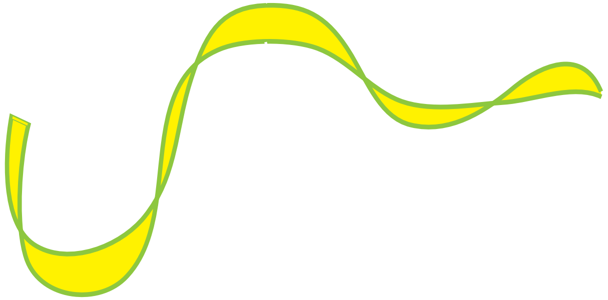


$$\text{Channel Activity} = \frac{\textit{Area change}}{\textit{Length x } \Delta T}$$



On average Channel Activity = 34m, reducing sinuosity ~2%





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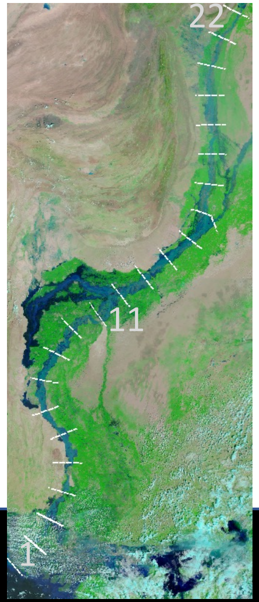
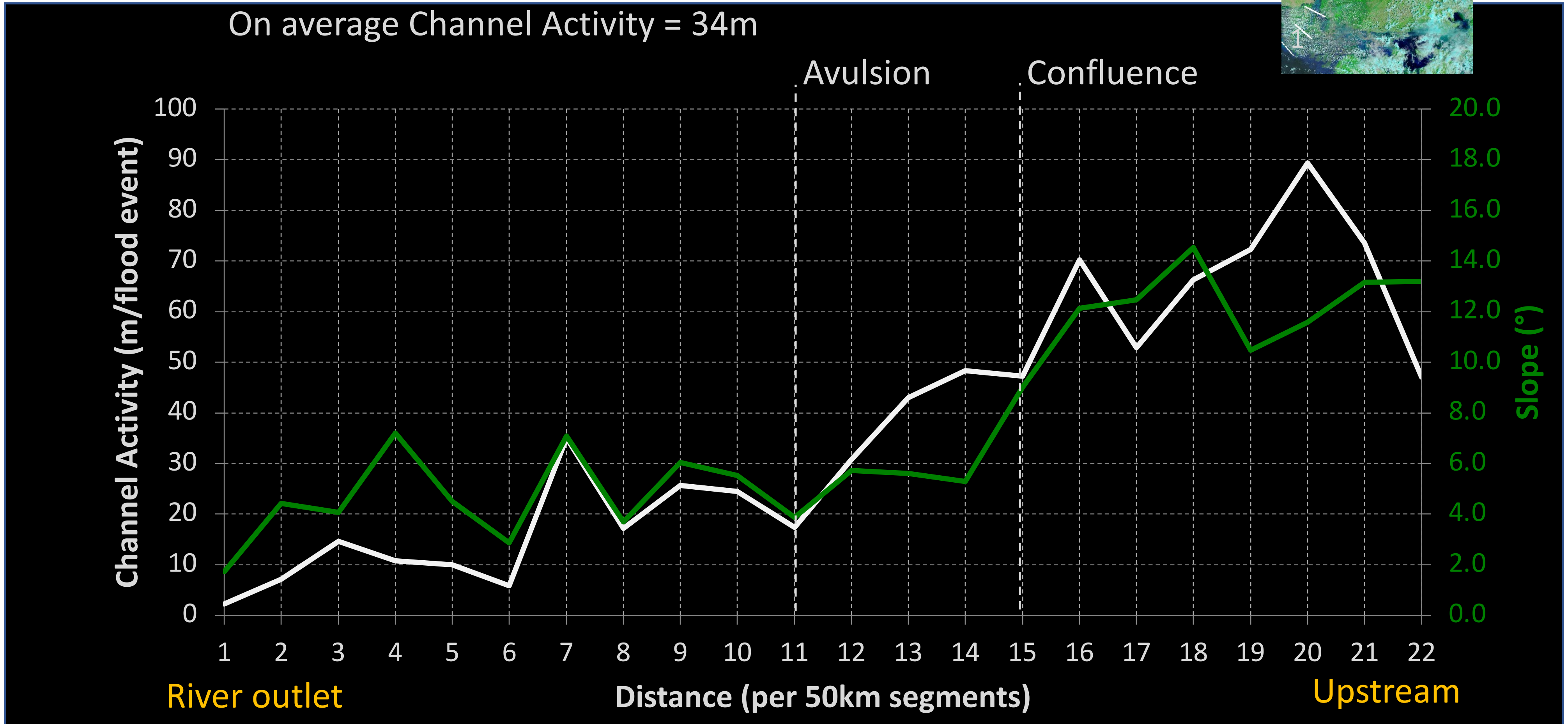
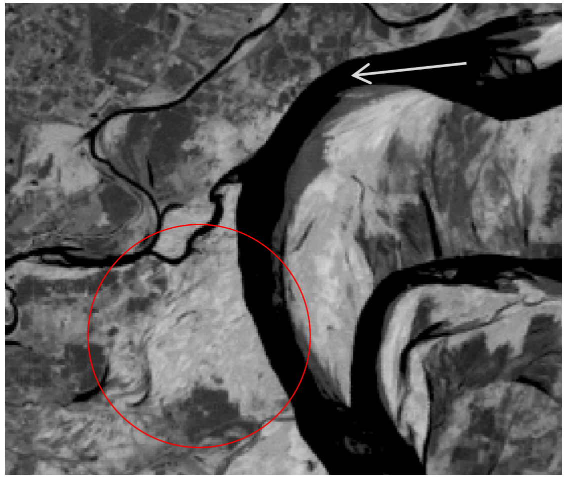
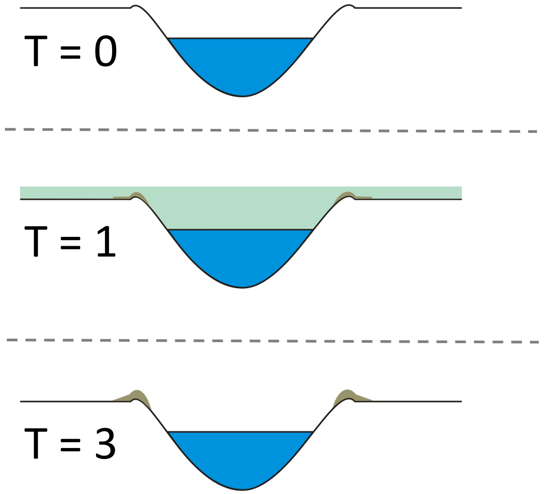


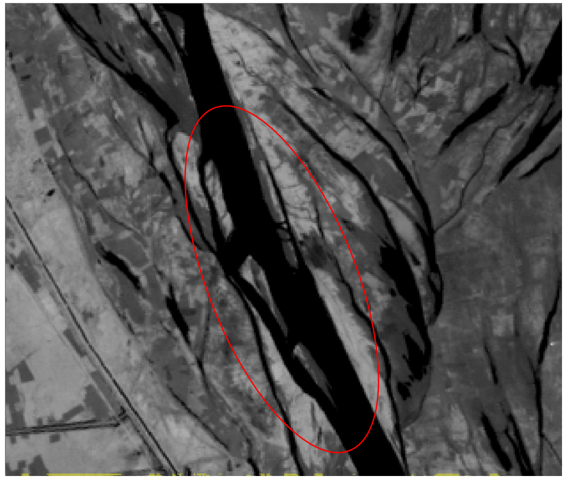


Crevasse splays

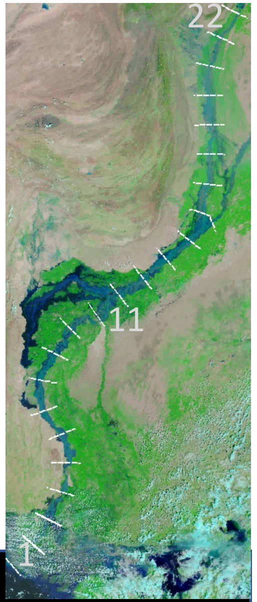


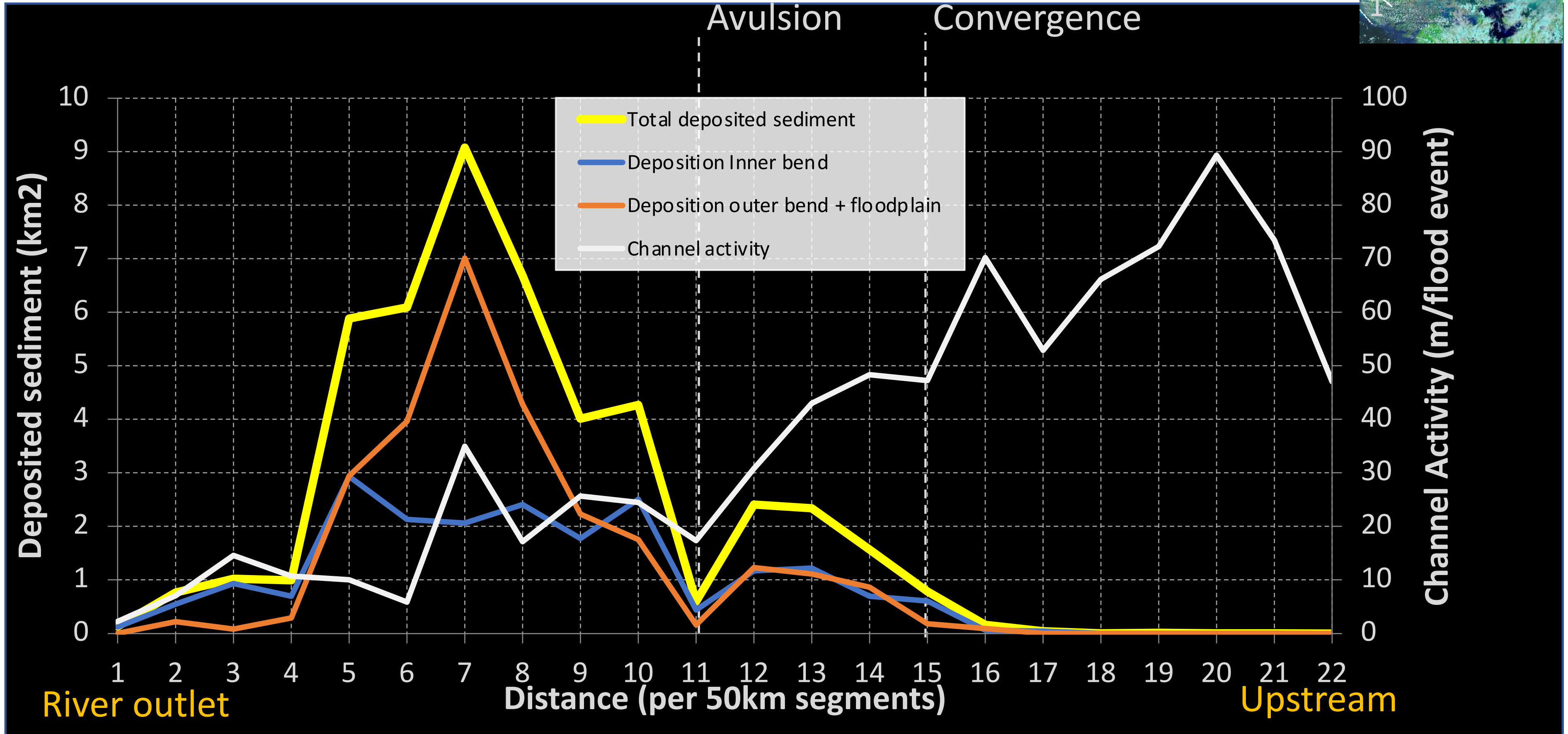


Levee deposits

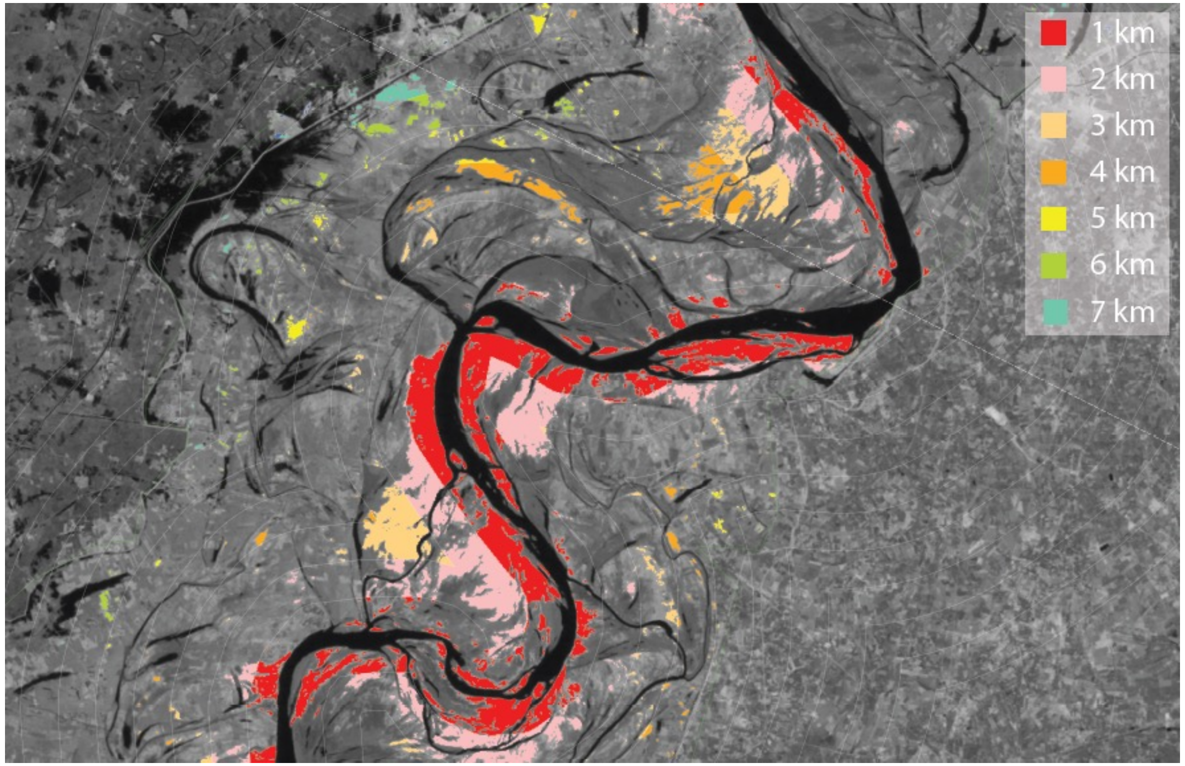


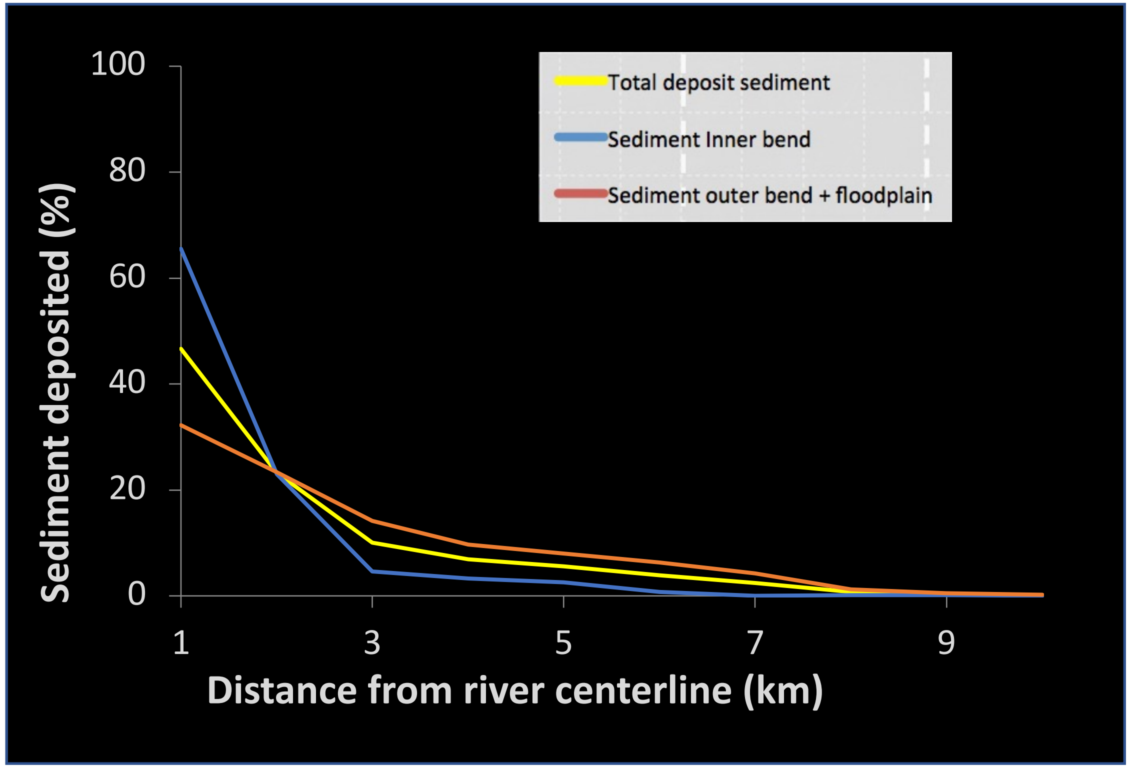
Findings 1: Longitudinal sediment deposition





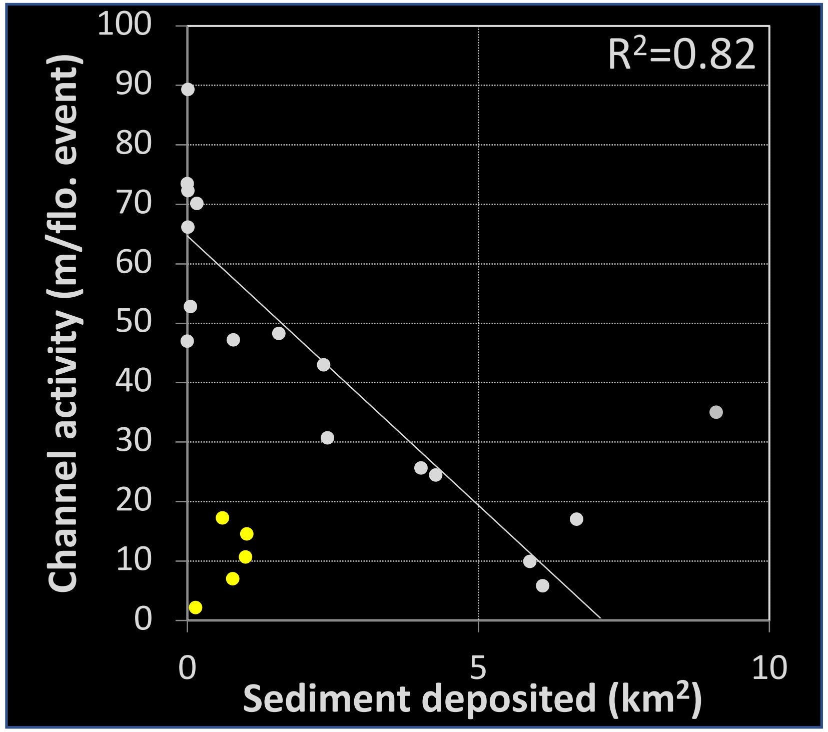
Findings 2: Lateral sediment deposition

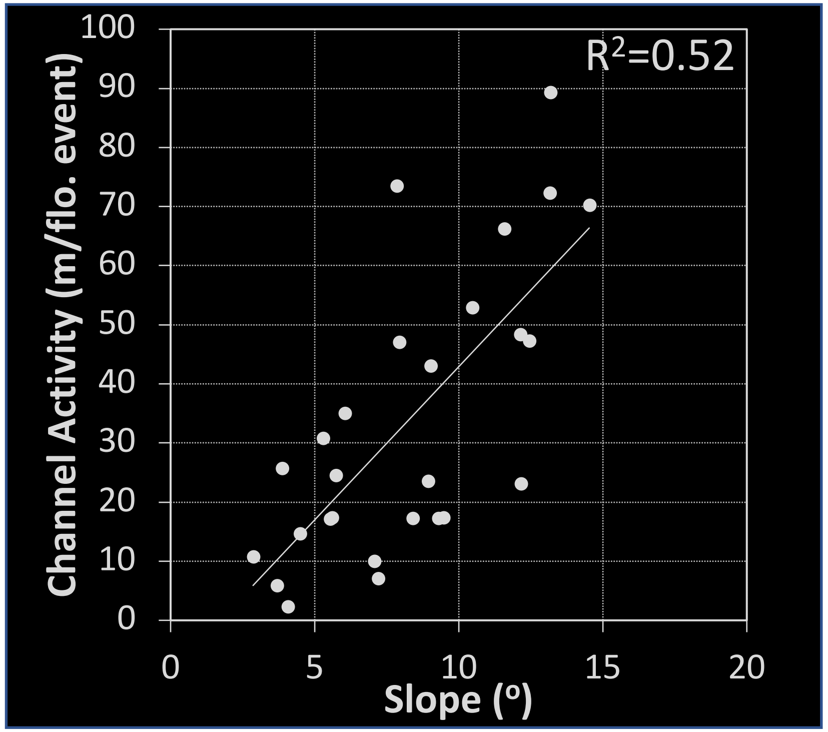




- 47 km^2 of bedload was deposited
- Most sediment is deposited within 1km of the channel (82%)
- Only 43% of sediment is deposited in inner bends

Findings 3: Correlations with channel activity



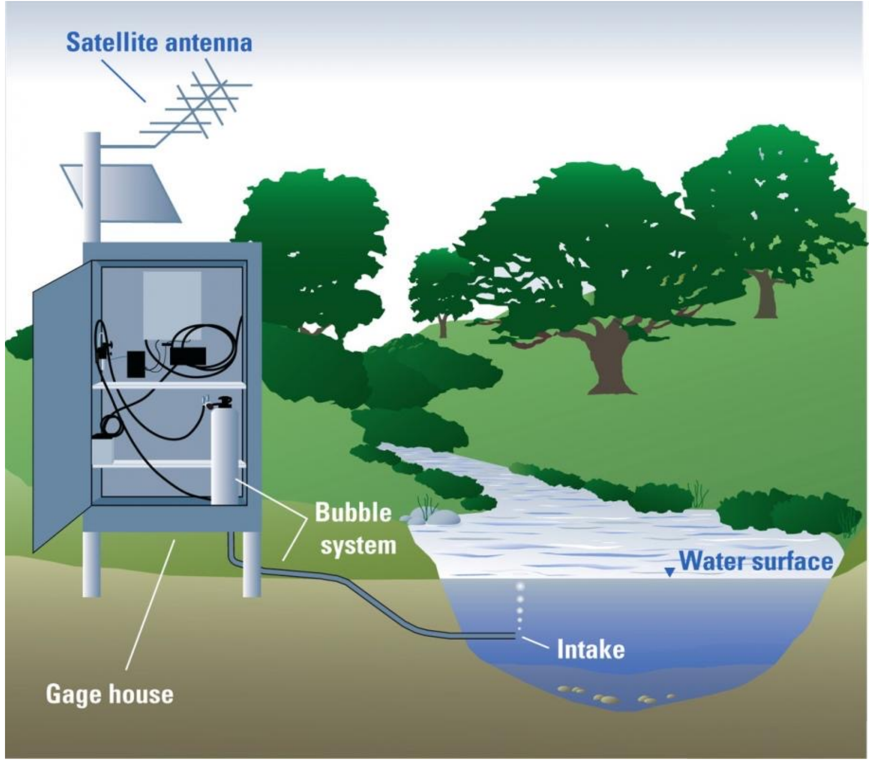


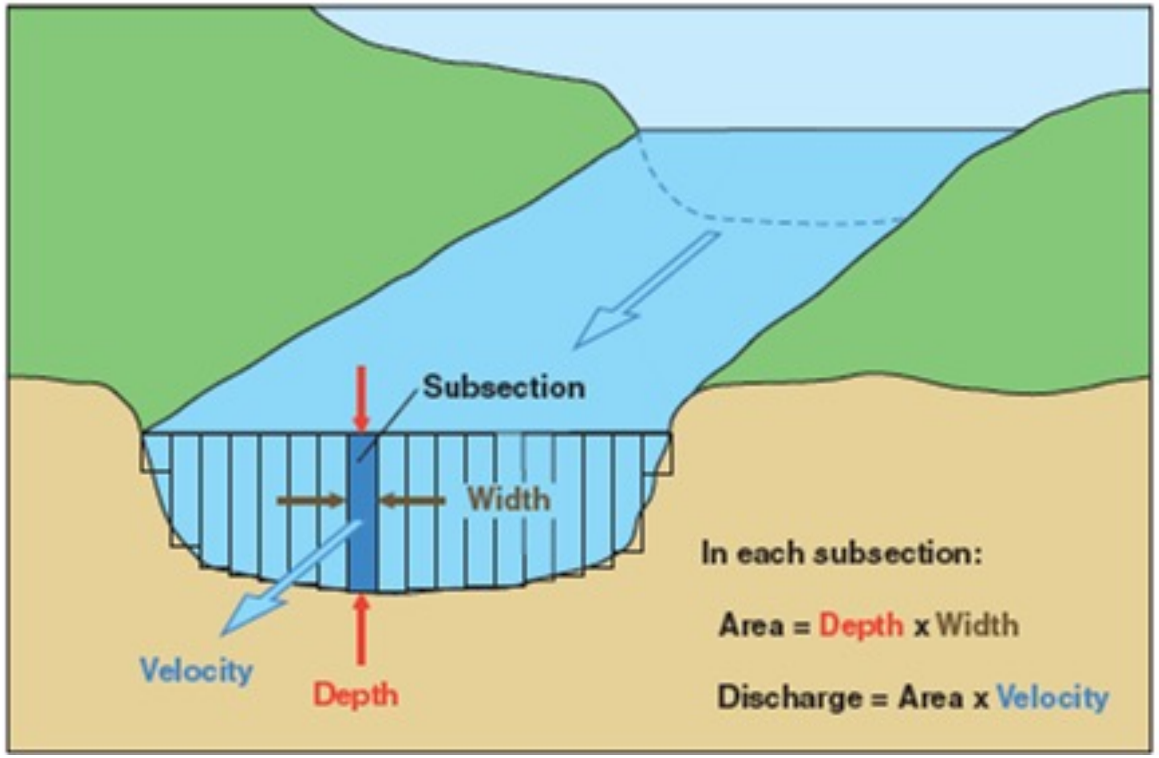
Utilizing remote sensing

Monitoring water discharge

Monitoring water discharge from space, why?

I mean, there are gauging stations!

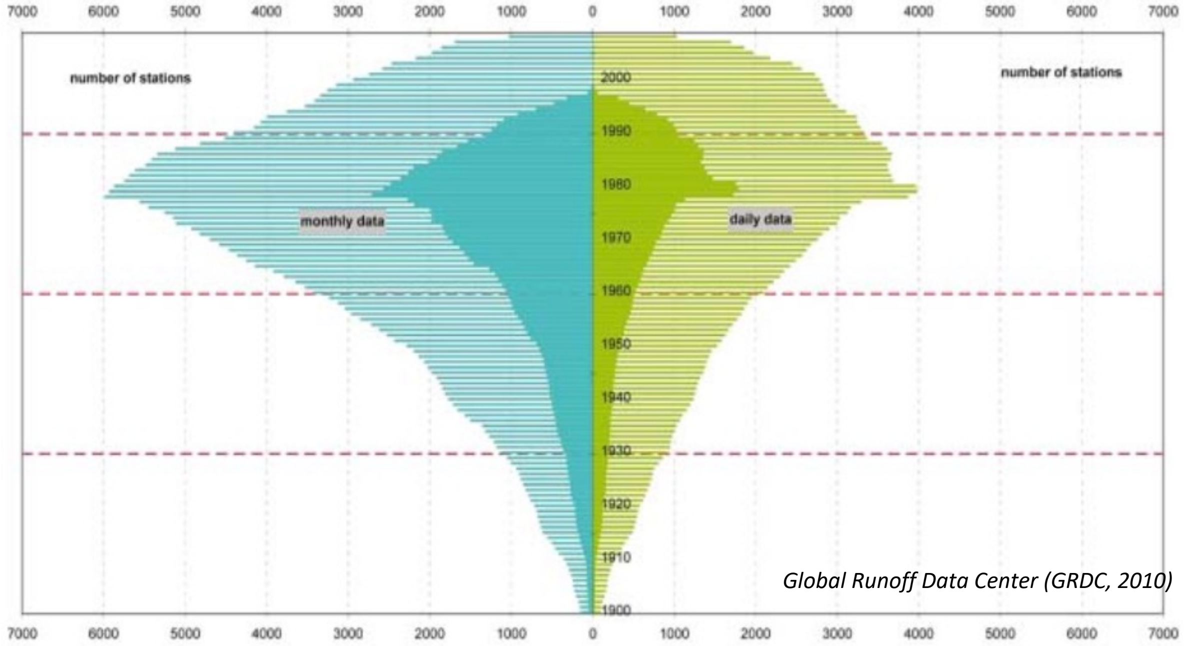




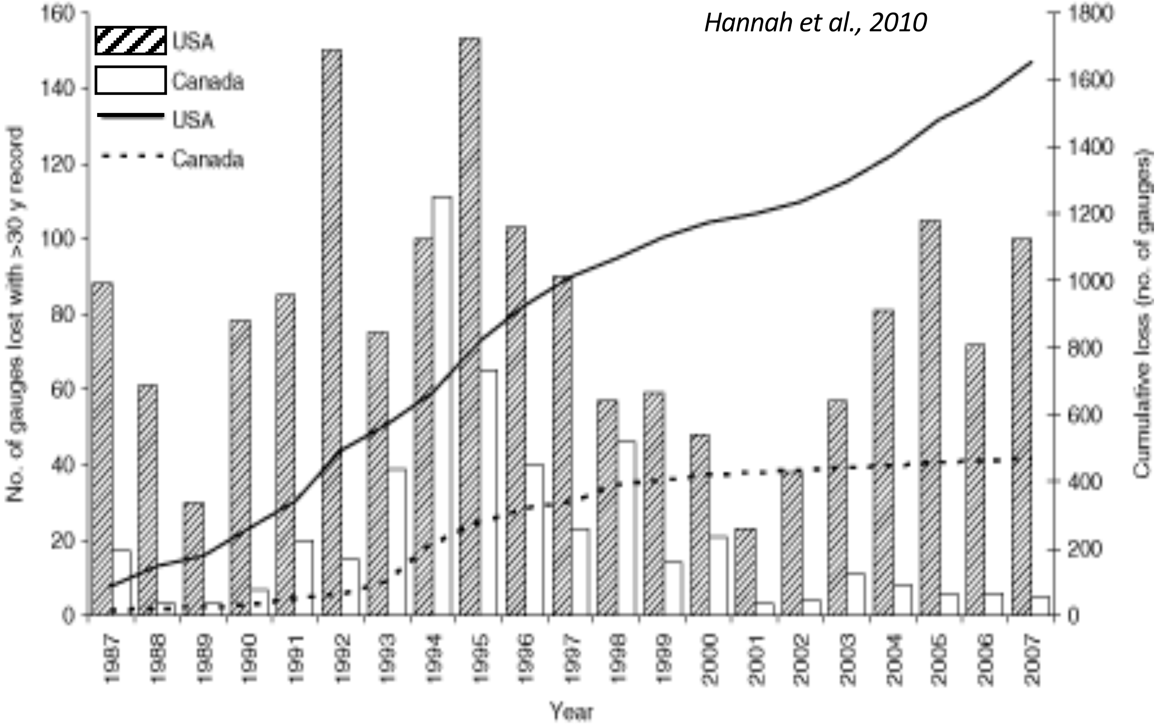
Ground based observations Water discharge

Gauging stations are expensive to build and maintain. And if a gauging station is there, data gets hardly shared with other countries, although rivers cross boundaries.

Availability of historical discharge data in the GRDC database



Loss of gauging station with data record > 30 years



Additional advantages and disadvantages of Remote Sensing water gauging stations

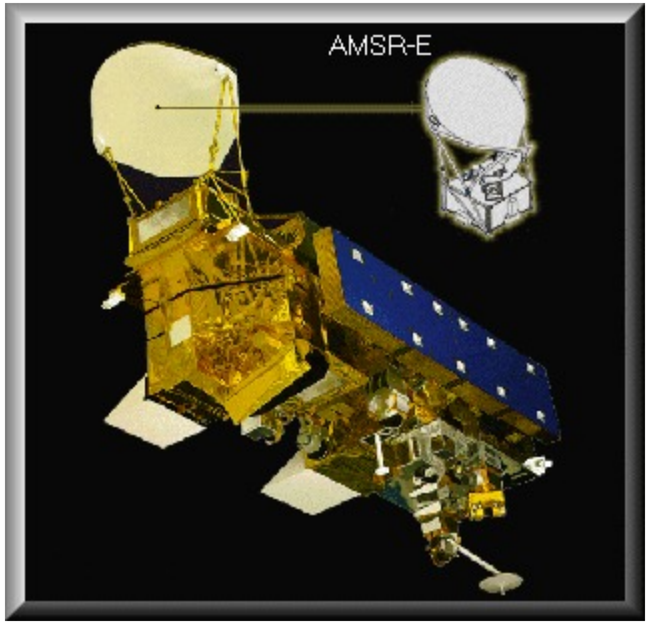
Additional advantages

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

Additional disadvantages

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

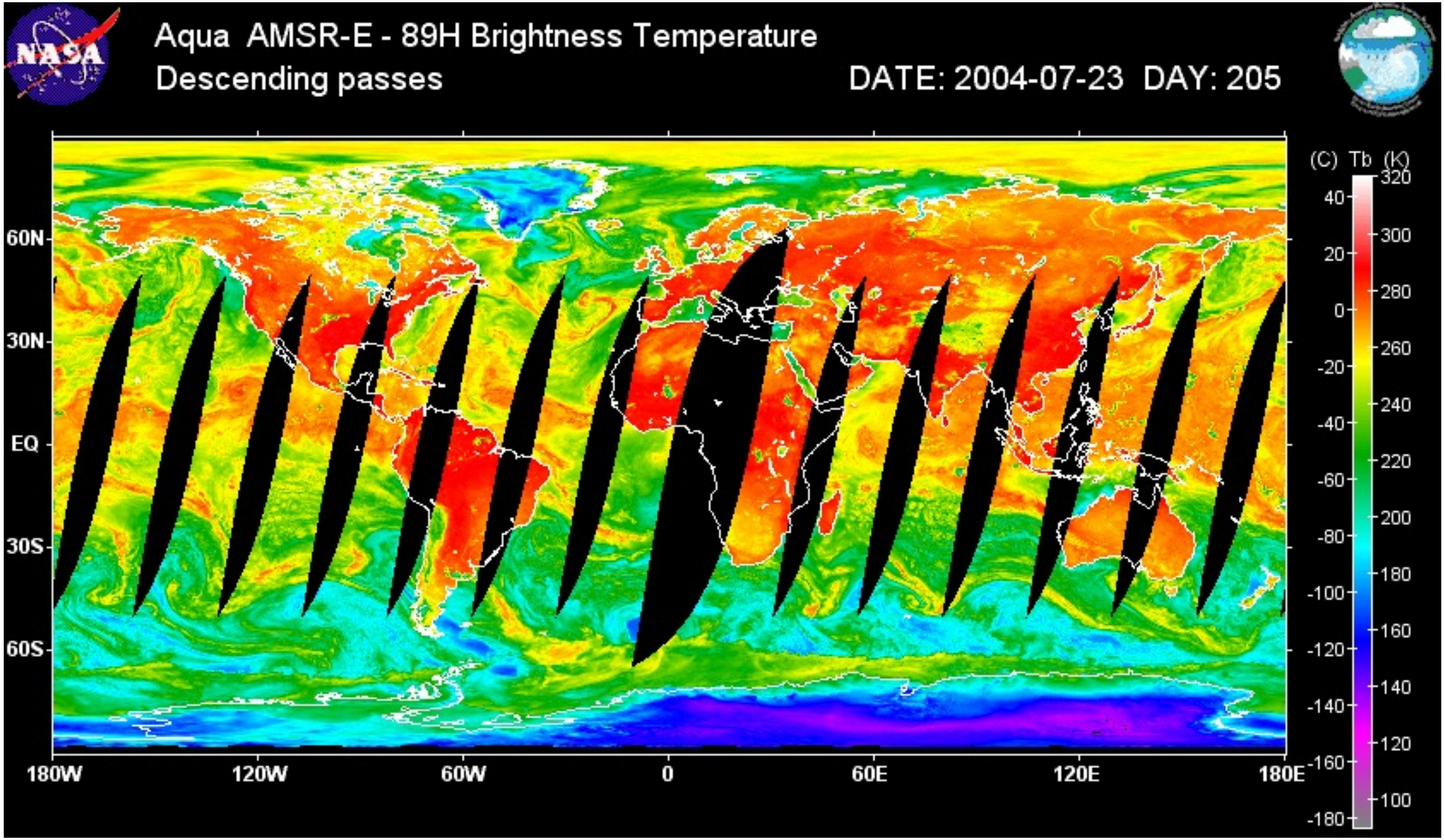
The Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) is a twelve-channel, six-frequency, passive-microwave radiometer. It measures horizontally and vertically polarized brightness temperatures, including at 36.5 GHz.



AMSR-E was developed by the Japan Aerospace Exploration Agency (JAXA) and launched by the U.S. aboard Aqua in mid-2002. It ceased operations in late 2011

Before AMSR-E, there was the TRMM satellite, which had a ground-sensing 37 GHz channel. 1998 to 2015.

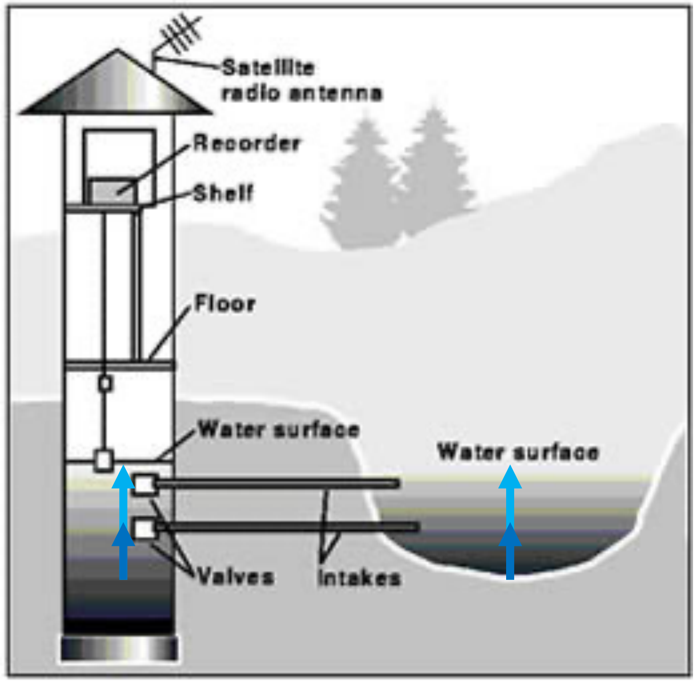
In 2012, AMSR-2 became operational, and has a brightness temperature at 36.5 GHz available (same as the GPM satellite, 2015 and ongoing



Several passive microwave satellites provide near complete daily coverage and their data can be used to measure river discharge changes. Availability of these data very likely to extend permanently into the future. Little interference by cloud cover.

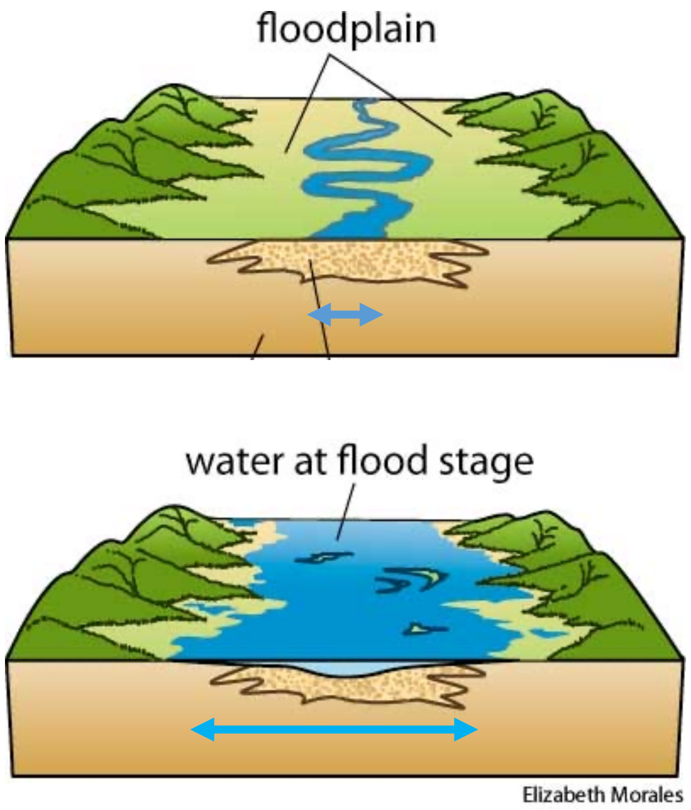
Ground based Gauging station

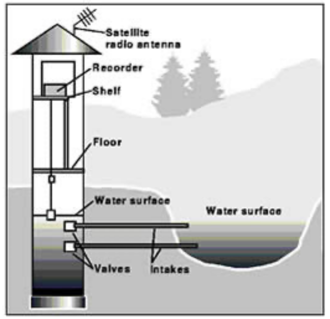
DEPTH



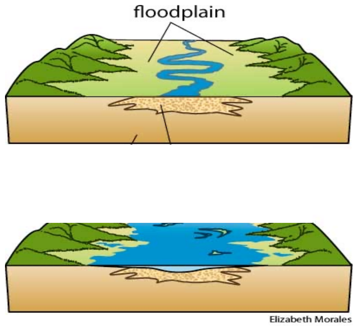
Satellite based Gauging station

WIDTH





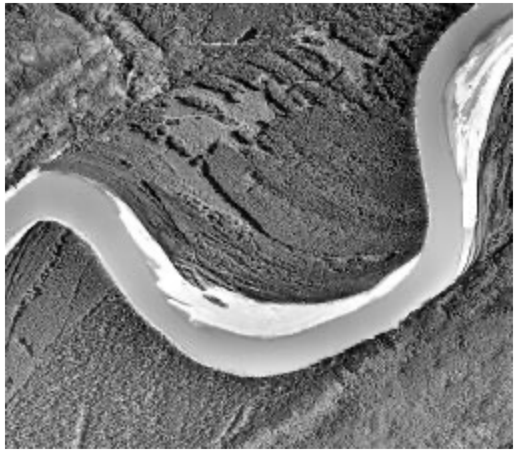
River discharge

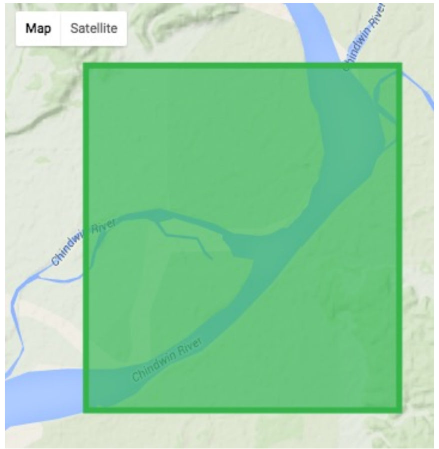


$$Q = \text{Width} \times \text{Depth} \times \text{Velocity}$$

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

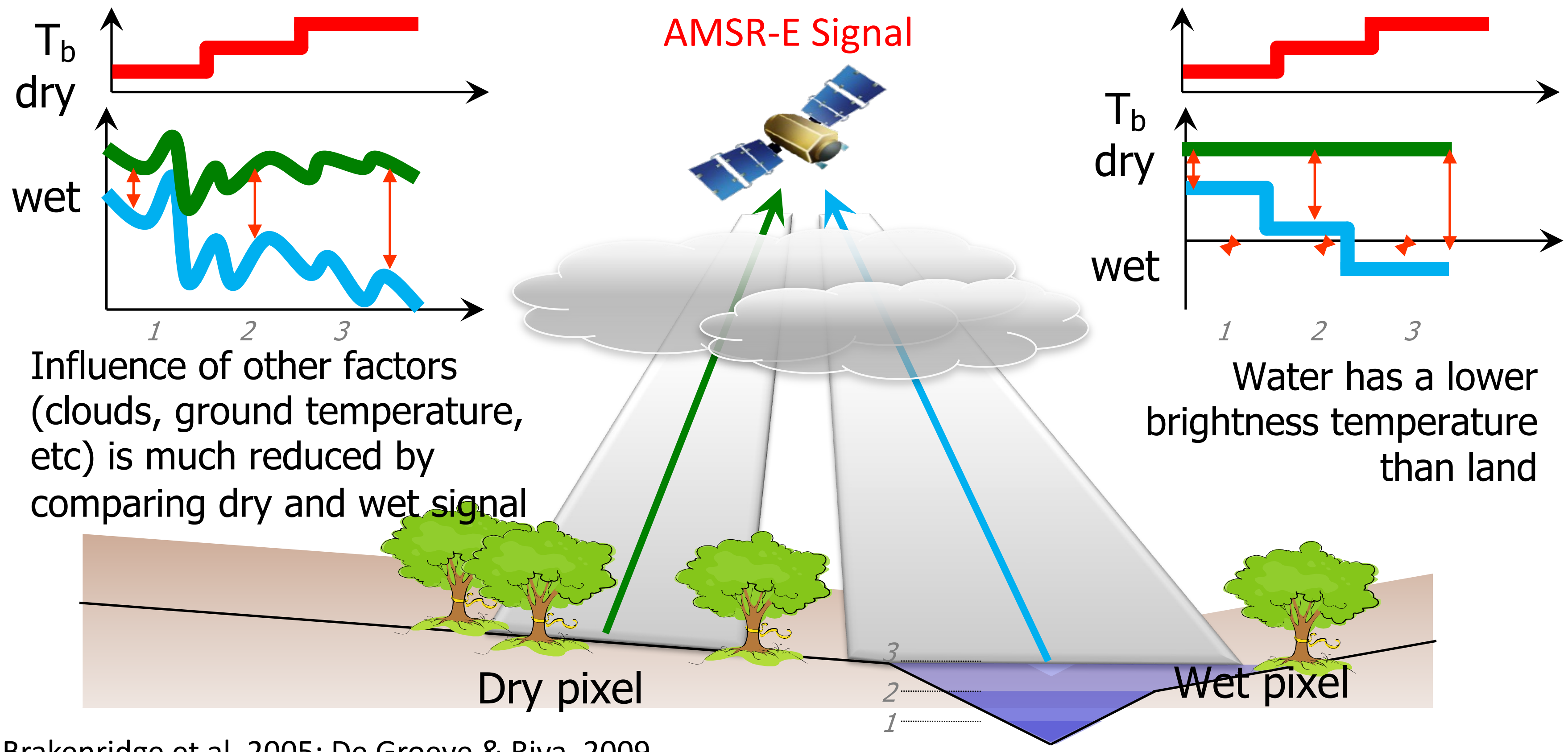
River Watch sites use satellite passive microwave radiometry to sensitively monitor this in-pixel surface temperature change.





AMSR-E/AMSR-2 River discharge Measurement Method

Measuring temperature change by passive microwave signal



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

GFDS satellite-born sensors

GFDS calculates water surface metrics from brightness temperatures recorded at 36.5 GHz, both ascending and descending swaths. Full time series of four sensors constitute the input data (Table 1).

Table 1. GFDS sensors and characteristics

Sensor	Name	Satellite	Characteristics	Comments
AMSR-E	Advanced Microwave Scanning Radiometer - EOS	NASA's Earth Observing System (EOS) Aqua Satellite	2002-2011 Polar orbit, full geographic coverage 36.5 GHz (V, H)	AMSR-E antenna stopped spinning at 07:26GMT Oct 4, 2011
TRMM-TMI	TRMM Microwave Imager	Tropical Rainfall Measuring Mission	1997-2015 37.0GHz (V,H) 40S to 40N	Operations stopped on 15/04/2015
AMSR2	Advanced Microwave Scanning Radiometer 2	GCOM-W	2013-ongoing Polar orbit, full geographic coverage 36.5 GHz (V, H)	Integrated under ERCC1/MIC7
GPM-GMI	GPM Microwave Imager	Global Precipitation Mission	2015-ongoing 37 GHz (V, H) 65S to 65N	Integrated under ERCC2/MIC8

Figure 3. Timeline of GFDS data sources.

European Commission's "Global Flood Detection System" (GFDS) currently processes GPM and AMSR2 37 GHz data as soon as they are available at the JRC. Latency times vary: from around 3 hours (AMSR2) to around 24 hours (GPM; could be improved in future). In gap between AMSR-E and AMSR2, TRMM provided coverage, but not including latitudes above 40 deg N and S (*no coverage* over these large areas, late 2011-early 2013; the entire system would have been defunct save for back-up provided by TRMM). The merged product is also more reliable: better signal/noise due to averaging of additional data over a site.

The position value *P* indicates the relative position of the calibration pixel *C* to the measurement pixel *M*. The calibration pixel *C* is chosen as the 95 percentile of the pixels in a grid of 9by 9 pixels centered on the measurement pixel *M*. (It is not the hottest pixel to exclude outliers due to measurement error.) The position numbers of calibration pixels are listed in the figure below.

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	32	33	34	35	36
37	38	39	40	41	42	43	44	45
46	47	48	49	50	51	52	53	54
55	56	57	58	59	60	61	62	63
64	65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80	81

Figure 4. Position numbers of calibration pixels around the measurement pixel (41).

GDACS Global Flood Detection System - Version 2

An experimental system to detect and map in near-real time major river floods based on daily passive microwave satellite observations. The purpose is to ider

Home | Current floods | Global map | Search areas | Regions | Download | About

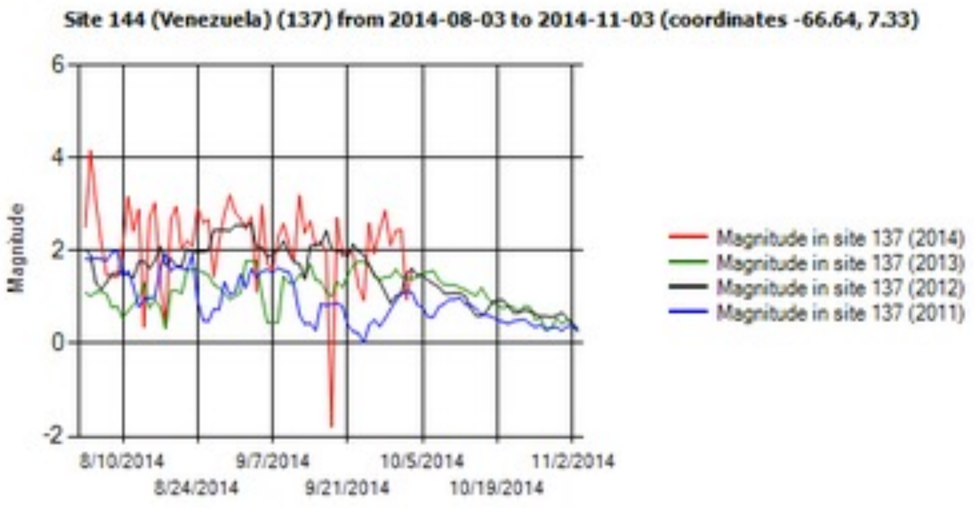
Site 144 (Venezuela) (Area 137 on Orinoco in Venezuela)

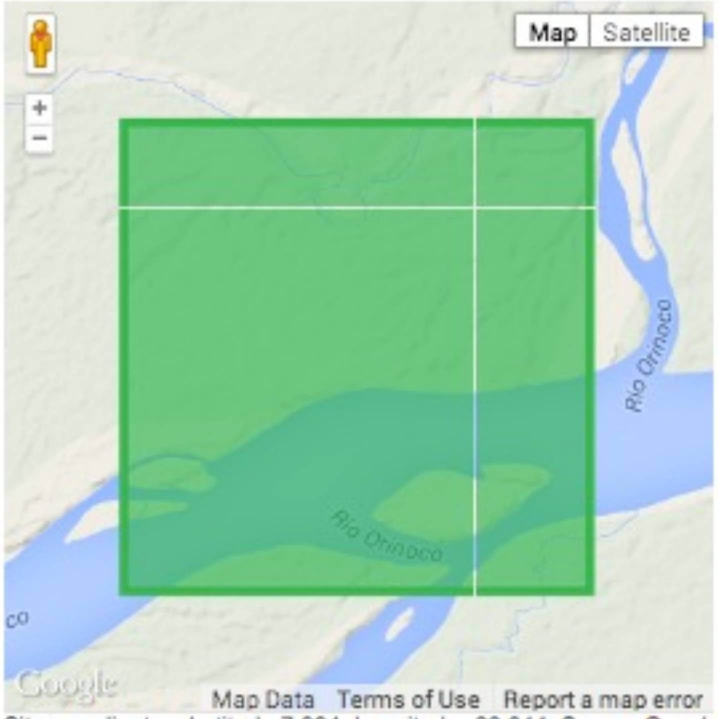
See other areas in Venezuela, on the Orinoco

Current Status | Data | Maps and animation | Graphs

Current Data

The flood magnitude is a measure of the size of the flood. Since lower signals generally accounts for increased water coverage, extreme events, or major floods, should represent anomalies in the time series of a given site. The reference value for normal flow is calculated as the average signal for the site since June 2002. Flood magnitude is defined as the number of standard deviations (sd) from the mean (avg). Read more...





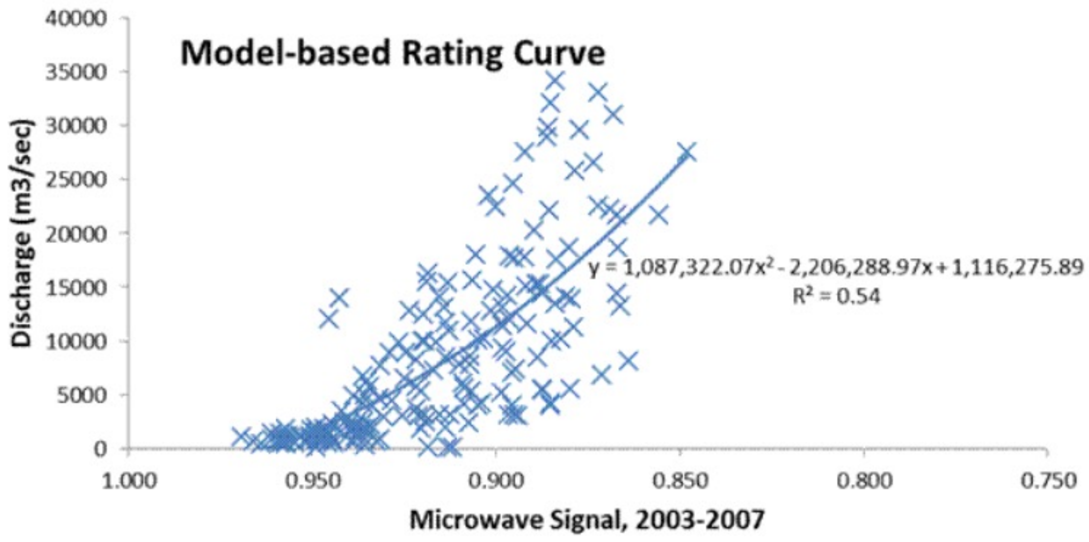
Site coordinates: Latitude:7.334, Longitude:-66.644. See on Google Maps.

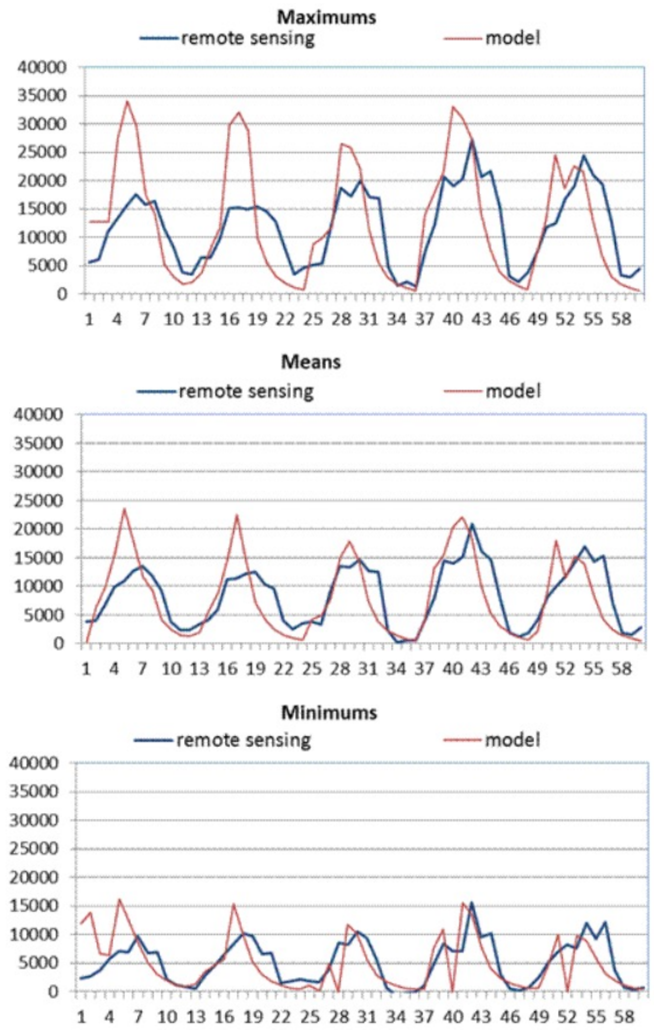
Customize this graph | Download data: HTML RSS

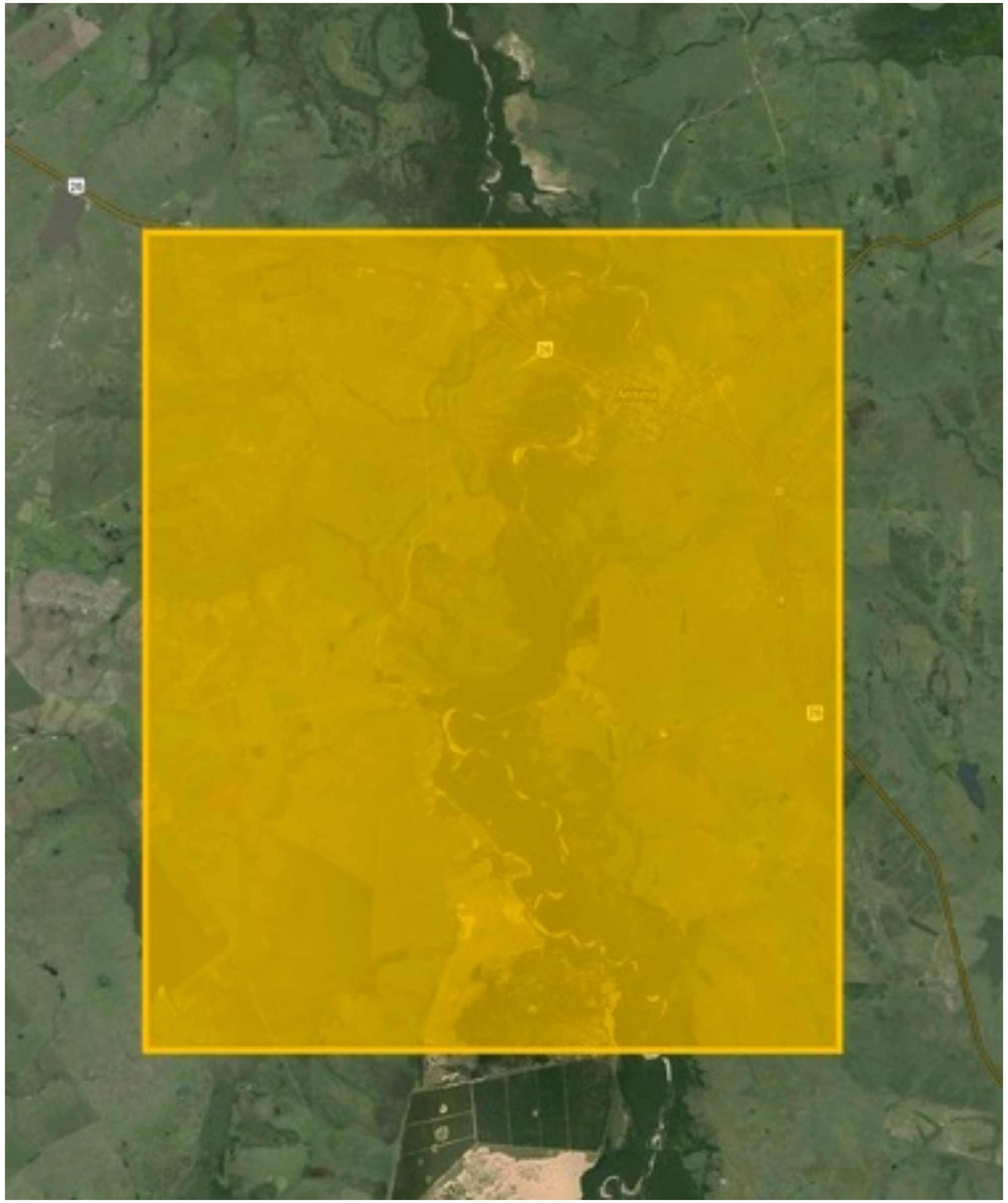
Translate Temperature to Discharge

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



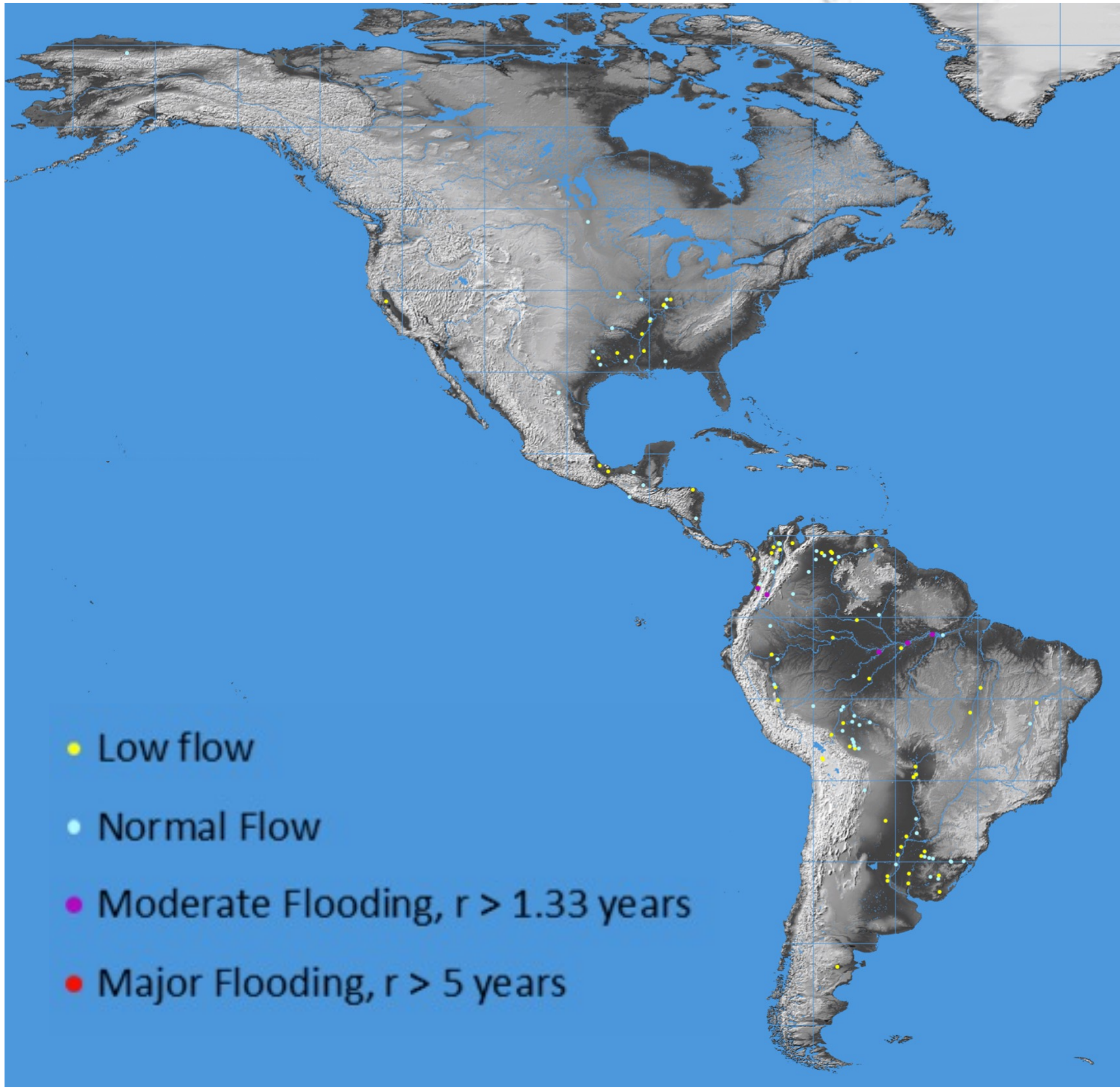




Measurement Site 787. The river channel is only ~ 70 m in width, but a 10 km long floodplain is monitored. At this site, modeled discharge is strongly correlated with the remote sensing signal.

The accuracy estimate for the signal is “Good”

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).

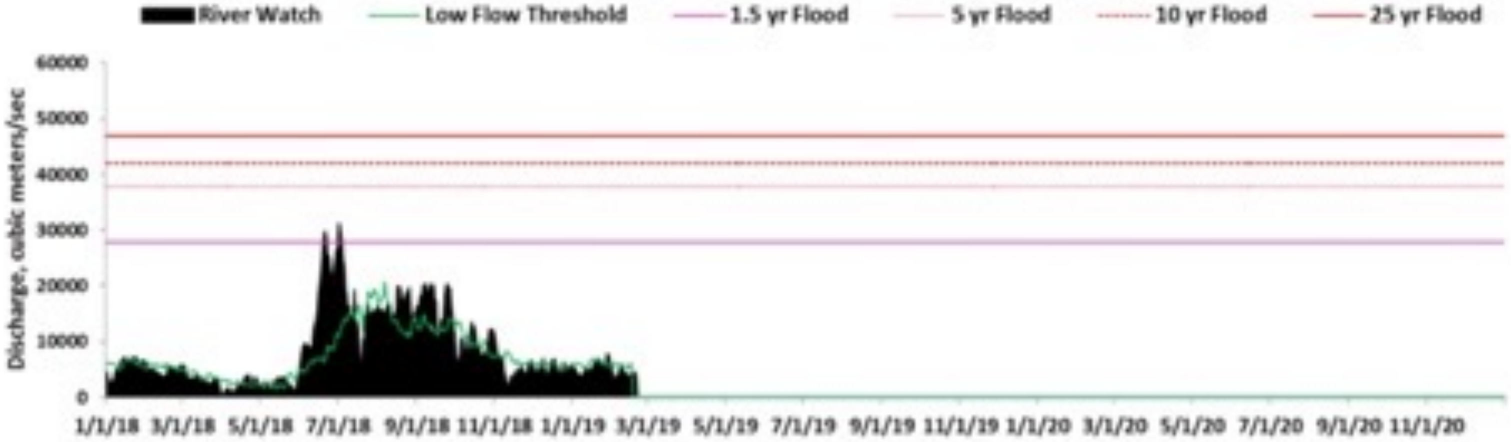


River and Reservoir Watch Version 3.5

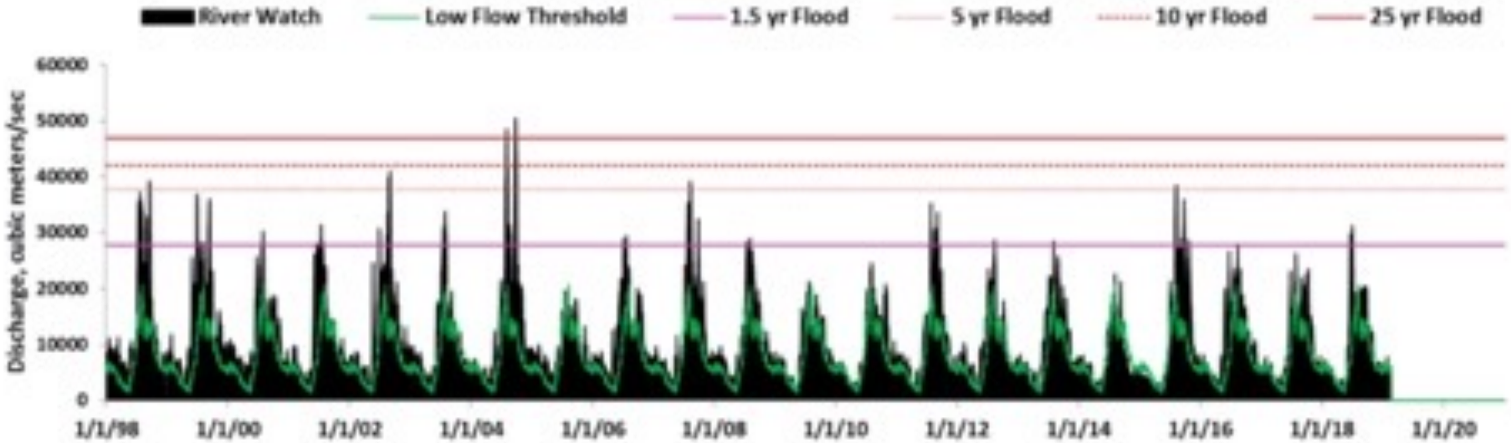
River Discharge and Reservoir Storage Changes Using Satellite Microwave Radiometry

			Irrawaddy	Center:	95.445	Long.	Signal/Model agreement: Very Good	S/N rating: Very Good
GFDS Site Number	30	Modis History	Myanmar	Center:	18.044	Lat.		
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		

*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*



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)

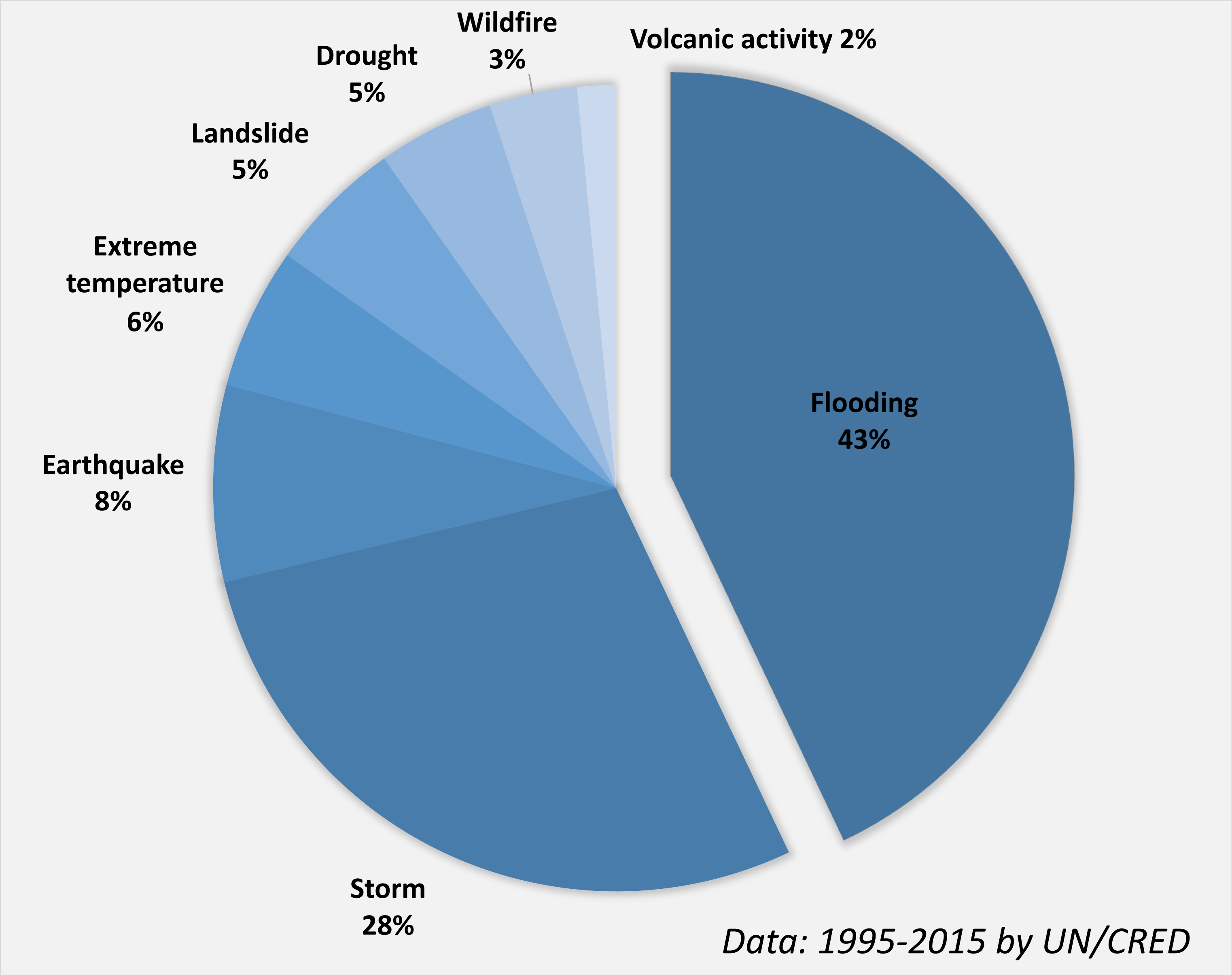
Takeaway message
Monitoring water discharge

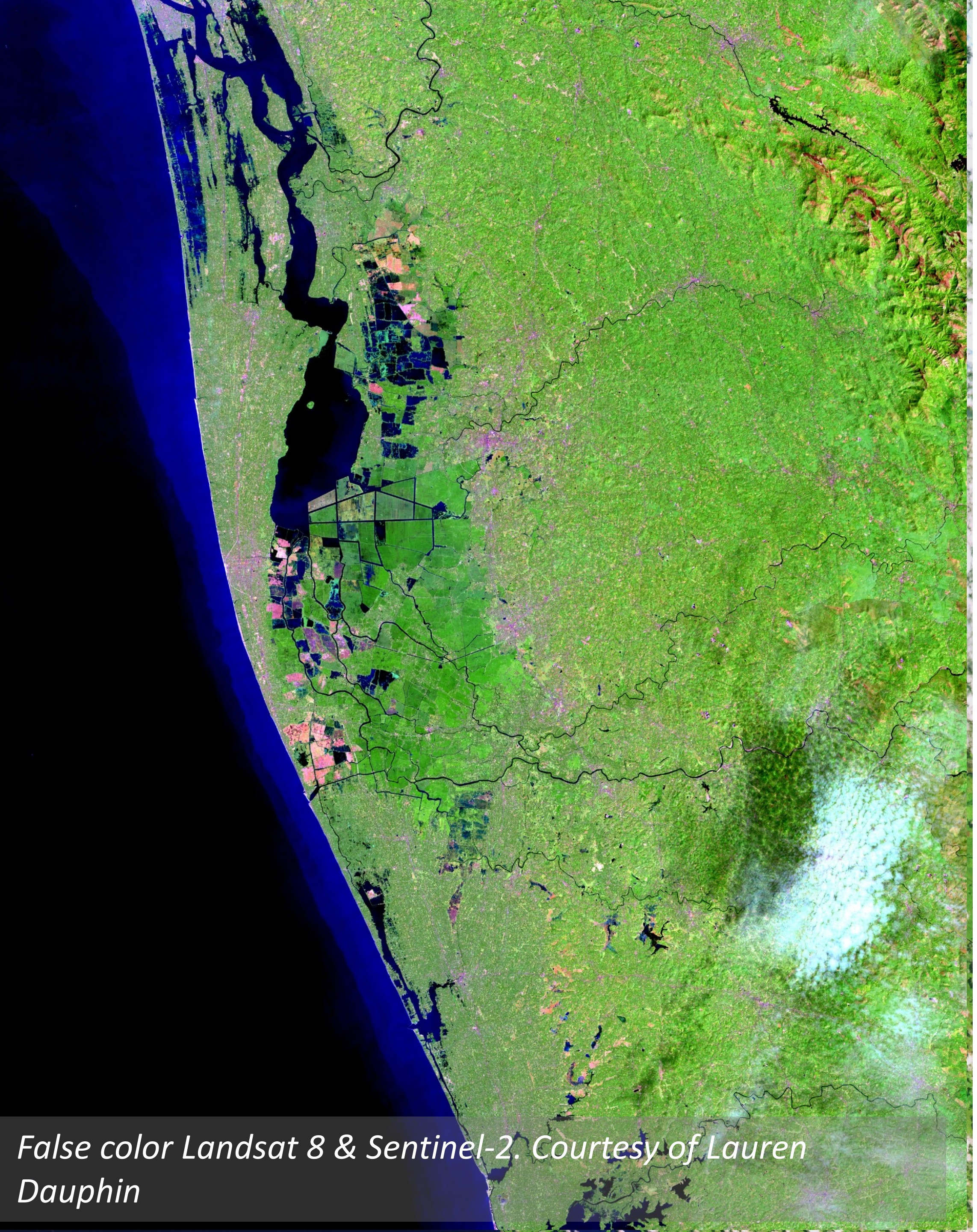
- One method to measure water discharge (not biased by using different measurement techniques)
- Long daily time series (1998, onwards)
- Not dependent on having to contact government departments to order data (not hampered by country boundaries)
- Being able to construct daily water discharges back to 1998

Utilizing remote sensing
Monitoring surface water extend

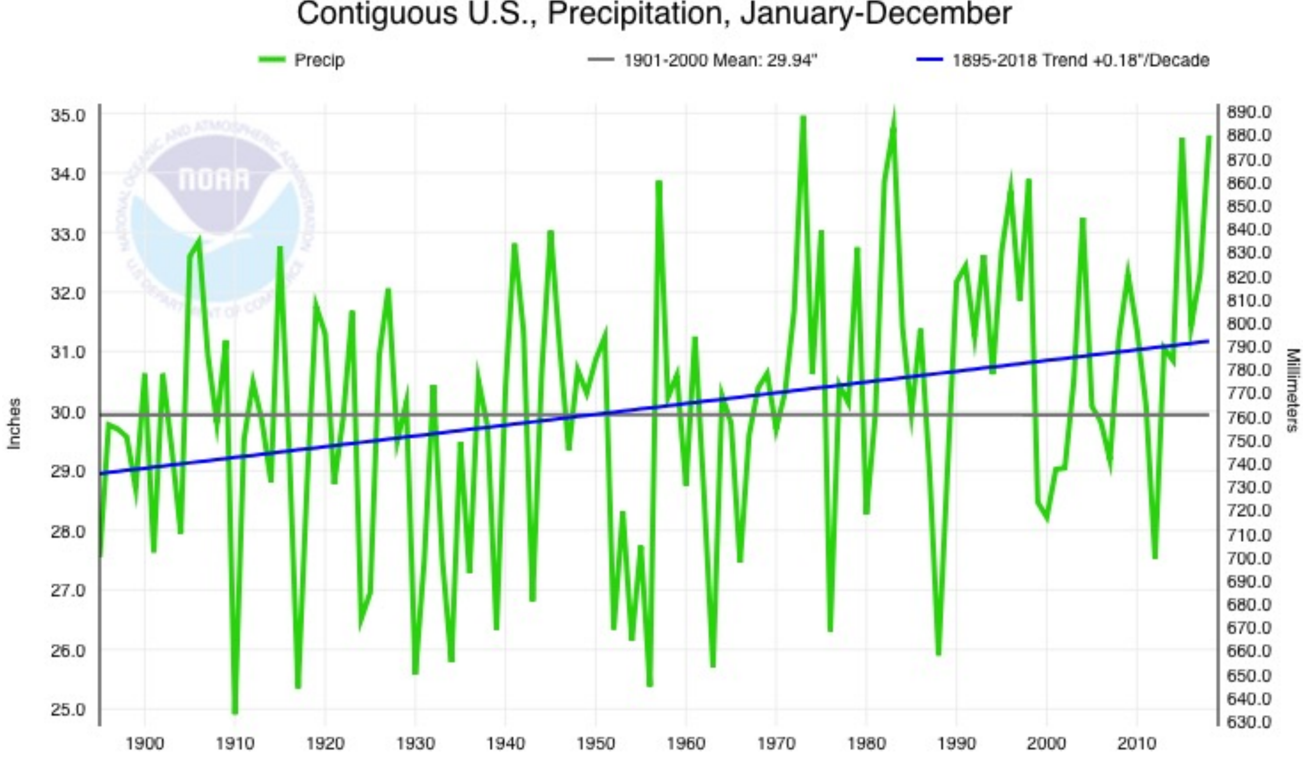
Natural disasters

- 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

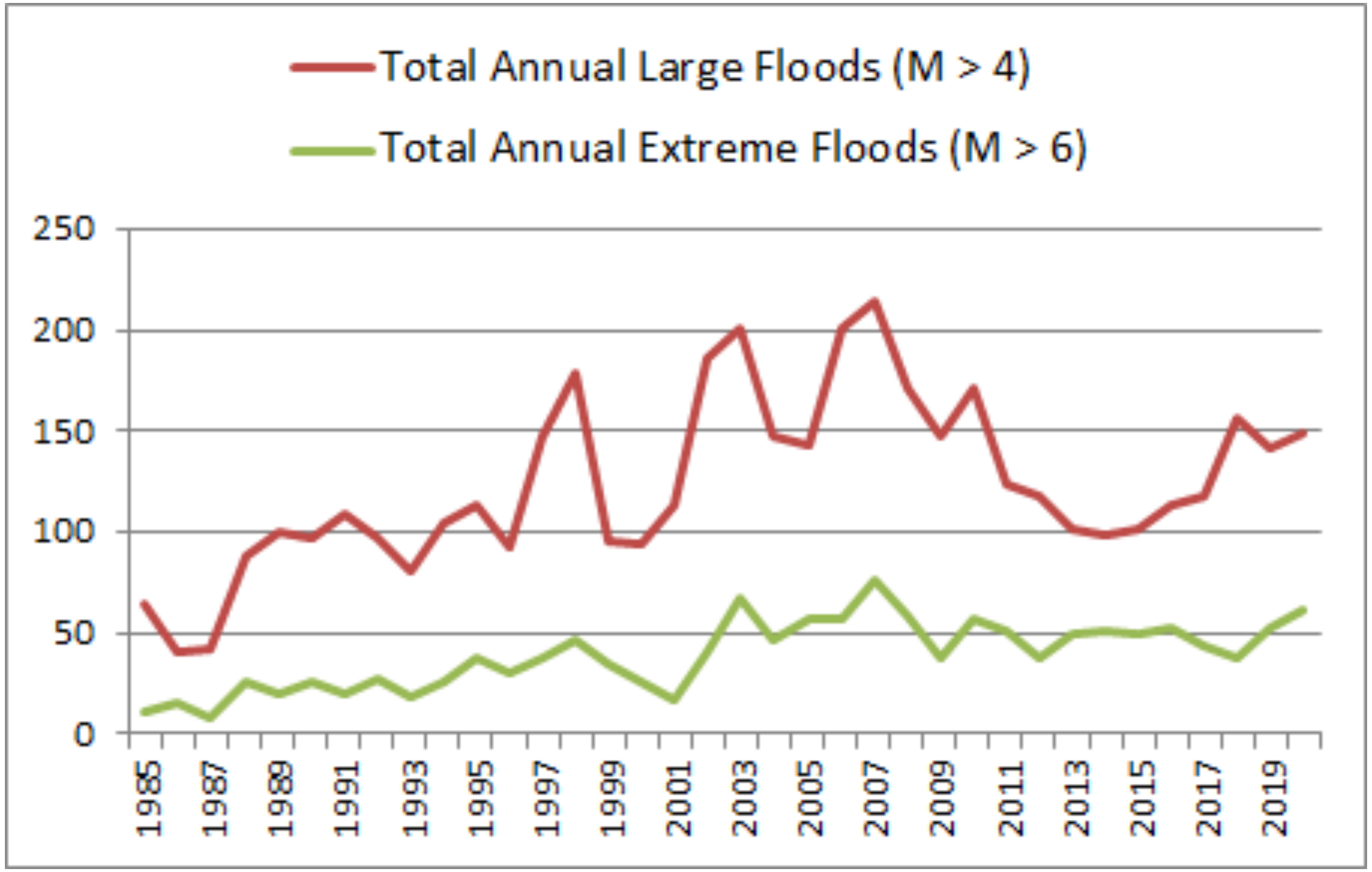
World Resources Institute

By 2050 *for Europe*

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

European Environment Agency

On a global scale:
increase in major flood events (M>6)

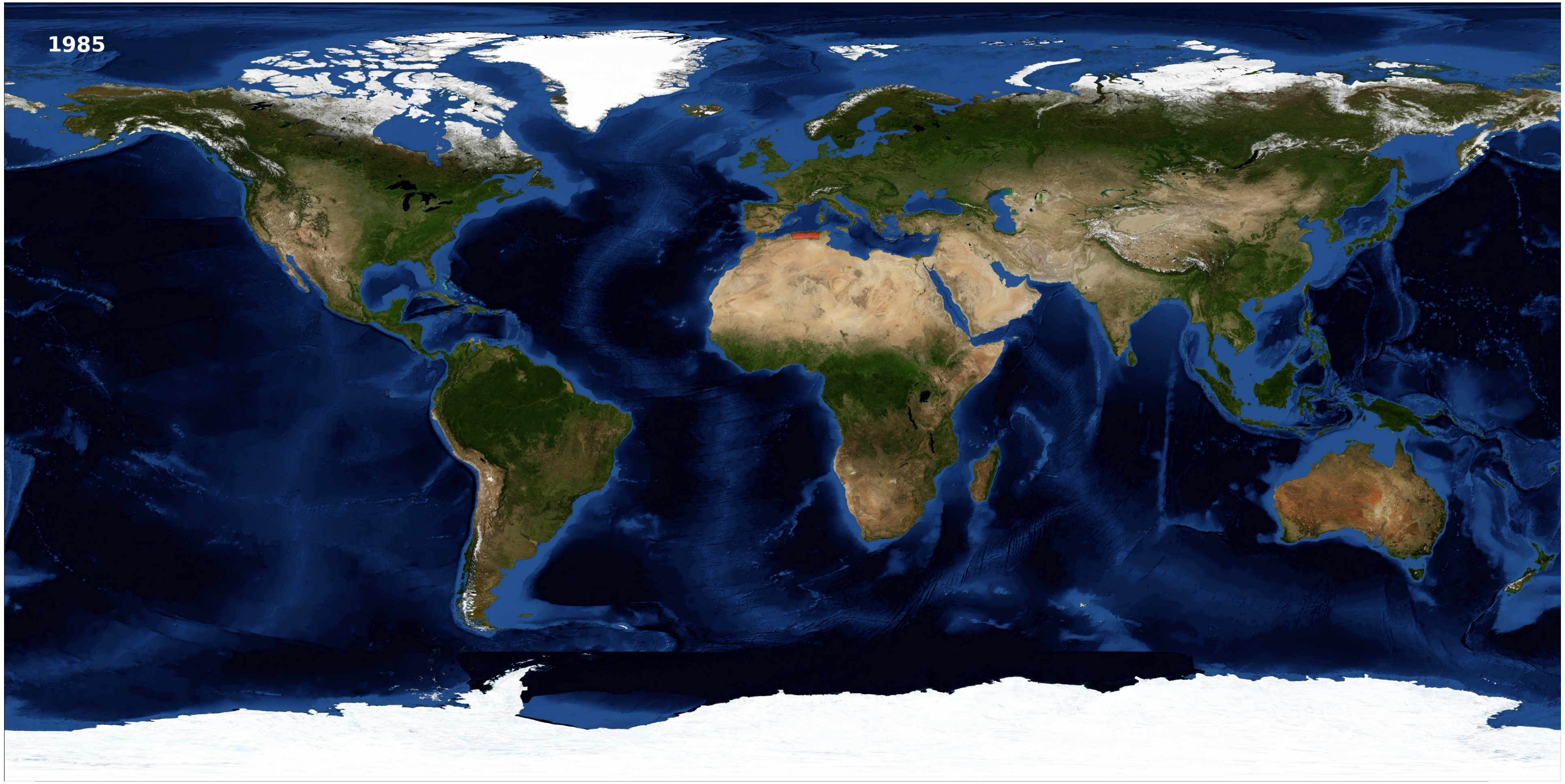


Flood Severity Class (1-2)

- **Class 1:** large flood events: significant damage to structures or agriculture; fatalities; and/or 1-2 decades-long reported interval since the last similar event.
- **Class 1.5:** very large events: with a greater than 2 decades but less than 100 year estimated recurrence interval, and/or a local recurrence interval of at 1-2 decades and affecting a large geographic region (> 5000 sq. km).
- **Class 2:** Extreme events: with an estimated recurrence interval greater than 100 years and affecting a large geographic region (> 5000 sq. km).

Magnitude (M) - ***Flood Magnitude =LOG(Duration x Severity x Affected Area)***

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	

Establishing a flood archive

Many years of flood map data can help:

- better understanding geomorphological processes (changes in: channel activity, sinuosity, Pra-Pra-Pra)
- improving flood resilience, making people aware that they live in a flood prone area
- determine flood engineering solutions: cities / towns can build flood protection
- flood risk management: regulate (reduce) development in flood prone areas

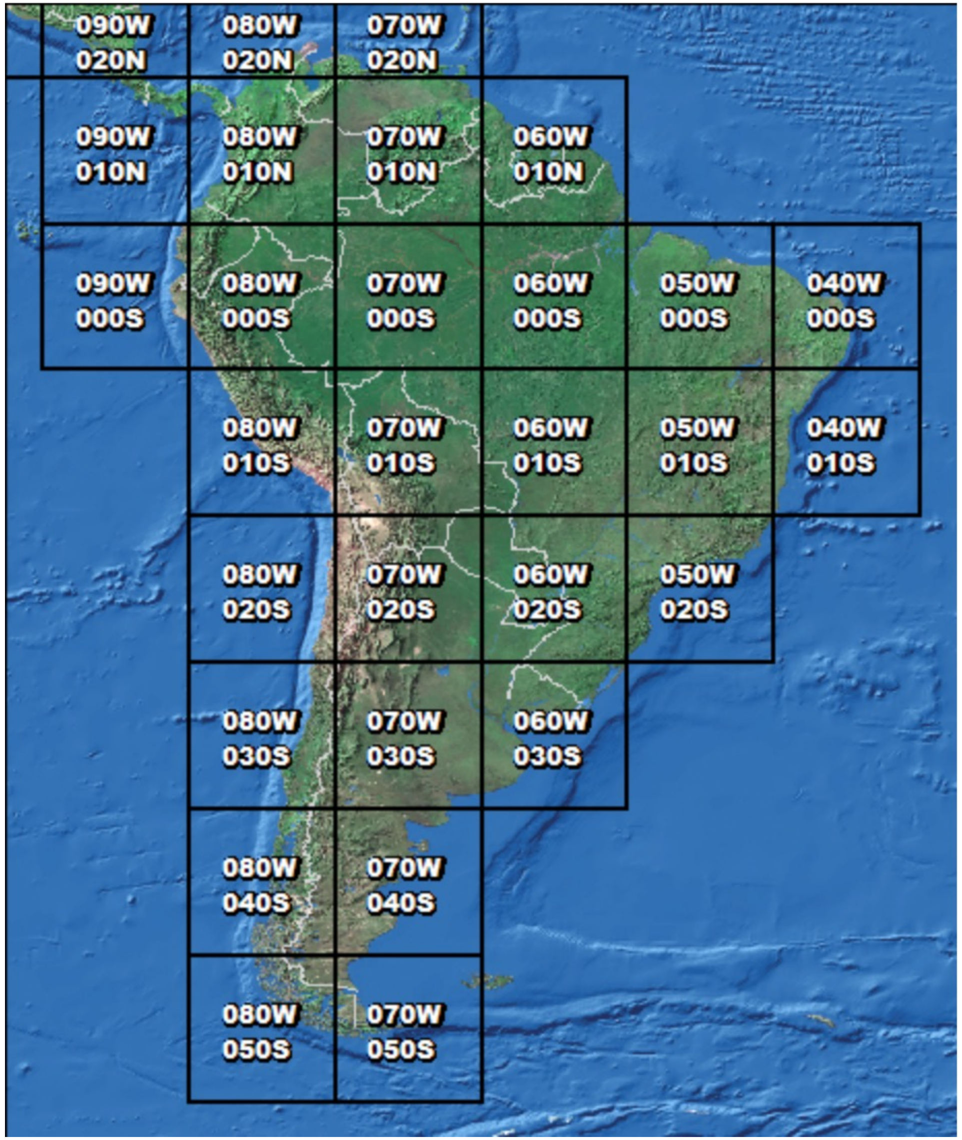
Flood protection along the Rhine River, Germany

Water extent detection methods

Automated: daily, global

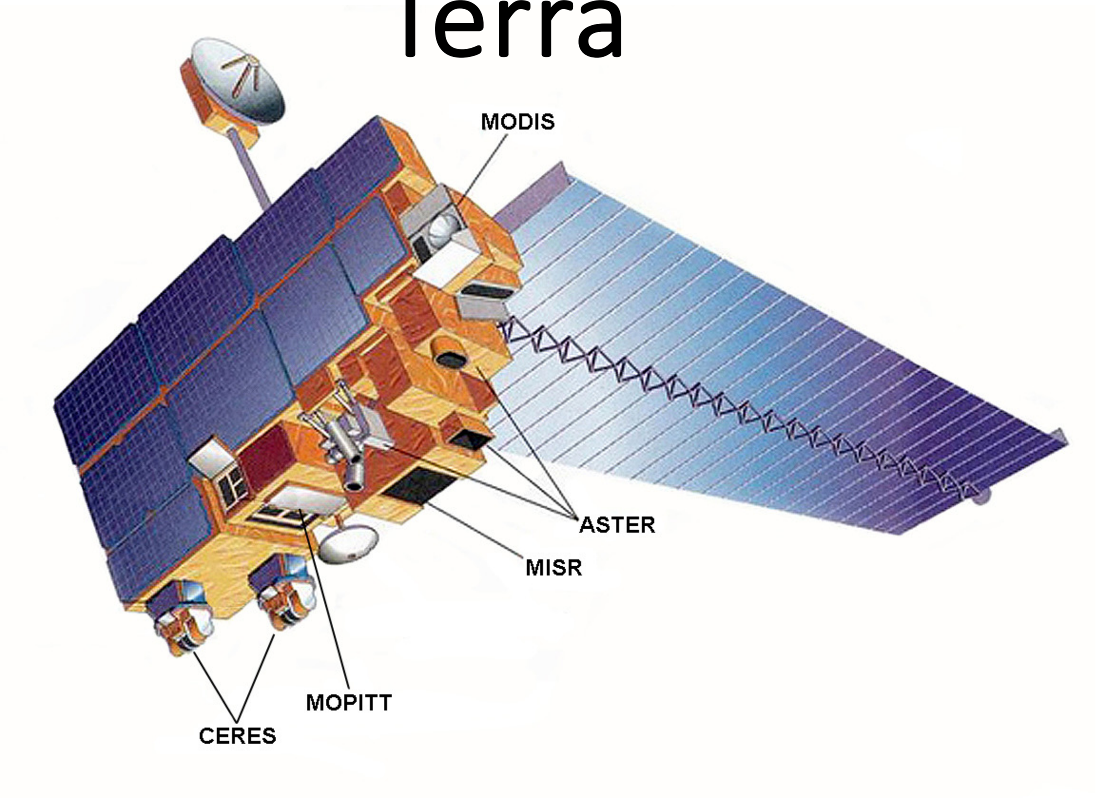
- Water mapping using NASA's MODIS sensor on satellites Aqua and Terra
- Optical bands are used to classify water, applying a ratio (Band2 + A) / (Band1 + B) and a threshold on Band7

  [band1 = visible; band 2 = Near infrared; band7 = short-wave infrared or SWIR]
- Collaboration with NASA Goddard Spaceflight Center to automate this to deliver Near-Real-Time water extents (from 2011 ->)

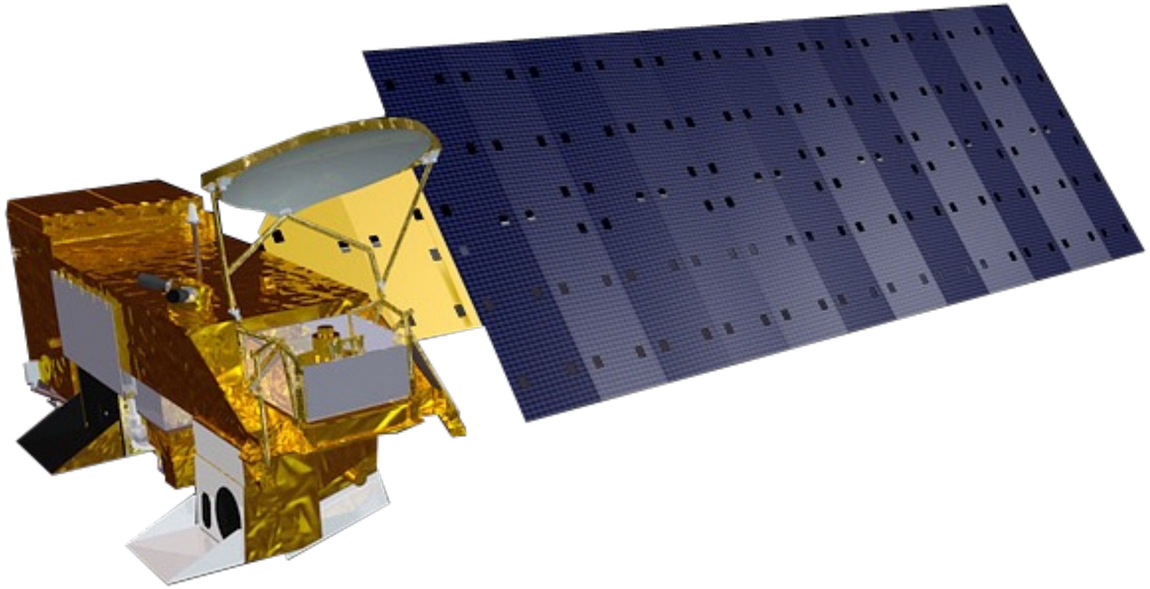


https://worldview.earthdata.nasa.gov

Terra



Aqua



	Terra	Aqua
Launch date	December 18, 1999	May 4, 2002
Mission duration	6 years (lasting over 23 years)	6 years (lasting over 21 years)
Dimensions	3.5m x 3.5m x 6.8m	4.8m x 8.0m x 16.7m
Orbit	Pole orbiting, 16 times a day, crossing equator at 10:30am	Pole orbiting, 16 times a day, crossing equator at 1:30pm (south to north)

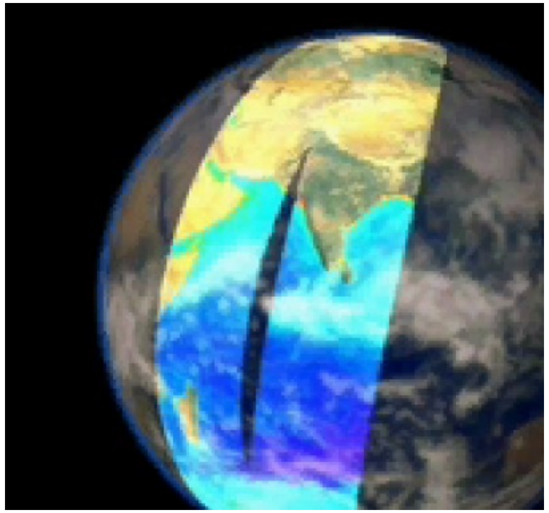
Terra

- Pole orbit
- Circles 16 times a day the earth
- Near global coverage

Using MODIS satellite data

Advantage of MODIS satellite derived data

a) Daily, near global coverage with 2 images
b) High resolution (250m)
c) Consistent use of methods globally
d) Over 2 decades of imagery -> long history of flooding



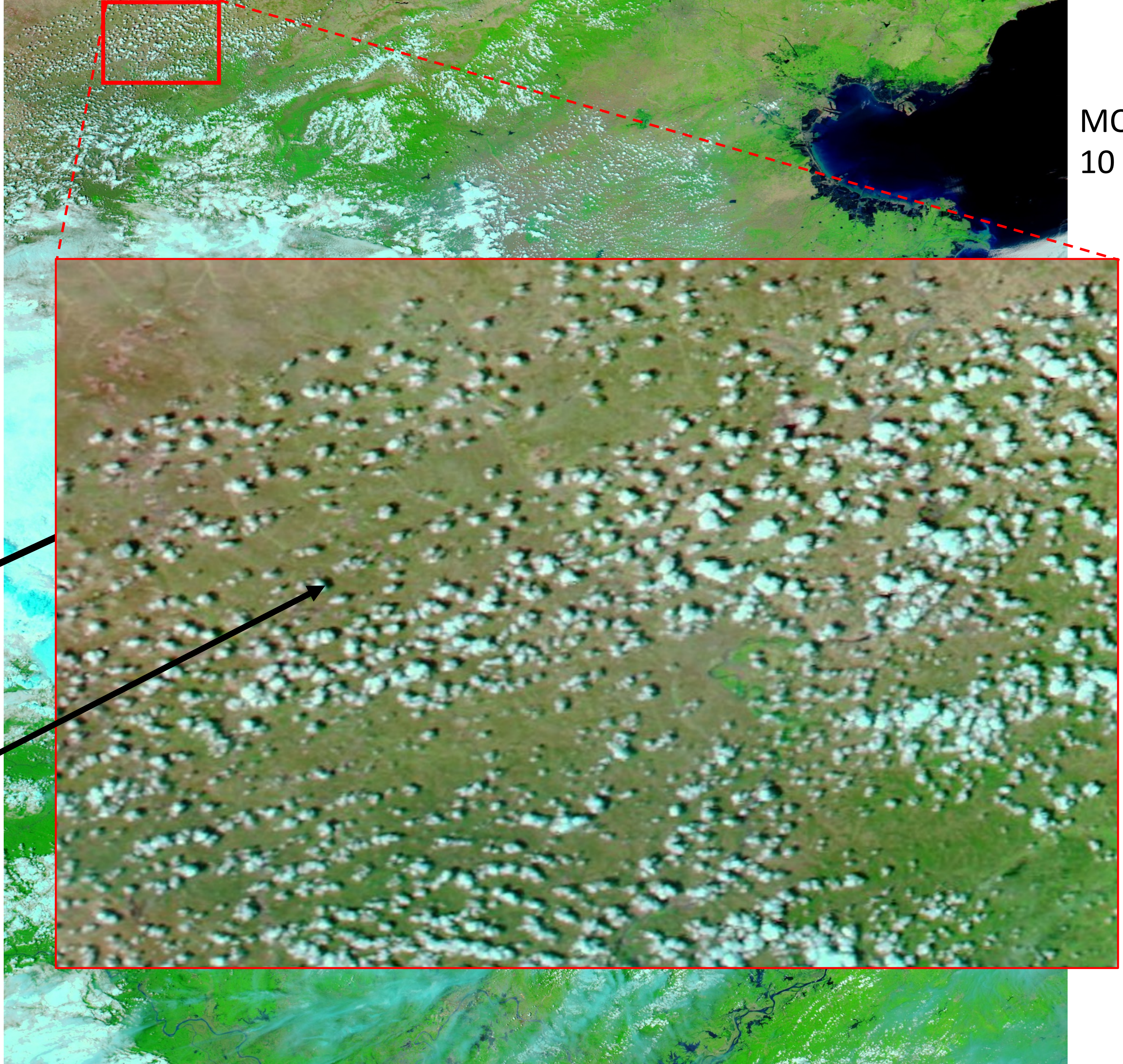
Disadvantage (when using visual bands)

a) …..

…..

Disadvantage

MODIS (1,2,7)
10 x 10 degree 'tile'

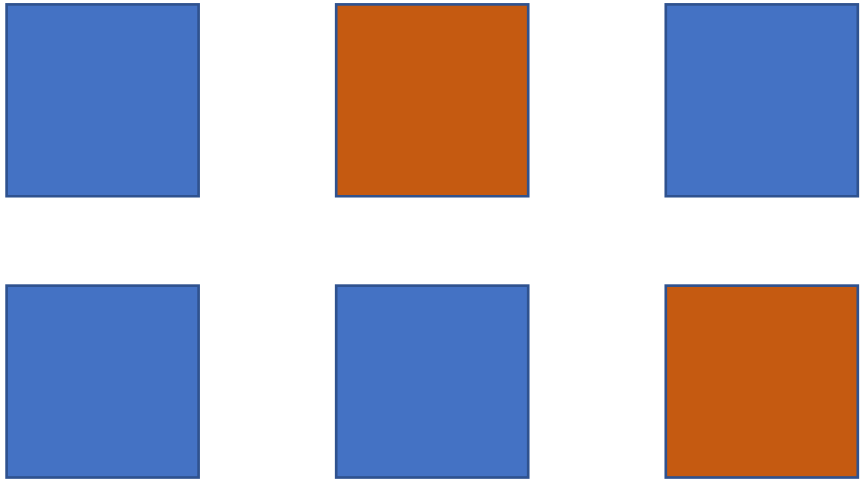


To overcome cloud shadows

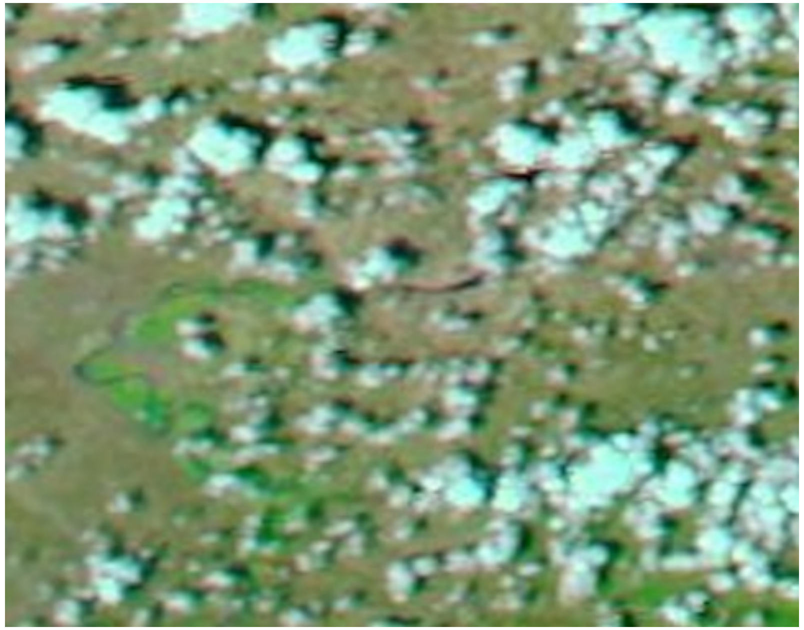
Day 1 **Day 2** **Day 3**

Terra

Aqua



3-day composite
pixel = water when detected 4 times



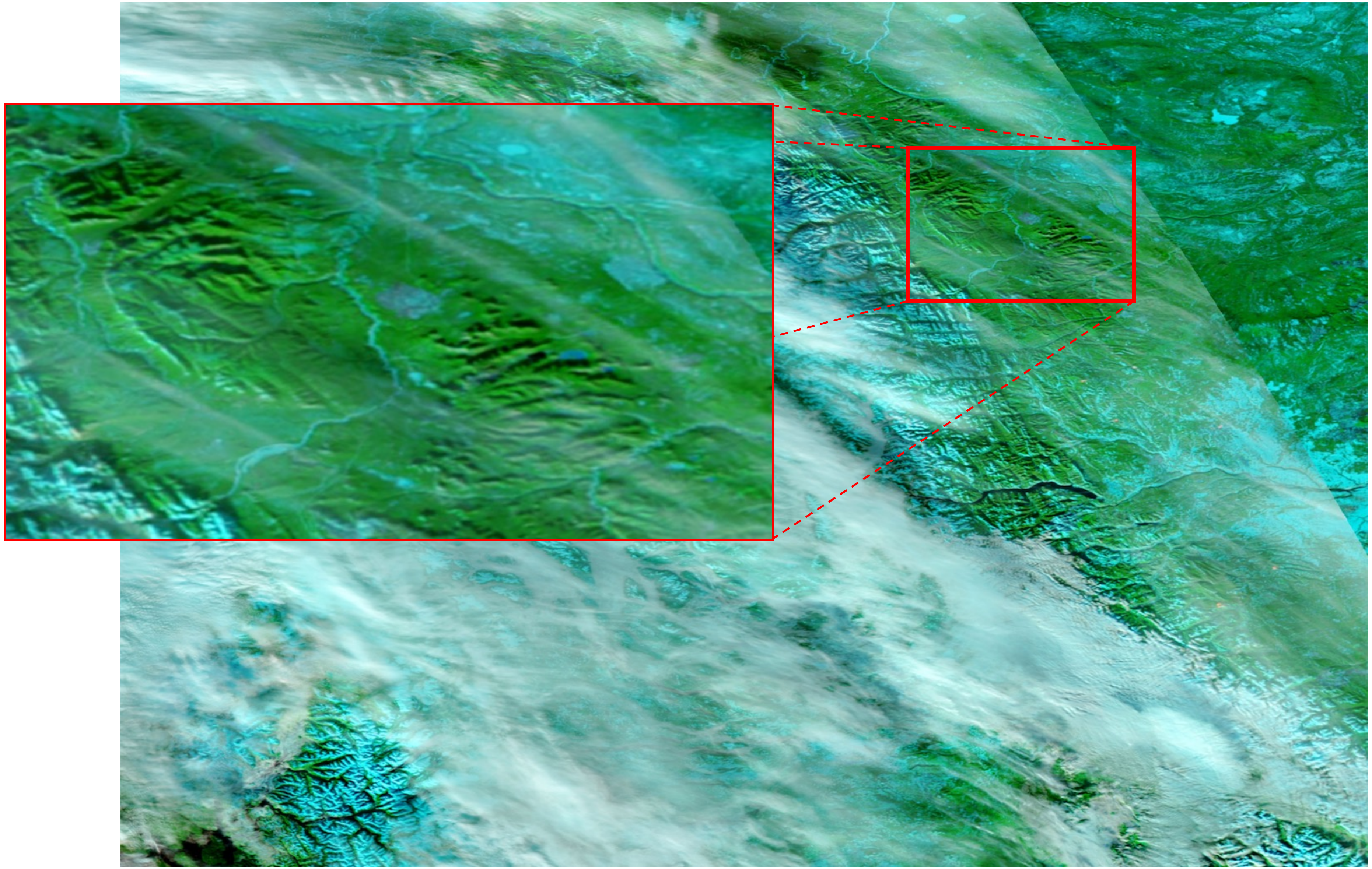
So day product = 3-day composite

Disadvantage (II)

Northern Rocky mountains, North America
17 December 2018

Mountain shadows
- Mountains
- Low sun angle

Mountains at higher latitudes, during winter



Using satellite data

Advantage of (some) satellite derived data:

a) Daily, near global coverage
b) Consistent use of methods globally

Over 2 decades of water related products

Disadvantage (when using visual bands):

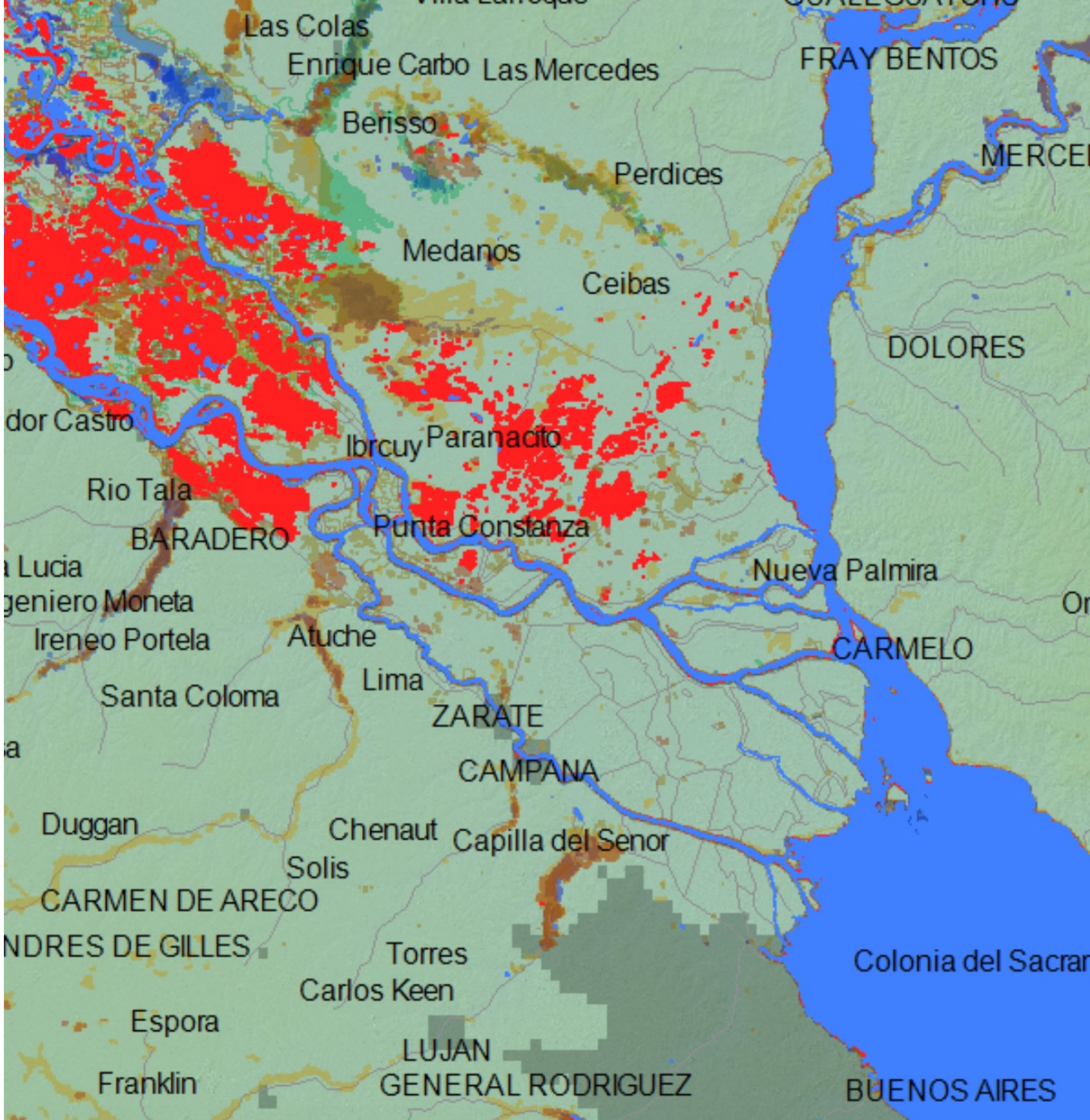
a) Obstruction of view due to clouds
b) false positives due to cloud shadow
c) Mountain shadows

Daily water extent

Red layer

Water detected over last 3 days (at least 4 out of 6 images detect water for a grid cell).

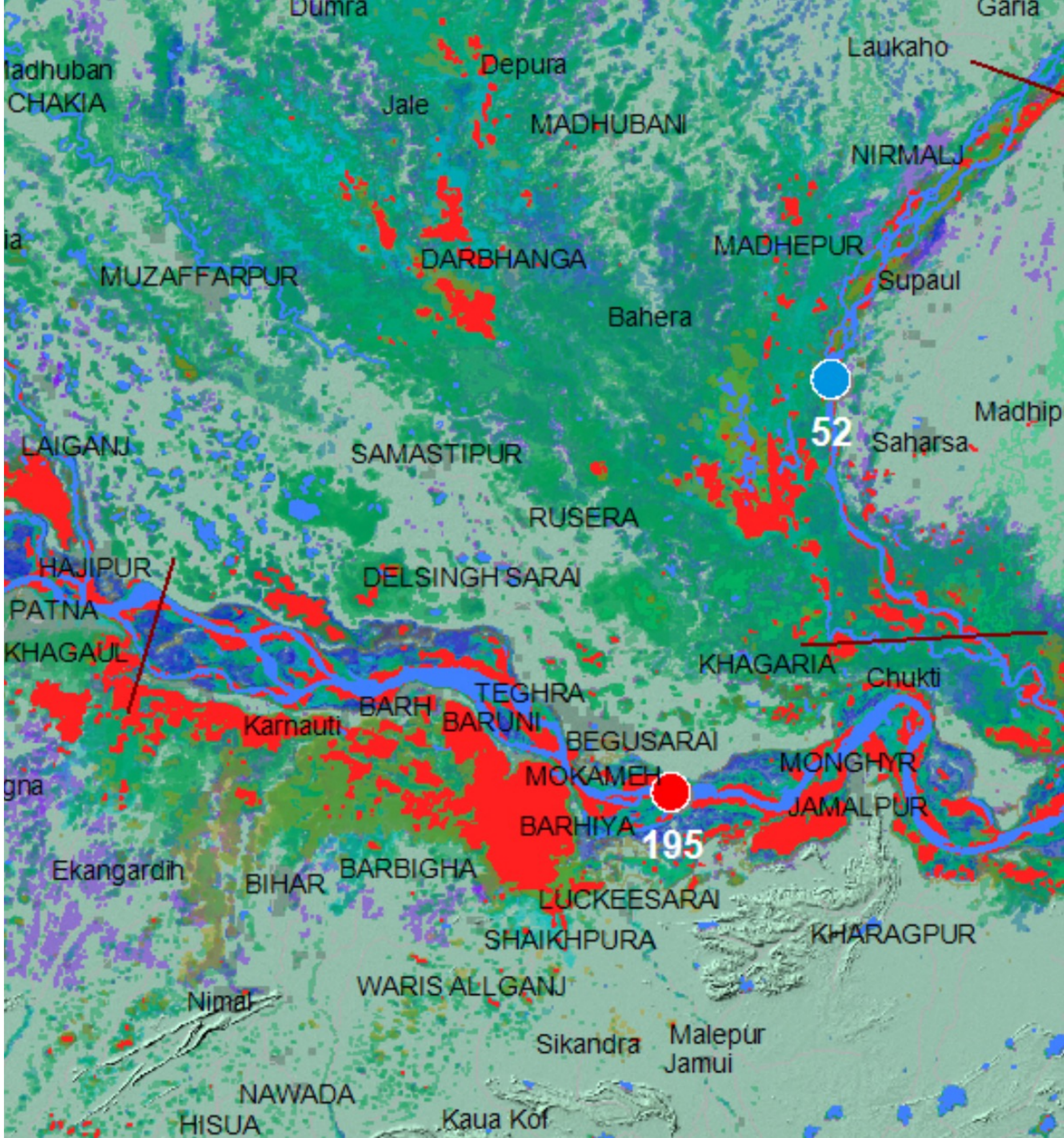
Parana River, Argentina



Annual accumulated water extent

2017
2016
2015
2014
2013
2012
2011
2010
2009
2008
2007
2006
2005
2004
2003
2002
2001
2000
pre-2000

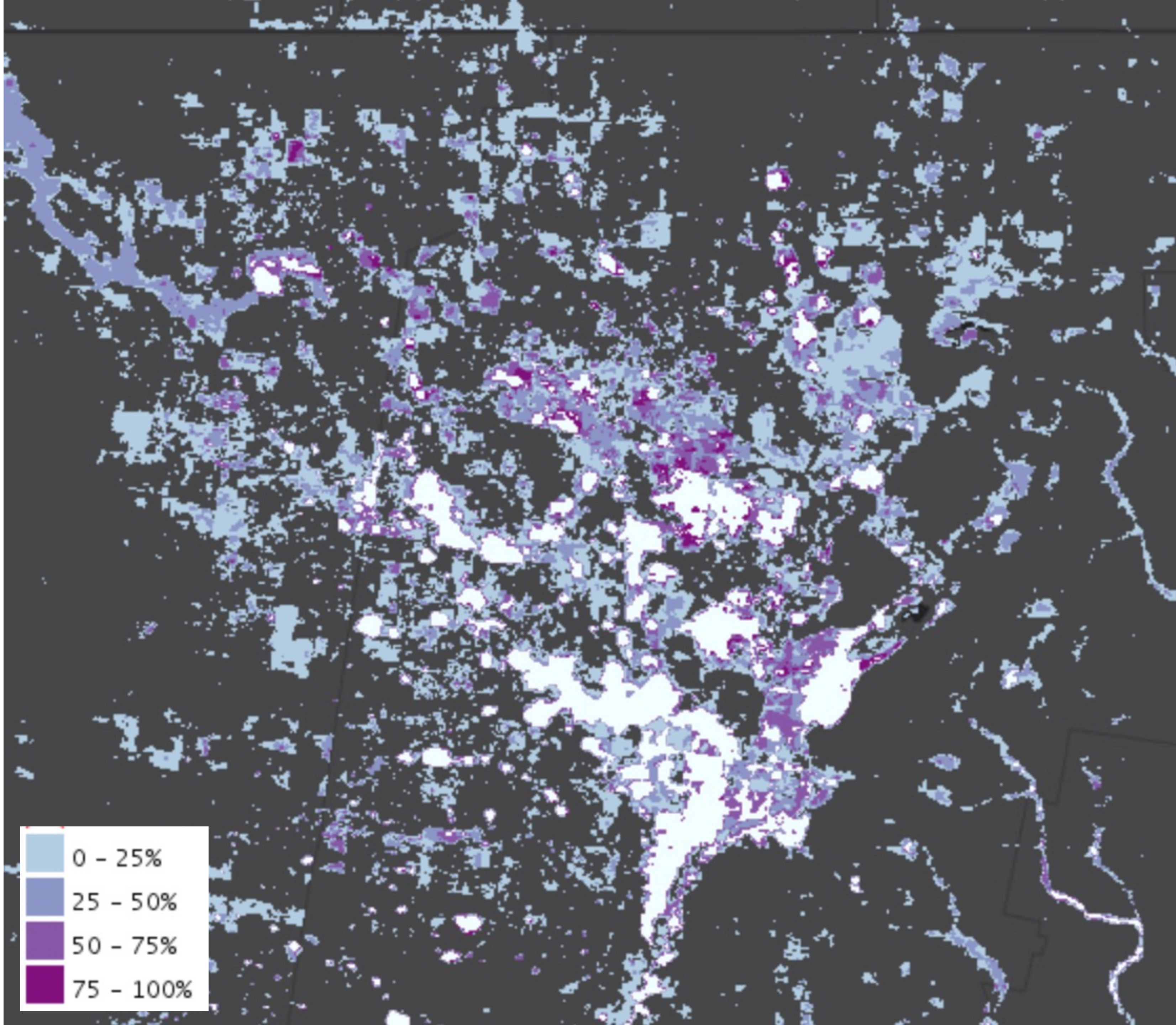
Water detected per year (accumulated per year).



Ganges, Bangladesh

“Flood heat map”

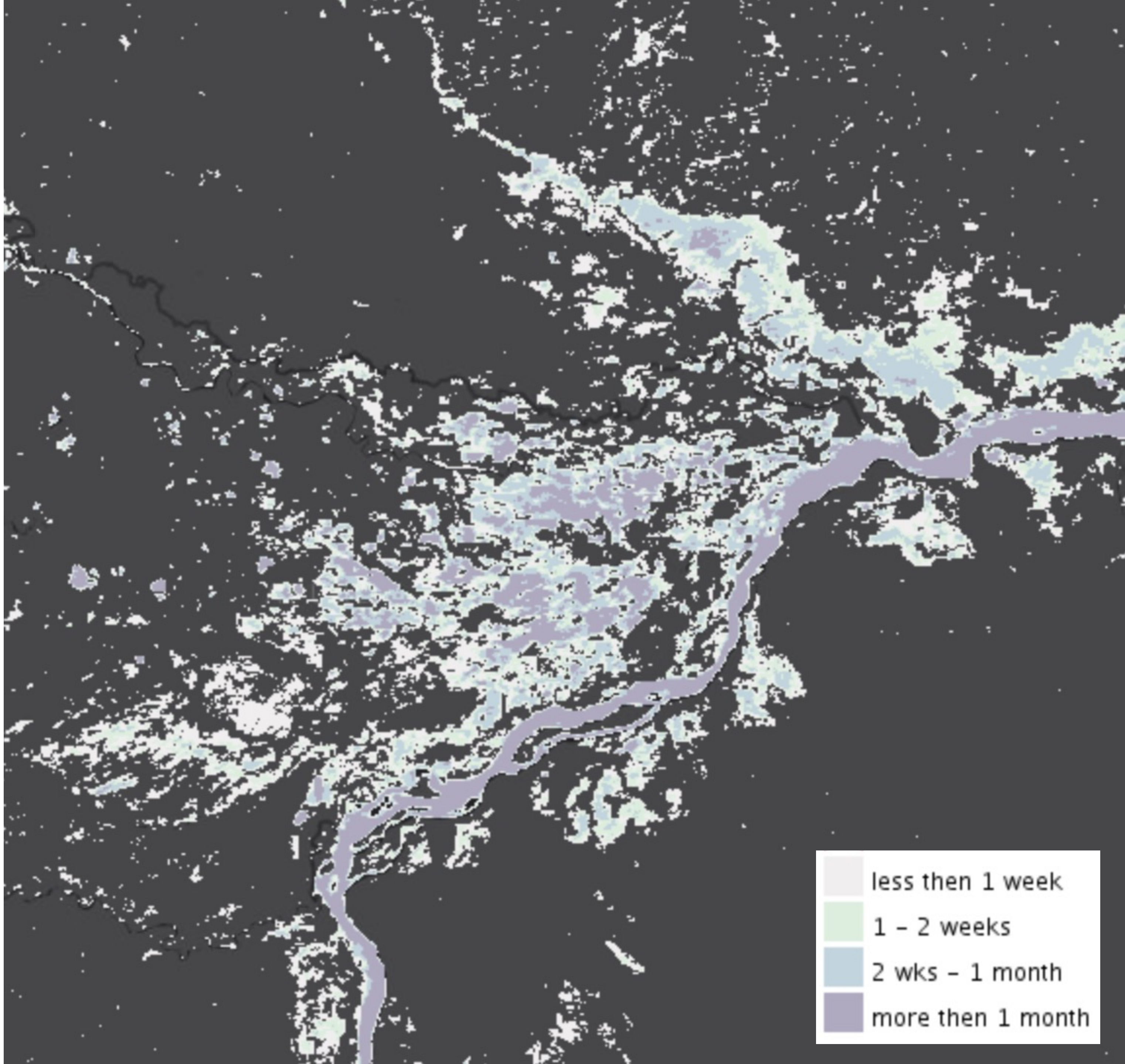
Frequency of how often an area is flooded on an annual base over a 5 year period (2013 – 2017).



Santa Fe region, Argentina

“Flood heat map”

Frequency of how often an area is flooded for a given year.



Rio Orinoco, Venezuela

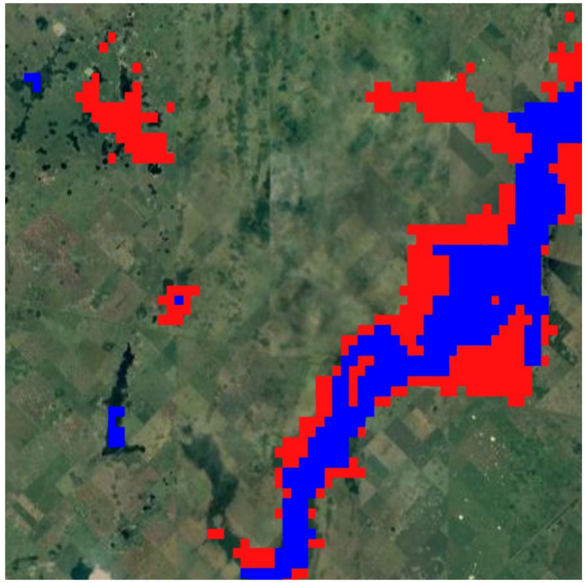
Information some Satellites used

Satellite	Algorithm	Resolution / return interval	Reference	Active since
(Terra / Aqua) MODIS	Dartmouth Flood Observatory (DFO) NIR/RED < T_1; RED < T_2 ; SWIR < T_3 T = Threshold determined by Otsu (1979) optimization	**250 m** Daily 2 images	Brakenridge and Anderson, 2006, Otsu, 1979	~2000 - >
Landsat	Automated Water Extraction Index (AWEI) AWEI = BLUE +2.5xGREEN – 1.5x(NIR+$SWIR_1$)-0.25x$SWIR_2$	**30 m** 16 days (8 days if combined with LS 7)	Feyisa et al., 2014	1984 -> (Different Landsat satellites)
Sentinel-1 (1a & b) Radar (SAR)!	DFO C-band Synthetic Aperture Radar	**10 m** 2-6 days location depended	Matgen et al., 2011	2014 ->
(Suomi NPP) VIIRS	DFO, more or less same as MODIS	**375 m** Daily 1 image	Brakenridge and Anderson, 2006	~2012 ->
Sentinel-2 (2a & b) (optical)	AWEI DFO	**10 m** 10 days (5 if combined 2a & b)	Feyisa et al., 2014 Brakenridge and Anderson, 2006	
Digital Globe satellites (WorldView 1, 2, 3 & 4) (GeoEye-1) (QuickBird)		**~30 – 50 cm** (Panchromatic) 1.7 (WV1) to daily (WV 3&4) but small areas		2007 (WV1) -> 2008 (GeoEye) -> 2010 (WV3) -> 2017 (WV4) -> 2001 (QB) - 2015

Various Sensors and Satellites

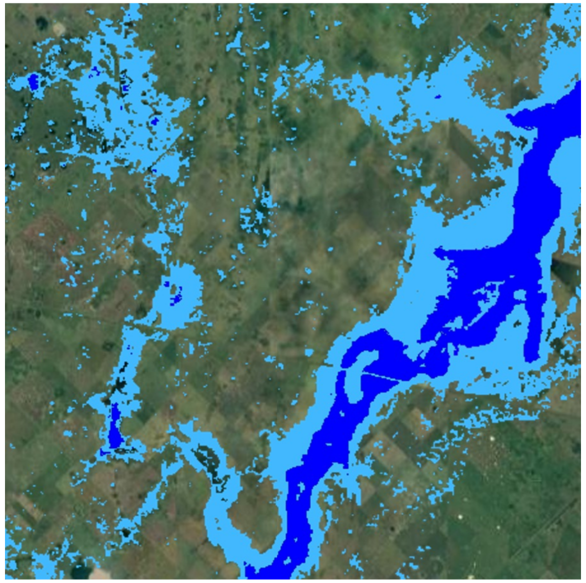
LOW, daily though! Resolution **HIGH**, infrequent though!

MODIS (Terra / Aqua)



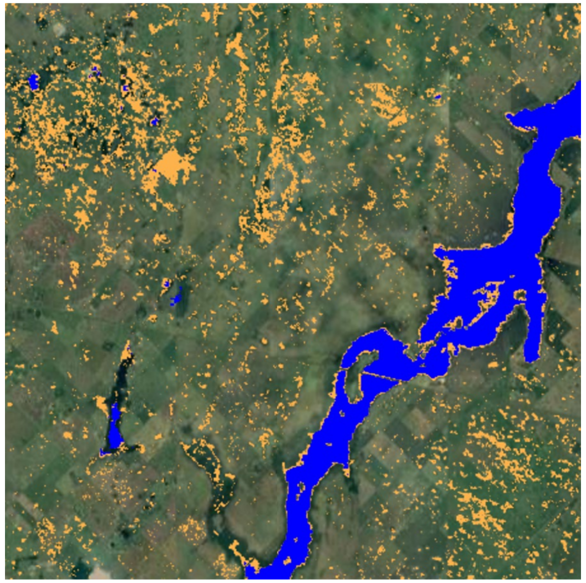
250m, 2 daily , 2000-present

Landsat



30m, 16 days, 1984-present

Sentinel 1a,b (SAR)



10m, 2-6 days, 2014-present

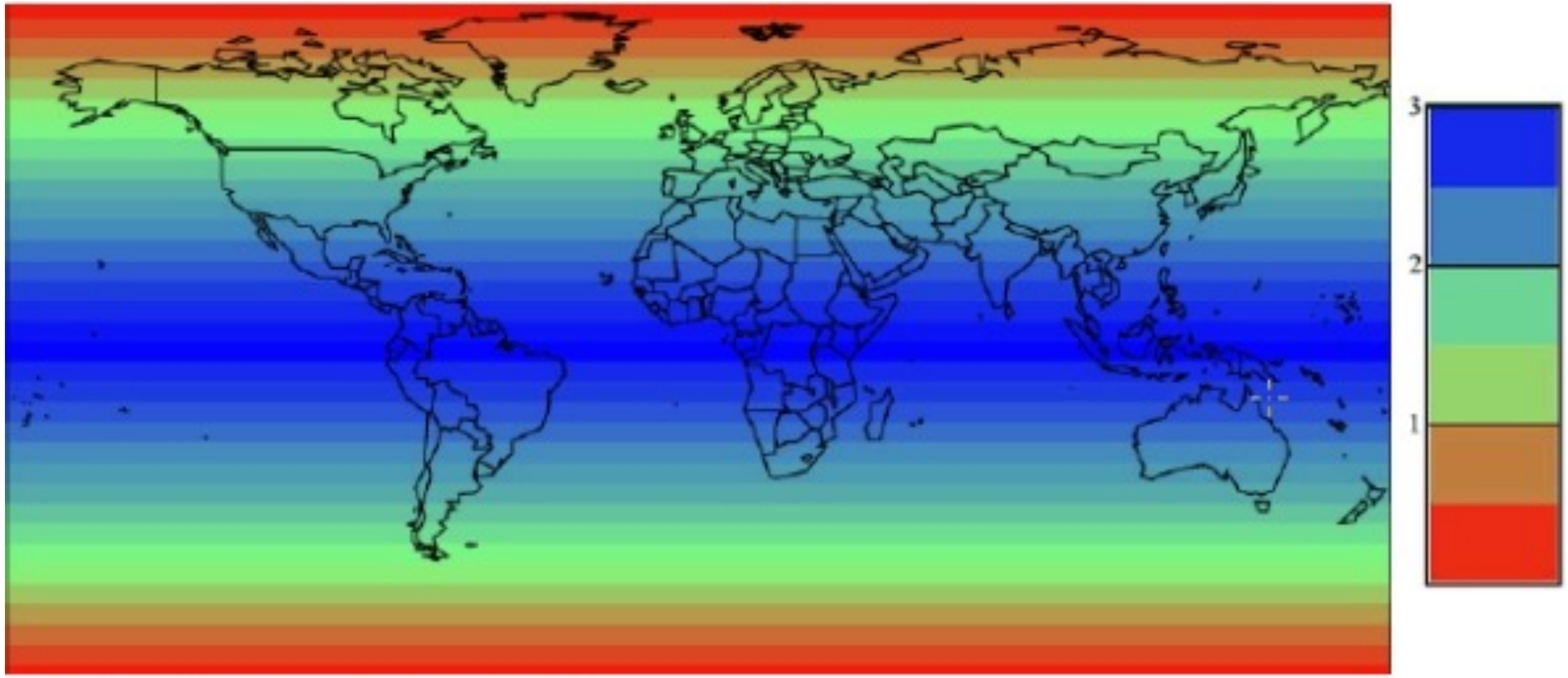
Permanent Water

Automated Sentinel 1a,b flood products

Satellite: Sentinel-1 is a space mission funded by the European Union. Executed by ESA within the Copernicus Program.
Launched: April 2014; April 2016
Resolution: ~10m.
Sensor: Synthetic-aperture radar (SAR).

Advantage: '*looks through clouds*'

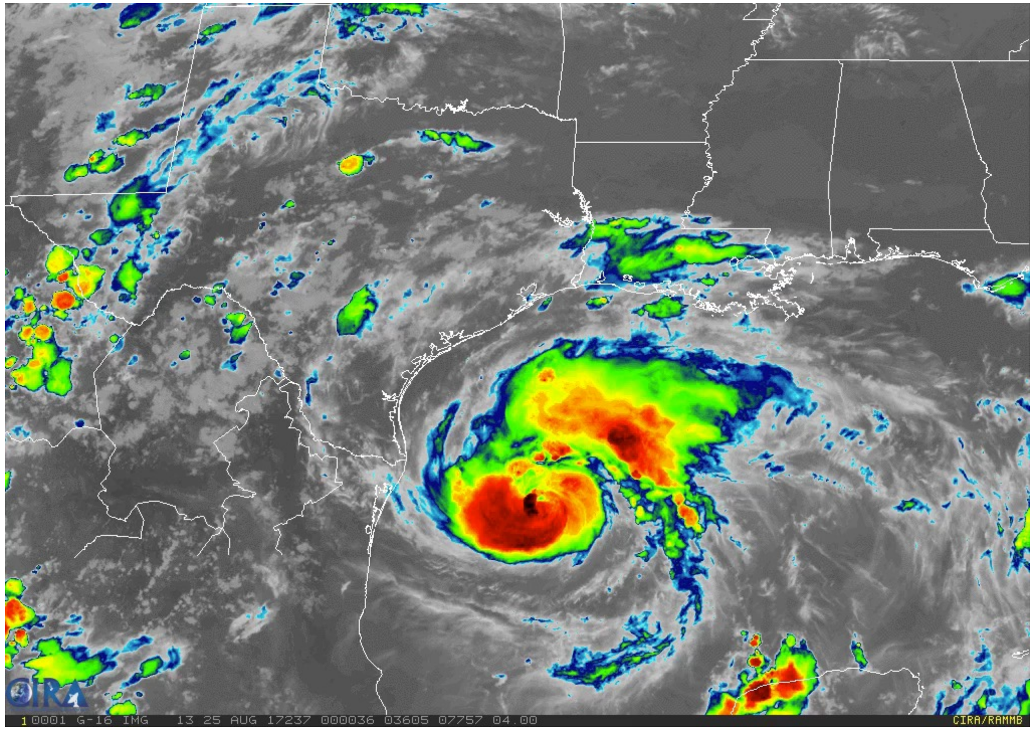
Revisit time of Sentinel 1a & 1b combined

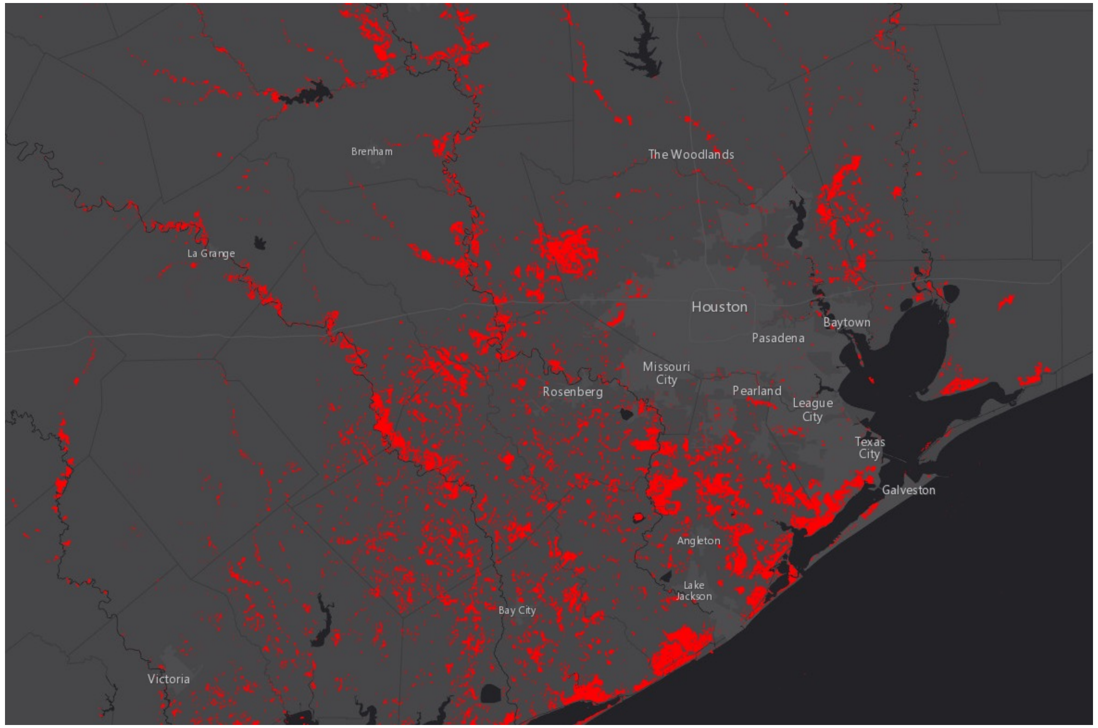


- ✓ Two satellites in a 12 day orbit
- ✓ Repeat frequency: 6 days (important for coherence)
- ✓ Revisit frequency: (asc/desc & overlap): 3 days at the equator, <1 day at high latitudes (Europe ~ 2 days)

High resolution flood mapping

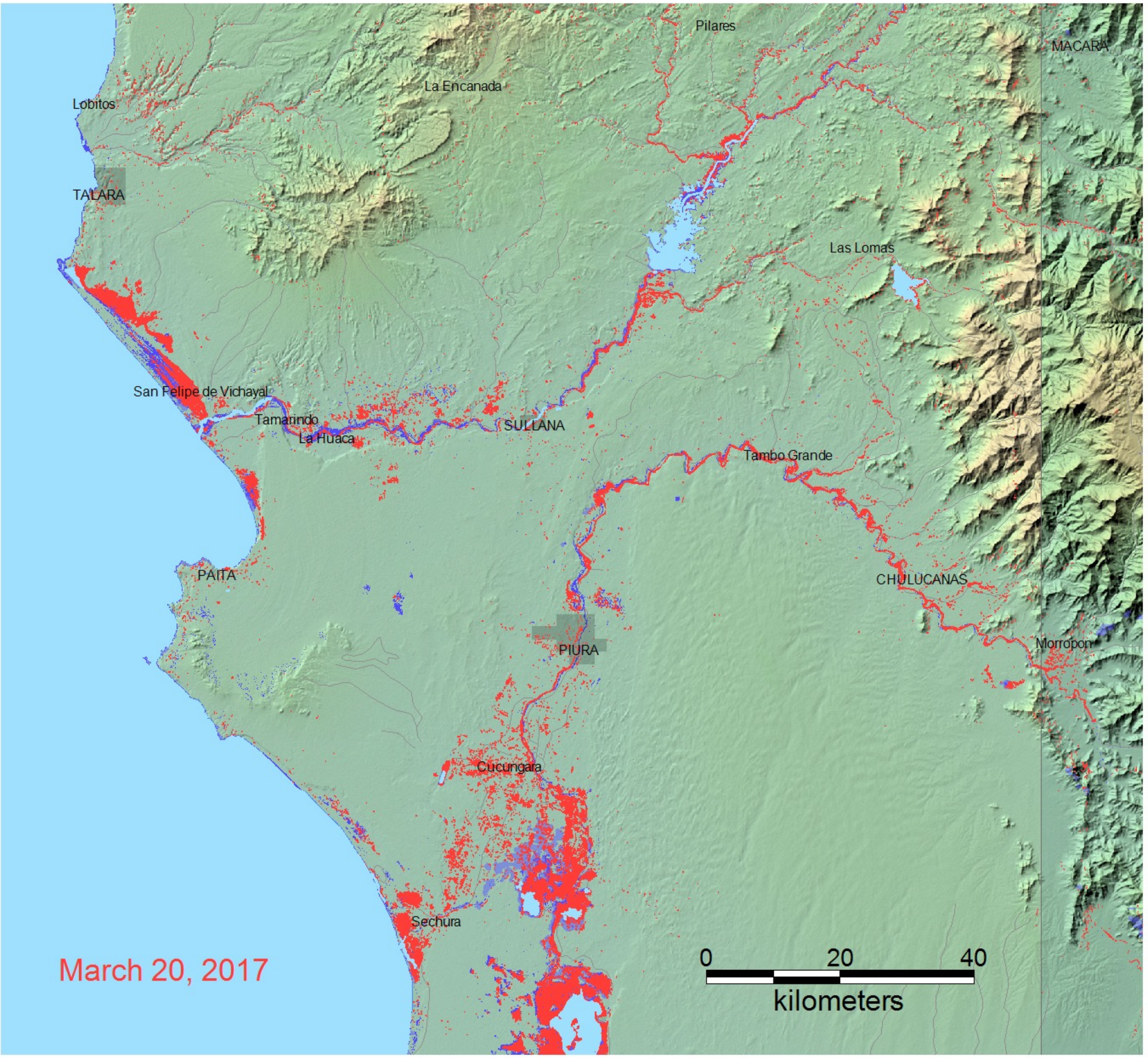
Hurricane Harvey (08/28/2017)





- Category 4 hurricane at landfall
- 4-day period, many areas received ~1m of rain
- Displaced ~30,000 people, 107 fatalities, ~$125 billion damage
- Flooding the greater Houston area

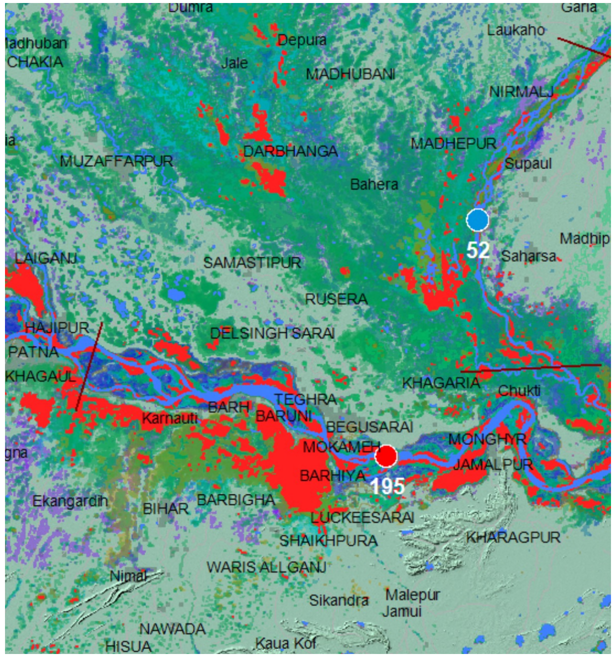
Peru Floods: 20 March 2017

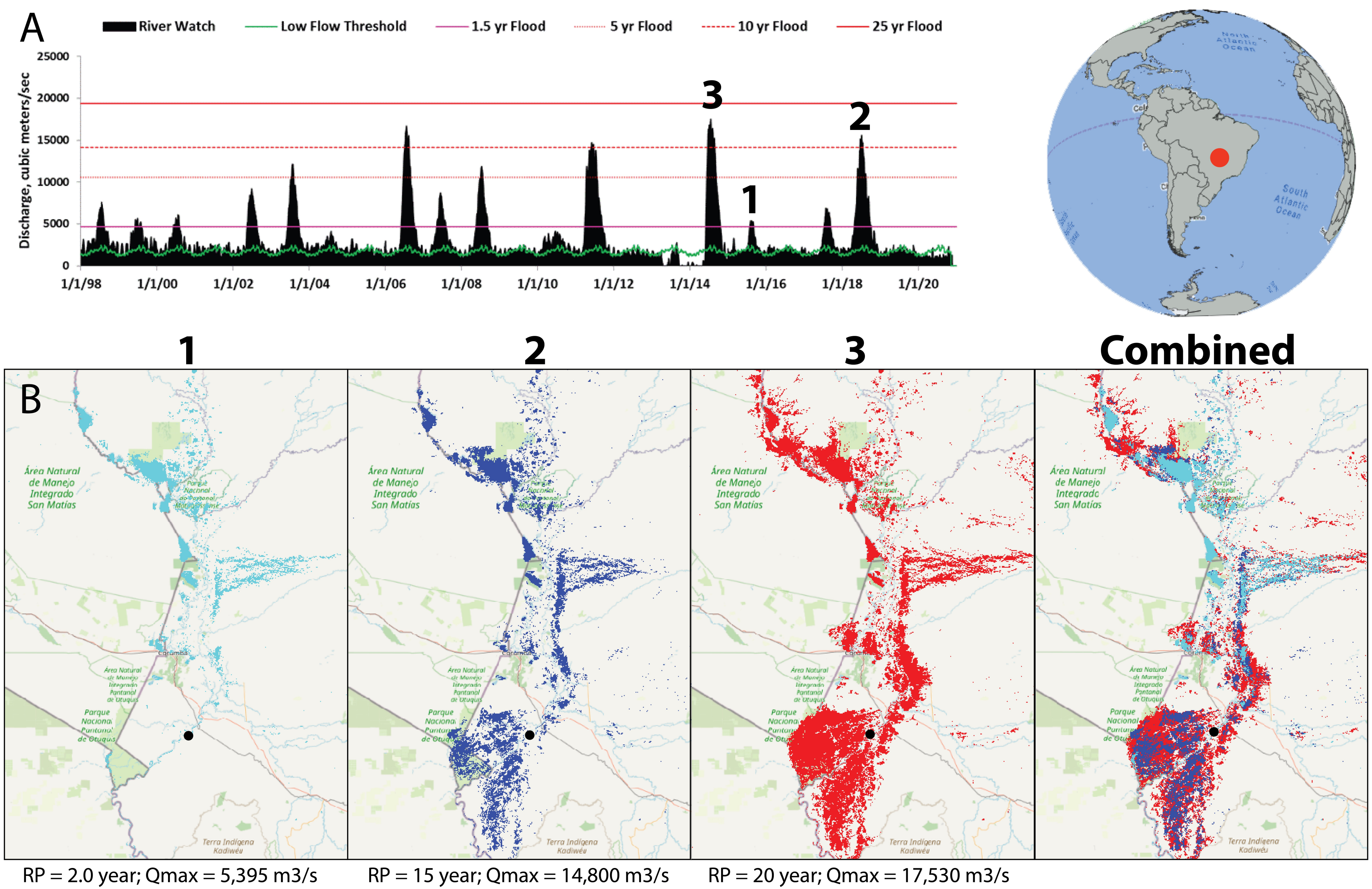


Estimate of flood extent based on SAR data from Sentinel-1A

Utilizing remote sensing

Analyzing flood frequency




A
River Watch
Low Flow Threshold
1.5 yr Flood
5 yr Flood
10 yr Flood
25 yr Flood
Discharge, cubic meters/sec
25000
20000
15000
10000
5000
0
1/1/98
1/1/00
1/1/02
1/1/04
1/1/06
1/1/08
1/1/10
1/1/12
1/1/14
1/1/16
1/1/18
1/1/20
3
2
1
North Atlantic Ocean
South Atlantic Ocean
1
2
3
Combined
B
Área Natural de Manejo Integrado San Matías
Parque Nacional Pantanal de Otuquis
Área Natural de Manejo Integrado Pantanal de Otuquis
Terra Indígena Kadiwéu
RP = 2.0 year; Qmax = 5,395 m3/s
RP = 15 year; Qmax = 14,800 m3/s
RP = 20 year; Qmax = 17,530 m3/s

Summary