HYDROSAR – WEATHER-RELATED HAZARD INFORMATION FROM SAR

Contributors:

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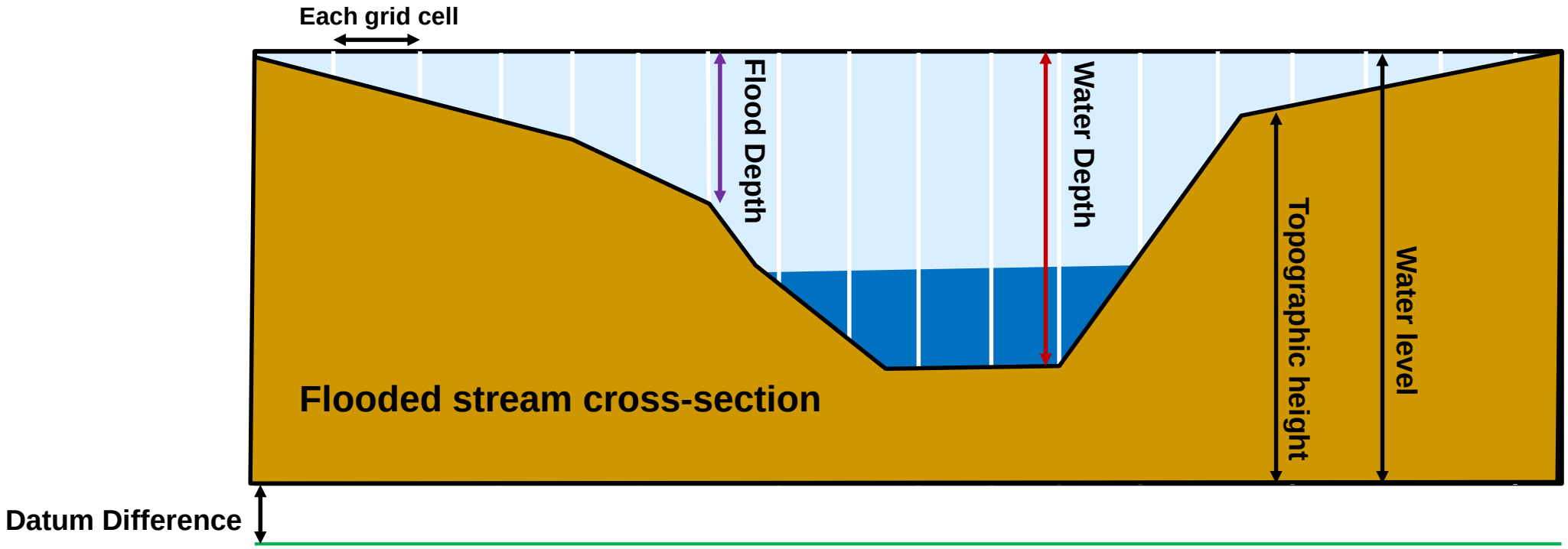
Lecture 5: Flood Depth Cal/Val results

Initiation of Flood Depth Cal/Val

- Water depth: The depth of water above highest adjacent terrain.
  - The ***'Flood_Depth_Estimation_with_Flood_Extent_Maps'*** program estimates water depth.
- Water level: The elevation of surface water including terrain height.
  - We need to check if the gauge data is water level or water depth for validation.
- Datum difference between measurements and validation data needs to be considered.

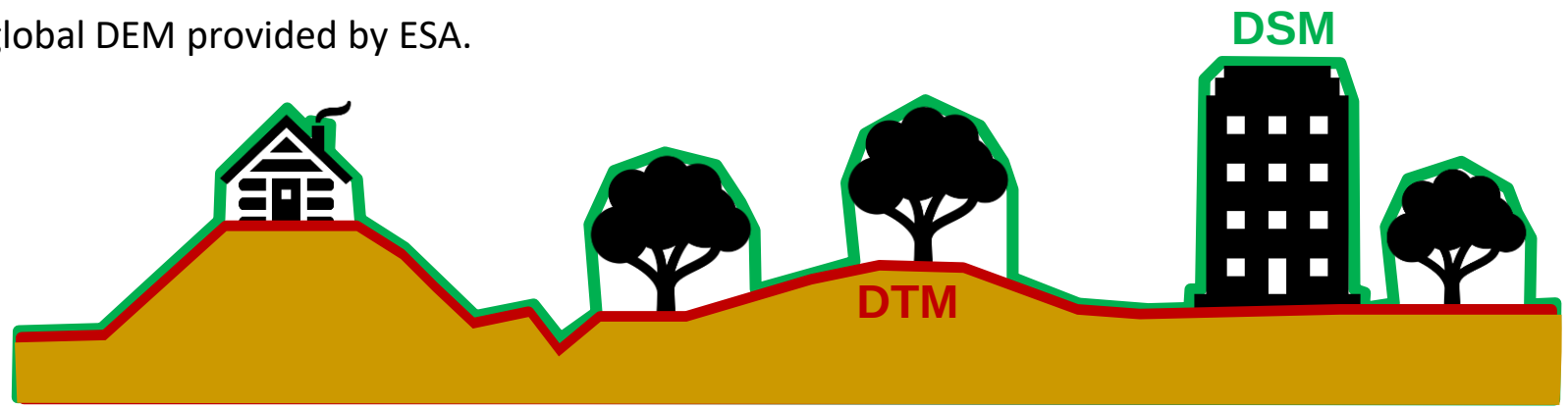


Digital Elevation Model (DEM)

What kind of DEM we should use for flood depth mapping?

- Importance of the use of appropriate DEM
  - Estimated flood depth can be different depending on the DEM we use.
  - Accuracy of DEM is one of the critical factors for flood depth mapping.
  - Digital Terrain Model (DTM) needs to be used.
  - DSM from stereo images can be inadequate to generate a water depth map.

- Different DEM sources
  - NASADEM (reprocessed SRTM) Global 1 arc second (30m) DEM
  - Copernicus DEM 30m - TanDEM-X global DEM provided by ESA.
  - Local DEMs (e.g. LIDAR)

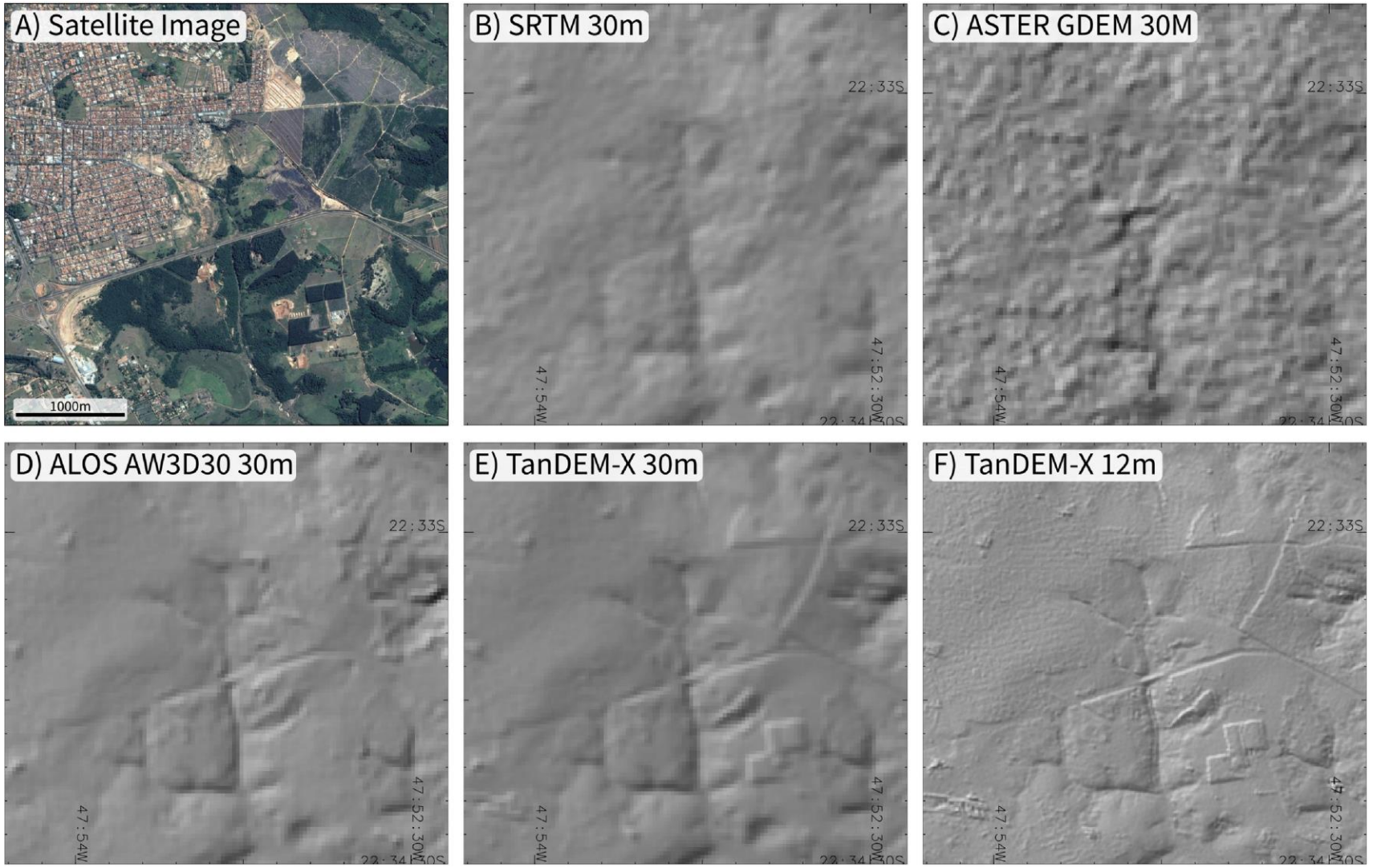


DEM Accuracy

What kind of DEM we should use for flood depth mapping?

- Spatial Resolution
- Resolution is not accuracy
- Imaging artifacts

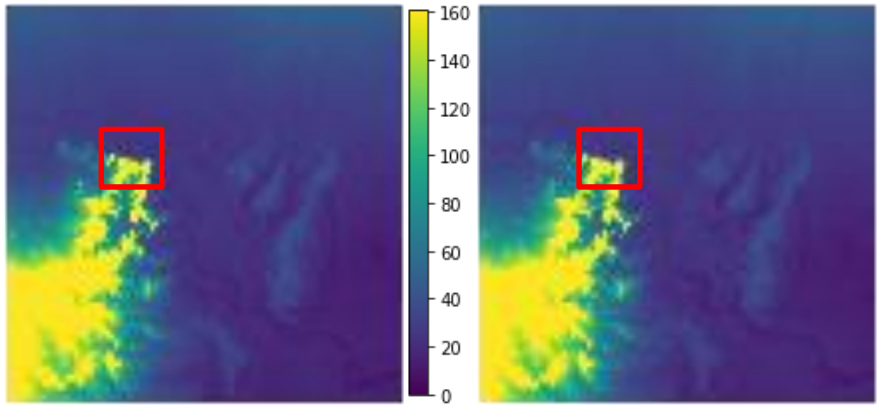
DEM	Vertical Accuracy (m)
SRTM 1 arcsec	9
ASTER GDEM	17
AW3D30	5
TanDEM-X	<10



Grohmann, C. H. (2018). *Remote Sensing of Environment.*

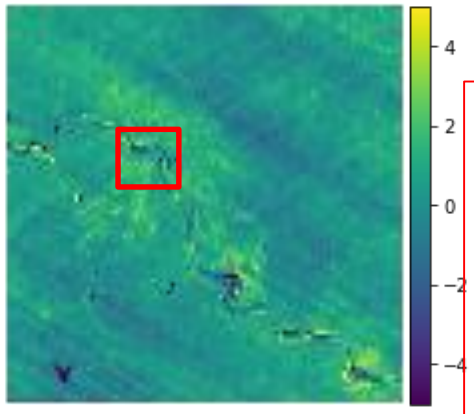
DEM Accuracy

What kind of DEM we should use for flood depth mapping?

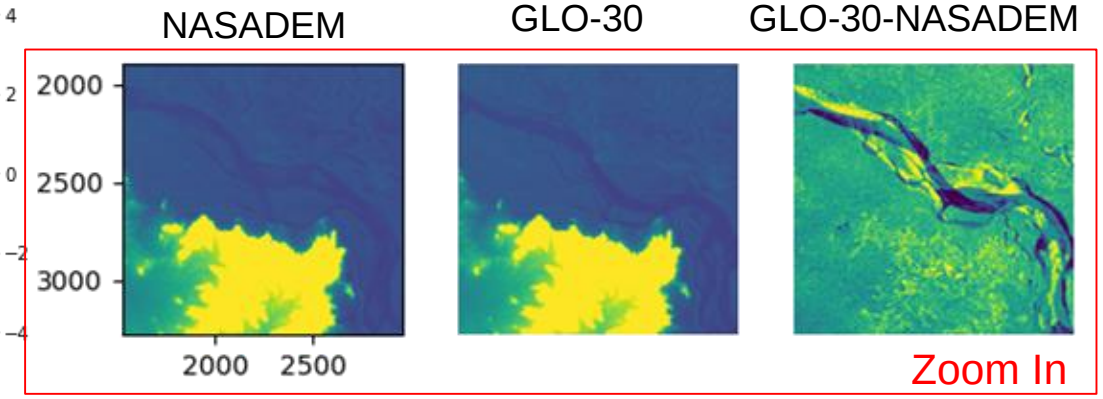


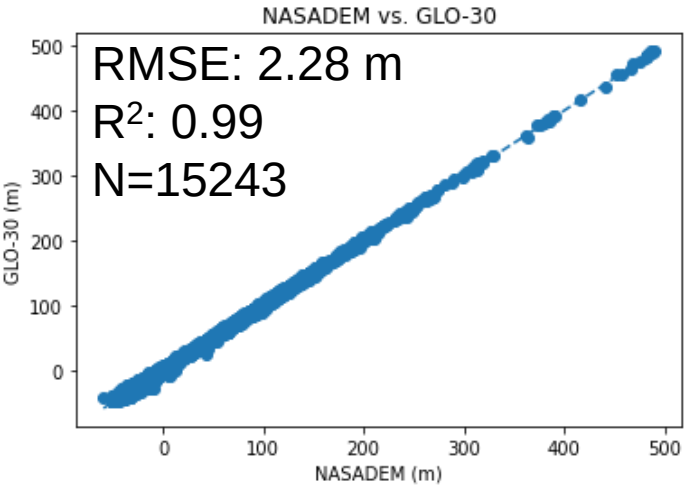
NASADEM

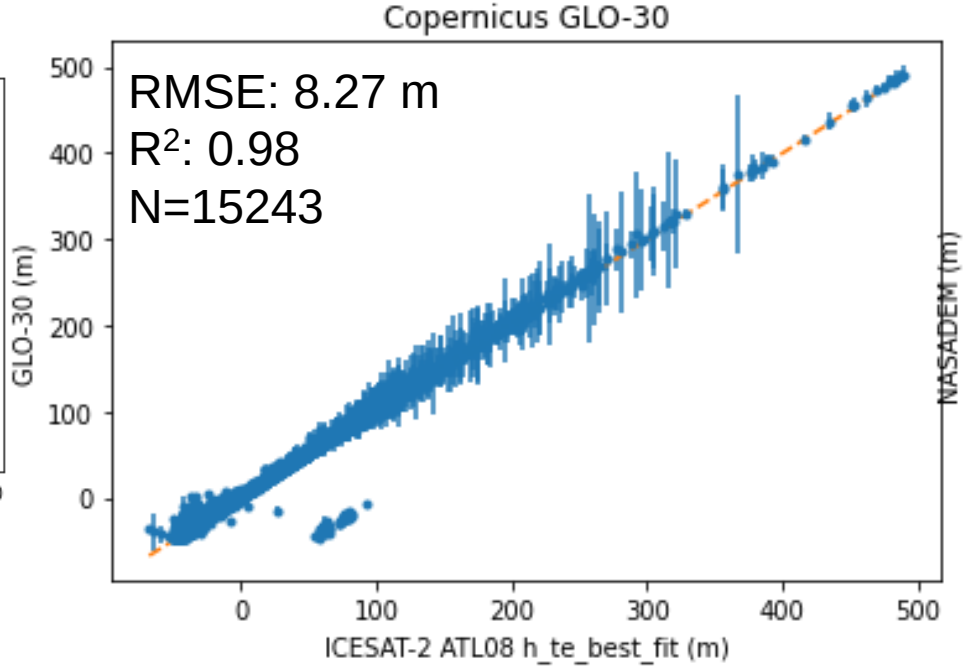
GLO-30

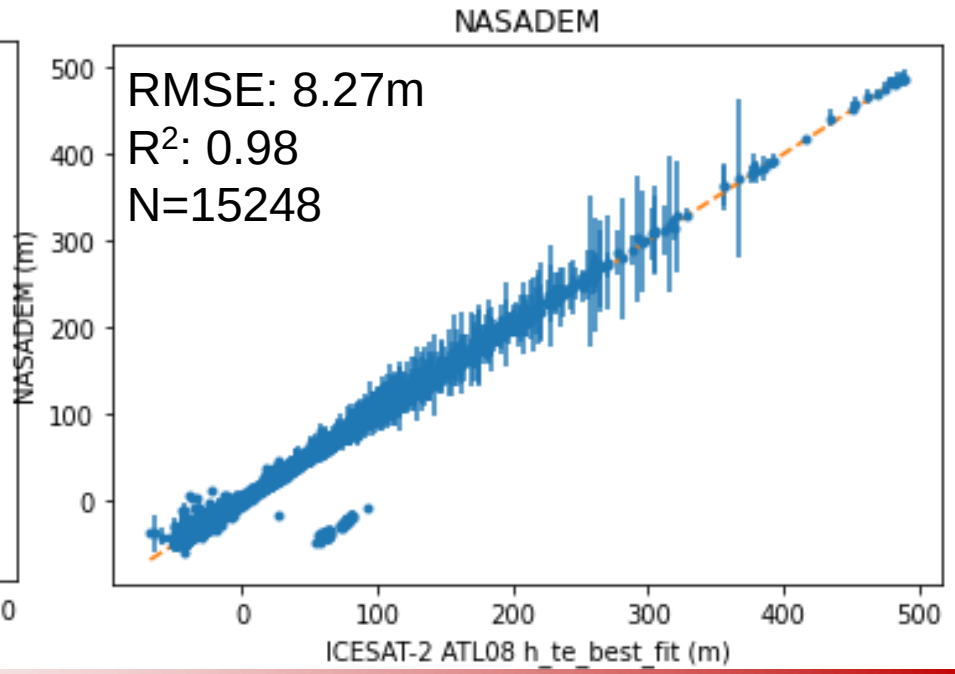


GLO-30-NASADEM







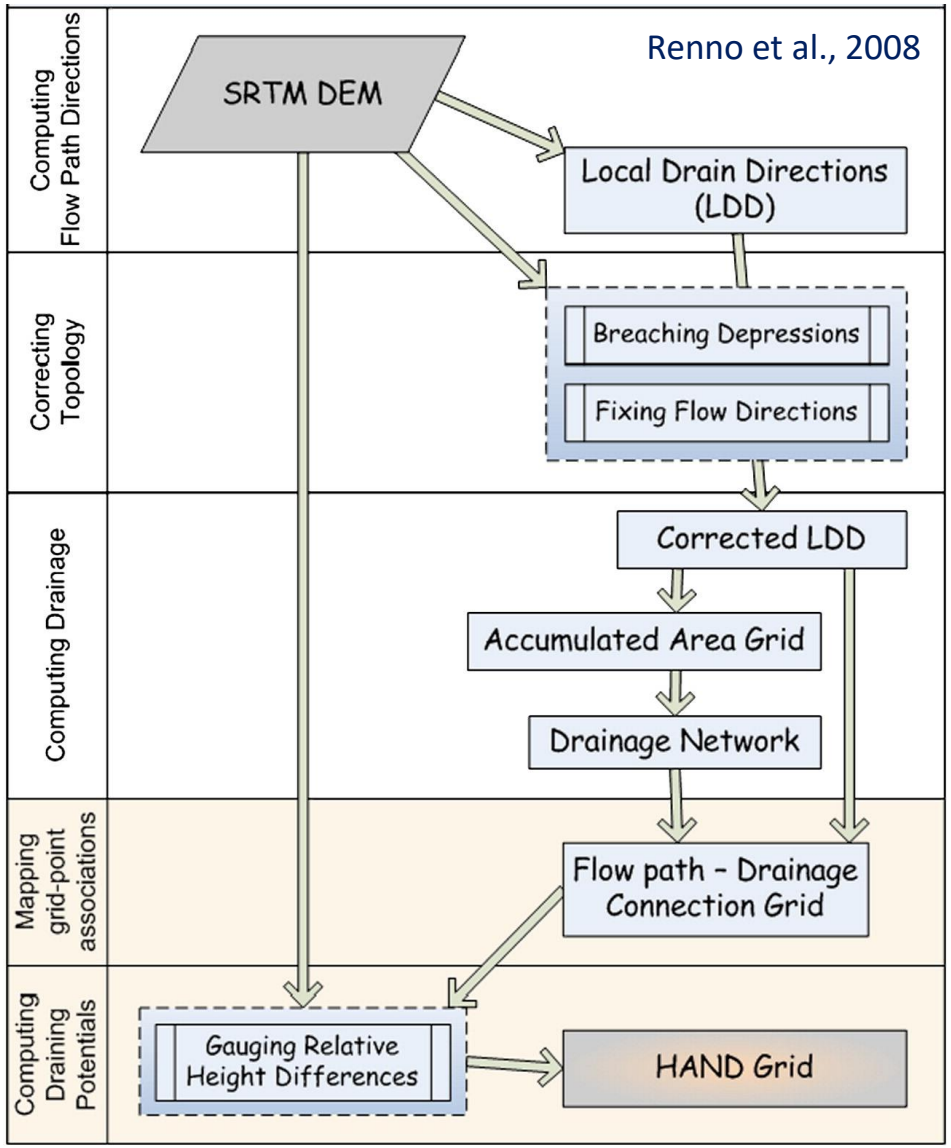


HAND CALCULATION AND ISSUES

What is HAND DEM?

- Height Above Nearest Drainage (HAND) DEM
  - The HAND model normalizes the topography in respect to the drainage network.
  - The vertical distance between a location and its nearest stream.

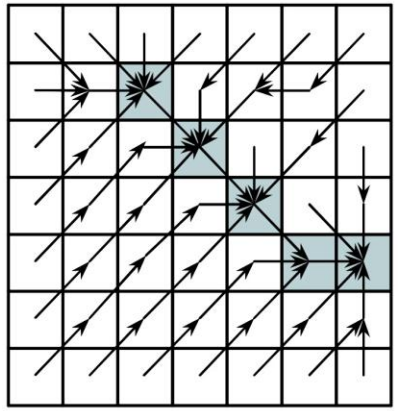
- To produce HAND, a hydrologically conditioned DEM and a representation of the DEM flow field are required.



How is HAND calculated?

HAND Model procedure

- HAND can be calculated with:
  - Accumulation areas
  - Drainage directions
- Blue squares represent grid points belonging to the drainage network.
- Black arrows are considered as flow paths.



LDD
+
Drainage Network

5	5	5	5	4	4	4
5	5	5	4	4	4	3
5	5	4	4	3	3	1
5	4	4	3	3	1	1
4	4	3	3	2	2	1
4	3	3	2	2	1	1
3	3	2	2	1	1	1

Flow Path - Drainage Connection Grid

56	55	56	59	62	68	70
59	52	53	55	58	66	71
67	60	56	55	58	63	66
72	68	59	56	54	55	54
72	70	67	58	54	53	50
71	70	69	65	60	55	53
72	71	72	70	67	61	57

DEM

HAND Grid

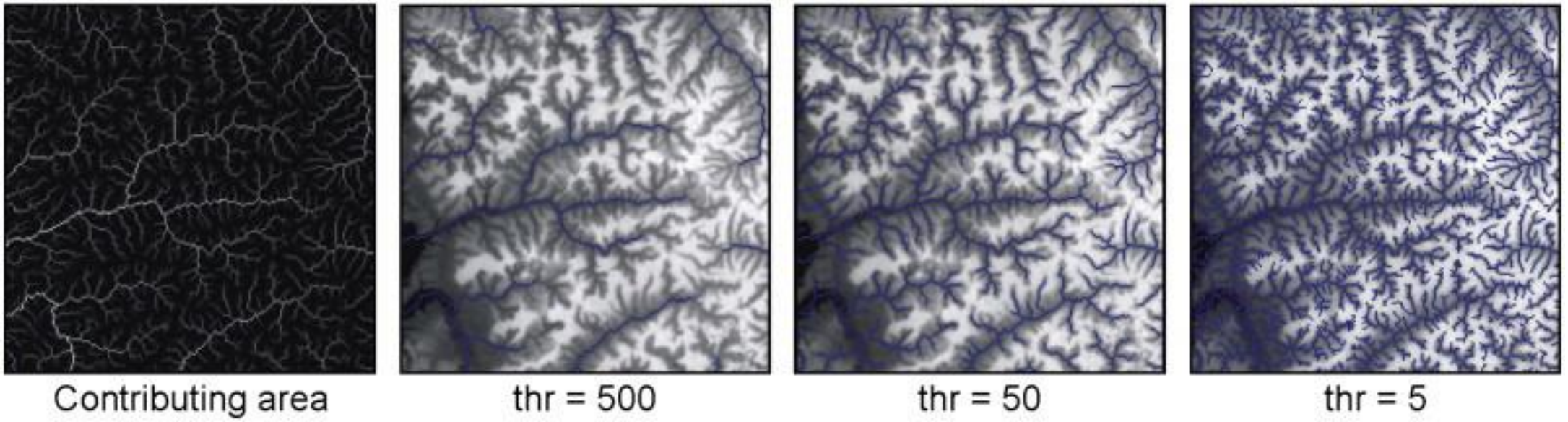
3	2	3	6	7	13	15
6	0	0	0	3	11	17
14	7	1	0	4	9	16
19	13	4	2	0	5	4
17	15	13	4	1	0	0
16	16	15	12	7	5	3
18	17	19	17	17	11	7

72 - 53 = 19

Renno et al., 2008

How is HAND calculated?

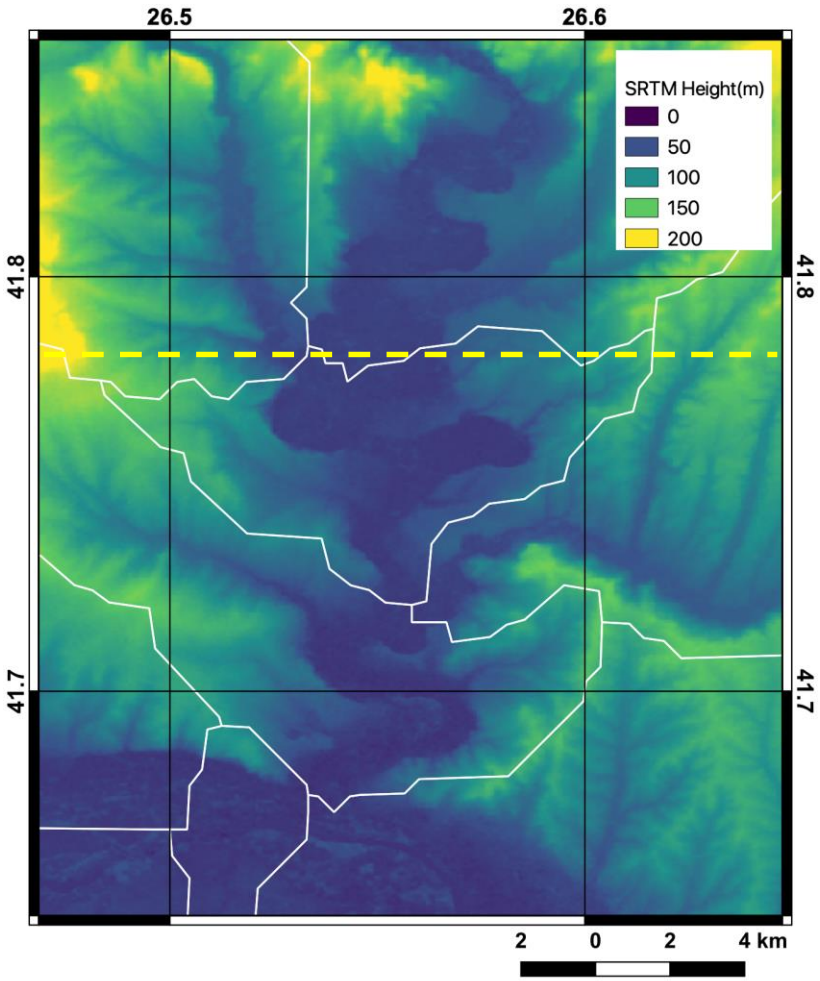
- During HAND calculation, a threshold is applied to the accumulation area. Small accumulation area threshold results in high density drainage networks.



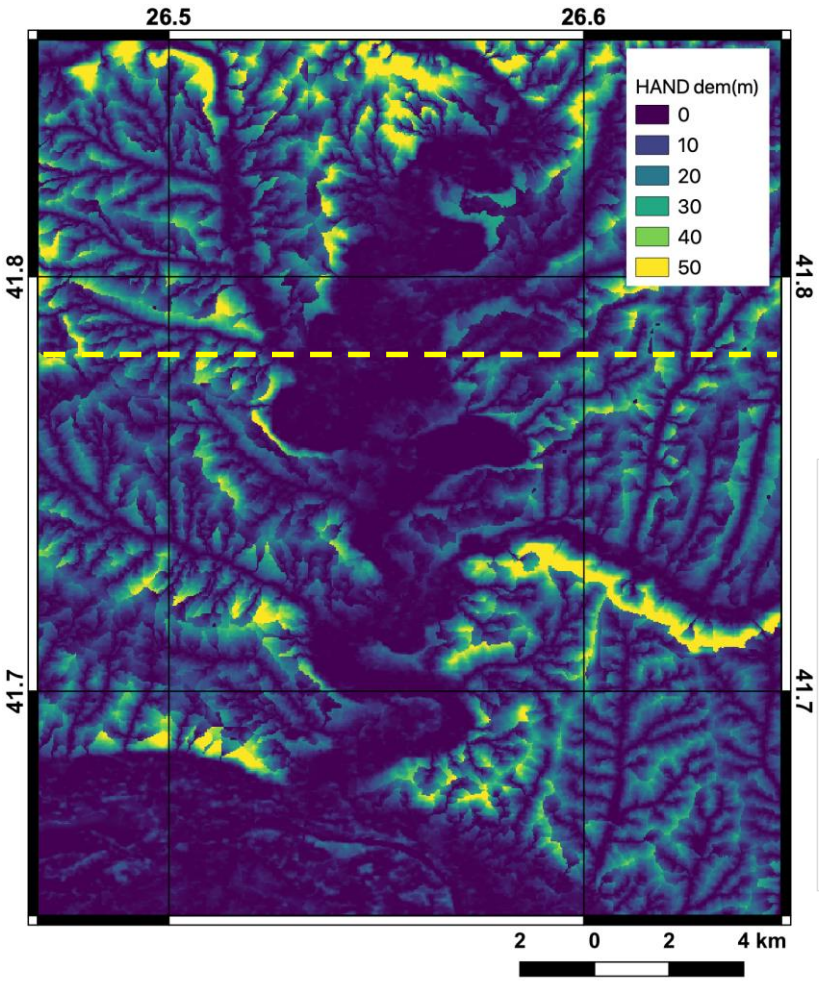
Contributing area (left) and drainage networks plotted on SRTM image, with varying contributing area thresholds (in number of grid points).

Renno et al., 2008

Original DEM and HAND Grid Profiles

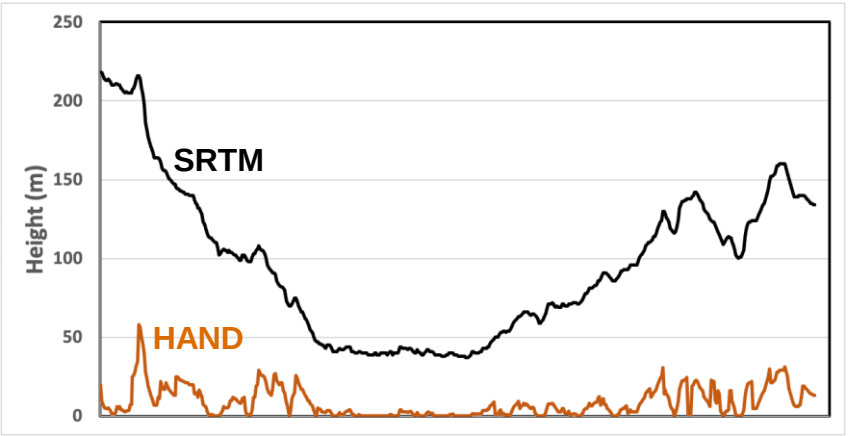


DEM + Hydro Basins



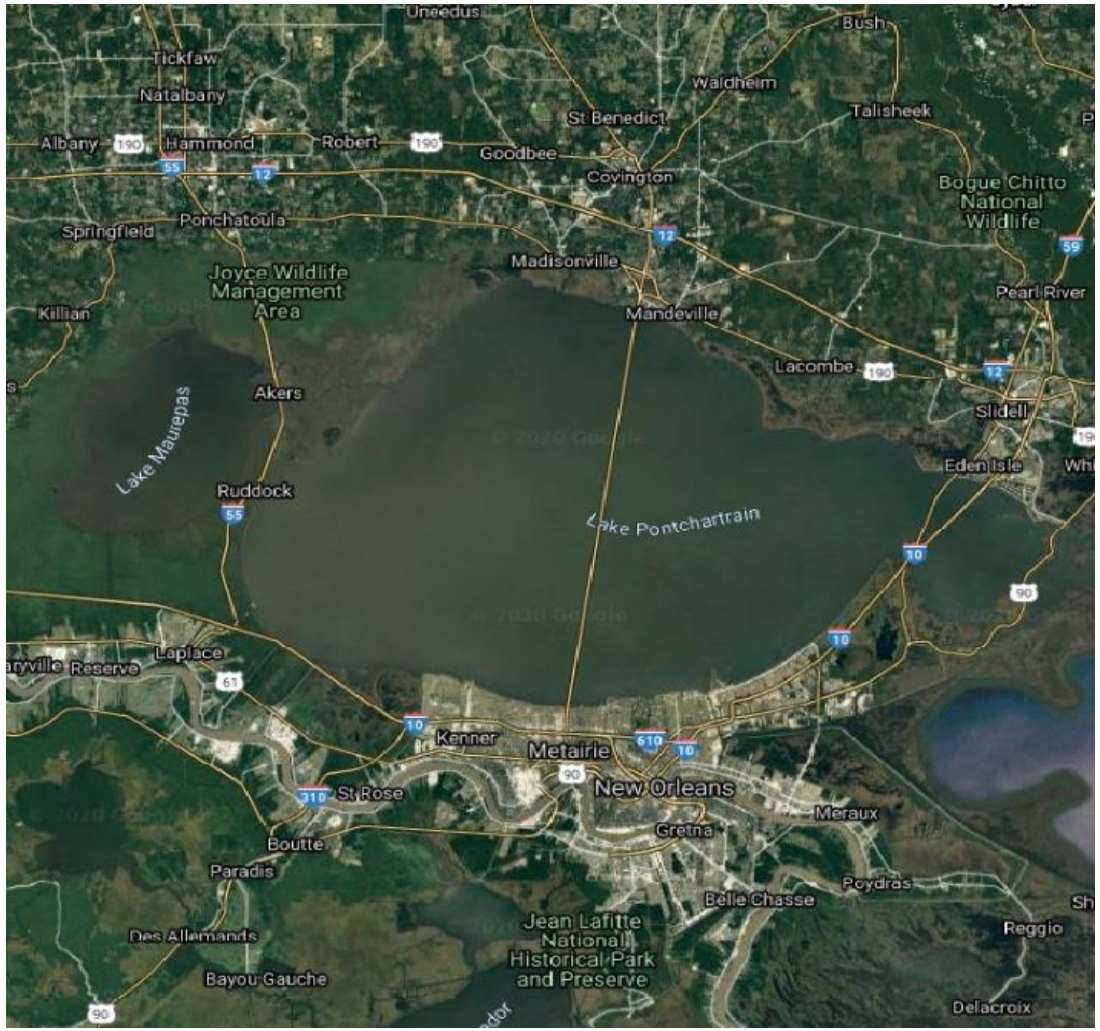
HAND DEM

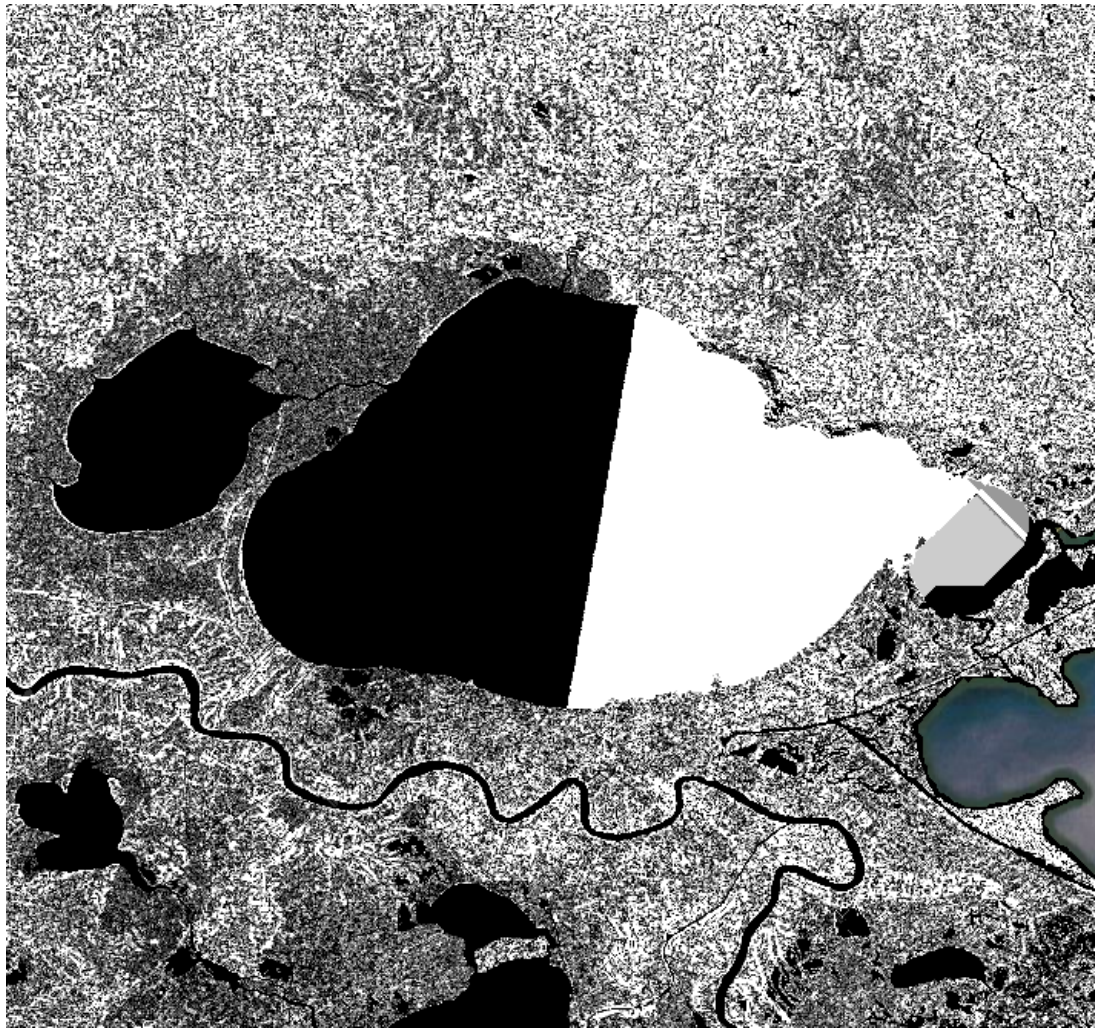
- Comparing profiles between SRTM DEM and the HAND grid normalized for the drainage network.



Issues with HAND results

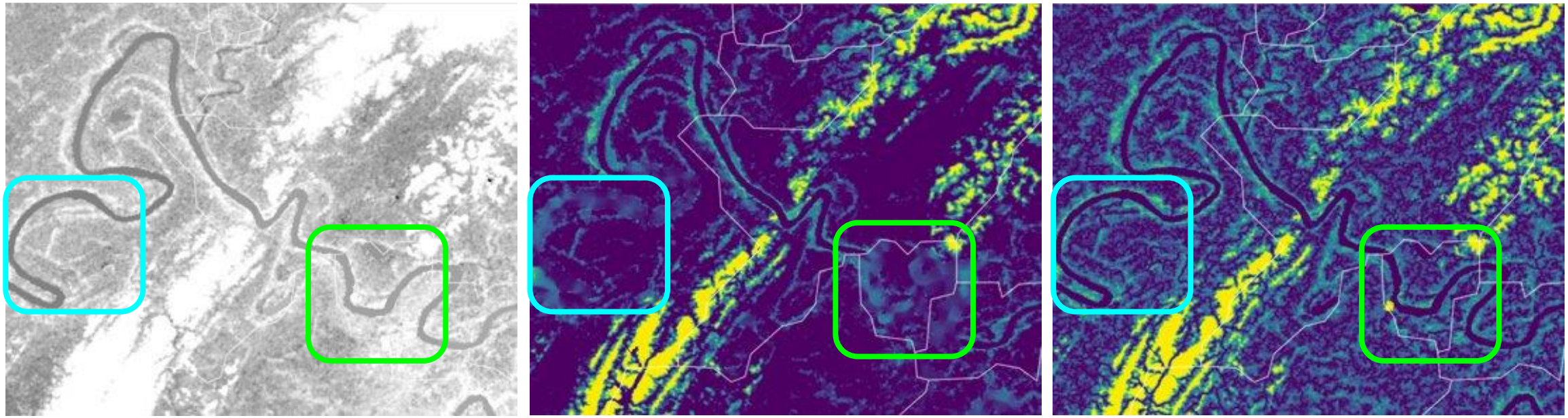
- Bridges





Issues with HAND results

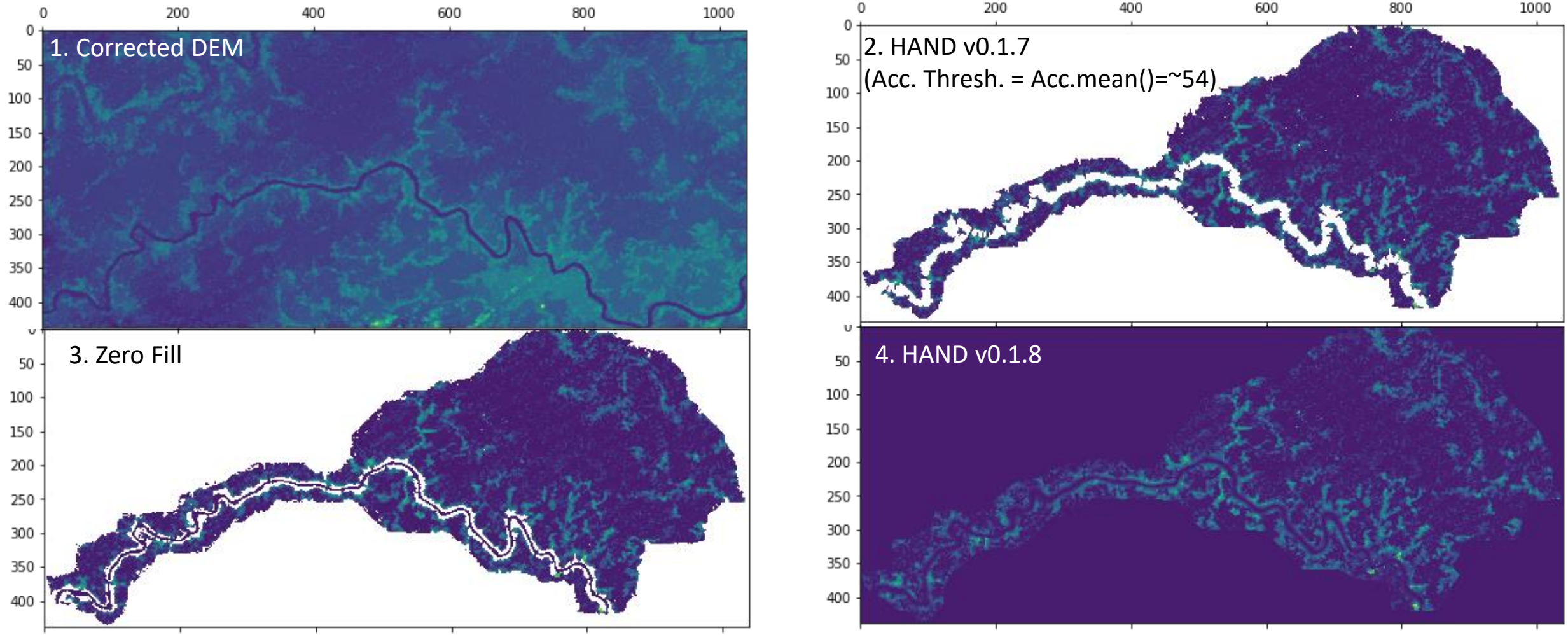
- NaN issues for HAND
  - Anomalies found in some rivers; the river looks disconnected in the HAND DEM.
  - This issue is mainly due to the accumulation threshold parameter.



SRTM DEM | HAND v0.1.6 | GEE HAND

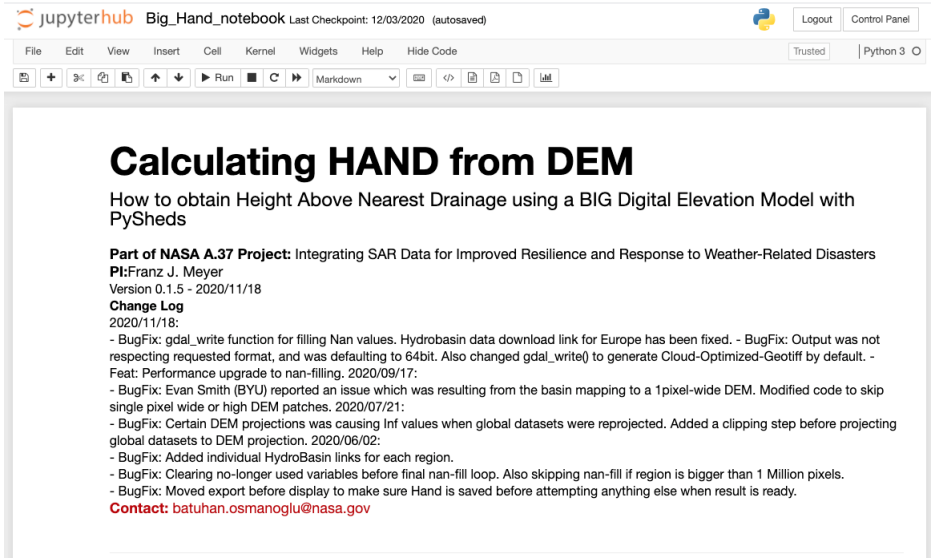
Issues with HAND results

- Undefined areas within HAND
  - Some rivers are being NaN because the edge of the river has high elevation values resulting in the water not draining into the river.

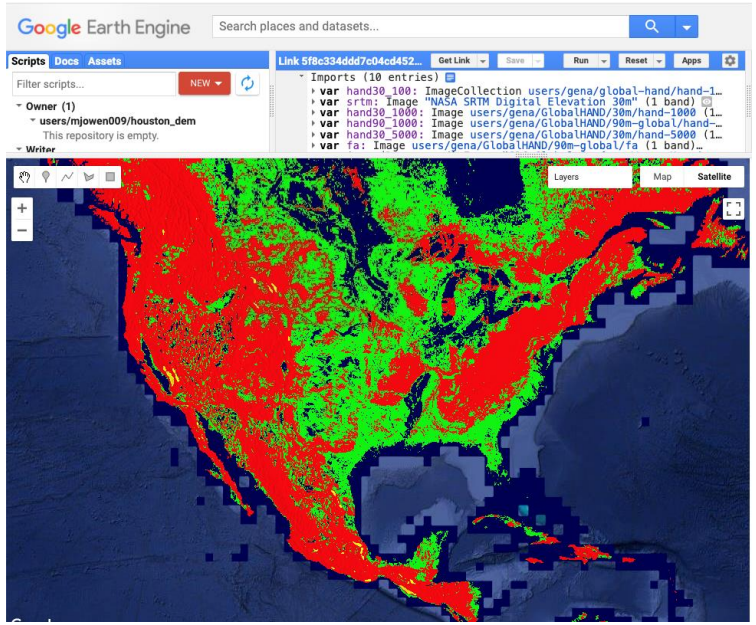


HAND DEM Sources

- Different ways to obtain HAND DEM
  - Calculating HAND directly from Digital Elevation Model using the Big Hand notebook.
  - Getting HAND dem from the web site of Google Earth Engine. (https://code.earthengine.google.com/1bbbff7c908ad6482ccdc627191d4003)
  - Getting Google HAND through the notebook (An account is required for Google Earth Engine)

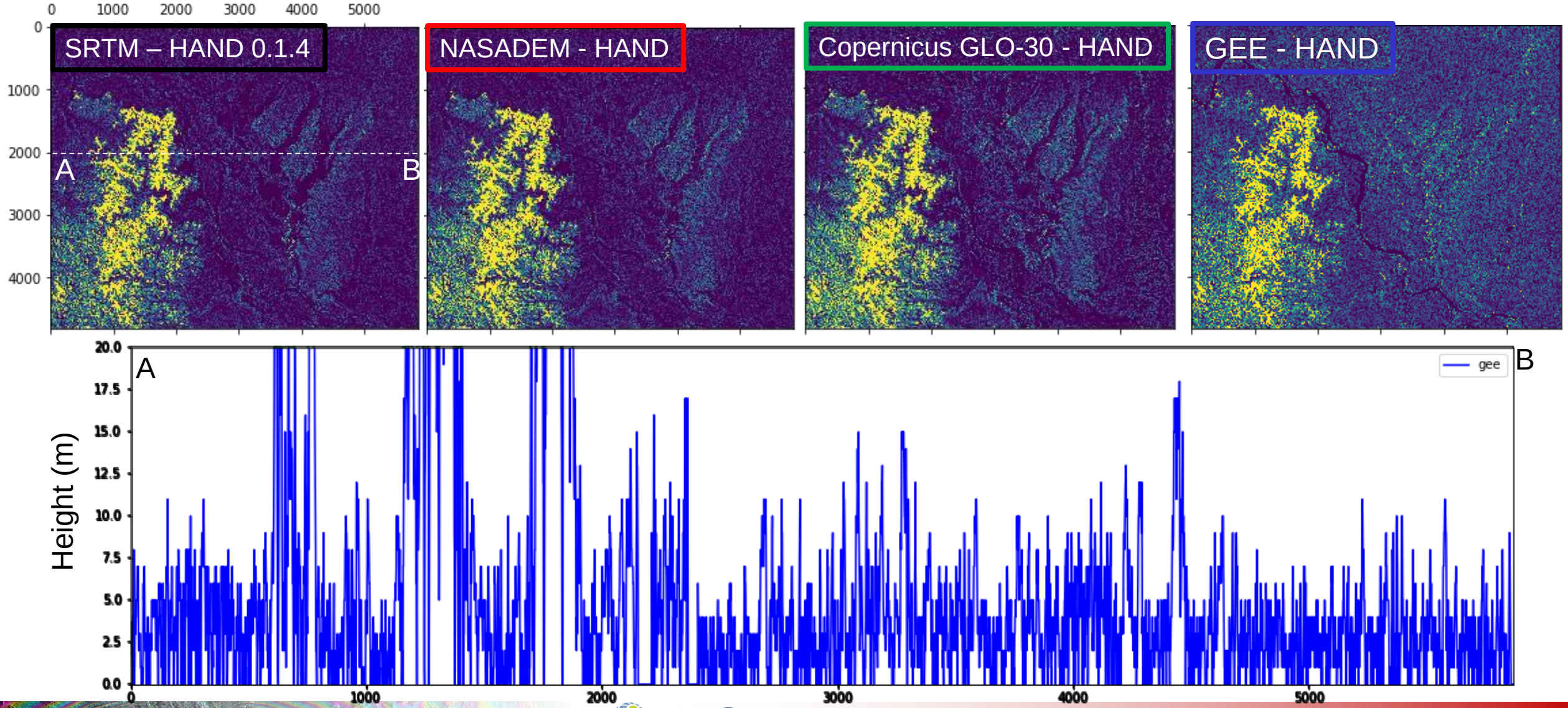


Bing Hand notebook



Google Earth Engine HAND

HAND DEM Differences over Study Area



FLOOD DEPTH ESTIMATION

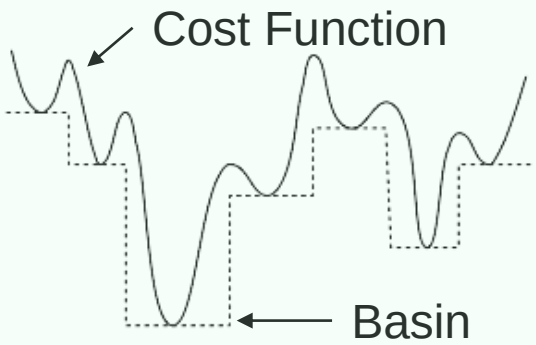
What are the estimators for water height?

Numpy: $\mu = \frac{1}{N}\sum_{i}^{N} Z_i$ $\sigma^2 = \frac{1}{N}\sum_{i}^{N} |Z_i - \mu|^2$ $W.H. = \mu + C\sigma,\ 0 < C \leq 3$

NMAD: $\mu = \frac{1}{N}\sum_{i}^{N} Z_i$ $\sigma = median\left(\left|\left|Z_i - \tilde{Z}\right|\right|\right),\quad \tilde{Z} = median(\vec{Z})$ $W.H. = \mu + C\sigma,\ 0 < C \leq 3$

LogStat: $\mu = \exp\left[\frac{1}{N}\sum_{i}^{N} \log(Z_i)\right]$ $\sigma^2 = \exp\left[\frac{1}{N}\sum_{i}^{N} \log(|Z_i - \mu|^2)\right]$ $W.H. = \mu + C\sigma,\ 0 < C \leq 3$

Iterative: $W.H. \equiv$



Critical Success Index (Threat Score) $\frac{TP}{TP + FP + FN}$

Accuracy $\frac{TP + TN}{TP + TN + FP + FN}$

	W.L.>Zi	Extent
TP	1	1
TN	0	0
FP	1	0
FN	0	1

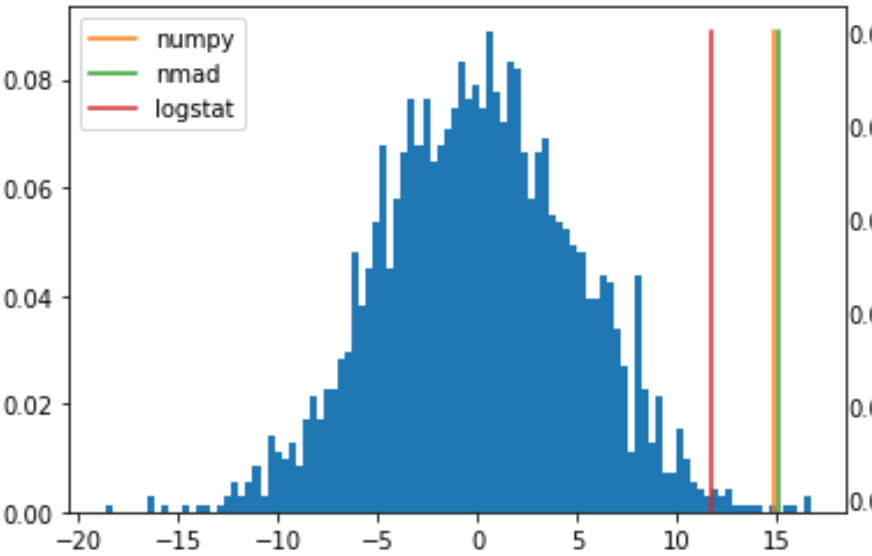
How do different estimators perform?

- Depending on the height distribution different estimators provide different statistical estimates.

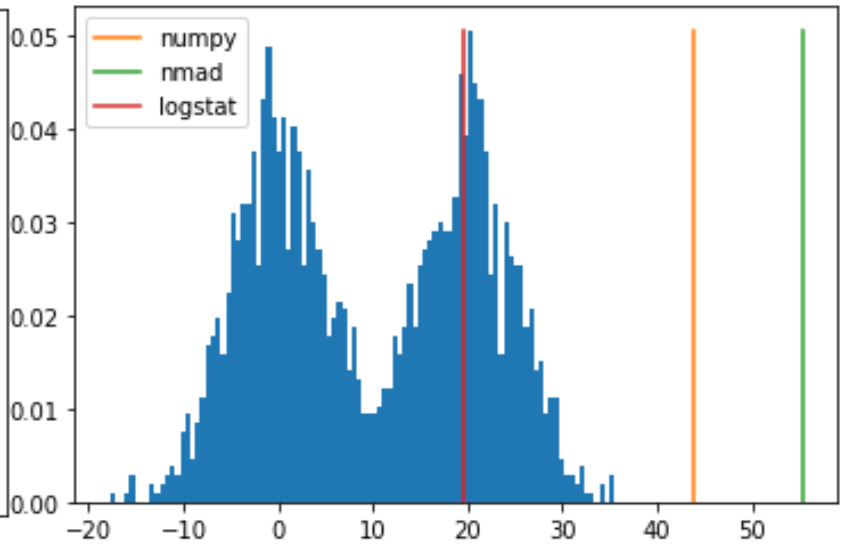
Estimator	μ	σ
Numpy	0.08	4.93
NMAD	*ditto*	4.99
Log. Stat.	2.64	3.04

Estimator	μ	σ
Numpy	9.96	11.30
NMAD	*ditto*	14.83
Log. Stat.	10.20	3.85

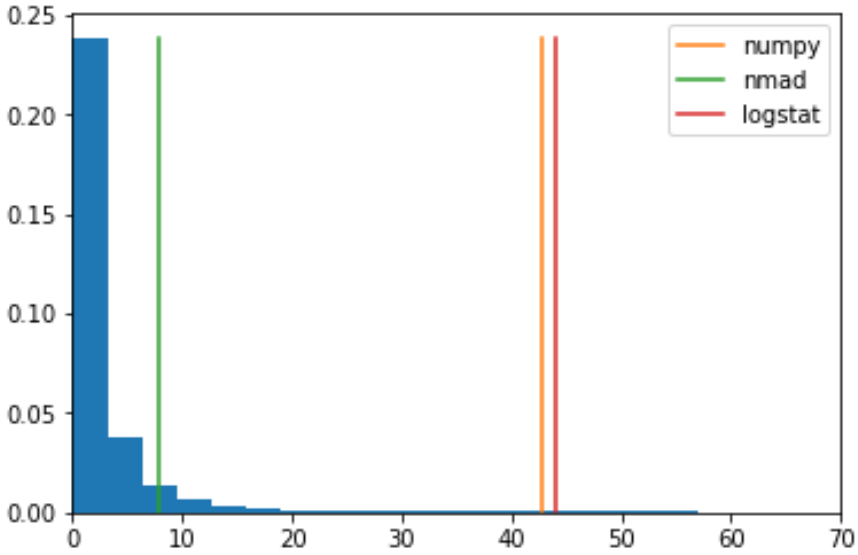
Estimator	μ	σ
Numpy	4.12	12.88
NMAD	*ditto*	1.22
Log. Stat.	0.48	14.52



randn()*5



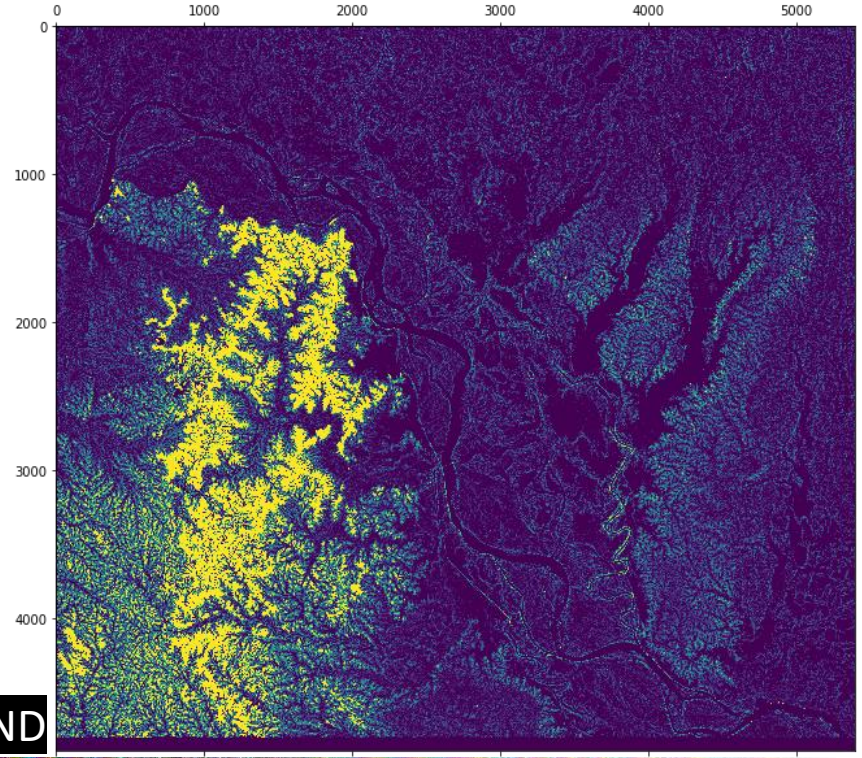
randn()*5+(randn()*5+20)



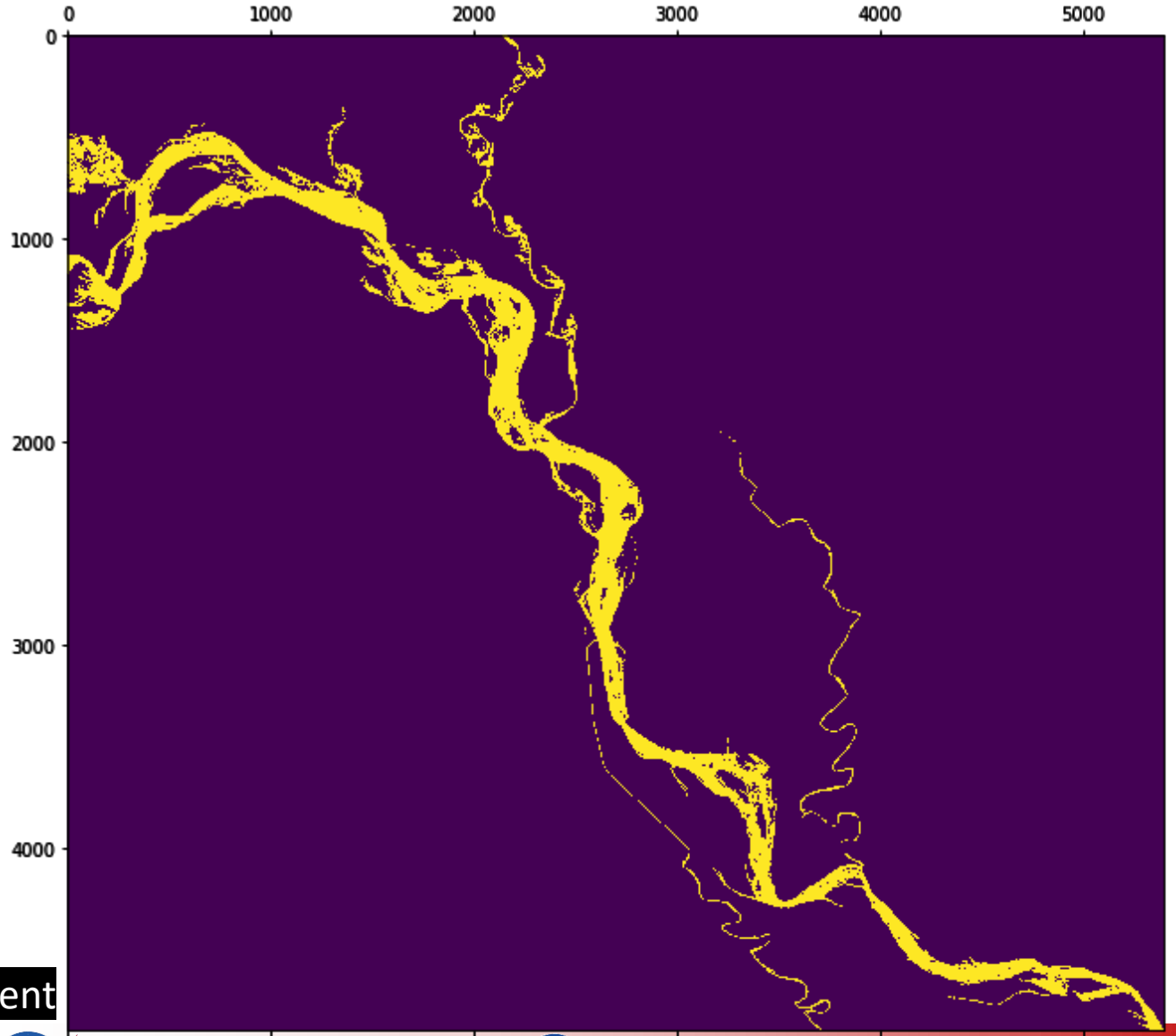
HAND DEM from Lab2

SAR determined flood depth to water level conversion

Estimator	μ	σ	μ+3σ
Numpy	0.89	1.60	5.69
NMAD	*ditto*	0.06	1.07
Log. Stat.	0.08	19.35	58.31
Iterative	-	-	6.4



HAND



Extent

Water Level Data (IGARSS Domain)

- Copernicus Global Land Service - Water Level V2 Rivers

V.S. ID	Date Time	Obs
5489	2020/06/27 23:26	30.88±0.2
	2020/07/27 17:22	33.76±0.02
5503*	2020/08/09 15:54	31.43±0.15
5512*	2020/08/12 04:26	30.27±0.11
5470	2020/07/06 04:25	25.31±0.84
	2020/08/02 04:25	27.98±0.11
5518	2020/06/03 15:52	23.25±0.11
	2020/07/27 15:52	27.51±0.14
5499	2020/07/06 04:25	24.84±0.14
	2020/08/02 04:25	26.3±0.09
5471	2020/06/03 15:52	22.96±0.09
	2020/07/27 15:52	25.97±0.17
5572	2020/06/27 04:19	11.18±1.00
	2020/07/24 04:19	13.82±0.08

Date	Count
06/03	2
06/27	2
07/06	2
07/24	1
07/27	3
08/02	2

* No SAR observation matching this station.

Method Comparison

- On a machine with 128GB RAM, 32 core Intel(R) Xeon(R) Platinum 8259CL CPU @ 2.50GHz

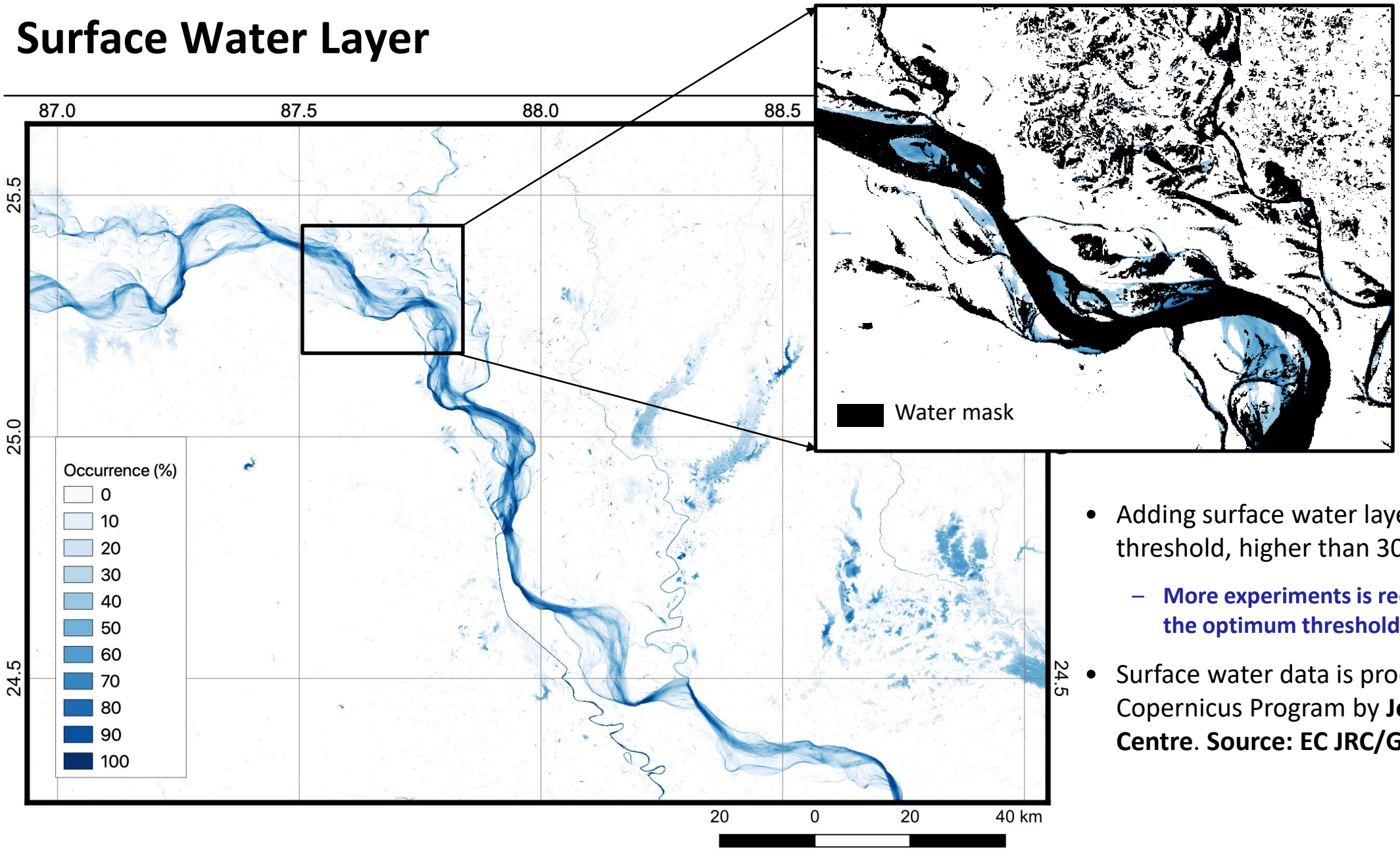
Water Objects	Numpy	NMAD	LogStat	Iterative
47K	00:00:07	00:00:10	00:00:09	00:40:07
197K	00:00:18	00:00:27	00:00:19	01:40:24

- Sigma's are set the same for all runs, but actually changing them could yield better results. For example, setting Numpy with 3 sigma for NASADEM would reduce the RMSE.
- SRTM HAND is calculated with Big Hand notebook v0.1.4, while others were calculated with v0.1.8.

RMSE (#)	Numpy (1σ)	NMAD (3σ)	LogStat (1σ)	Iterative
SRTM (v0.1.4)	*3.28* (2)	4.7 (2)	13.66 (2)	**0.84** (2)
NASADEM	3.54 (2)	4.11 (2)	*1.73* (2)	**1.12** (2)
Copernicus	*2.89* (2)	4.05 (2)	79.01 (2)	**2.27** (2)
GEE-Hand	1.65 (2)	*0.89* (2)	5.68 (2)	**0.79** (2)

Shows RMSE (m) and (number of validation points)
Bold: lowest RMSE
Italics: 2nd lowest RMSE

Surface Water Layer



- Adding surface water layer based on threshold, higher than 30% occurrence.
  - **More experiments is required to determine the optimum threshold.**
- Surface water data is produced under the Copernicus Program by **Joint Research Centre**. **Source: EC JRC/Google**'

Pekel et al., 2016

VALIDATION FOR BANGLADESH 2017 CASE

Validation for Bangladesh 2017 flooding case

Water level data in Bangladesh

- Flood Forecasting & Warning Centre from Bangladesh Water Development Board (BWDB) is monitoring daily basis water level (http://www.ffwc.gov.bd/index.php#).

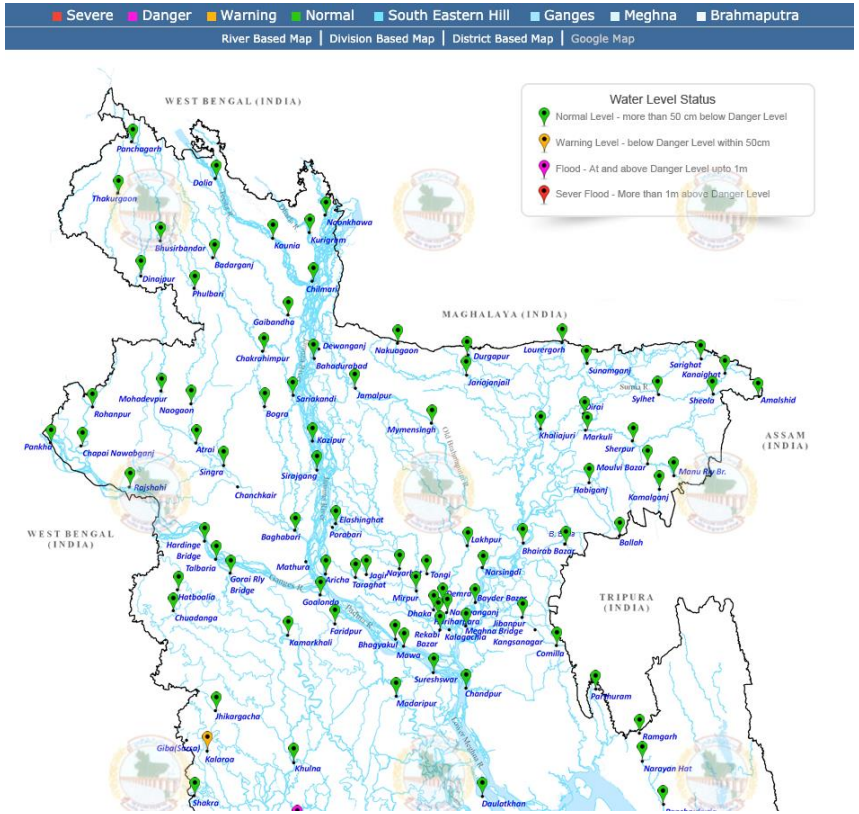


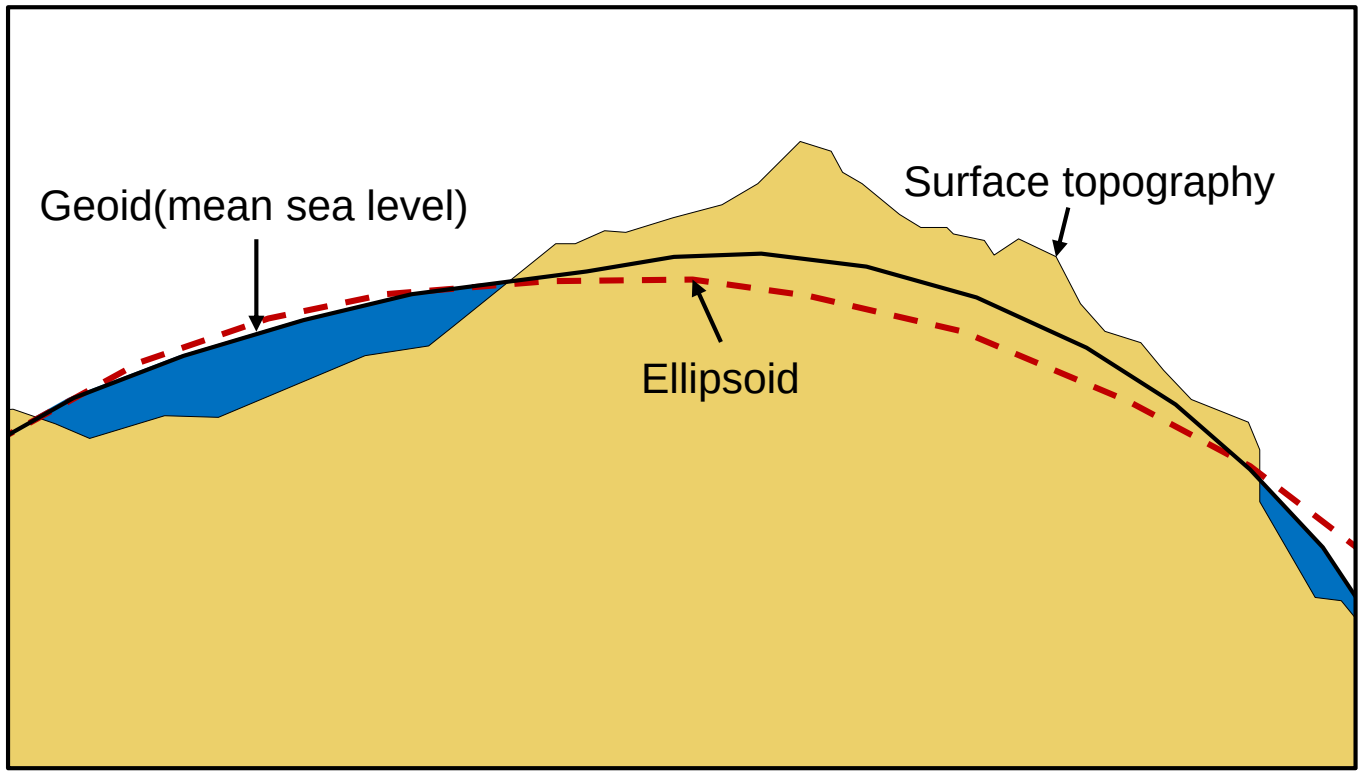
TABLE OF WATER LEVELS : 11-11-2020

River Name	Location	Danger Level (mPWD)	WL - Observe (m) 10-11 06:00 AM	WL - Observe (m) 11-11 06:00 AM	WL - Forecast (m)
Brahmaputra Basin					
Jamuna	Aricha	9.40	5.59	5.44	1
Atrai	Atrai	13.70	11.12	10.97	1
Jamuneswari	Badarganj	32.15	NP	NP	1
Karatoa-Atrai-GGH	Baghabari	10.40	6.16	6.11	1
Jamuna	Bahadurabad	19.50	15.25	15.34	1
Upper Atrai	Bhusirbandar	39.60	35.88	35.87	1
Karatoa	Bogra	16.30	12.10	12.07	1
Karatoa	Chakrahimpur	20.15	17.16	17.14	1
Brahmaputra	Chilmari	23.70	20.01	20.08	1
Teesta	Dalia	52.60	50.95	51.04	1
Balu	Demra	5.75	2.86	2.97	1
Jamuna	Dewanganj	19.00	NP	NP	1
Buriganga	Dhaka	6.00	2.62	2.58	1
Dhaleswari	Elasinghat	11.40	6.85	6.84	1
Ghagot	Gaibandha	21.70	18.34	18.32	1

Validation for Bangladesh 2017 flooding case

Water level data in Bangladesh

- BWDB and other government departments of Bangladesh refer water level to the Public Works Datum (PWD)
  - PWD is located approx. 1.5 ft (0.4572 m) below the mean sea level (MSL).



Water Level + Offset (0.4572)

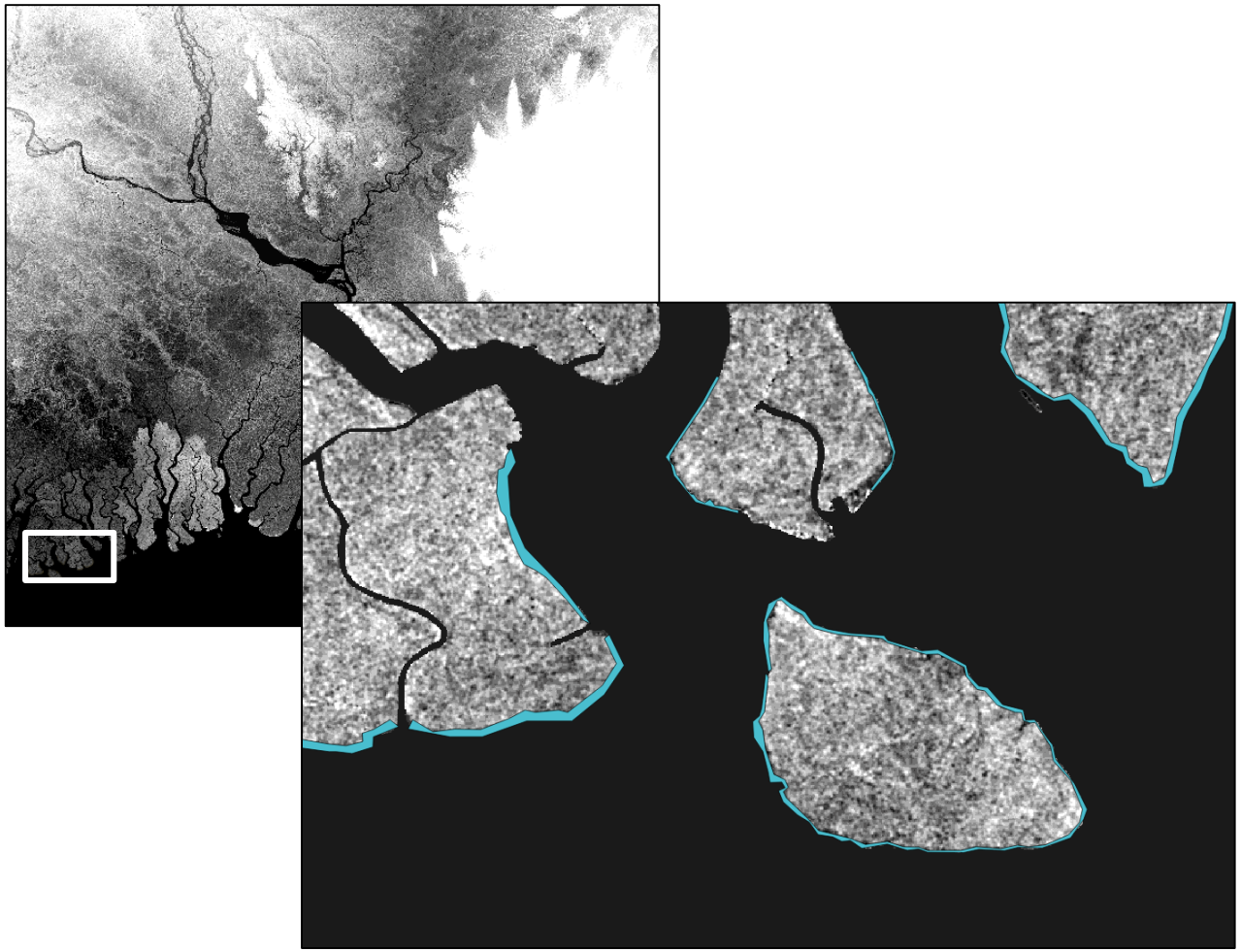
↓

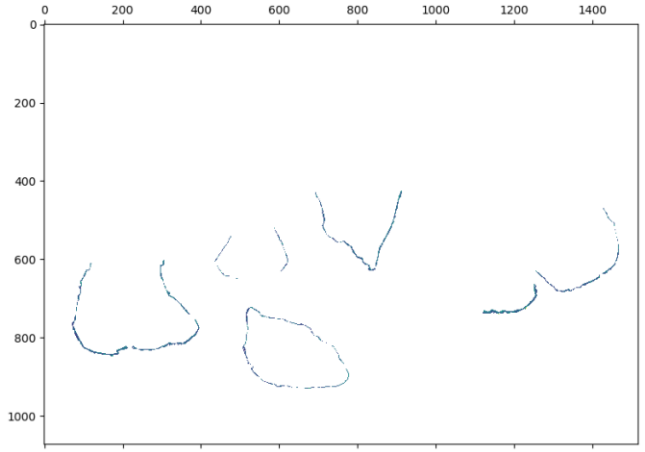
Water Level (m)

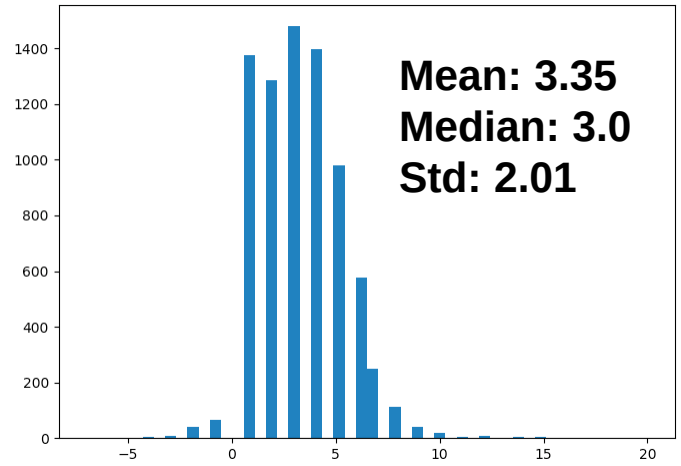
But what is mean sea level?
EGM84, EGM96, EGM2008 ?

Validation for Bangladesh 2017 flooding case

Converting measurements to water level





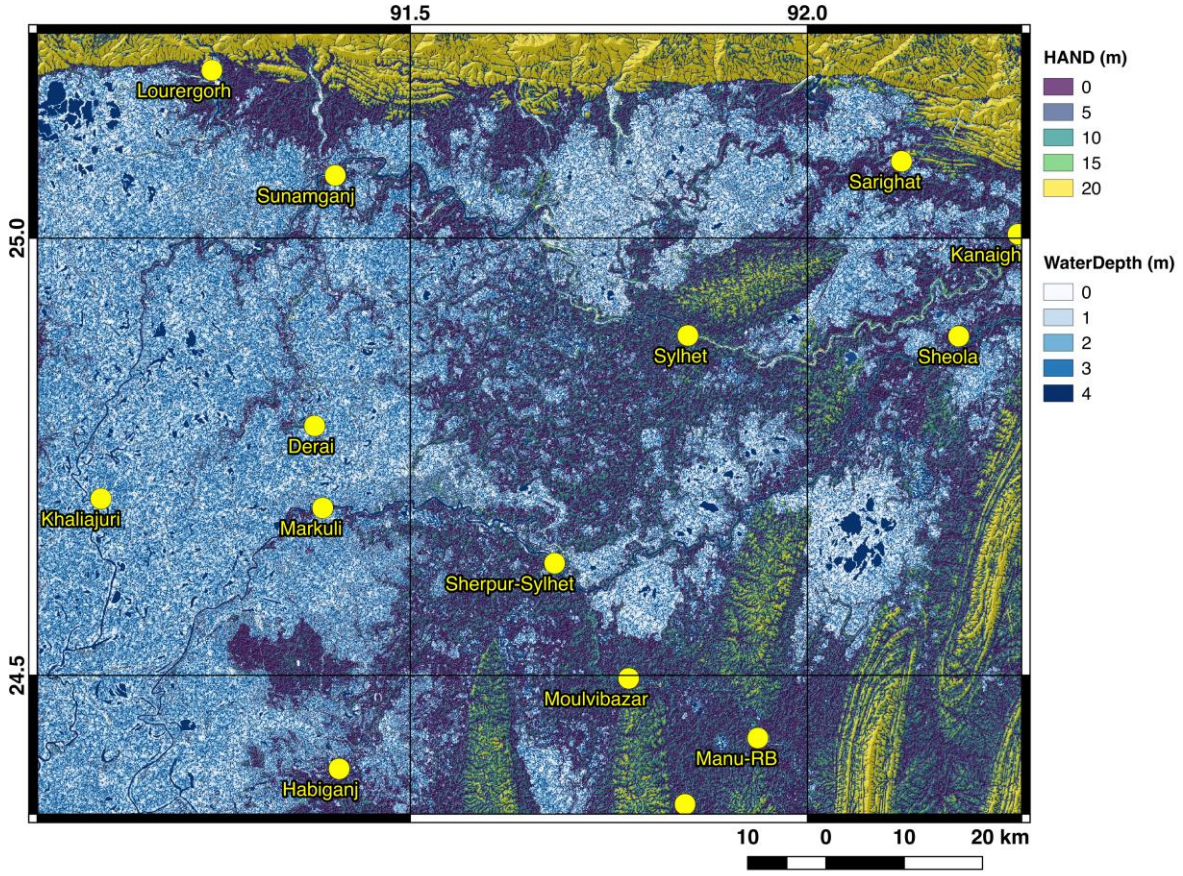


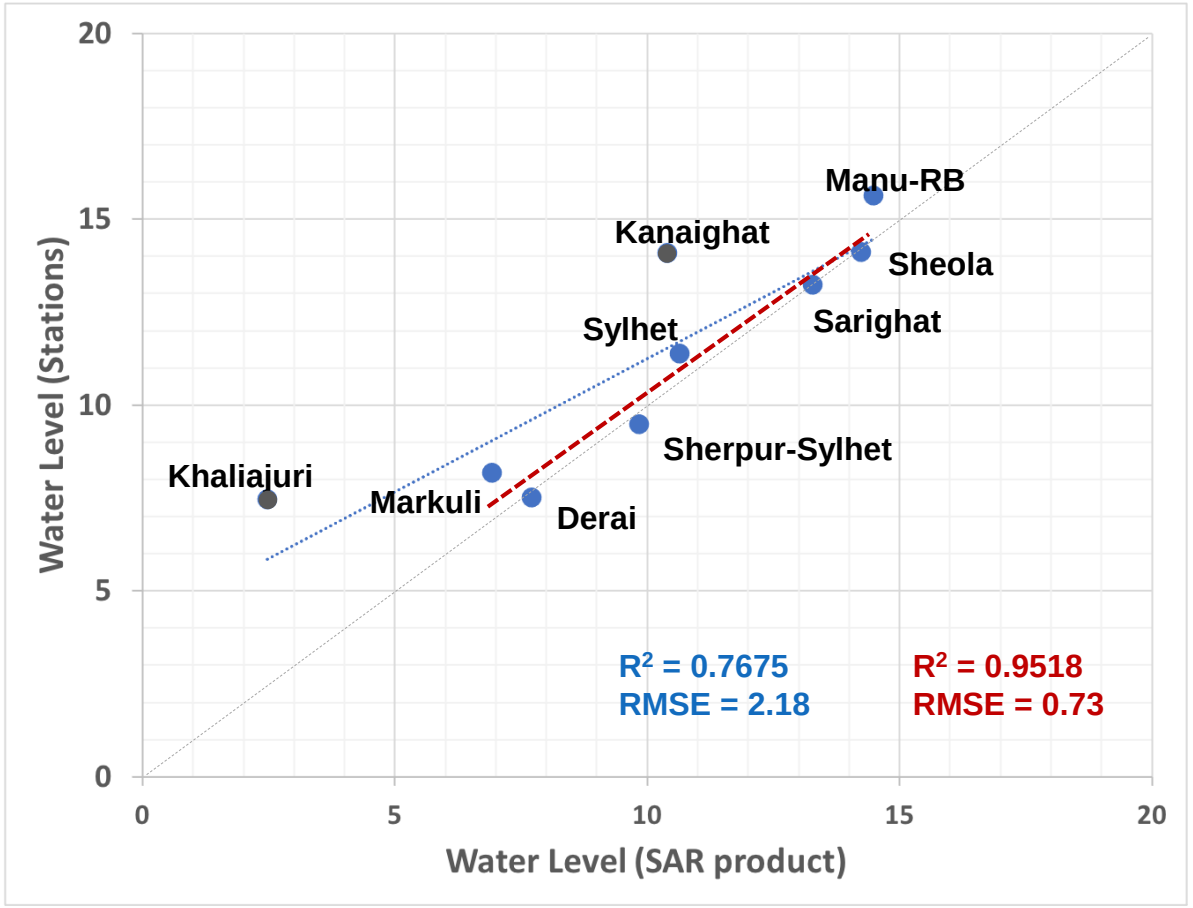
Water Depth + Topographic Height – Offset (3.35) → Water Level (m)

Validation for Bangladesh 2017 flooding case

Accuracy assessment

- Event: 2017 Bangladesh flood
  - Observation date: September 10, 2017





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QUESTIONS?