EGSIEM

European Gravity Service for Improved Emergency Management

WP6: An automated approach to estimate flood volumes based on SAR satellite imagery and DEMs

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DLR

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Universität Bern | Université du Luxembourg | GFZ Helmholtz Centre Potsdam | TU Graz – Graz University of Technology | Leibniz Universität Hannover | cnes | DLR | géode & cie | Horizon2020

Objectives

- Establish a method for flood volume estimation for large scale floods based on EO data and DEMs
  - Higher level product compared to 2-D flood masks
  - Can be compared to gravity measurements from space

- Implement gravity based flood indicators into the operational workflow of DLR's Center for Satellite-based Crisis Information
  - Early-warning component for potential large scale flood events
  - Reduce lead time in satellite tasking (e.g. TerraSAR-X)

Introduction

- Flood depth & volume estimations are mostly done by hydraulic modelling (1-D, 2-D)

  > BUT the more complex & precise they get :

  - computational cost increases
  - study areas get smaller
  - more input parameters are needed

→ sometimes complex hydraulic models are not suitable for real-world flood risk analysis (BATES 2012)

BATES (2012:2515) *„… argued that the use of remote sensing data had allowed a significant breakthrough to be made in flood inundation modelling.“*

-> in terms of higher resolutions, shorter revisit times, better availability

-> improving terrain data resolution leads to better performances than improving the hydraulic model!

Flood volumes without hydraulic modelling

but with improved remote sensing data?

Few publications tried to estimate flood volumes only with remote sensing data or a combination of RS data and hydraulic modelling before:

- HORRIT 1999: **Snake algorithm** for delineation
- NÉELZ et al 2006: **Airborne** SAR data & LiDAR, inundation extent delineation
- MASON et al. 2007: **Waterline delineation** with ERS SAR & LiDAR, hydraulic model
- MATGEN et al. 2007: SAR water mask extent, hydraulic modelling for flood depths
- ZWENZNER & VOIGT 2009: heights from **cross sections** for each river bank
- SCHUMANN et al. 2009: Flood depths from airborne photography and LiDAR, **SAR too coarse**
- KAWAK et al. 2013 flood volume & depths modeled with 1-D hydraulic model, **optical data**, low resolution (500 m)
- HUANG et al. 2014: inundation extent & LiDAR => **shift small tiles till they fit the DEM**

=> So far no study for large scale flood volumes & depths derived from SAR derived flood masks & DEMs with world wide coverage

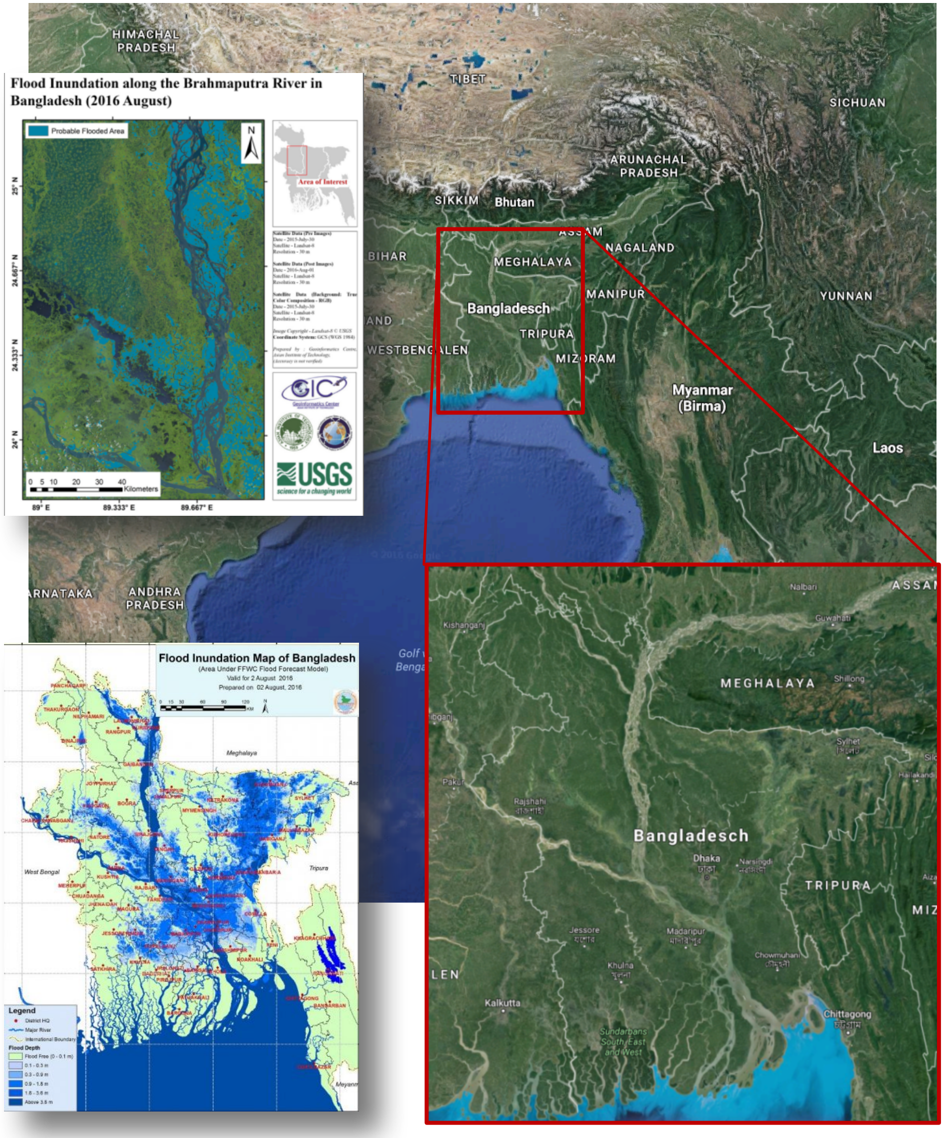
Study Area: Bangladesh

- Seasonal flooding due to monsoonal precipitation
- Regular Charter activations
- Huge affected area

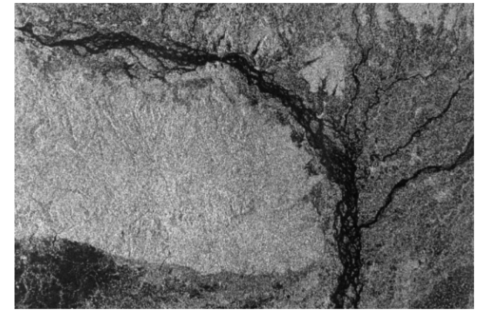
<u>Selected Event:</u>

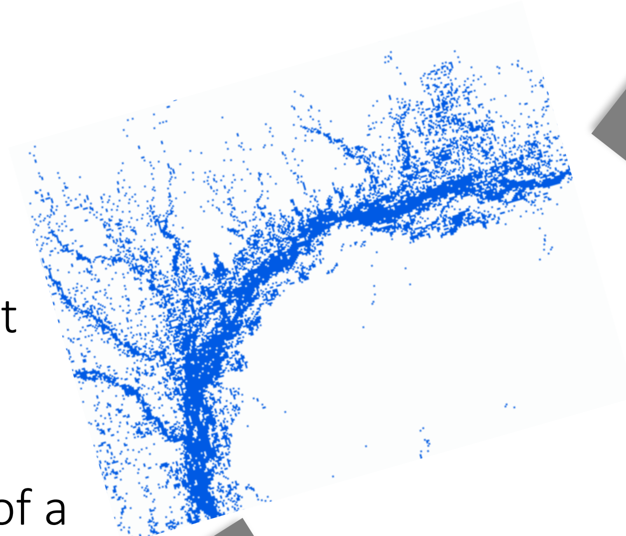
Activation of the International Charter on 1st of August 2016

- 16 people killed
- 1.5 million people affected
- flooding of Ganges and Brahmaputra due to heavy rainfalls for several days

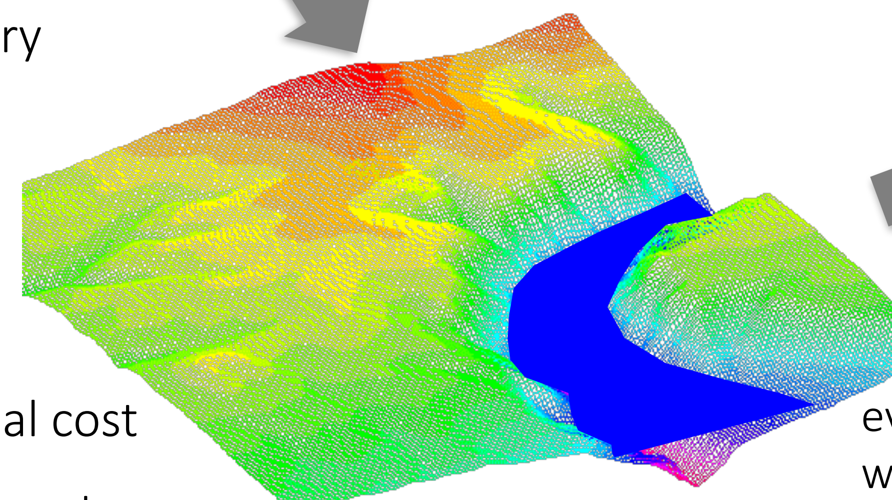


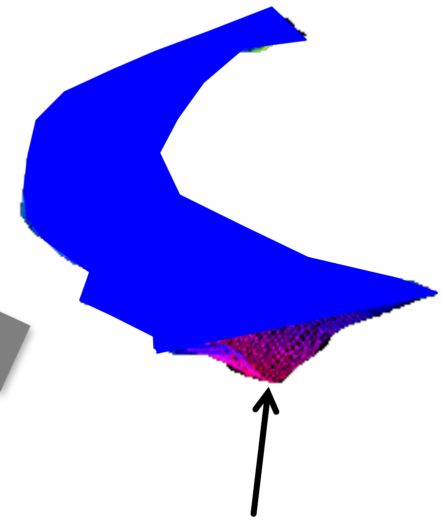
Method





Develop a method to get accurate flood volumes through a combination of a DEM and SAR imagery





everything in-between the water surface and the DEM is flood volume

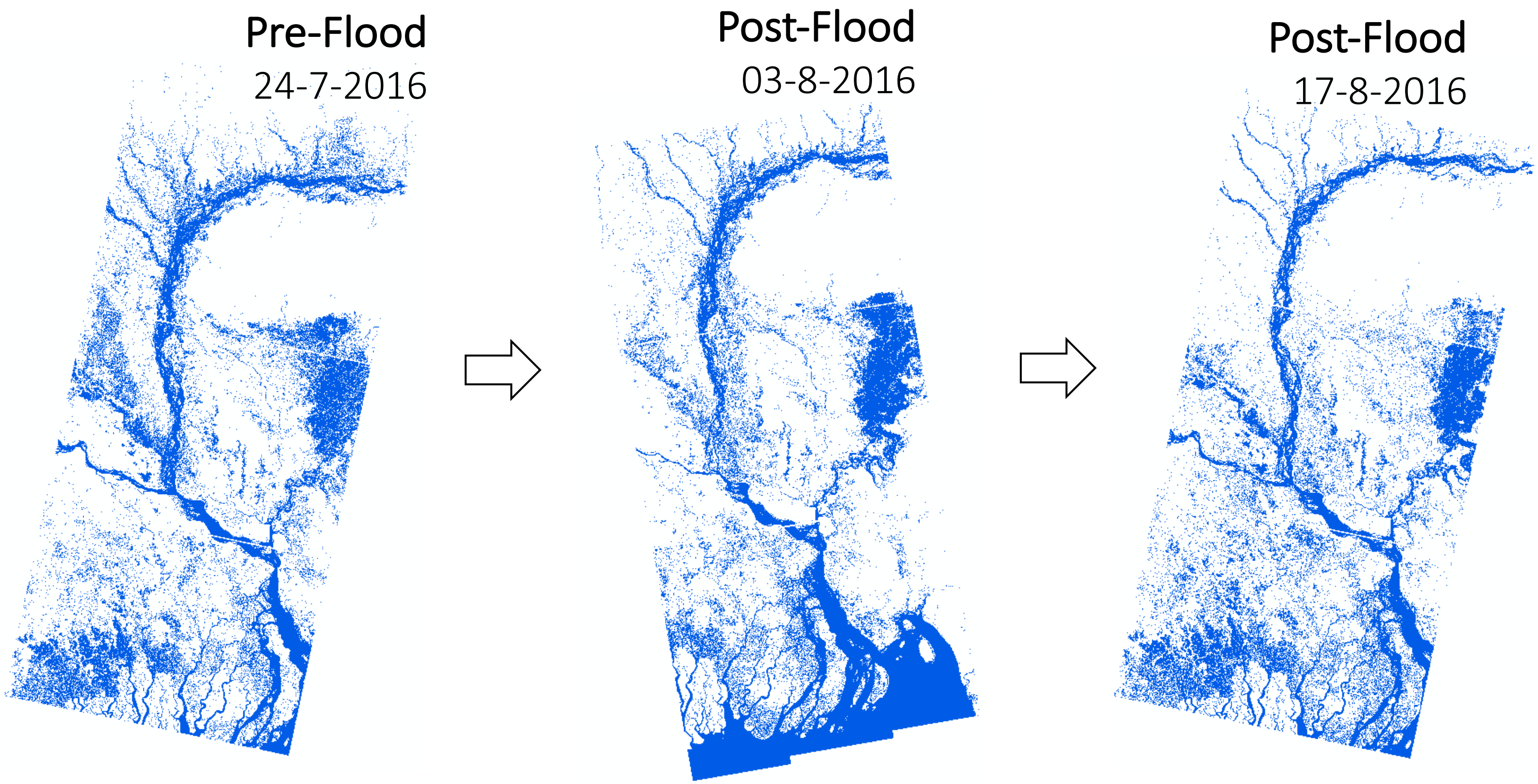
<u>Important criteria:</u>

- low computational cost
- usage of up to date data

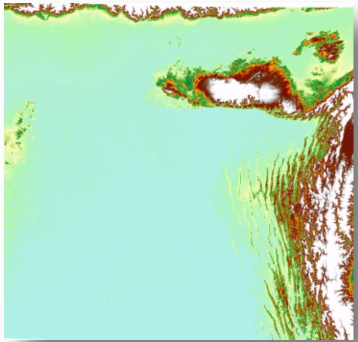
Input data

Flood Masks

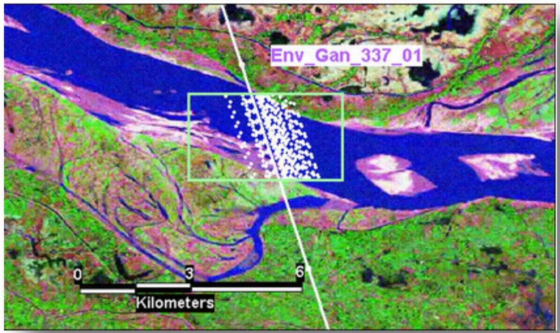
- Sentinel-1 Scenes (SAR-Data) for Pre- & Post-Flooding, time-series
- ENVISAT ASAR



Input data



Digital Elevation Models (DEM)
- SRTM 30 m integer
- SRTM 30 m interpolated to 32-bit float (still height artefacts)
- TanDEM-X 30 m 32-bit float (Proposal submitted)

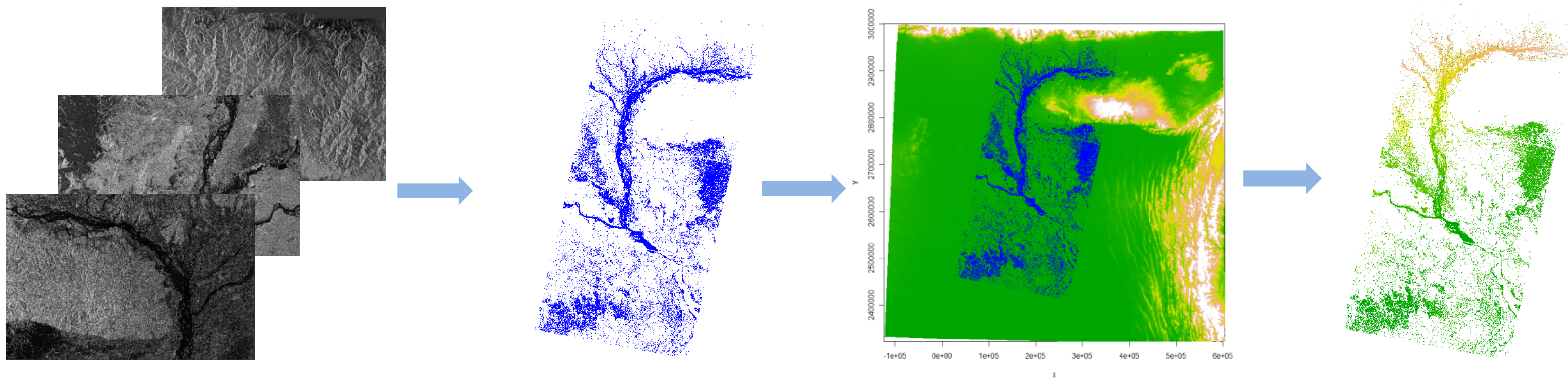


www.legos.obs-mip.fr

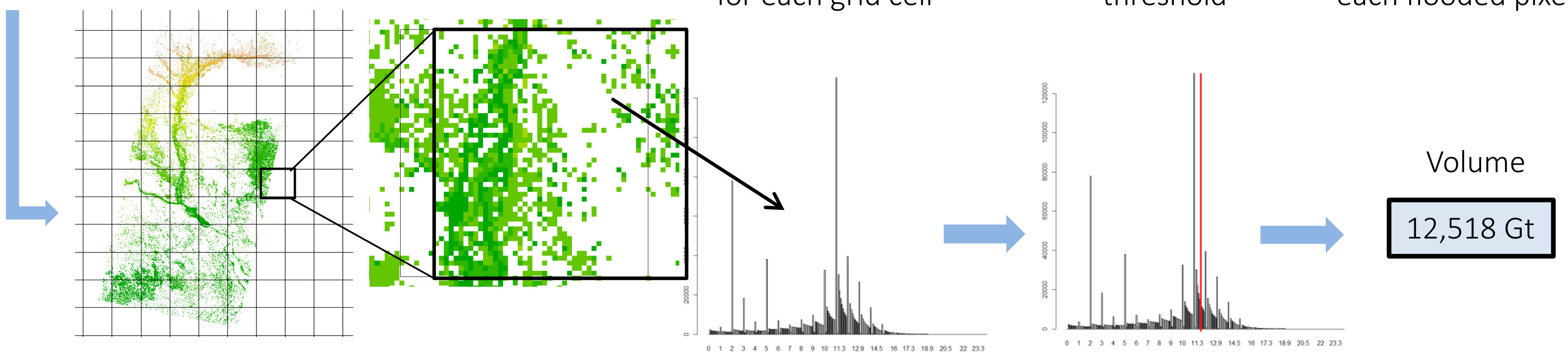
Gauge Validation Data
- Water level data for automatic in situ stations from the Bangladesh Water Development Board (BWDB)
- Altimeter data from Jason-2 for virtual gauges

Workflow

Pre-Processing of Sentinel-1 Scenes → Water classification Sentinel-1 Flood Processor (ZKI) → Clip DEM with water mask → Only height information for flooded pixels remains

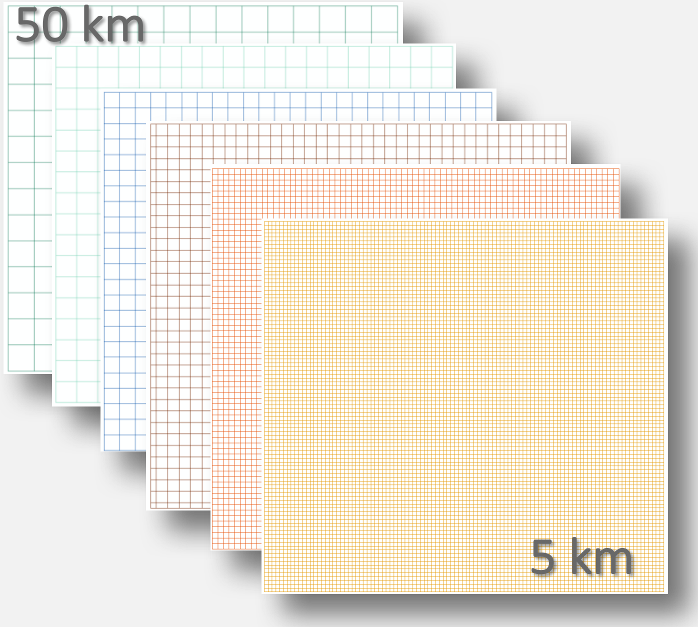


overlay with grid → create histogram for each grid cell → Apply individual threshold → sum of the volume of each flooded pixel

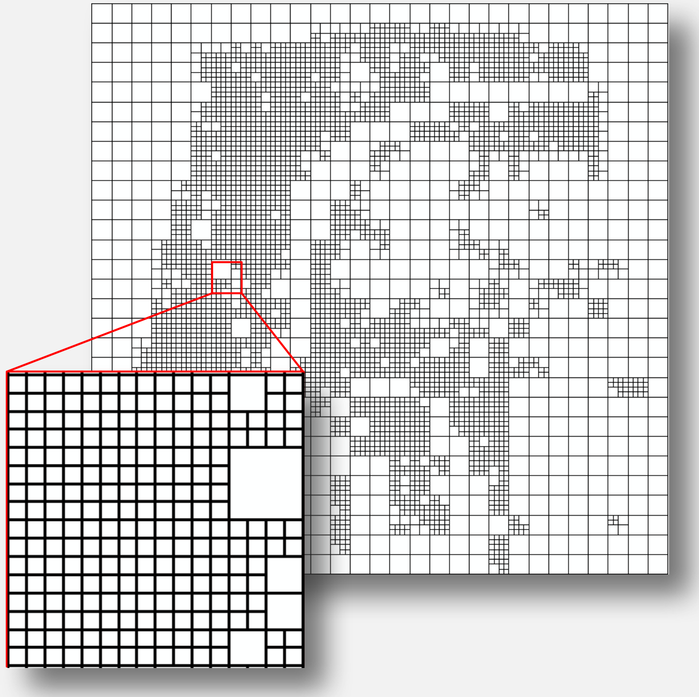


Raster approach

Classic Fishnet
with different cellsizes



Sub-Tiles
created by slope-dependent threshold



Threshold I
apprupt change

Histogram for one grid cell

DEM values
=> height information

	07.09.07
	Gan_524
	OID_3909
1	0
2	0
3	2000
4	3111
5	3046
6	198
7	139
8	439
9	285
10	371
11	673
12	320
13	354
14	355
15	377
16	341
17	184
18	279
19	63
20	27
21	28
22	15
23	10

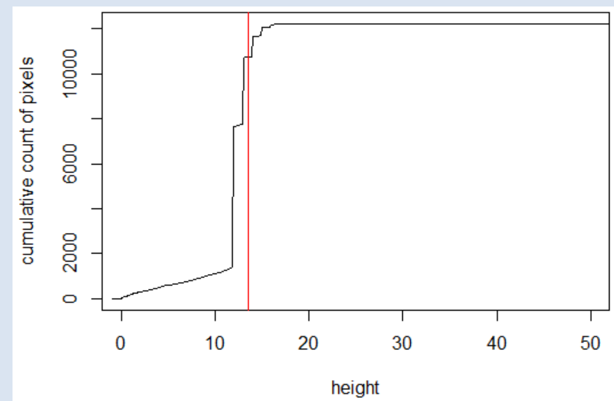
WATER

EXCLUDED PIXELS

get the point of drastic change => **Water height is 5 m**

Threshold II
cummulative

1. Sum up the pixel counts of the histogram
2. Set threshold until pixels are included
3. **70 %** of pixels is a good value



=> Still not appropriate for all grid cells

Threshold I
appruprt change

Histogram for one grid cell

DEM values
=> height information

	07.09.07
	Gan_524
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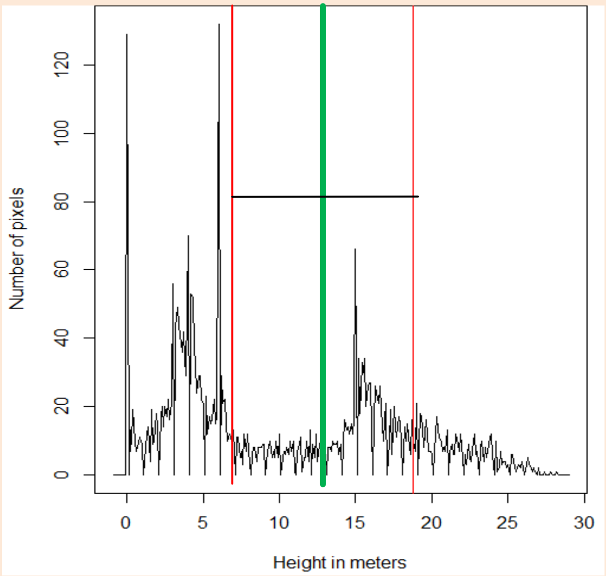
WATER

EXCLUDED PIXELS

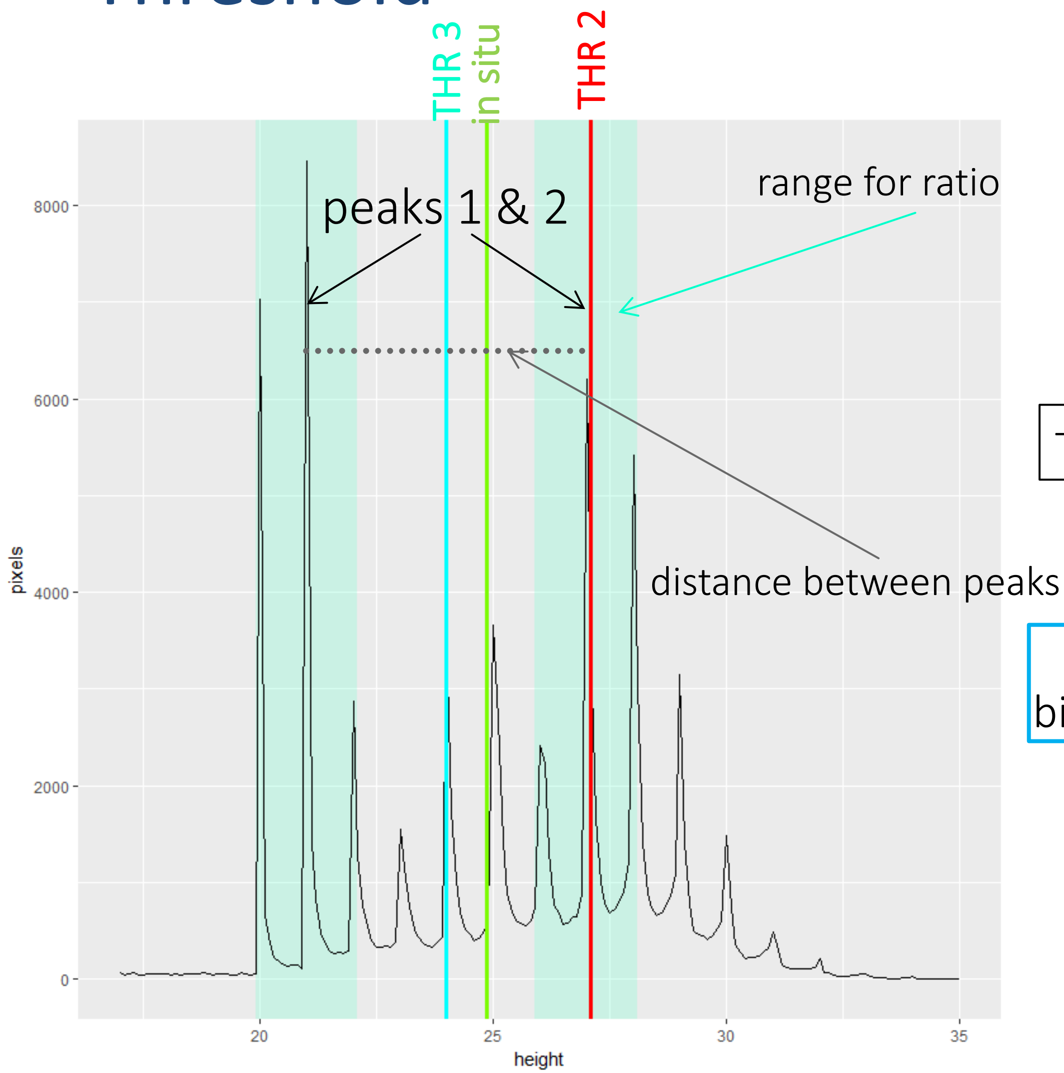
get the point of drastic change
=> **Water height is 5 m**

Threshold III
advancement of THR 2

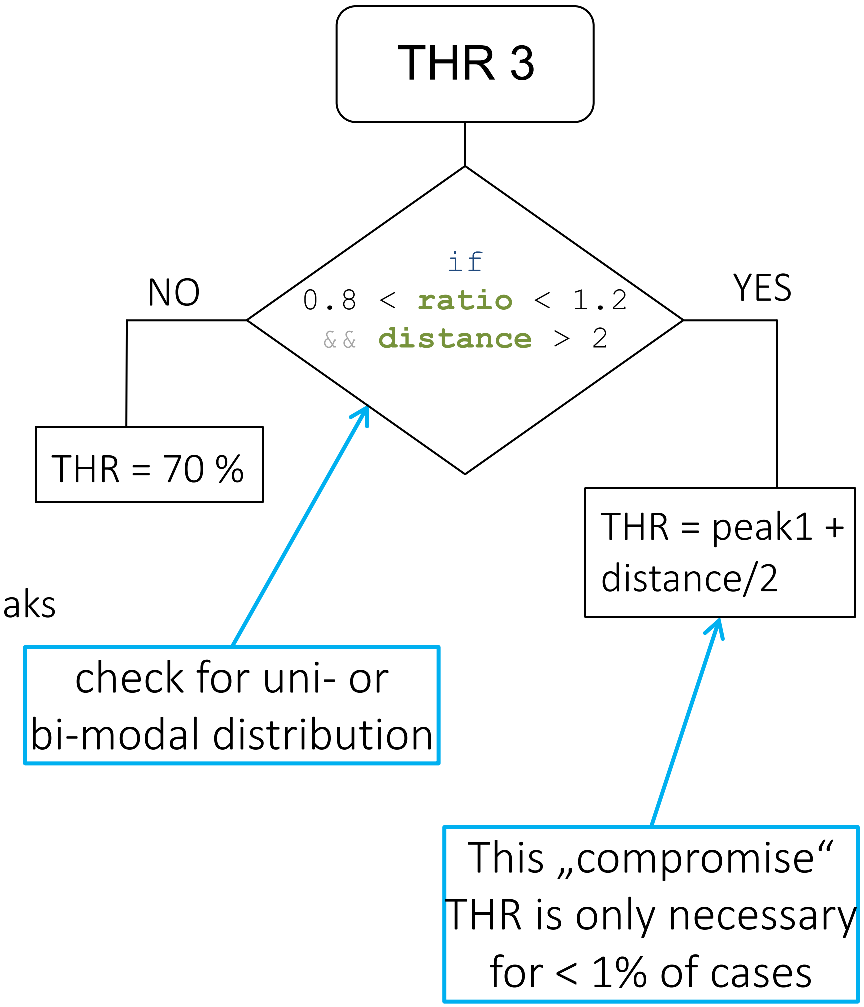
Difficulty to handle bi-modal distributions
⇒ Actually two thr's needed
Compromise for lower level



Threshold



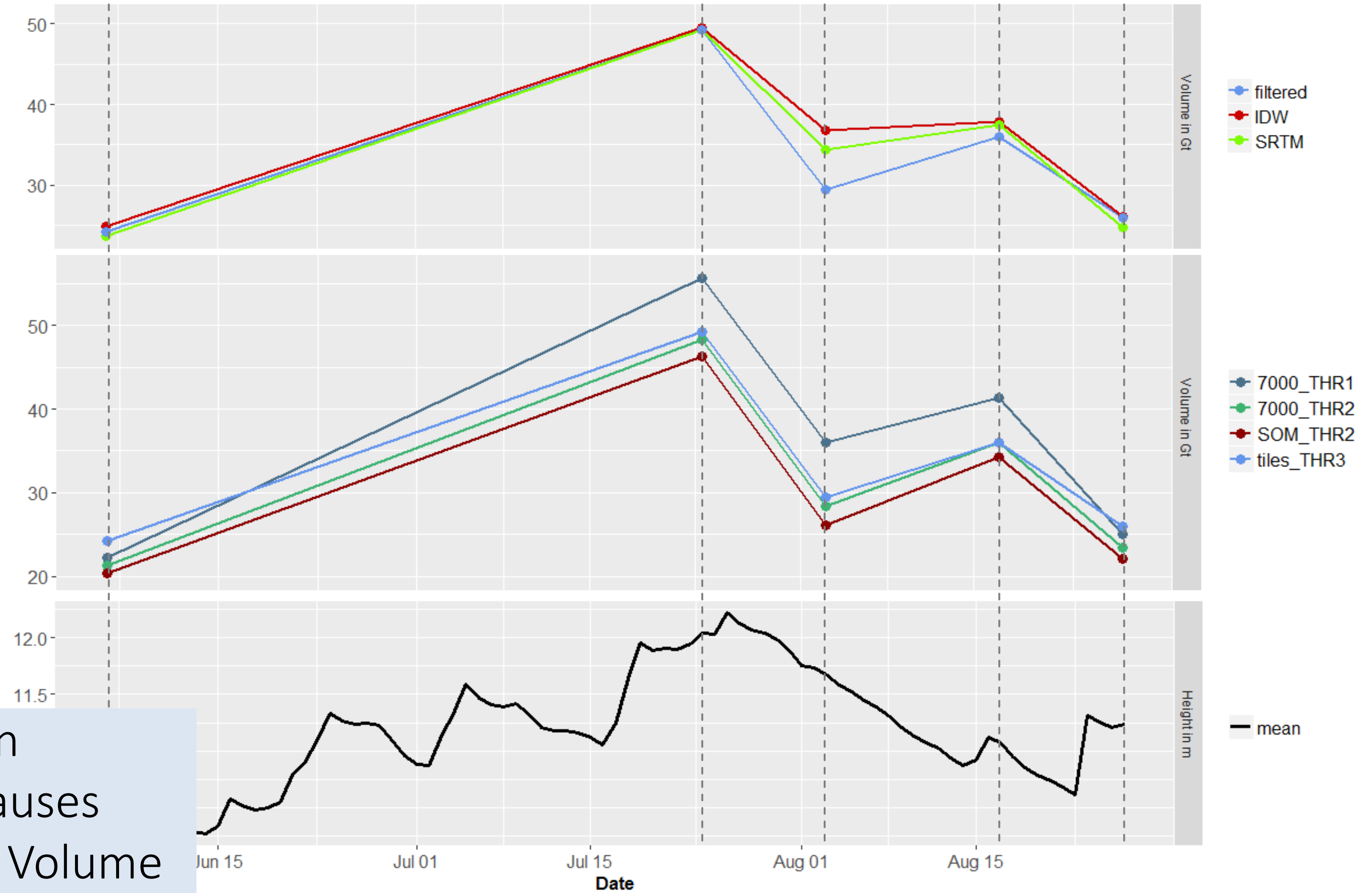
THR 3
in situ
THR 2
peaks 1 & 2
range for ratio
distance between peaks
pixels
8000
6000
4000
2000
0
20
25
30
35
height



THR 3
if
0.8 < ratio < 1.2
&& distance > 2
NO
YES
THR = 70 %
THR = peak1 + distance/2
check for uni- or bi-modal distribution
This „compromise“ THR is only necessary for < 1% of cases

Results

Calculated volumes compared to the mean of water level gauge measurements

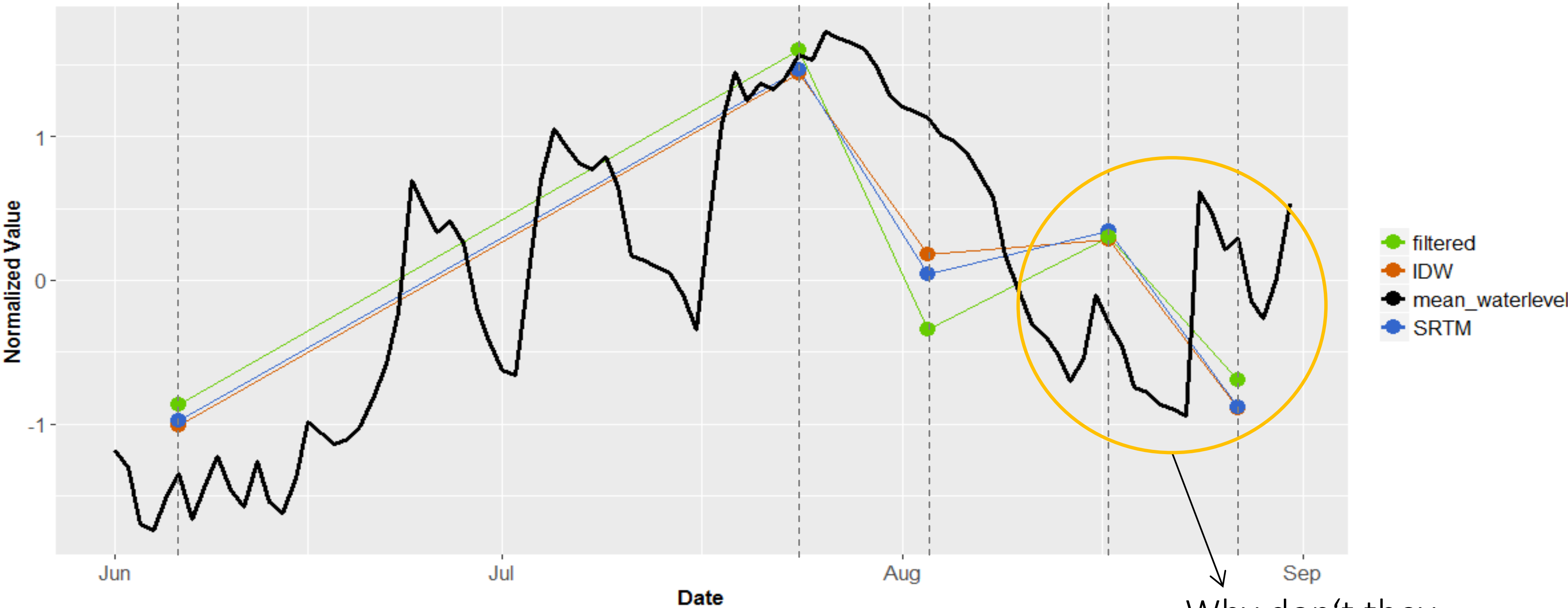


=> Impact of choosen threshold and grid causes higher differences in Volume than the impact of the DEM

Discussion

Normalized volumes & mean water levels

For comparison, the mean value of seven water level gauges in Bangladesh is displayed.



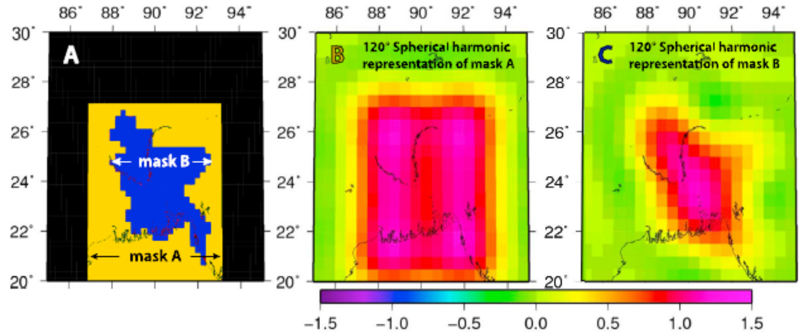
Why don‘t they match with the gauge measurement?

Uncertainties

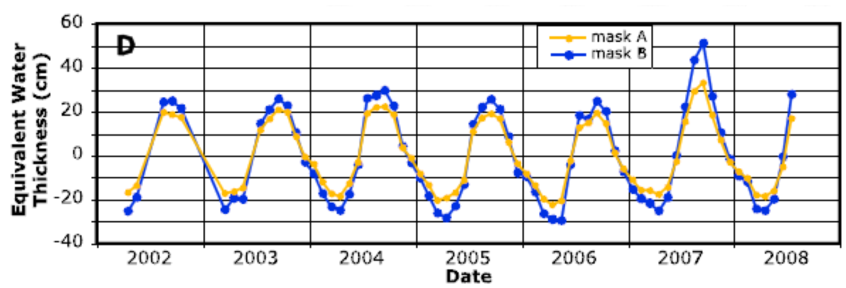
- Inaccurately orthorectified imagery
- Errors in the DEM (*absolute* ***vertical accuracy is better than 9 m)***
- Errors in the gauge measurements
- Inaccuracy of the altimeter measurements (especially over rivers)
- Comparison from point to area values
- Wrong threshold/ grid size
- Inaccuracy in the correction for the same geoid/ellipsoid, ground lowering/deformation(STECKER et al. 2010)
- Zero of mean sea level of the gauge in Calcutta
- Inaccuracy of in situ water level measurements (but rather cm than meters)
- Time shift in gauge measurement and aquisiton of SAR scene
- Change in elevation of river bed -> braided river!
- ……

Reference Study

Mask used for volume estimations with GRACE



Relative change in water thickness



<u>**Comparing results :**</u>

STECKER et al. (2010:10):

„Both sets of data indicate that in an average year just over 100 GT of water is stored within Bangladesh. The Storage can reach 150 GT during exeptional floods…“

⇒ Up to 50 Gt are stored due to flooding

⇒ Results show 45 to 55 Gt of flood volumes depending on DEM and THR

⇒ still accuracy in range of Gt is not accurate enough!

Conclusions

- So far, it is possible to calculate inundation depth to an **accuracy of ≈2 m** compared to water level measurements
- The volume estimations fit to the results of other values in literature in a range of Gt
  - the **kind and size of a grid** has highly influences the results => a dynamic fishnet grid derived best results
  - **THR 3 delivered best results** as it can handle bi-modal distributions
  - Different DEMs deliver different results, full magnitude will be defined by TanDEM-X data
- The volume estimation is automated, as the script is fully automatic