EGSIEM

European Gravity Service for Improved Emergency Management

WP6: An automated approach to estimate flood volumes based on SAR data and DEMs – final results

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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 (3D) 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)

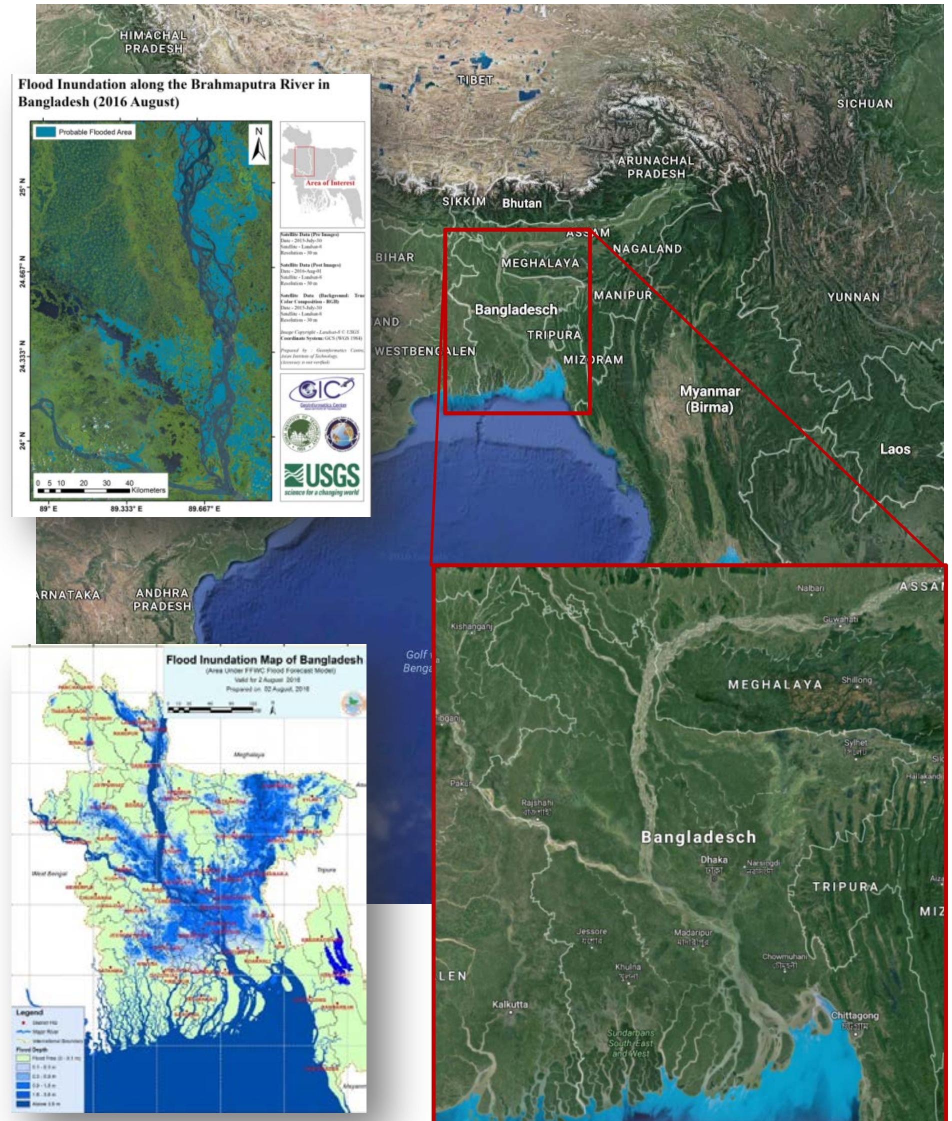
Study Area: Bangladesh

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

Selected Event:

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

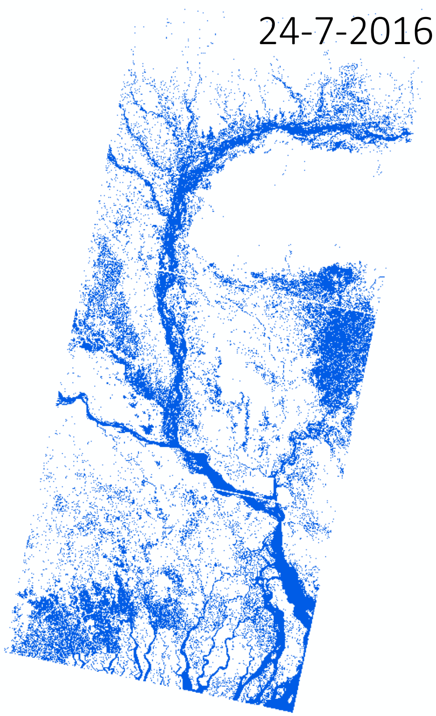


Input data

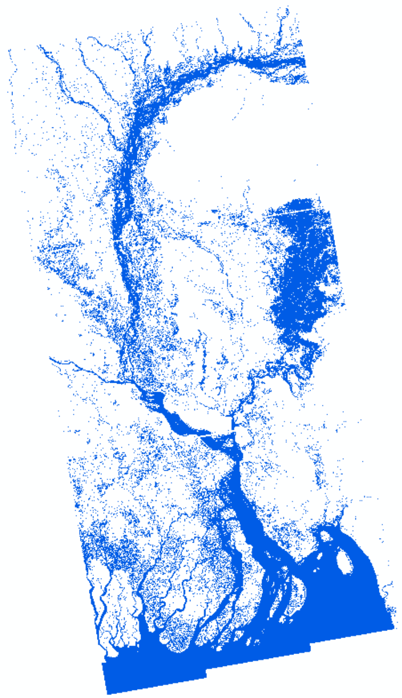
Flood Masks

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

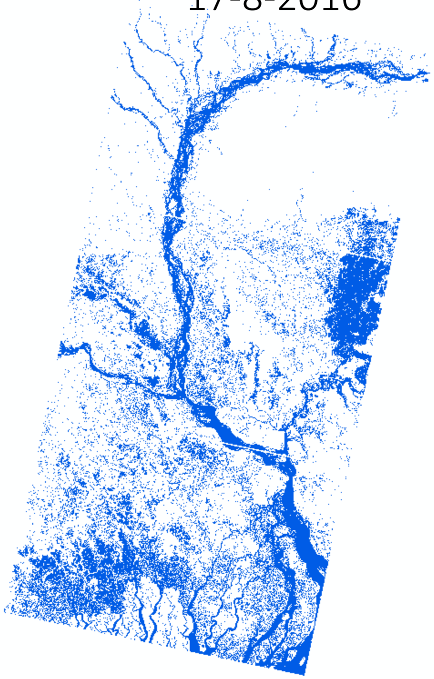
Pre-Flood
24-7-2016



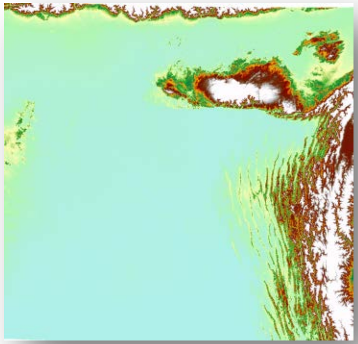
Post-Flood
03-8-2016



Post-Flood
17-8-2016

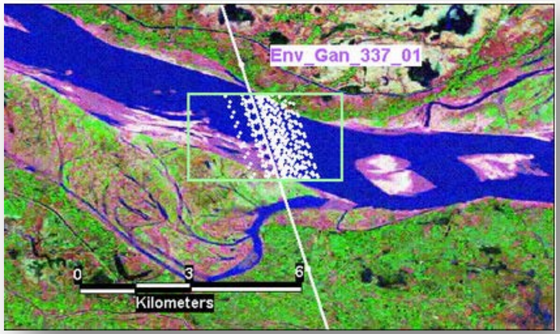


Input data



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)

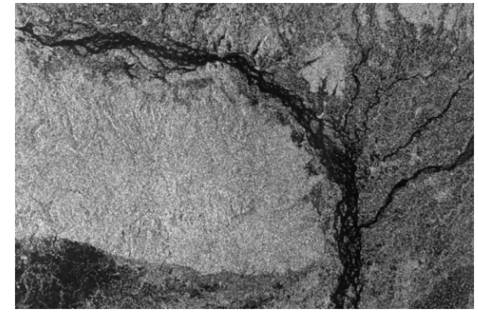


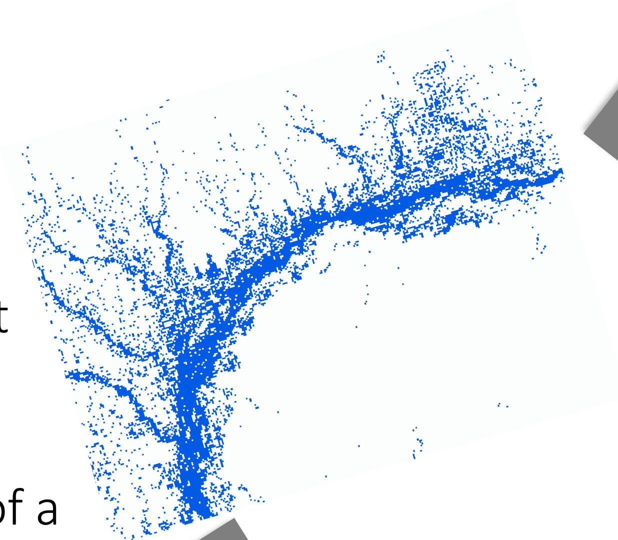
www.legos.obs-mip.fr

Gauge Validation Data

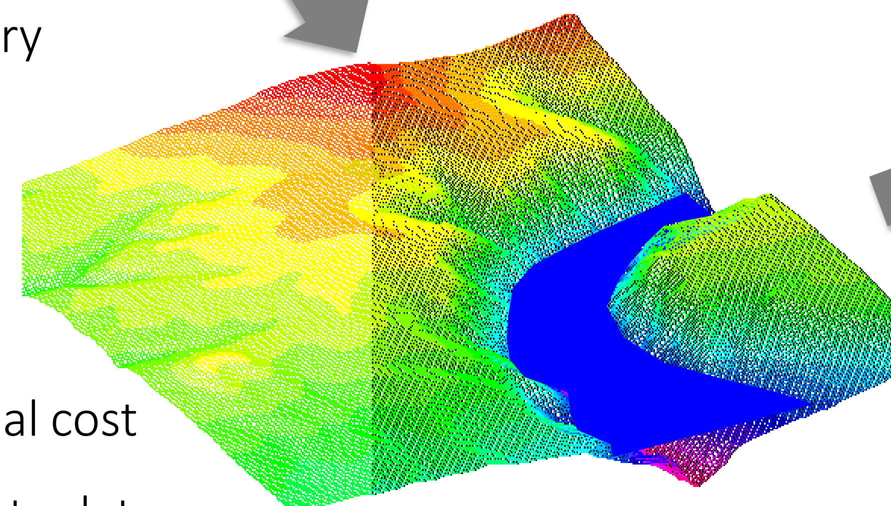
- Water level data for automatic in situ stations from the Bangladesh Water Development Board (BWDB)
- Altimeter data from Jason-2 for virtual gauges

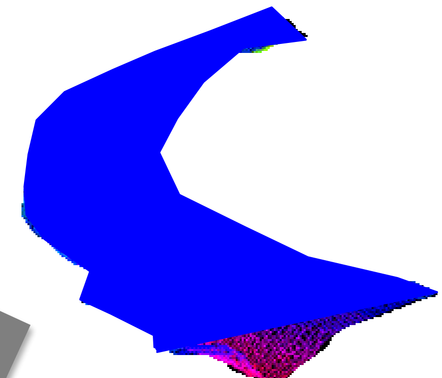
Method





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

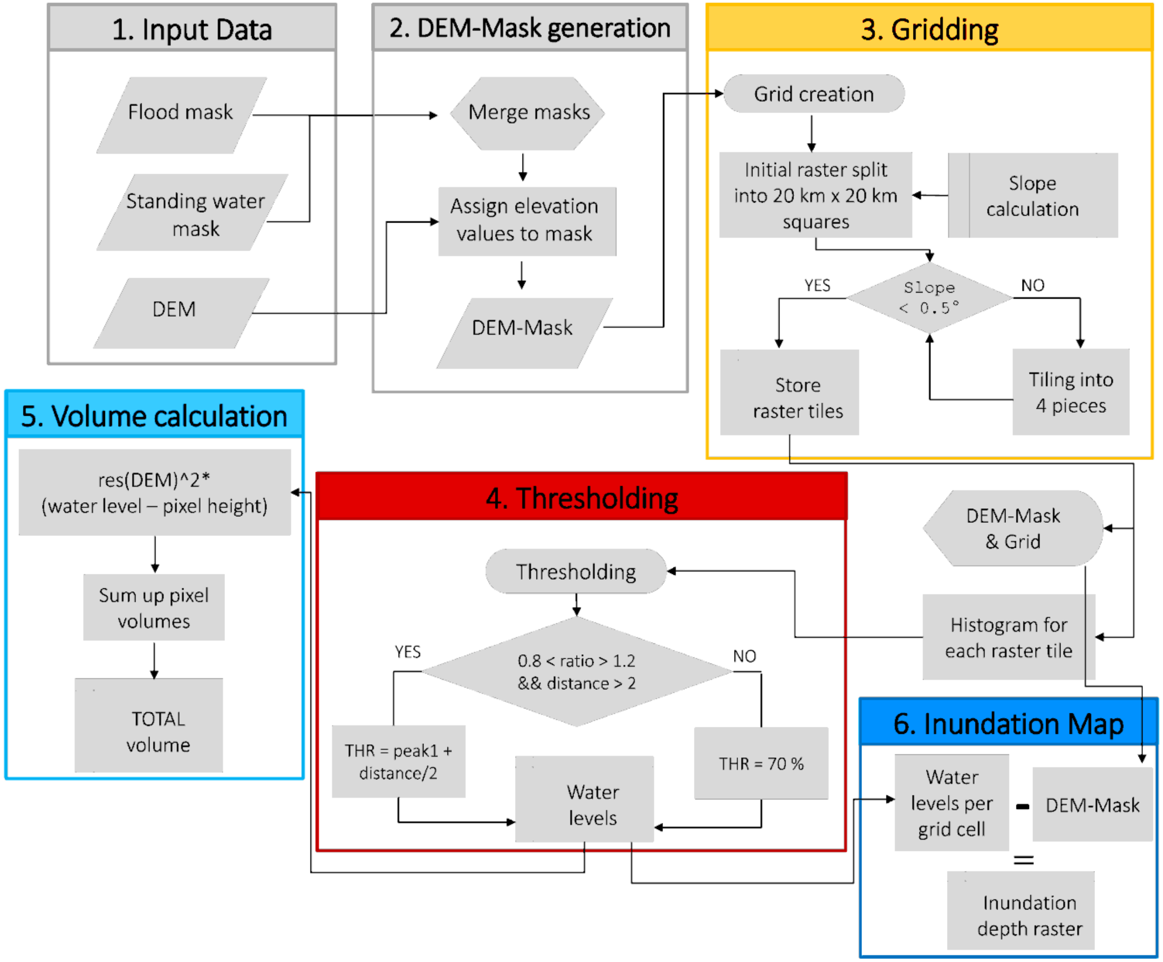




<u>Important criteria:</u>

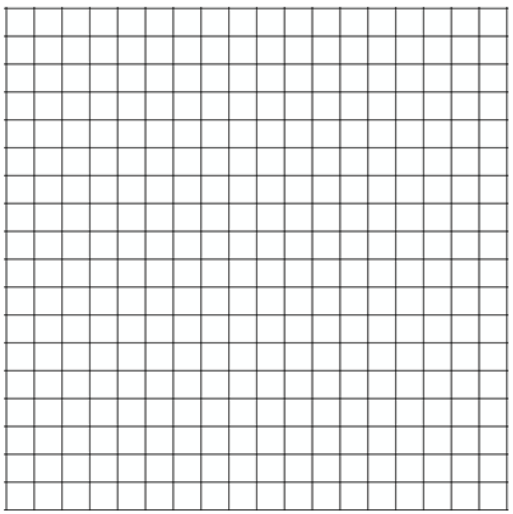
- low computational cost
- usage of up to date data

Workflow

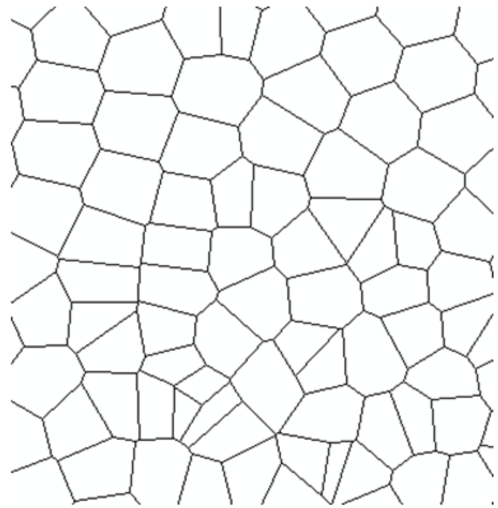

1. Input Data
Flood mask
Standing water mask
DEM
2. DEM-Mask generation
Merge masks
Assign elevation values to mask
DEM-Mask
3. Gridding
Grid creation
Initial raster split into 20 km x 20 km squares
Slope calculation
YES
Slope < 0.5°
NO
Store raster tiles
Tiling into 4 pieces
5. Volume calculation
res(DEM)^2* (water level – pixel height)
Sum up pixel volumes
TOTAL volume
4. Thresholding
Thresholding
YES
0.8 < ratio > 1.2 && distance > 2
NO
THR = peak1 + distance/2
THR = 70 %
Water levels
DEM-Mask & Grid
Histogram for each raster tile
6. Inundation Map
Water levels per grid cell
-
DEM-Mask
=
Inundation depth raster

Raster approach

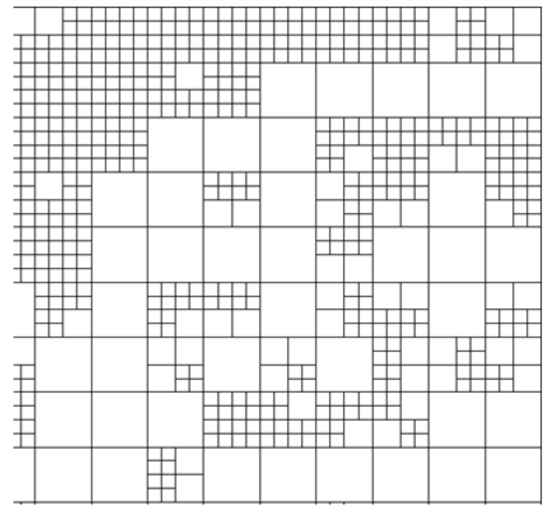
FISHNET



SOM



DYNAMIC FISHNET

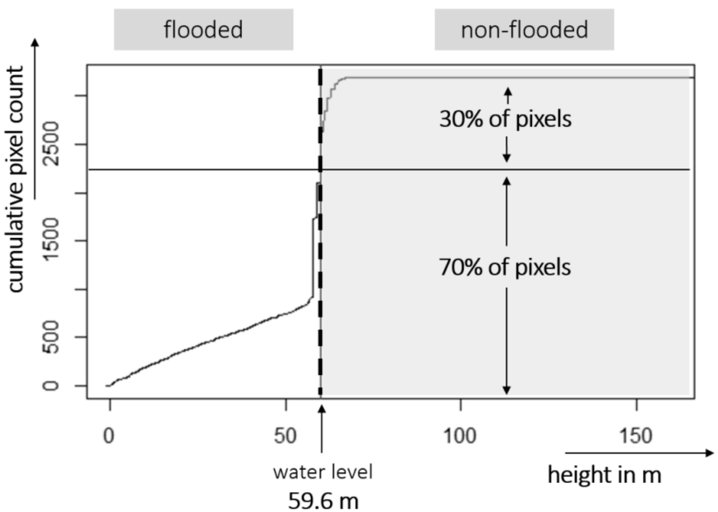


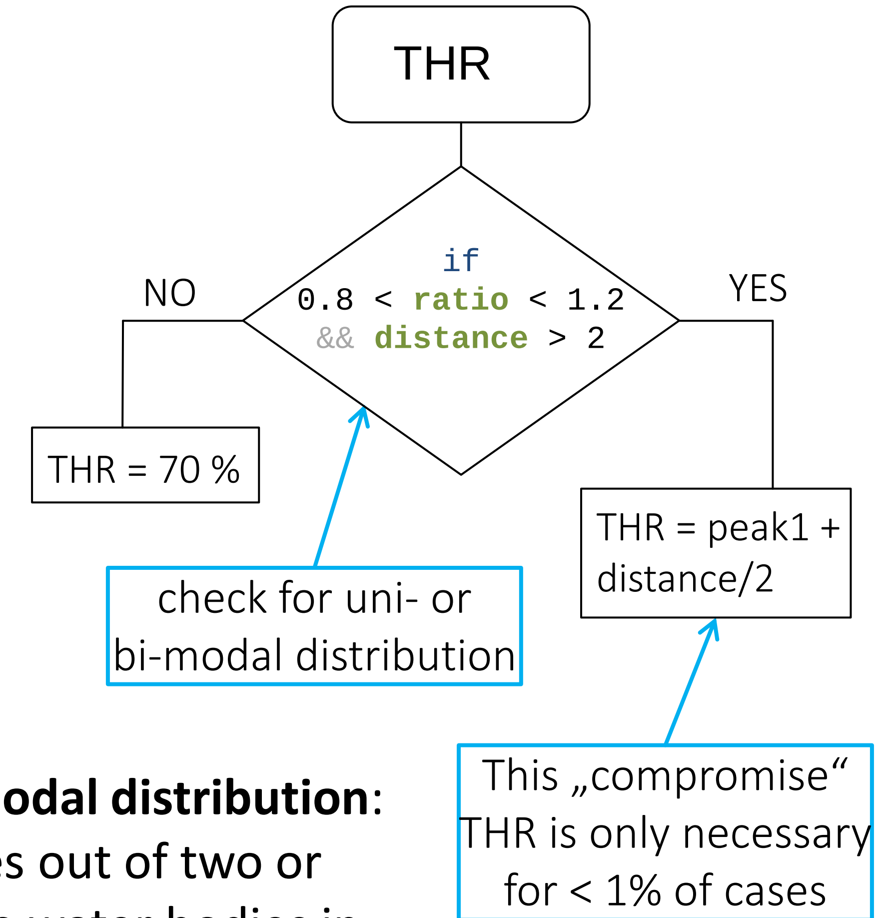
Static fishnet with different grid cell sizes (5- 50 km)

Self-Organizing Map (SOM): a dynamic approach of a net gridded on the basis of similar height values

Dynamic fishnet forming grids based on further tiling (5-20 km) according to the slope of the terrain

Threshold

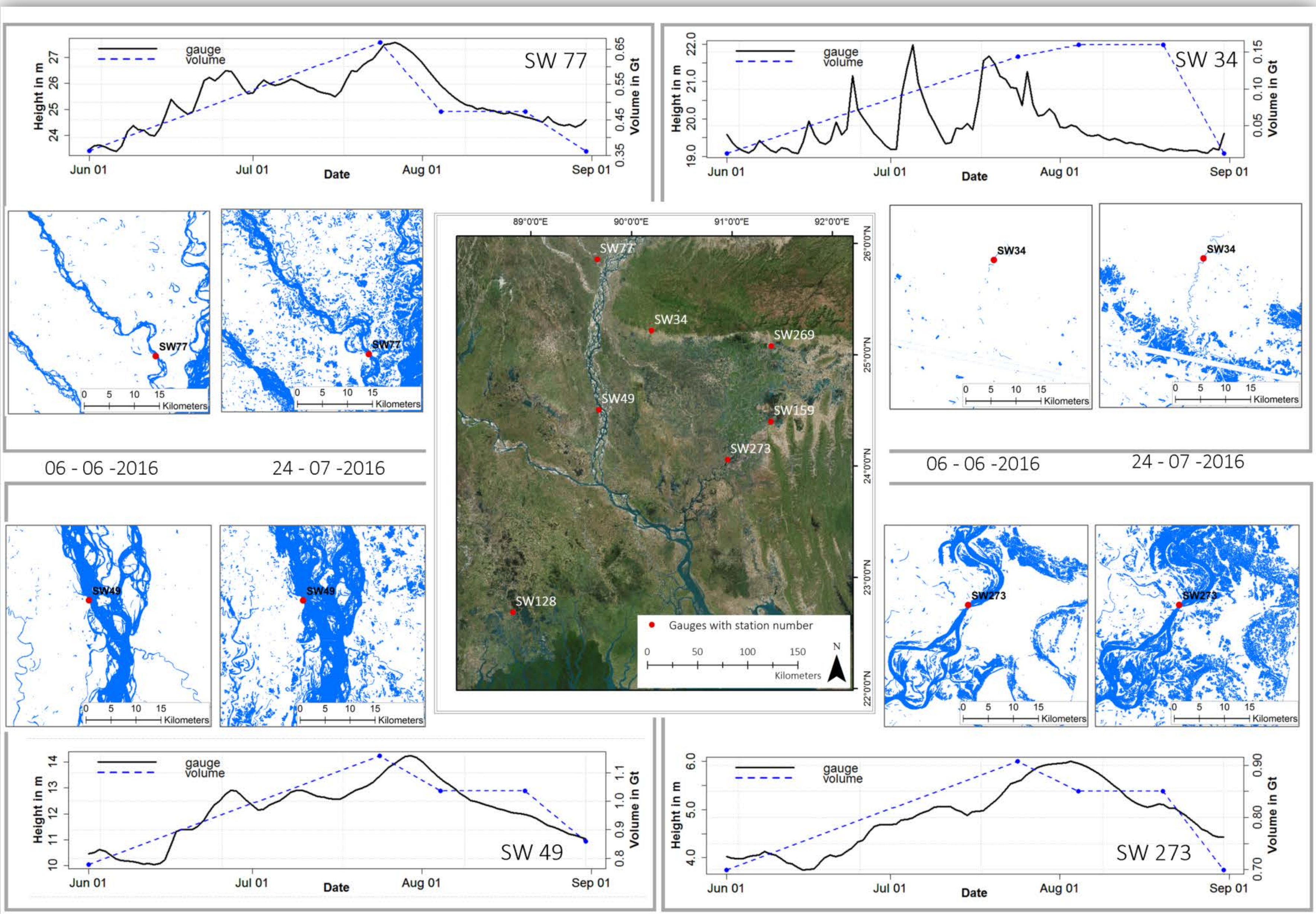




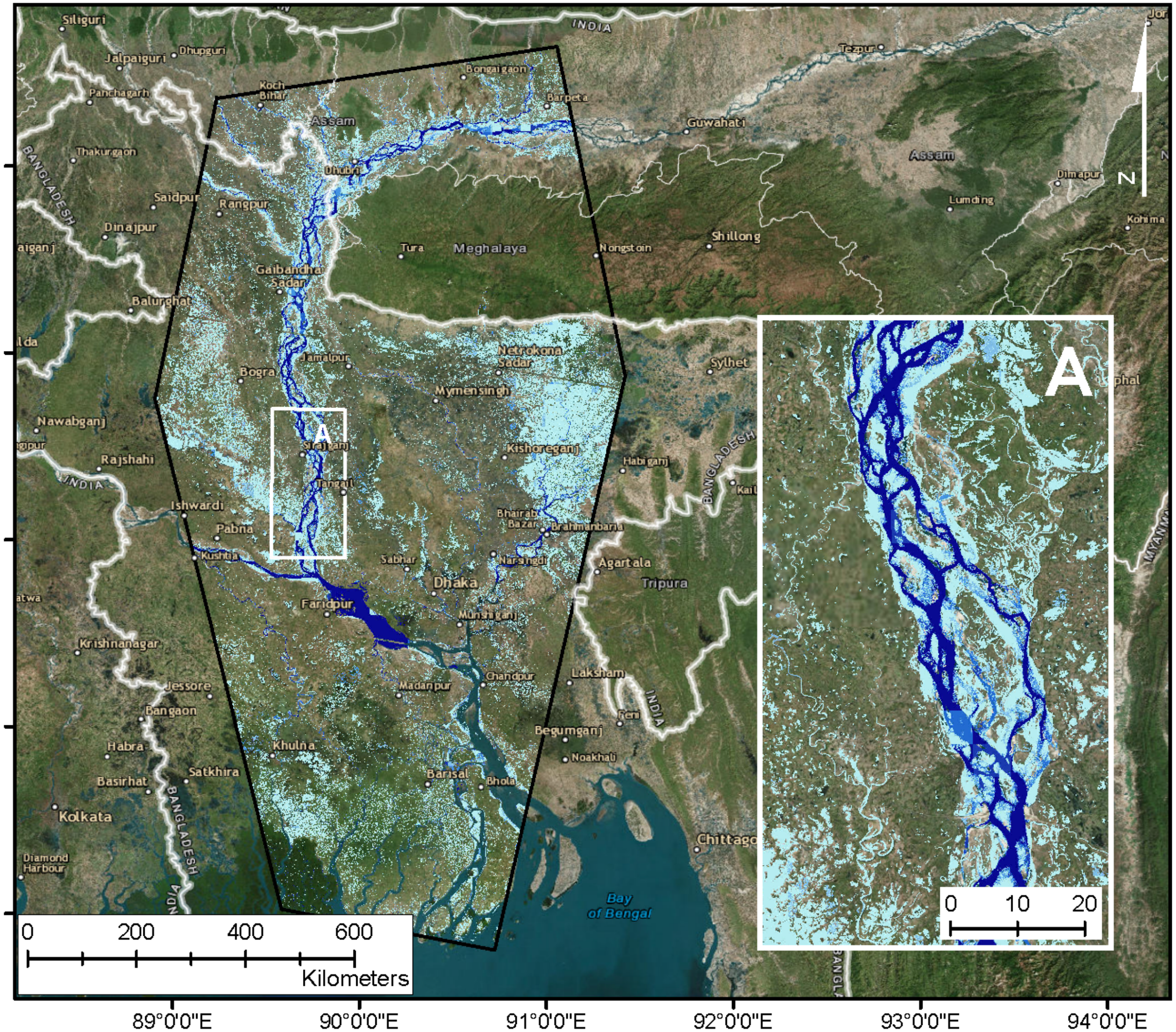
Optimal water level calculation with **uni-modal distribution**:

➔ empirical threshold: 70 % of the cumulative pixel sum

bi-modal distribution: arises out of two or more water bodies in one grid cell


SW 77
gauge
volume
Height in m
Volume in Gt
Date
Jun 01
Jul 01
Aug 01
Sep 01
SW 34
SW 49
SW 273
06 - 06 -2016
24 - 07 -2016
SW77
SW34
SW269
SW49
SW159
SW273
SW128
89°0'0"E
90°0'0"E
91°0'0"E
92°0'0"E
26°0'0"N
25°0'0"N
24°0'0"N
23°0'0"N
22°0'0"N
Gauges with station number
0 50 100 150
Kilometers
N
0 5 10 15
Kilometers

FLOOD VOLUME & INUNDATION DEPTH IN BANGLADESH - Estimtated for 24/07/2016



Estimated flood volume for the entire area: 40.13 Gt

Data Source:
Watermask: derived from Sentinel-1
Digital Elevation Model: SRTM 30 m

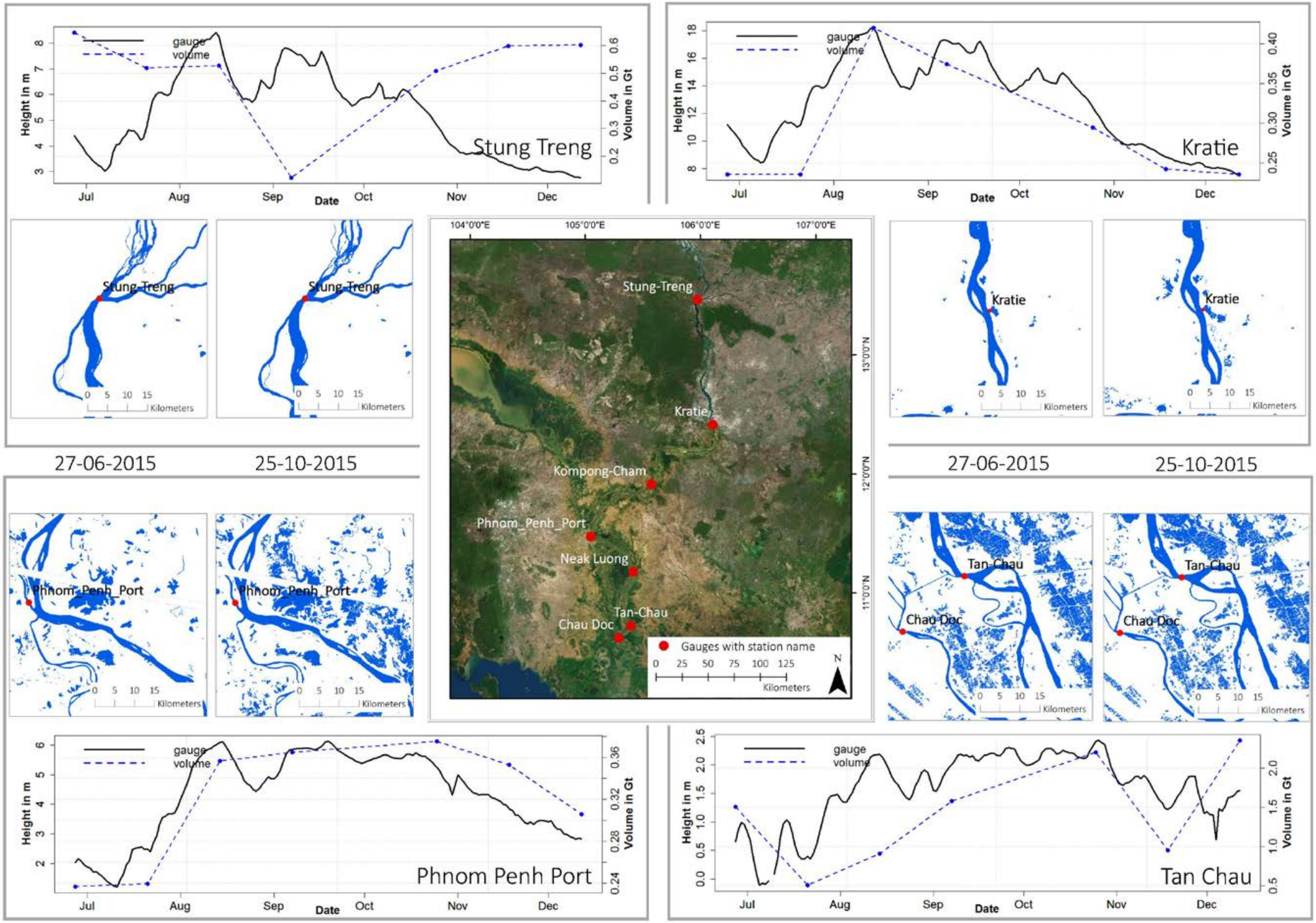
Local Projection UTM Zone 46N
Datum: WGS84
Vertical Geoid Reference: EGM96
Scale: 1:3 000 000
Author: Celia Baumhoer

Background Map:
ESRI, DigitalGlobe, GeoEye
Service Layer:
ESRI, HERE, OpenStreetMap

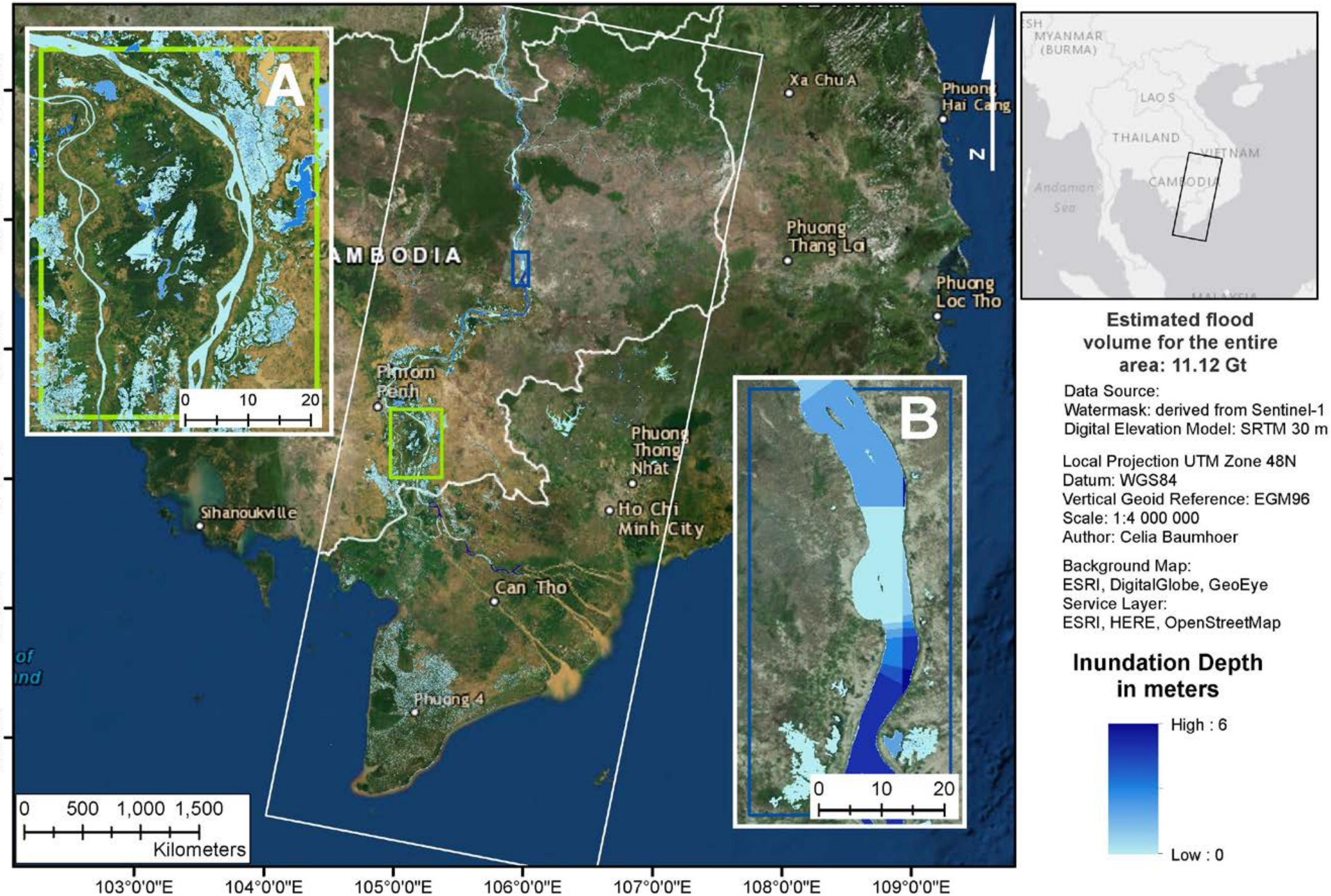
Inundation Depth in meters

High : 5

Low : 0


Stung Treng
Kratie
Phnom Penh Port
Tan Chau
gauge
volume
Height in m
Volume in Gt
Date
Jul
Aug
Sep
Oct
Nov
Dec
27-06-2015
25-10-2015
Stung-Treng
Kratie
Kompong-Cham
Phnom_Penh_Port
Neak Luong
Tan-Chau
Chau Doc
Gauges with station name
Kilometers
104°0'0"E
105°0'0"E
106°0'0"E
107°0'0"E
13°0'0"N
12°0'0"N
11°0'0"N

FLOOD VOLUME & INUNDATION DEPTH FOR THE LOWER MEKONG - Estimated for 07/09/2015



Conclusions

- For volume estimates areas with horizontal water surface have to be defined (**TILING/GRIDDING**)
- Dynamic tiling which accounts for **local topography and slope of the water surface** yielded best results
- Static grids did not work because too small sizes do not cover the river banks of the braided river, whereas too big cell sizes overestimate water levels for smaller mountain tributaries
- Applying a **THRESHOLD** works well for **uni-modal distributions**. In case of bi-modal distributions a compromise had to be found to prevent unrealistic estimates of water levels.
- The **vertical resolution of a DEM** is important. Higher accuracy yields much better results. Acquisition date of the DEM as well as the editing for water surfaces has a high influence on the results.

Conclusions

- Best combinations were chosen for each threshold and grid (according to the correlation with in situ water level measurements)
- Uncertainties are lowest for **unimodal THRESHOLD** and **dynamic fishnet grid** (RMSE = 1.73 m for Bangladesh)
- **SRTM DEM** was filtered to reduce the influence of 1-meter steps in the initial SRTM
- Tests with **TanDEM-X DEM** promised even more accurate results, whereas lower resolution flood masks (e.g. ENVISAT-ASAR) gave less accurate results

- **It is possible to estimate flood volumes for large flood plains**
  - **40 Gt for Bangladesh 2016**
  - **11 Gt for Lower Mekong 2015**