EGSIEM

European Gravity Service for Improved Emergency Management

WP6: Flood volume estimation and the use of wetness indicator maps at DLR/ZKI

Sandro Martinis

DLR

EGSIEM Final Review Meeting
University of Bern
8.-9. February 2018

Horizon2020

Objectives

1. Establish a method for **flood volume** estimation for large scale floods based on EO data and DEMs
    1. Higher level product (3D) compared to 2-D flood masks
    2. Can be compared to gravity measurements from space

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

Objectives

1. Establish a method for **flood volume** estimation for large scale floods based on EO data and DEMs
    1. Higher level product (3D) compared to 2-D flood masks
    2. Can be compared to gravity measurements from space

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

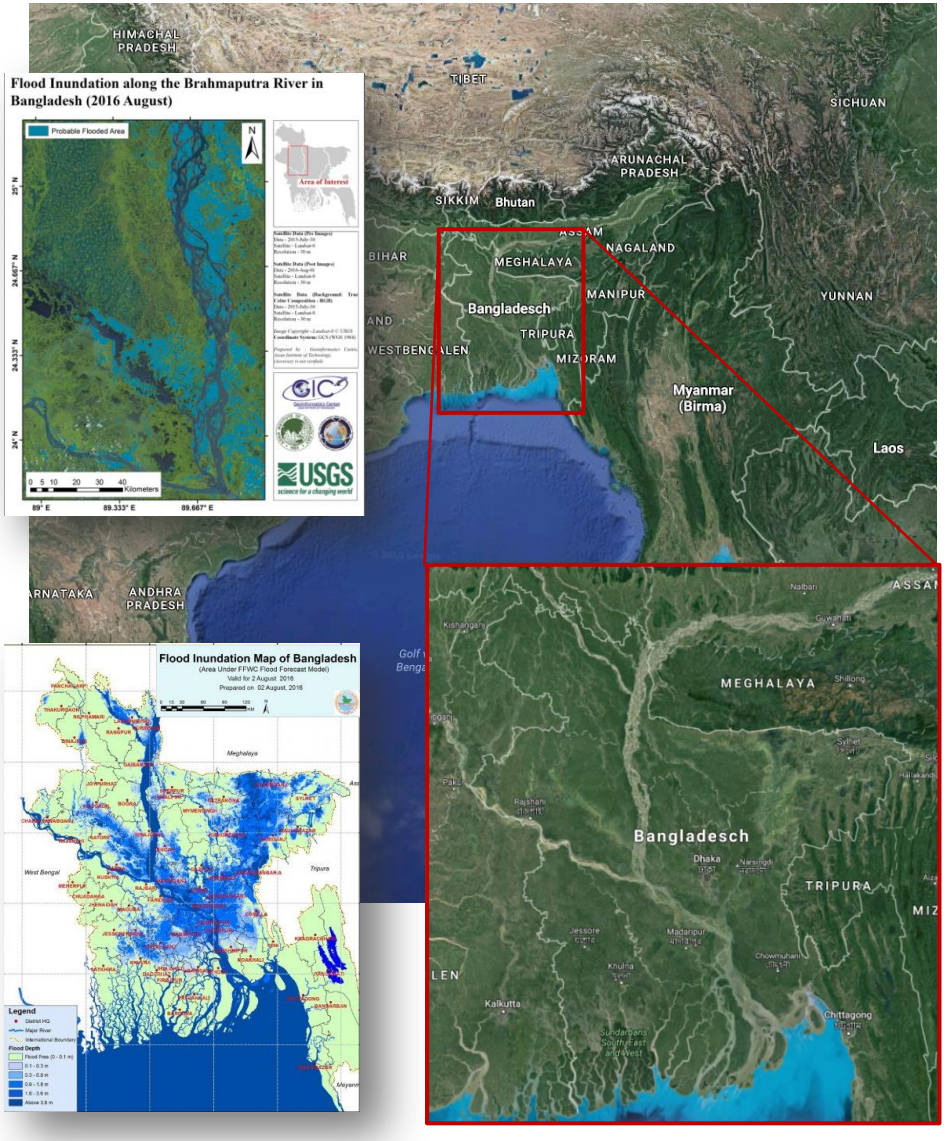
Study Area: Bangladesh

- 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



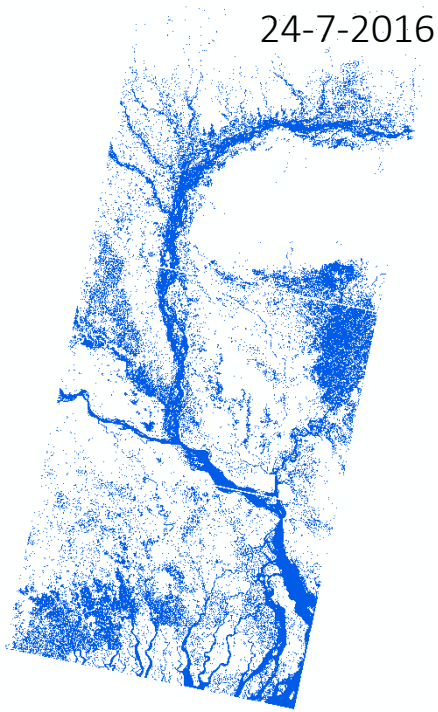
Horizon2020

Input data

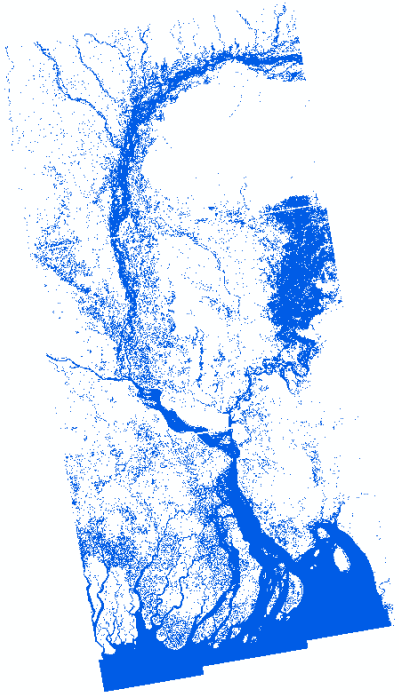
Flood Masks

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

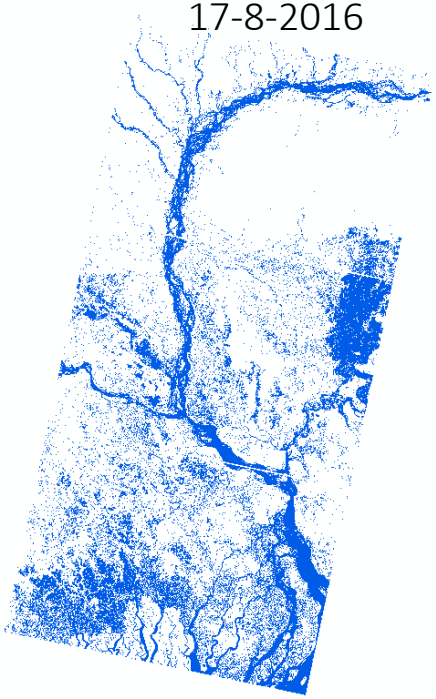
Pre-Flood
24-7-2016



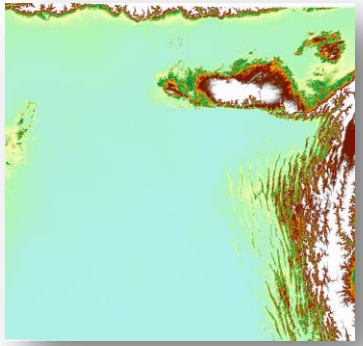
Post-Flood
03-8-2016



Post-Flood
17-8-2016

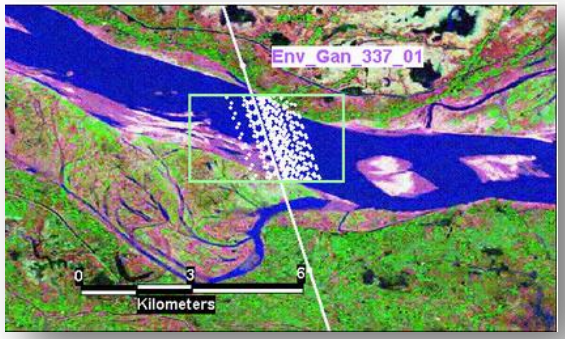


Input data



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)



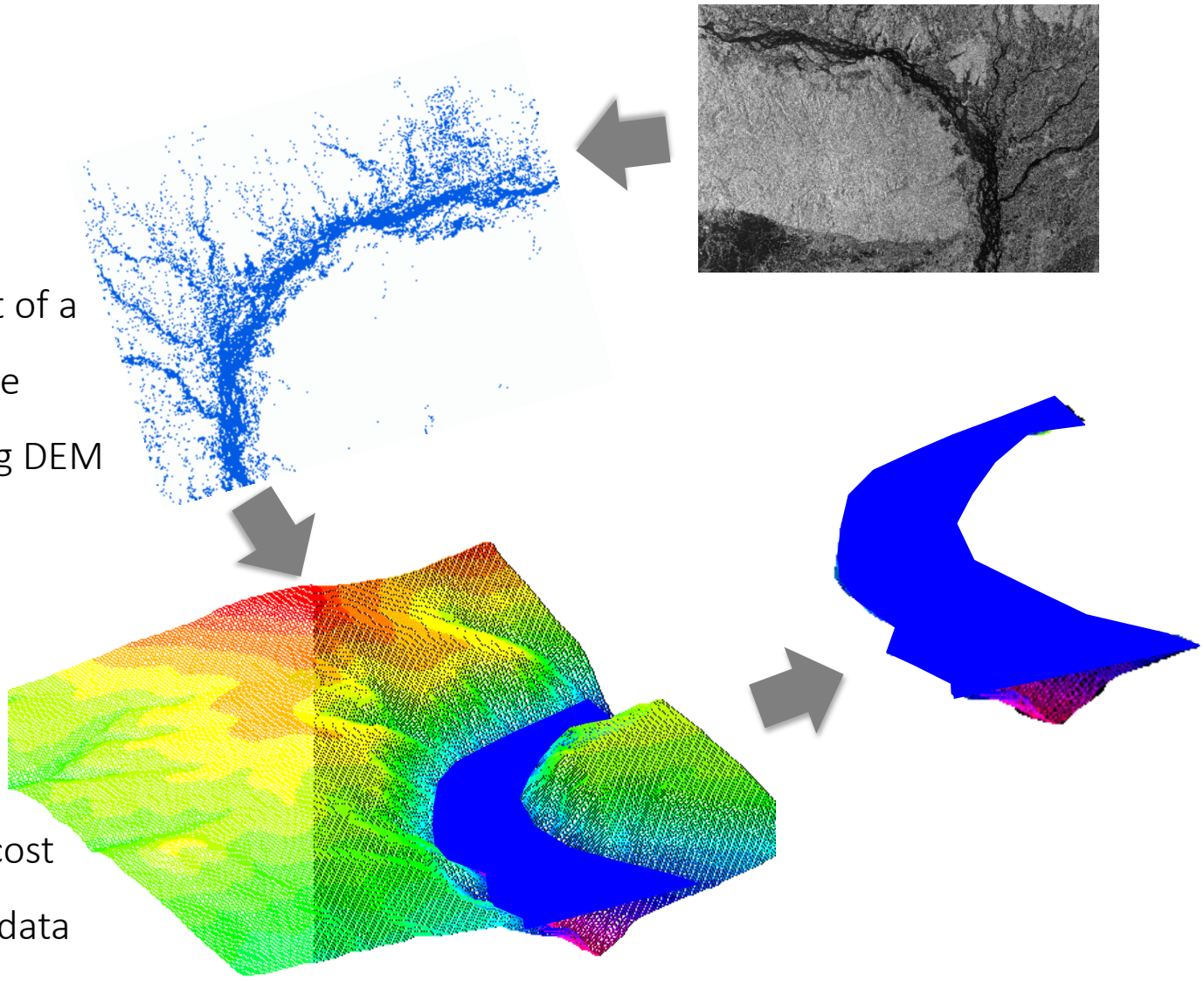
www.legos.obs-mip.fr

Gauge Validation Data

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

Method

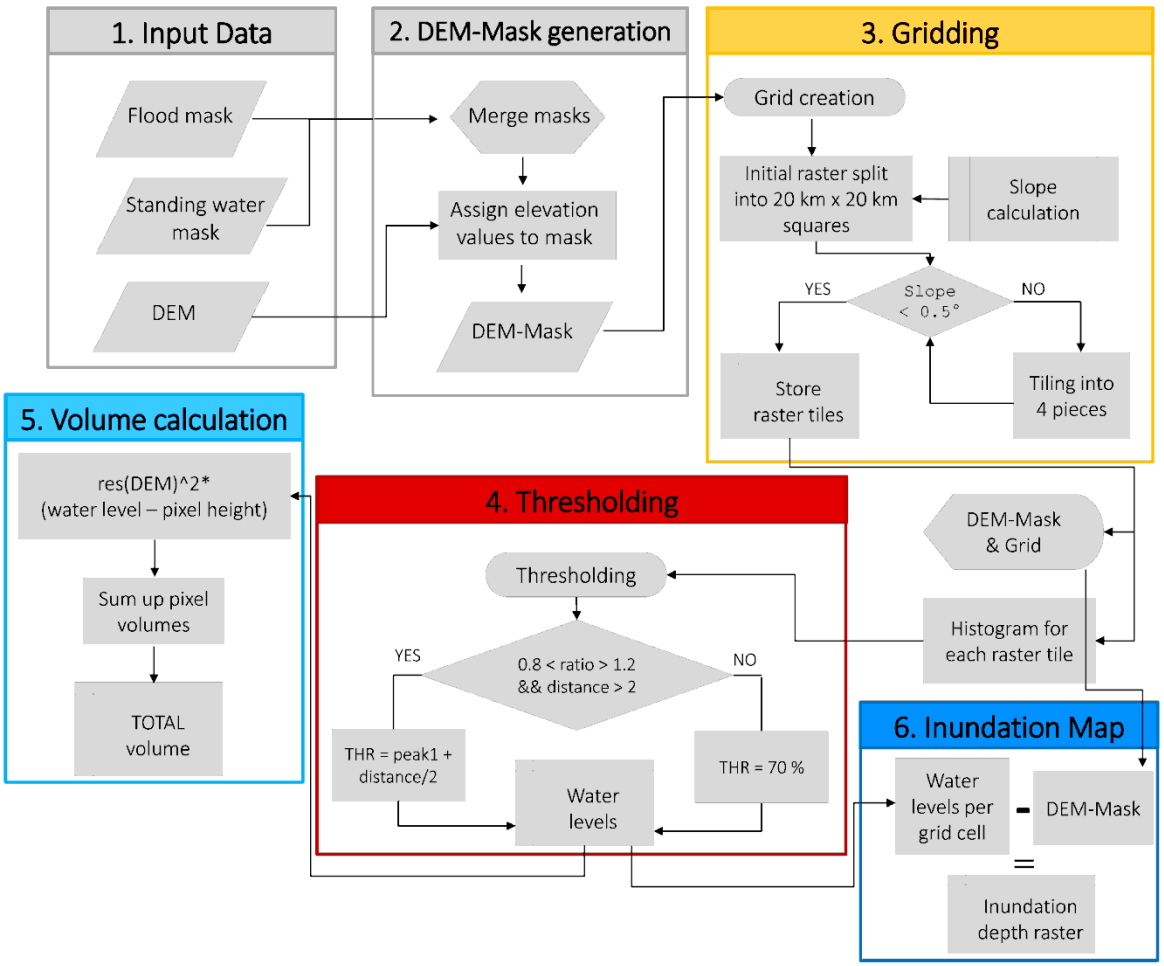
Objective: Development of a method for flood volume estimation by combining DEM and SAR data

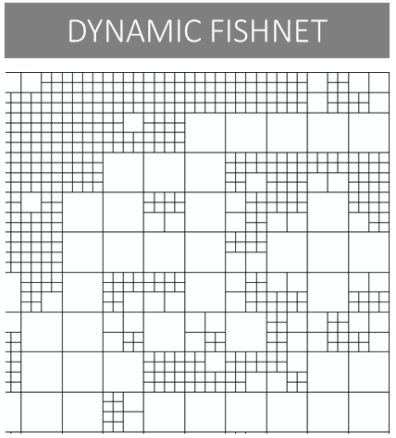


<u>Important criteria:</u>

- low computational cost
- usage of up to date data

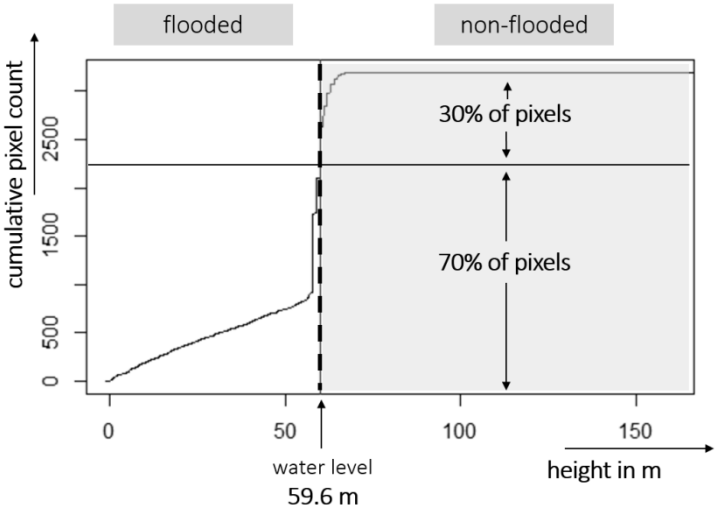
Workflow

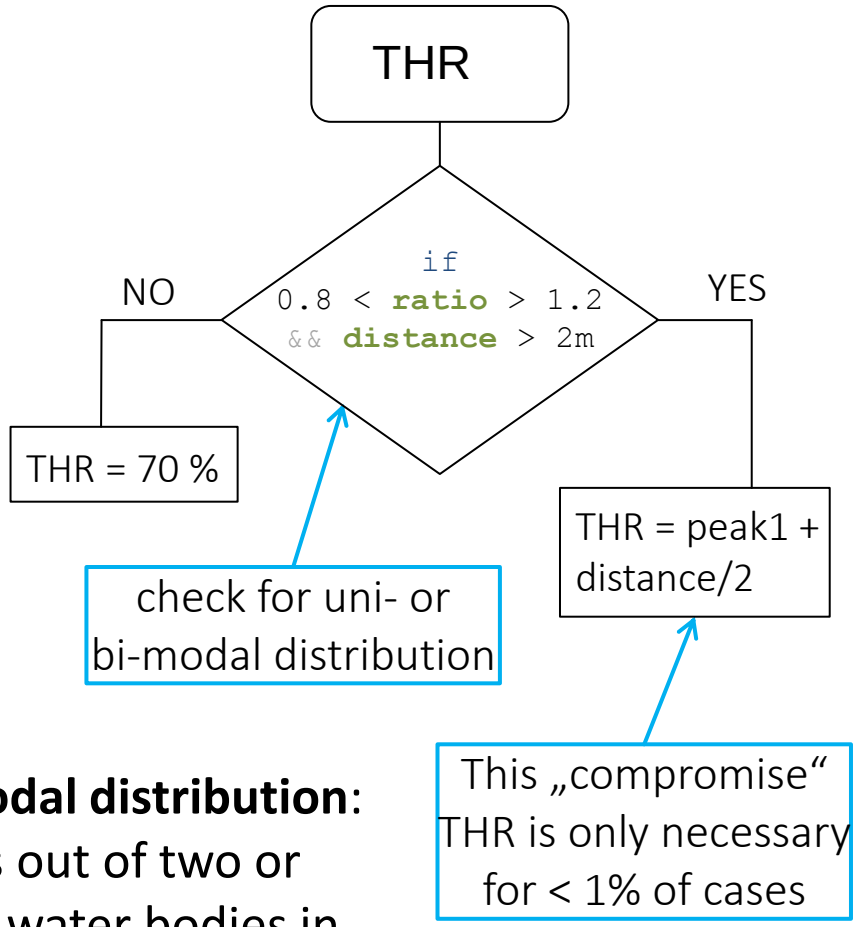




Definition of tiles with nearly horizontal terrain → the grid is initialized with a size of 20*20 km and decreased up to a size of 5*5km according to the slope of the terrain.

Threshold

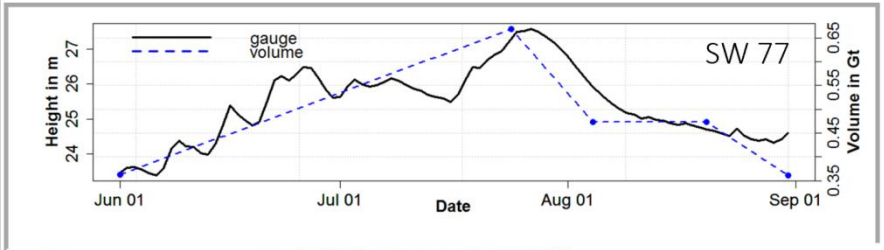


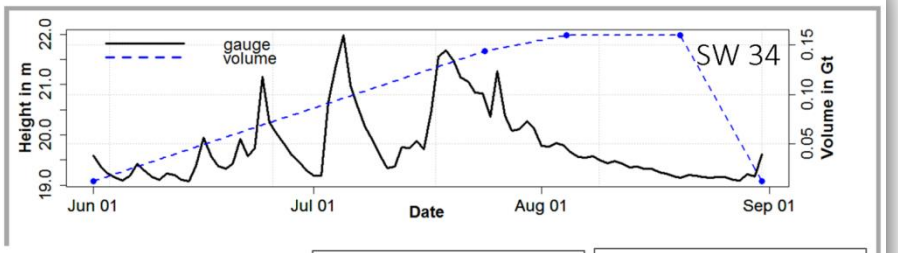


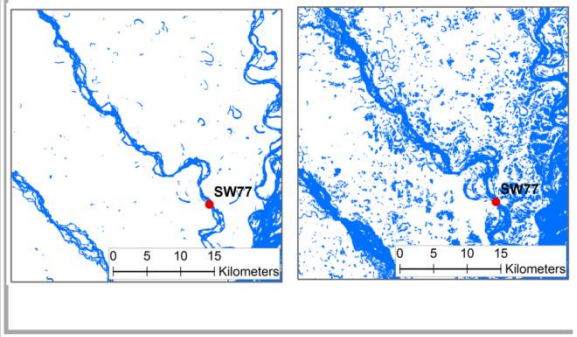
Optimal water level calculation with **uni-modal distribution**:

➔ empirical threshold: elevation below which 70 % of all the flood pixels are situated

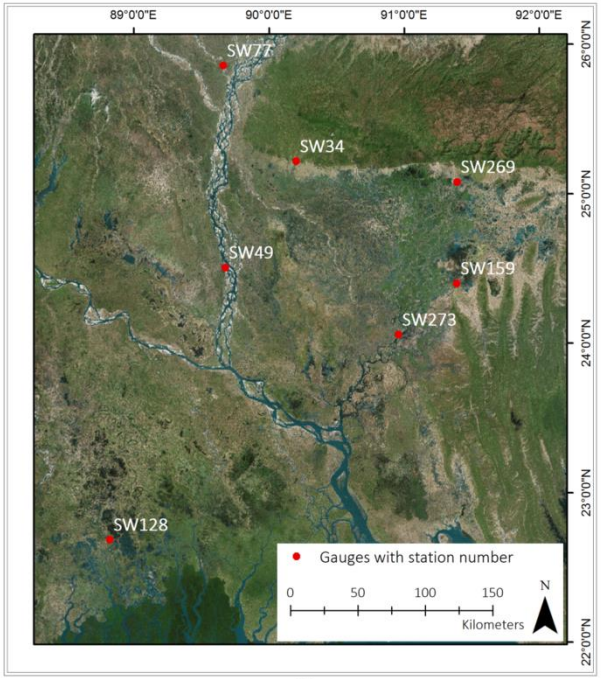
bi-modal distribution: arises out of two or more water bodies in one grid cell

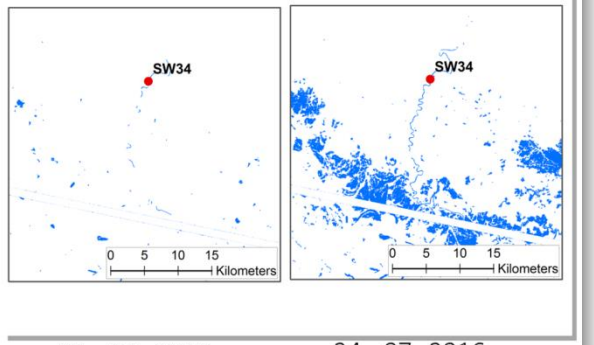




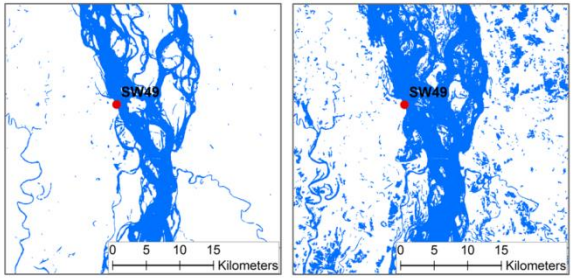


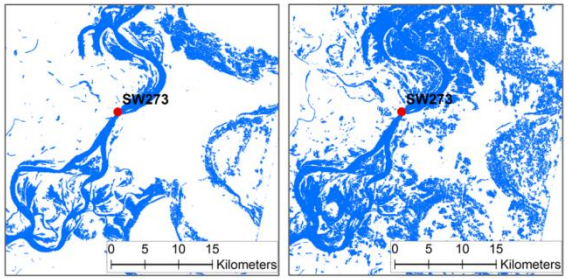
06 - 06 -2016 24 - 07 -2016

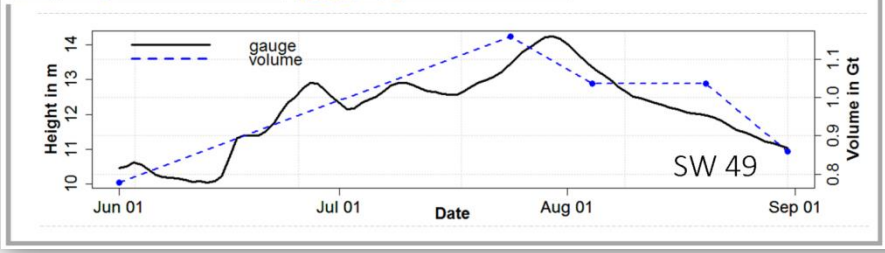


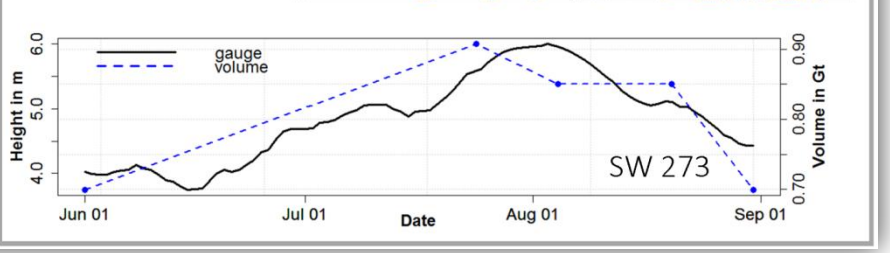


06 - 06 -2016 24 - 07 -2016

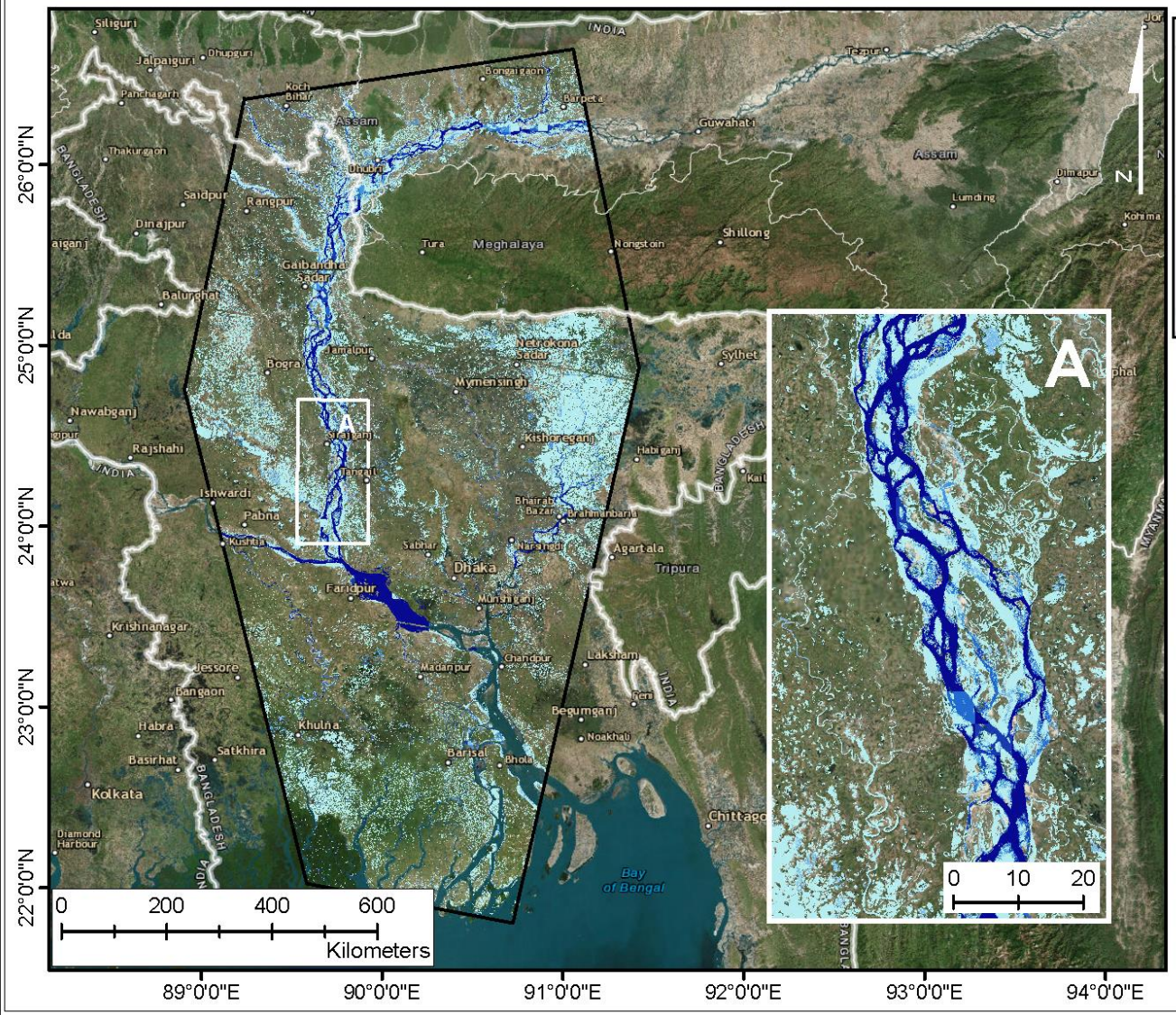








FLOOD VOLUME & INUNDATION DEPTH IN BANGLADESH - Estimtated for 24/07/2016



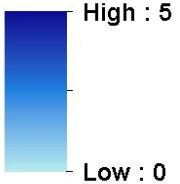
Estimated flood volume for the entire area: 40.13 Gt

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

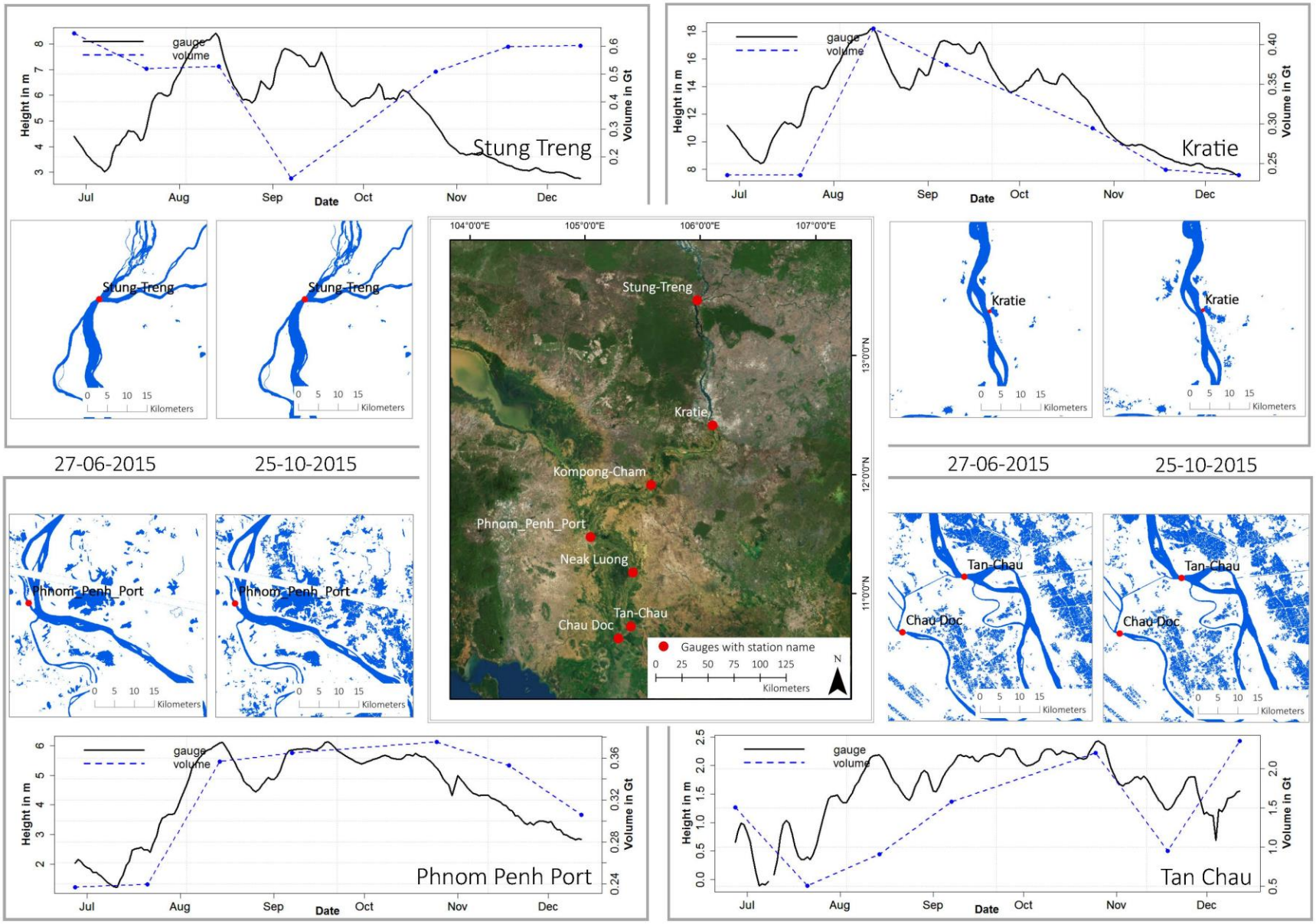
Local Projection UTM Zone 46N
Datum: WGS84
Vertical Geoid Reference: EGM96
Scale: 1:3 000 000
Author: Celia Baumhoer

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

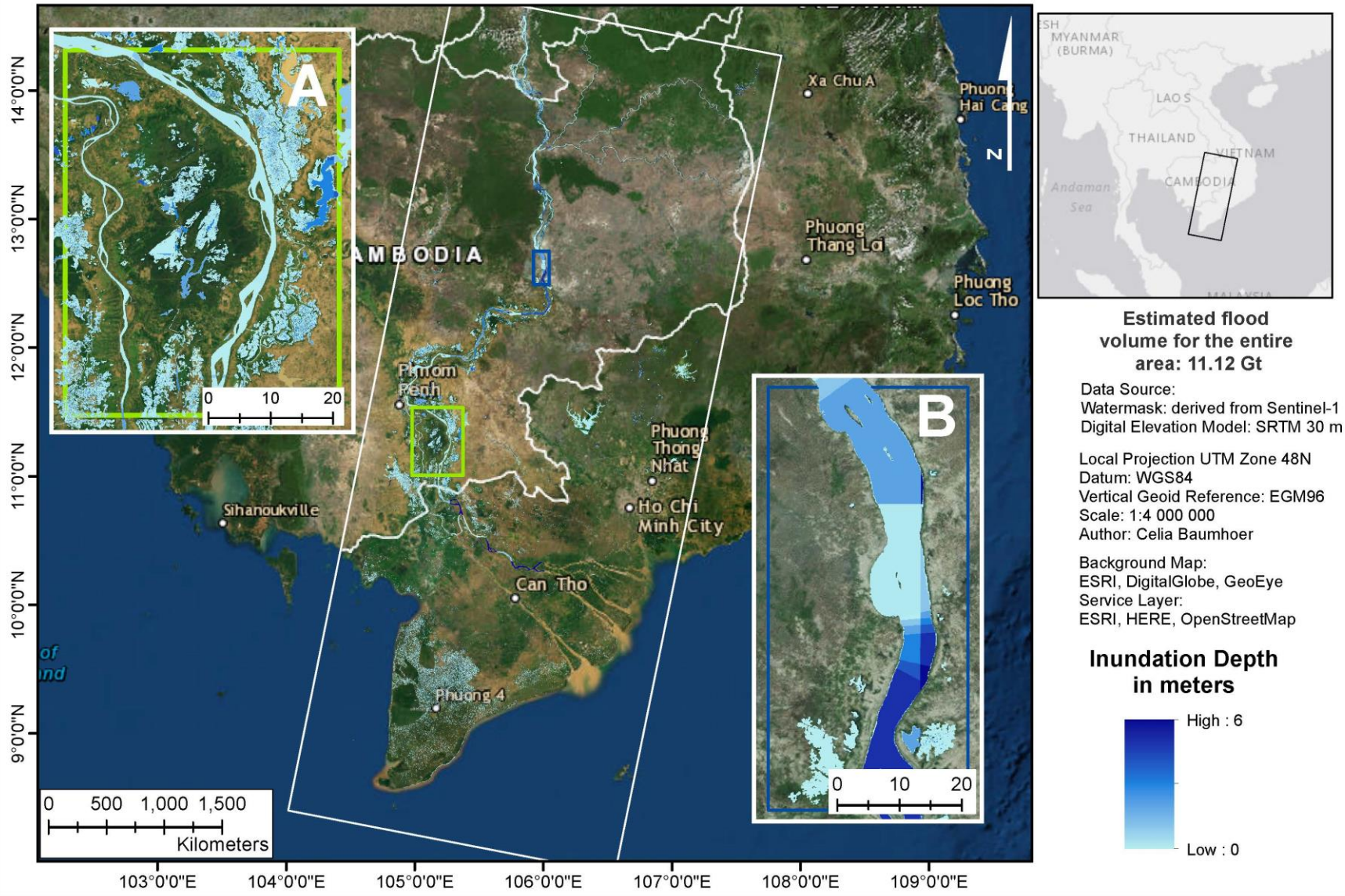
Inundation Depth in meters



Horizon2020


gauge
volume
Height in m
Volume in Gt
Stung Treng
Jul
Aug
Sep
Oct
Nov
Dec
Date
Kratie
Stung-Treng
Kratie
Kompong-Cham
Phnom_Penh_Port
Neak Luong
Tan-Chau
Chau Doc
Gauges with station name
0 25 50 75 100 125
Kilometers
N
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
0 5 10 15
27-06-2015
25-10-2015
Phnom Penh Port
Tan Chau

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



Estimated flood volume for the entire area: 11.12 Gt

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

Local Projection UTM Zone 48N
Datum: WGS84
Vertical Geoid Reference: EGM96
Scale: 1:4 000 000
Author: Celia Baumhoer

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

Inundation Depth in meters

High : 6

Low : 0

Conclusions

- For estimating flood volumes from space 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
- 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.
- 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)

Conclusions

- 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.
- 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

Objectives

1. Establish a method for **flood volume** estimation for large scale floods based on EO data and DEMs
    1. Higher level product (3D) compared to 2-D flood masks
    2. Can be compared to gravity measurements from space

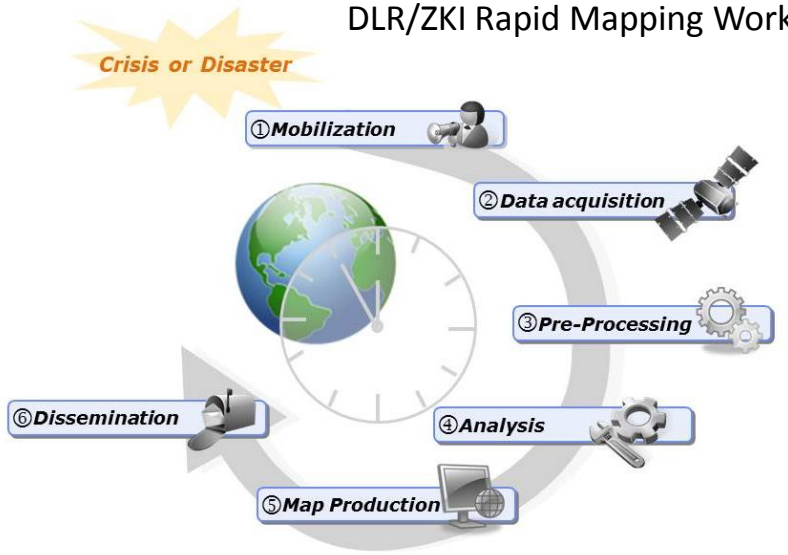
2. Implement **gravity-based water indicators** into the operational workflow of DLR's Center for Satellite-based Crisis Information
    1. Early-warning component for potential large scale flood events
    2. Reduce lead time in tasking of on-demand satellite sytems (e.g. TerraSAR-X)

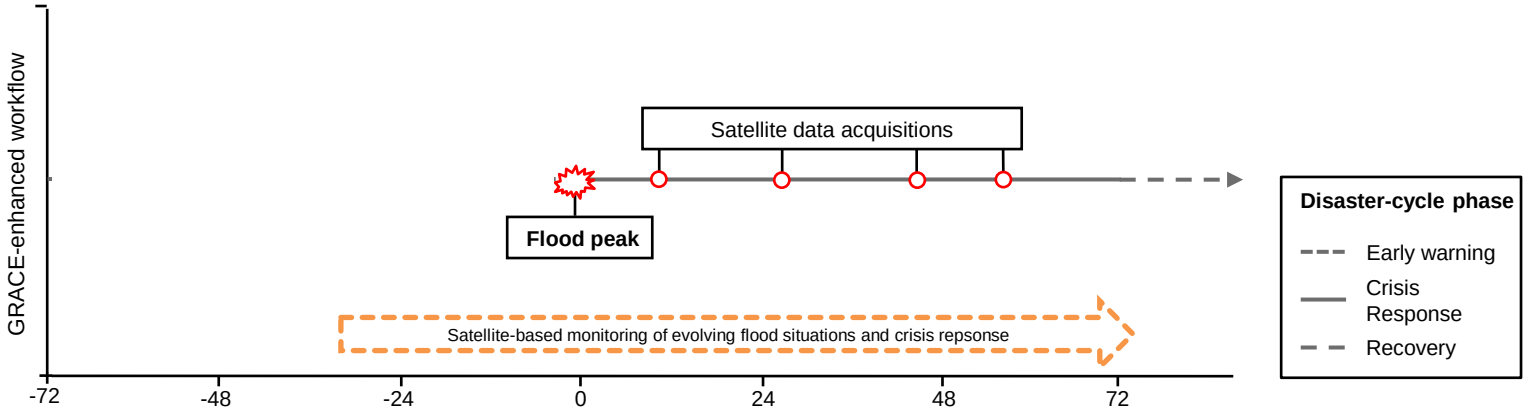
Application of GRACE-derived Flood Indicators at DLR/ZKI

- Early-warning component for large scale floods
- Increases the lead time for satellite tasking (e.g. TerraSAR-X)
- Enhances the satellite-based monitoring of large scale floods

➔ better crisis response and disaster management

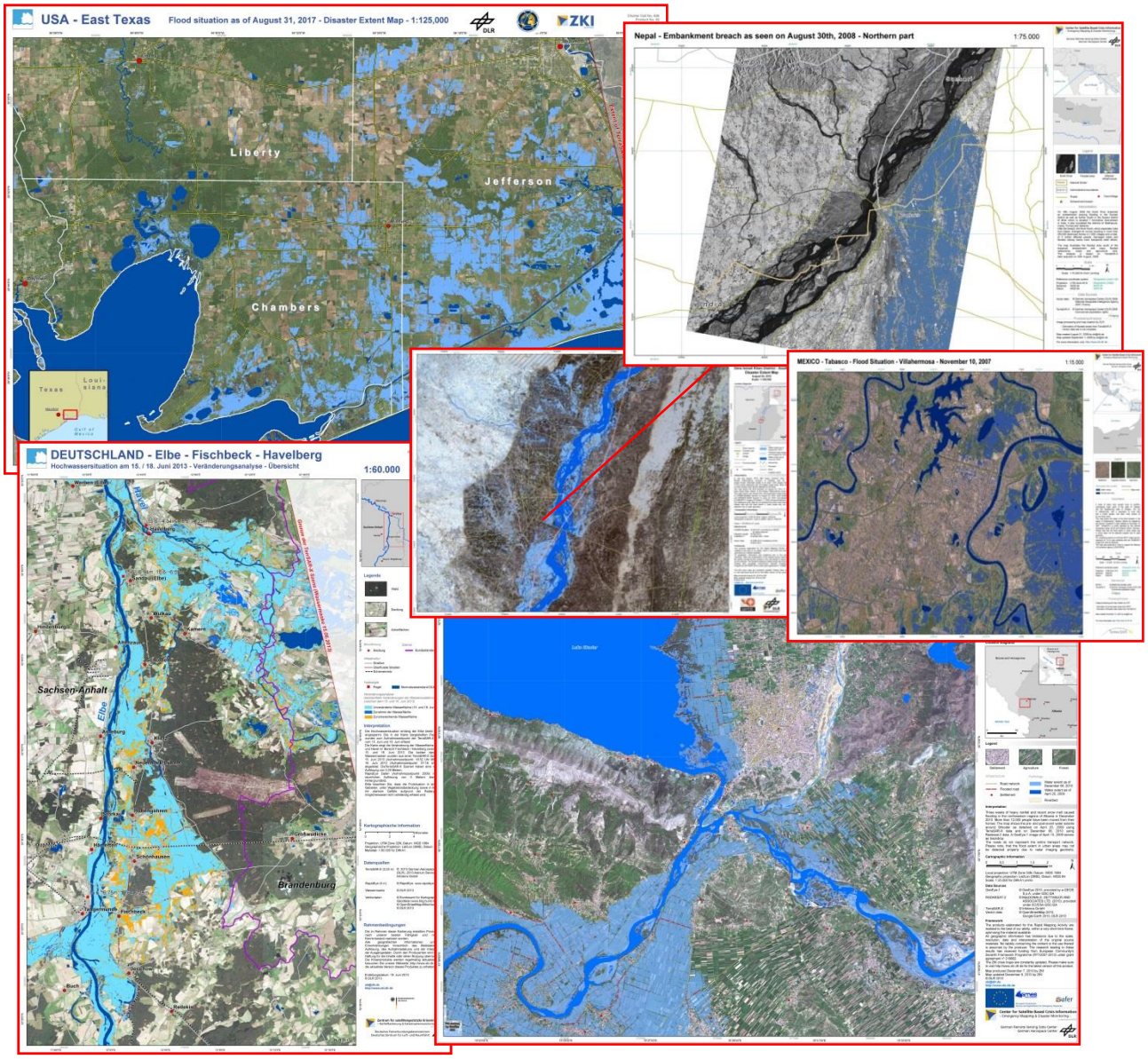
DLR/ZKI Rapid Mapping Workflow





Horizon2020

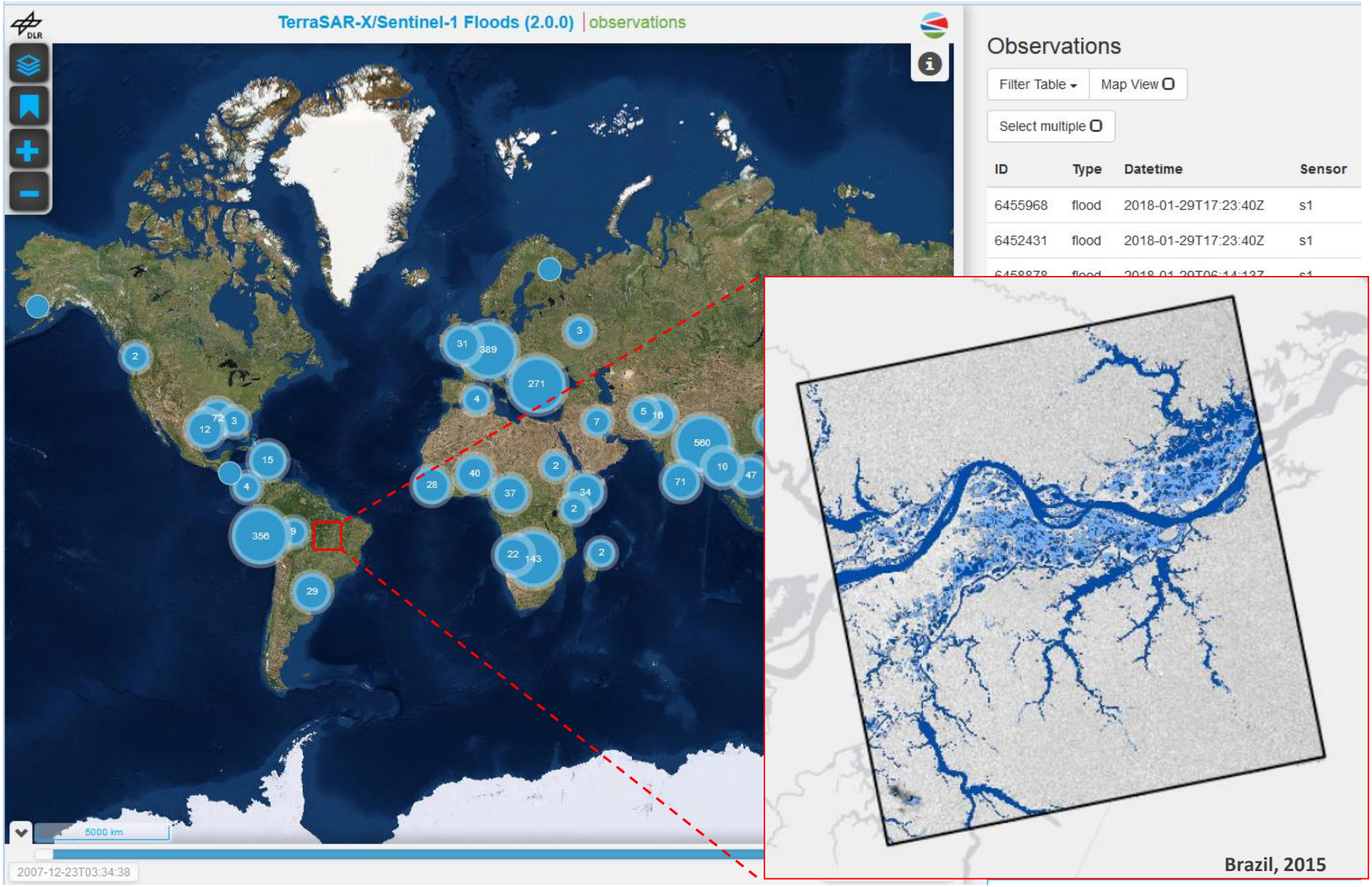
TerraSAR-X Flood Service



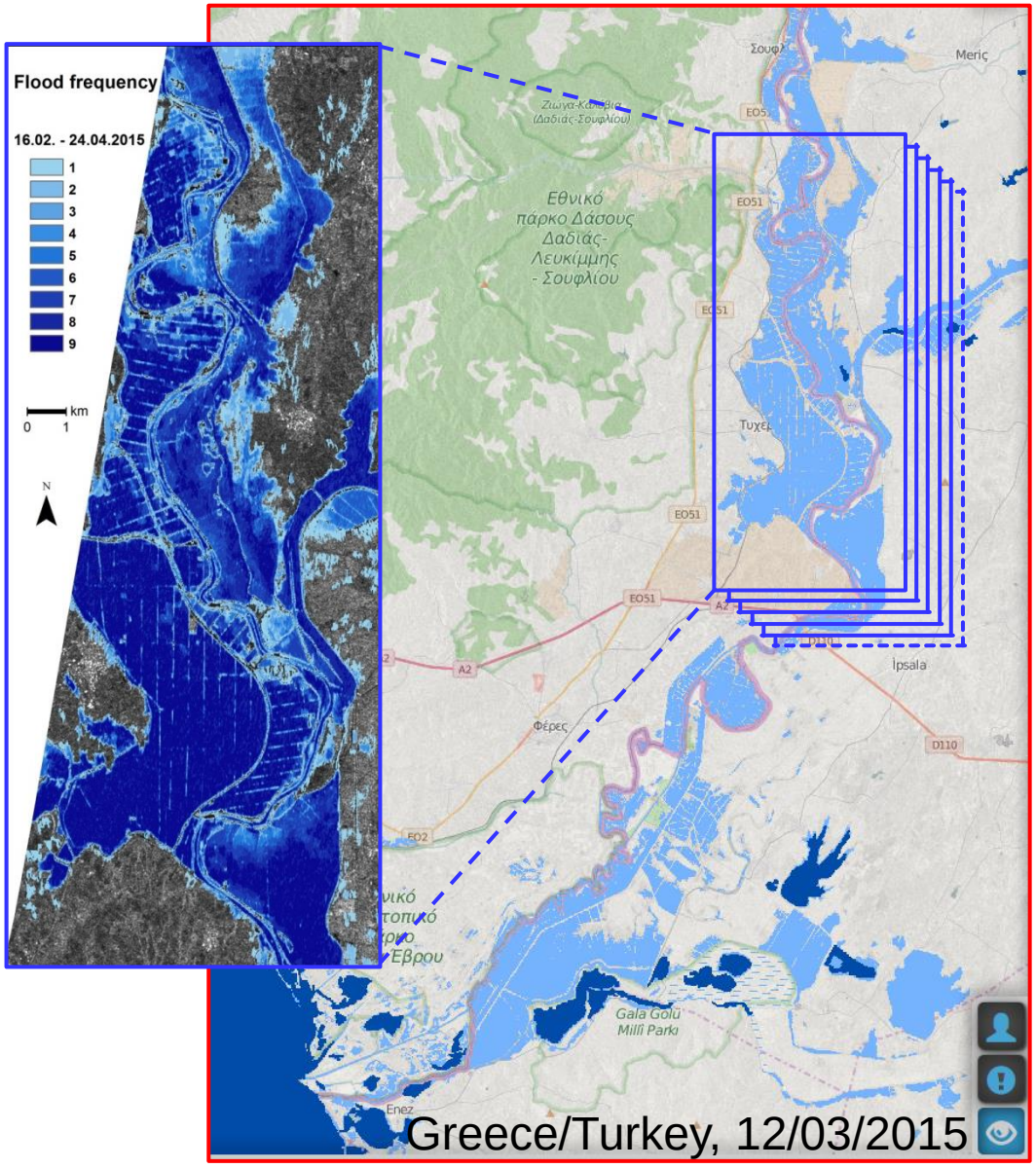
Characteristics

- Fully automatic service
- Local/regional scale flood mapping
- Resolution: 1-40m
- On-demand triggering in case of emergencies

TerraSAR-X Flood Service: *Results (Brazil, 2015)*



Sentinel-1 Flood Service



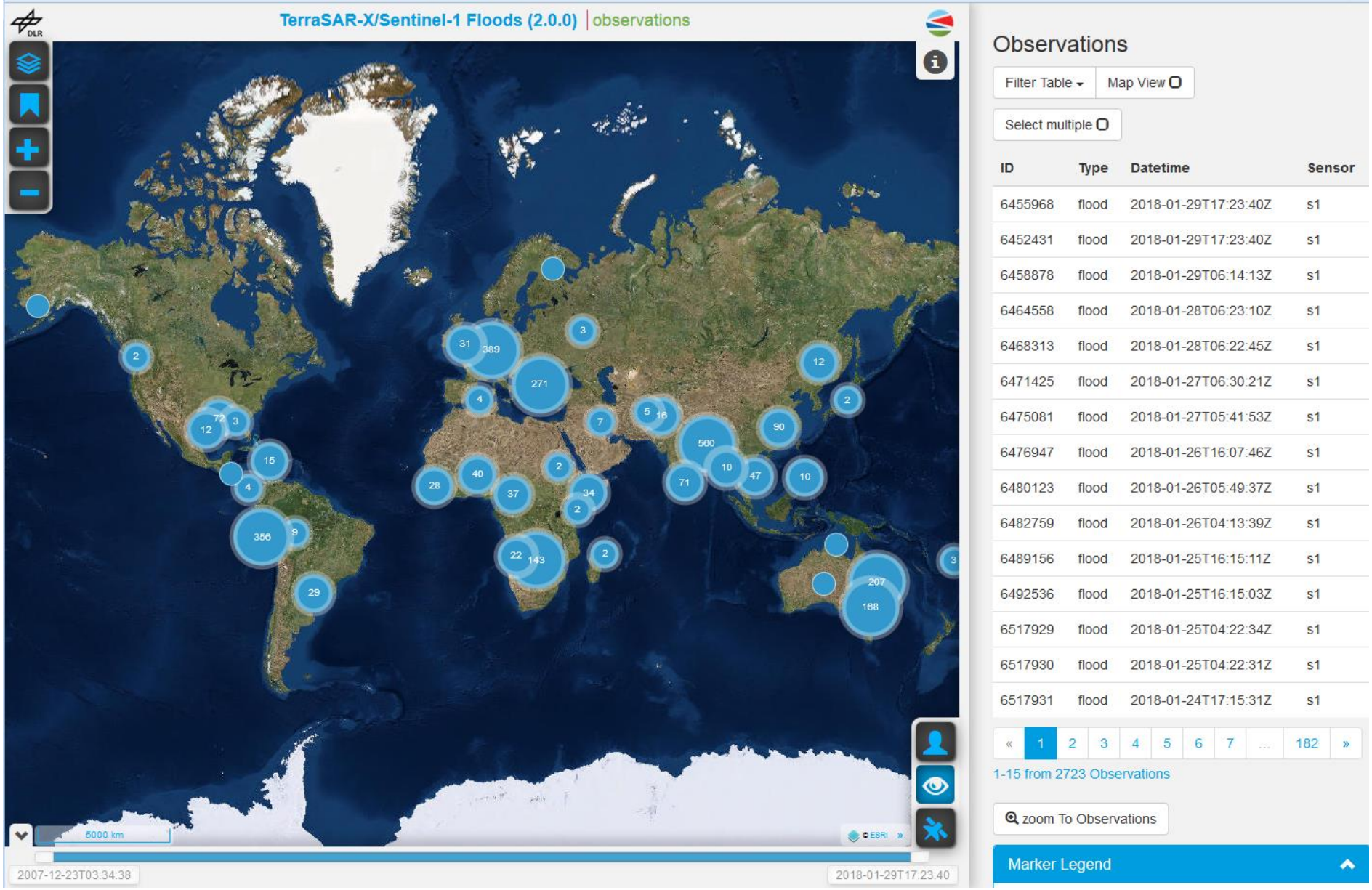
Greece/Turkey, 12/03/2015

Characteristics

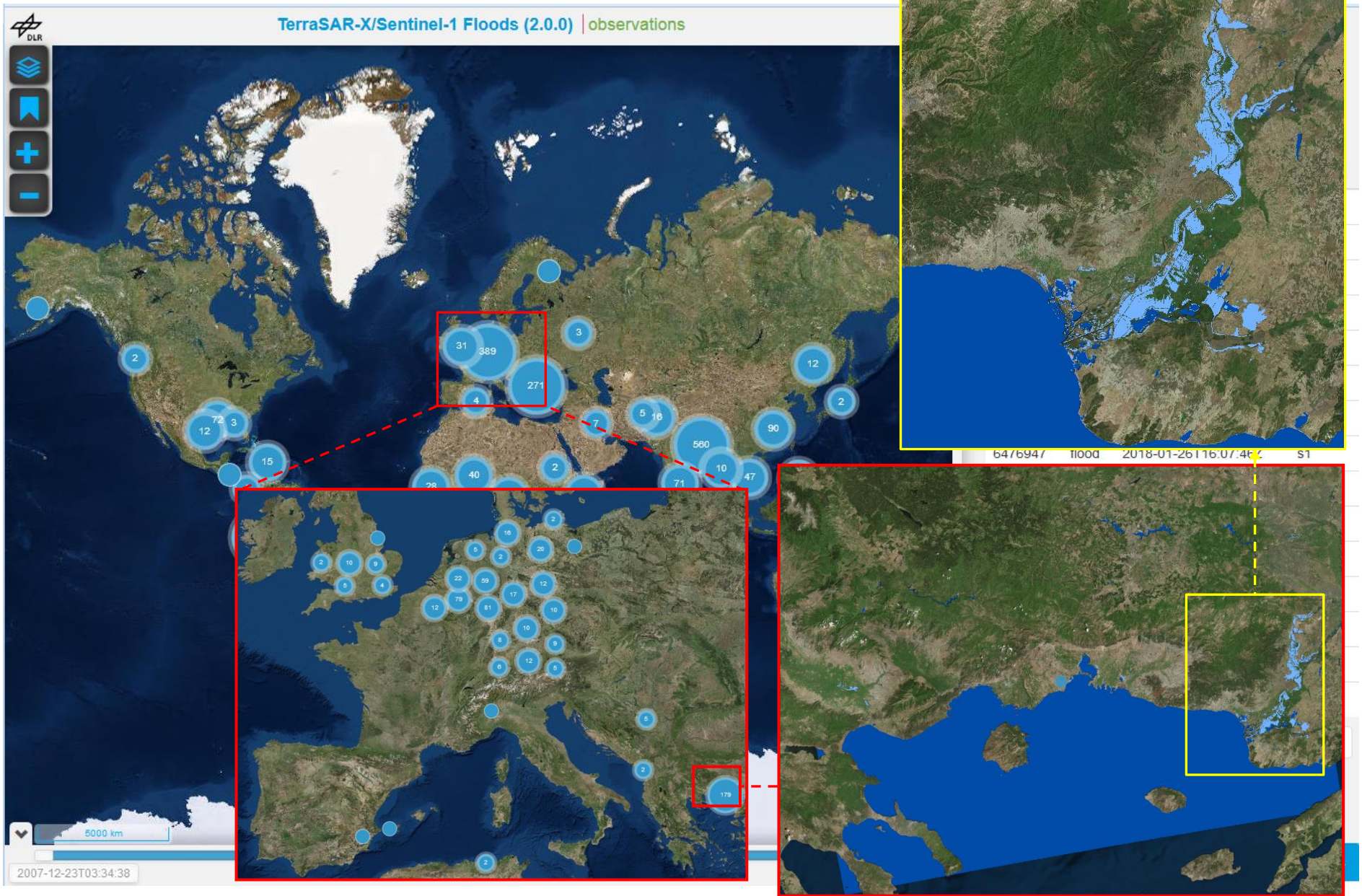
- Fully automatic service
- Systematic flood monitoring
- Large-scale flood monitoring
- Resolution (IW): ~20m
- Repeat frequency: 6 days (Sentinel-1A/B)
- Revisit frequency: ~2 days (Europe)
- Interactive access via Browser/WebGIS

Sentinel-1 (© ESA)

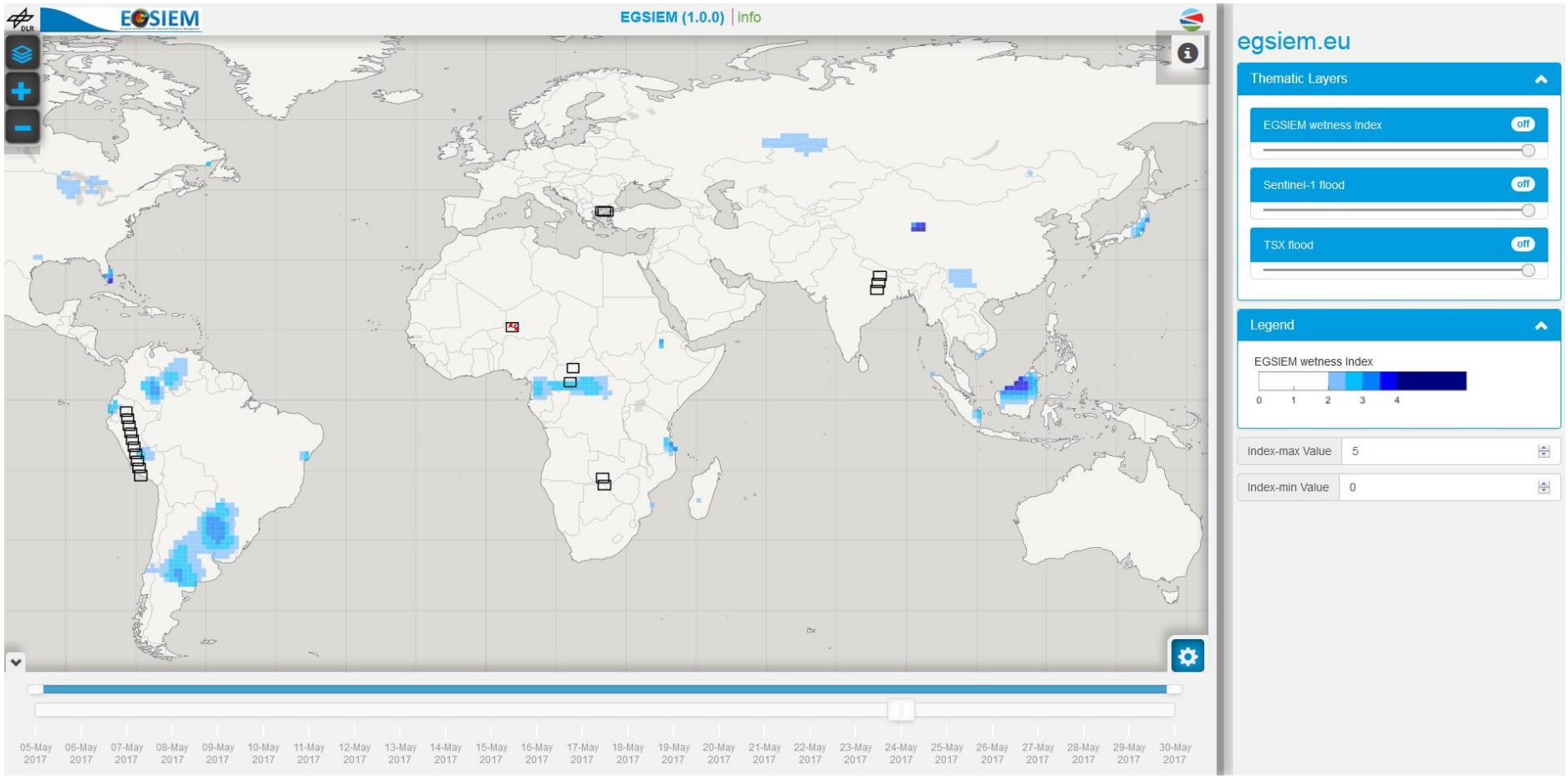
Sentinel-1 Flood Service



Sentinel-1 Flood Service



EGSIEM: daily GRACE-based Wetness Index in combination with daily results from Sentinel-1 & TerraSAR-X flood service



Retrospective analysis of possible satellite acquisitions for past flood events

Floods at Upper Danube

	WI Flood Warning Upper Danube	Peak flow @Achleiten
2002 Flood	17.08.2002	13.08.2002
2006 Flood	13.03.2006	29.03.2006
2010 Flood	28.05.2010	03.06.2010
2013 Flood	03.06.2013	03.06.2013
2014 Flood	-	01.08.2014

Floods in Danube basin

	WI Flood Warning Danube Basin	Peak Flow @Ceatal Izmal
2002 Flood	-	31.08.2002
2006 Flood	14.03.2006	26.04.2006
2010 Flood	30.05.2010	06.07.2010
2013 Flood	06.06.2013	-
2014 Flood	-	-

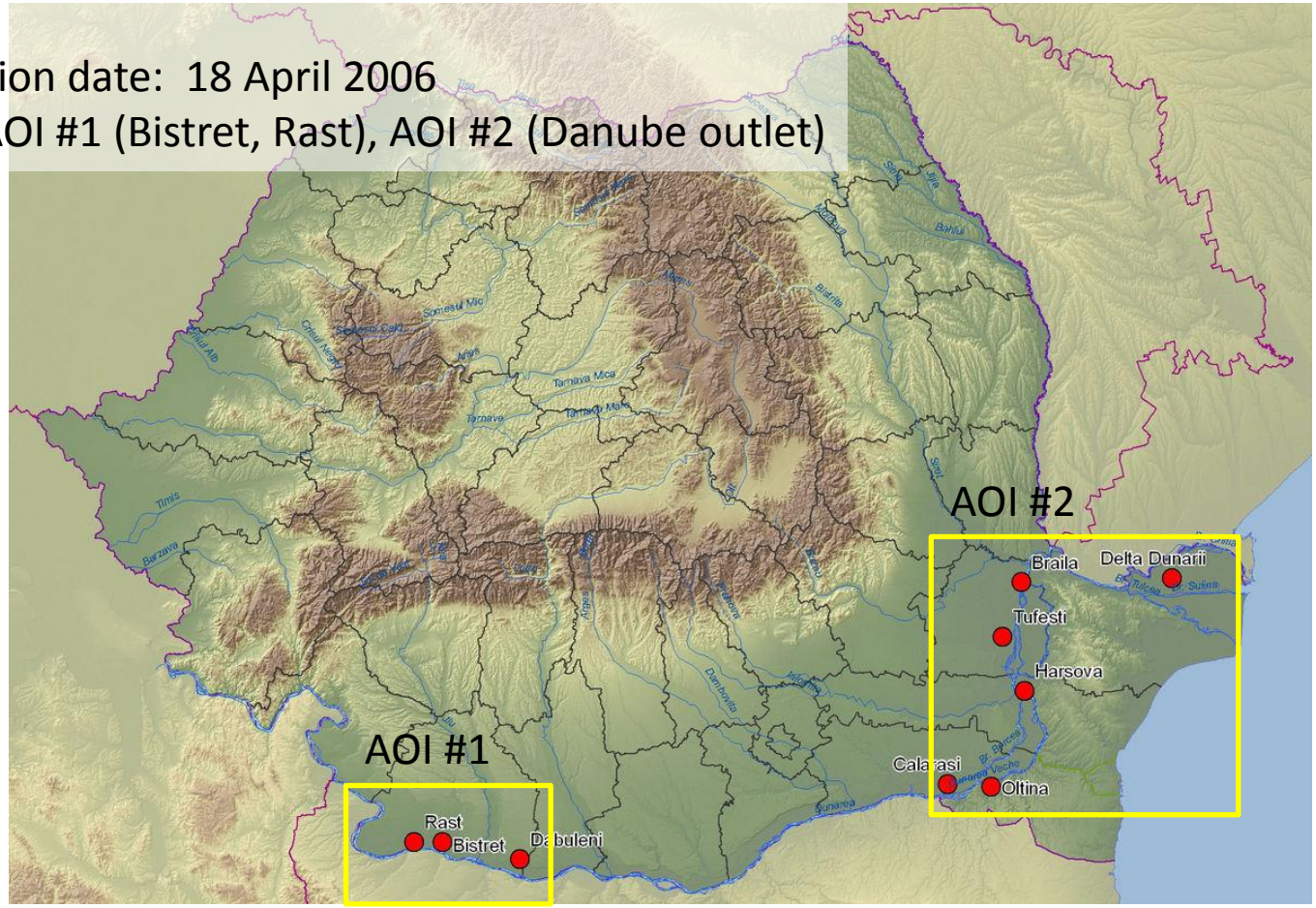
Analysis to investigate if the gravity-based WI would habe been useful for early warning and improved satellite tasking.

→ In most hisorical events the WI would have been a useful flood indicator several days before the flood peak (e.g. 2006: 43 days).

Retrospective analysis of possible satellite acquisitions for past flood events

Charter Call #121 – Floods in Romania

- Activation date: 18 April 2006
- AOIs: AOI #1 (Bistret, Rast), AOI #2 (Danube outlet)

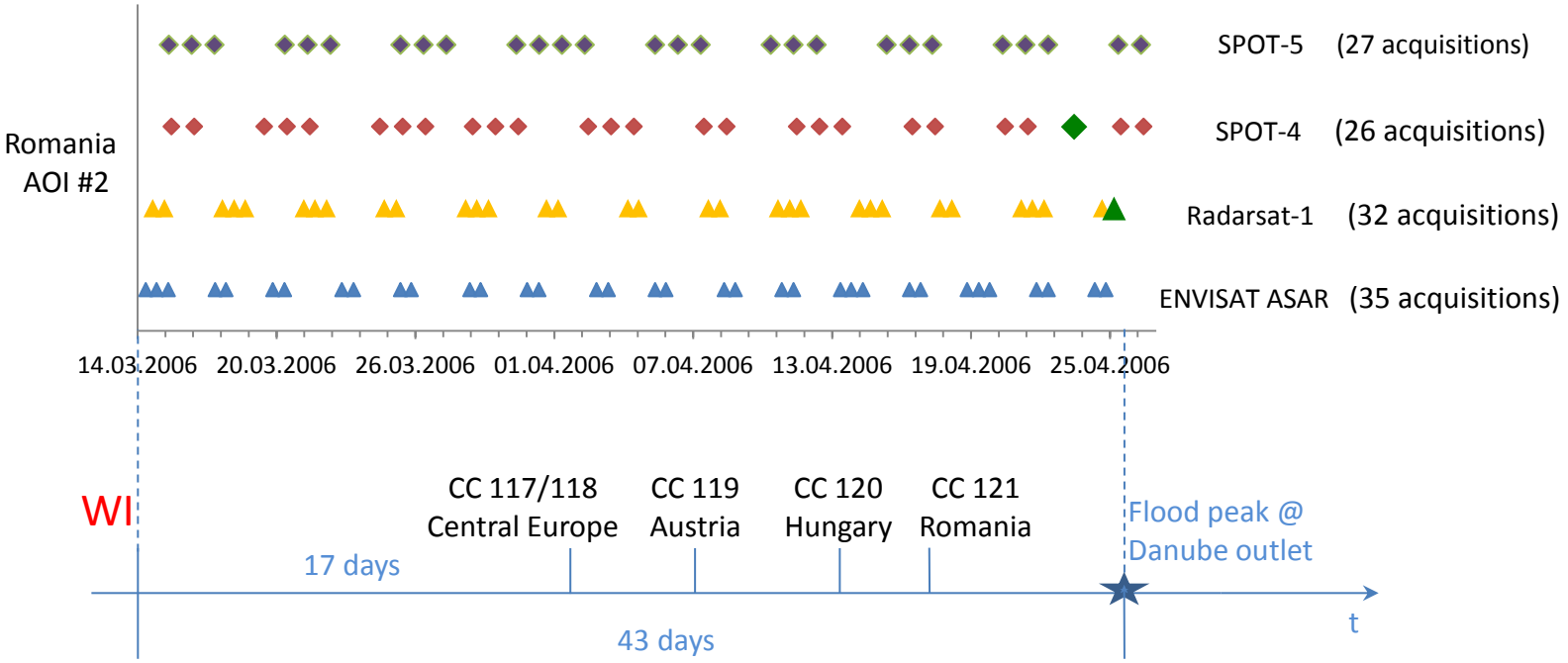


Danube floods: Wetness Index and Lead Times for possible satellite acquisitions

	WI Flood Warning Upper Danube	Peak flow @Achleiten	WI Flood Warning Danube Basin	Peak Flow @Ceatal Izmal
2006 Flood	13.03.2006	29.03.2006	14.03.2006	26.04.2006

Danube flood 2006: Analyis performed using SAVOIR Charter - Swath Acquisitions Planner; © Taitus Software) → number of theoretically possible acquisitions including any high priority acquisitions/time-outs concerning system health, calibration, etc. which are not available for the Charter

Two acquisitions (dark green) have been realized during Charter Call #121



Conclusions

- **Current/future systematic disaster monitoring capabilities** are very good due to European **Sentinel satellite fleet** (continuous acquisitions every 5-6 days for S1 & S2)
- **GRACE-based WI** is useful for satellite tasking of on-demand wide area coverage systems for early stage (prior to flood peak) monitoring and for an efficient use of satellite resources
- Acitvations (e.g. International Charter) are user-driven and in most cases **end users are local or regional authorities** (municipality or provincial level) who are interested in damage assessment
  - Pro-active very high resolution satellite tasking over large areas is in most cases not useful or too expensive
- European **Emergency Response Coordination Centre** (ERCC, formerly MIC) would be a good user of the WI since it can activate Copernicus-EMS and the International Charter

Thank you very much for your attention!