living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE OF OUR PLANET FROM SPACE

Monitoring of temporary inundations using Sentinel-1 and -2

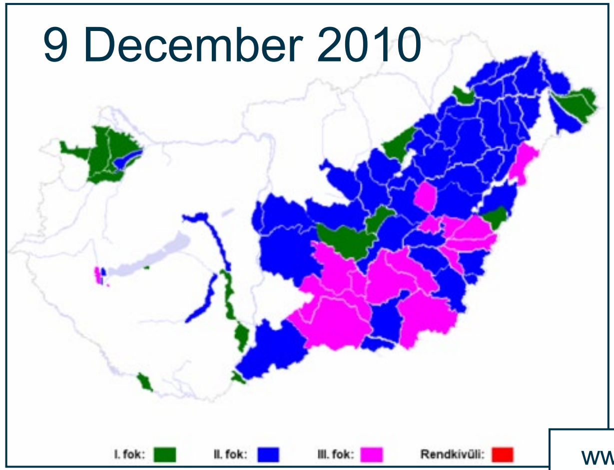
Boudewijn van Leeuwen, Zalán Tobak,Ferenc Kovács, Balázs Kajári
Department of Geoinformatics, Physical and Environmental Geography,
University of Szeged, Hungary

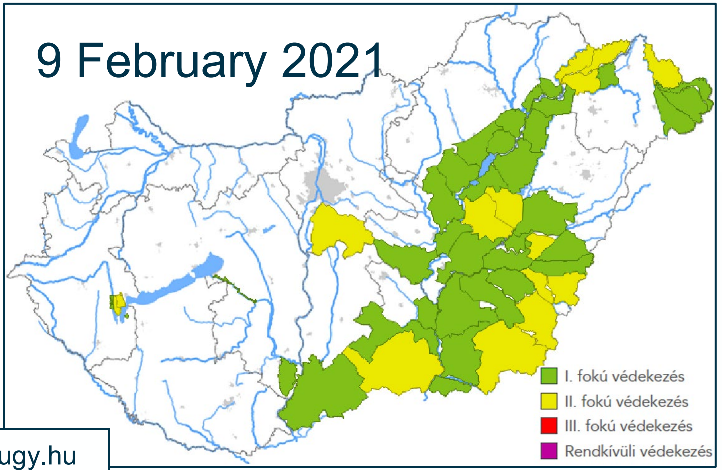
Inland excess water background

- Definition?
- Factors
- Temporal distribution
- Spatial distribution
- Impact

„Floods that occur when – due to limited runoff, infiltration and evaporation – superfluous water remains on the surface, or at places where groundwater – flowing towards lower areas – appears on the surface by leakage through porous soil."

Inland excess water, excess water, inland water, surface ponding, standing water, sitting water, areal flood, surface water flood.



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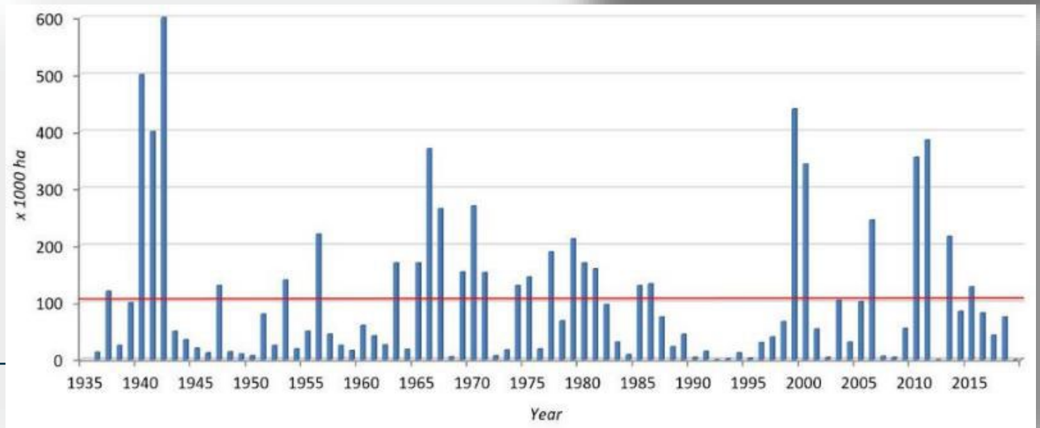


Management of IEW

IEW is a problem or an opportunity?

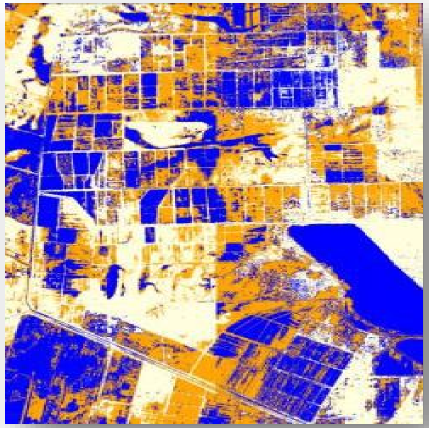
Key reason for IEW mapping/monitoring:

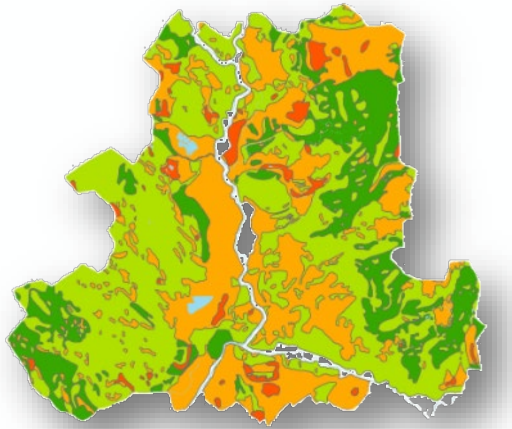
- **to *locate* inland excess water**
- to understand the *formation* of the inundations
- to find the possibilities for *intervention*

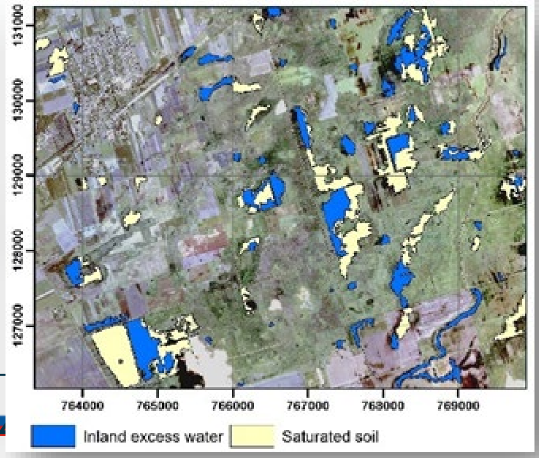
Methods of IEW mapping

- In situ measurements
- Hazard mapping
- Hydrological modelling
- Remote sensing based mapping

(RGB/NIR aerial photographs, multi- and hyperspectral aerial and satellite imagery, radar satellite images, drone images)



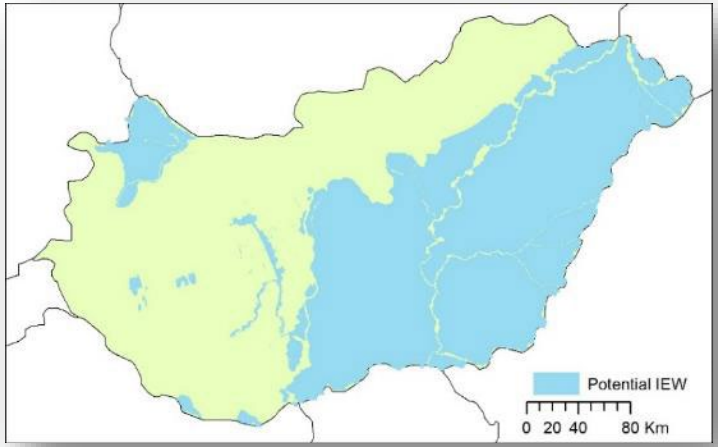


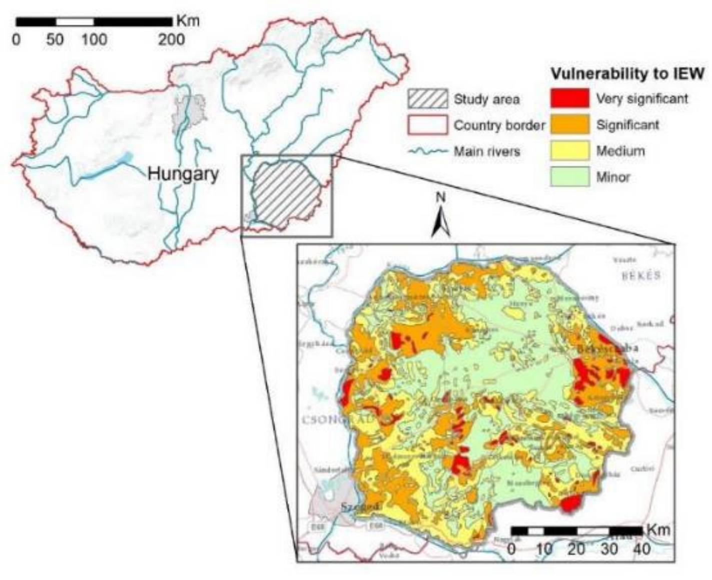


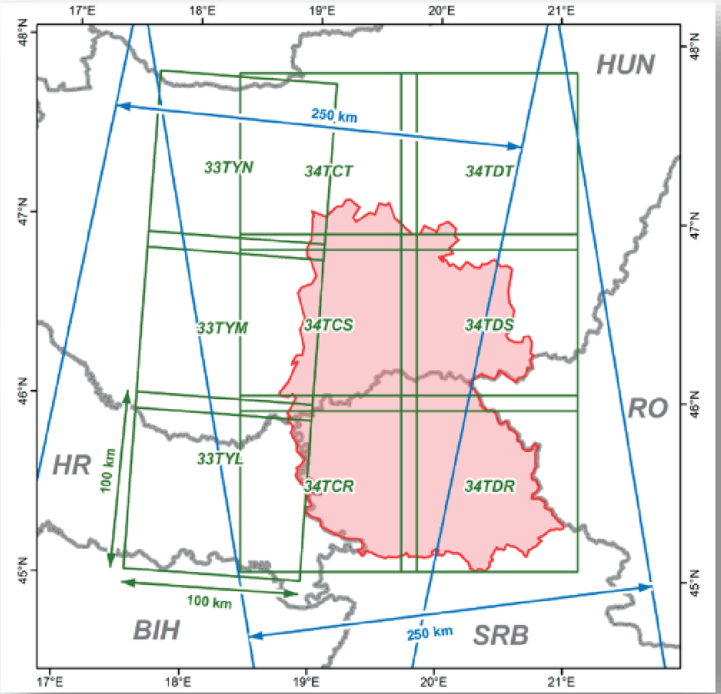
Continuous monitoring of inland excess water

- Aims:
  - Operational (not just for science)
  - National (or at least regional)
  - Detailed (high spatial resolution)
  - Timely (high temporal resolution)
  - Completely automated (no user interference)
  - Accurate (better than what?)
  - Affordable (how much is it allowed to cost?)
- Since about 2016, continuous incremental improvements
- In collaboration with actual users
- Teamwork

Study areas


Potential IEW
0 20 40 80 Km


Km
0 50 100 200
Hungary
Vulnerability to IEW
Study area
Country border
Main rivers
Very significant
Significant
Medium
Minor
N
Km
0 10 20 30 40


17°E
18°E
19°E
20°E
21°E
48°N
47°N
46°N
45°N
HUN
RO
HR
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250 km
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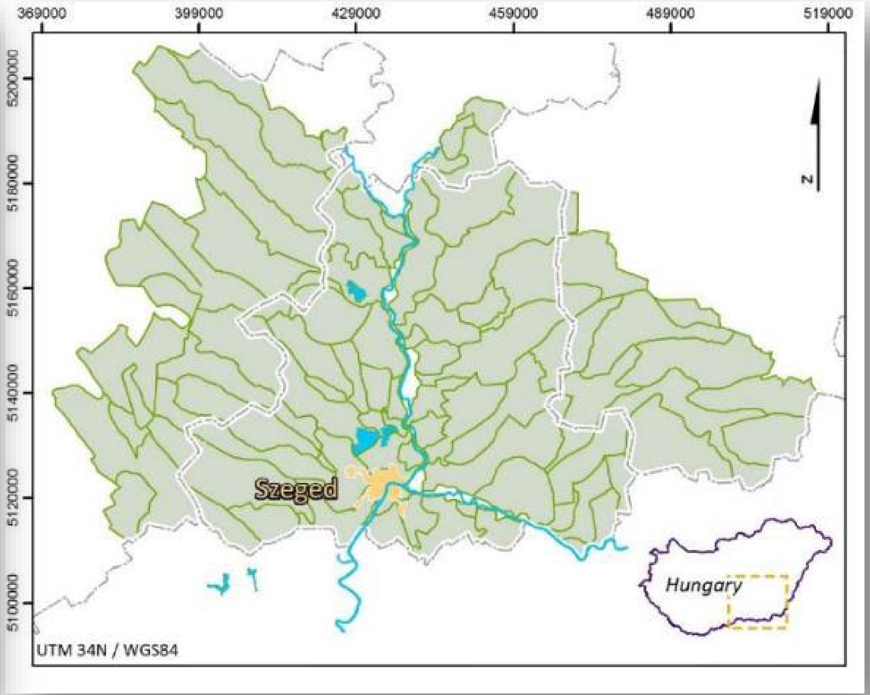
34TCT
34TDT
33TYM
34TCS
34TDS
33TYL
34TCR
34TDR


369000
399000
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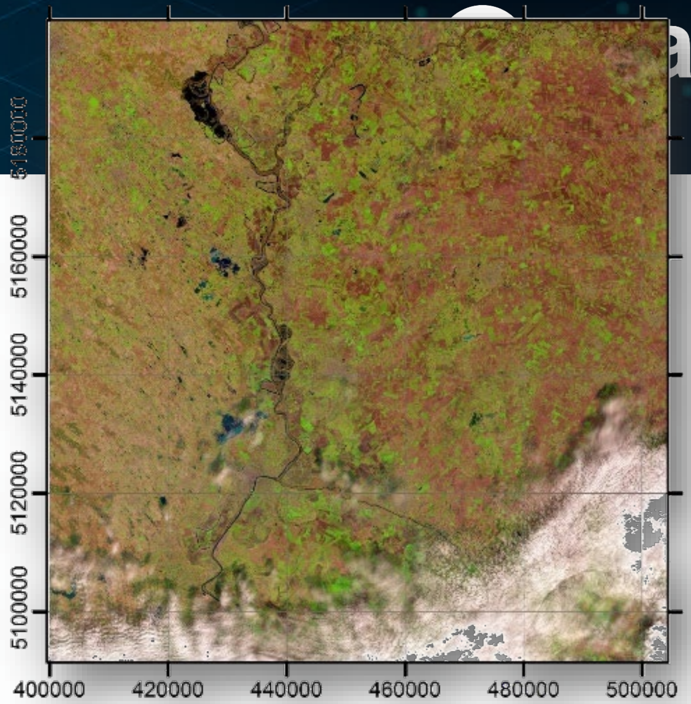
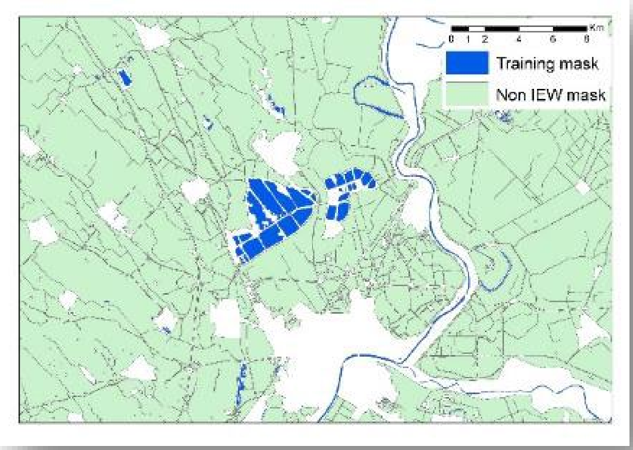
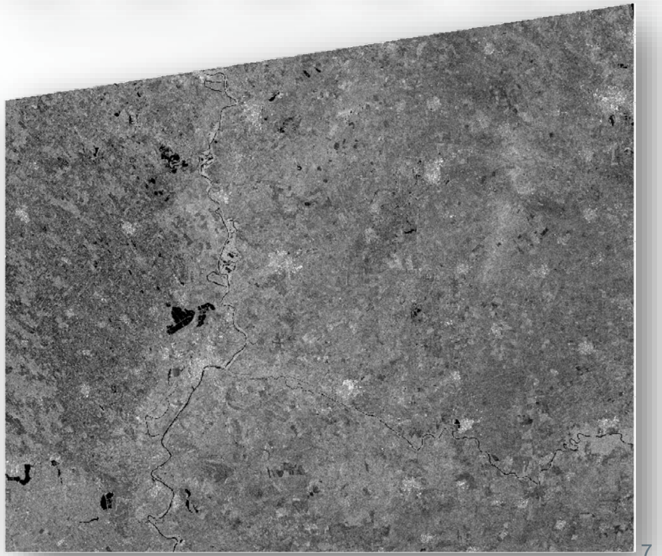
489000
519000
5200000
5180000
5160000
5140000
5120000
5100000
N
Szeged
Hungary
UTM 34N / WGS84

Data

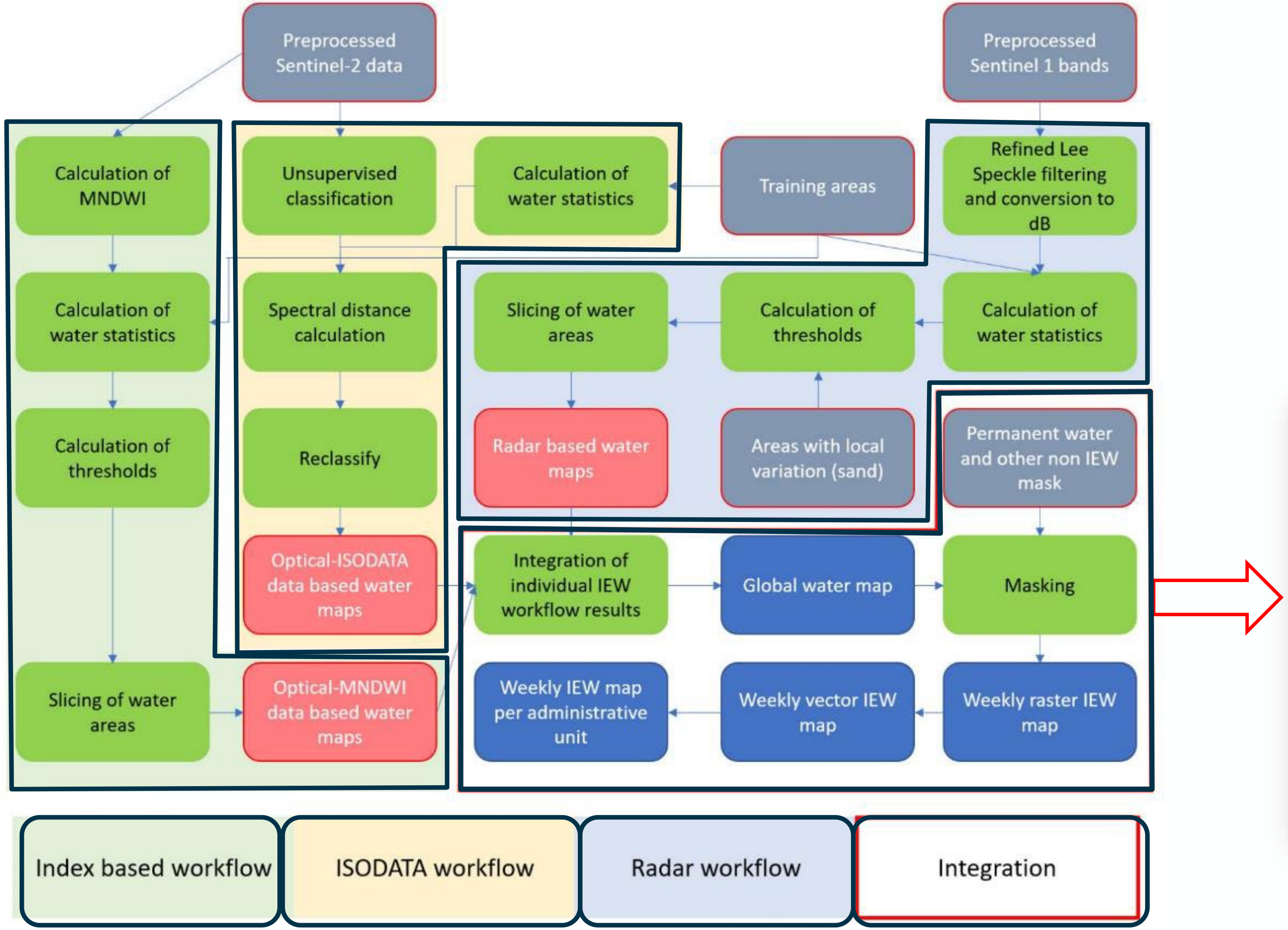
- Multispectral satellite data
  - Sentinel-2
- Radar satellite data
  - Sentinel-1
- Auxiliary data
  - Soil texture data
  - Mask for training
  - Mask for non-water areas (water, permanent wetlands, transportation infrastructure, built-up areas)

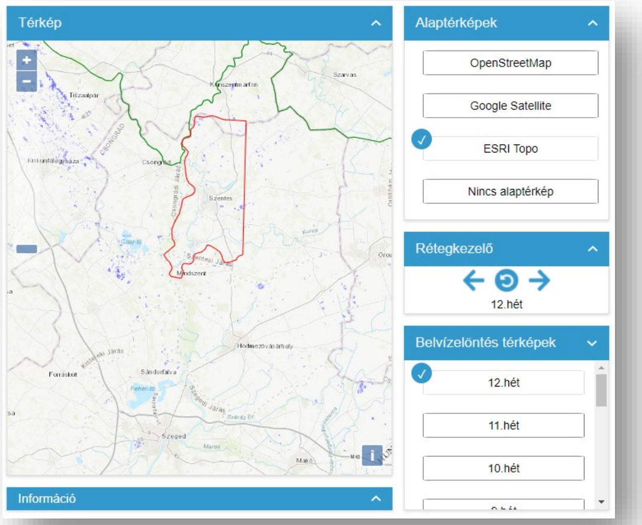






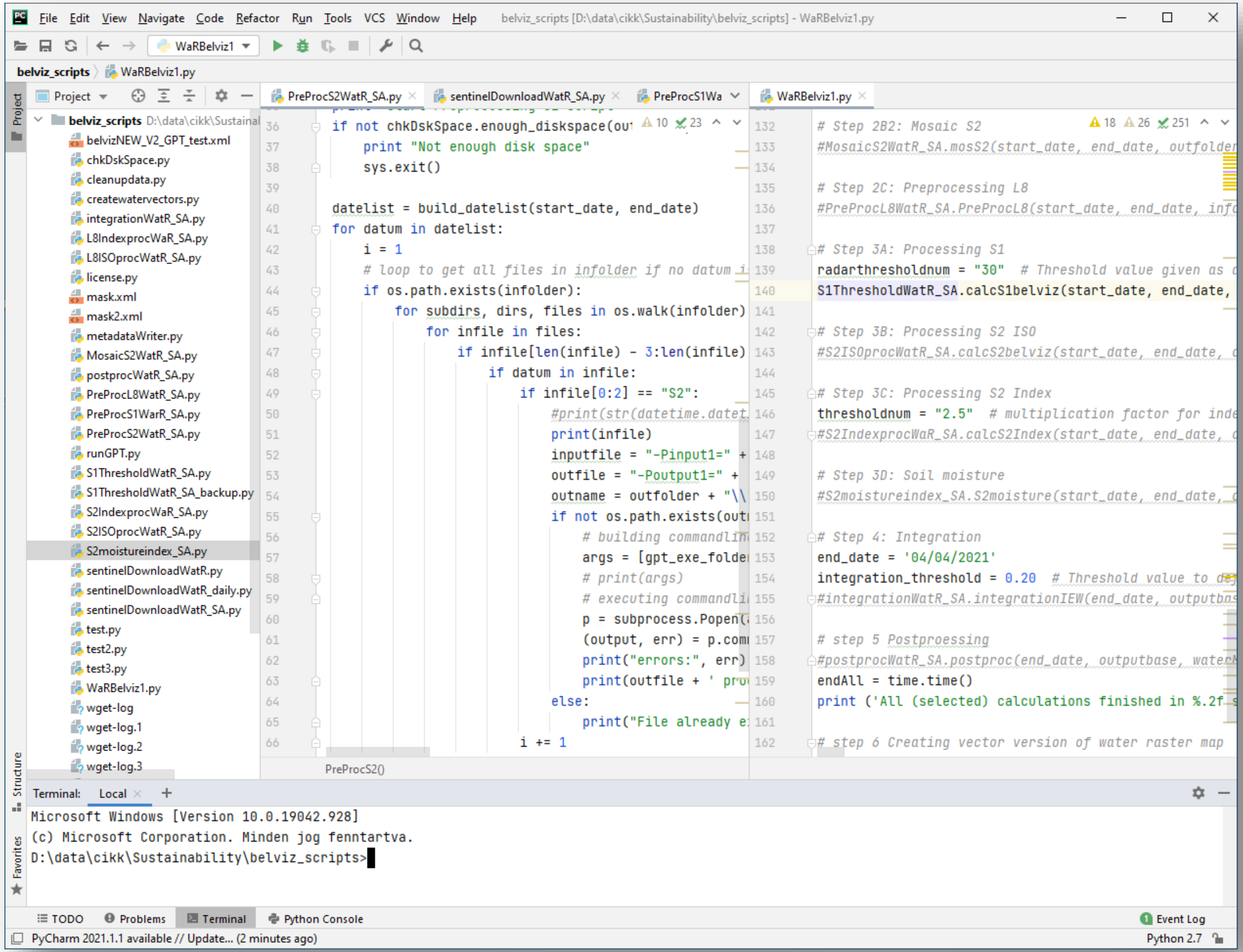
Monitoring framework





Automation

- 15 Python scripts
- ~ 3000 lines of code
- arcpy, numpy, gdal
- 2 sets: daily and weekly
- Manual start of sets of scripts



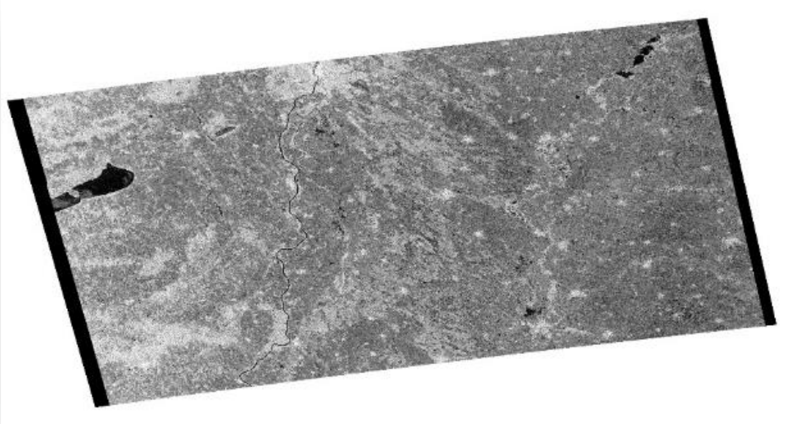
Preprocessing

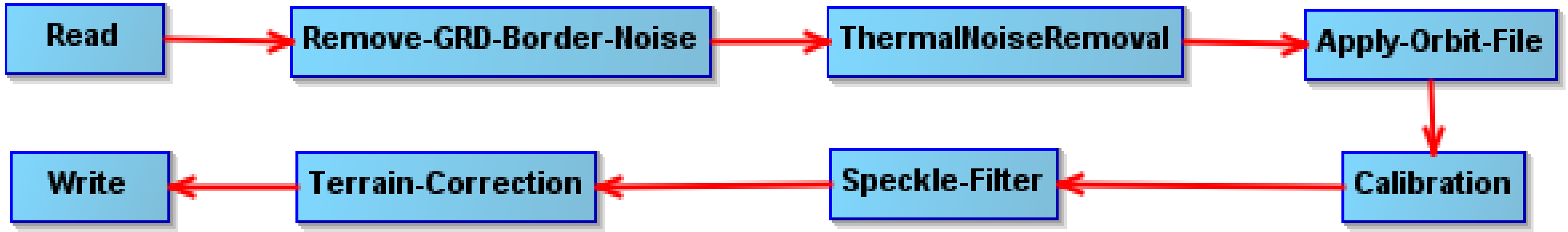
- ESA SNAP software – gpt tool

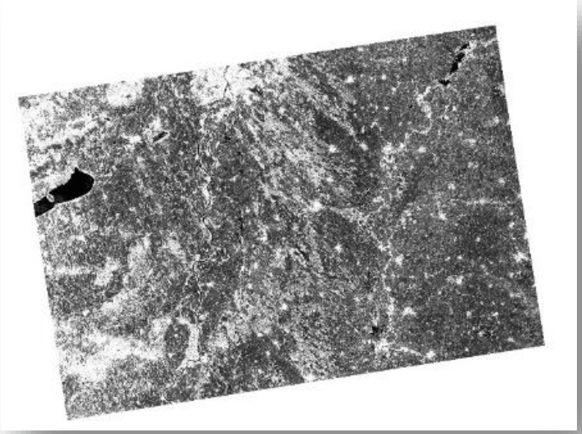
- Multispectral data:

  Level 2A: Band selection, resampling to 10 meter, cloud masking and mosaicking

- Radar preprocessing







Radar threshold:

$$uthr_b = \bar{x} + k * \sigma,$$
$$lthr_b = x_{min} + (3 * (\bar{x} - x_{min})/5)$$

b: VV / VH band,

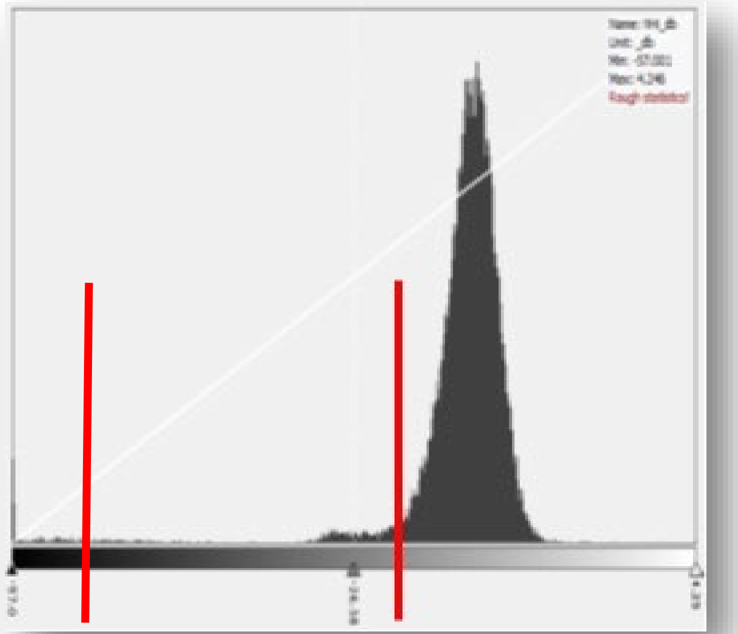
$uthr_b$, $lthr_b$: upper/lower threshold in db,

$\bar{x}$: mean backscatter of training samples in db,

σ : standard deviation of training samples in db,

x_{min} : minimum of training samples in db,

K: user defined constant



Water pixels:

$$water\ pixel = lthr_b < xVV_{,VH} < uthr_b$$

x: value of an individual pixel in both bands

➔ Adapted for sandy areas

Processing - Multispectral

A. ISODATA (Ball & Hall 1965)

- Iterative clustering
- ArcGIS/arcpy implementation
- Statistics of resulting classes are compared with statistics of reference water class
- Classes with the smallest spectral angle distance to the reference class are labeled as water

B. Modified Normalized Difference Water Index (Xu et al. 2006):

$$MNDWI = \frac{\rho_{green} - \rho_{SWIR}}{\rho_{green} + \rho_{SWIR}} = \frac{B3 - B11}{B3 + B11},$$ where B3 and B11 Sentinel-2 bands (10 meter)

$$MNDWI_{threshold} = MNDWI_{mean} - k * MNDWI_{std}$$

where

$MNDWI_{mean}$: mean index value of the reference pixels,

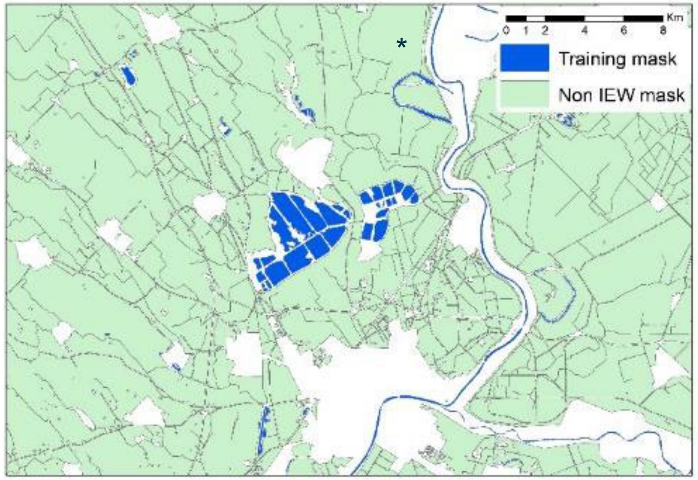
$MNDWI_{std}$: standard deviation of the reference pixels,

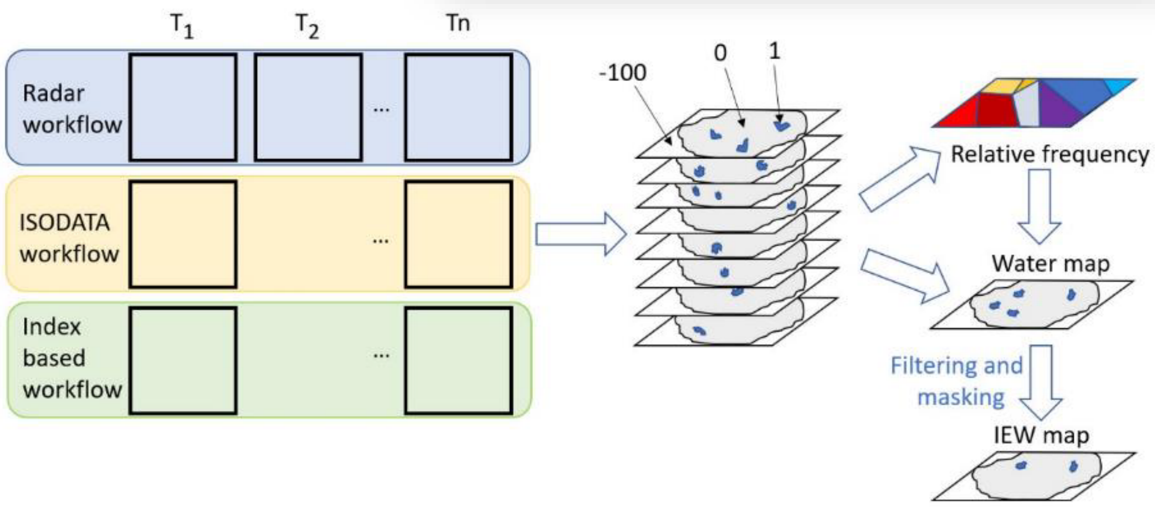
k: multiplication factor

Integration

Many water maps from different days and areas combined into one weekly map:

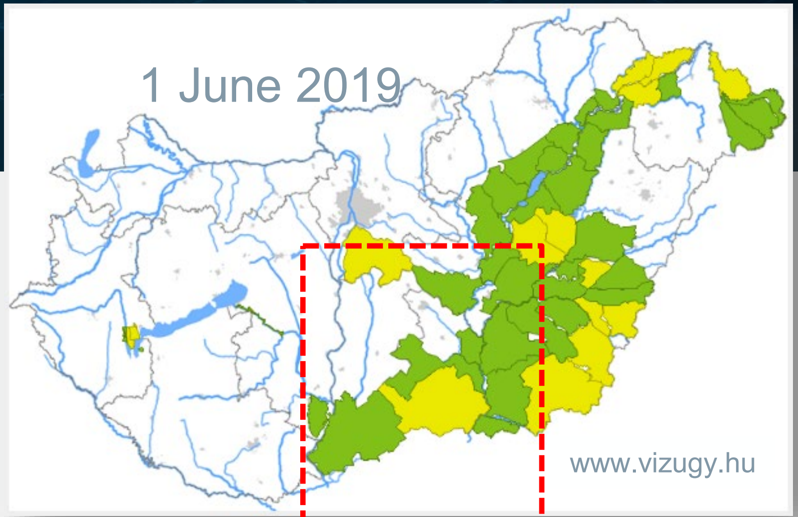
- Extend to total study area
- Reclassify (-100, 0, 1)
- Calculate relative frequency
- Slicing based on reliability threshold (e.g. 50%)
- Masking of non IEW areas
- Filtering
- Vectorizing
- Calculate statistics for administrative areas



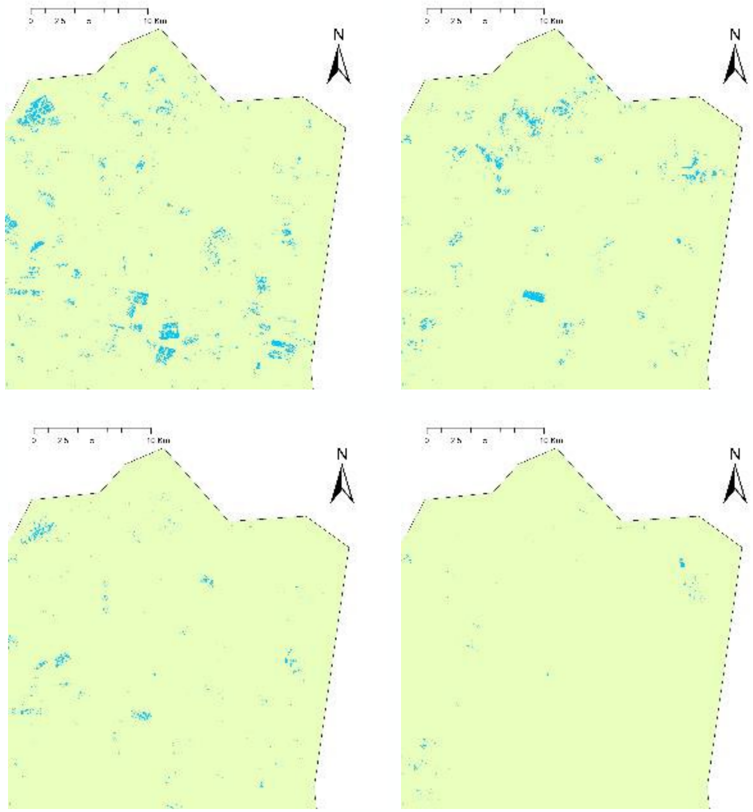


Results 2019

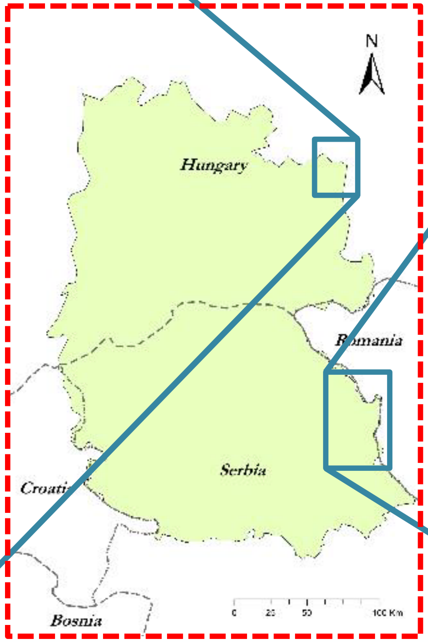
5 weeks in May-June 2019

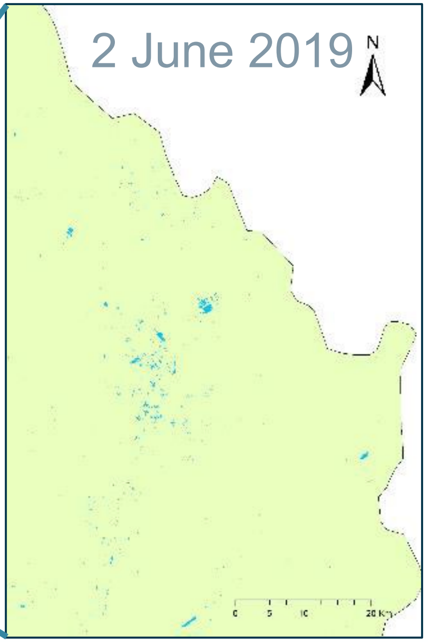


26 May 2019 | 2 June 2019



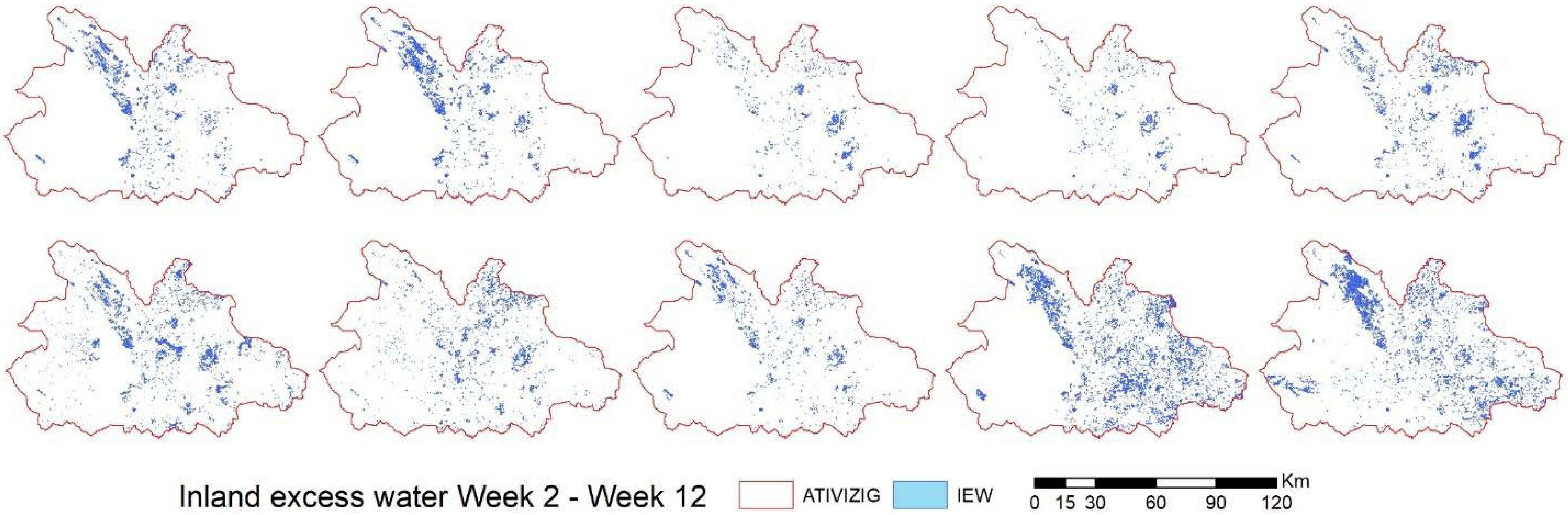
9 June 2019 | 16 June 2019



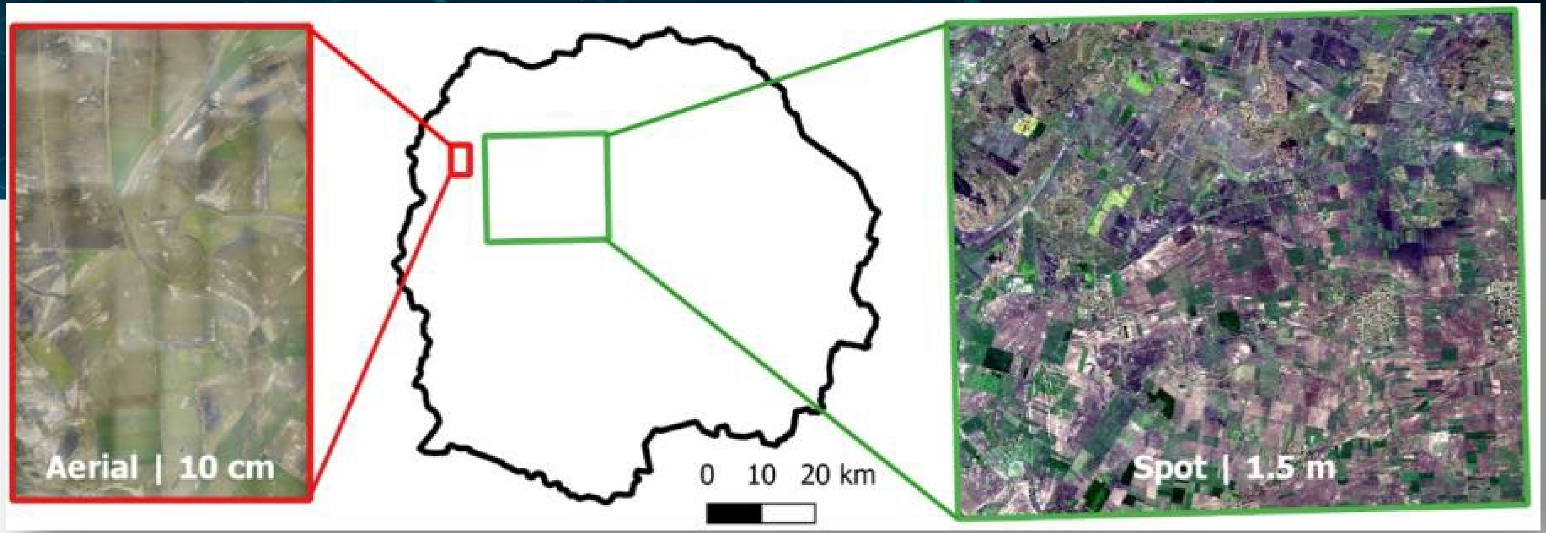


Results 2021

10 weeks in January – April 2021

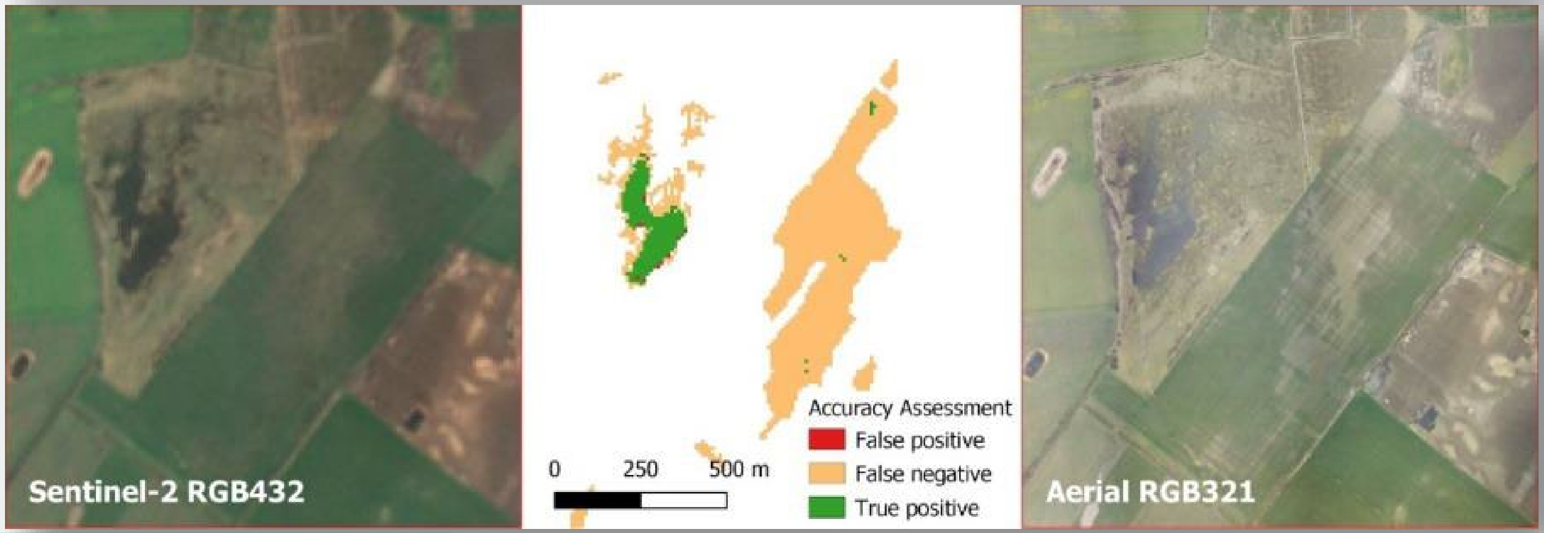


Validation



Based on:

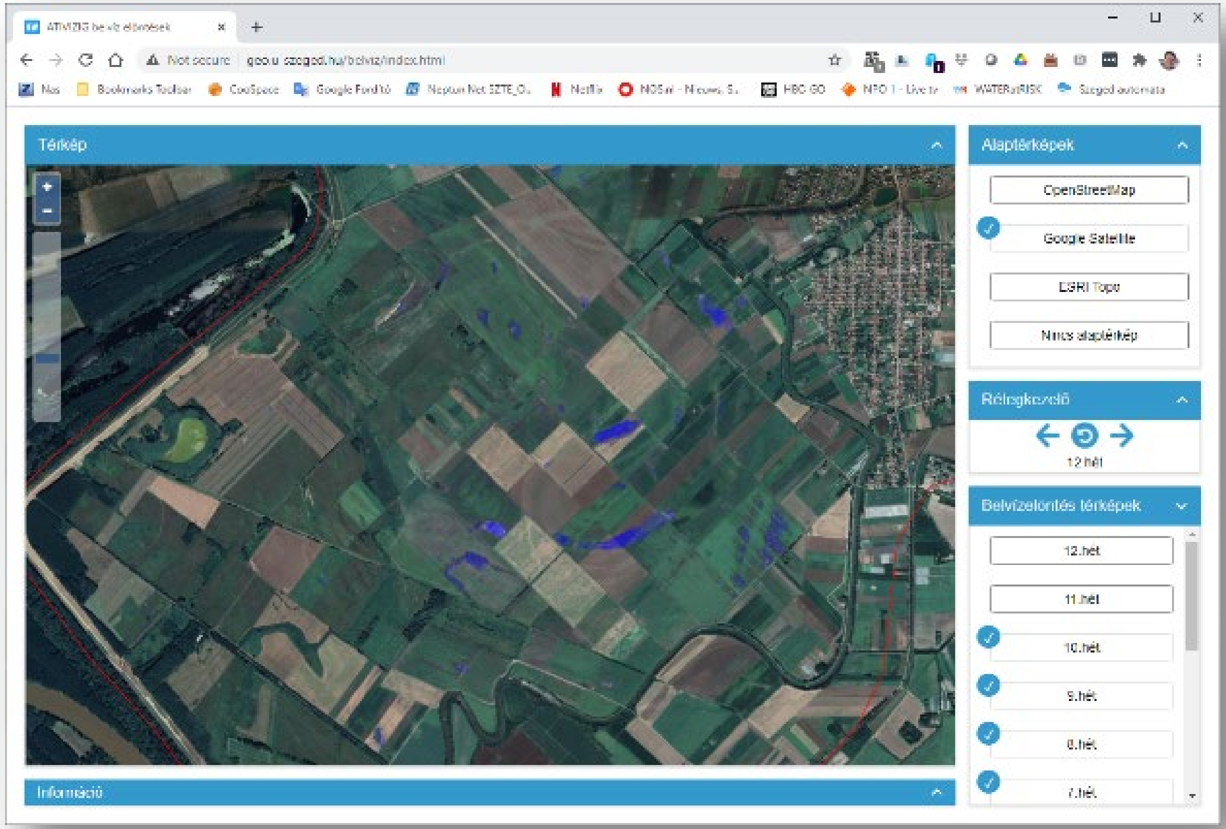
- Drone images
- Aerial photographs
- Very high resolution multispectral satellite data (Planet, Spot, Worldview-3)



		Reference						
	# pixels	no water	water	Total	Producer's Acc.	Omission error	User's Acc.	Commission error
Detected	no water	4454908	7807	4462715	99.92	0.08	99.83	0.17
	water	3494	4513	8007	36.63	63.37	56.36	43.64
	Total	4458402	12320	4470722	OA	99.74	Kappa	0.44

Possibilities for further development

- New data sources
- Calibration + validation based on high resolution satellite data of large areas
- Data cube storage
- New algorithms (AI)
- Geographic area specific parameters
- Include dynamic data
- Conversion to open source
- Data publication



Thank you for your attention

Posters:

Operational weekly inland excess water mapping - Zalán Tobak (Wednesday)

Inland excess water delineation using machine learning on medium resolution data - Balázs Kajári (Friday)

Acknowledgements:

Sentinel for Hungarian INland EXcess WaTer Volume Determination (SINEXT, ESA 4000124050/18/I-BG)

WATERatRISK projekt (HUSRB/1602/11/0057)

Boudewijn van Leeuwen, leeuwen@geo.u-szeged.hu