

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



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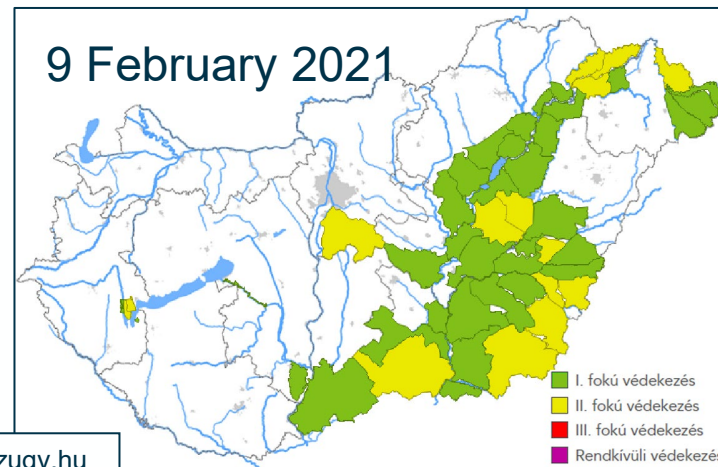
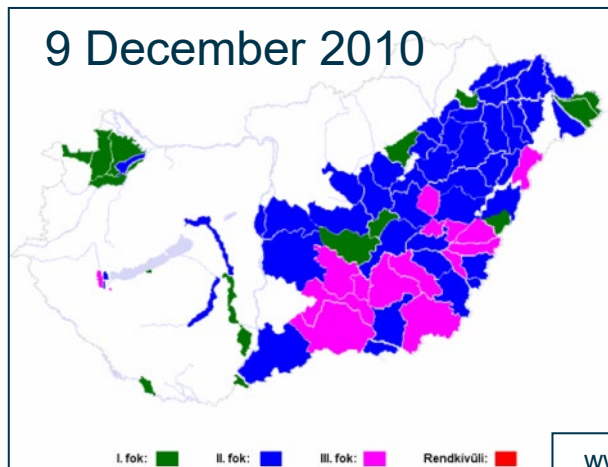
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Inland excess water background

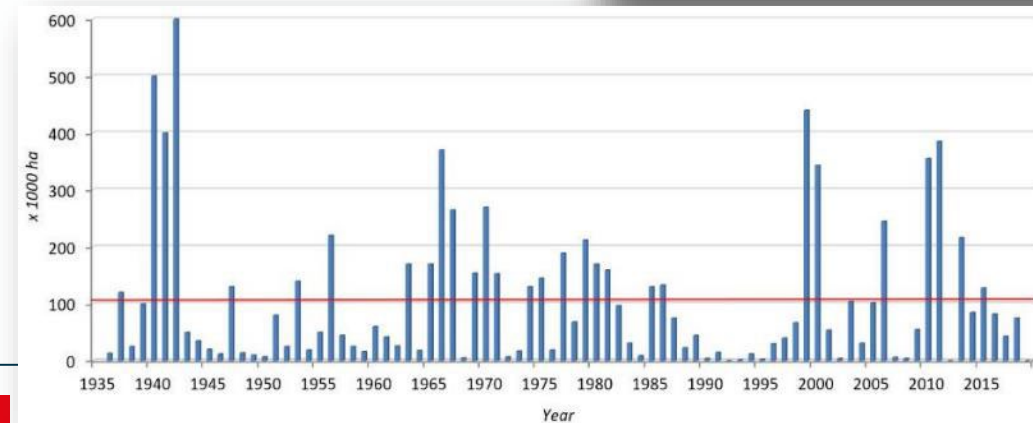
- Definition?
- Factors
- Temporal distribution
- Spatial distribution
- Impact

„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?

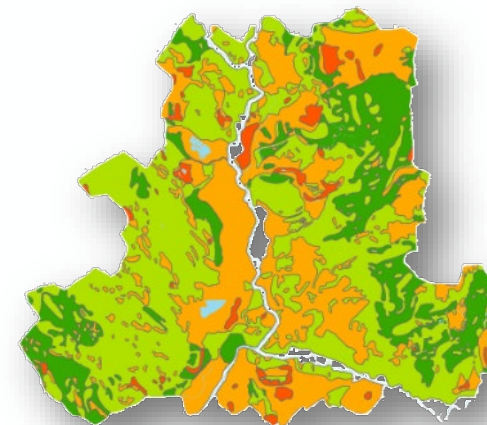
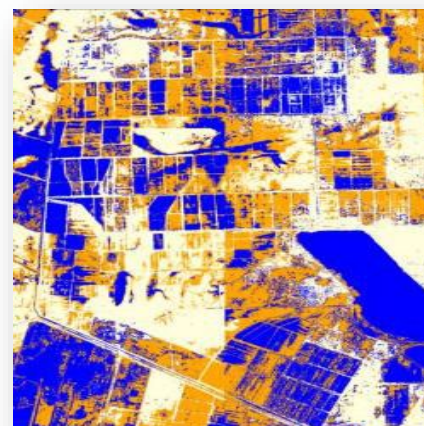
Key reason for IEW mapping/monitoring:

- 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)



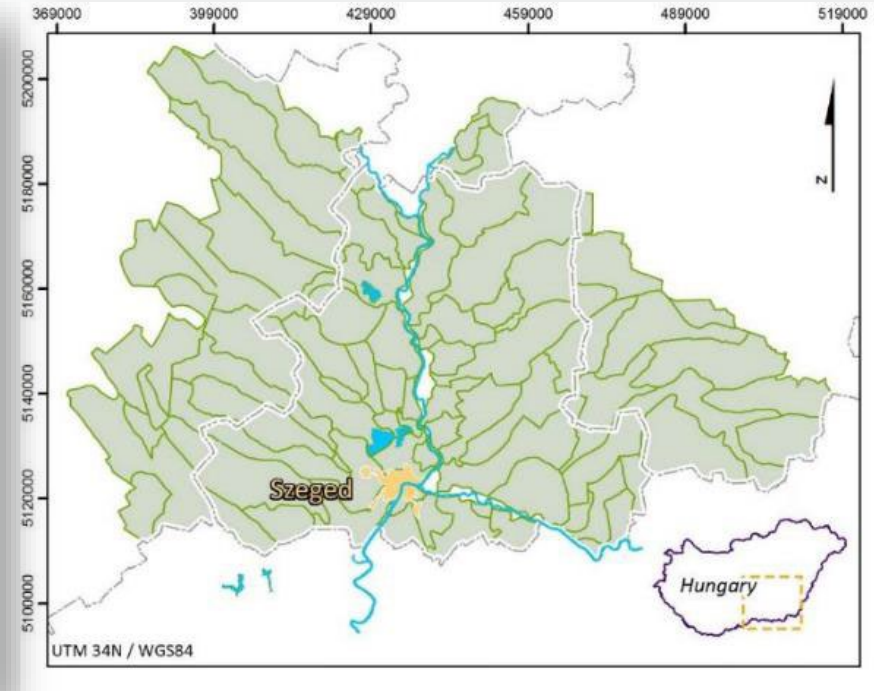
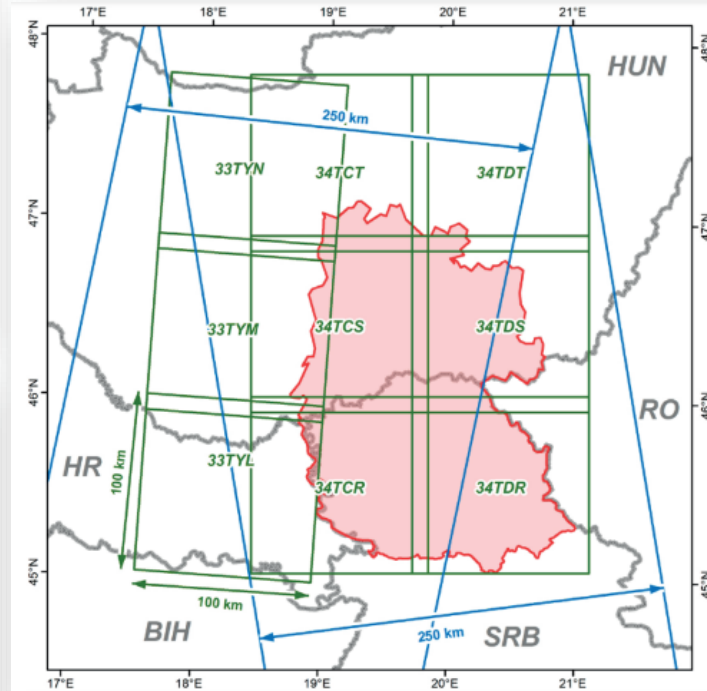
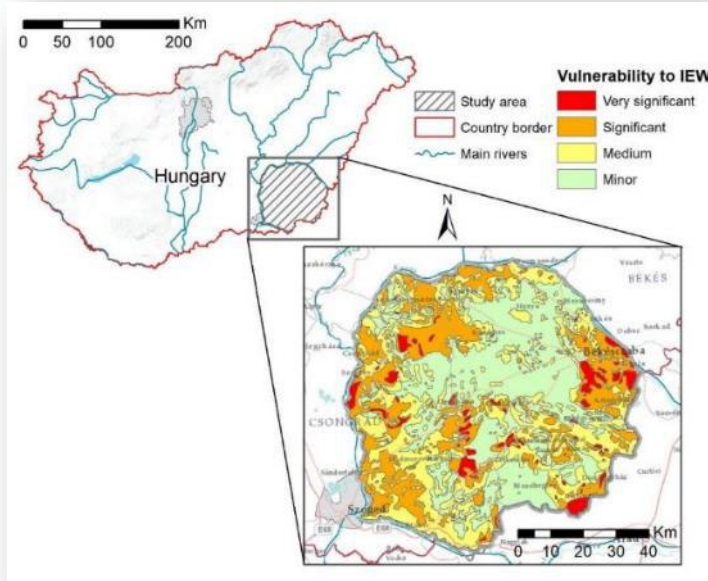
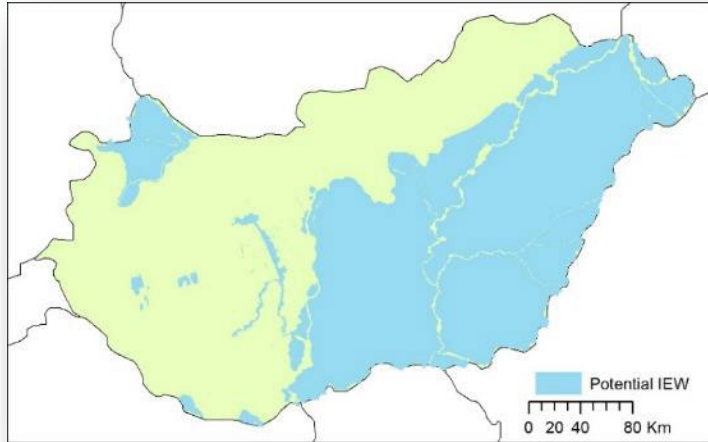
Continuous monitoring of inland excess water



- 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

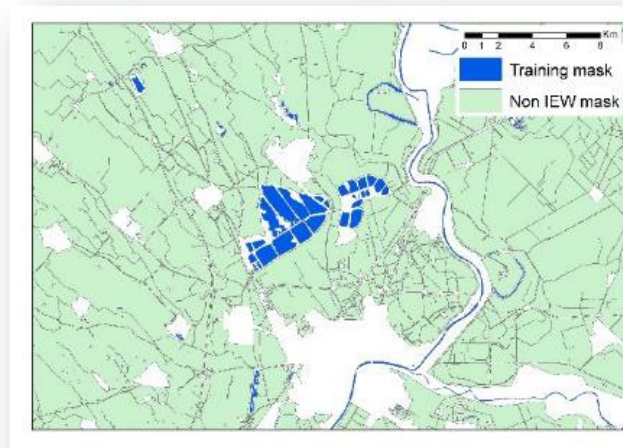
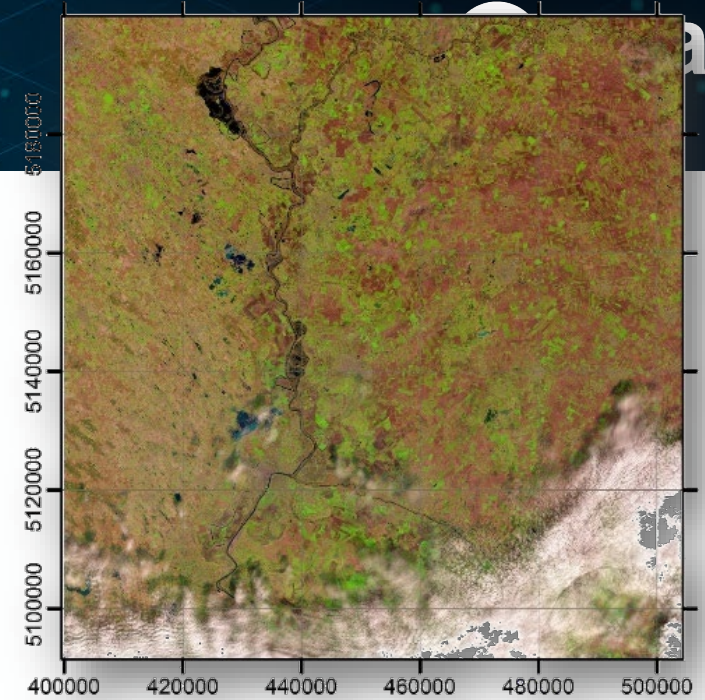


Study areas

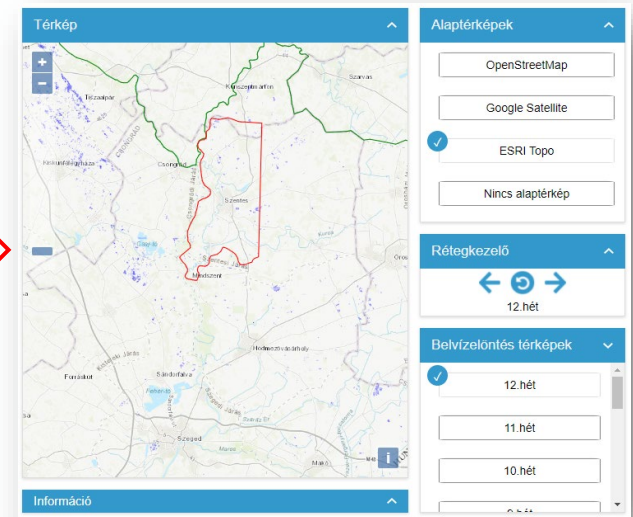
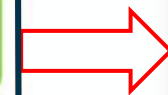
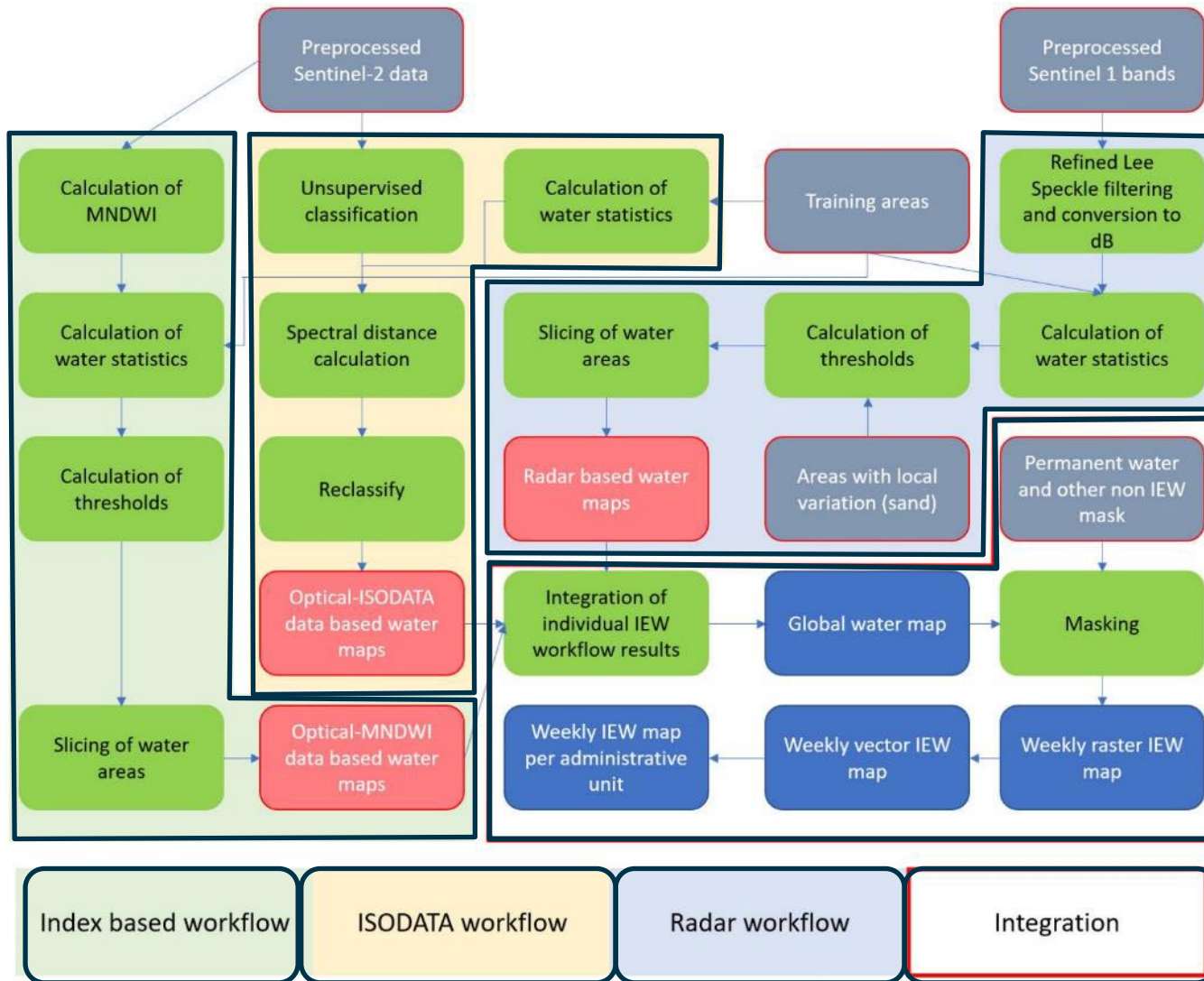


Data

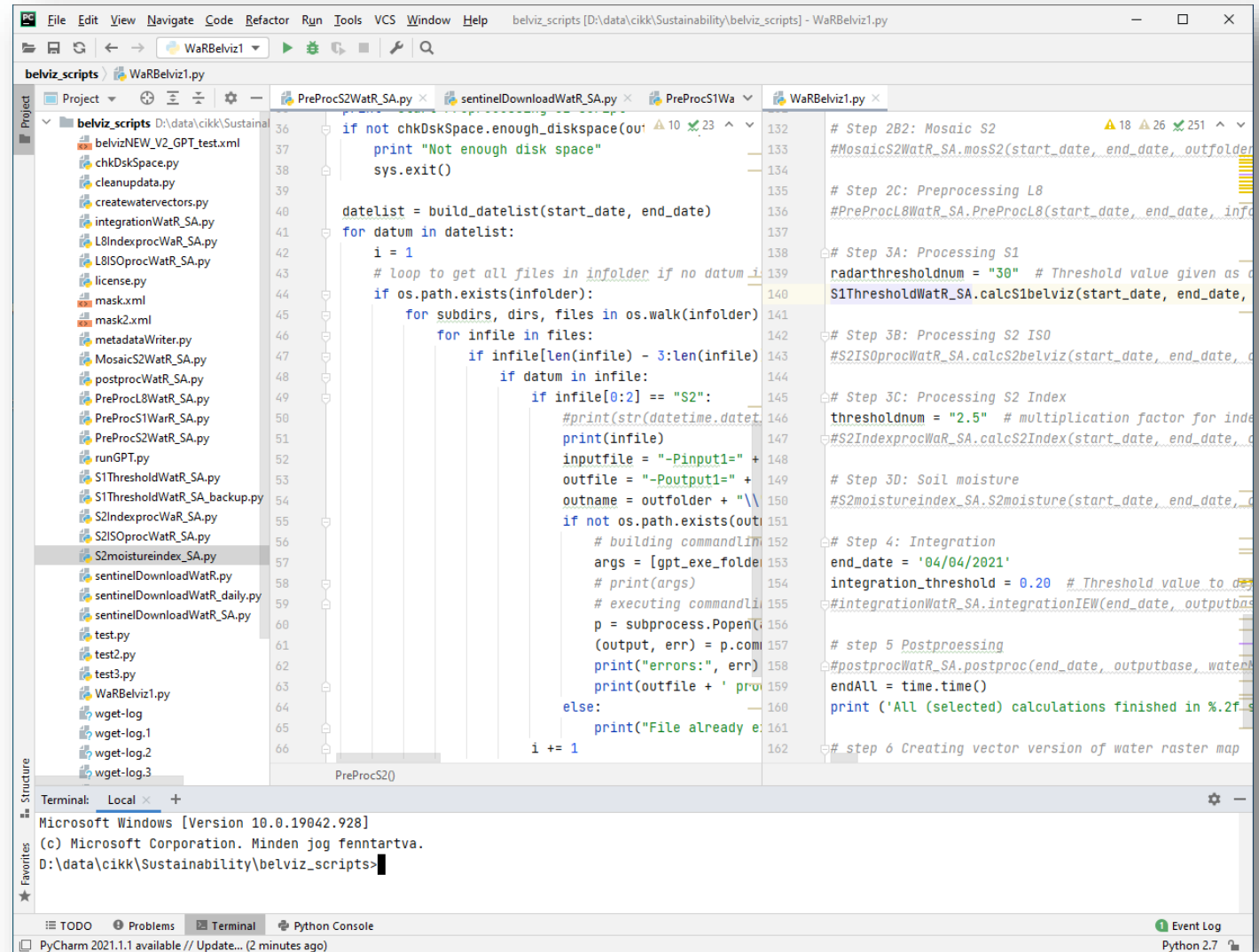
- Multispectral satellite data
 - Sentinel-2
- Radar satellite data
 - Sentinel-1
- Auxiliary data
 - Soil texture data
 - Mask for training
 - Mask for non-water areas (water, permanent wetlands, transportation infrastructure, built-up areas)



Monitoring framework

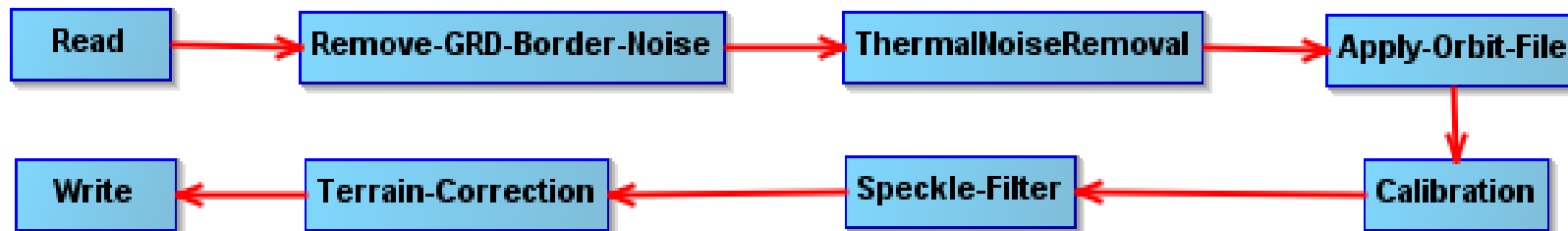
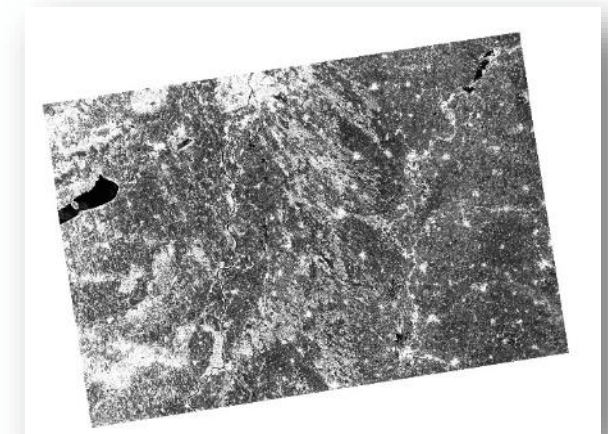
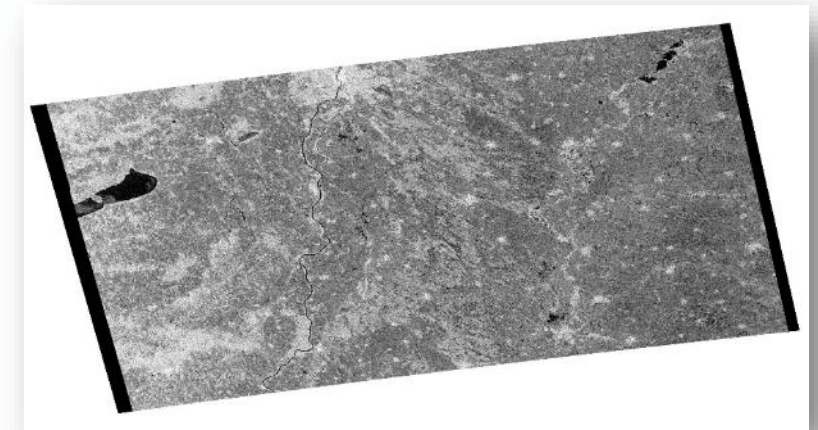


- 15 Python scripts
- ~ 3000 lines of code
- arcpy, numpy, gdal
- 2 sets: daily and weekly
- Manual start of sets of scripts



```
File Edit View Navigate Code Refactor Run Tools VCS Window Help belviz_scripts [D:\data\cikk\Sustainability\belviz_scripts] - WaRBelviz1.py
Project: belviz_scripts
Project: belviz_scripts
  belviz_scripts
    belviz_scripts
      belvizNEW_V2_GPT_test.xml
      chkDskSpace.py
      cleanupdata.py
      createwaterectors.py
      integrationWatR_SA.py
      L8IndexprocWatR_SA.py
      L8ISOProcWatR_SA.py
      license.py
      mask.xml
      mask2.xml
      metadataWriter.py
      MosaicS2WatR_SA.py
      postprocWatR_SA.py
      PreProcL8WatR_SA.py
      PreProcS1WatR_SA.py
      PreProcS2WatR_SA.py
      runGPT.py
      S1ThresholdWatR_SA.py
      S1ThresholdWatR_SA_backup.py
      S2IndexprocWaR_SA.py
      S2ISOProcWatR_SA.py
      S2moistureindex_SA.py
      sentinelDownloadWatR.py
      sentinelDownloadWatR_daily.py
      sentinelDownloadWatR_SA.py
      test.py
      test2.py
      test3.py
      WaRBelviz1.py
      wget-log
      wget-log.1
      wget-log.2
      wget-log.3
    WaRBelviz1.py
      PreProcS20
        36 if not chkDskSpace. enough_diskspace(out
        37 print "Not enough disk space"
        38 sys.exit()
        39
        40 datelist = build_datelist(start_date, end_date)
        41 for datum in datelist:
        42     i = 1
        43     # loop to get all files in infolder if no datum i
        44     if os.path.exists(infolder):
        45         for subdirs, dirs, files in os.walk(infolder)
        46         for infile in files:
        47             if infile[len(infile) - 3:len(infile)
        48             if datum in infile:
        49                 if infile[0:2] == "S2":
        50                     #print(str(datetime.date
        51                     print(infile)
        52                     inputfile = "-Pinput1=" +
        53                     outfile = "-Poutput1=" +
        54                     outname = outfolder + "\\
        55                     if not os.path.exists(out
        56                     # building commandLi
        57                     args = [gpt_exe_folde
        58                     # print(args)
        59                     # executing commandLi
        60                     p = subprocess.Popen(
        61                     (output, err) = p.com
        62                     print("errors:", err)
        63                     print(outfile + ' pro
        64                     else:
        65                         print("File already e
        66                     i += 1
        132 # Step 2B2: Mosaic S2
        133 #MosaicS2WatR_SA.mosS2(start_date, end_date, outfolder
        134
        135 # Step 2C: Preprocessing L8
        136 #PreProcL8WatR_SA.PreProcL8(start_date, end_date, info
        137
        138 # Step 3A: Processing S1
        139 radarthresholdnum = "30" # Threshold value given as d
        140 #S1ThresholdWatR_SA.calcS1belviz(start_date, end_date,
        141
        142 # Step 3B: Processing S2 ISO
        143 #S2ISOProcWatR_SA.calcS2belviz(start_date, end_date, d
        144
        145 # Step 3C: Processing S2 Index
        146 thresholdnum = "2.5" # multiplication factor for inde
        147 #S2IndexprocWaR_SA.calcS2Index(start_date, end_date, d
        148
        149 # Step 3D: Soil moisture
        150 #S2moistureindex_SA.S2moisture(start_date, end_date, c
        151
        152 # Step 4: Integration
        153 end_date = '04/04/2021'
        154 integration_threshold = 0.20 # Threshold value to de
        155 #integrationWatR_SA.integrationIEW(end_date, outputbas
        156
        157 # step 5 Postprocessing
        158 #postprocWatR_SA.postproc(end_date, outputbase, waterh
        159 endAll = time.time()
        160 print ('All (selected) calculations finished in %.2f s
        161
        162 #_step 6 Creating vector version of water raster map
```

- 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,

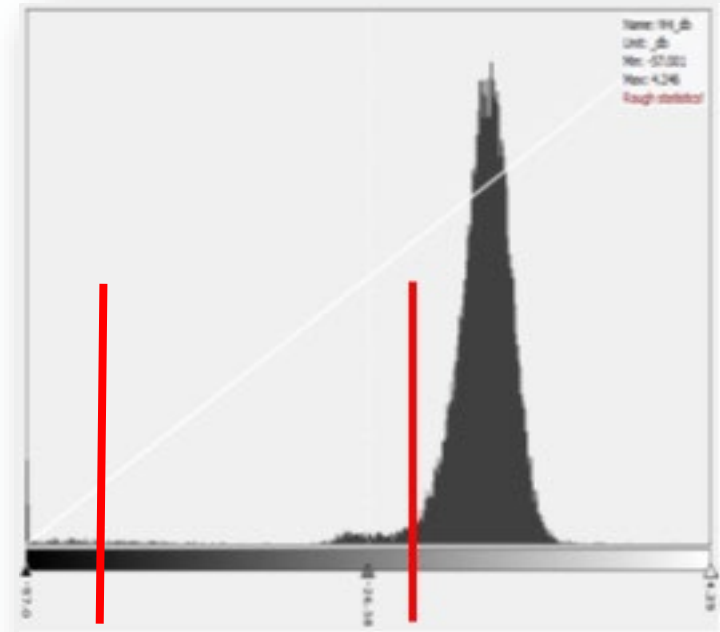
K: user defined constant

Water pixels:

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

x: value of an individual pixel in both bands

→ Adapted for sandy areas



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):

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

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

where

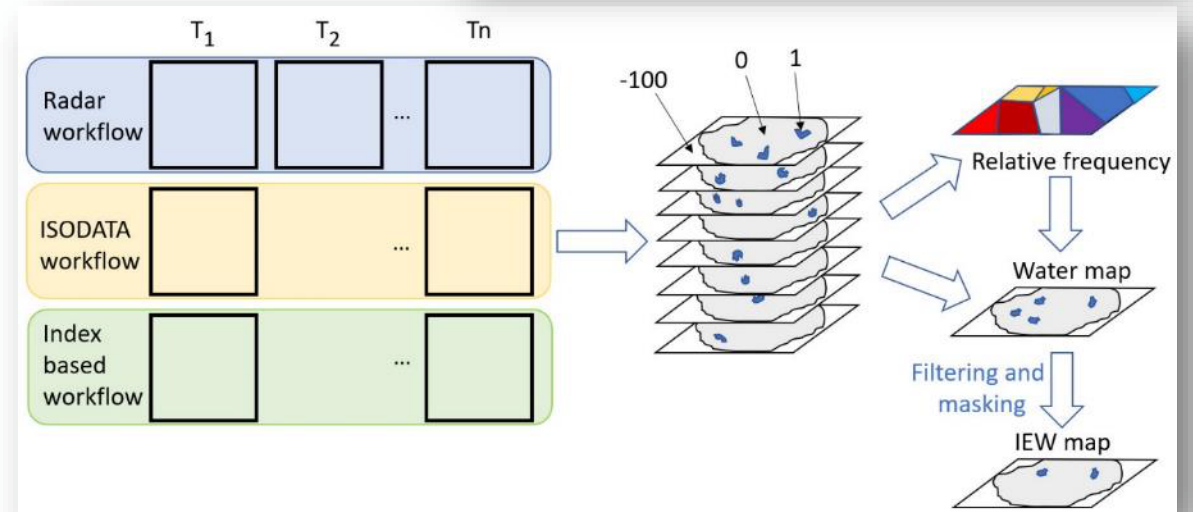
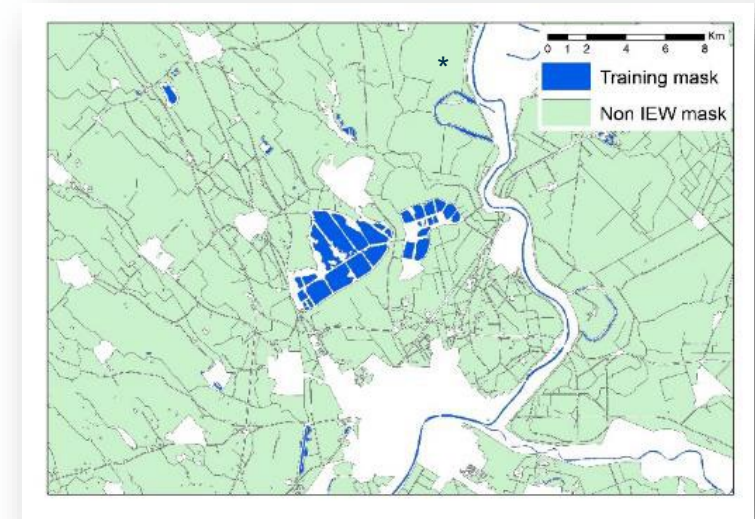
$MNDWI_{mean}$: mean index value of the reference pixels,

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

k: multiplication factor

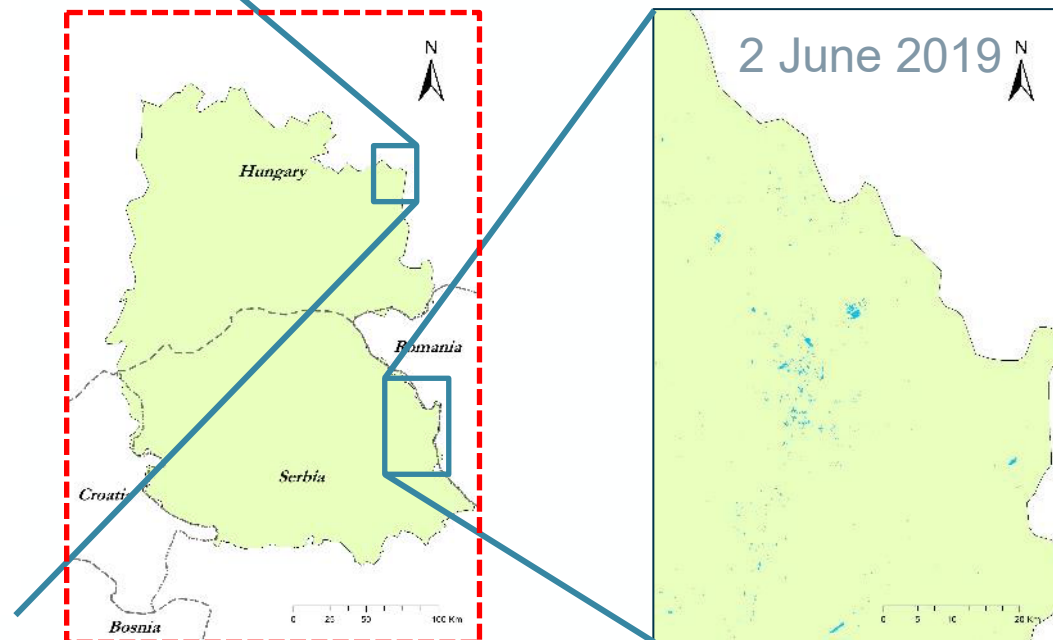
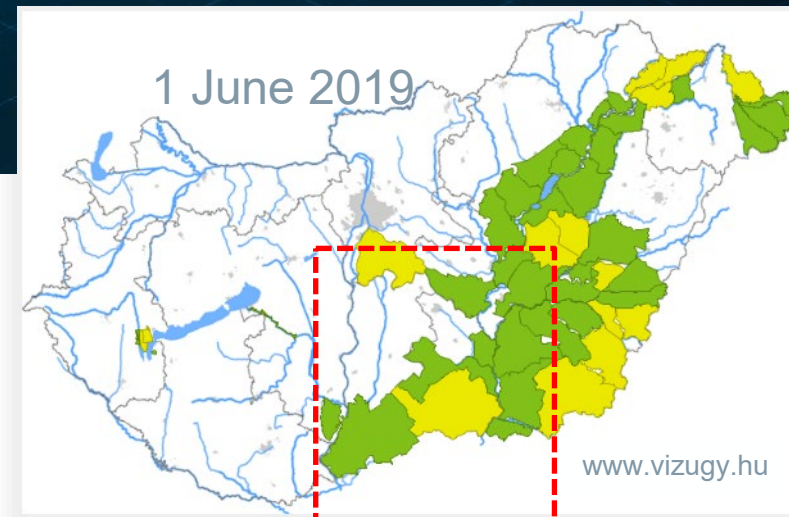
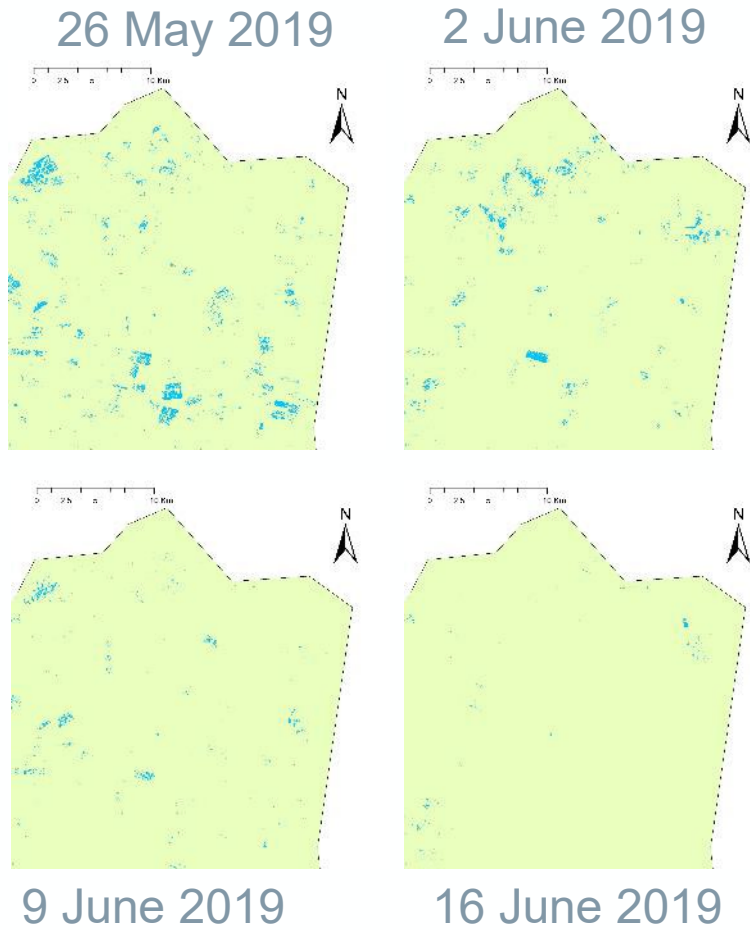
Many water maps from different days and areas combined into one weekly map:

- 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

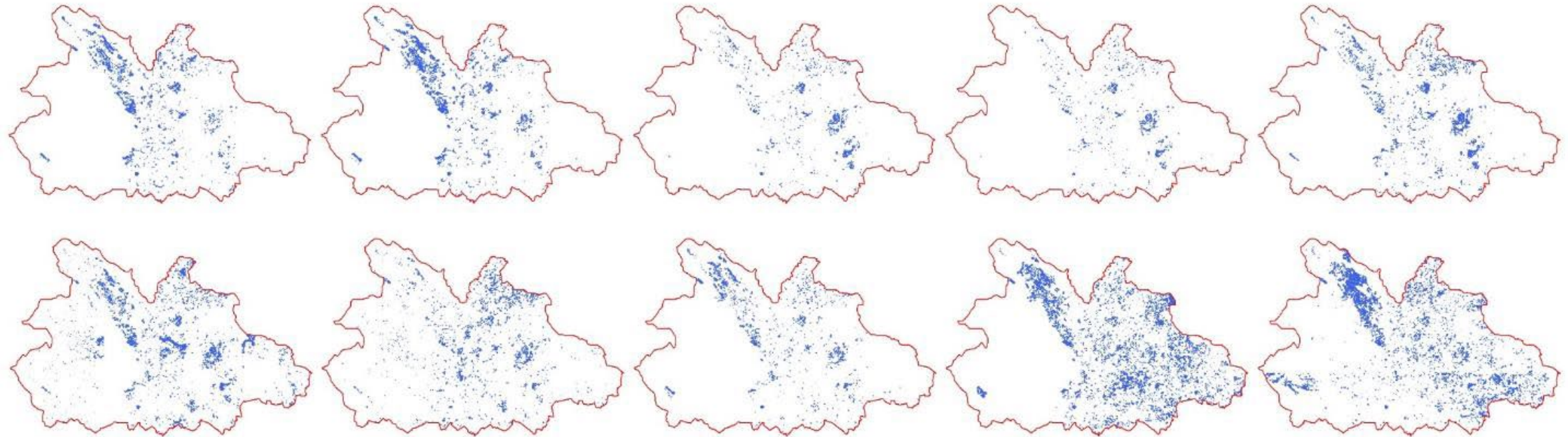


Results 2019

5 weeks in May-June 2019



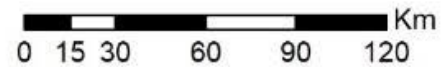
10 weeks in January – April 2021



Inland excess water Week 2 - Week 12

ATIVIZIG

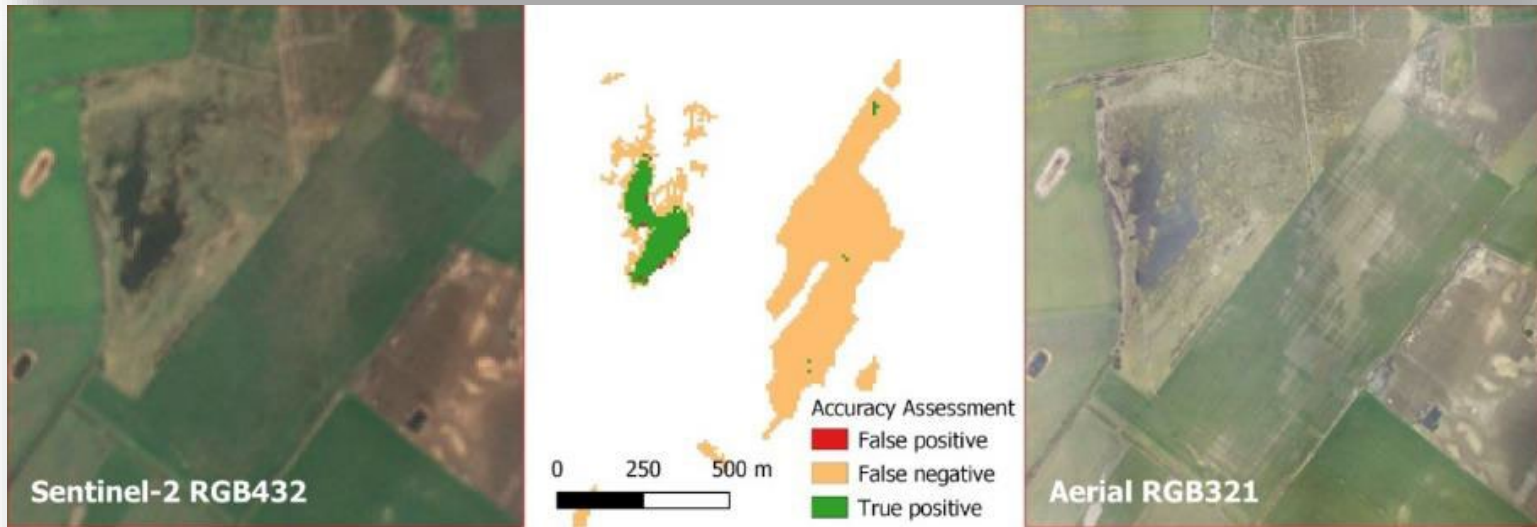
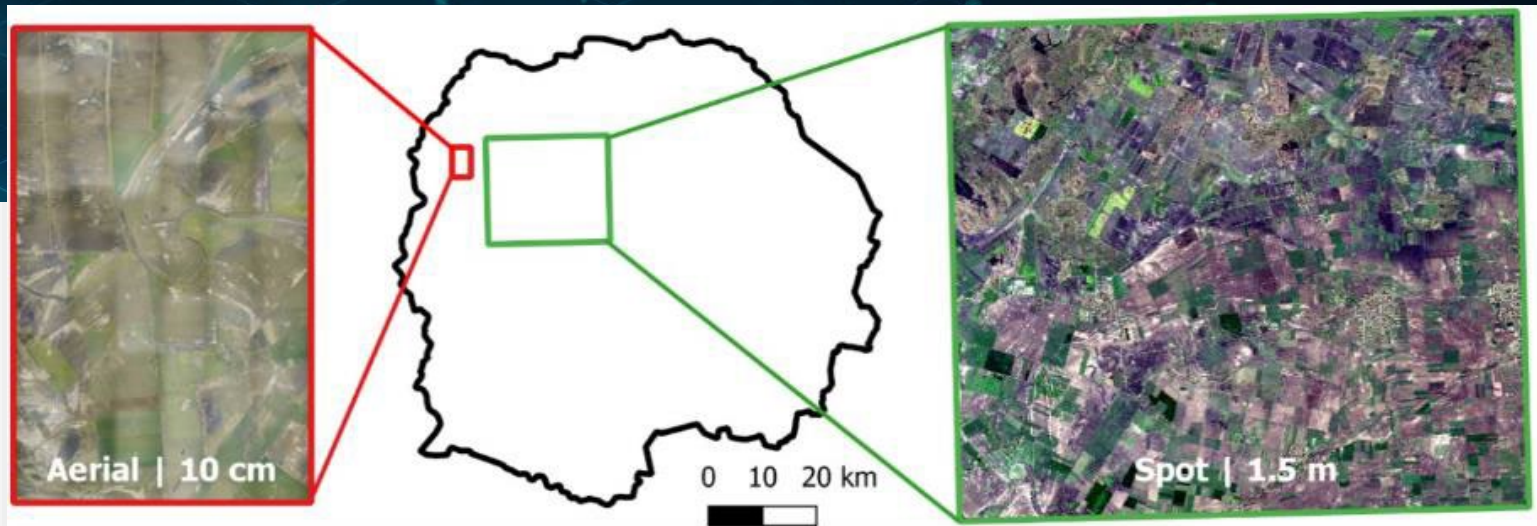
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Validation

Based on:

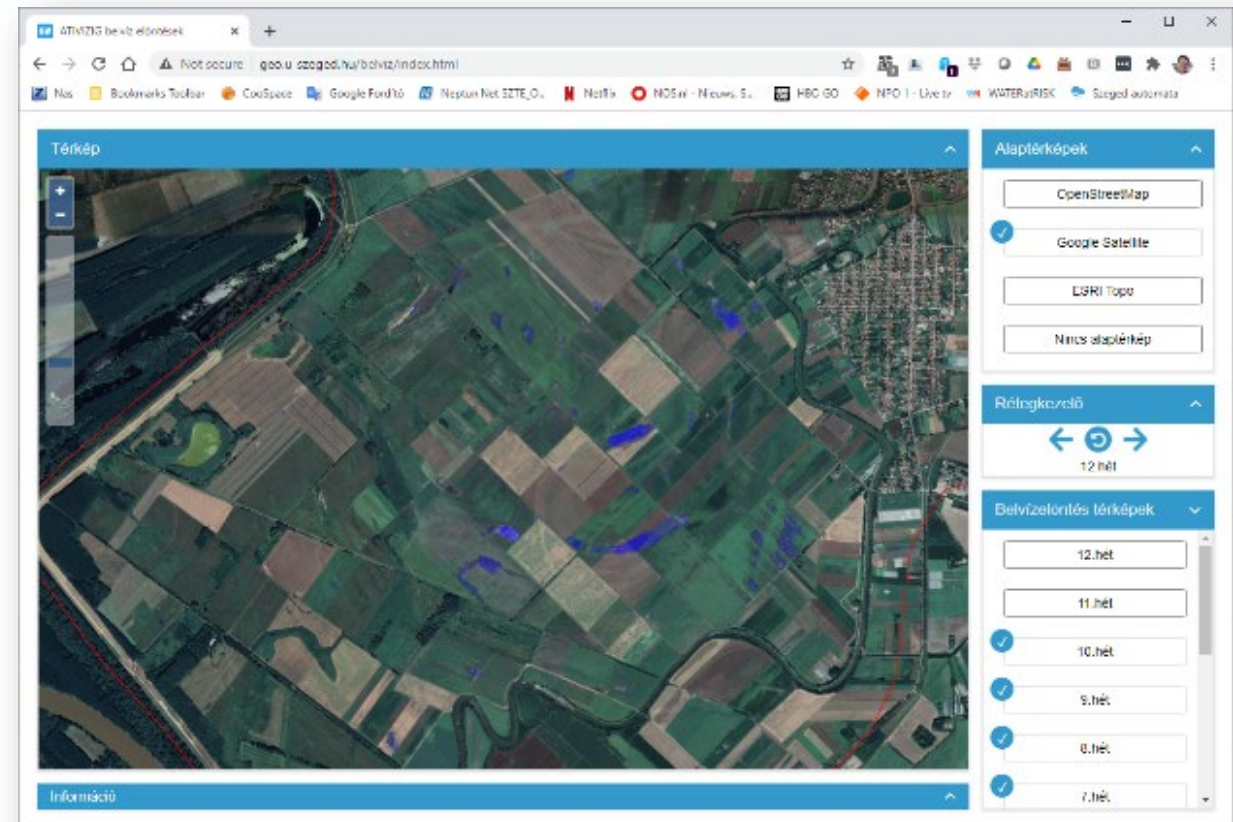
- Drone images
- Aerial photographs
- Very high resolution multispectral satellite data (Planet, Spot, Worldview-3)



		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)

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