INSAR MONITORING RESULTS OF TRANSCARPATHIA IN THE GEOSES CBC PROJECT

Presenter: Balint Magyar[1][2]

[1] Budapest University of Technology and Economics – Faculty of Civil Engineering – Department of Geodesy and Surveying
[2] Lechner Nonprofit Ltd. - Satellite Geodetic Observatory

In: Rédey Seminar
2022.05.10. 12:15 CET

CONTENT

GEOSES

Project description
Area of Interests
Timeline

INSAR

Technology, Materials
Applied workflow,
Problems

RESULTS

Preliminary and
Regional Monitoring

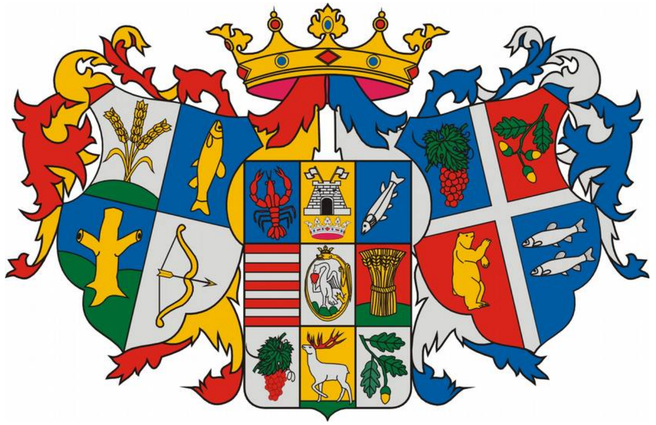
OUTLOOK

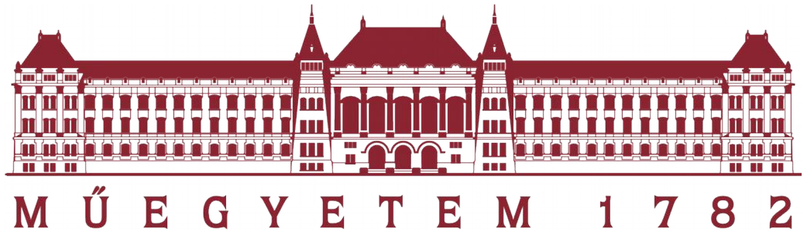
WebDevelopment
Upgrades,
Discussion

GEOSES PROJECT

Project description, Area of Interests and Timeline

GeoSES Partners





Hungary
Slovakia
Romania
Ukraine

UNIVERSITATEA TEHNICĂ
DIN CLUJ-NAPOCA

UZHGOROD
NATIONAL UNIVERSITY

GeoSES Objectives

Dedication

- ENI Cross-border Cooperation Programme 2014-2021
- Extension of the operational Space Emergency System

Partners

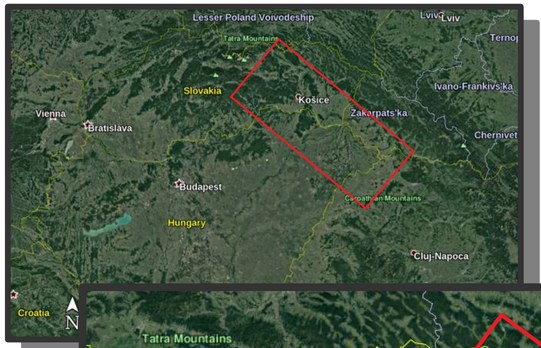
- Hungary: Self Government of SZSZB County / BME (+LTK)
- Slovakia (UPJS), Romania (UTC-N) , Ukraine (UZHNU - lead)

Specified objectives

- Monitoring natural and anthropogenic geo-processes
- Integration innovative and advanced techniques, including EO with InSAR

InSAR specific roles

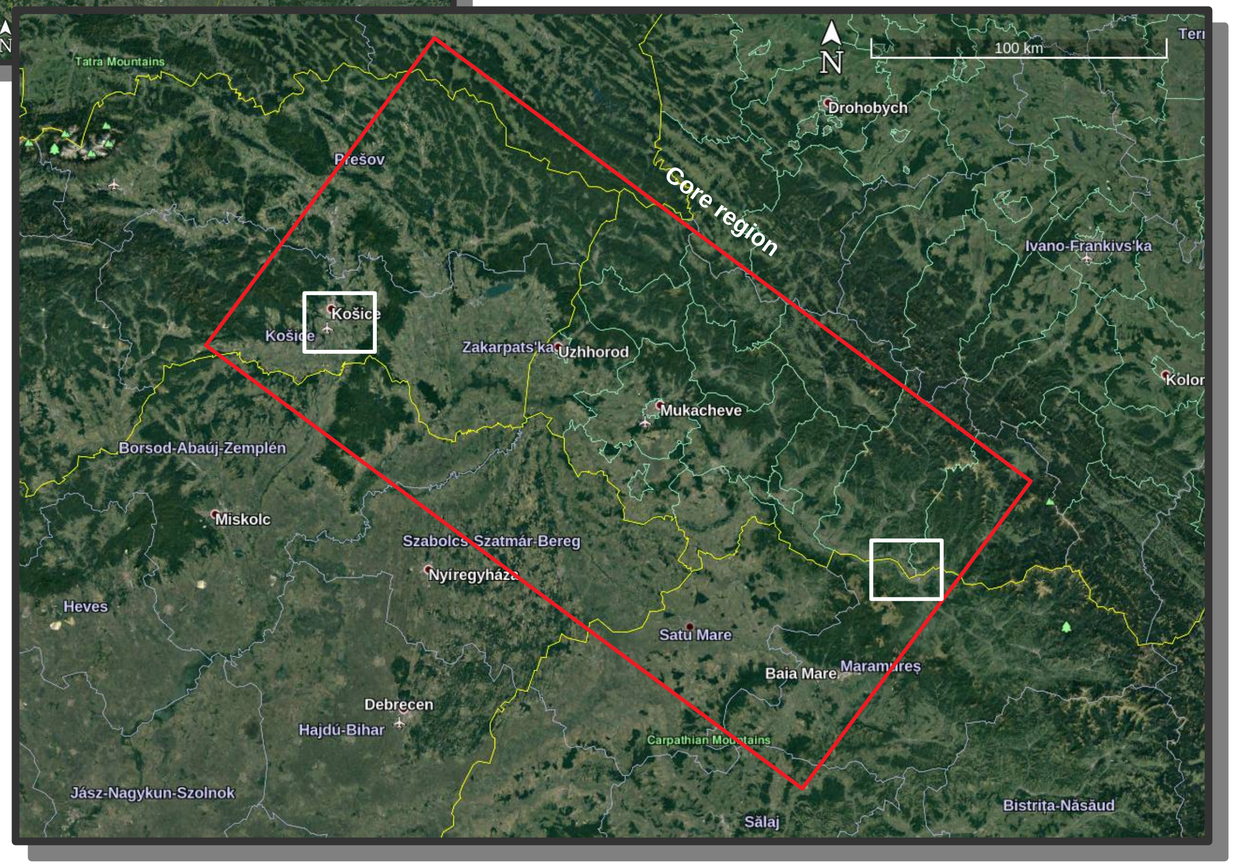
- Processing chain development and analysis (AOIs – Requests of Partners', preliminary, core region) - PSI/SBAS



Hungary
Slovakia
Romania
Ukraine

GeoSES

GeoSES - HUSKROUA/1702/8.1/0065



Scopes of Activity Group 1

Activity #	Activity title	Brief description
Activity 1.1	Collection of SAR imagery and endangered sites of the HUSKROUA region	Satellite based radar imagery is collected from various satellite missions to determine the deformation regime of the focus area in the past decade. As an initial action, a general survey of the region will be performed to identify natural radar reflectors and then as a 2nd step will be select one or two endangered locality to perform a monitoring. To collect information from endangered sites with natural or industrial burdens, it is necessary to develop cooperation with local authorities (local self-governments), state and private companies and firms with a view to geological exploration, extraction of raw materials, waste management, water management, flood rescue system and the like.

	Title of the output	Brief description of the output	Corresponding activity(ies)	Target value
Output 1.1	Satellite Based Radar imagery database and information from endangered sites	The database will involve the available radar imagery of the HUSKROUA area. These data sets (raw and preprocessed) will be made available to project partners and other institutions in the eligible area for further analysis. Collecting information from endangered sites with natural or industrial burdens to select one or two endangered locality to perform a monitoring (semiannual analysis as default and dedicated analysis anytime if needed due to any event.	A1.1	1.00

Activity #	Activity title	Brief description
Activity 1.2	Interpretation and dissemination of the InSAR deformation and geodetic monitoring results	During the implementation of this activity is to perform a general radar survey of the whole HU-SK-RO-UA region with InSAR technique, especially existing or abandoned mining areas, deposits, dams to detect endangered spots. Based on the deformation history of the persistent scatterers those areas will be identified, where significant subsidences can be observed. Then any geodetic/geographic methods and techniques (GNSS - Global Navigation Satellite Systems, TLS - Terrestrial Laser Scanning, ALS - Aerial Laser Scanning, UAV - Unmanned Aerial Vehicle, high-precision levelling) will be applied to the discovered subsidences. The resulting information will be widely distributed to all project partners and the relevant governmental and societal players using active and passive communication channels. Each of the methods will be perform in 4 cycles of measurement.

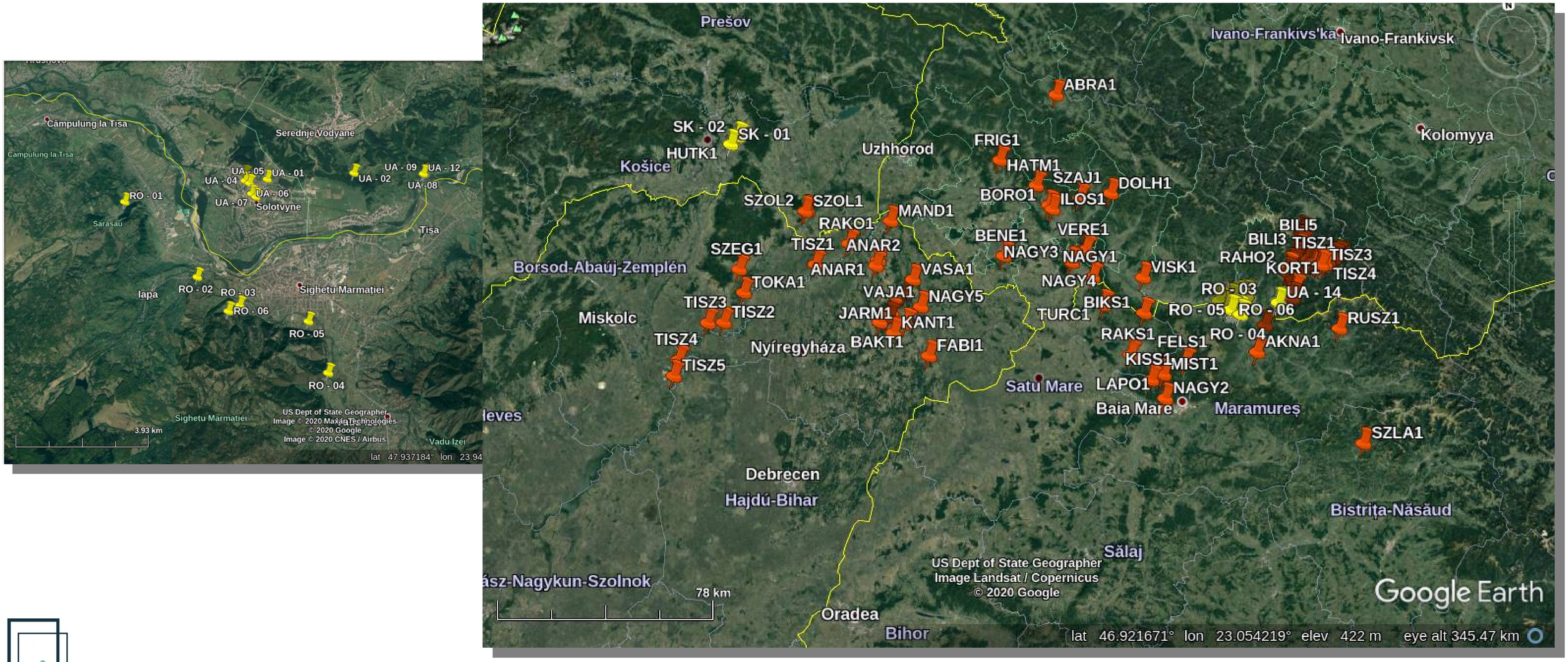
	Title of the output	Brief description of the output	Corresponding activity(ies)	Target value
Output 1.2	Deformation history database and technical documentation on the interpretation of the deformation analysis	Based on the InSAR analysis the vertical displacements of the points will be stored in a database. The database will be made available to the project partners. This database will help to identify areas suffering from significant vertical displacements. Then to the discovered subsidences will be carried out by any geodetic/geographic methods and techniques (GNSS, TLS, ALS, UAV and high- precision levelling) to define the deformation model and improve the risk assessment.	A1.2	5,00

Which are the expected **results of your project** (e.g. number of regional policy changes, , percentage reduction of certain pollutants in a river system, number of new business start-ups). Please mention all project expected results as well as the corresponding Activities Group where they are achieved				
Deformation map	1 digital map in Uzhhorod, digital maps (4 units) in Department of State Emergency Service in cross-border region	0,00	5,00	Deformation monitoring (DP)

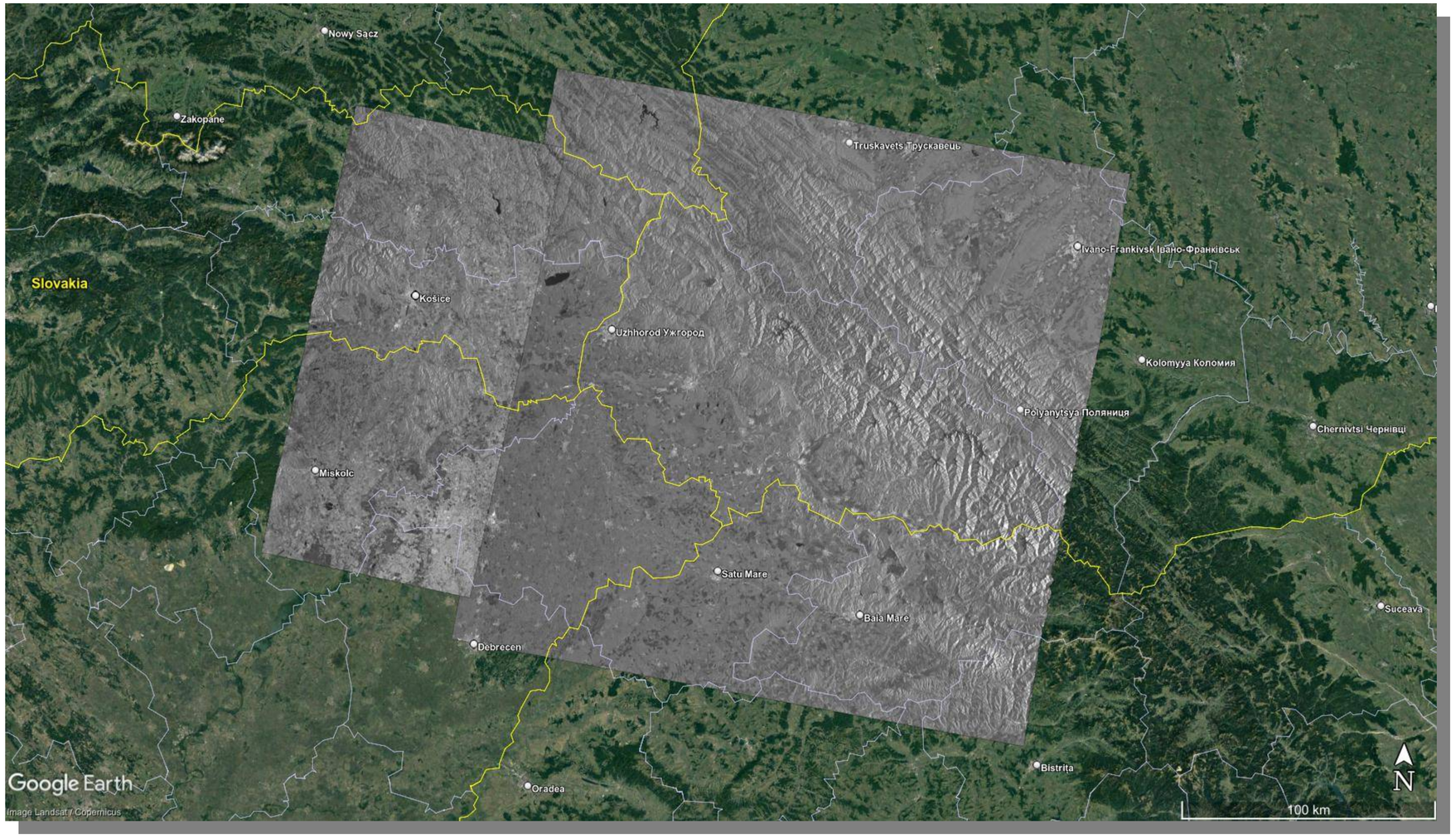
Result #	Results title	Please provide a brief description of the results emerging from this AG	Programme output indicator or other indicators to which the result will contribute	Target value
Result 1.1	Deformation map	The proposed deformation map will clearly classify the different regions according to deformations rates and identify those regions, that are suffering significant deformations, that can lead to damages to public and private properties.	Number of awareness raising initiatives regarding emergency situations	5,00

Which are the **outputs that define your project** and would measure its progress (e.g. number of reports written, number of seminars held, number of members of target group given additional training, kilometres of riverbed cleaned, number of innovation centres opened)? Please mention all project expected outputs as well as the corresponding Activities Group where they are achieved				
Satellite Based Radar imagery database and information from endangered sites	Database containing a radar imagery from at least the ESA Sentinel- 1 missions since 2014. if the budget allows historic (from 1992) ERS-1 monthly imagery will also be included	0,00	1,00	Deformation monitoring (DP)
Deformation history database and technical documentation on the interpretation of the deformation analysis	Height variation map of the area including the indication of areas with the risk of significant ground deformations.	0,00	5,00	Deformation monitoring (DP)

+ Predefined investigation areas



Area of Interest – SAR RMLI



Core Area

- Transcapathia (UKR)
- E-Slovakia (SLO)
- NW-Romania (ROM)
- NE-Hungary (HUN)

Characteristics

- Area: ~60 000 km^2
- Timespan: 2014-2021
- **>460 diff int / ROI**
- Combined PS+DS (SL)

RONs

- DESC 153
- DESC 080

GOAL:
Obtain LOS & U-D components

GeoSES Project: InSAR Timeline

T0: start of project

Grant Contract

START PROJECT

2020.11

Planned start of Activity 1.2: T0+4

Realization of HW procurement

LTK Software integration

Data migration (**WORK START T0+12**)

2021.04

Preliminary PSI of AOIs aiming field Measurements, Report to project team

2022.04

Regional processing workflow development, First presentation of regional results

2022.05

Reporting period, Preparing products

Transfer data to Beneficiaries

(planned: T0+24+6)

NOTE: *HW procurement delays and Covid19 situation results to project extension (~6 months), some delay due to technical (HW+SW+WF) problems*

INSAR WORKFLOW

Technology, Utilized data and applied workflow

Technology

- Atmosphere is transparent in SAR bands
- Utilizes EM relative phase differences

Band designation*	Wavelength (λ), cm	Frequency (ν), GH_z (10^9 cycles · sec^{-1})
Ka (0.86 cm)	0.8 to 1.1	40.0 to 26.5
K	1.1 to 1.7	26.5 to 18.0
Ku	1.7 to 2.4	18.0 to 12.5
X (3.0 cm, 3.2 cm)	2.4 to 3.8	12.5 to 8.0
C (6.0)	3.8 to 7.5	8.0 to 4.0
S	7.5 to 15.0	4.0 to 2.0
L (23.5 cm, 25 cm)	15.0 to 30.0	2.0 to 1.0
P (68 cm)	30.0 to 100.0	1.0 to 0.3

$$\Delta\varphi = \frac{4\pi}{\lambda}\Delta D_0 + \frac{4\pi}{\lambda}\frac{HB_{\perp}}{R\sin\theta} + \frac{4\pi}{\lambda}B_{//} + \Delta\varphi_{atm} + \Delta\varphi_{diele} + \Delta\varphi_{pn} + 2n\pi \quad (3)$$

Various techniques exists to specify/compensate phase components

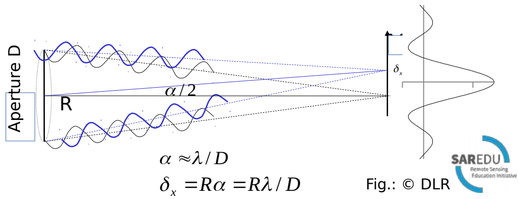
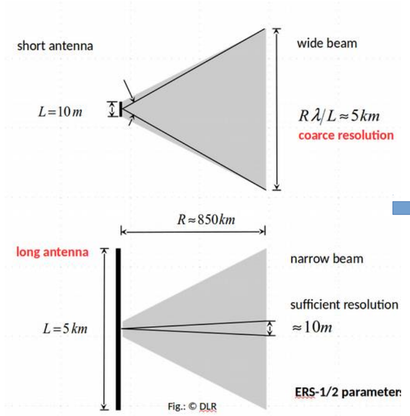


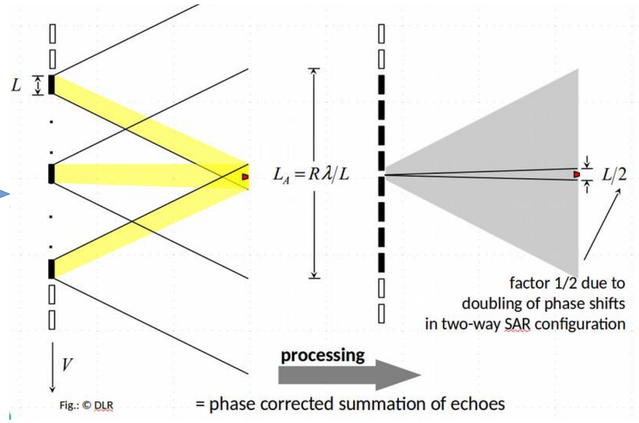
Fig.: © DLR

Fig.: DLPNG

Real Aperture Radar (RAR)

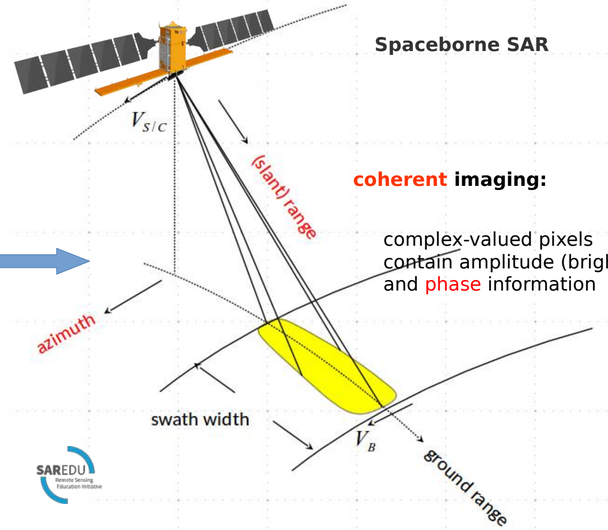


Solution: Synthetic Aperture Radar (SAR)



= phase corrected summation of echoes

Spaceborne SAR



coherent imaging:

complex-valued pixels contain amplitude (brightness) and phase information

Advantages

- Weather and day/night independent
- Submillimeter accuracy
- Various Ground-Range Resolution

Excellent tool to perform Earth Observation (EO) / Surface deformation monitoring

Input data and management

SAR Level-1 SLC products

- Interferometric researches requires SLC products
- Copernicus Schihub (archive data on request)
- Alaska Satellite Facility (ASF) – **quick access**

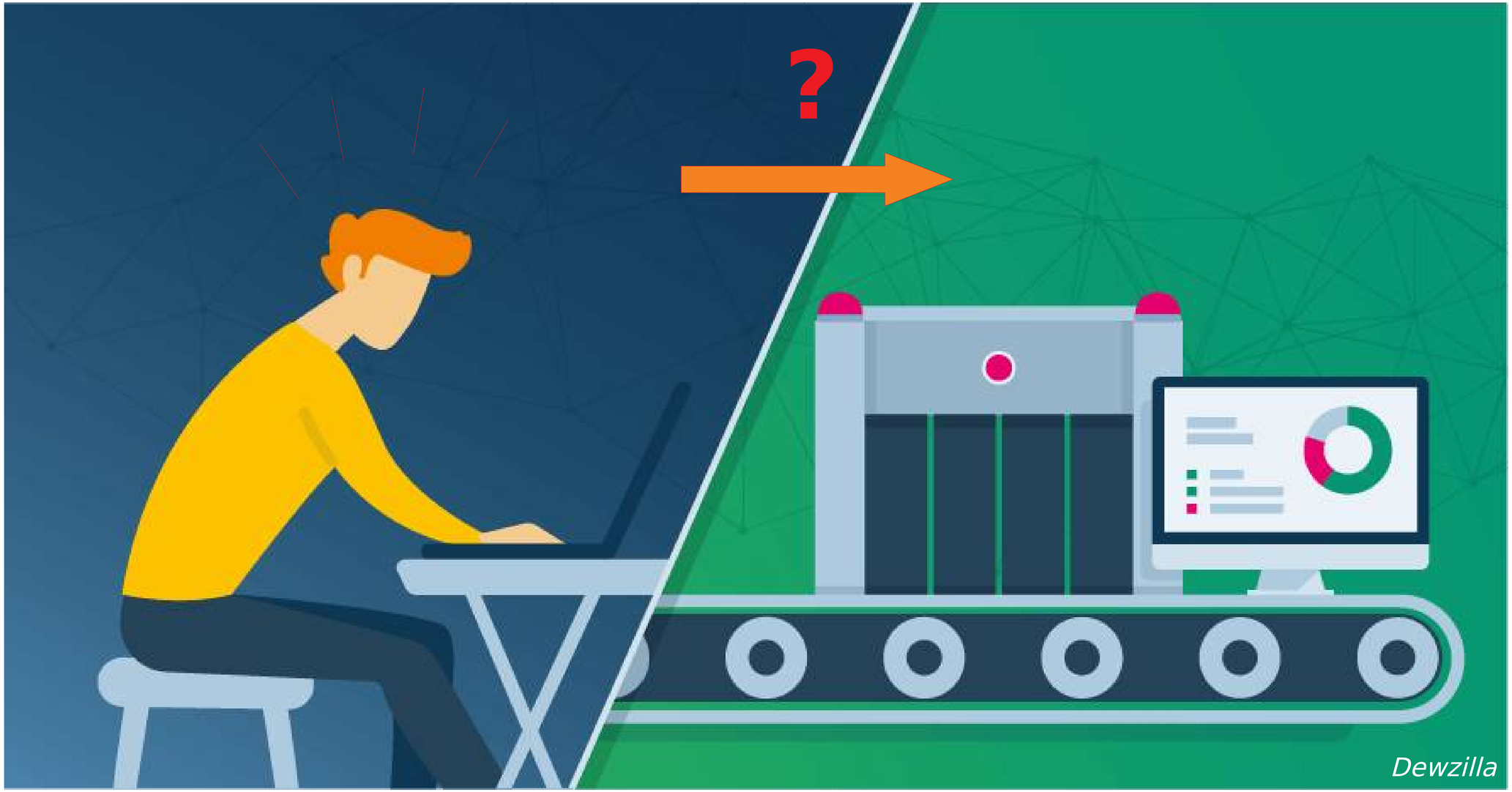
Auxiliary data

- Digital Elevation Model (DEM) 1 arcsec
- Precise orbit data
- Ground Control Points, AOI metadata

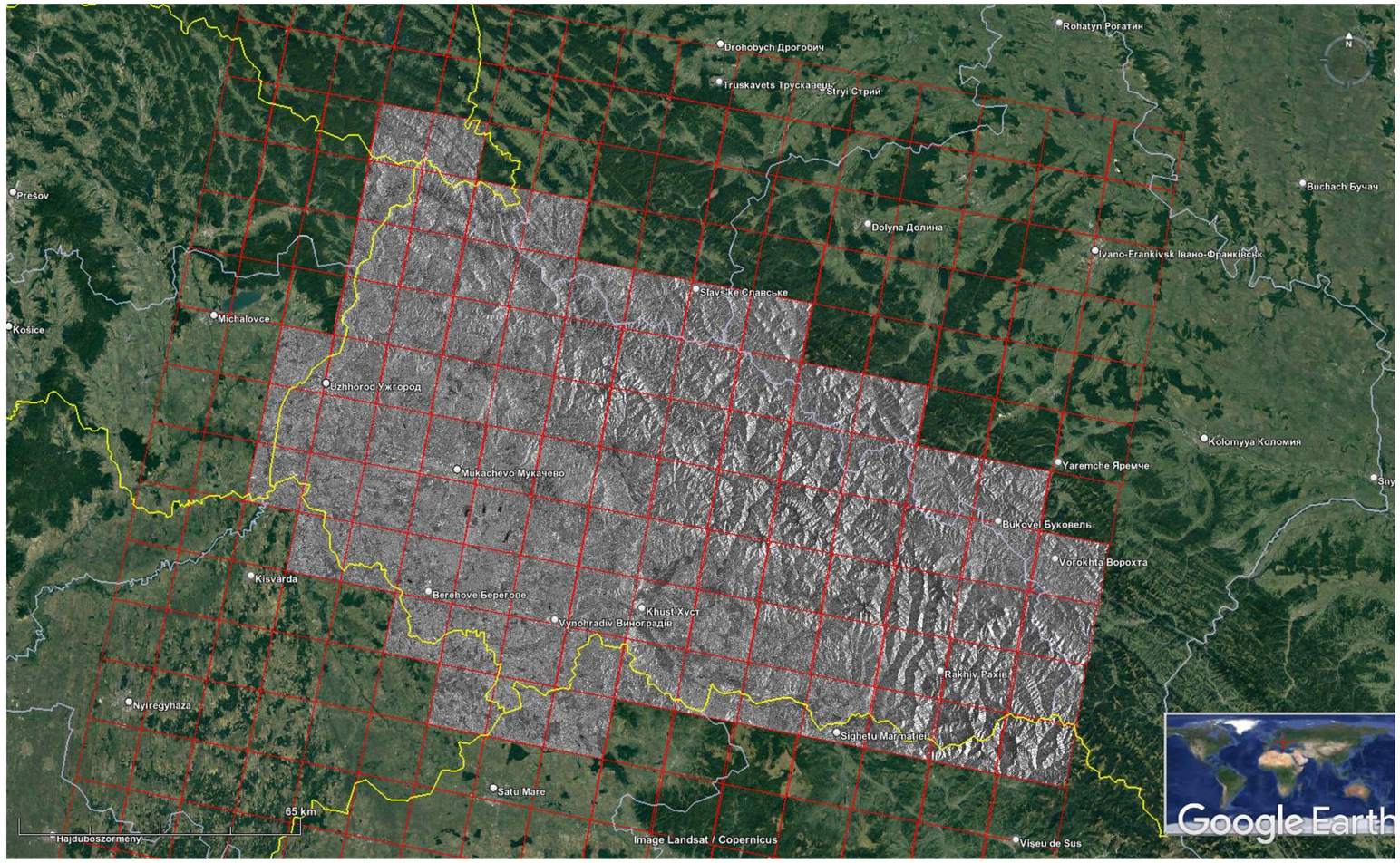
Softwares

- GAMMA Remote Sensing (all modules)
- ANACONDA + required packages
- PC: Ubuntu 18.04, SERVER: DEBIAN 10

Problems of the horizon ...



TILING - AOIs



First Attempt

- Full IW frame approach with 951 layers
- **HW AND SW ARE NOT SUFFICIENT**
- Cannot handle such data – **deprecated approach**

Second Attempt

- Tiled to 30 images with 50m DSC resolution
- HW and SW may can handle **BUT it is slow**
- Resolution increase have made it ineffective – **deprecated appr.**

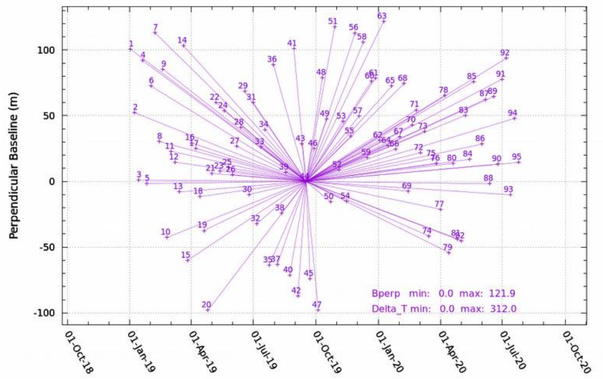
Third Attempt (Recent)

- Tiled to 256 images, core-area: 92 image
- Both HW and SW can process: 92x951 dcubes
- approx 160km2 tiles – **operational**

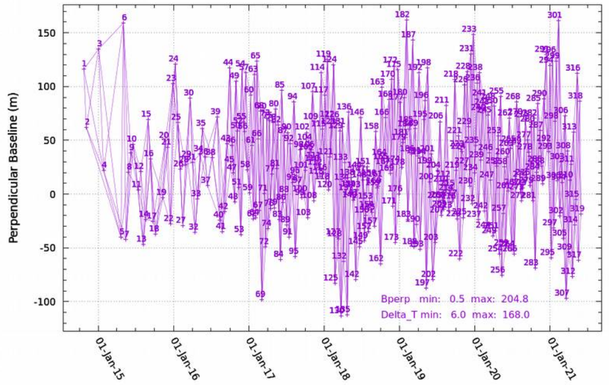
PERFORMANCE IS REASONABLE WITH THIS TILE SIZE

TILING – EXPANDING THE MODEL

Single-Reference

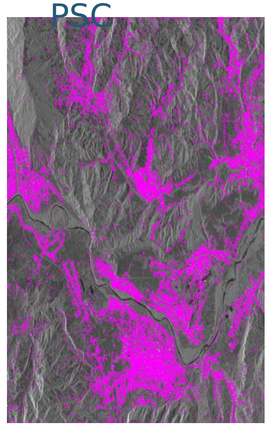


Multi-Reference



Single-look phases (PSC)

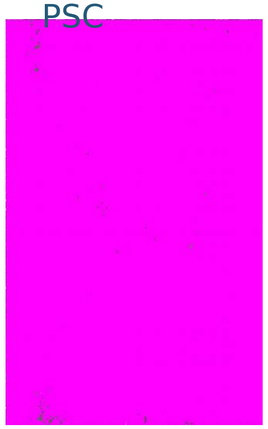
121 293 PSC



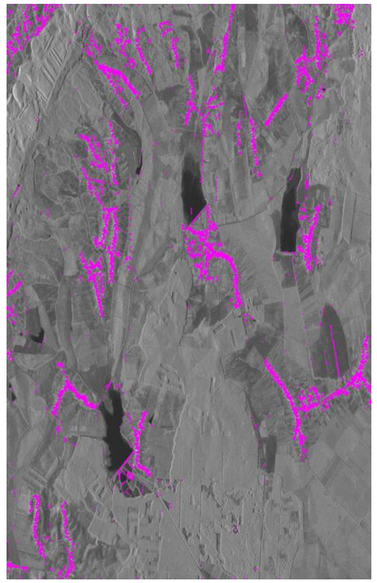
+

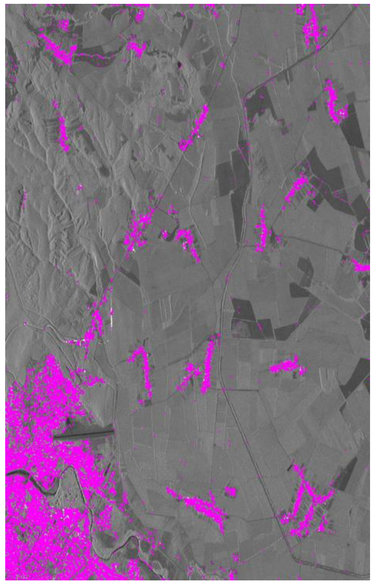
Multi-look phases(DSC)

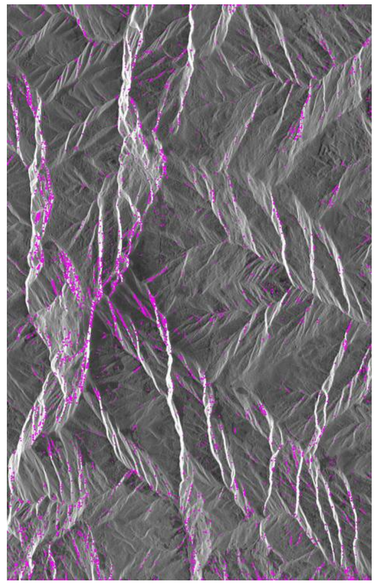
634 462 PSC



755 755 TOTAL per TILE







PSC Targets of 3 tiles

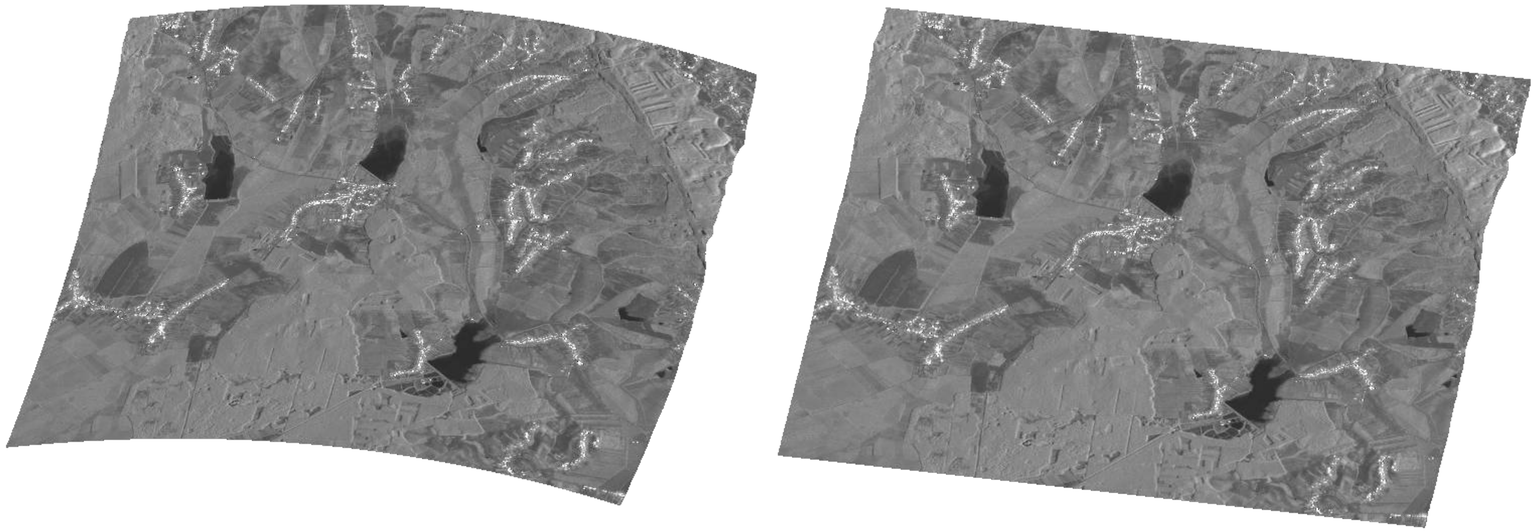
AUTOMATED SRP SELECTION + VARIOUS TERRAIN

AVERAGED ~650 000 COMBINED PSC+DSC PER TILE! (15 meter res.)

YIELDS ~ 60 MILLION TARGETS ONLY FOR THE INDICATED 92 TILE!

YIELDS ~ 164 MILLION TARGETS FOR THE FULL FRAME! --→ REALLY NEEDED?

Troubleshooting – I.



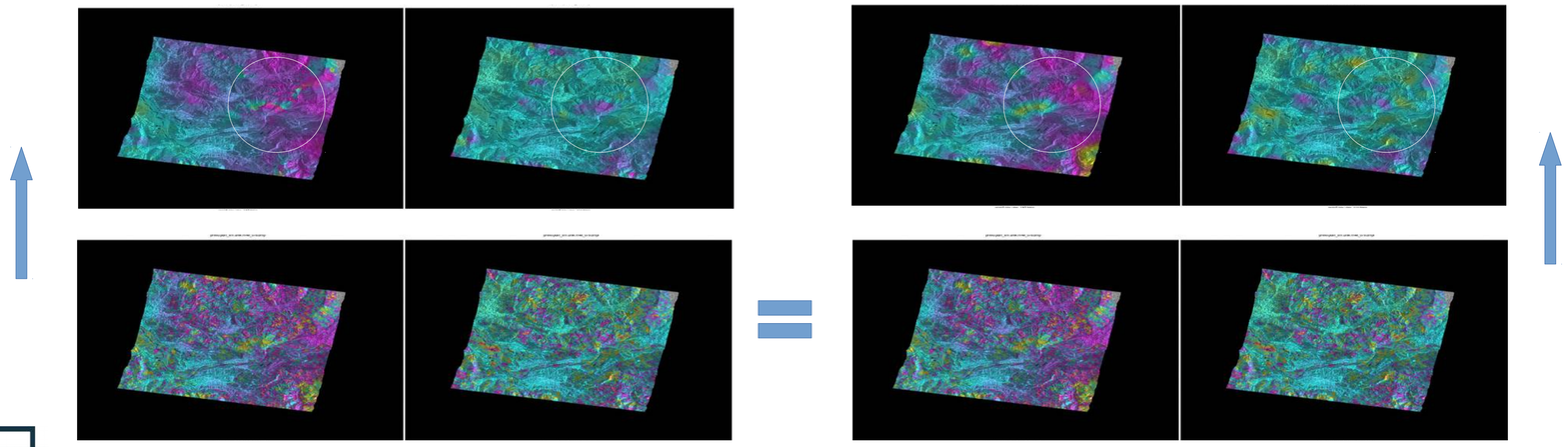
AUTOMATIC GEOCODING SUBROUTINE

Offset tracking – CC parameter tuning

OVERFITTING of the polynomial model

SOLUTION → Change Poly(6) to Poly(1)

- LSQ fitting of offsets can be done
- Applicable for various terrain



ESTIMATION OF APS

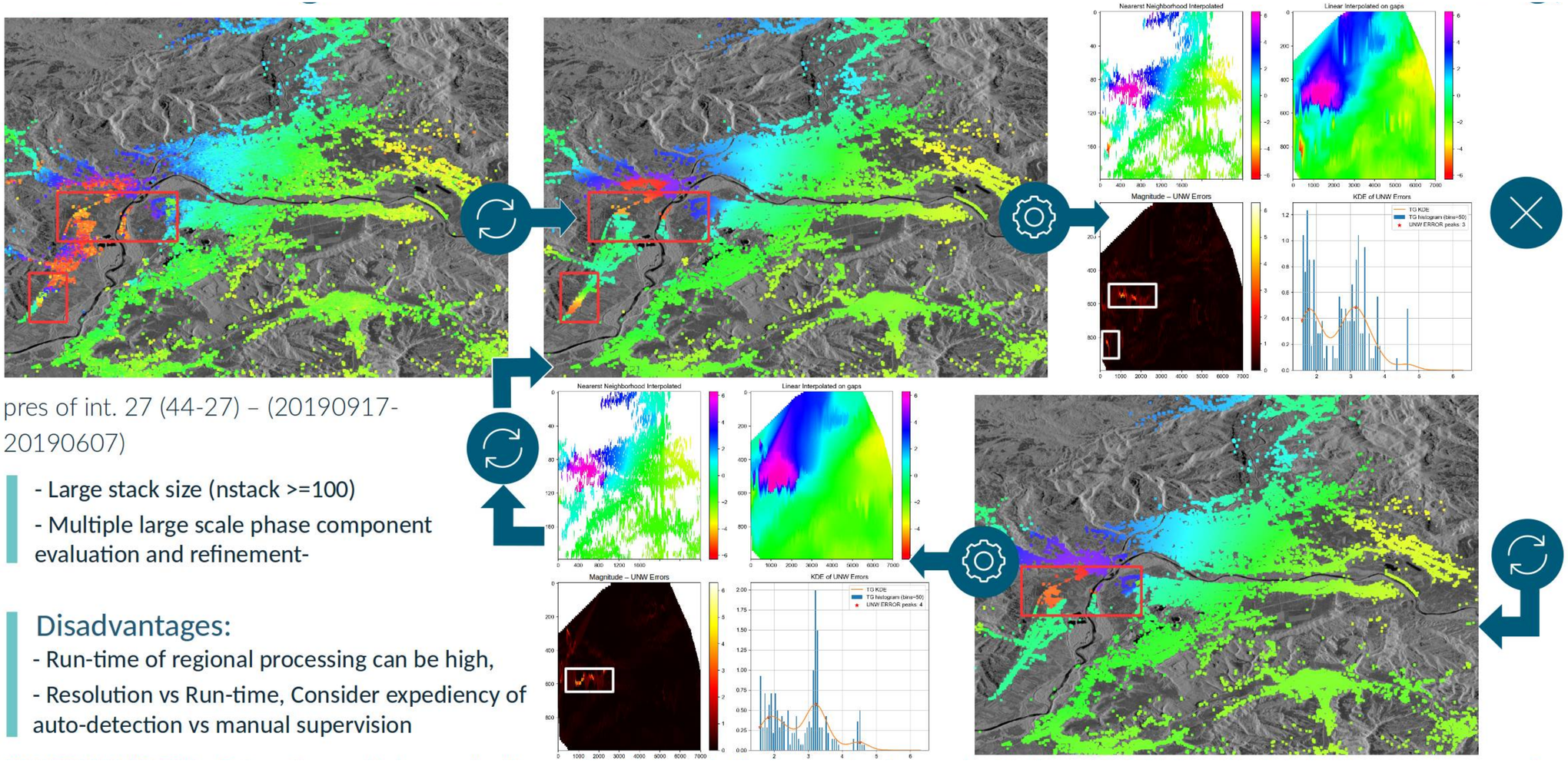
Offset tracking – CC tuning

PROBLEM: re-wrapping / filtering / unwrapping residual phase before APS estimation creates artificial unwrapping errors, which are negatively affect the processing

SOLUTION → avoiding such approach, and perform only filtering

II. PUNW Error Detection

Solution demonstrated at ESA Fringe 2021



SCAN ME

pres of int. 27 (44-27) – (20190917-20190607)

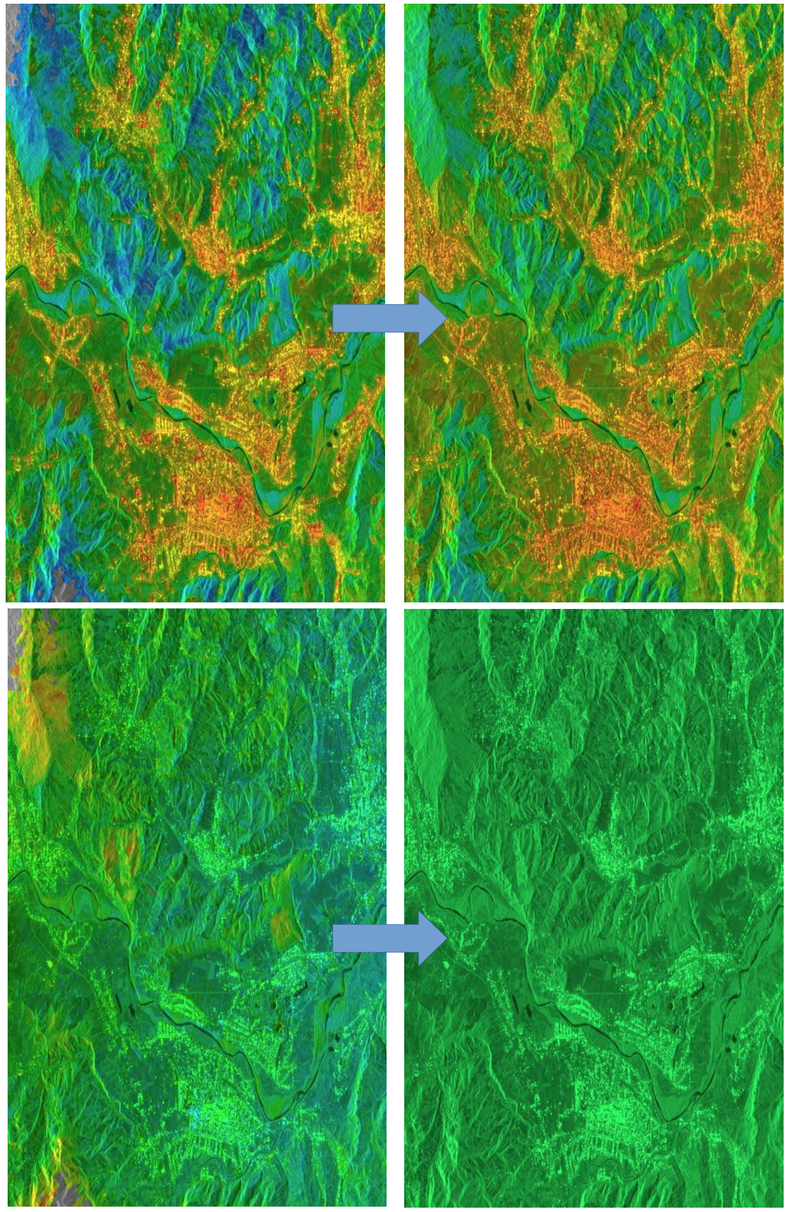
- Large stack size (nstack >=100)
- Multiple large scale phase component evaluation and refinement-

Disadvantages:

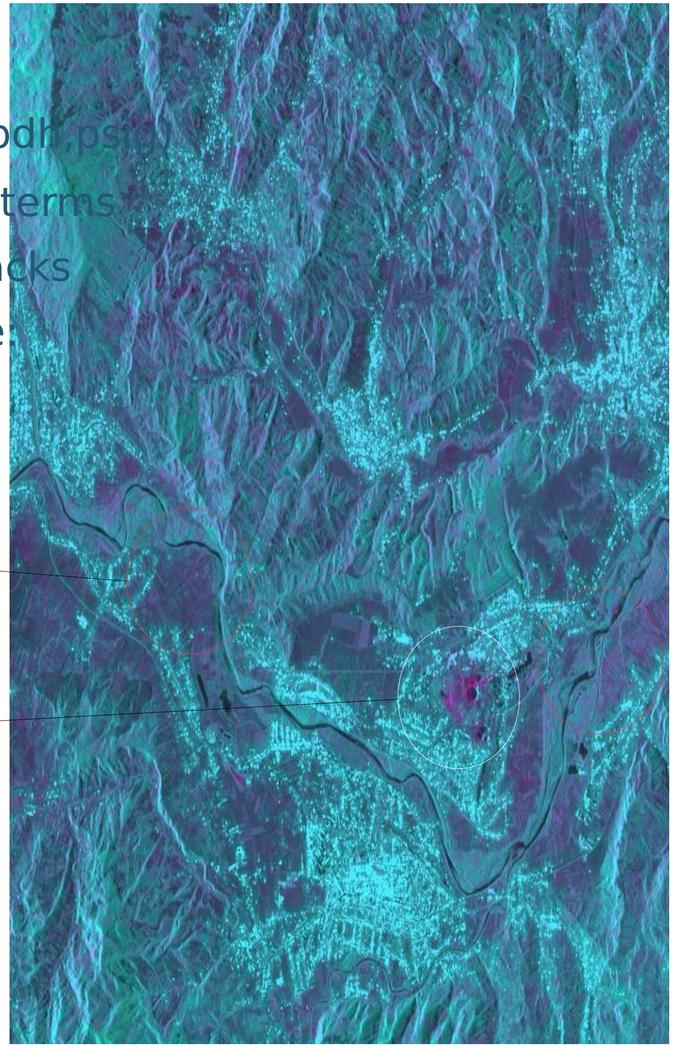
- Run-time of regional processing can be high,
- Resolution vs Run-time, Consider expediency of auto-detection vs manual supervision

ONGOING UPGRADES: SPEEDUP BY ML TECHNIQUES

Troubleshooting – III.



AKNASZLATINA AOI



IPTA STEPS:

Adaptive parameter optimization (pdh, ps)

Evaluation of APS and other phase terms

Processing multi-reference data stacks

After converting to single reference

Pseudo Deformation!

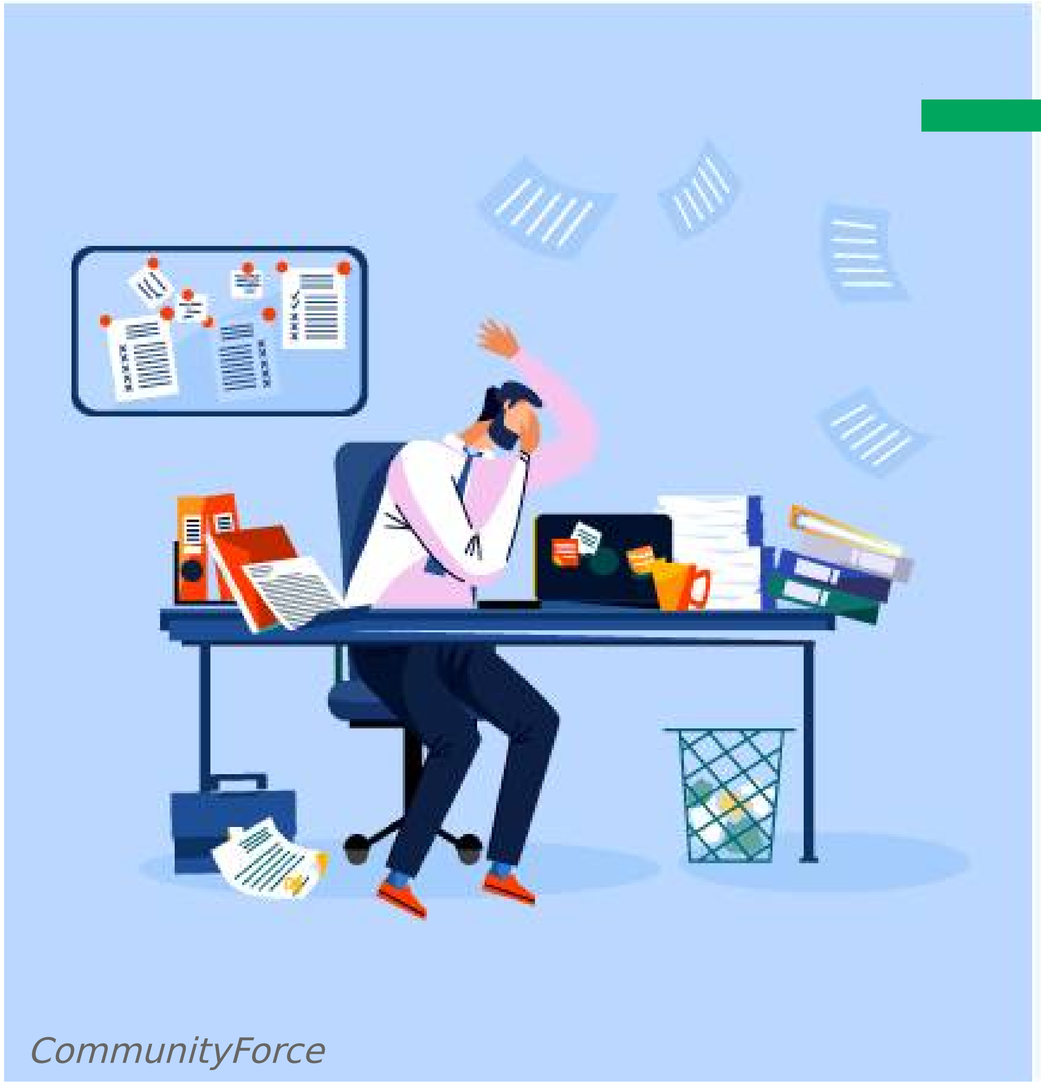
- Apparent def affects areas where Multi look phases are the dominant!
- Noise? Unw Err?

Recent Deformation!

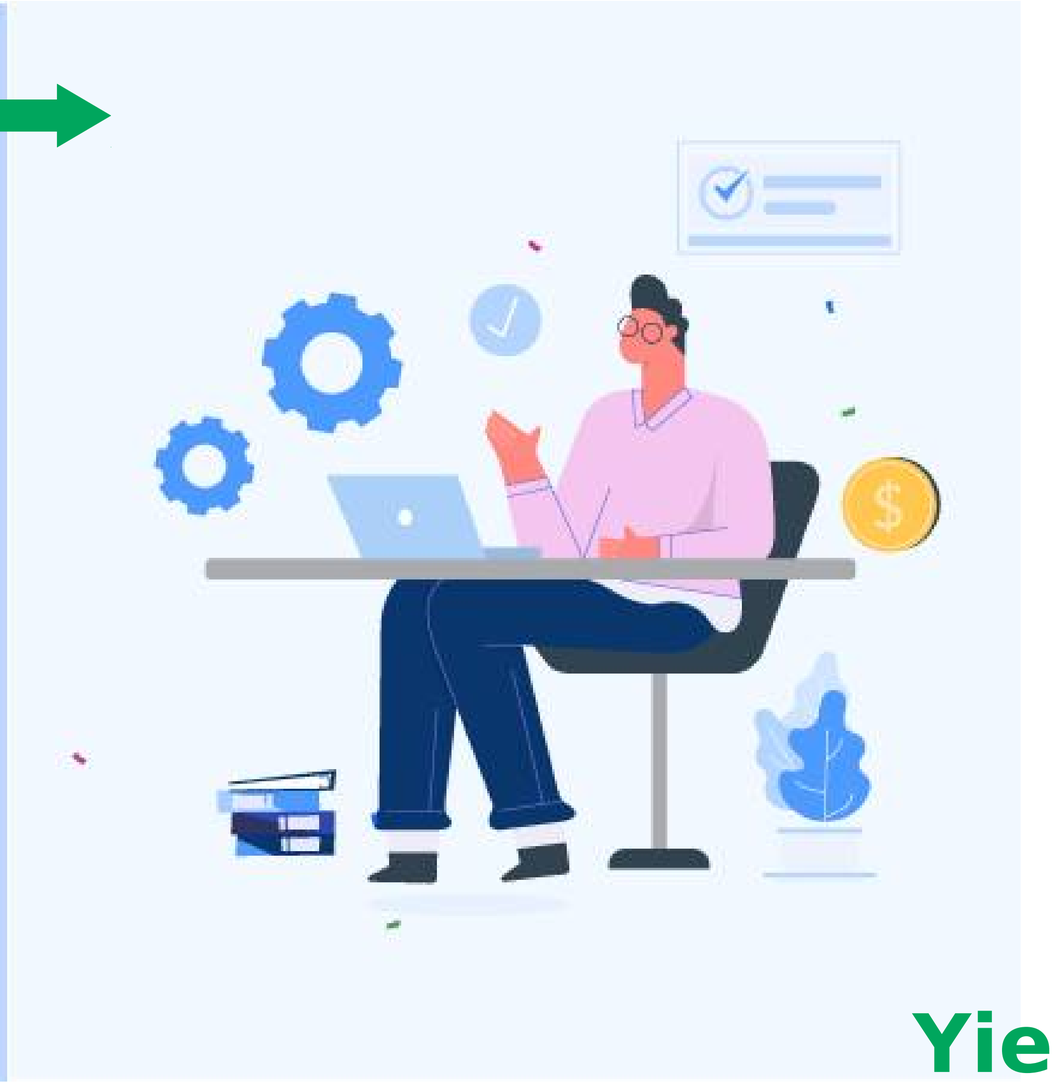
- Solotvyno Karst Lakes

CAUSED BY DS PH AMBIGUITIES

… finally successfully solved

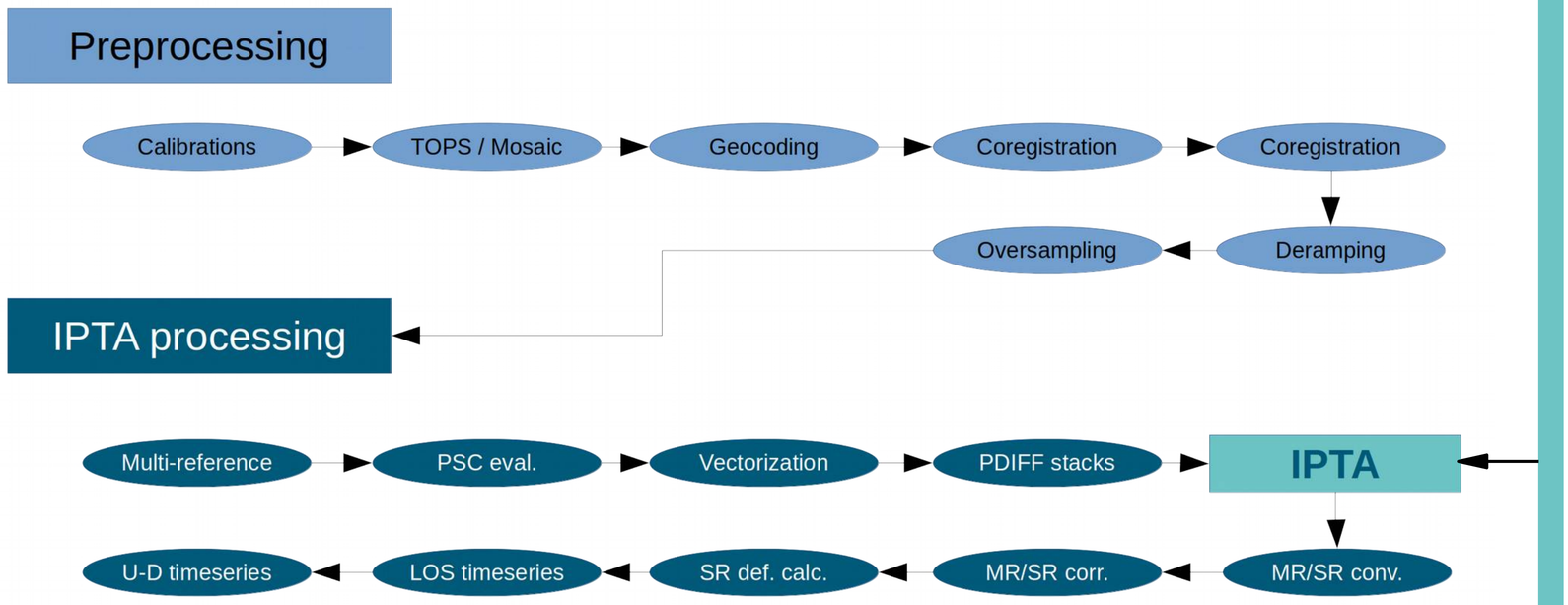


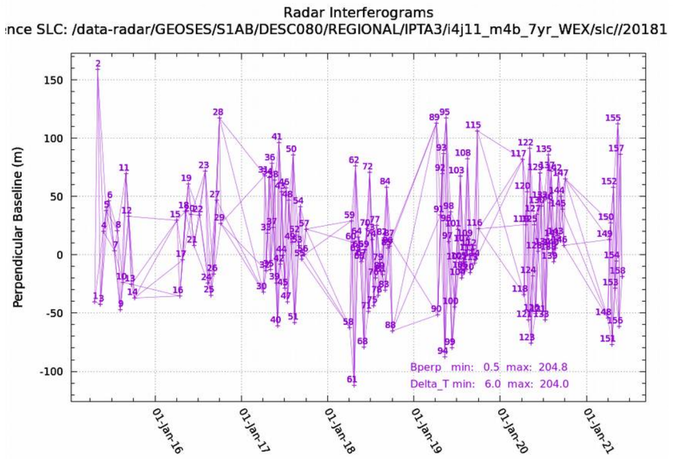
CommunityForce

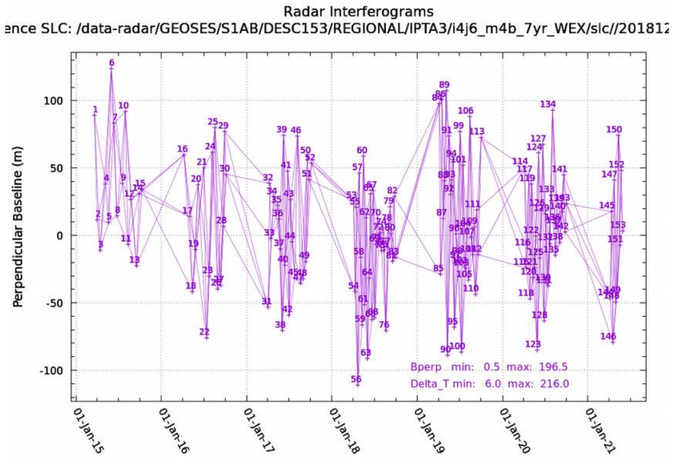


Yields:

Automated workflow (MultiRef)





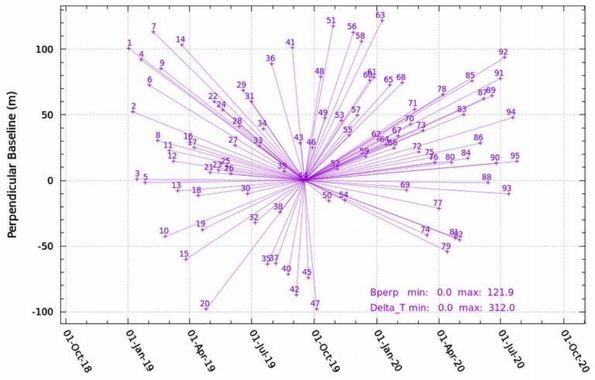


IPTA data and processing characteristics

- Regional scale proc. (HUSKROUA area)
- Sentinel 1A and Sentinel 1B
- 158 acquisitions / RON
- Bperp < 250m, 6 days interval, 6mnt between years interval
- Single look phases (SL) and Vector format
- Multi-reference stack (>460 diff intf.)
- No reduced point list application
- Automatically selected SRP
- Unwraping strategy (spatial → reg)
- Model parameter estimation order: *1. remove height dependent phase term, apply height correction, 2. Initial APS, 3. Height correction (large scale passed to APS), 4. APS estimated from residual phase, 5. Iterative update, 6. Estimate deformation rate*
- APS: 1.5 km
- Adequate for uniform and non-uniform defs.
- Snow strategy: exclude October-April data
- No hydrostatic APS, No temperature depend.
- No temporary and redundant point stratgy

Results

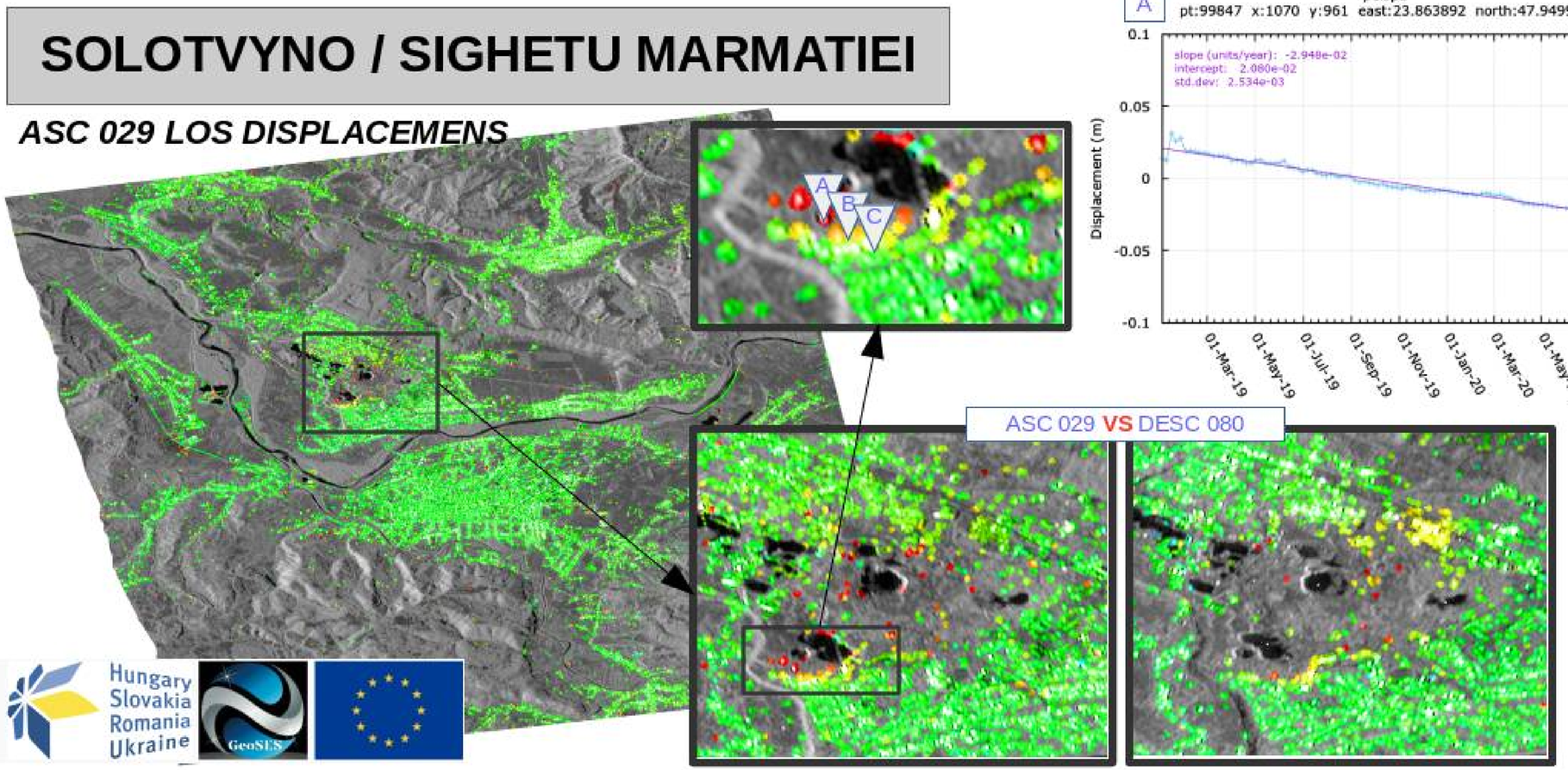
Preliminary and Regional Monitoring

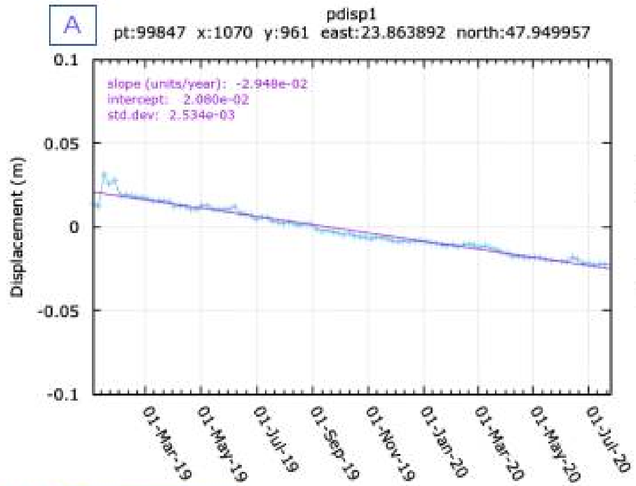


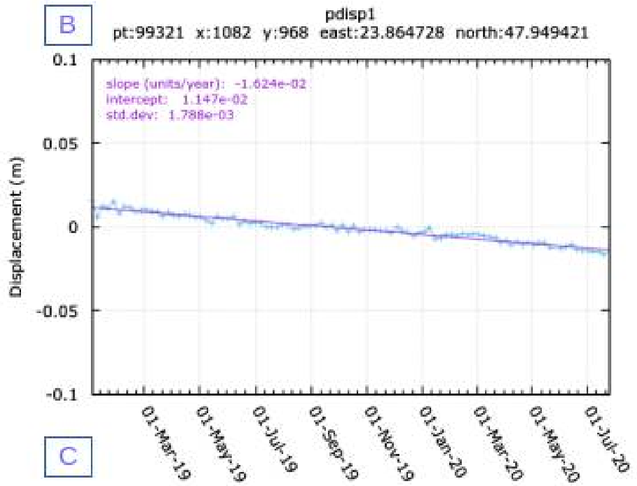
PRELIMINARY RESULTS

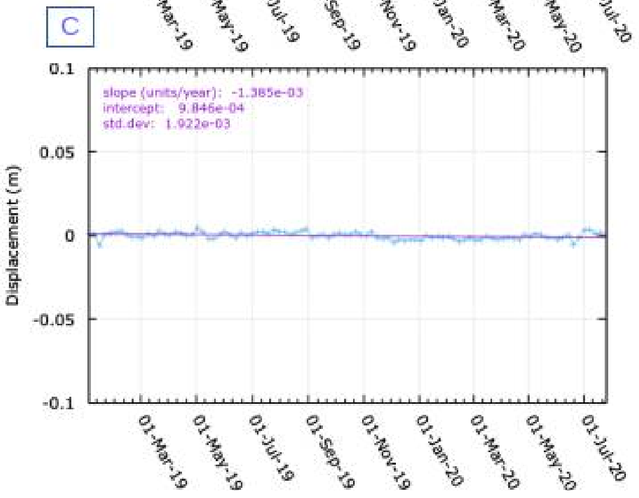
SINGLE REFERENCE LOS EXAMPLES

Singe Reference Processing:

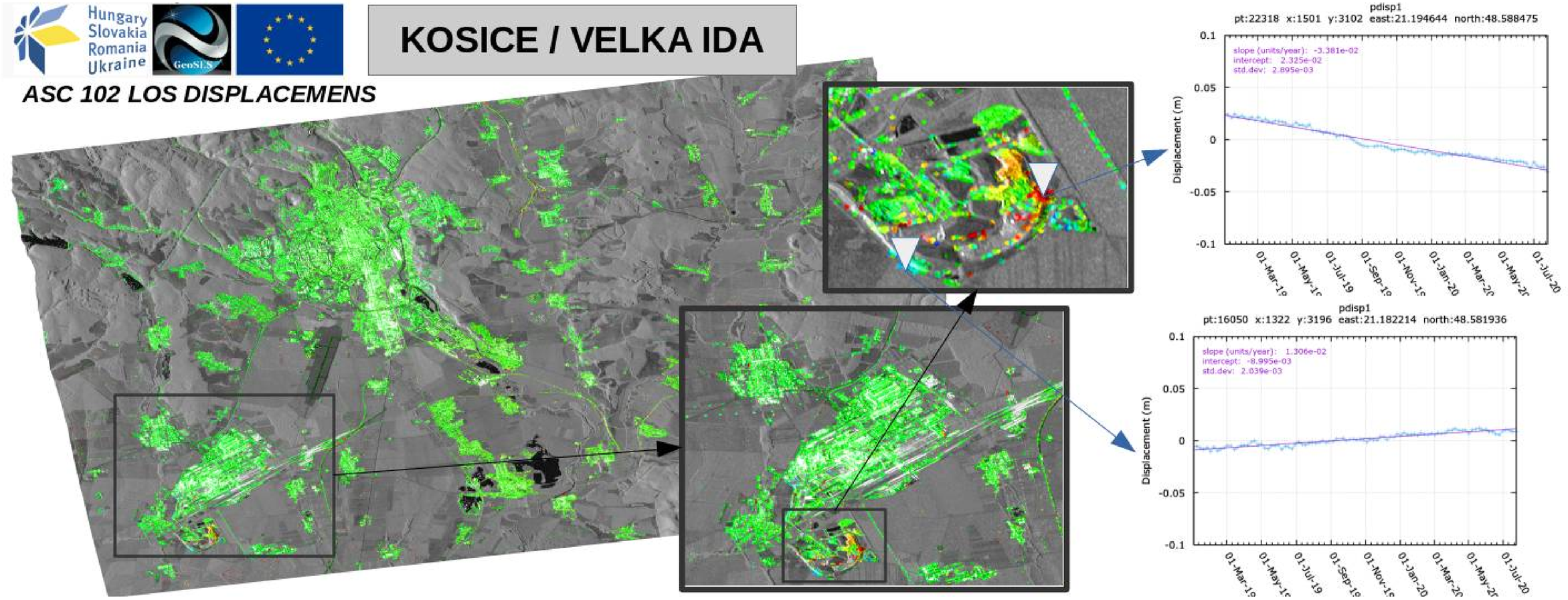




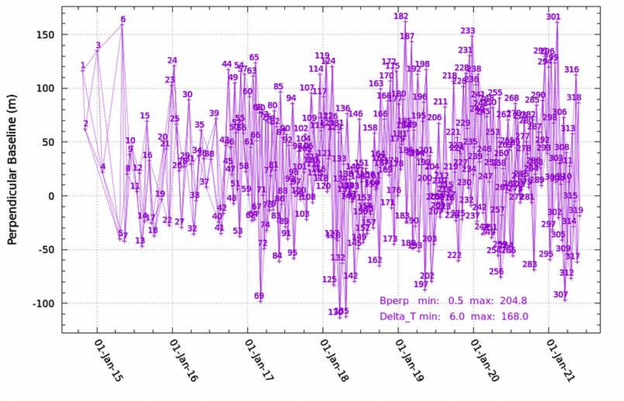




Single Reference Processing:

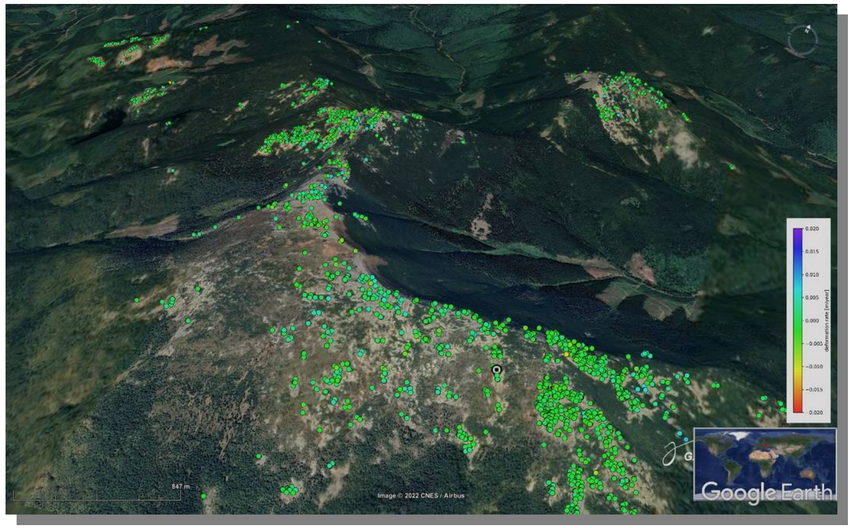


REGIONAL MONITORING RESULTS:

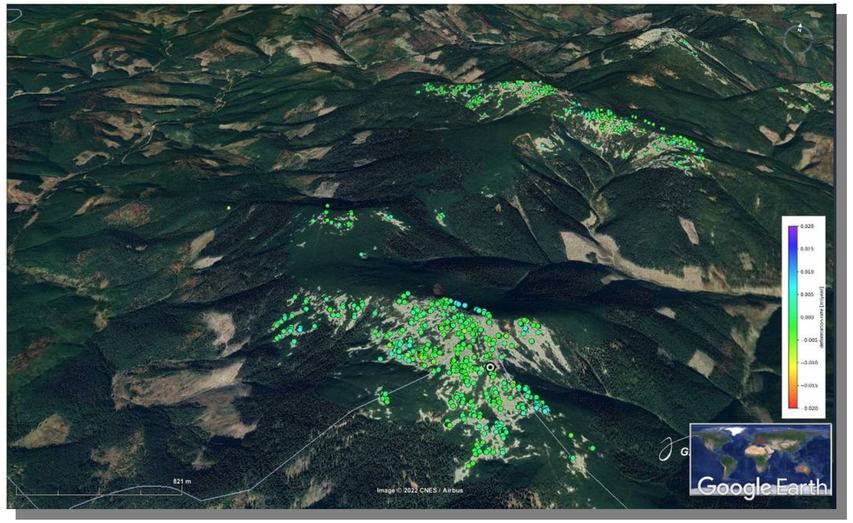


MULTI REFERENCE LOS EXAMPLES

LOS – Mountain ridges

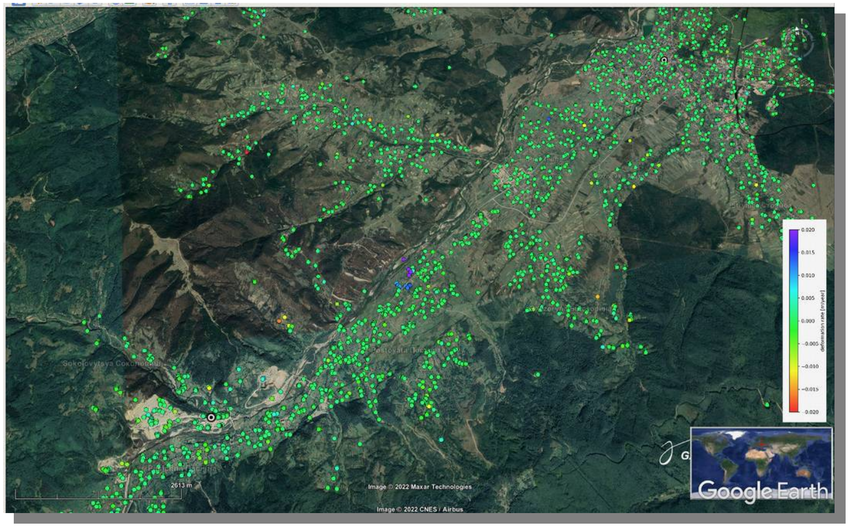


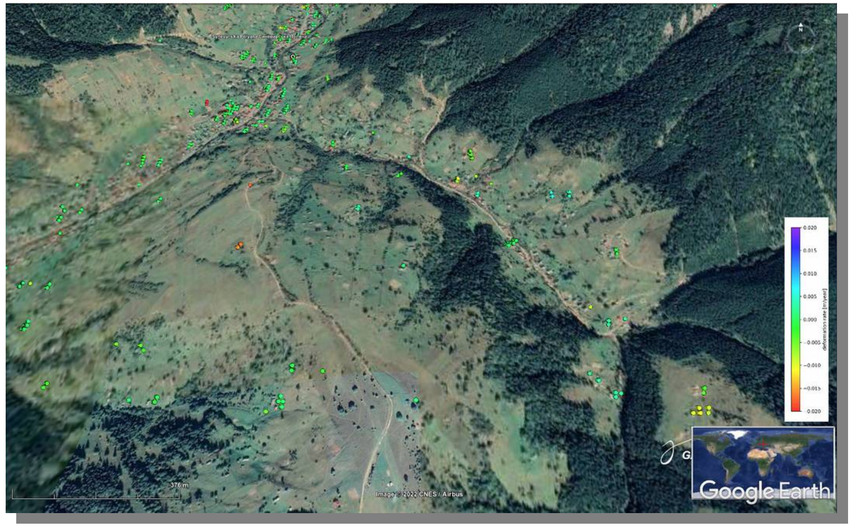
NE Carpathian Mnts



LOS – Landslides 1.

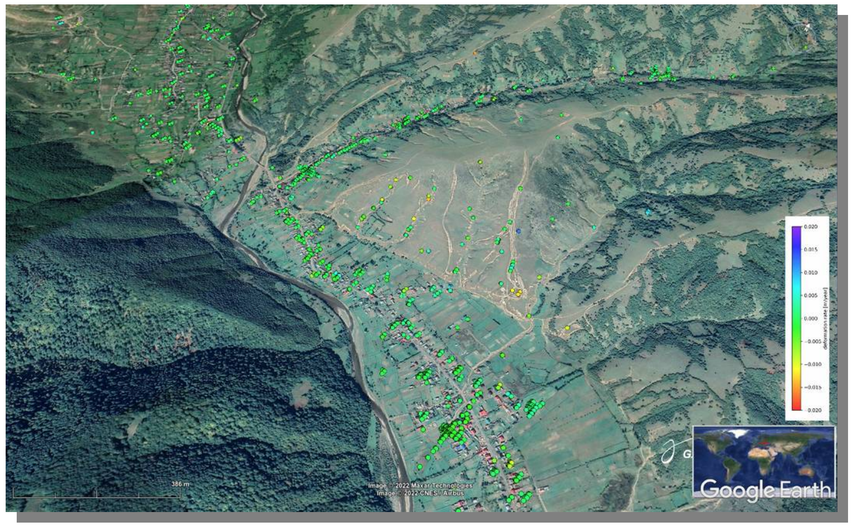
Postoyata
UKR





Felsőszinevér
UKR

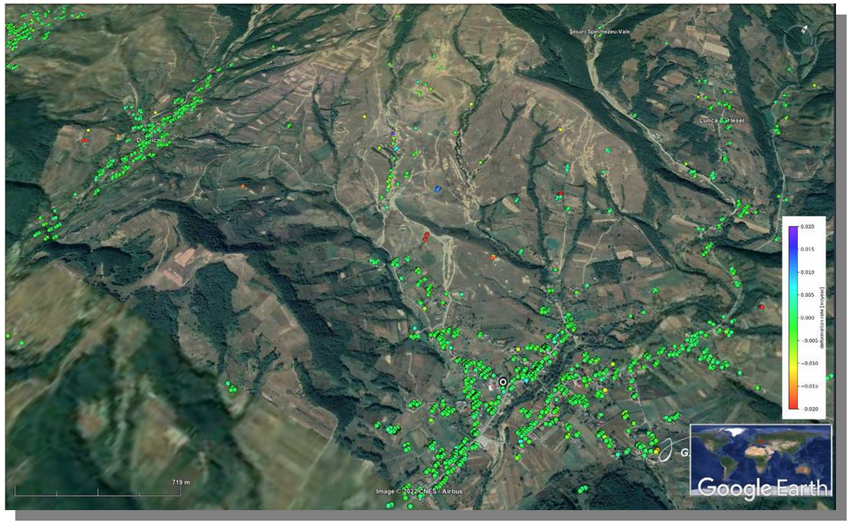
Felsőkalocsa
UKR



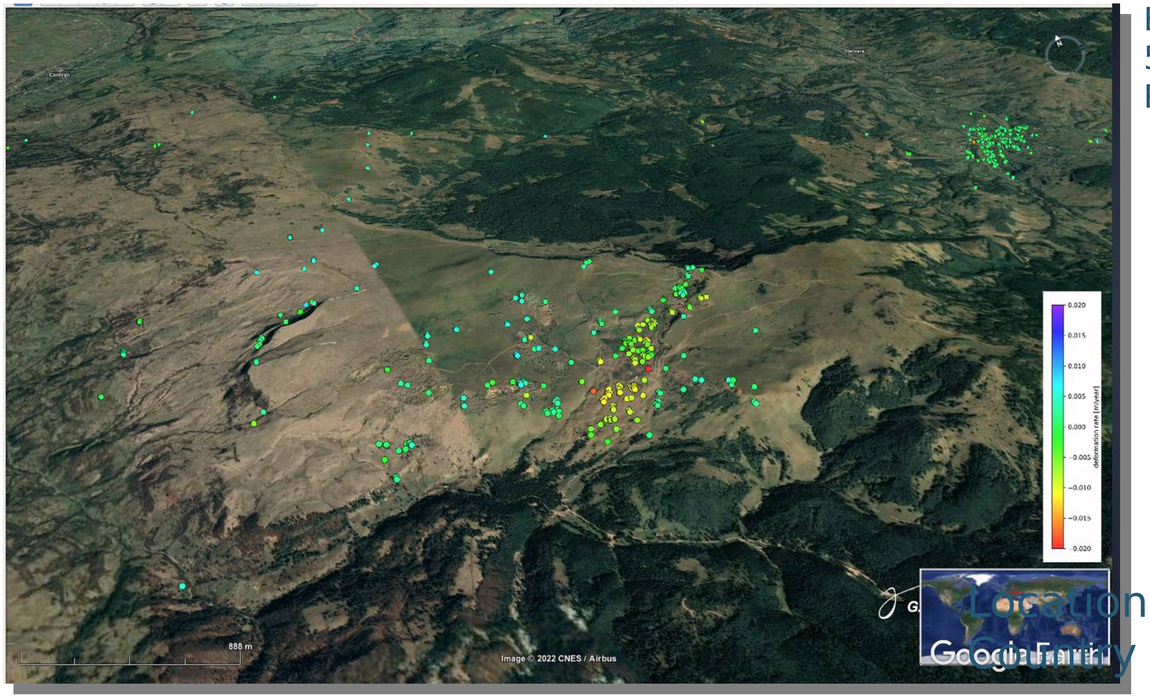
Felsőszinevér
UKR

LOS – Landslides 2.

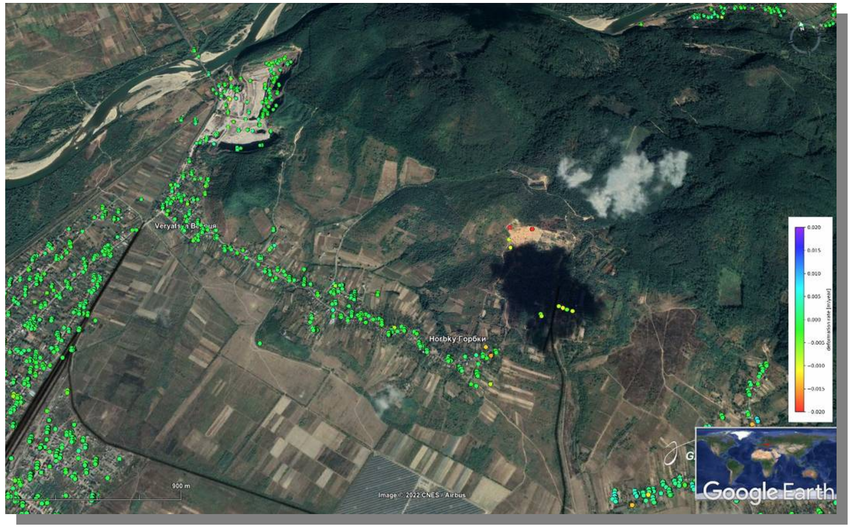
Ispánmző
ROM



Budfalva
5km SE
ROM



Rákospatak
UKR



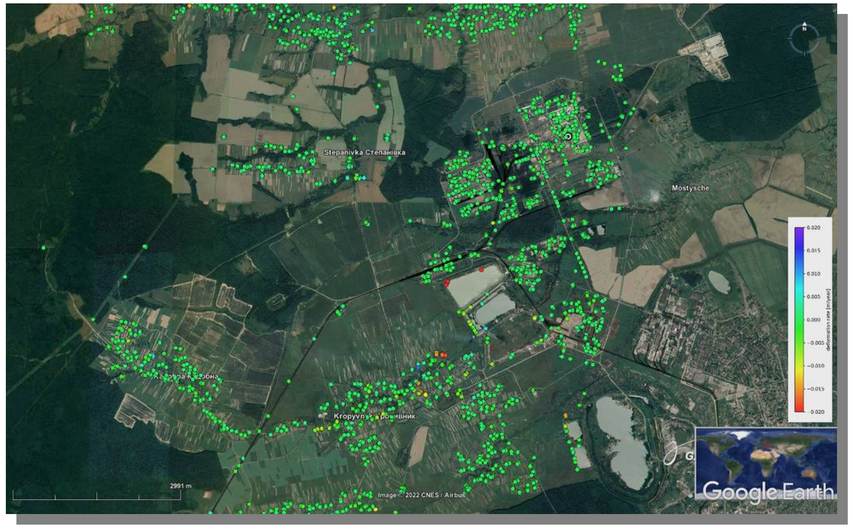
Location
Country

LOS – Mines & Reservoirs 1.

Kalush
UKR

Stebnyk
UKR

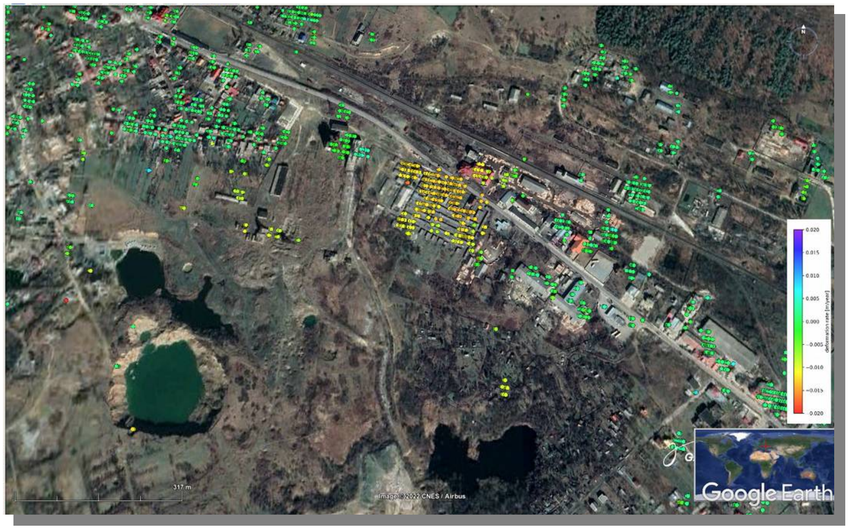
Kalush
UKR



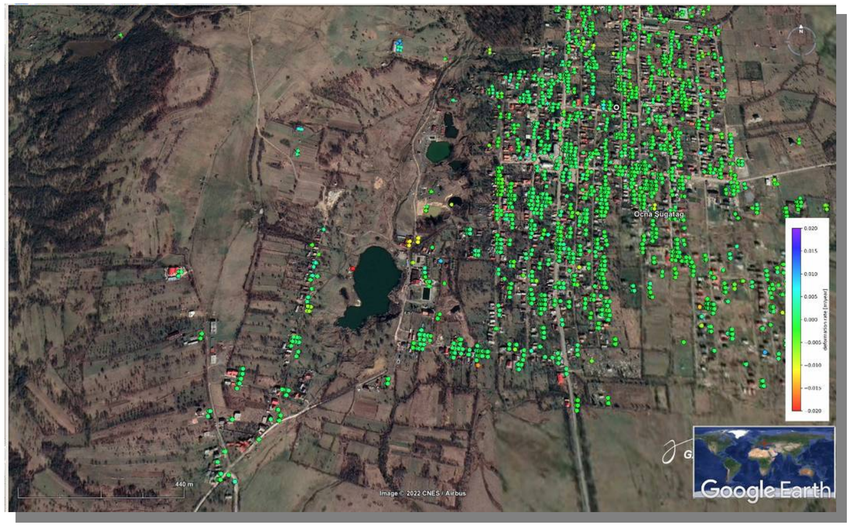
Kropyvnyk
UKR

LOS – Mines & Reservoirs 2.

Aknaszlatina
UKR



Aknasugatag
ROM

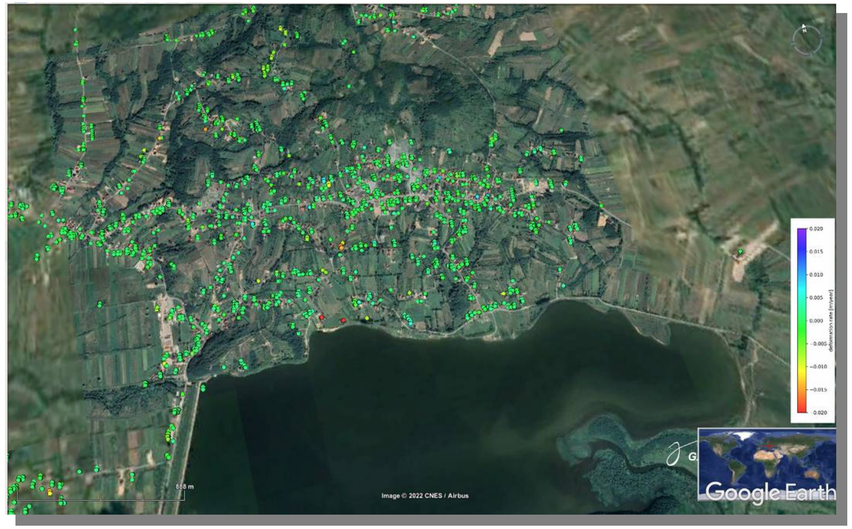


Szeklence
UKR

Nagybánya
ROM

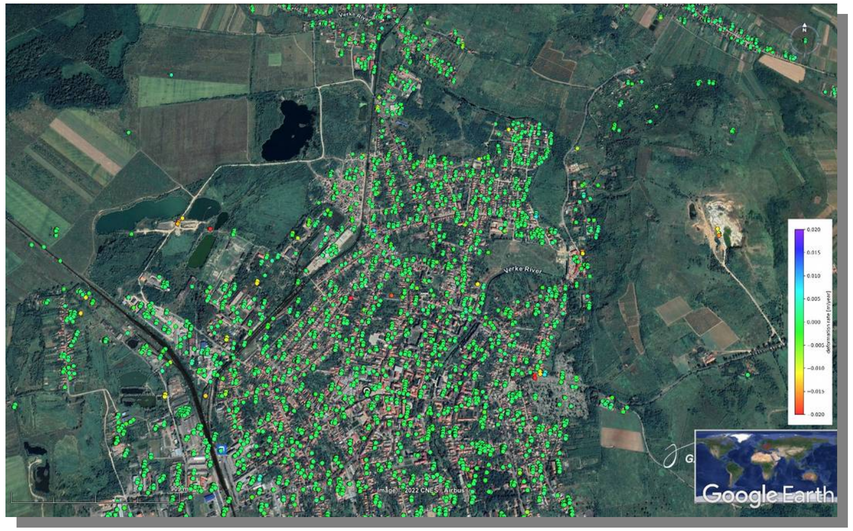
LOS – Mines & Reservoirs 3.

Széles-tó
SLO



Sztarina
SLO

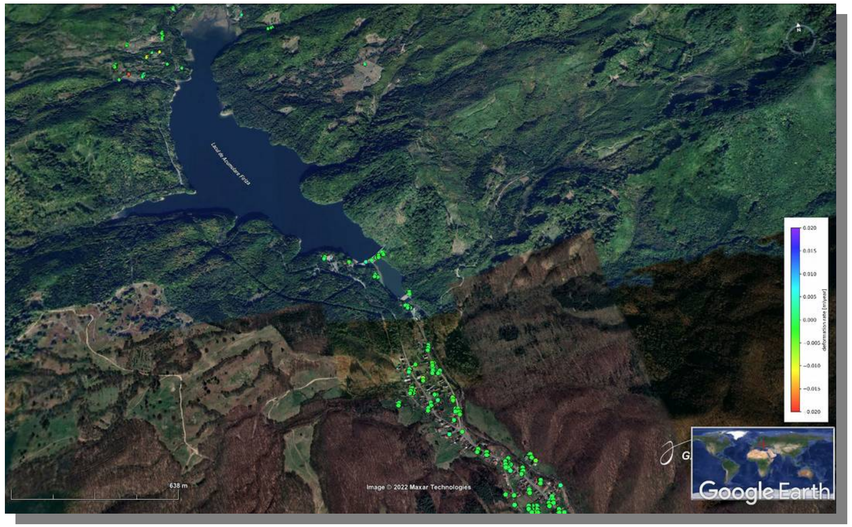
Ungvár
UKR

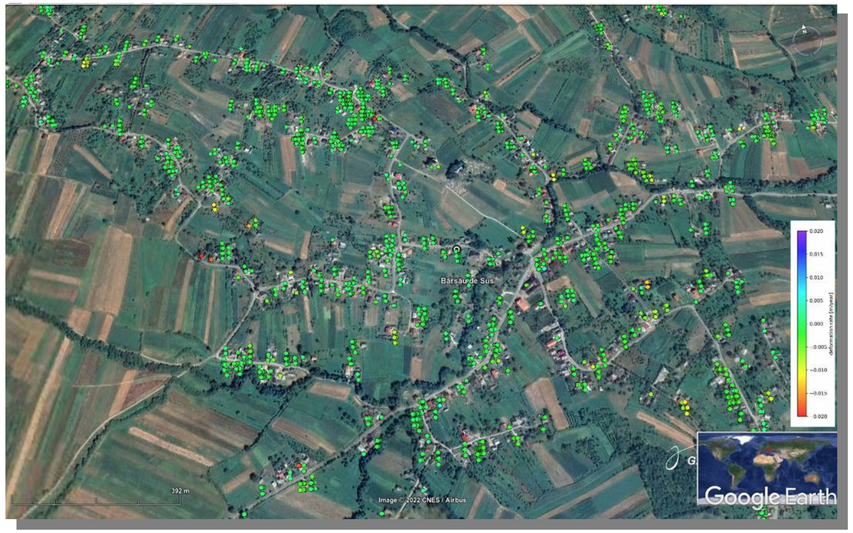


Beregszász
UKR

LOS – Infrastructure 1.

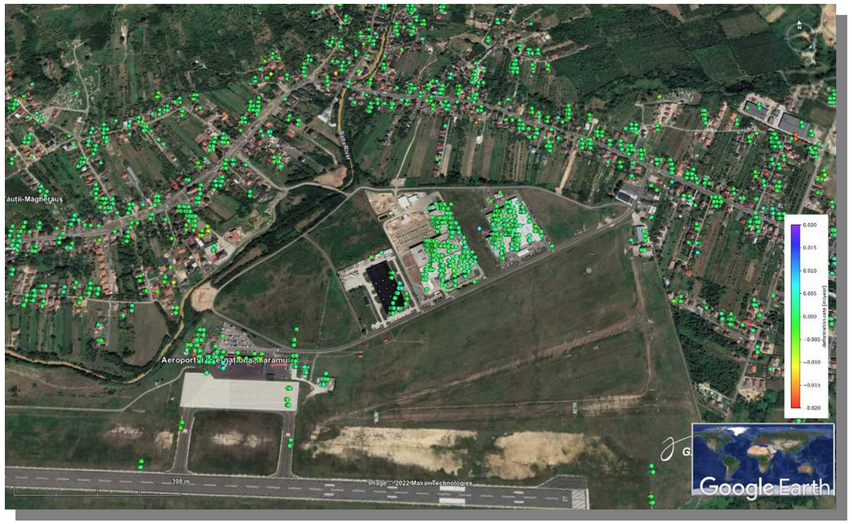
Fernezely
ROM





Felsőberekszó
ROM

Máramaros
Int. AP, ROM



Bazesti
ROM

LOS – Infrastructure 2.

Ungvár
UKR

Industrial
Plant
SLO

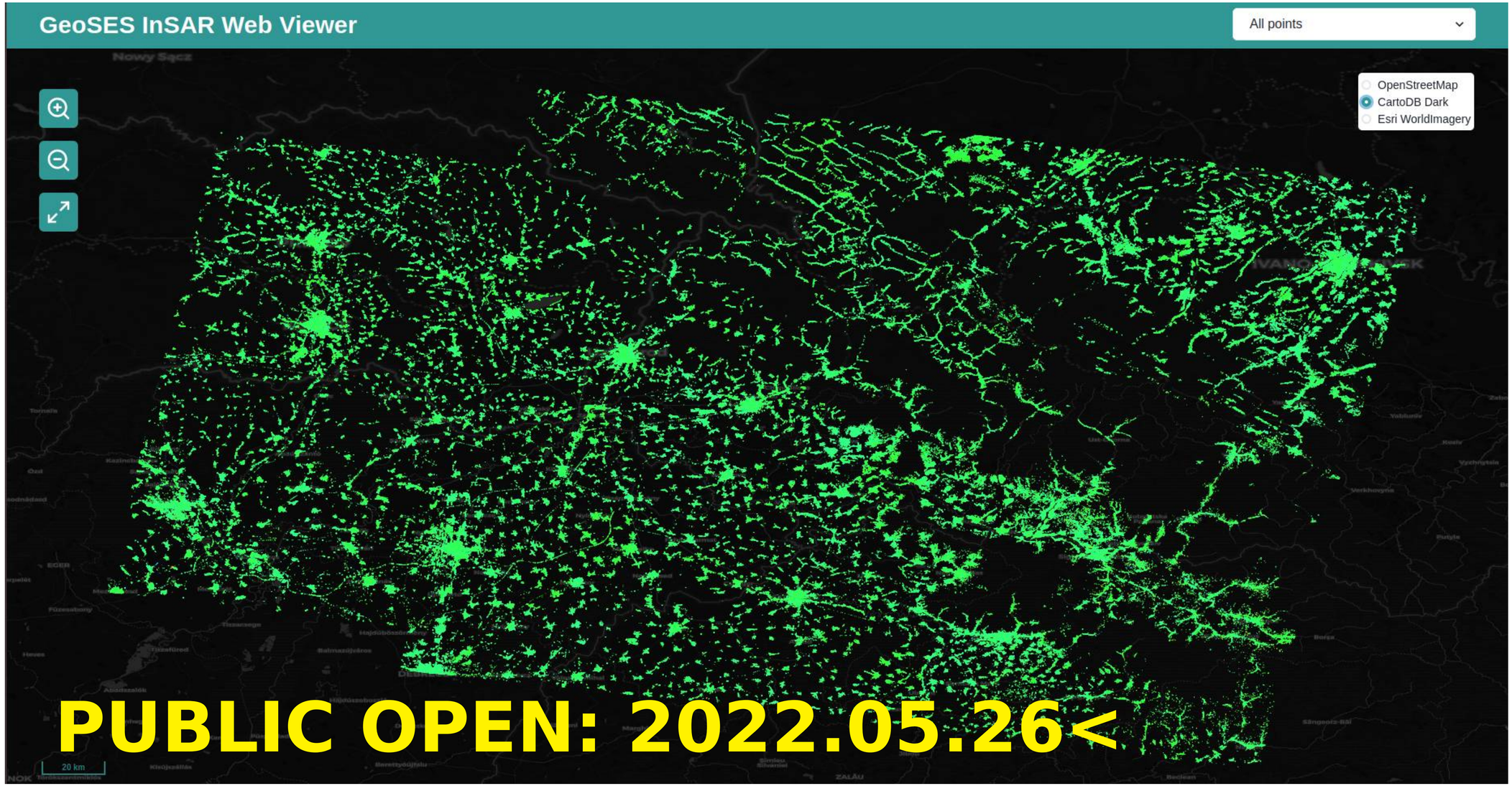
Szamosdara
ROM

Vásárosnamény
HUN

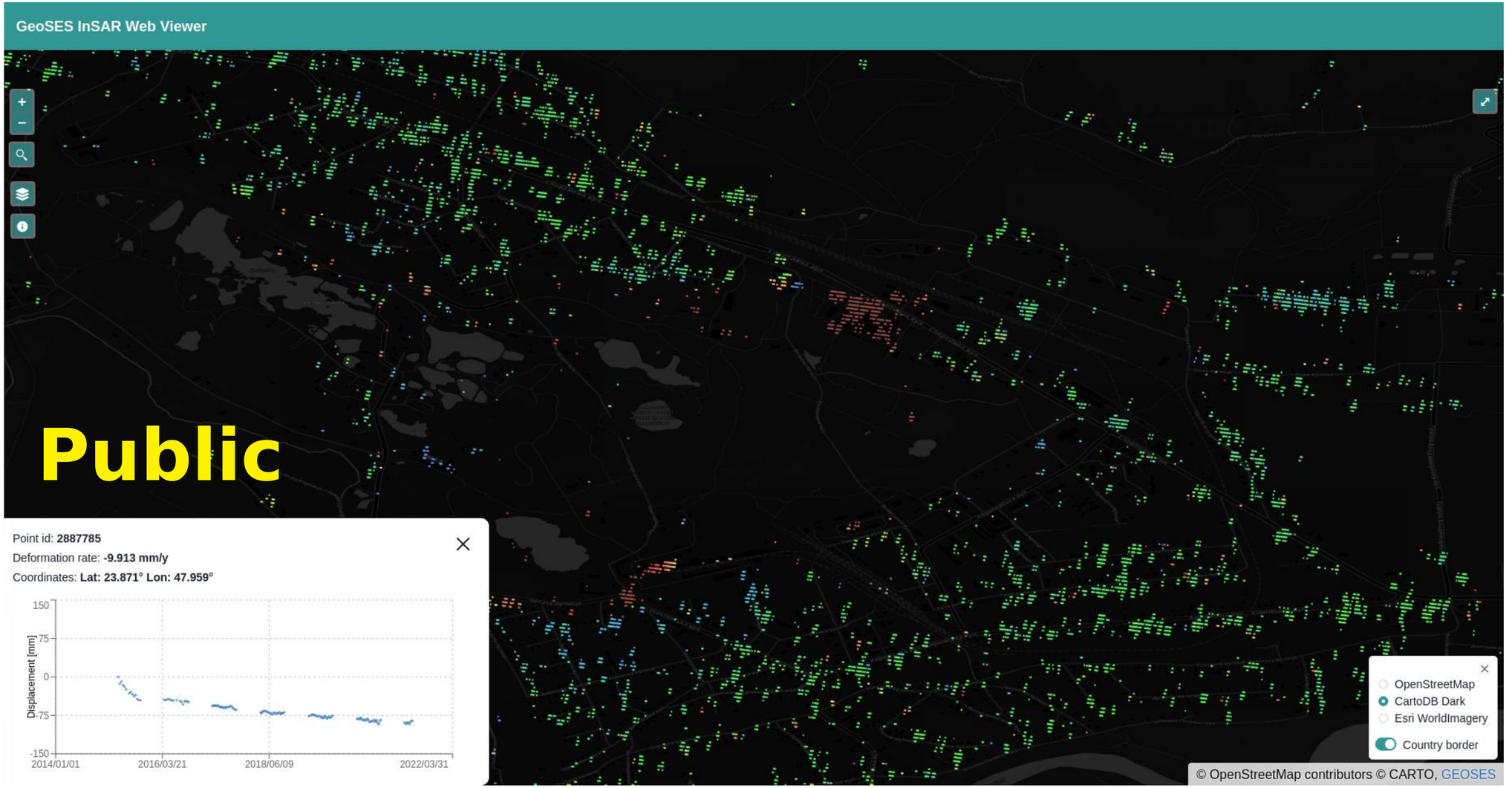
Outlook

Web development

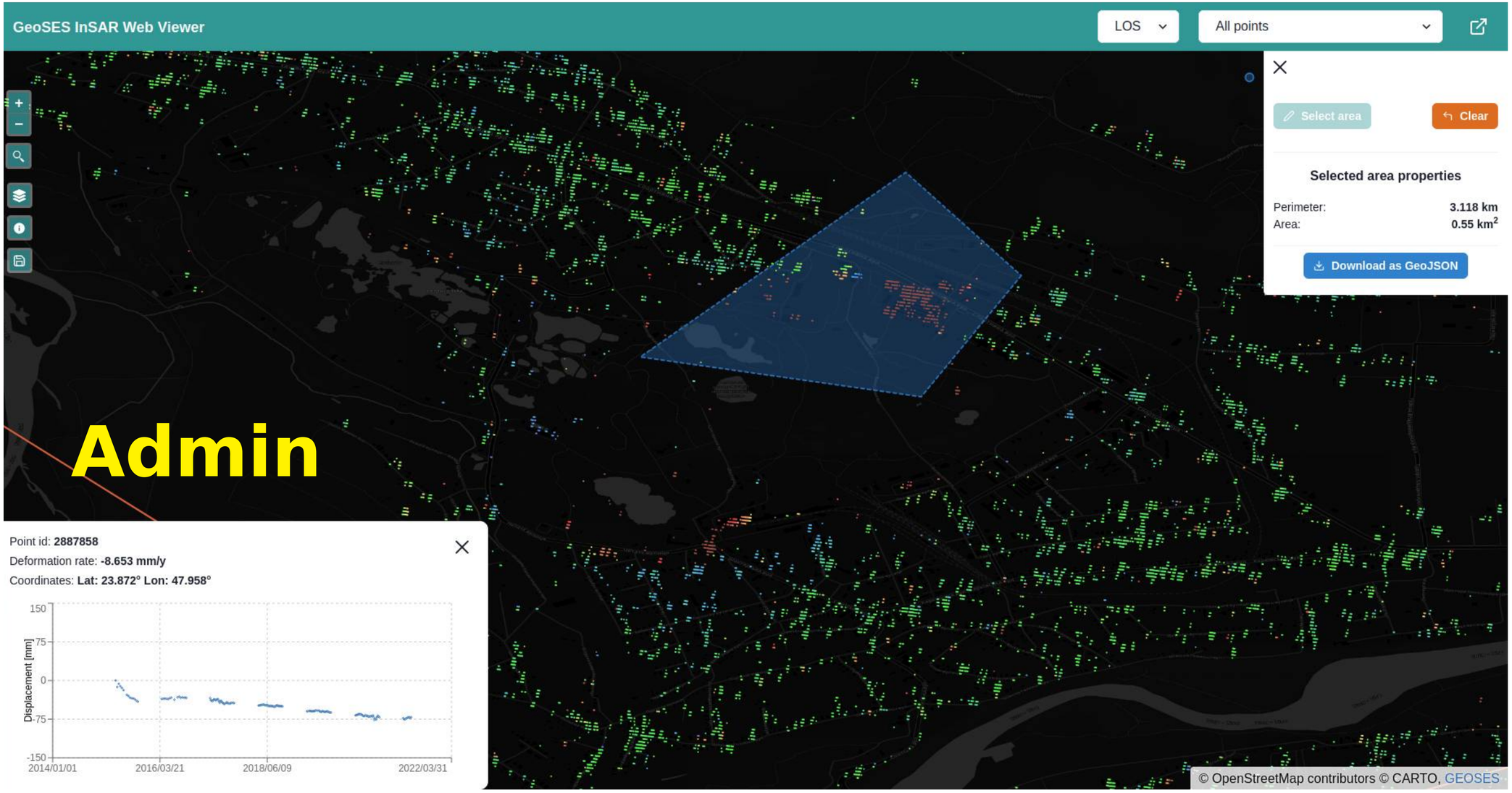
Web development



Web development - Features



Web development - Features



Discussion

	Title of the output	Brief description of the output	Corresponding activity(ies)	Target value
Output 1.1	Satellite Based Radar imagery database and information from endangered sites	The database will involve the available radar imagery of the HUSKROUA area. These data sets (raw and preprocessed) will be made available to project partners and other institutions in the eligible area for further analysis. Collecting information from endangered sites with natural or industrial burdens to select one or two endangered locality to perform a monitoring (semiannual analysis as default and dedicated analysis anytime if needed due to any event.	A1.1	1.00

	Title of the output	Brief description of the output	Corresponding activity(ies)	Target value
Output 1.2	Deformation history database and technical documentation on the interpretation of the deformation analysis	Based on the InSAR analysis the vertical displacements of the points will be stored in a database. The database will be made available to the project partners. This database will help to identify areas suffering from significant vertical displacements. Then to the discovered subsidences will be carried out by any geodetic/geographic methods and techniques (GNSS, TLS, ALS, UAV and high- precision levelling) to define the deformation model and improve the risk assessment.	A1.2	5,00

Which are the expected **results of your project** (e.g. number of regional policy changes, , percentage reduction of certain pollutants in a river system, number of new business start-ups). Please mention all project expected results as well as the corresponding Activities Group where they are achieved				
Deformation map	1 digital map in Uzhhorod, digital maps (4 units) in Department of State Emergency Service in cross-border region	0,00	5,00	Deformation monitoring (DP)

Result #	Results title	Please provide a brief description of the results emerging from this AG	Programme output indicator or other indicators to which the result will contribute	Target value
Result 1.1	Deformation map	The proposed deformation map will clearly classify the different regions according to deformations rates and identify those regions, that are suffering significant deformations, that can lead to damages to public and private properties.	Number of awareness raising initiatives regarding emergency situations	5,00

Which are the **outputs that define your project** and would measure its progress (e.g. number of reports written, number of seminars held, number of members of target group given additional training, kilometres of riverbed cleaned, number of innovation centres opened)? Please mention all project expected outputs as well as the corresponding Activities Group where they are achieved				
Satellite Based Radar imagery database and information from endangered sites	Database containing a radar imagery from at least the ESA Sentinel- 1 missions since 2014. if the budget allows historic (from 1992) ERS-1 monthly imagery will also be included	0,00	1,00	Deformation monitoring (DP)
Deformation history database and technical documentation on the interpretation of the deformation analysis	Height variation map of the area including the indication of areas with the risk of significant ground deformations.	0,00	5,00	Deformation monitoring (DP)

InSAR related AG outputs and result are finalized. All products and documentation will be reported on **2022.05.15**

WebViewer serves as **Deformation Map and Database** to disseminate (public) and distribute results with project partners (admin).

All data/database are located in BME-AFGT GeoSES Server (physically located in SGO). All processed data/database are available on request.

Planned and scheduled updates in the next 3 years.

Conferences and Publications

Published papers:

Magyar, B., Horváth, R., & Völgyesi, L. (2021). Regional Scale Monitoring of Surface Deformation in Transcarpathia using InSAR Techology, Scientific Bulletin Series D : Mining, Mineral Processing, Non-Ferrous Metallurgy, Geology and Environmental Engineering, 35(2), 59-67

Conference attendance and oral presentations in GeoSES topic:

Project Meetings and Workshops + ESA Fringe 2021, International Seminar "Complex Monitoring System of Solotvino 2021, International Workshop – Disaster Risk Reduction Through Joint Collaboration In HU-SK-RO-UA Region 2021, GIS Open 2021, Magyar Űrkutatási Fórum 2021, G.I.C.2021 International Conference, HSPACE 2022, **EGU 2022** (Coming soon) and **Living Planet Symposium 2022** (Coming soon)

Acknowledgment

Prepared with the professional support of the Doctoral Student Scholarship Program of the Co-operative Doctoral Program of the Ministry for Innovation and Technology from the source of the National Research, Development and Innovation Fund.

This research was co-financed by the HUSKROUA ENI CBC 2014-2020 Programme and it directly linked to the HUSKROUA/1702/8.1/0065 GeoSES project.

Thank you for the research related consultancies for Lajos Völgyesi[2], Szabolcs Rózsa[2] , Béla Paláncz[2] and Ambrus Kenyeres[1]

Discussion: Q&A

Thank you for your attention!

Contacts

Balint Magyar

00 36 27 200 802

magyar.balint@emk.bme.hu / balint.magyar@lechnerkozpont.hu

www.sgo-penc.hu