

living planet symposium

BONN
23–27 May
2022

TAKING THE PULSE
OF OUR PLANET FROM SPACE



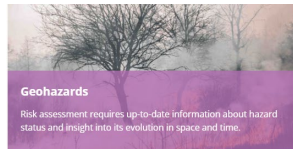
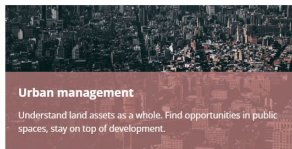
InSAR monitoring of subsidence and surface faulting risks over abandoned and active mines in Ostrava region, Czech Republic

J. Kolomazník, I. Hlaváčová, J. Struhár, E. Orlitová (GISAT s.r.o.)

26.5.2022



- Private owned SME
- Remote Sensing & geoinformation services
- Solutions



- Operational services

- Copernicus EMS (Risk & Recovery FLEX)

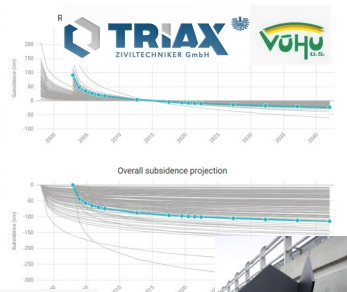
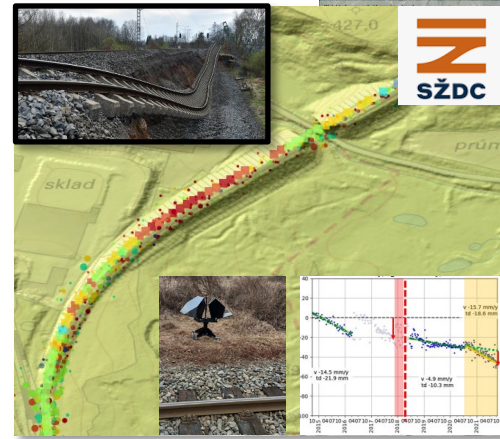
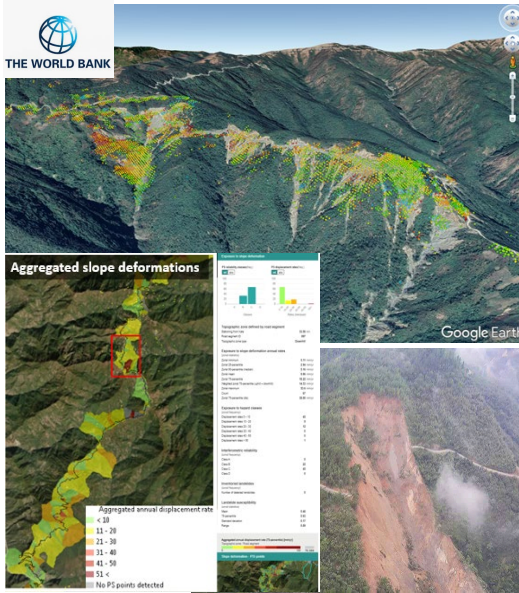
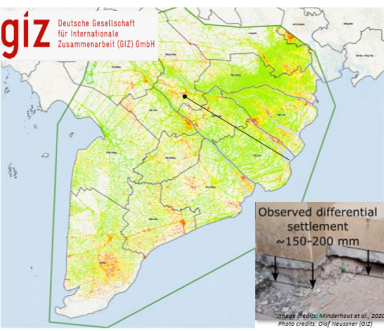


- ESA



- National agencies: Agriculture intervention fund, Infrastructure operators

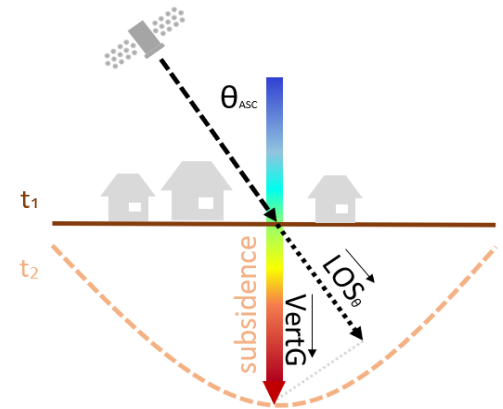
- 15+ years of PS-InSAR experience and competences
- ©SARProZ, cloud-based PS/DS, **InSARviz** platform



- Pilot service demonstrating utility of Copernicus datasets & multi-temporal InSAR
 - In the context of urban resilience
 - **Regional landscape planning** in the area affected by mining
- POHO = Post-mining landscape (Havířov-Karviná-Orlová)
 - Gradual closing of black coal mines
 - Investments into **transformation of the landscape and brownfields**
 - Innovative projects
 - Development & cultural hubs
 - Leisure areas



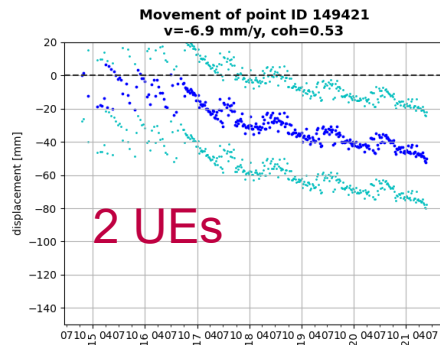
- The region has been **strongly affected by ground subsidence**
- Structural stability and geotechnical risks for existing and new assets
- Geodetic measurements and networks suboptimal
 - Suboptimal coverage, frequency or recency
- Solution = **retrospective MT-InSAR mapping**
 - **Evidence of spatial and temporal patterns** for **development zones**
 - Sinking bowls
 - Potential geotechnical hazard



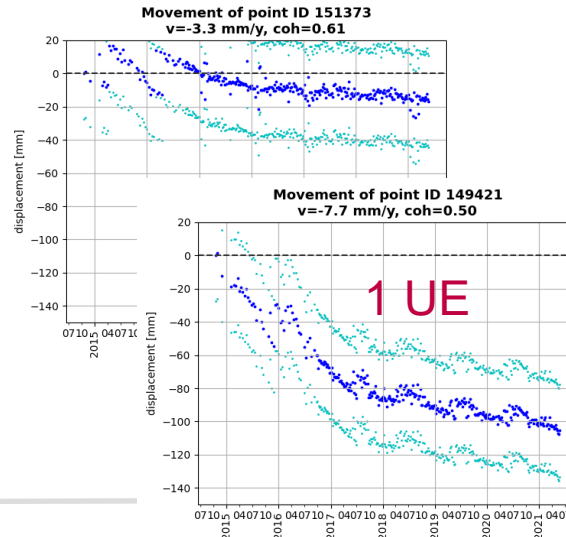
- *Dense PS points map, retain points with non-linear trends and interpret them*
- Active, large, heterogeneous mining area
 - Frequent **changes in displacement rates** and displacement trends
 - **Fast displacements** over limited periods
 - **Non-linear displacement trends**
 - Frequent Unwrapping errors
 - Low coherence + noise
 - Standard **PS candidates selection** techniques (of PSI) **fail**
 - Amplitude stability
 - Coherence

- **PSI algorithm** (©SARProZ) – cloud based
- **Sentinel-1a/b**
 - Period: 2015-2021 (*> 6.5 years, > 300 scenes*)
 - 1 **Ascending** (A 175), 2 **Descending** tracks (D 51, D 124)
- **Augmented post-processing routines**
 - Unwrapping error correction
 - Classification of temporal patterns
 - Decomposition of LOS velocities to vertical and horizontal components
 - Geotechnical risks estimation

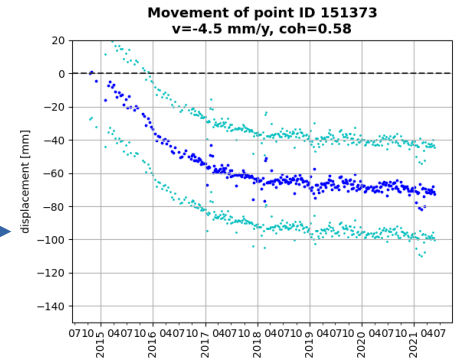
- Individually **for each PS candidate** in temporal dimension (automatic)
 - Break down of time series into **temporal segments**
 - **Piecewise linear model fitting** to estimate **local displacement velocities**
 - **Corrections** by sticking pieces together



UE corr



UE corr

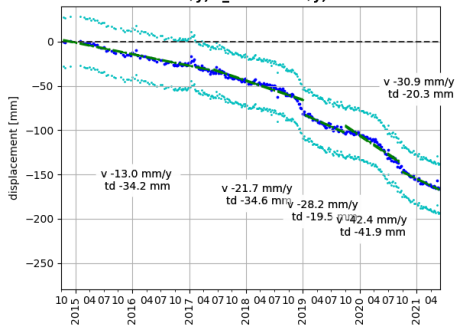


- **Temporal segmentation**

- **Noise & velocity** evaluation & filtering
- Assignment **trend dynamics** class – classification algorithm

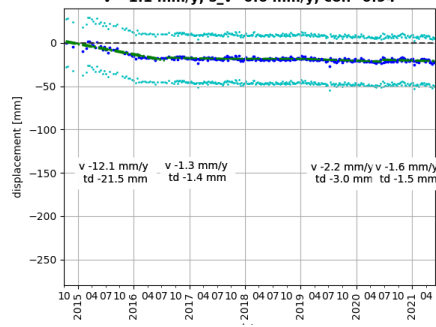
ACCELERATION

Movement of point ID 63416
 $v = -27.2$ mm/y, $s_v = 5.2$ mm/y, $coh = 0.83$



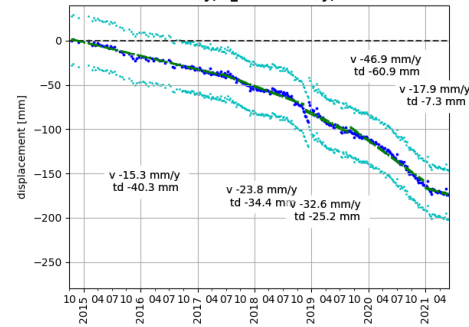
DECELERATION

Movement of point ID 95878
 $v = -1.1$ mm/y, $s_v = 0.6$ mm/y, $coh = 0.94$



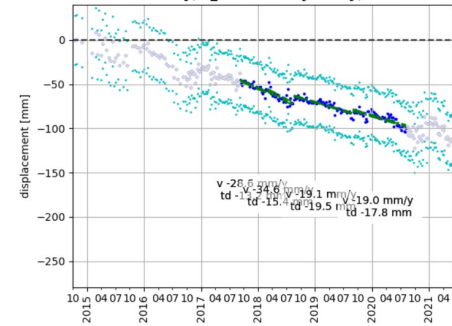
A+D

Movement of point ID 64206
 $v = -28.2$ mm/y, $s_v = 3.3$ mm/y, $coh = 0.81$

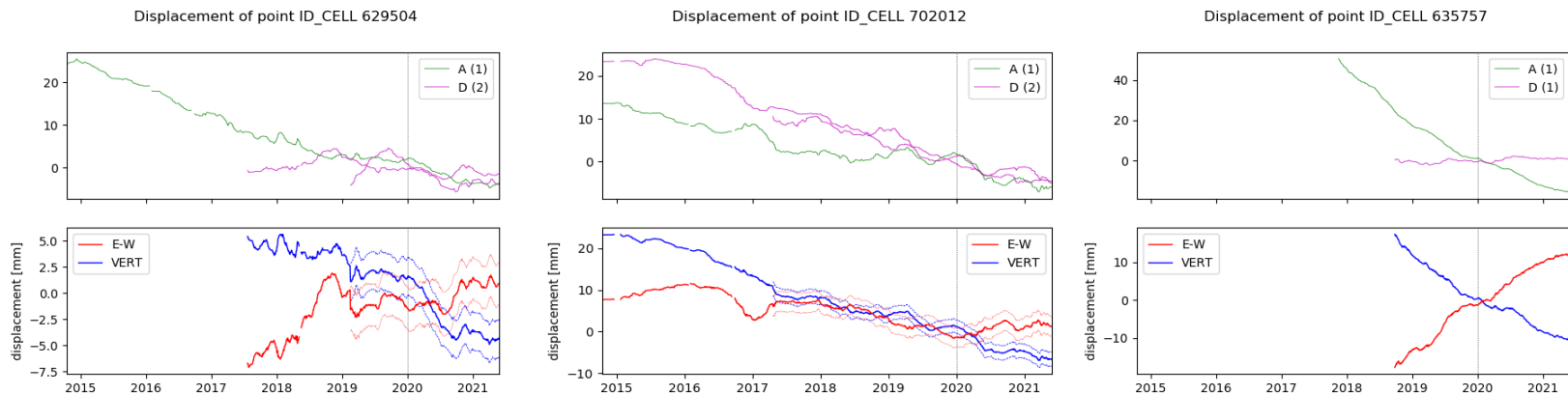


TEMPORAL IRRELIABILITY

Movement of point ID 65059
 $v = -16.5$ mm/y, $s_v = 2.8$ mm/y, $coh = 0.43$



- Standard LOS decomposition to estimate Vert & E-W defo field components
- Time series composition
 - Aggregated, Smoothed & Cross-validate output
 - Evolution of dynamics in different directional motion fields



- Demonstrated on recent methodologies:

- 1) García et al. (2019):

Subsidence in Como historic centre (northern Italy): Assessment of building vulnerability combining hydrogeological and stratigraphic features, Cosmo-SkyMed InSAR and damage data. International Journal of Disaster Risk Reduction. Volume 56, 1 April 2021, 102115

- Indexes providing basic characterization (velocity, coverage, distribution, accel.)
 - *Buildings, VHR*

- 2) Nappo N., Peduto D. et al. (2021):

Empirical fragility curves for settlement-affected buildings: Analysis of different intensity parameters for seven hundred masonry buildings in The Netherlands. Soils and Foundations 59 (2019) 380–397

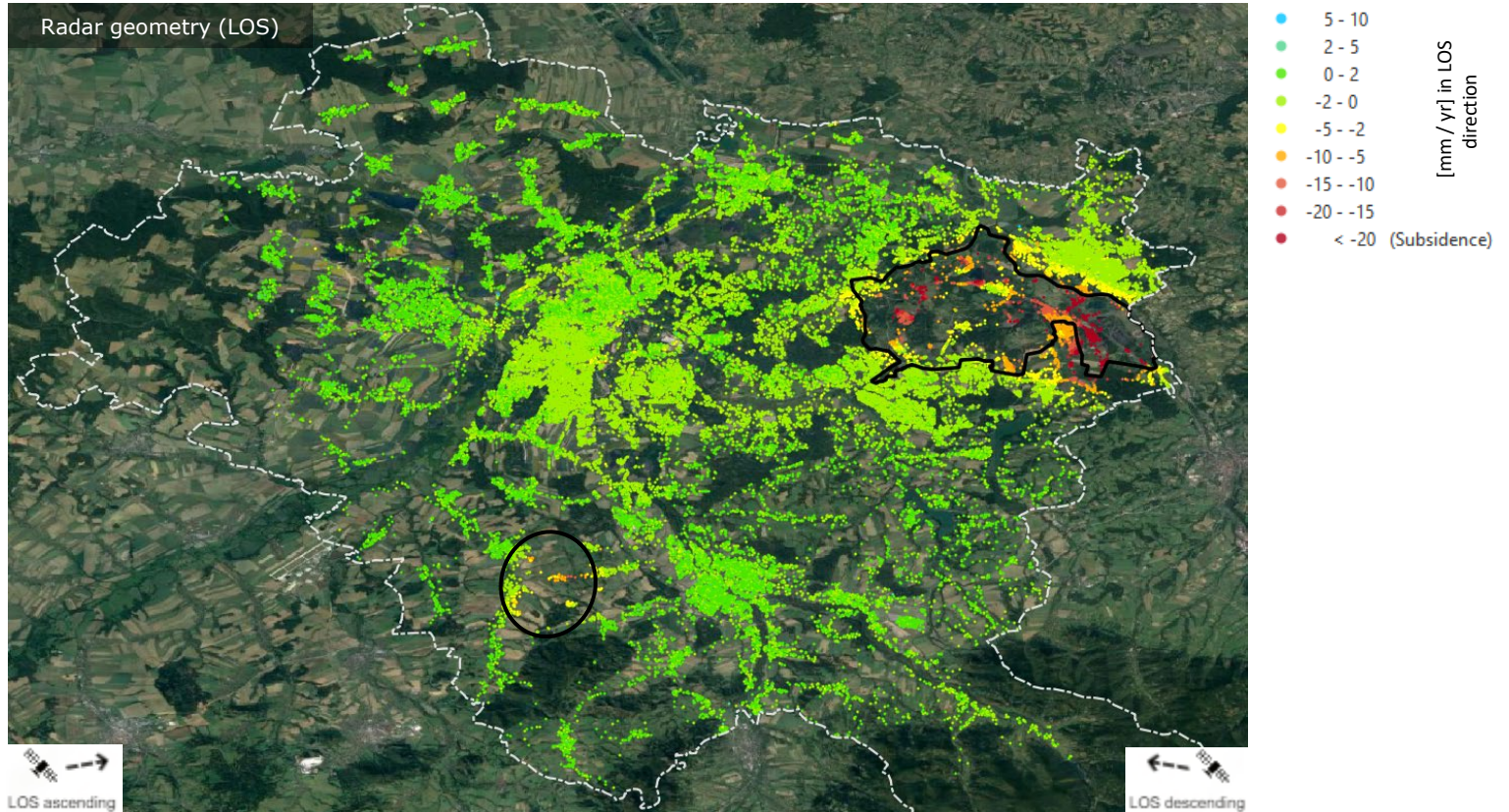
- Subsidence-related intensity \sim differential settlement & relative rotation
 - *Buildings, VHR*

- **3) Cigna F. & Tapete D. (2021)**:

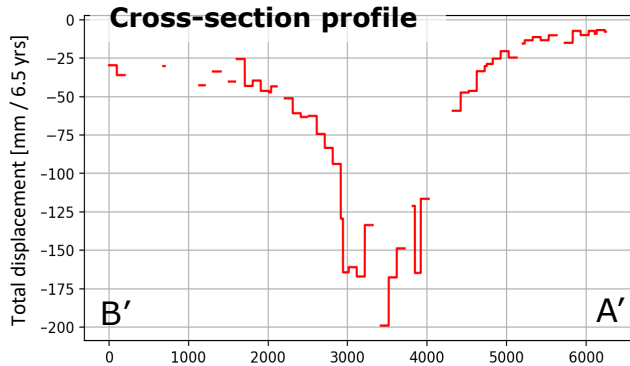
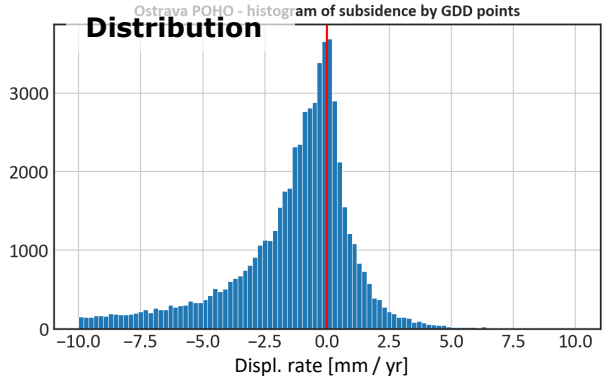
Satellite InSAR survey of structurally-controlled land subsidence due to groundwater exploitation in the Aguascalientes Valley, Mexico. Remote Sensing of Environment 253 (2021) 112161

- Differential displacements (in vert & horiz)
 - **Tensile strain zones:** extension (sagging) & compression (hogging)
 - Aggregate indicator: Surface faulting hazard.
 - *Grid, HR*

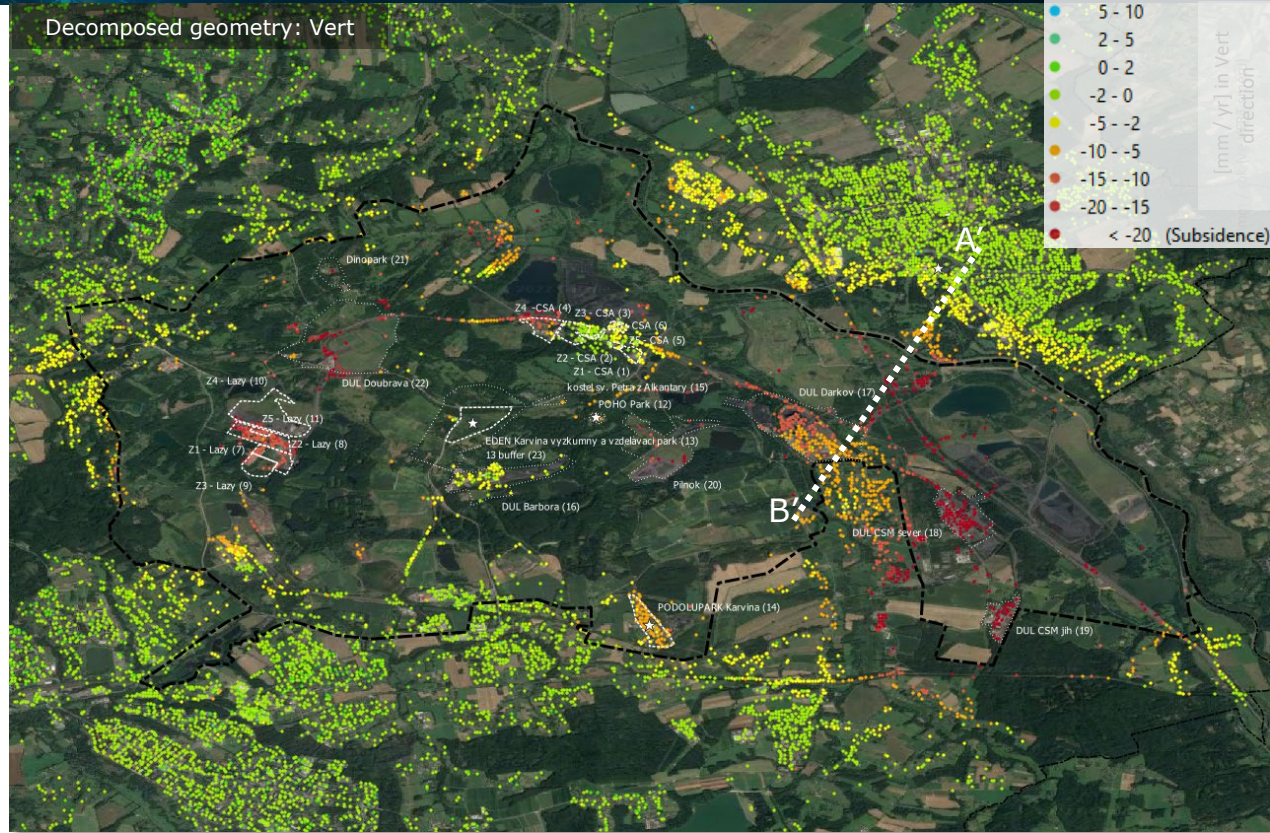
Ground motions map (regional) | LOS



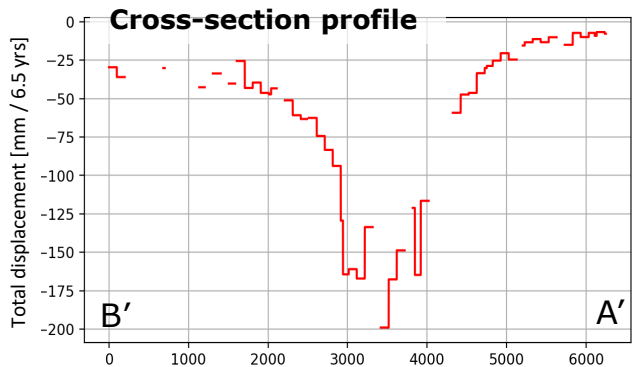
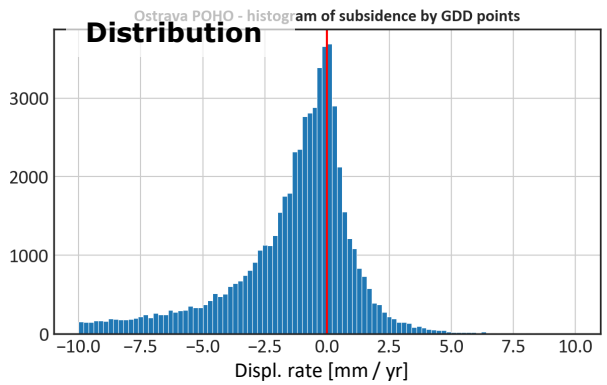
Ground motions map | Decomposed: Vertical



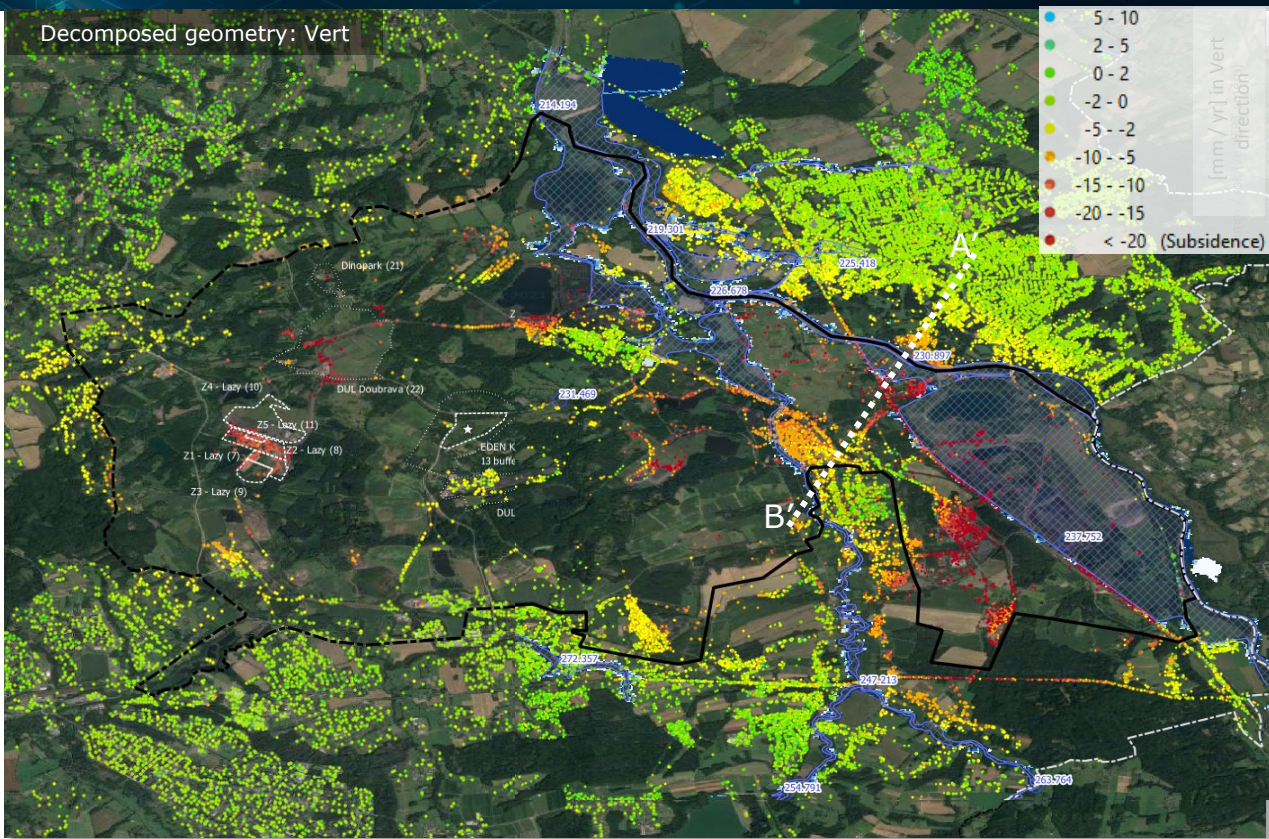
Decomposed geometry: Vert



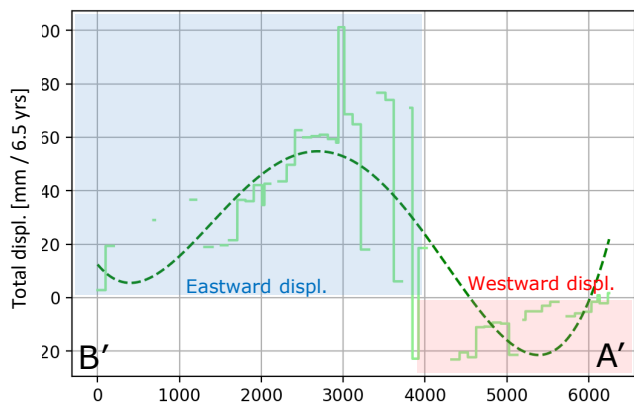
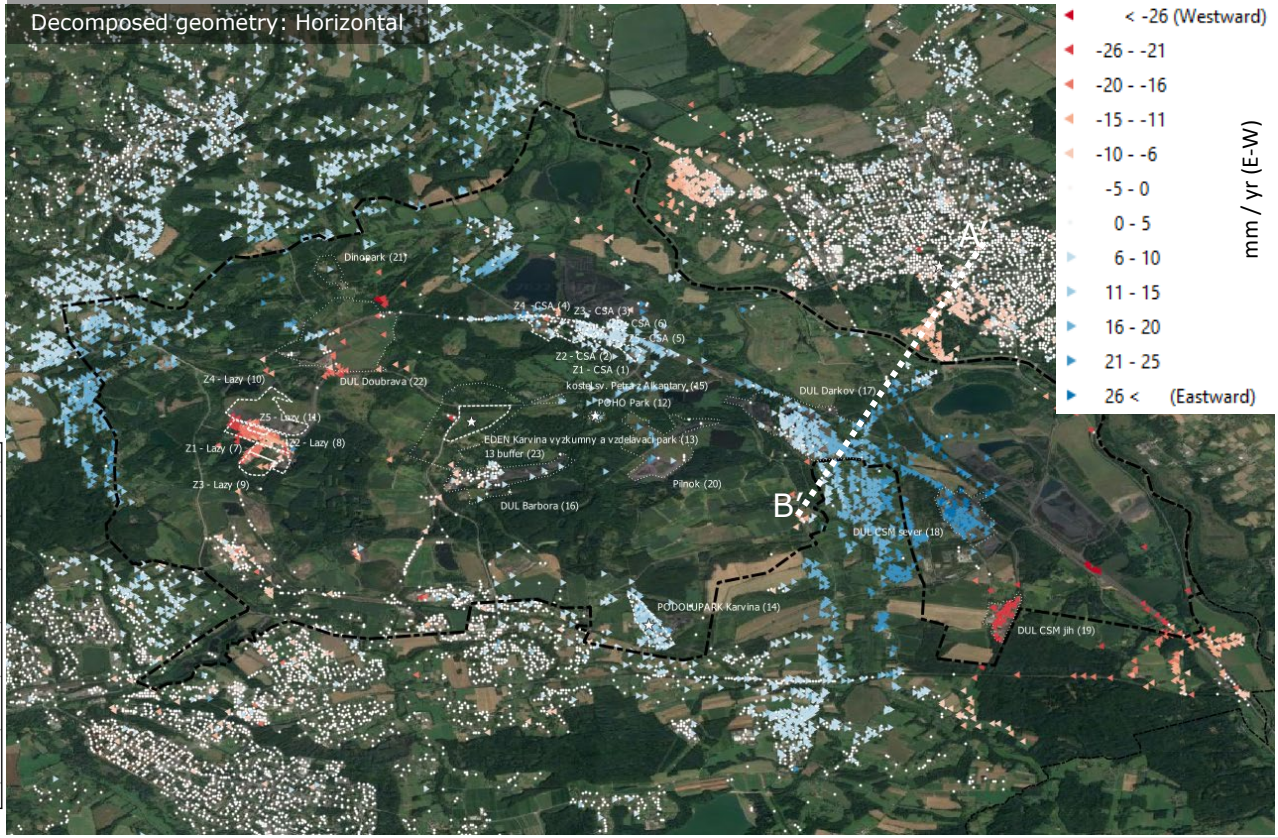
Ground motions map | Decomposed: Vertical



Decomposed geometry: Vert

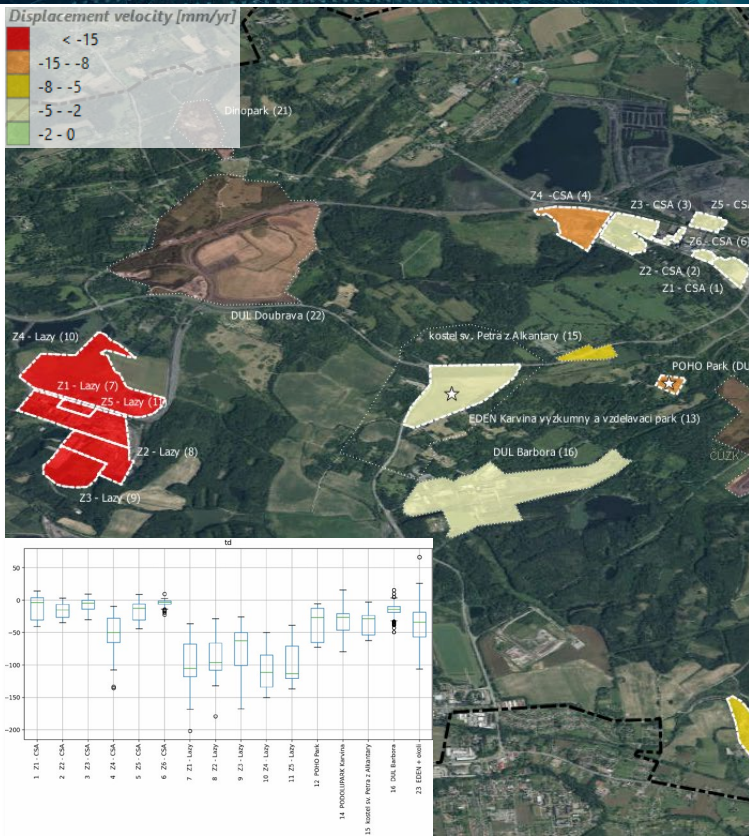
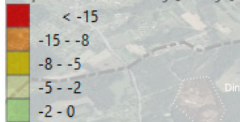


Ground motions map | Decomposed: East-West



Development zones | Risk profiles

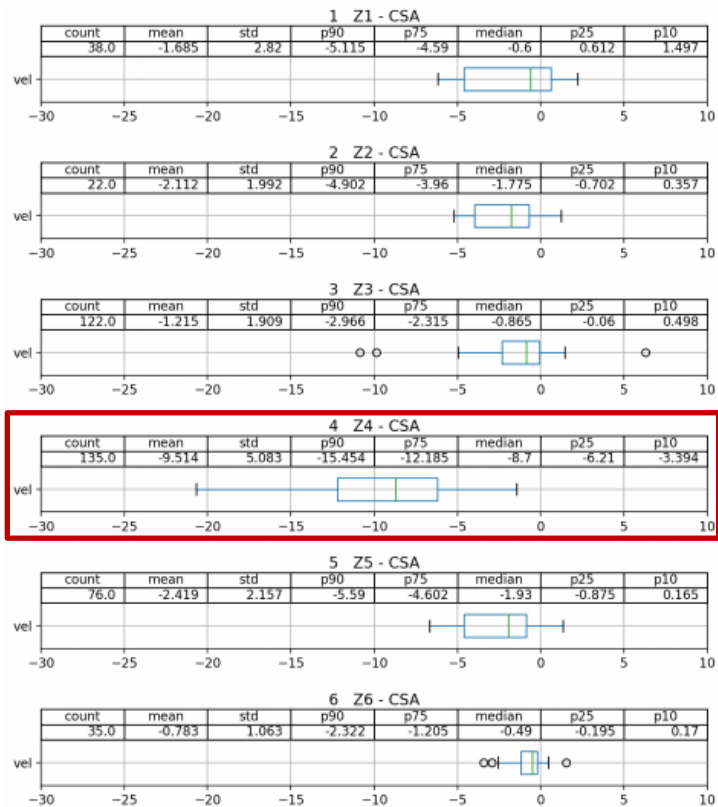
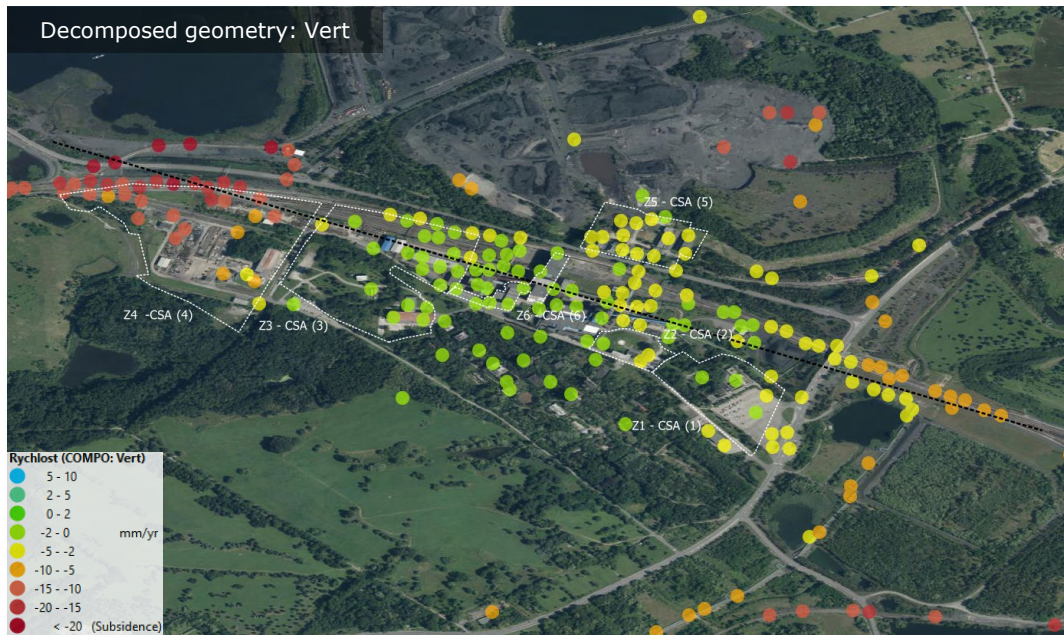
Displacement velocity [mm/yr]



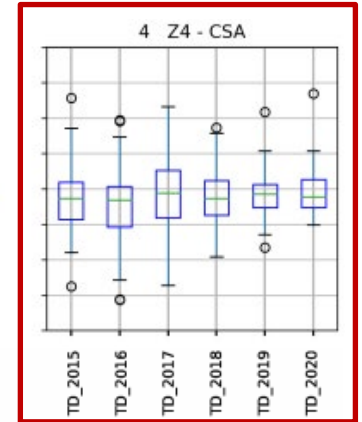
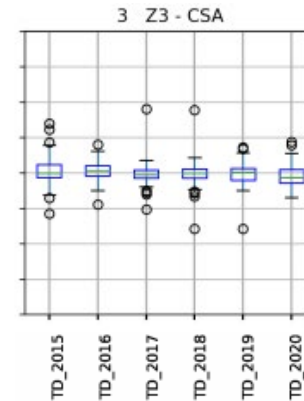
Zone id	Zone name	Mining finished*	VEL (REL >0.9)		ACC = VEL ₂₀₂₀ - VEL ₂₀₁₅ ([ACC] > 5 [mm/rok ²])				CL_DYN (from classification)					
			p75	I _{VEL}	N/C**	Const.	Accel.	Decel.	Prevailing dynamics	N/C	Const.	Accel.	Decel.	Prevailing dynamics
13	EDEN Karvina vyzkumny a vzdelavaci park *	-	-8,5	D	46%	33%	13%	9%	constant	36%	47%	14%	3%	constant
14	PODOLUPARK Karvina	-	-7,3	C	56%	28%	12%	5%	constant	28%	52%	14%	6%	constant
15	kostel sv. Petra z Alkantary	-	-7,9	C	47%	29%	6%	18%	constant	24%	59%	6%	12%	constant
20	Pilnok	-	-29	E	94%	1%	1%	4%	acceleration	37%	25%	27%	11%	deceleration
21	Dinopark	-	-27	E	91%	5%	5%	0%	deceleration	27%	32%	36%	5%	deceleration
23	EDEN buffer	-	-8,45	D	46%	33%	13%	9%	constant	36%	47%	14%	3%	constant
12	POHO Park (DUL Gabriela)	2000	-9,7	D	37%	32%	21%	11%	deceleration	32%	53%	11%	5%	constant
16	DUL Barbara	2002	-3,0	B	43%	52%	2%	4%	constant	29%	59%	4%	8%	constant
22	DUL Doubrava	2011	-25	E	79%	6%	10%	6%	deceleration	25%	29%	29%	17%	deceleration
17	DUL Darkov	2016	-12	D	44%	33%	11%	12%	constant	21%	53%	16%	11%	constant
7	Z1 - Lazy	2019	-19,1	E	57%	18%	8%	17%	acceleration	24%	24%	44%	8%	deceleration
8	Z2 - Lazy	2019	-17,0	E	53%	17%	15%	16%	acceleration	25%	36%	36%	4%	deceleration
9	Z3 - Lazy	2019	-16,4	E	77%	10%	11%	2%	deceleration	34%	43%	20%	3%	constant
10	Z4 - Lazy	2019	-21,4	E	77%	10%	2%	11%	acceleration	23%	18%	49%	10%	deceleration
11	Z5 - Lazy	2019	-19,1	E	55%	20%	7%	18%	acceleration	18%	27%	50%	5%	deceleration
1	Z1 - CSA	2021	-4,6	B	50%	39%	0%	11%	constant	39%	39%	8%	13%	constant
2	Z2 - CSA	2021	-4,0	B	27%	64%	0%	9%	constant	23%	41%	9%	27%	constant
3	Z3 - CSA	2021	-2,3	B	51%	37%	2%	10%	constant	45%	39%	8%	9%	constant
4	Z4 - CSA	2021	-12,2	D	74%	12%	10%	4%	deceleration	31%	34%	23%	12%	deceleration
5	Z5 - CSA	2021	-4,6	B	39%	55%	0%	6%	constant	31%	56%	5%	8%	constant
6	Z6 - CSA	2021	-1,2	A	33%	56%	3%	8%	constant	38%	41%	10%	10%	constant
18	DUL CSM sever	active	-52	E	60%	6%	21%	14%	deceleration	17%	18%	12%	52%	acceleration
19	DUL CSM jih	active	-44	E	62%	7%	21%	10%	deceleration	10%	15%	42%	33%	deceleration

- Sinking rates chronology ~ **seal closing etapization**
 - from East (Z1) to West (Z4)

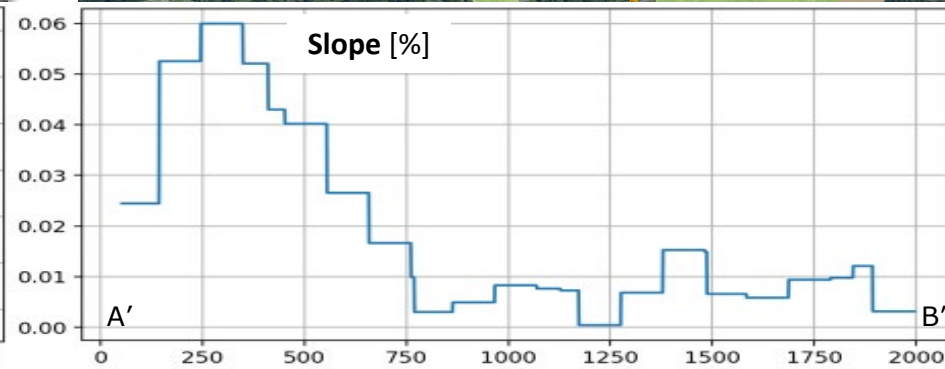
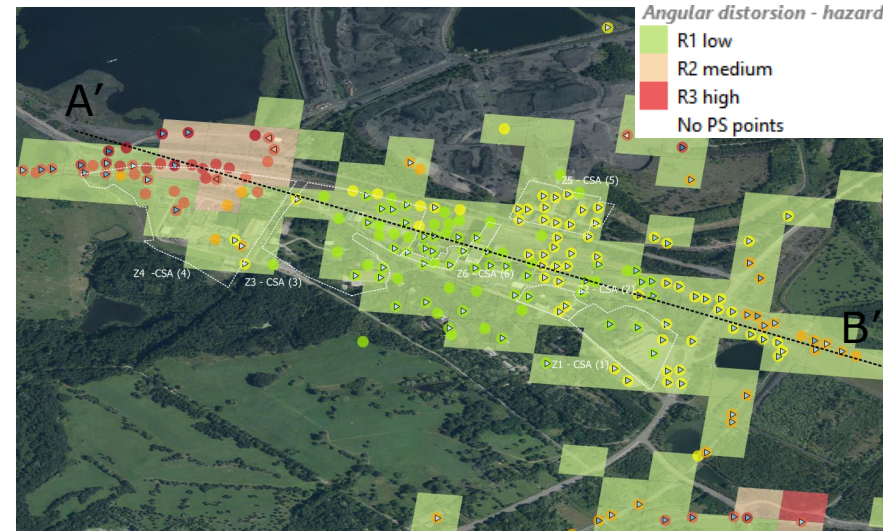
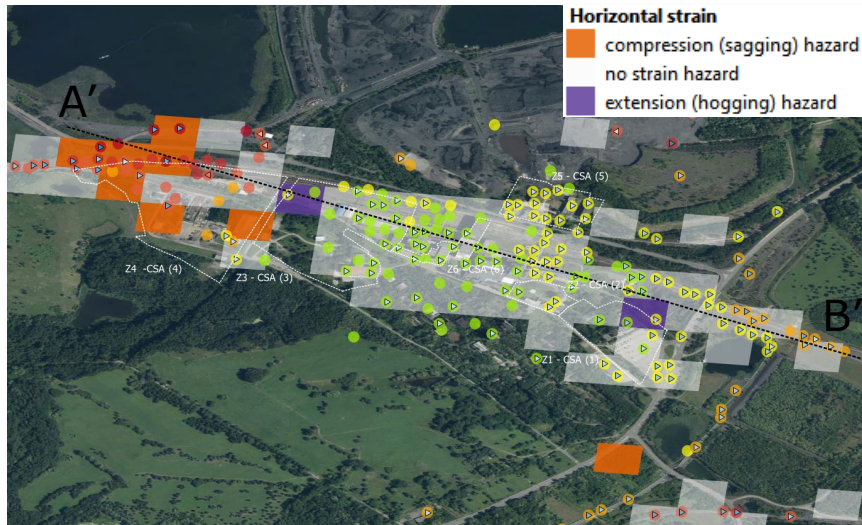
Decomposed geometry: Vert



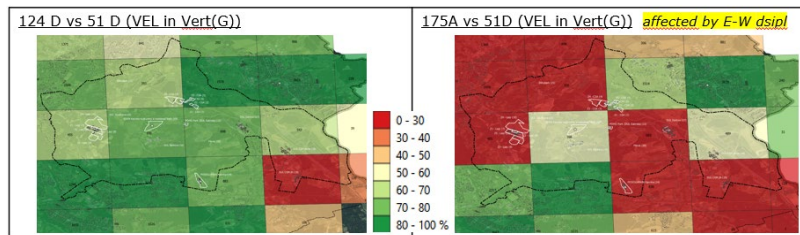
- Gradual deceleration of area above recently closed seal (Z4)
- Other seals: +- stable with constant trend



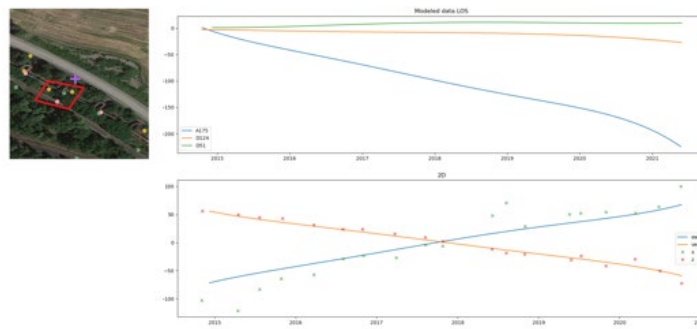
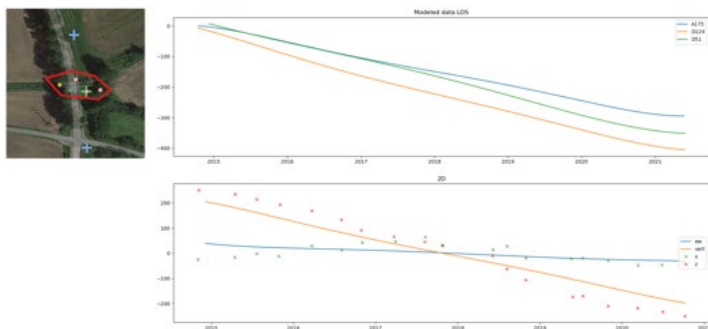
ČSA mine | Vertical distortion and horizontal strain



- Cross-validation
 - Hypothesis testing: equal distributions, offsets between pairs of tracks (D124-D51, A171-D51)



- Geodetic measurements *(courtesy of Jirankova E., INSTITUTE OF GEONICS, Czech Academy of Sciences)*

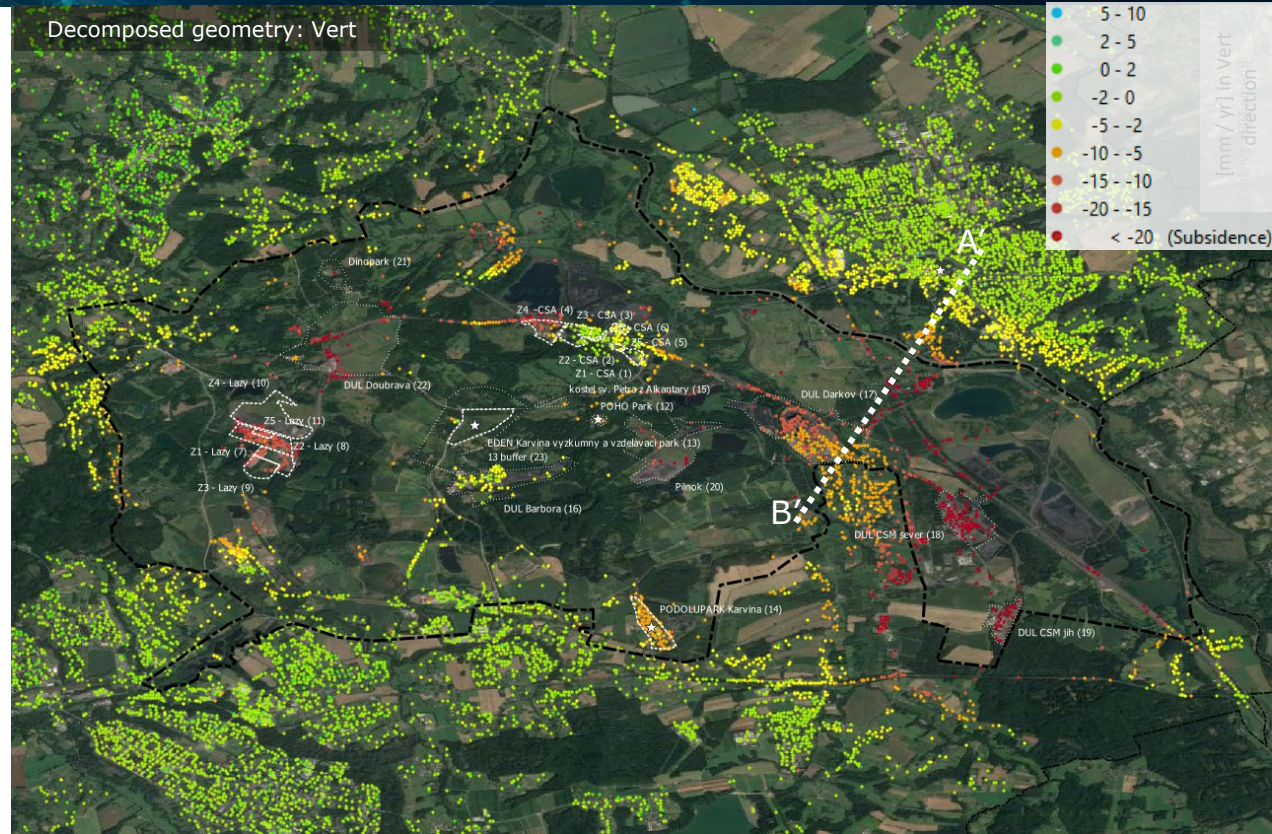


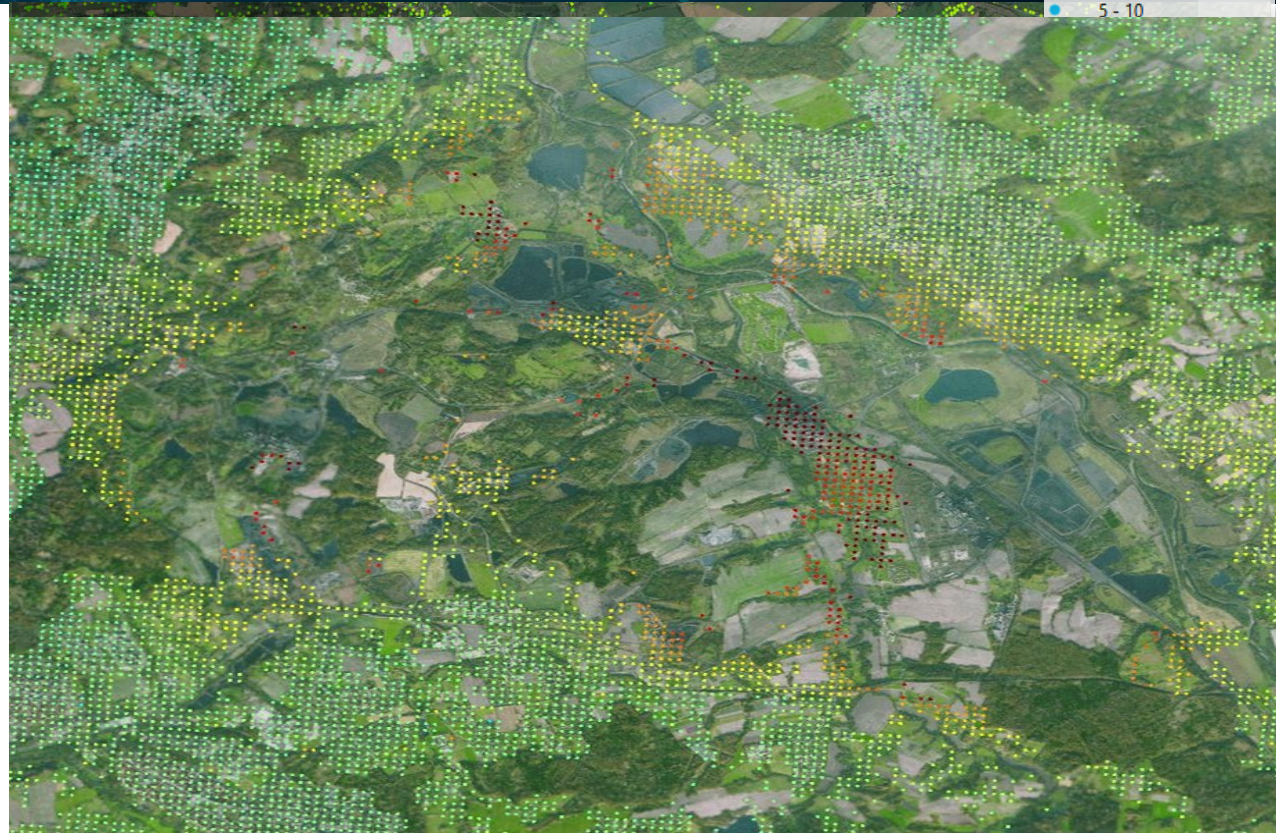
- Pilot demonstrates utility of MT-InSAR for post-mining landscape mapping
- Derived standard and value-adding characteristics
 - Proven methods
 - Development of new methods
 - Eliminate adversary patterns
 - Derive tailored characteristics
- Evidence of sinking within outcoming development zones
 - Hots-spots
 - Risk-profile
 - Evolution reflecting mine closing
- Regional administration council shall reflect results into development planning process

Thank you for your attention!

Ground motions map | Decomposed: Vertical

Decomposed geometry: Vert





Thank you for your attention!