RFCS i²Mon User Workshop

WP2: Satellite Radar Remote Sensing

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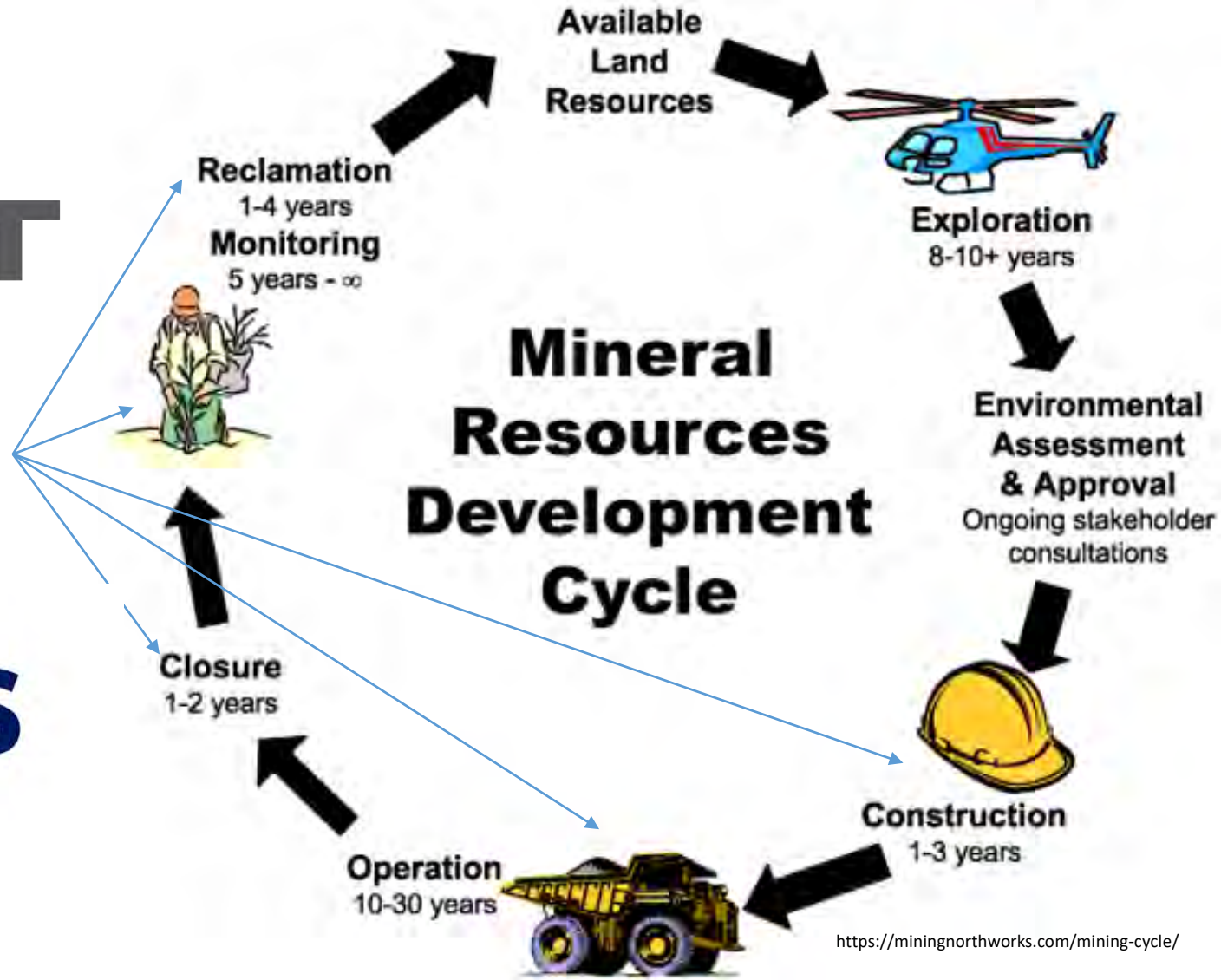
7th December 2021

Content

Topic	Speaker
Introduction	EFTAS
Open-pit mine with Sentinel-1	EFTAS
Open-pit mine with TerraSAR-X	AIRBUS
Underground mine with Sentinel-1	EFTAS
Conclusion	EFTAS

Integrated Mining Monitoring



https://miningnorthworks.com/mining-cycle/

To prevent catastrophes

Brumadinho dam failure (January 2019)

https://en.wikipedia.org/wiki/Brumadinho_dam_disaster

Mariana dam failure (November 2015)

https://en.wikipedia.org/wiki/Mariana_dam_disaster

WP2 - Satellite Radar Remote Sensing

1. Study on Suitable Remote Monitoring Data, Systems and Processing Technology

2. Development of Monitoring Data Acquisition and Processing Systems

3. Refinements and Final Development of the Monitoring System

Content

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Introduction	EFTAS
Open-pit mine with Sentinel-1	EFTAS
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Underground mine with Sentinel-1	EFTAS
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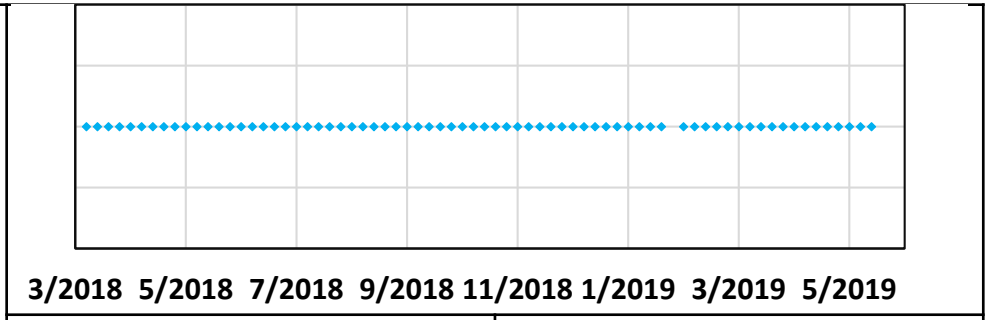
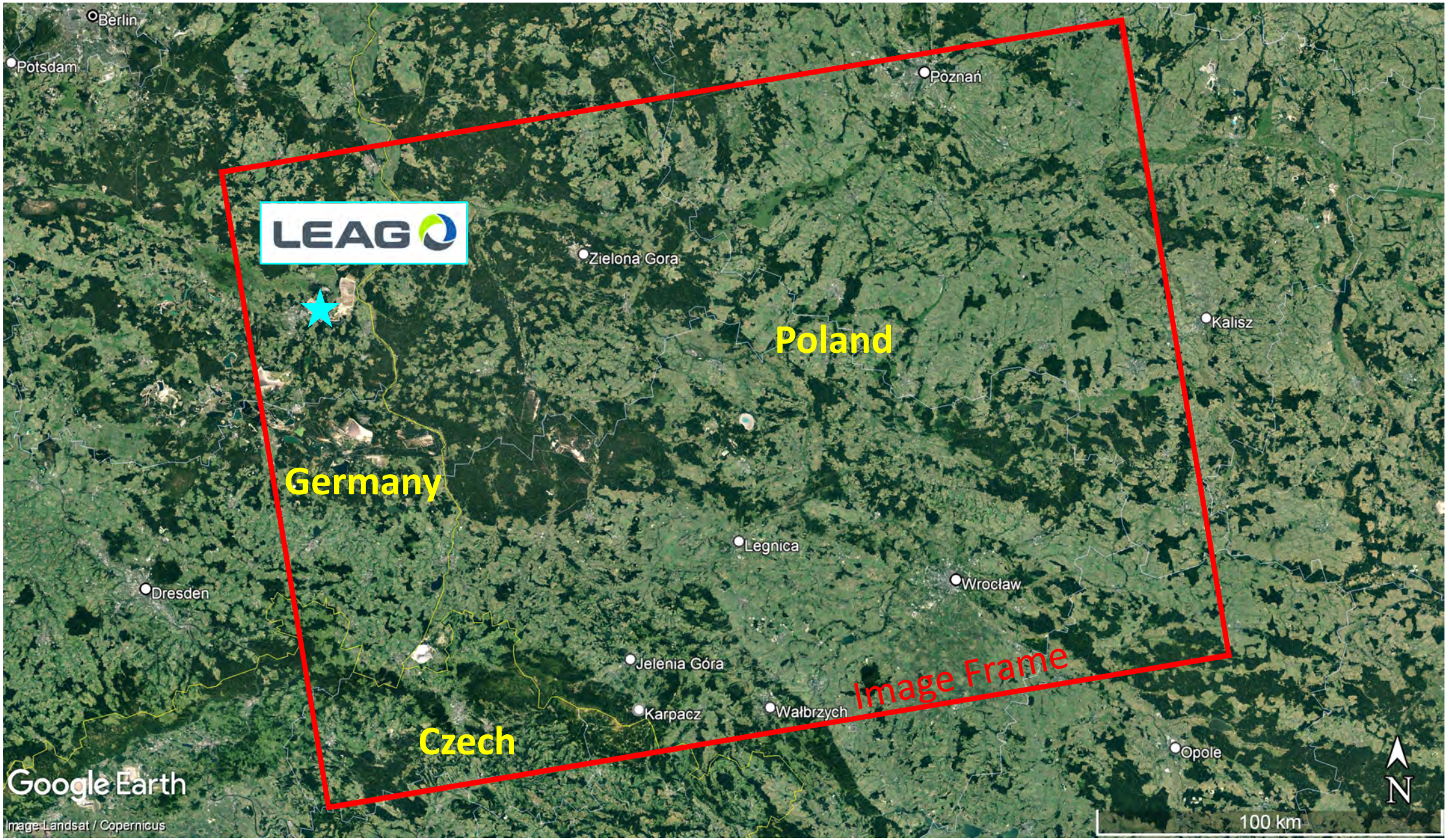
Sentinel-1 Dataset

Mode	**IW**
Resolution	**4.2 m × 13.9 m**
Amount	**71**
Orbit	**Ascending**
Polarization	**VV**

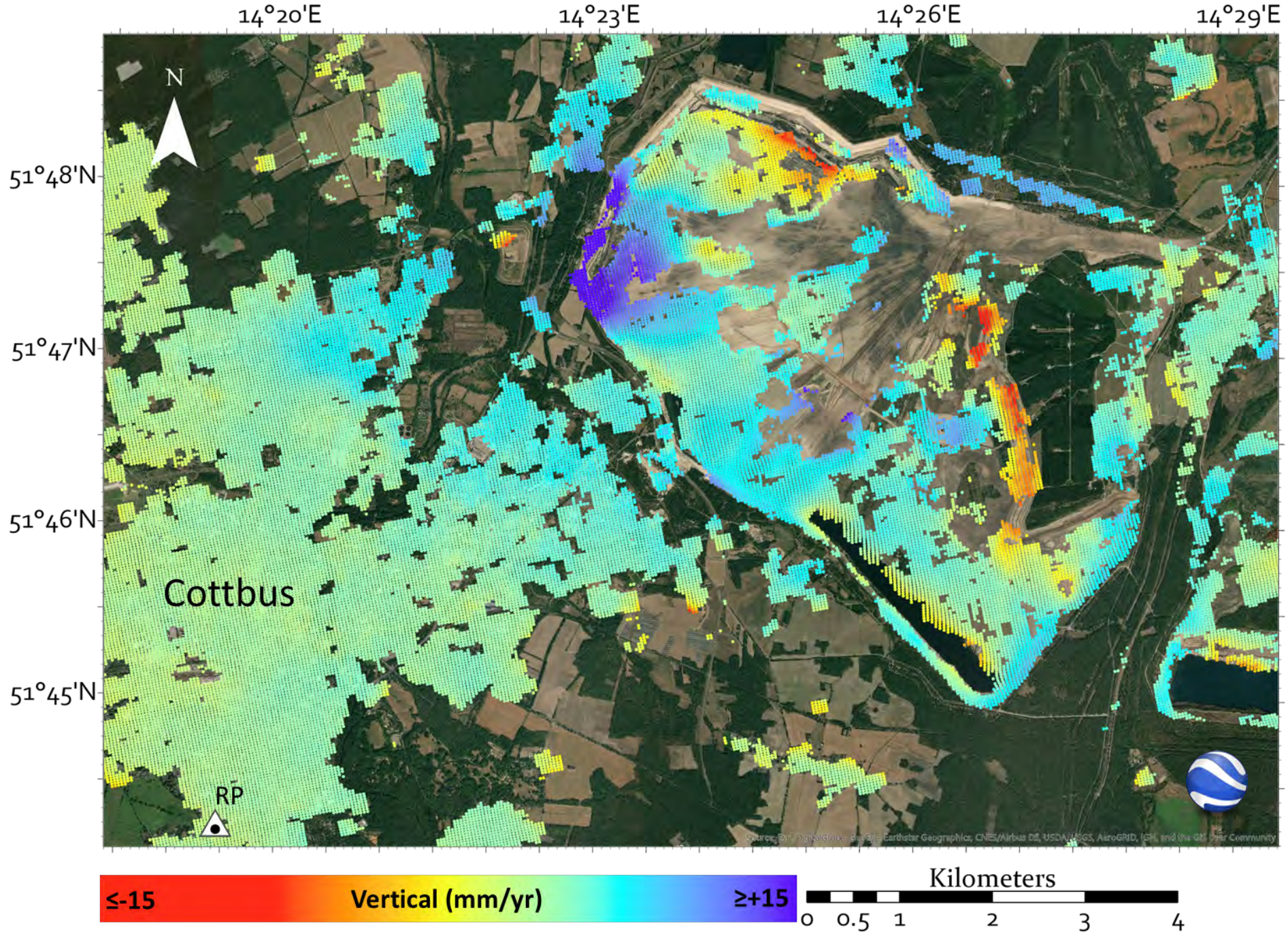


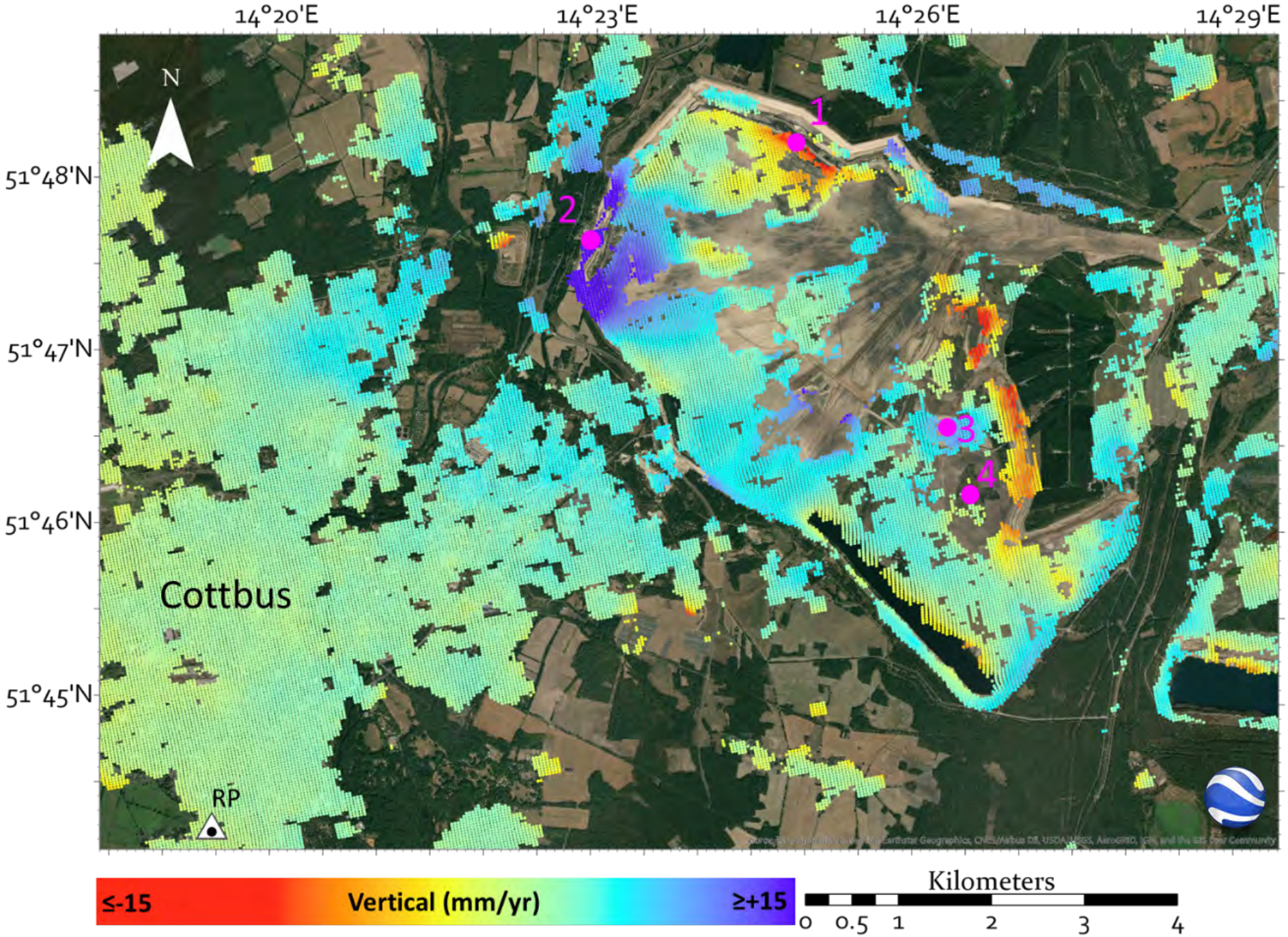
Time Span	**17.03.2018 – 17.05.2019**

Test in Cottbus

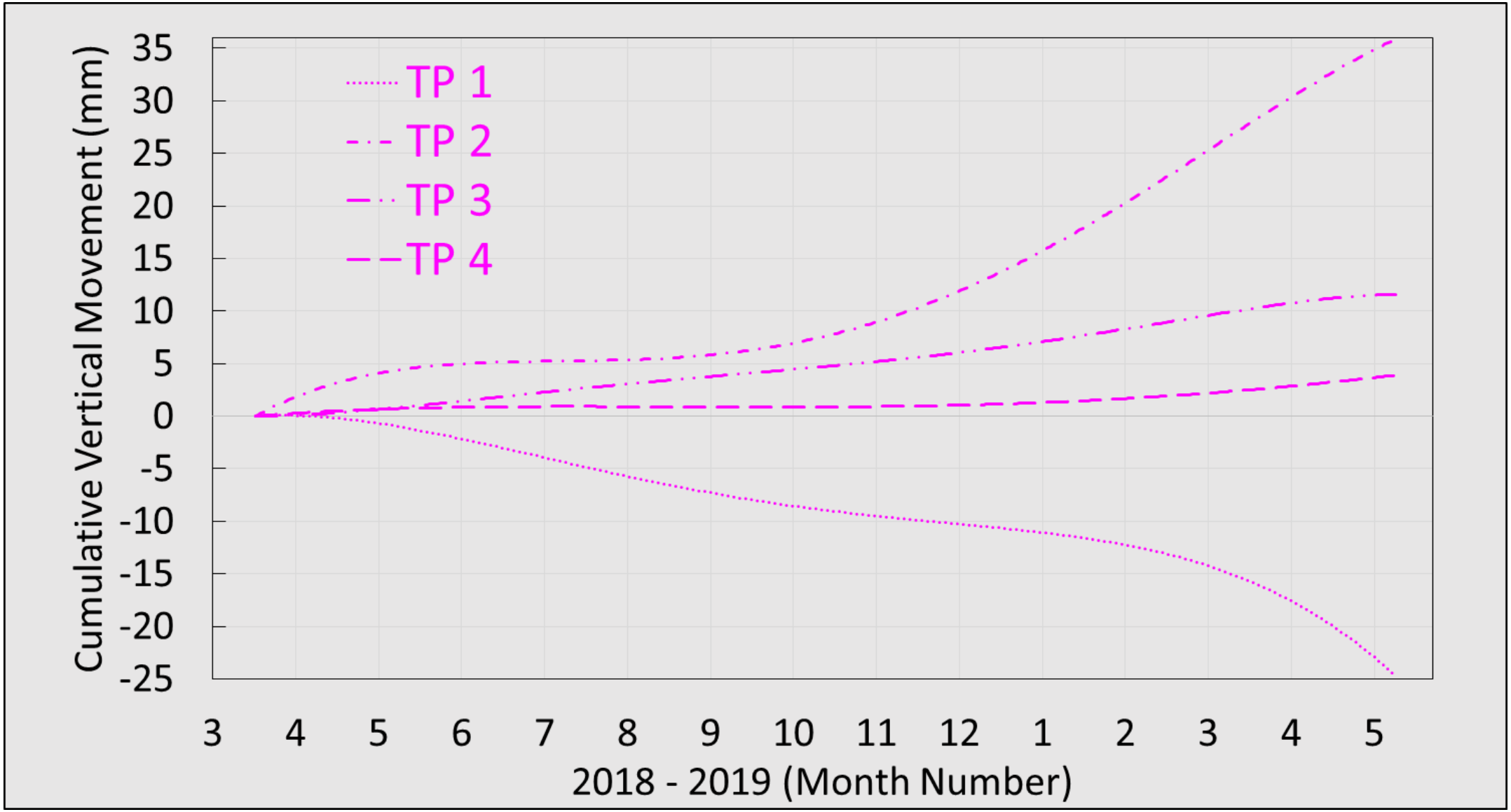


Test in Cottbus

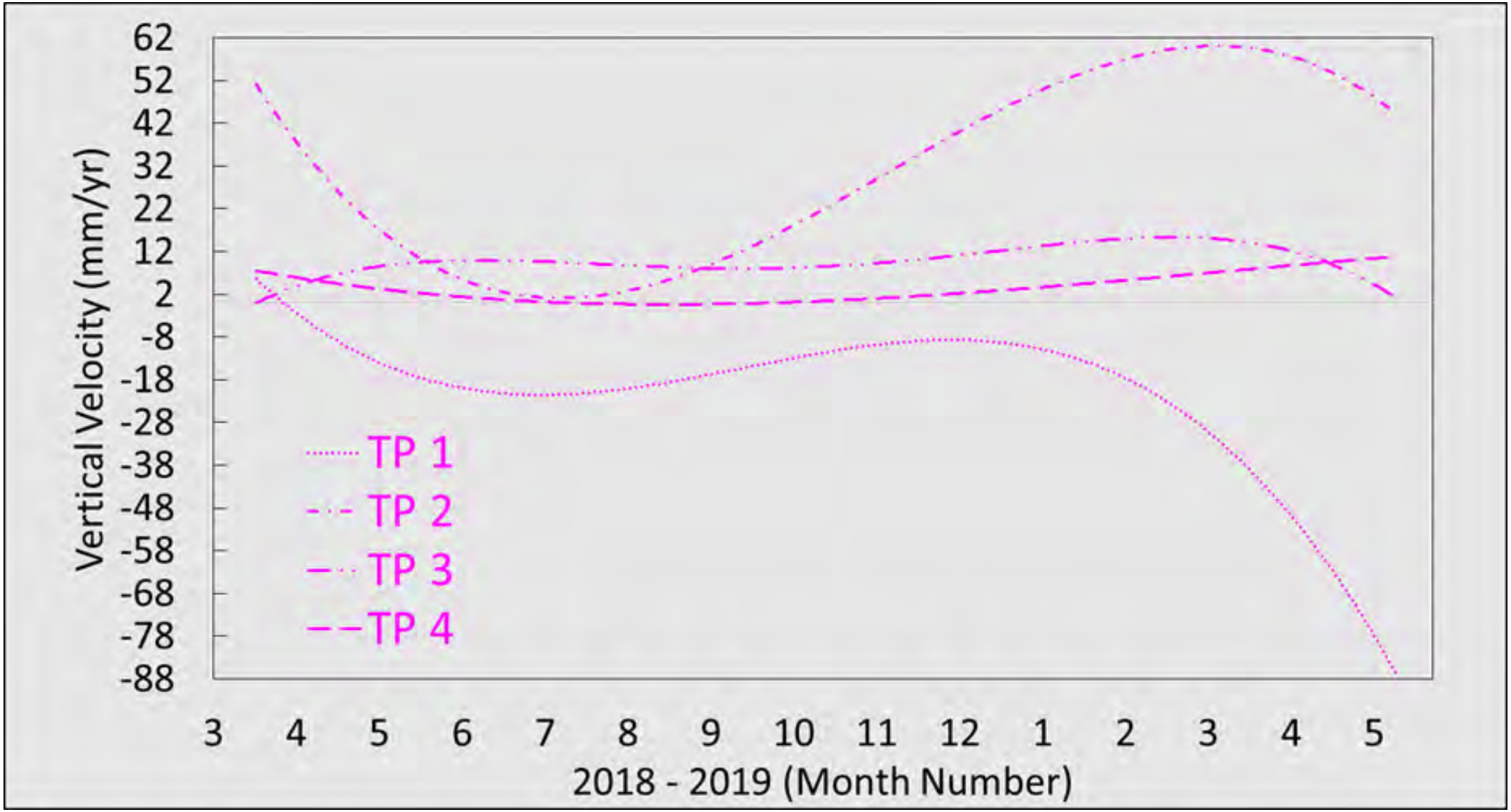

14°20'E
14°23'E
14°26'E
14°29'E
51°48'N
51°47'N
51°46'N
51°45'N
N
Cottbus
RP
≤-15
Vertical (mm/yr)
≥+15
Kilometers
0
0.5
1
2
3
4


14°20'E
14°23'E
14°26'E
14°29'E
51°48'N
51°47'N
51°46'N
51°45'N
N
1
2
3
4
Cottbus
RP
≤-15
Vertical (mm/yr)
≥+15
Kilometers
0
0.5
1
2
3
4

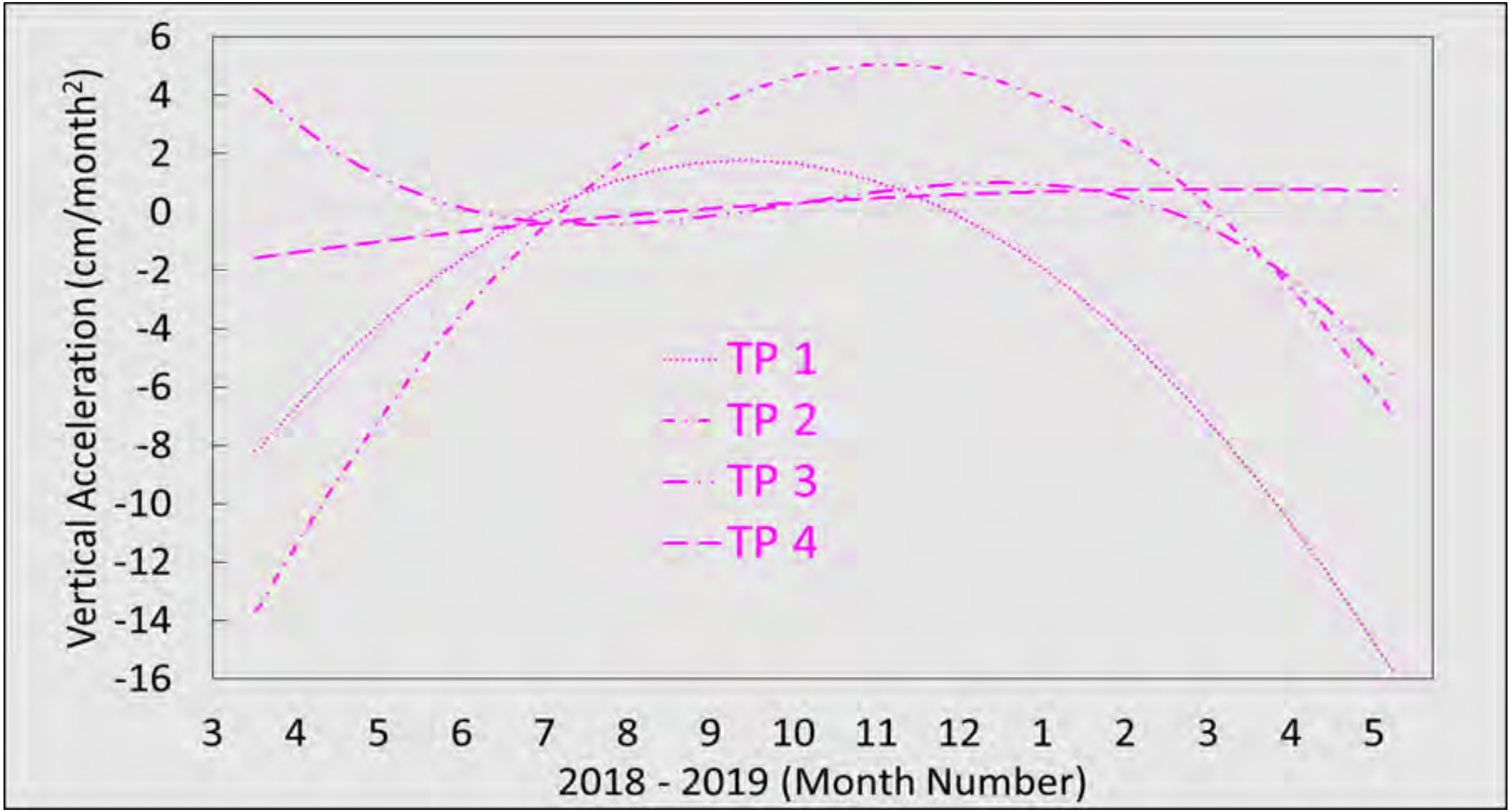
Cumulative Vertical Movement



Instantaneous Vertical Velocity



Instantaneous Vertical Acceleration



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DEFENCE AND SPACE

i2Mon - Integrated Mining Impact Monitoring

High Resolution TerraSAR-X Surface Movement Monitoring (LEAG Test Site)

Dr. Christin Lubitz

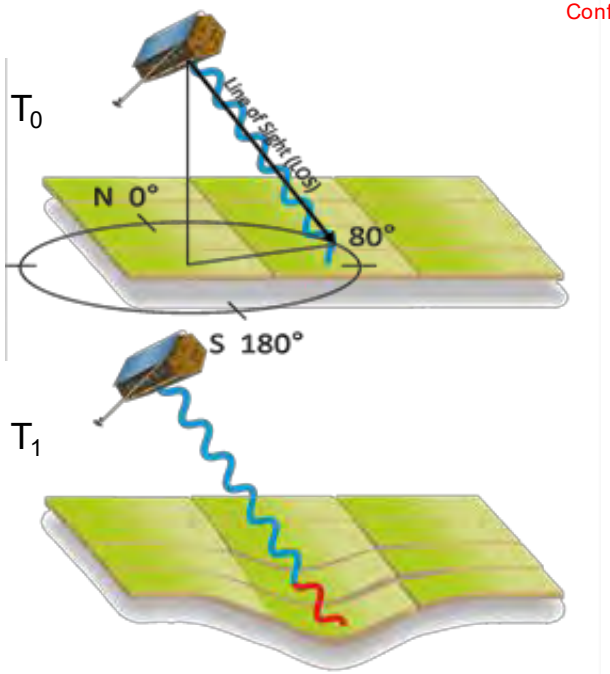
User Workshop, 07.12.2021

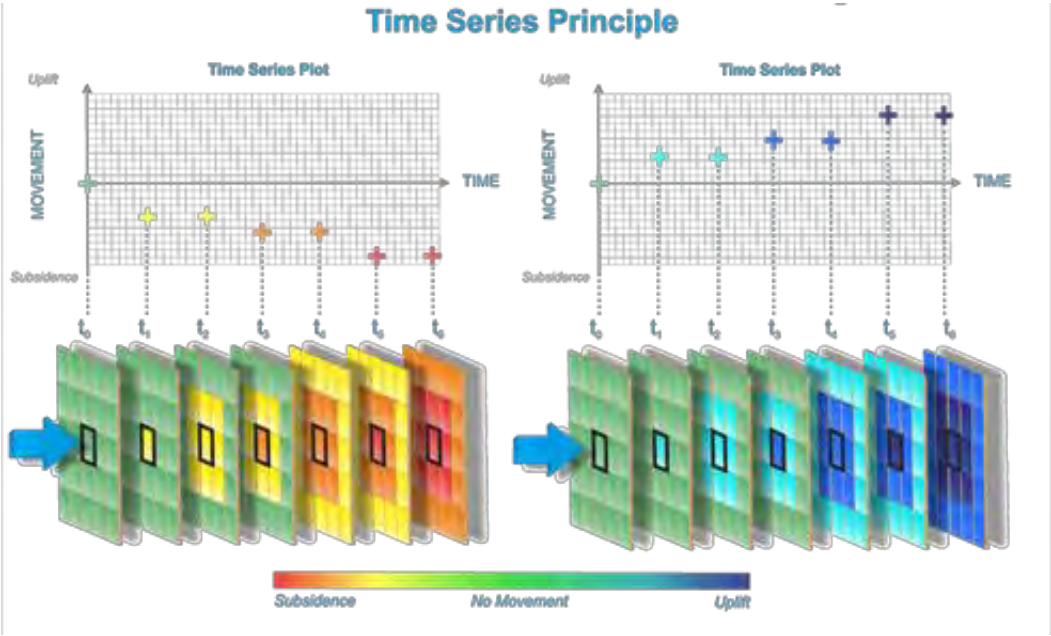
i2MON RFCS RESEARCH PROJECT

AIRBUS

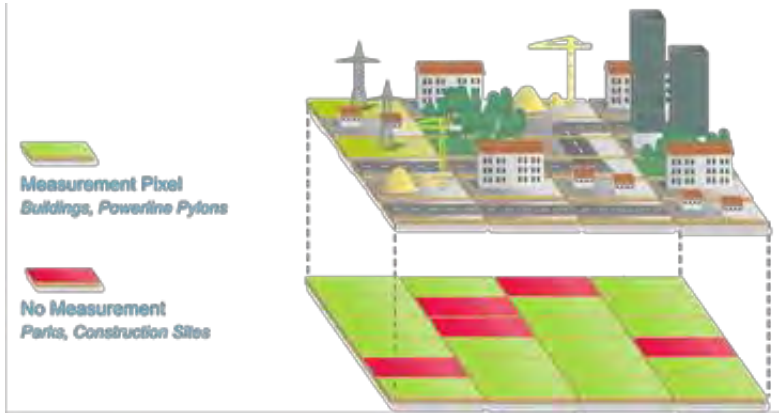
Precise long-term monitoring via SAR satellites

- Interferometric Synthetic Aperture Radar (InSAR) technique
- Movements are indicated by a path length difference
- The Measurement direction is along the line of sight (LOS) of satellite
  → i.e. both vertical & horizontal movement components contribute to the measurements
  → No sensitivity to horizontal displacements in flight direction
  → Small incidence angle → Low sensitivity for movements in East-West





- Comparing a pixel in a set of acquisitions at different time
- A time series analysis is possible only for pixels that do not change their reflect characteristics during the measurement period



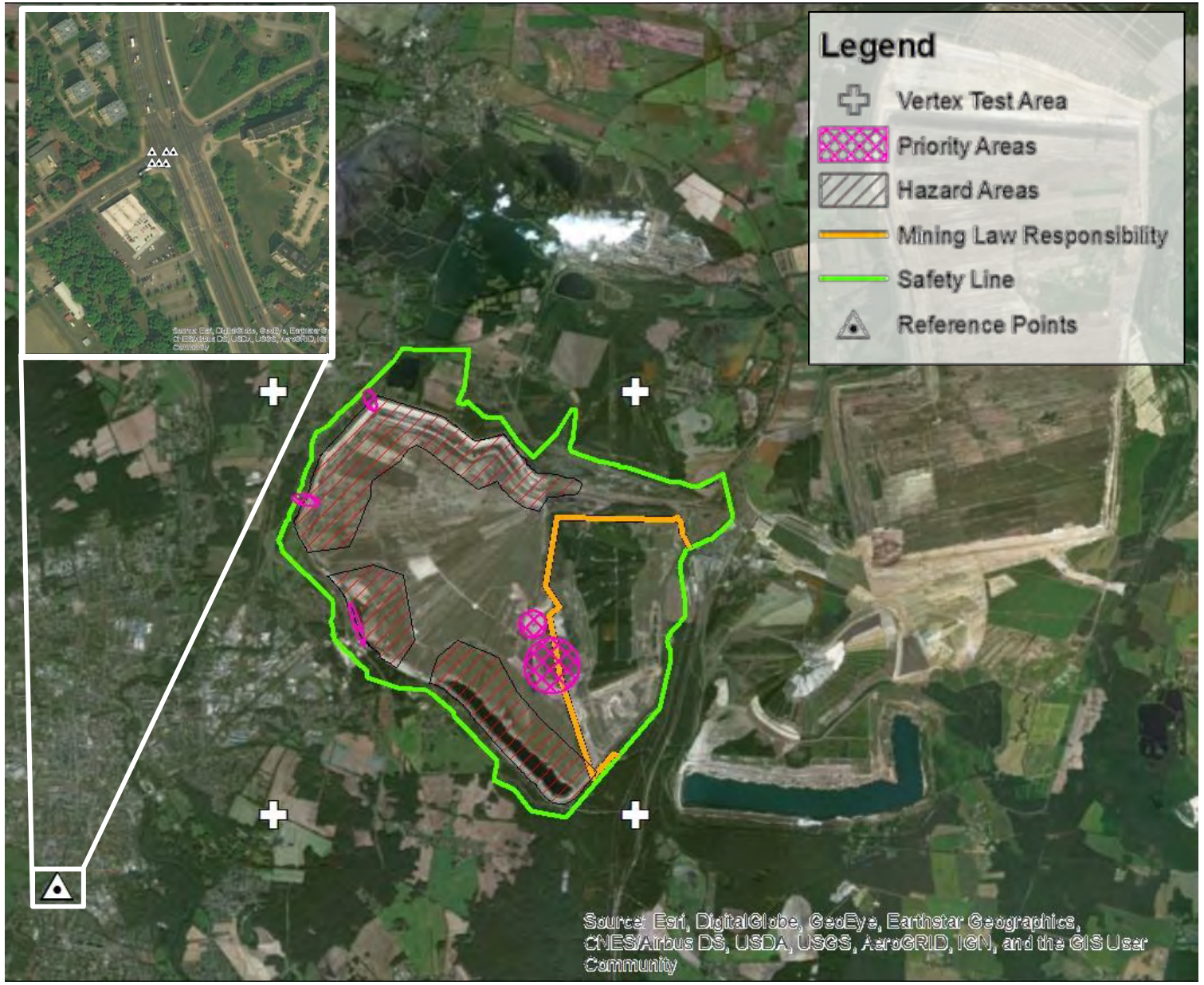
AIRBUS

Test site Cottbus-Nord

- LEAG test site “Cottbus-Nord” or “Cottbuser Ostsee”
- Sensor: TerraSAR-X
- Mode: Stripmap (SM)
- Spatial Resolution: ~ 3 m
- Image size: 30 km x 50 km
- One acquisition geometry: Ascending
- Reference Points: B169/Thiemstr.

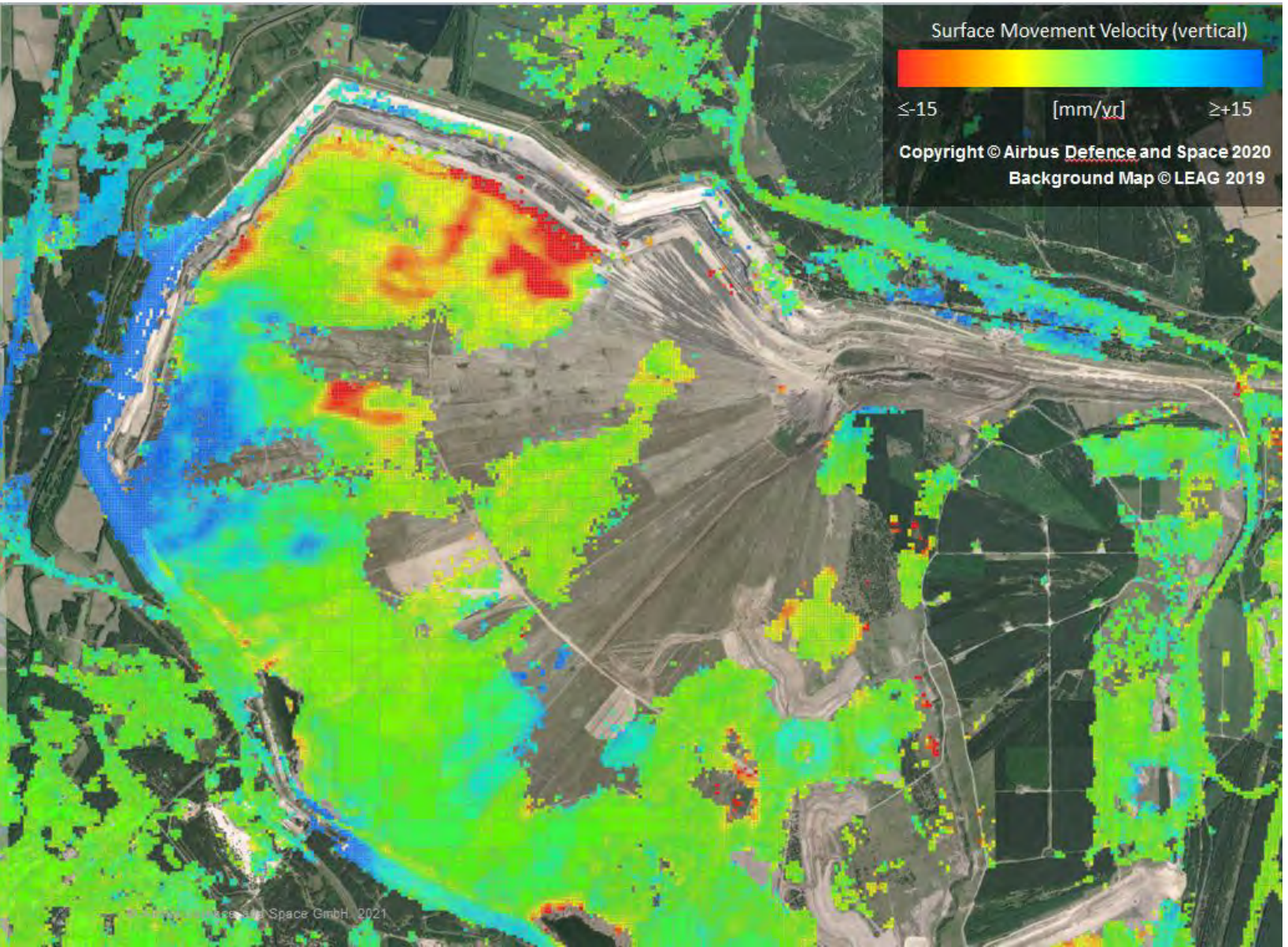
Aquisition Specification	Ascending Orbit
Orbit number	70
Incidence angle	21.1°
First acquisition	12.07.2016 (1)
Latest acquisition	21.11.2021 (166)
Repeat cycle	11 - 22 days

- Optimally suited for measurement of vertical movements
- Low sensitivity for movements in East-West → ~1/3 of the vertical sensitivity



AIRBUS

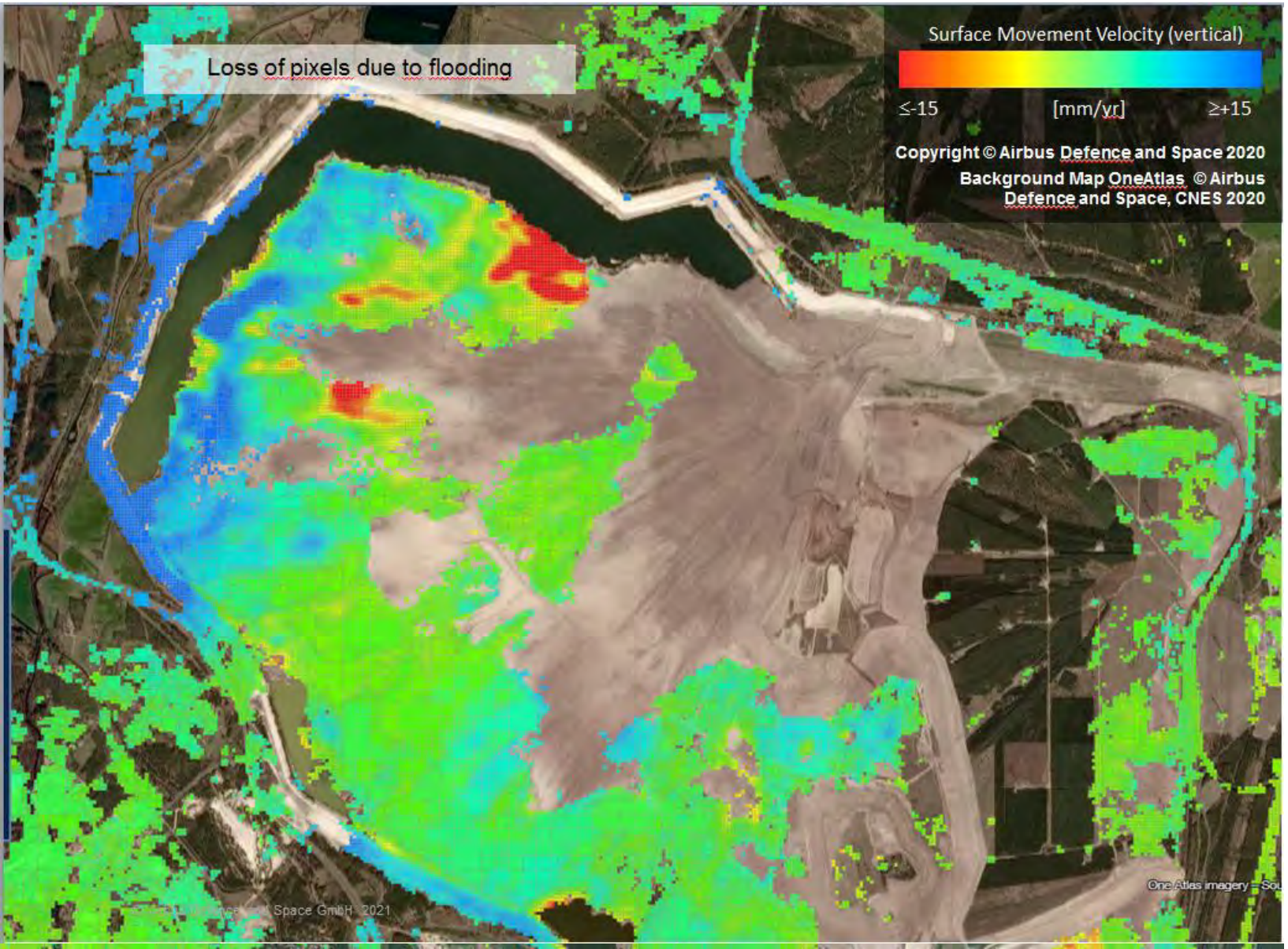
Test site Cottbus-Nord – High Resolution TerraSAR-X InSAR Analysis



- Initial Analysis: 20/03/2018 – 12/05/2019
  → 1 year 2 months
- 36 Scenes, SBAS Method applied

AIRBUS

Test site Cottbus-Nord – High Resolution TerraSAR-X InSAR Analysis

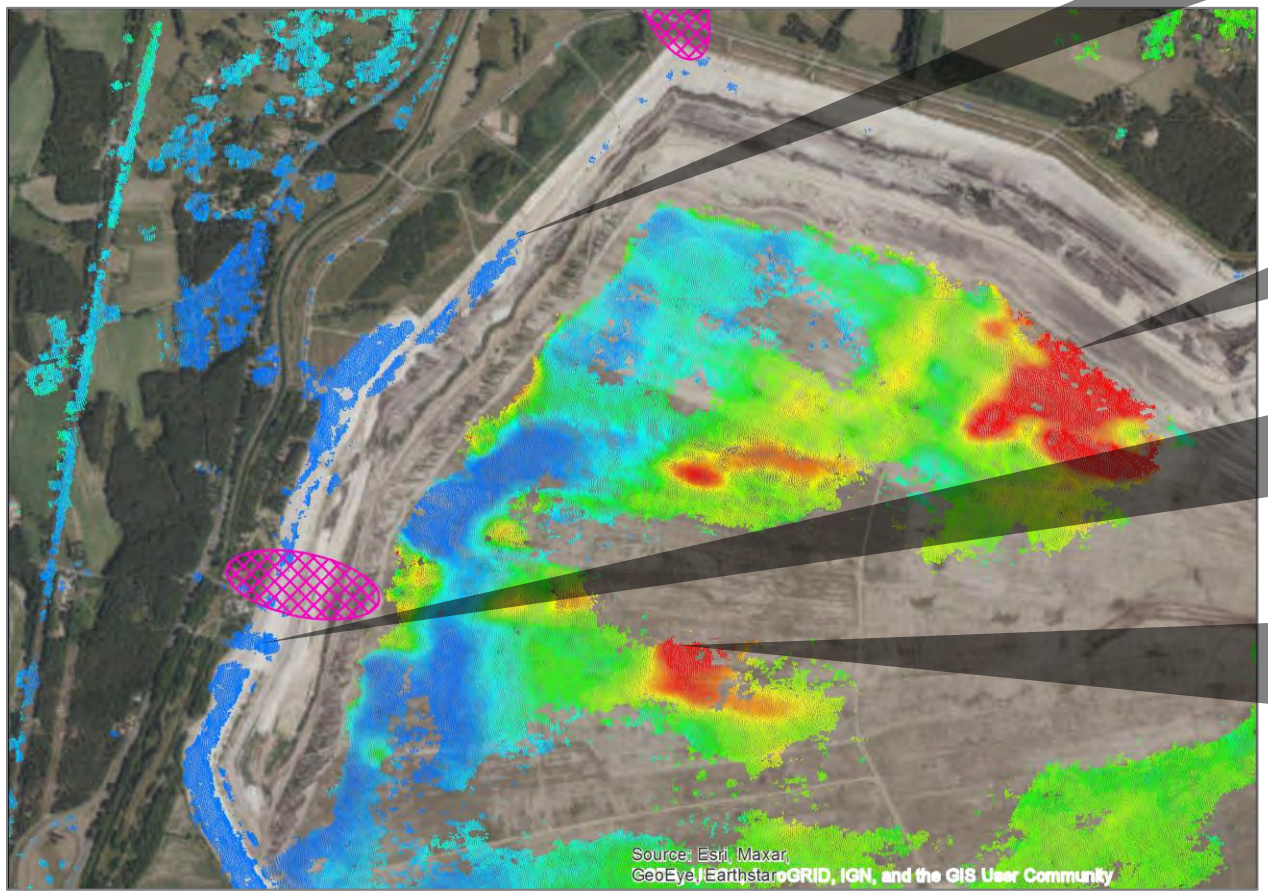


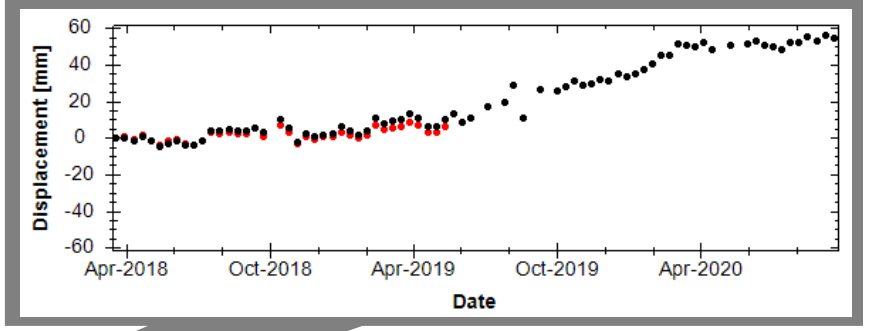
- Update Analysis: 20/03/2018 – 18/09/2020
  → 2.5 years
- 77 Scenes, SBAS Method applied

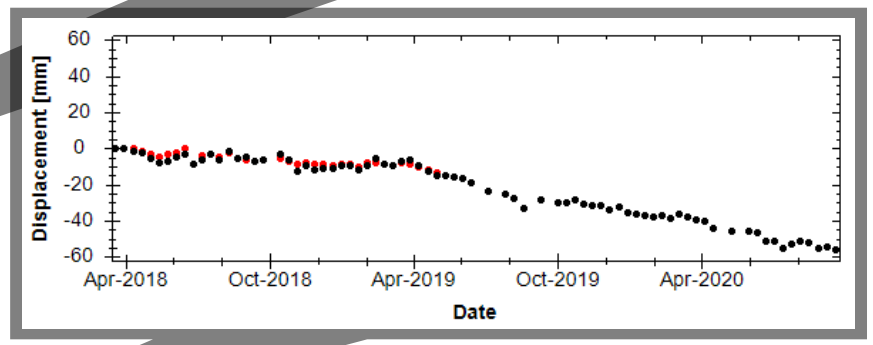
AIRBUS

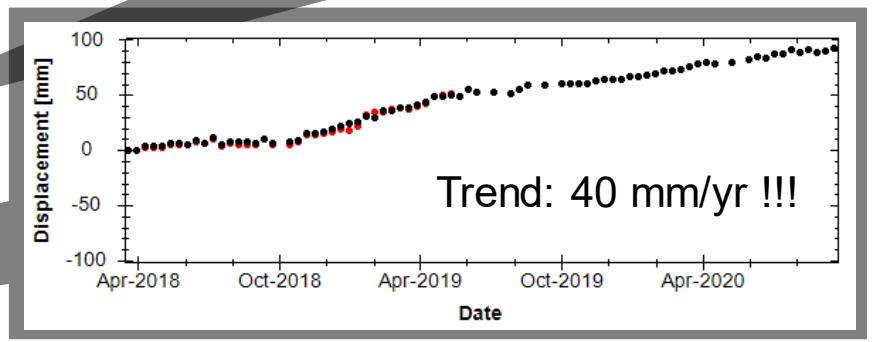
Test site Cottbus-Nord – North Restricted Area

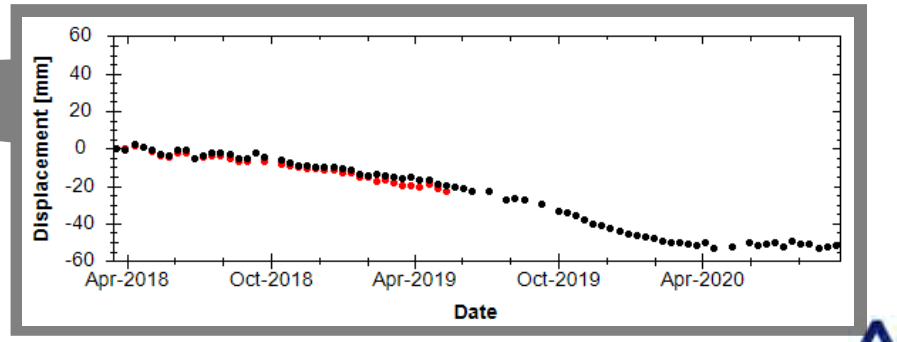
- Inlet Structure and Outlet Structure (in construction)
  → Note: The outlet structure will be built before the end of the flooding process!!!







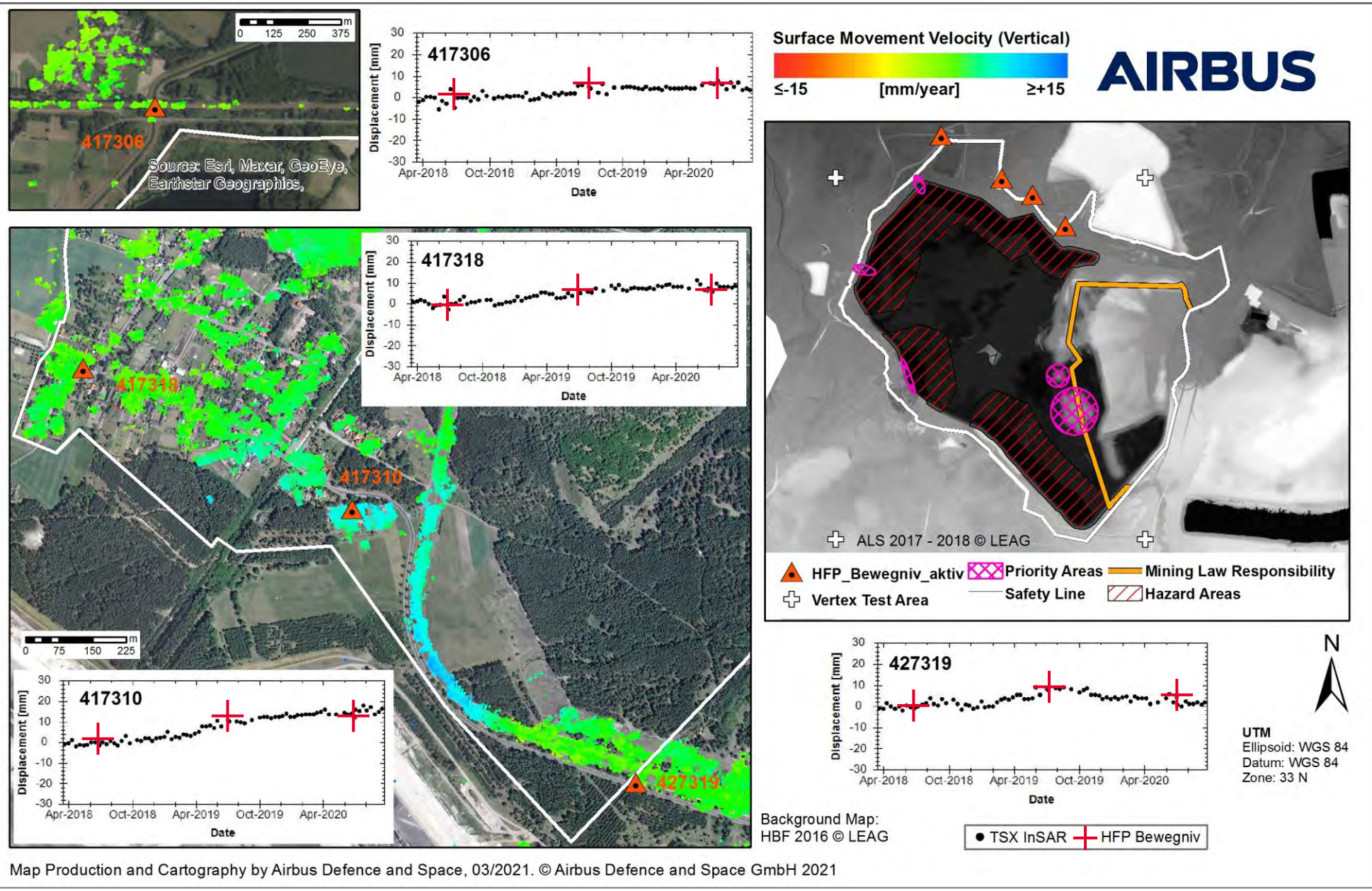




AIRBUS

TerraSAR-X vs. Levelling

- HFP Bewegungs-nivellement Jänschwalde/Cottbus
- North-West
- Mean RMSE: **1,06 mm**

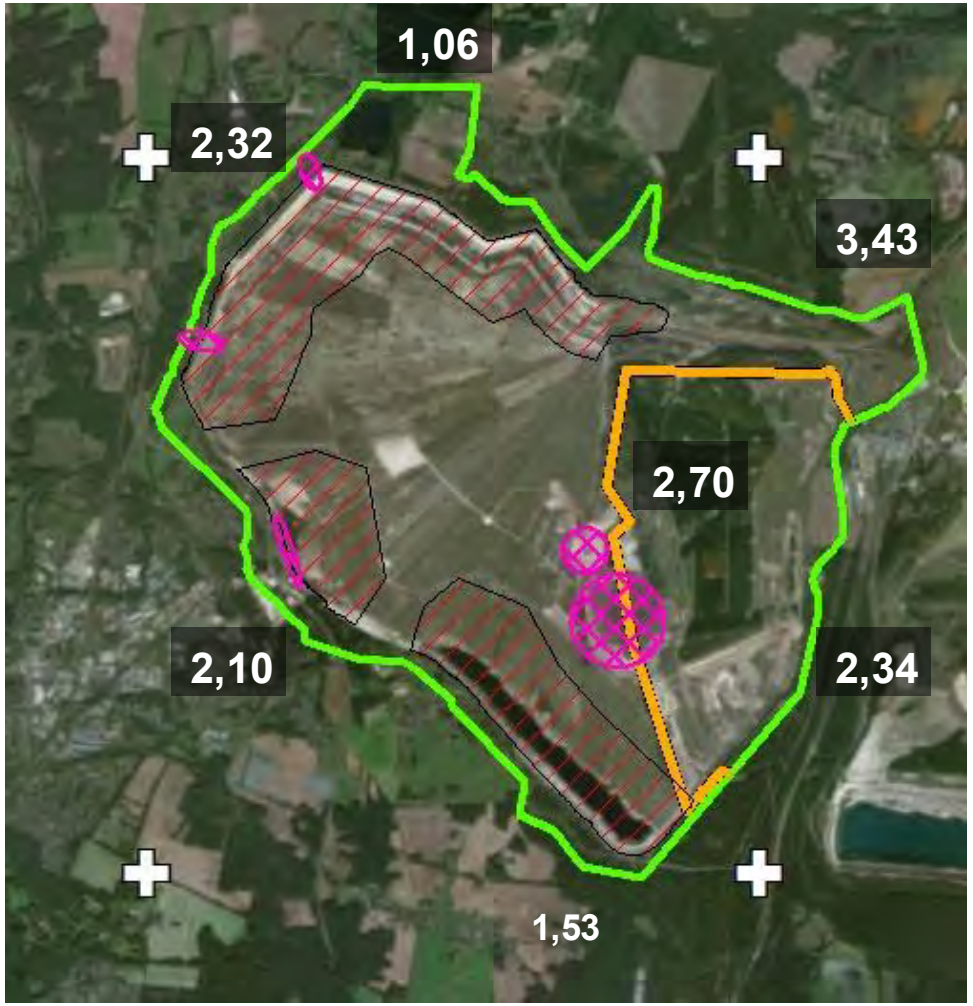


AIRBUS

TerraSAR-X vs. Levelling

- Several locations were investigated for validation
- Overall Mean RMSE: 2,3 mm

	Mean RMSE
Leitniv	2,32
Verbniv	2,34
Kippenniv	2,70
Bewegniv (NW)	1,06
Bewegniv (NE)	3,43
Bewegniv (SW)	2,10
Bewegniv (SE)	1,53

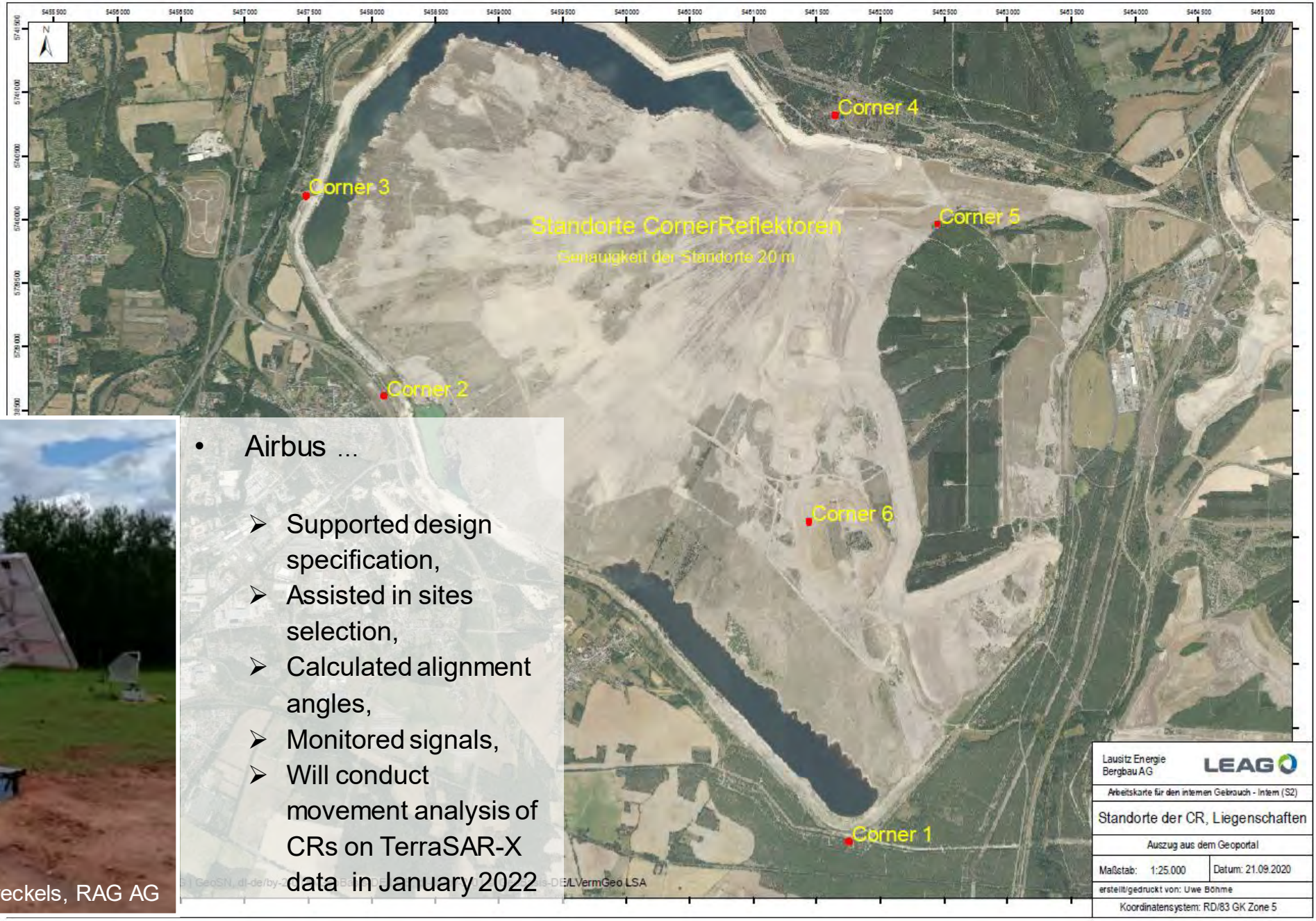


AIRBUS

Corner Reflectors

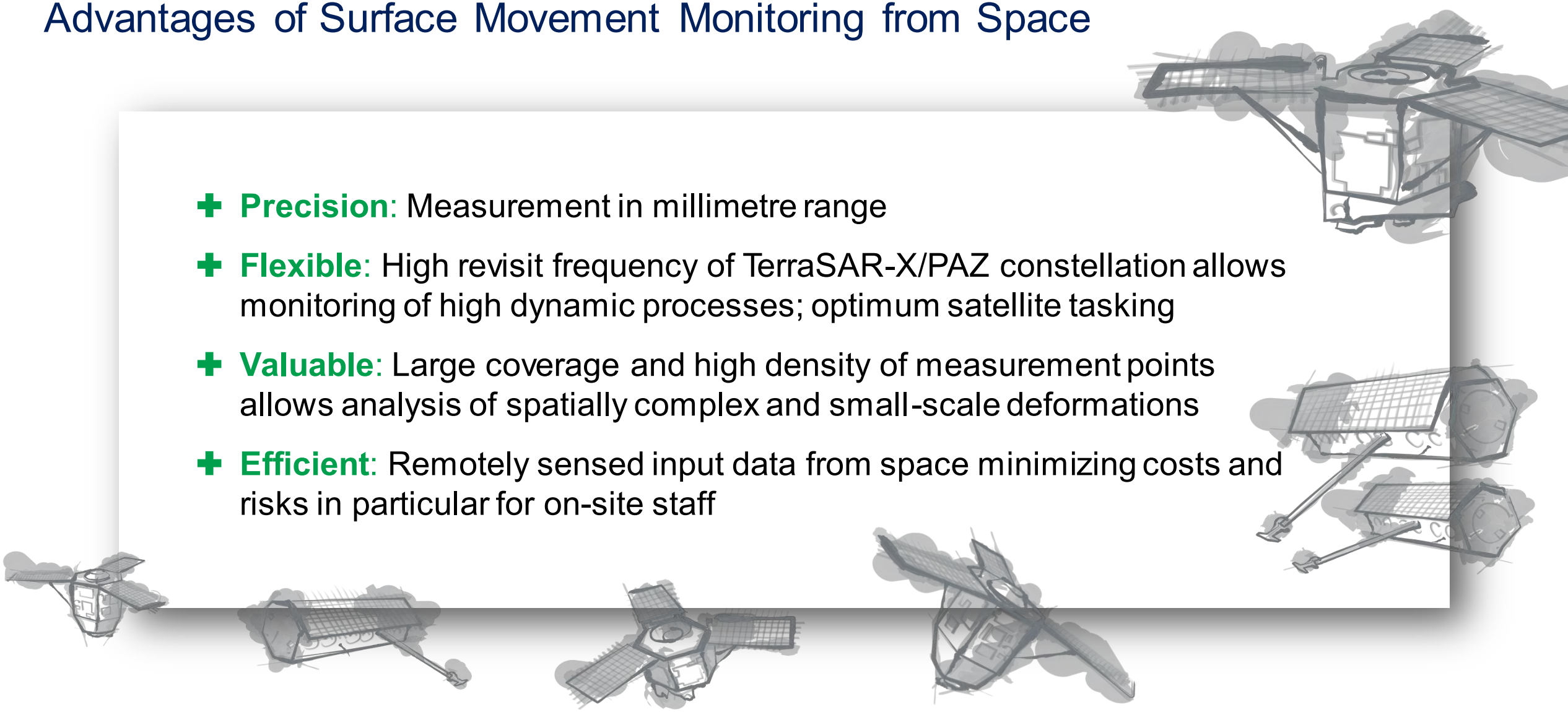
- Nov. 2020: Detailed planning of the installation locations
- CR design by RAG AG, CR construction by LEAG AG
- Dec. 2020 – Jun. 2021: CR installation

- Airbus …
  - ➢ Supported design specification,
  - ➢ Assisted in sites selection,
  - ➢ Calculated alignment angles,
  - ➢ Monitored signals,
  - ➢ Will conduct movement analysis of CRs on TerraSAR-X data in January 2022



Advantages of Surface Movement Monitoring from Space

- **Precision**: Measurement in millimetre range
- **Flexible**: High revisit frequency of TerraSAR-X/PAZ constellation allows monitoring of high dynamic processes; optimum satellite tasking
- **Valuable**: Large coverage and high density of measurement points allows analysis of spatially complex and small-scale deformations
- **Efficient**: Remotely sensed input data from space minimizing costs and risks in particular for on-site staff



AIRBUS

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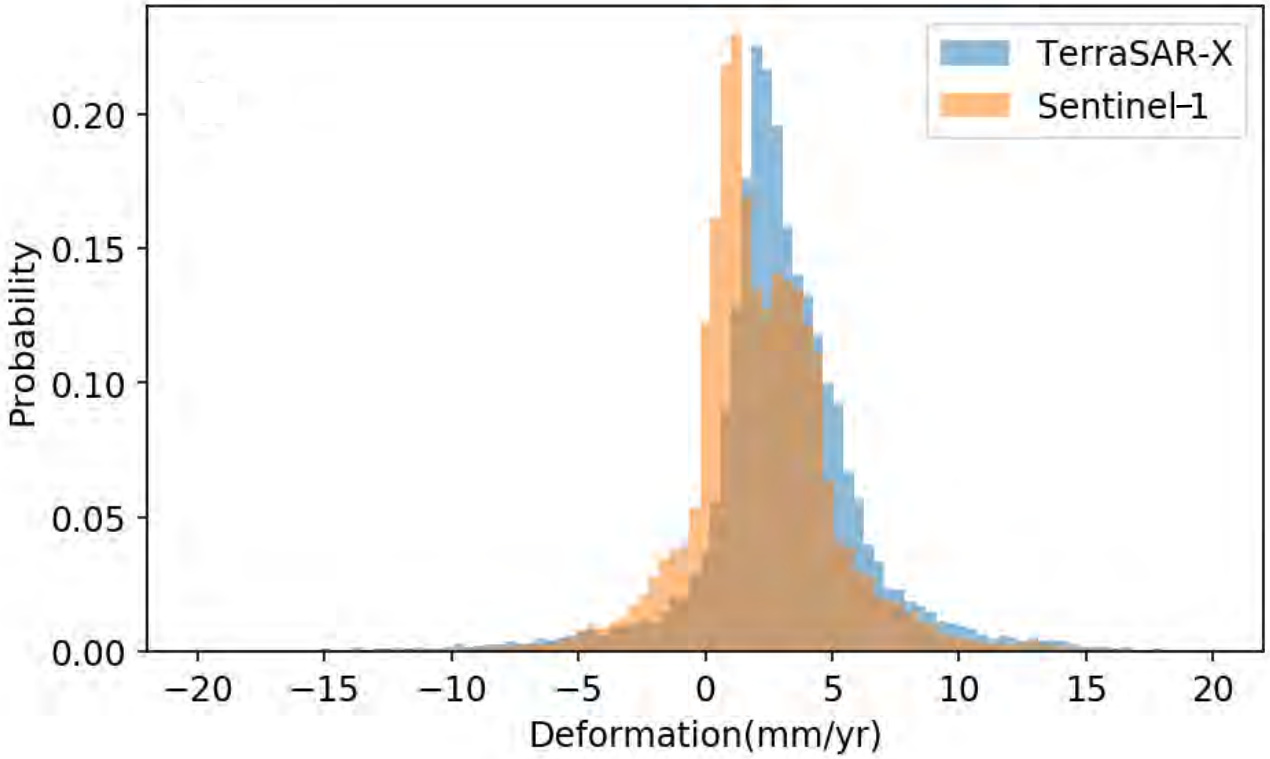
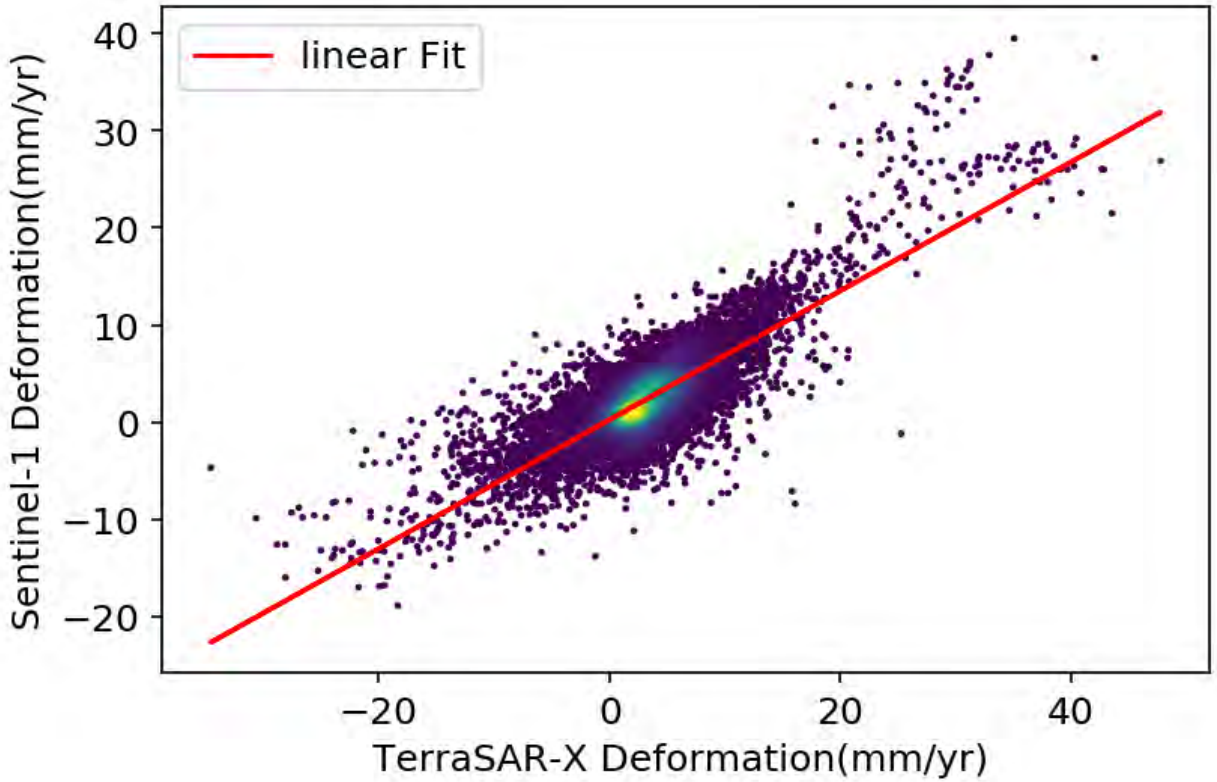
Thank you

AIRBUS

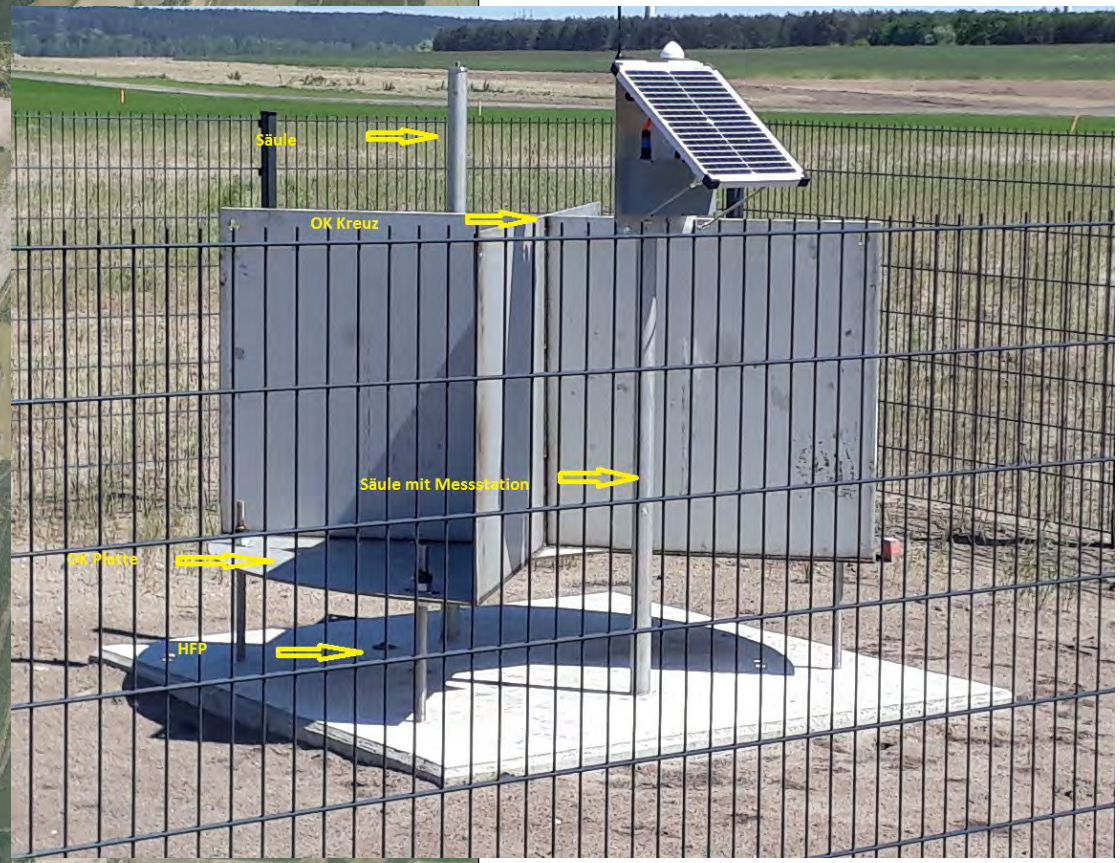
Comparison between Sentinel-1 and TerraSAR-X

	Sentinel-1	TerraSAR-X
Wavelength	~ 5.55 cm	~ 3.11 cm
Polarization	VV	HH
Orbit	Ascending	Ascending
Time Span	17.03.2018 – 17.05.2019	20.03.2018 – 12.05.2019
Ground Size	~ 4.2 m × 13.9 m	~ 3 m × 3 m
Repeat Cycle	6 days	11 days
Number of Scenes	71	36
Resampled Time Span	20.03.2018 – 12.05.2019	
Resampled Ground Size	~ 30 m × 30 m	

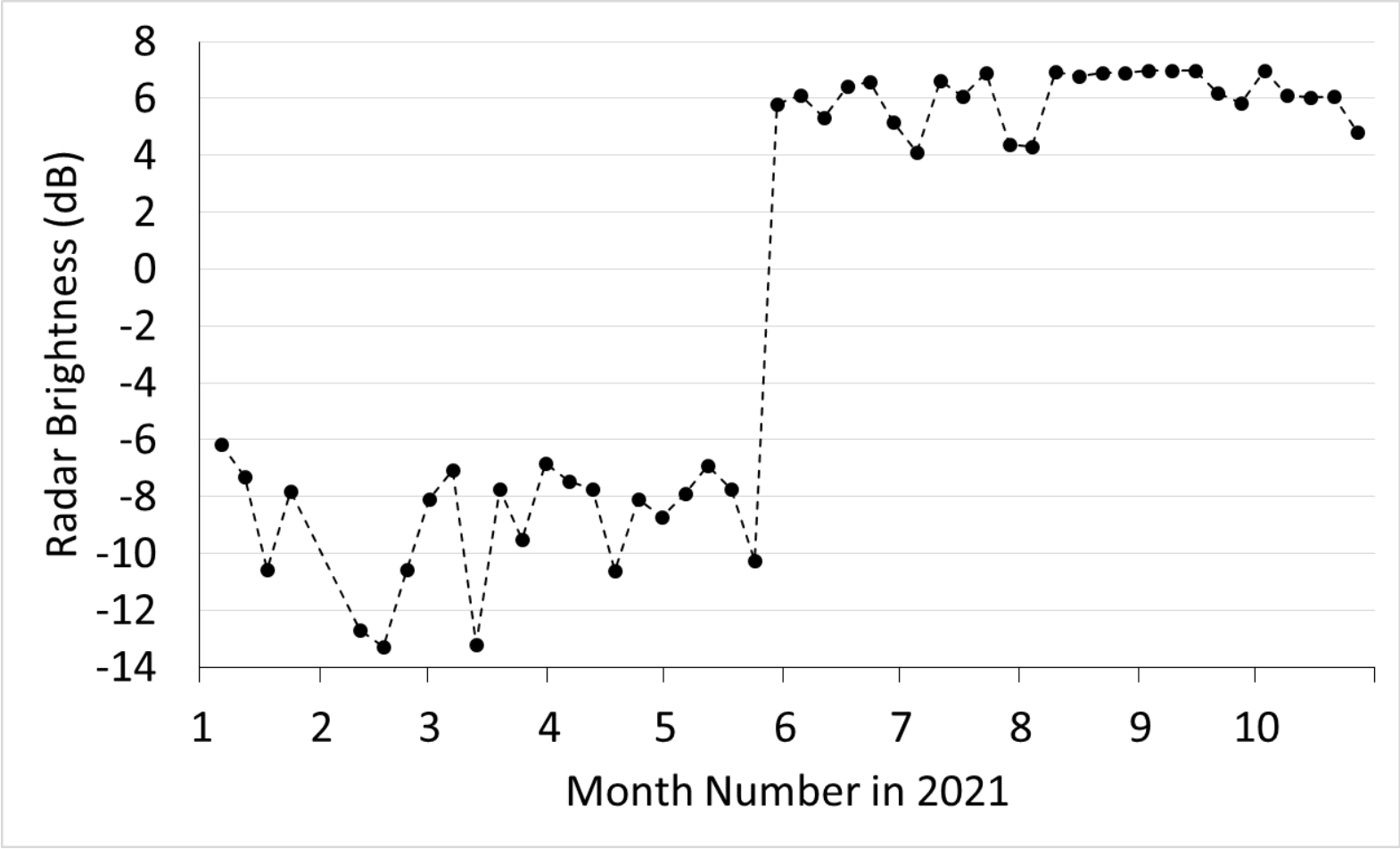

TerraSAR-X
Sentinel-1
Probability
0.00
0.05
0.10
0.15
0.20
−20
−15
−10
−5
0
5
10
15
20
Deformation(mm/yr)


linear Fit
Sentinel-1 Deformation(mm/yr)
40
30
20
10
0
−10
−20
−20
0
20
40
TerraSAR-X Deformation(mm/yr)

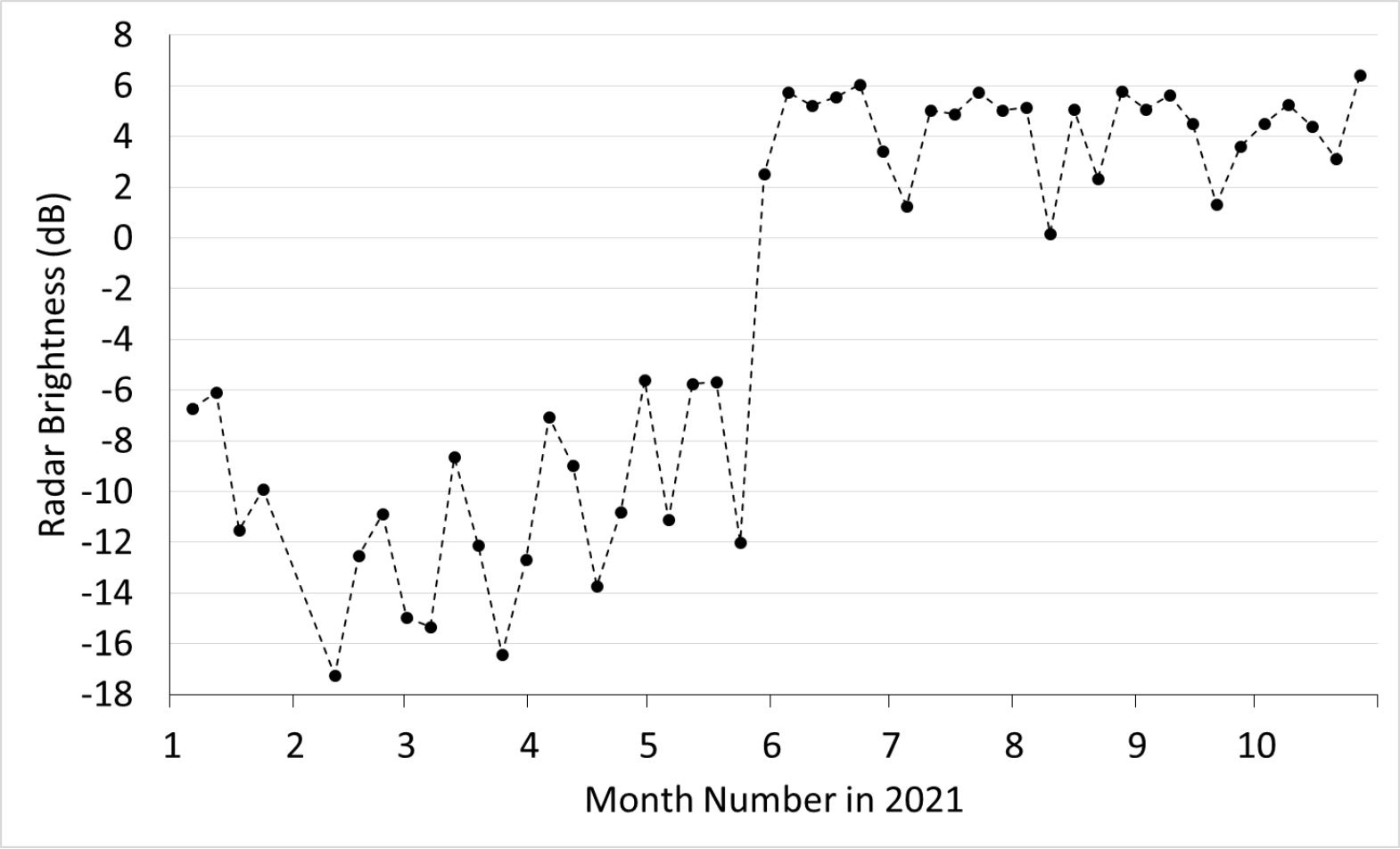
6 CRs deployed since June 2021



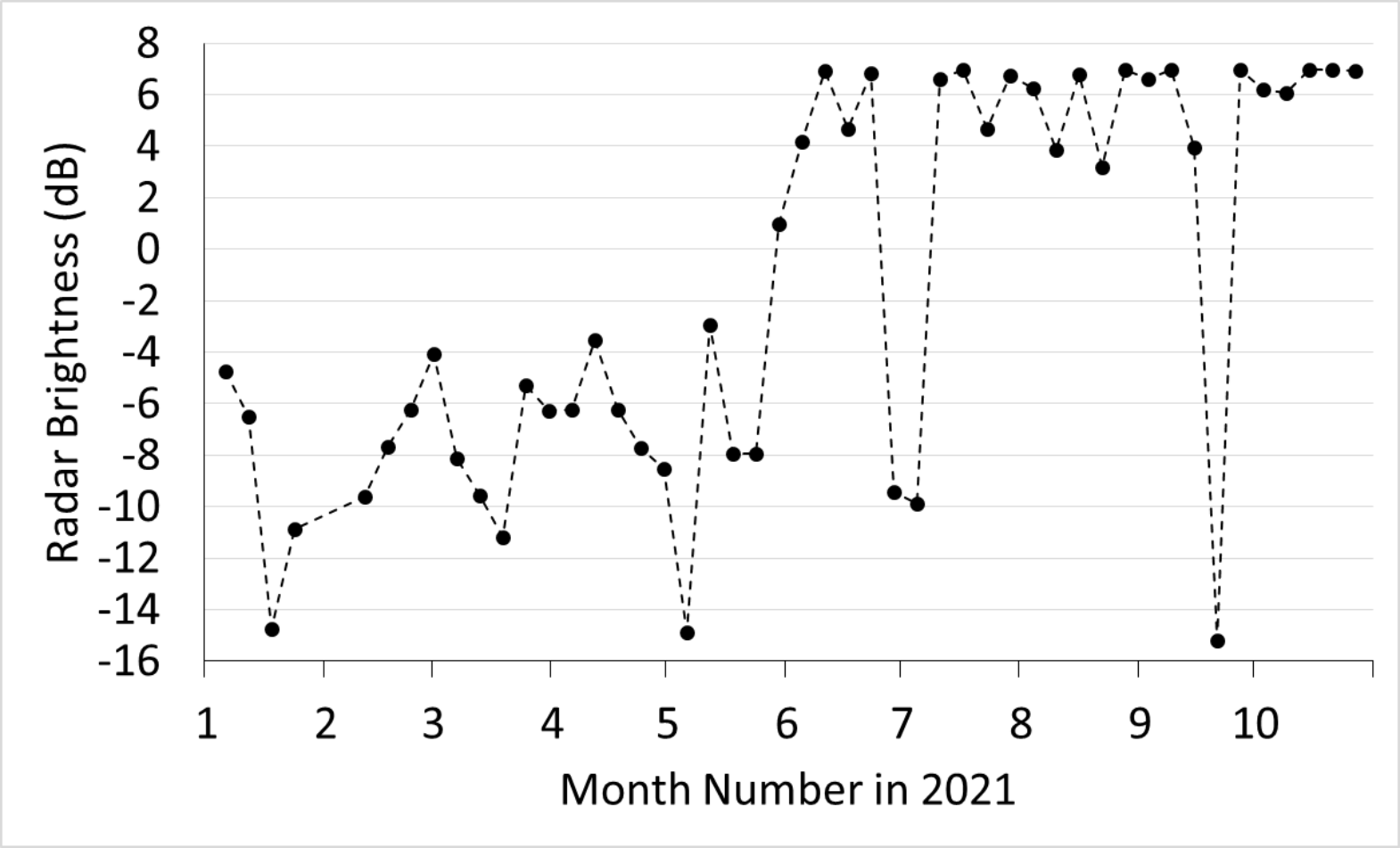
Sentinel-1 Brightness Series on CR 1



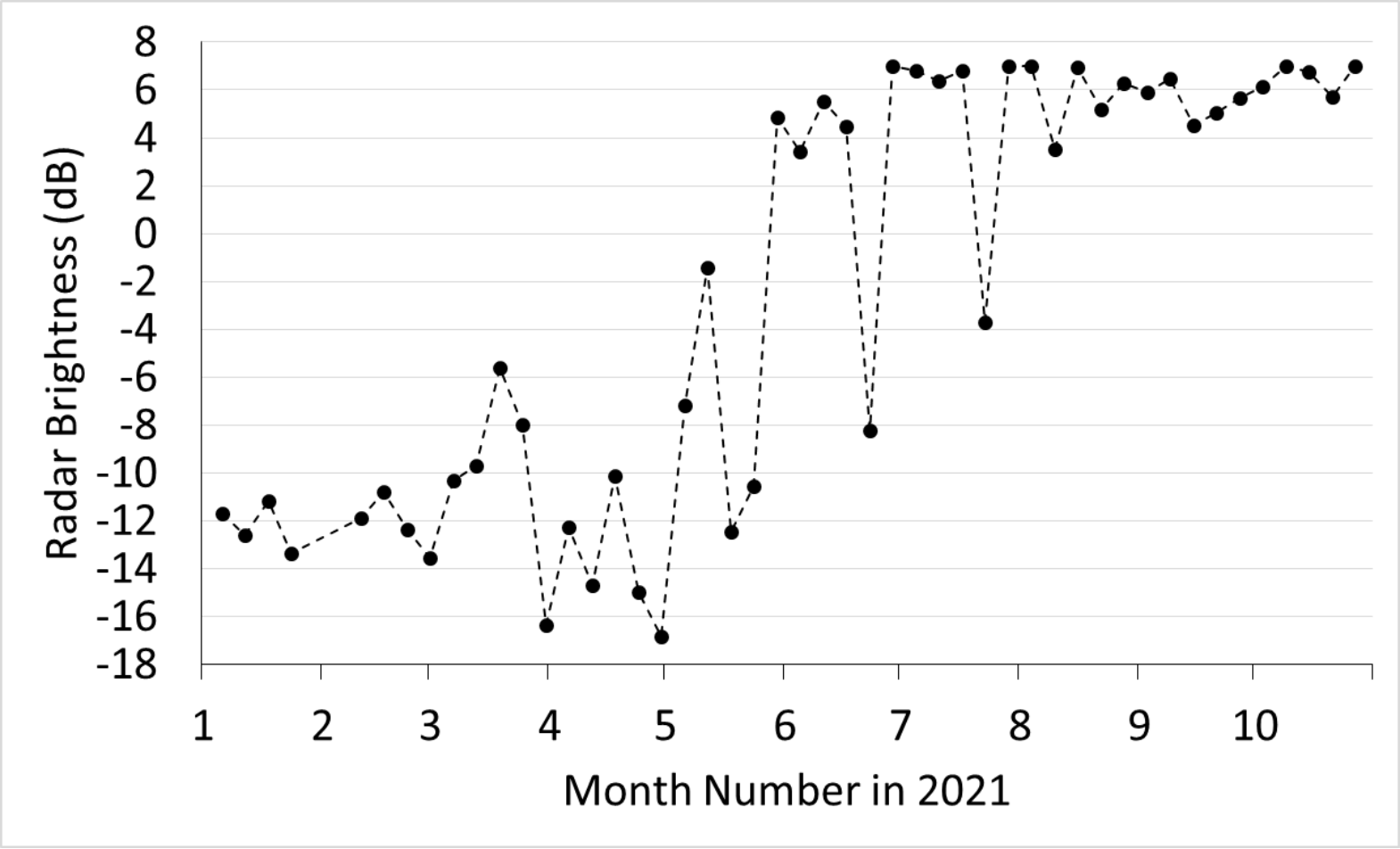
Sentinel-1 Brightness Series on CR 2



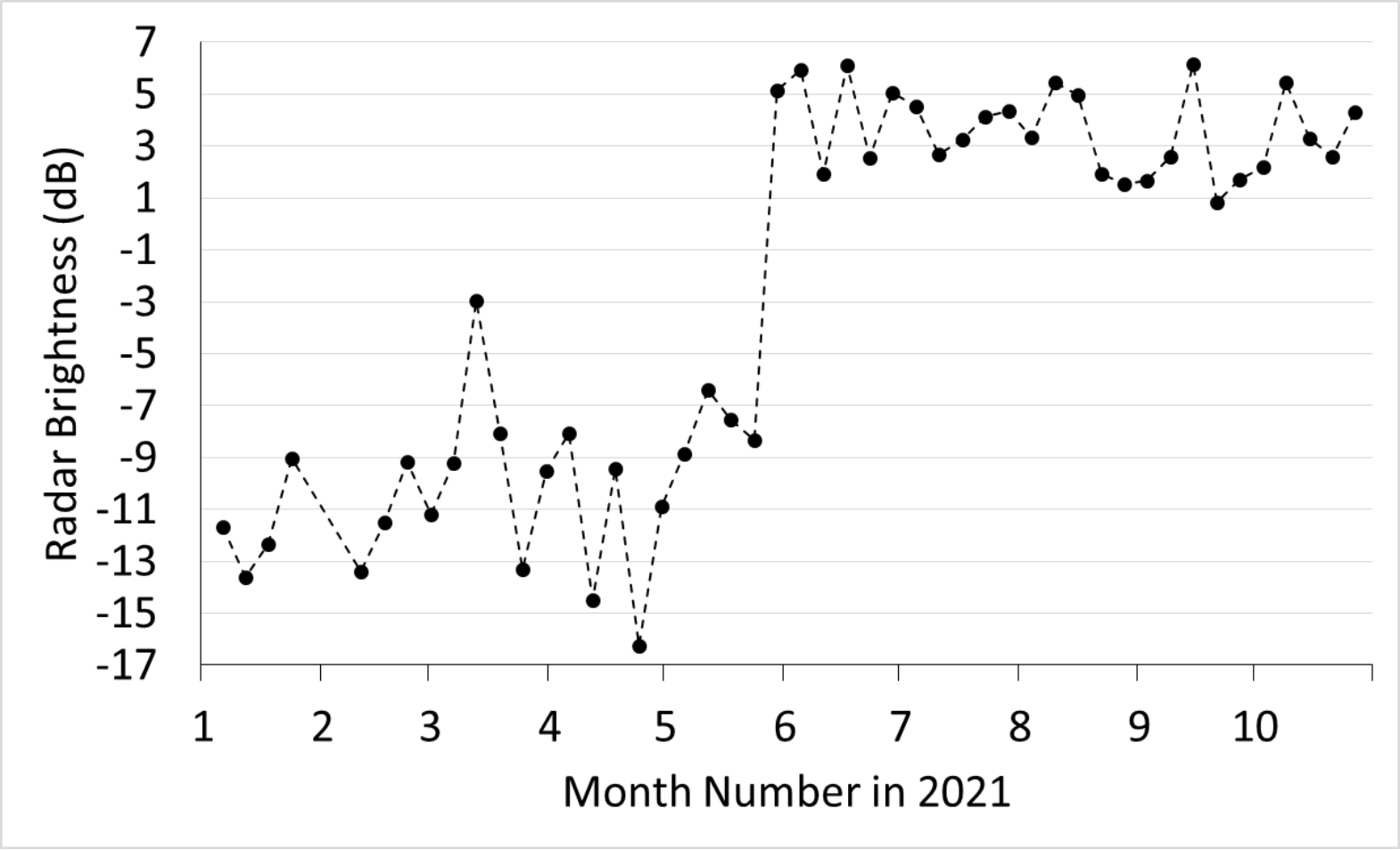
Sentinel-1 Brightness Series on CR 3



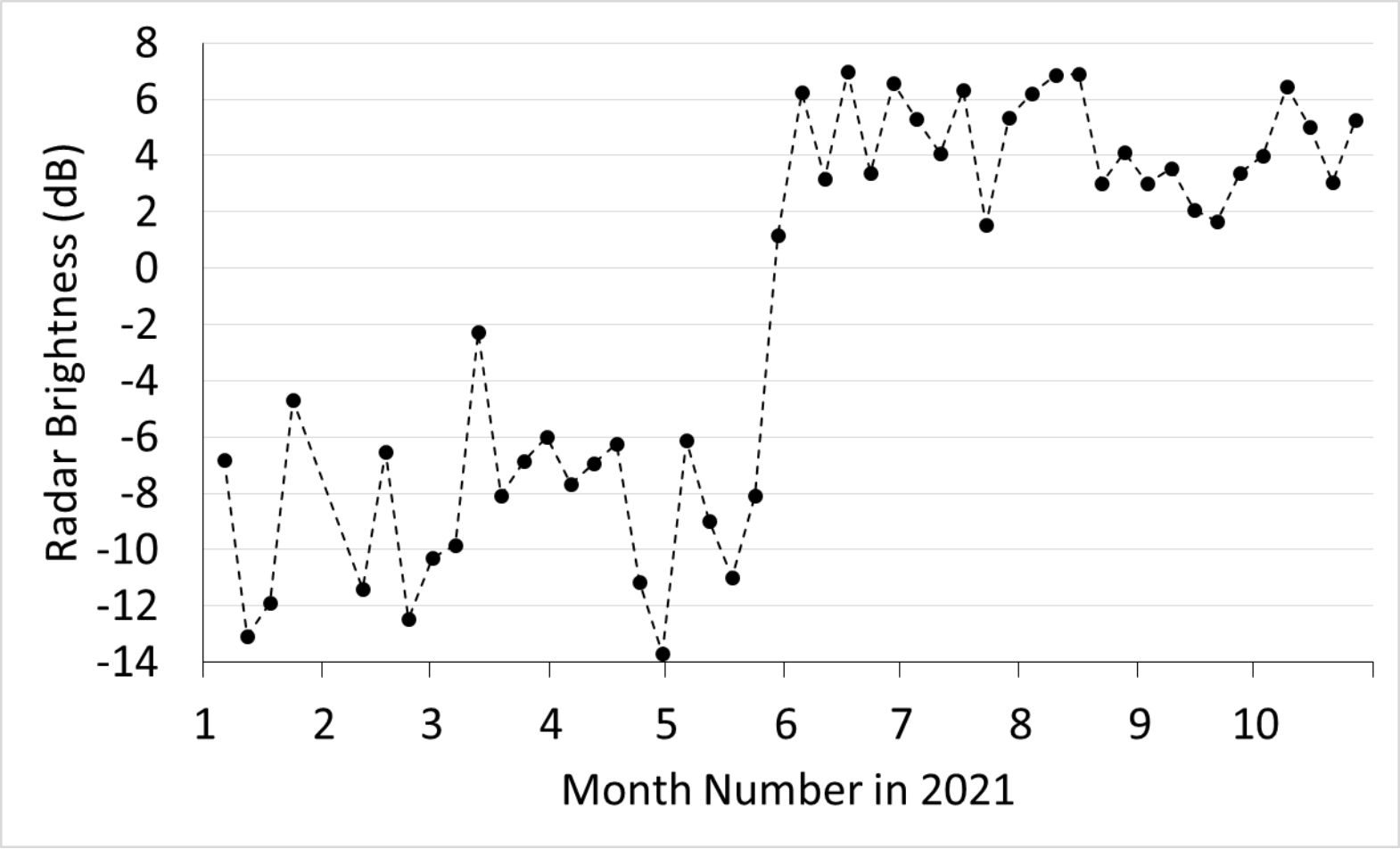
Sentinel-1 Brightness Series on CR 4



Sentinel-1 Brightness Series on CR 5



Sentinel-1 Brightness Series on CR 6



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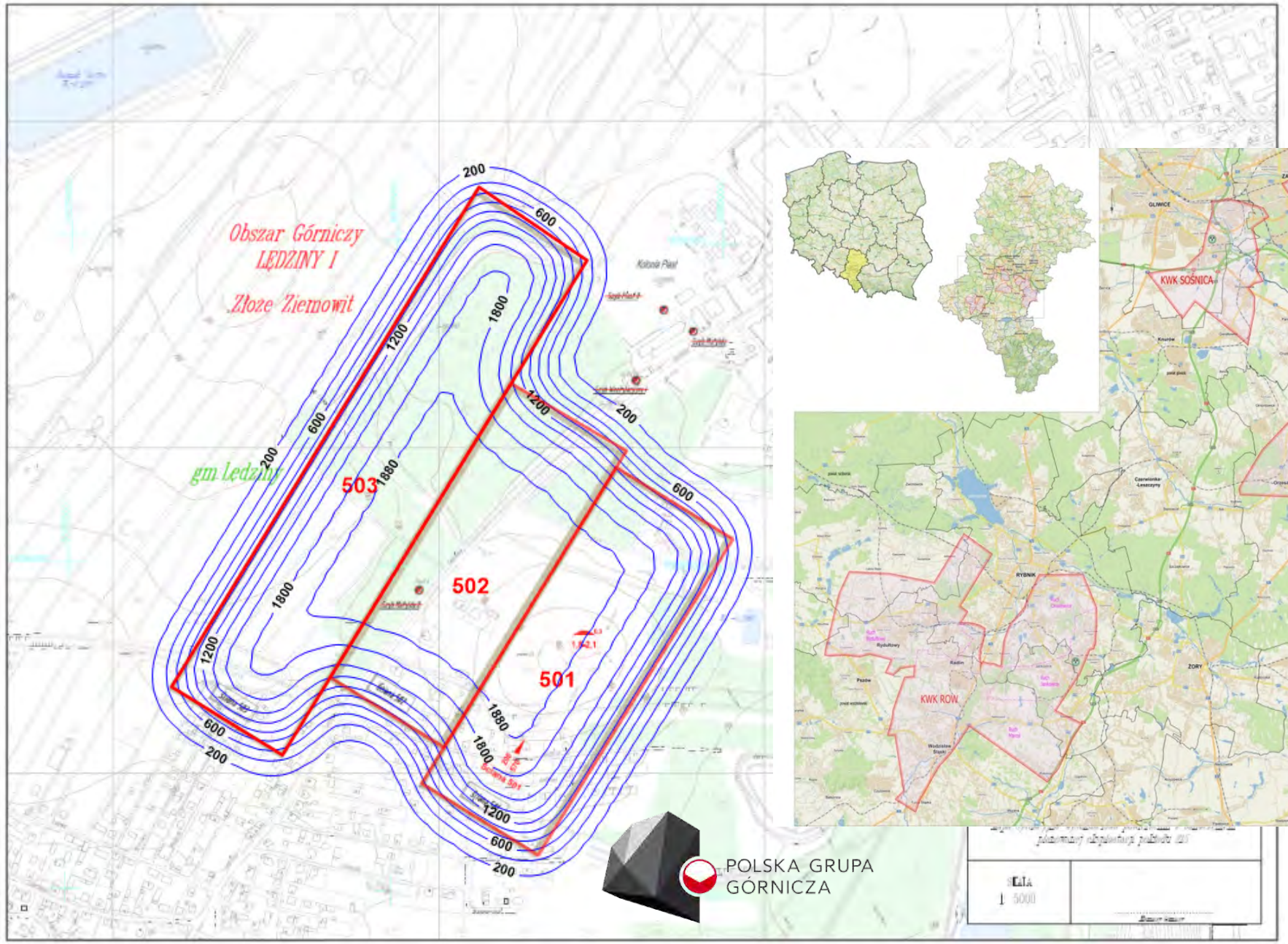
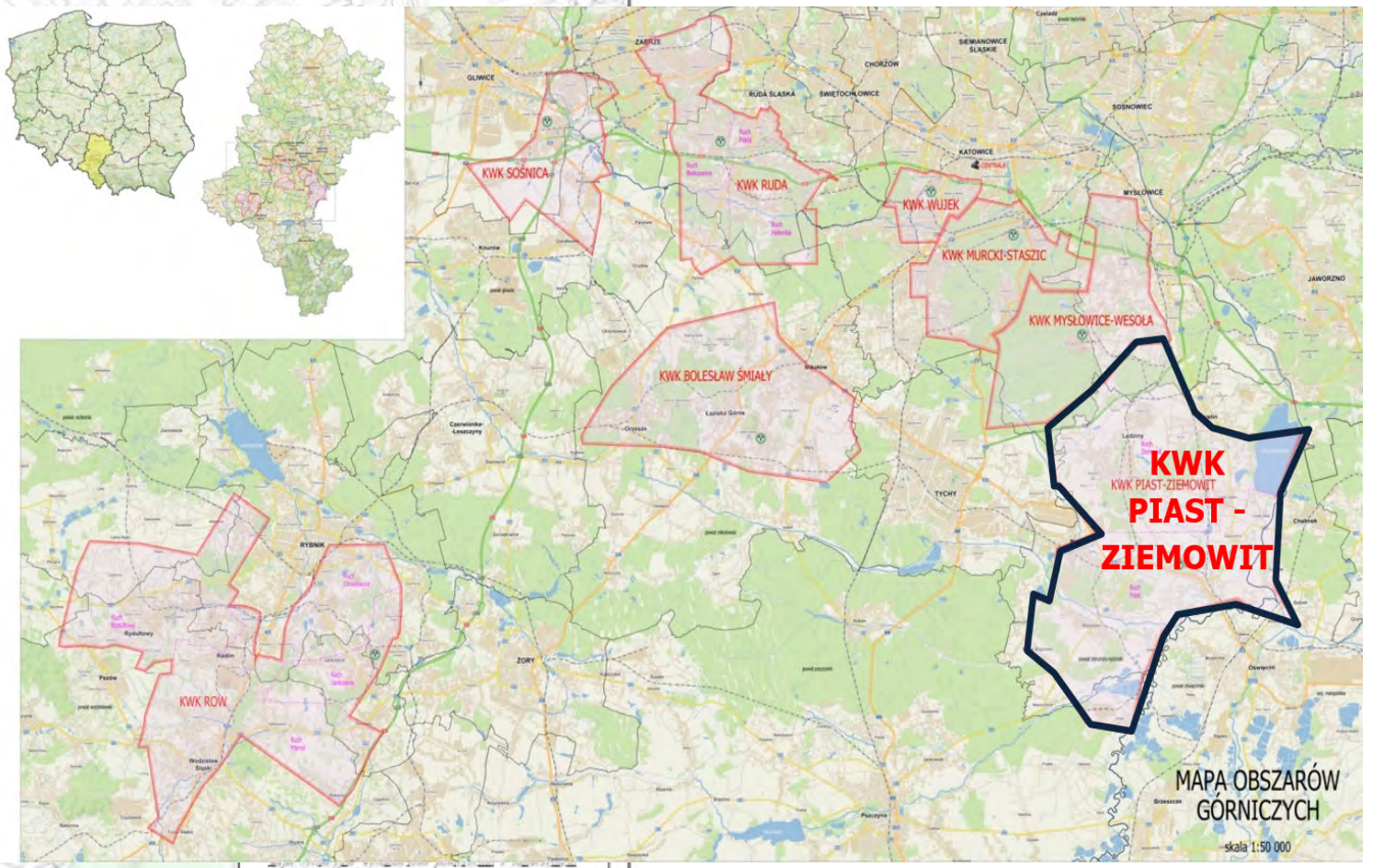
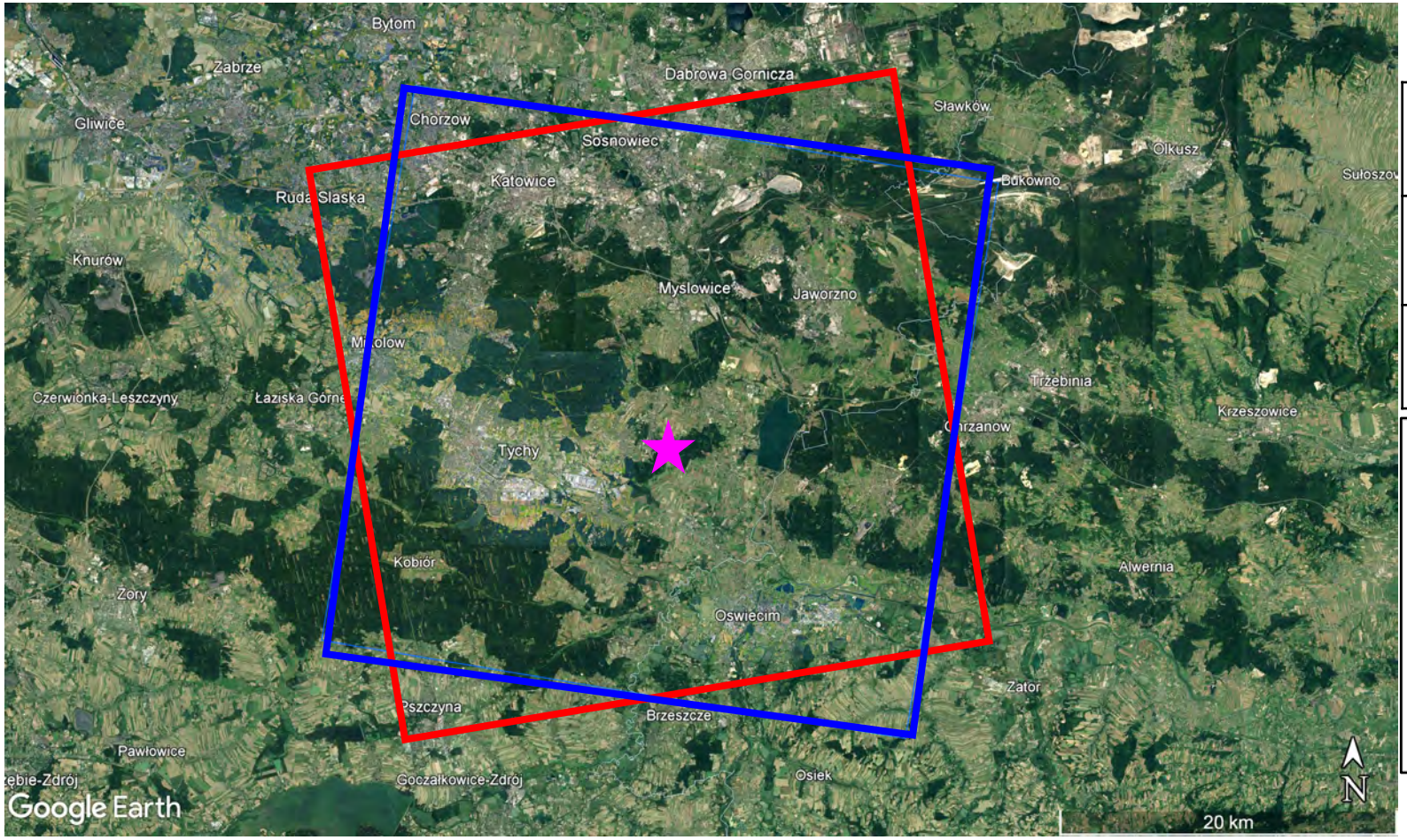
Underground Mining in Poland (PGG) since June 2021

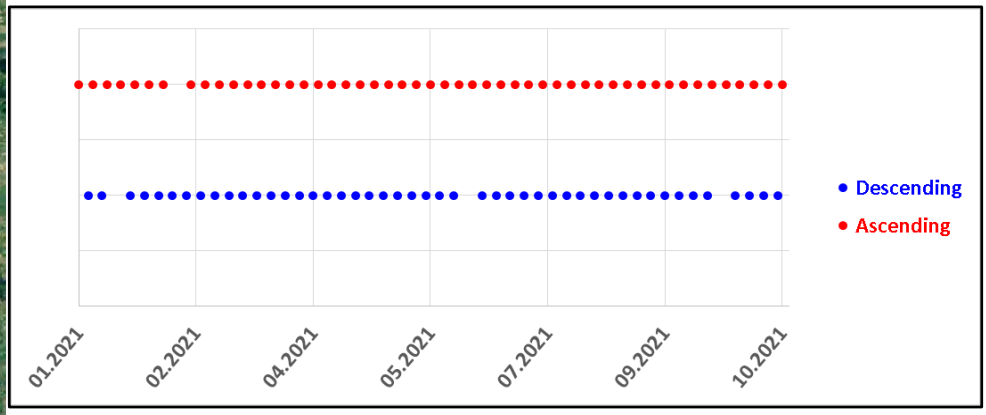




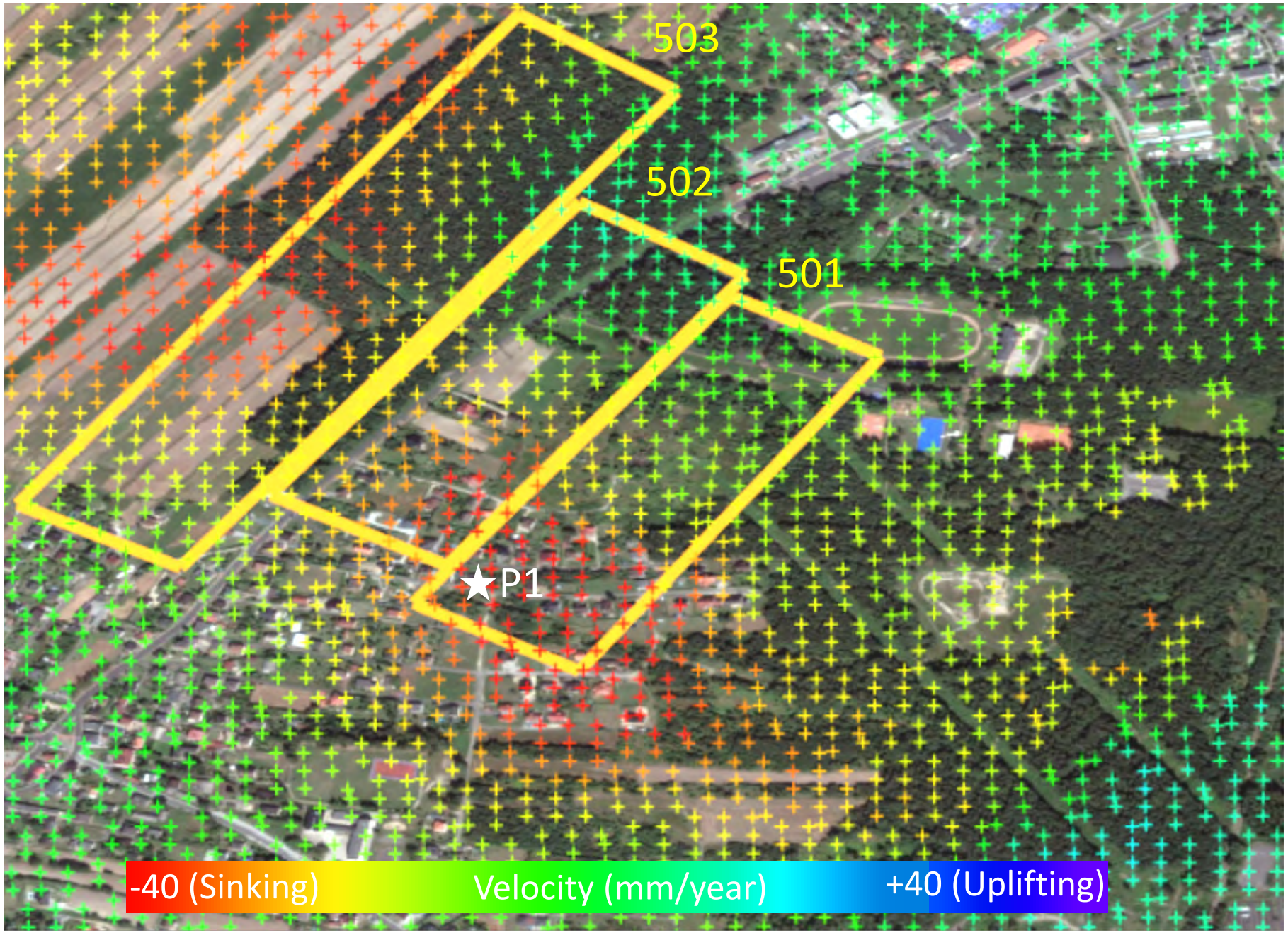
Sentinel-1 Dataset



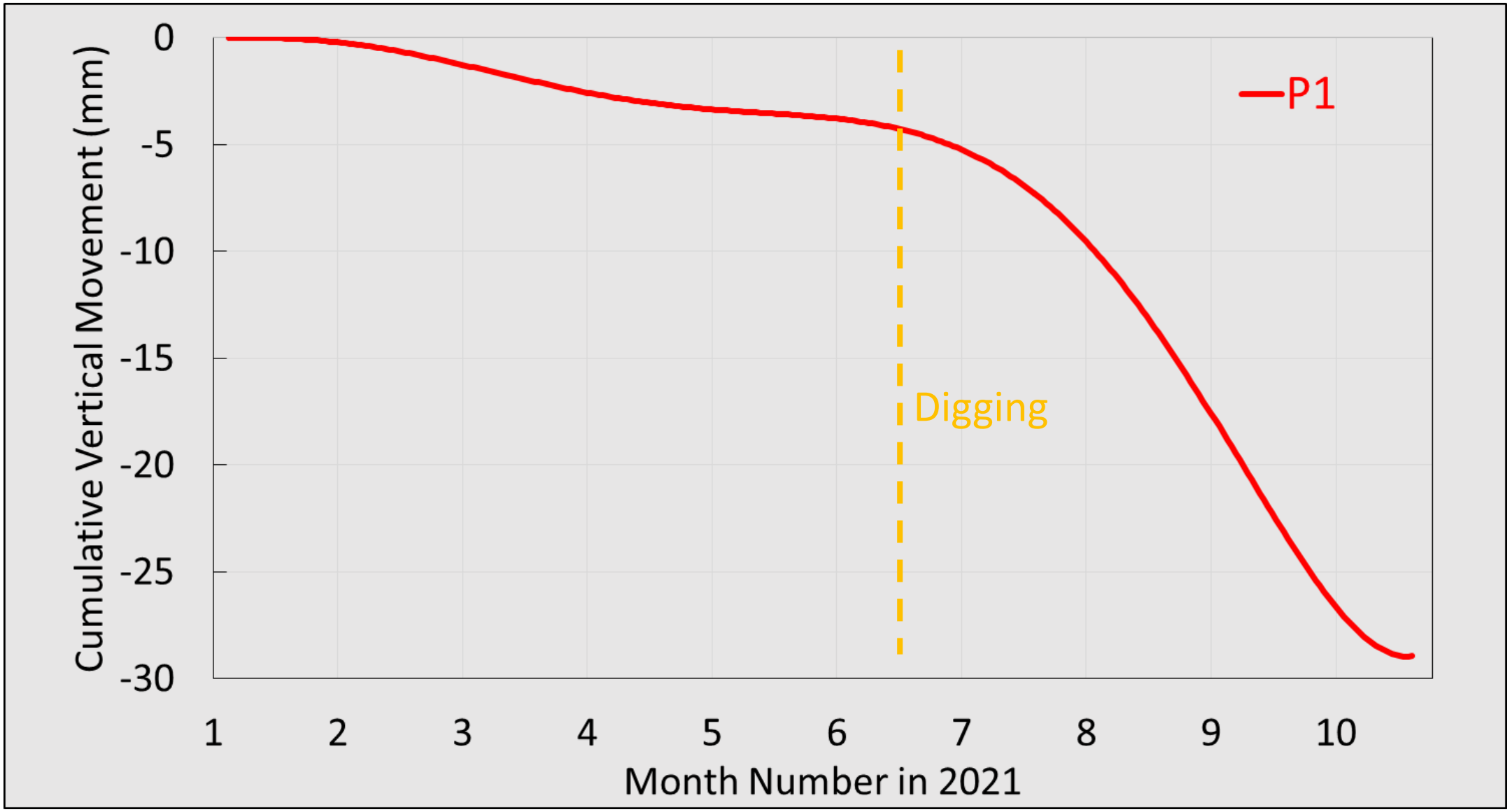
Orbit	Amount	Mode	Polarization	Resolution
Descending	50	IW	VV	5 m × 15 m
Ascending	51			



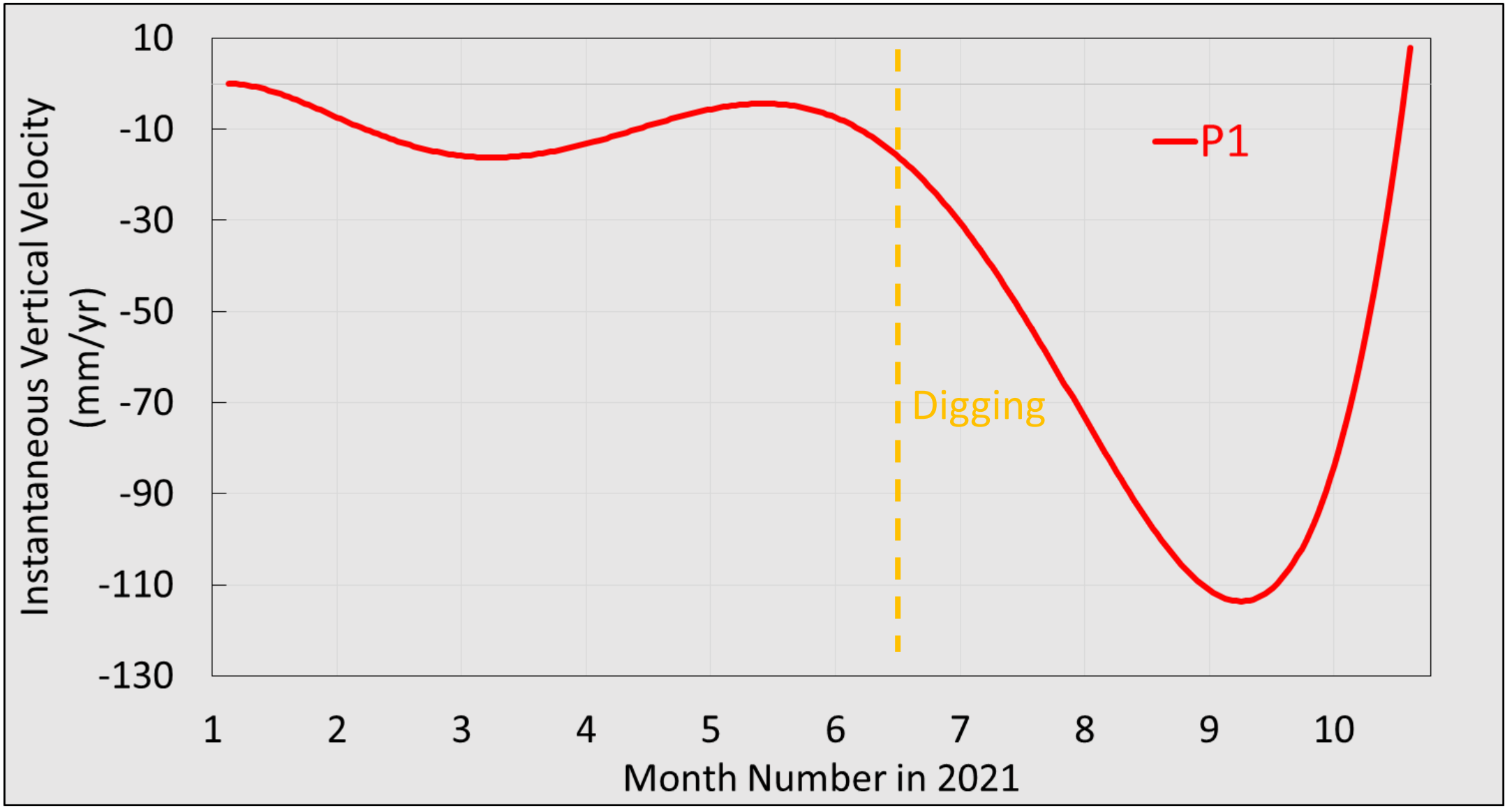
Vertical Movement



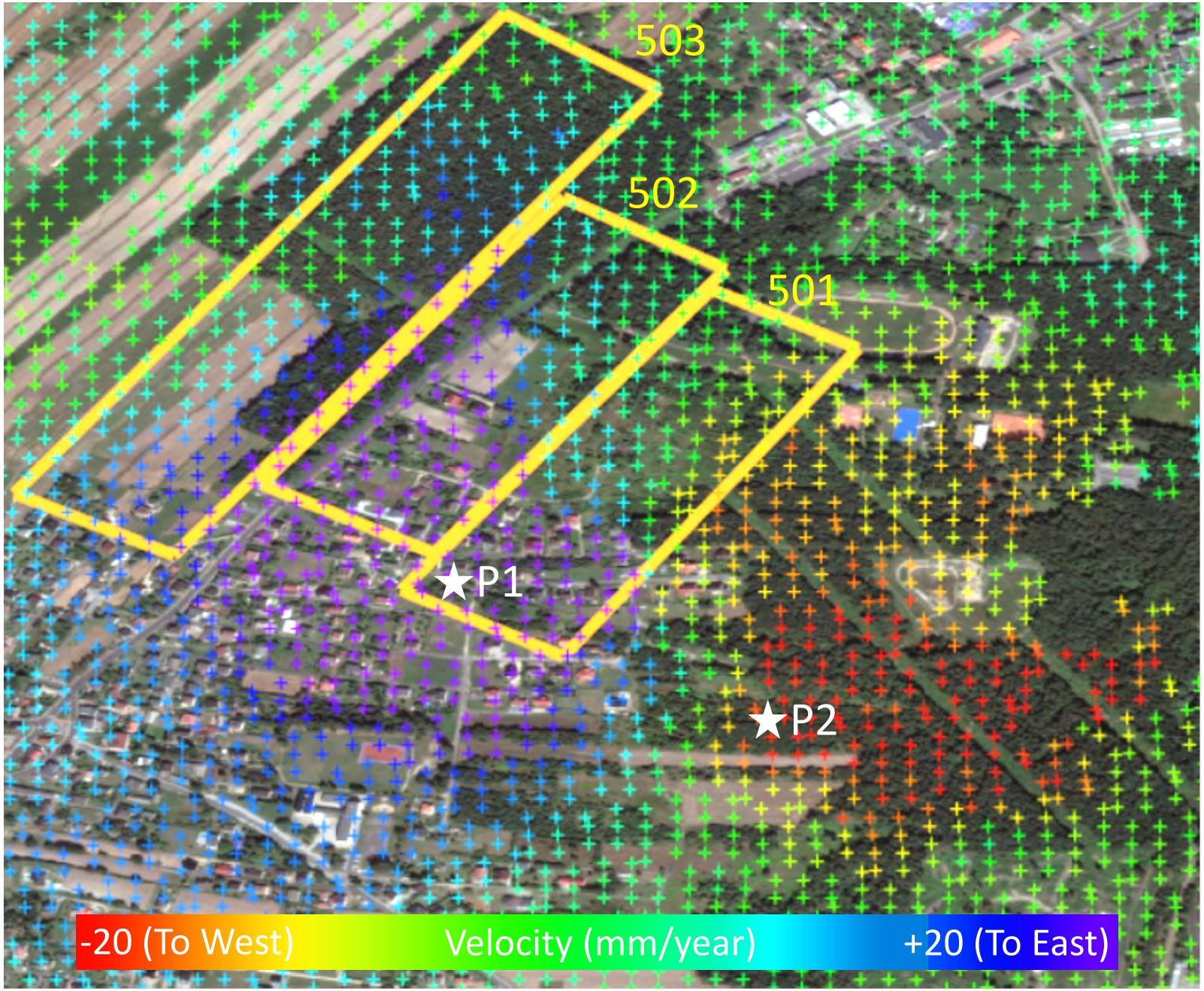
Point-based Cumulative Vertical Movement



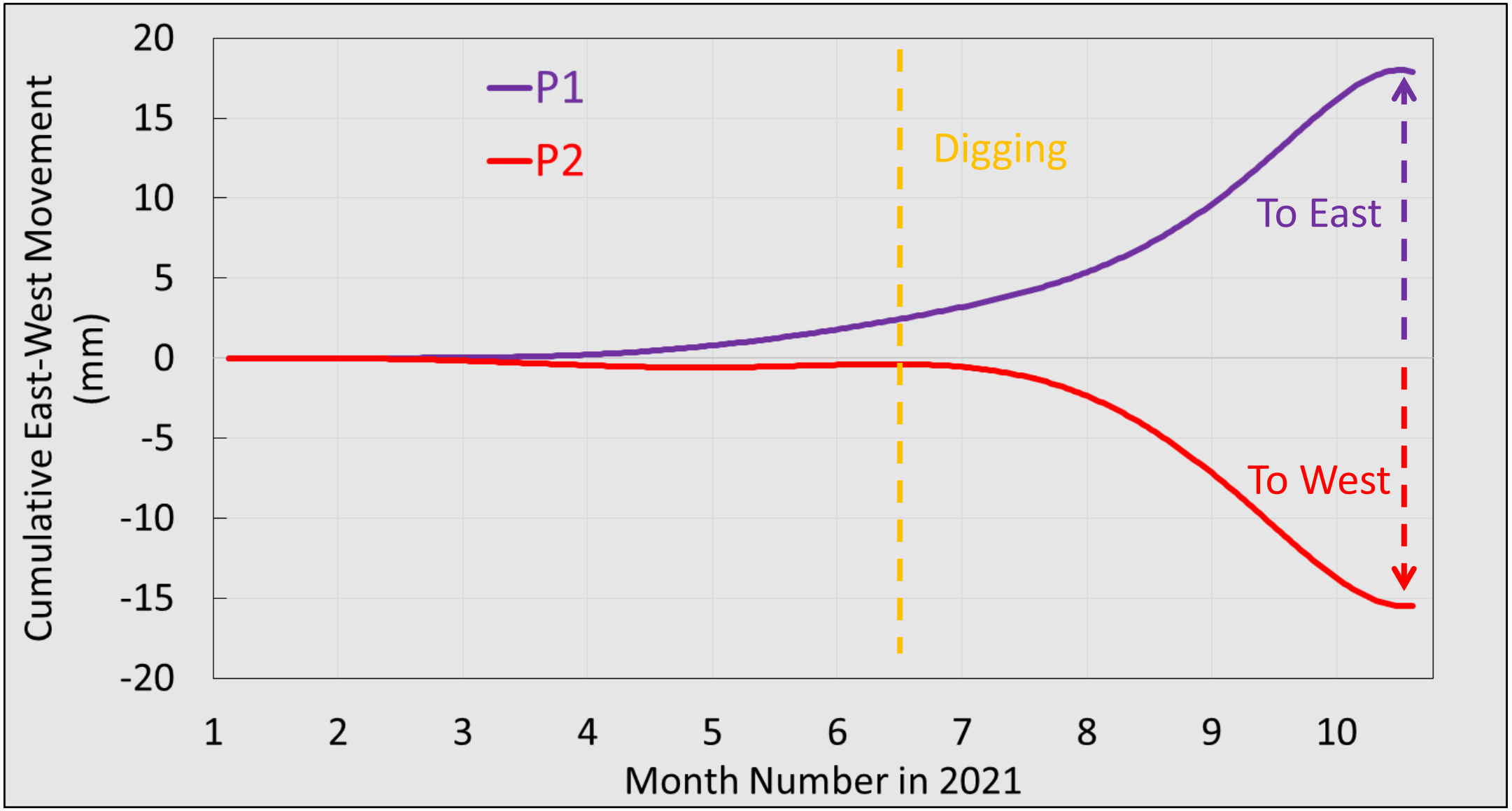
Point-based Instantaneous Vertical Velocity



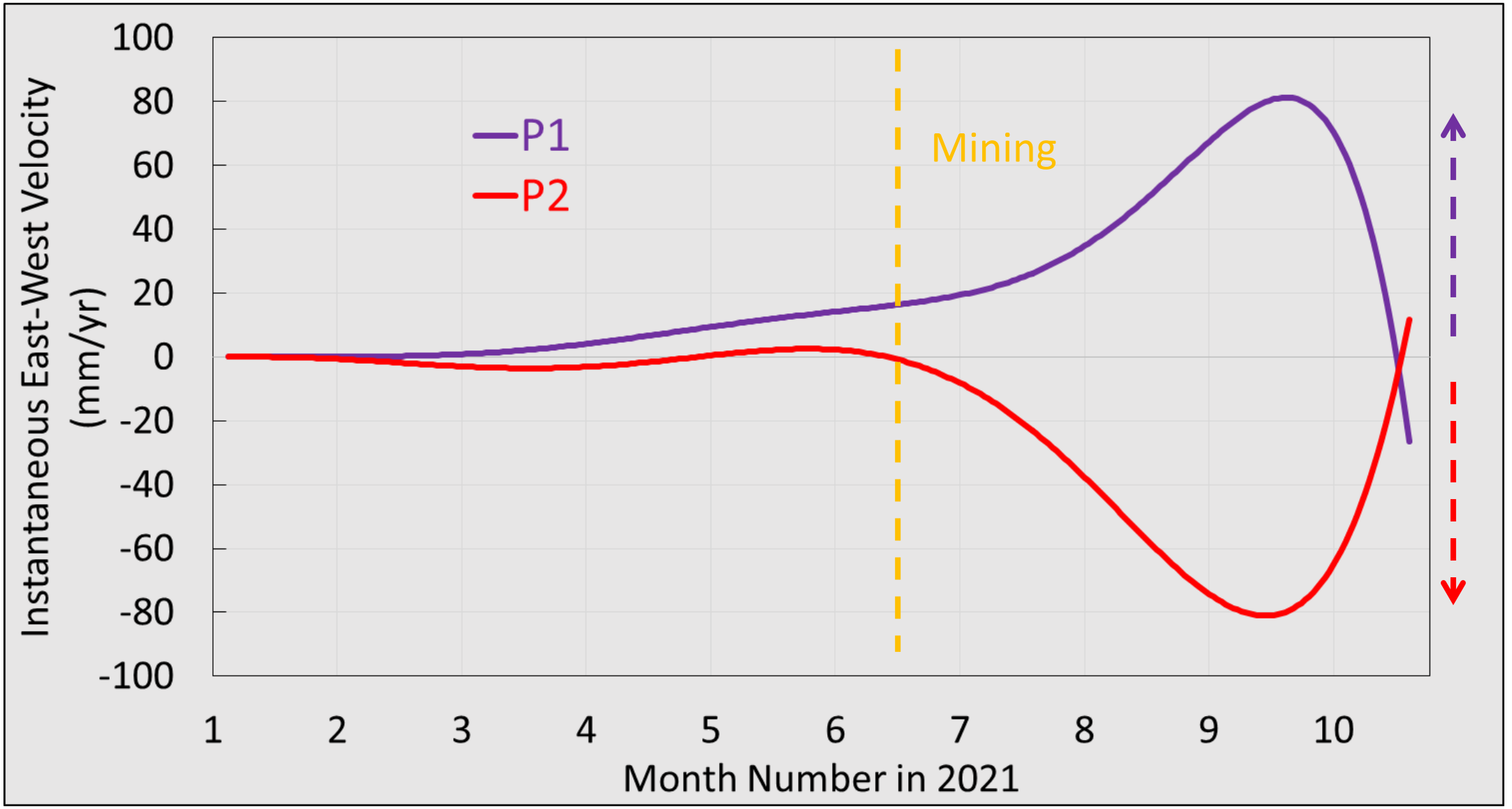
East-west Movement



Point-based Cumulative East-West Movement



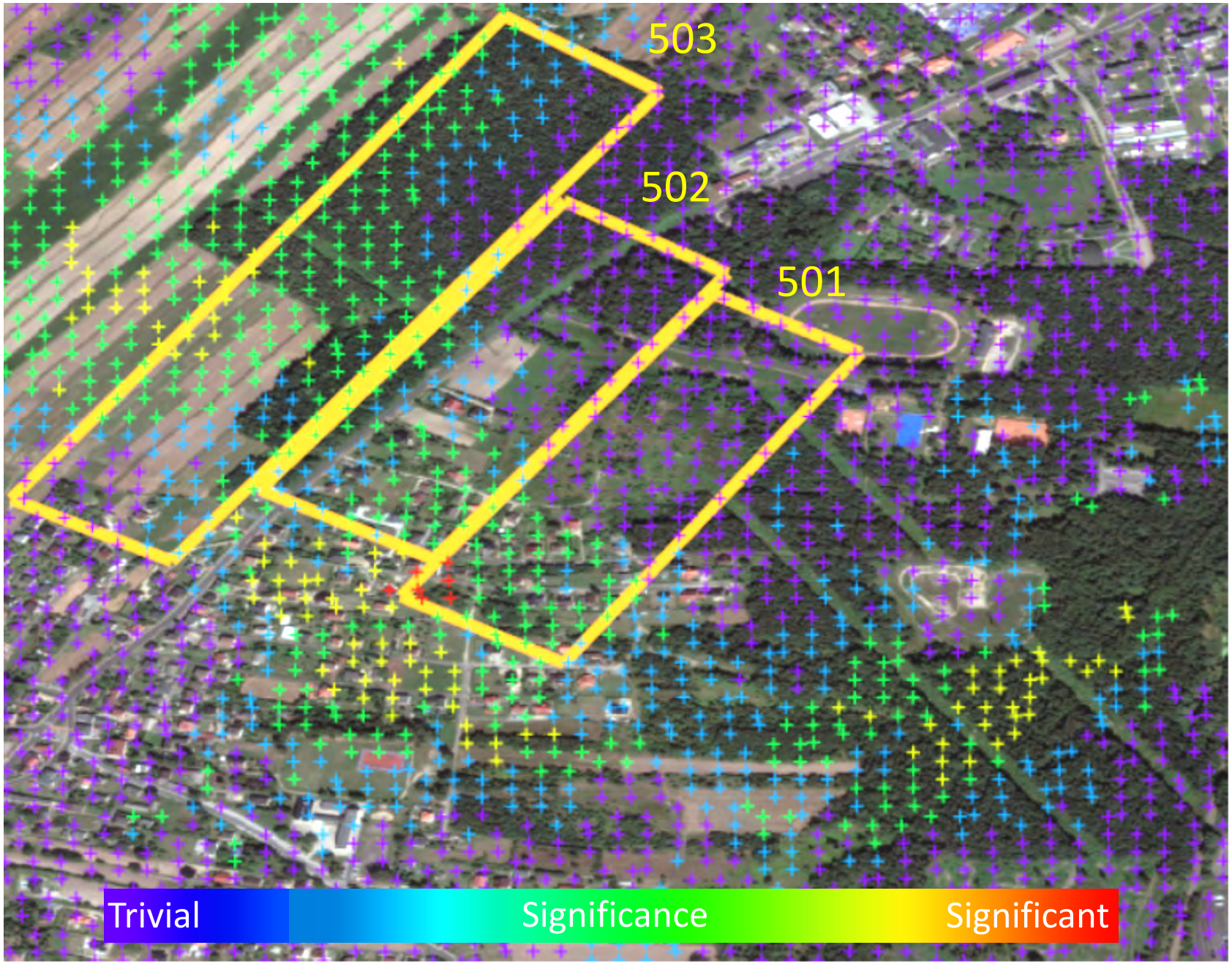
Point-based Instantaneous East-West Velocity



To East

To West

Movement Significance



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Combined Usage: Overview & Hotspot Monitoring Solution

Sentinel-1	TerraSAR-X
Costless	Commercial
Media Resolution	High Resolution
Less Sensitive to Small Movement	Sensitive to Small Movement
Repeat Cycle 6 days	Repeat Cycle 11 days