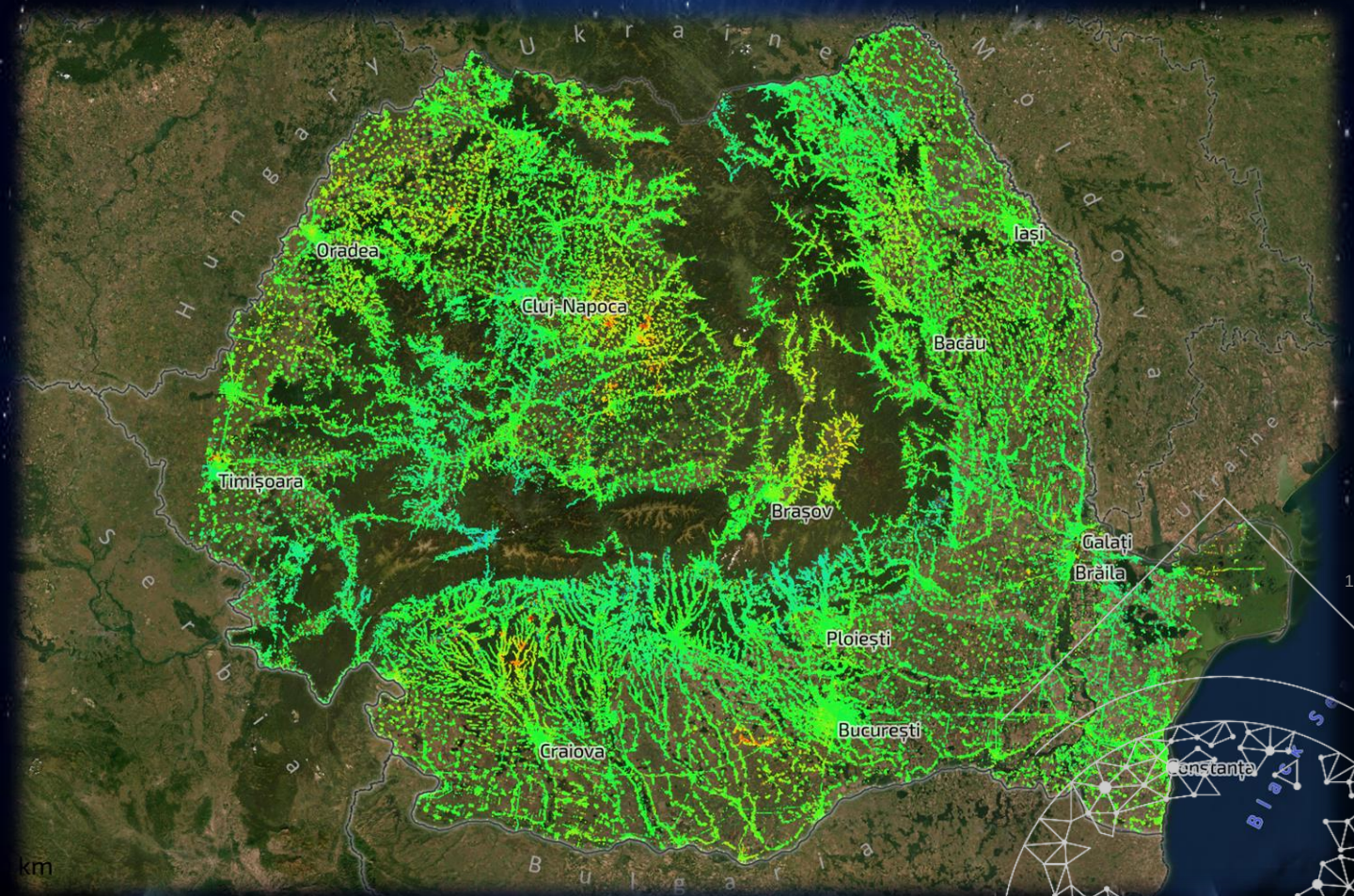
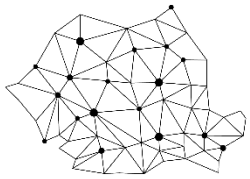
Monitoring Ground Motion from Space

National Ground Motion Monitoring: Romania between 2015 - 2020



TERRASIGNA™

Foreword



This book represents a collection of maps (so-called ground displacement rate maps), illustrating the power of satellite radar interferometry (InSAR) to detect and monitor subtle ground displacements associated with various phenomena. Natural or anthropogenic hazards related motions like subsidence/uplift (due to fluid dynamics, clay shrink/swell, mining activity, tunneling, water extraction, etc) or infrastructure deformations (e.g. water reservoirs, dams, bridges and other buildings) can be investigated with InSAR and they are to be demonstrated within this book.

More than 1500 Sentinel-1 A/B datasets acquired by the European Space Agency were processed by TERRASIGNA experts to produce the first ever ground displacement map of Romania.

With this result, and by measuring around 21 million targets over Romania, covering approximately 200.000 km^2, TERRASIGNA marks an important milestone towards using space-based technology to map ground surface movement for large areas, the technology being top state of the art at the European and even international level.

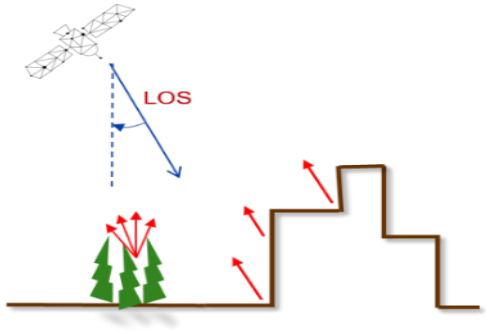
The maps presented are relevant examples of products offered by an InSAR-based monitoring service which can accurately detect and monitor the ground instabilities before catastrophic events take place, thus contributing to the mitigation of the damages caused by such processes.

The readers of this book are encouraged to freely distribute this material in order to reach the whole community and spread the word on the availability of such technologies to monitor ground displacement and infrastructure stability anywhere and anytime is needed.

Contents

A few words on InSAR

The InSAR techniques accurately measure millimeter-scale surface displacements. They use images acquired by **Synthetic Aperture Radar (SAR)** sensors, done by emitting a radar wave along the **satellite line of sight (LOS)** and recording the intensity and the phase of the reflected signal.



The phase of the return wave depends on the distance to the ground.

Interferometry uses two images of the same area taken from the same position and finds the difference in phase between them, producing an image known as an **interferogram**.

The signal measured in an interferogram represents the change in phase caused by an increase or decrease in distance from the ground pixel to the satellite. Therefore, **the component of a ground motion parallel to the satellite LOS vector will cause a phase difference to be observed, and the ground displacement can be calculated**.

Some characteristics differentiate the InSAR from the classic ground-based monitoring techniques, and **enable targeted in-situ measurements in problematic areas**. InSAR:

- ✓ does not require ground access (all measurements are from space),
- ✓ is non-invasive (employing remote sensing),
- ✓ is based on SAR satellite data, available independently of weather conditions, day or night,
- ✓ can be done periodically every 6-12 days, without extensive preparation, during the life of the space missions,
- ✓ provides a high density of measurement points, as opposed to GPS ,
- ✓ provides millimetric accuracy, similar to high accuracy GPS systems.

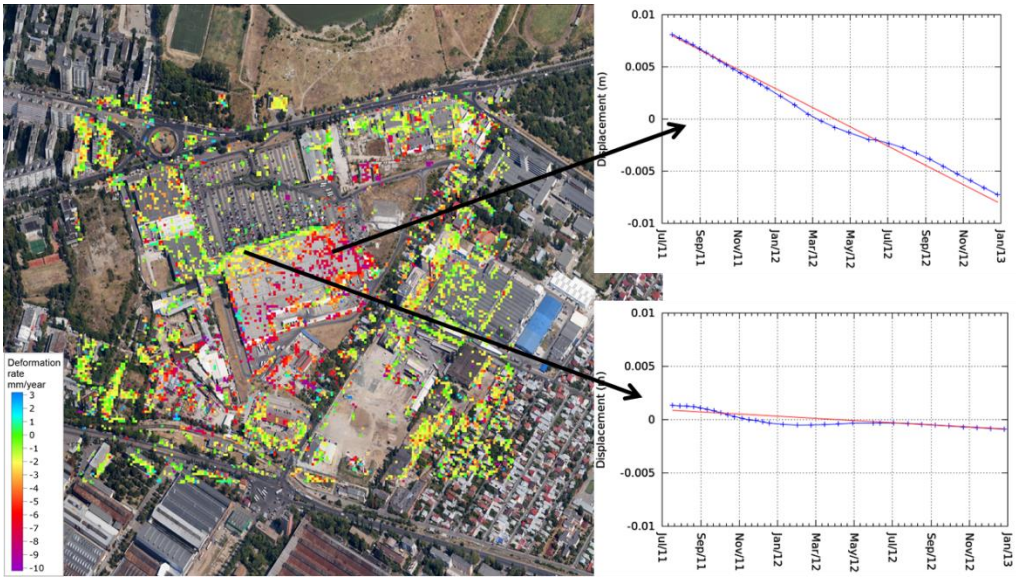
Persistent Scatterer Interferometry (PSI) represents a relatively recent development from conventional InSAR, and relies on studying pixels which remain coherent over a sequence of interferograms.

TERRASIGNA is a certified PSI service provider since 2014 and this technique was applied to produce the maps provided in this work.

Ground displacement rate maps

The PSI technique uses a large number of satellite radar images to provide:

- Deformation/displacement rate map,
- Time series for each measurement point.



The displacement rates are usually displayed using colored symbols overlaid on a background of the area of interest.

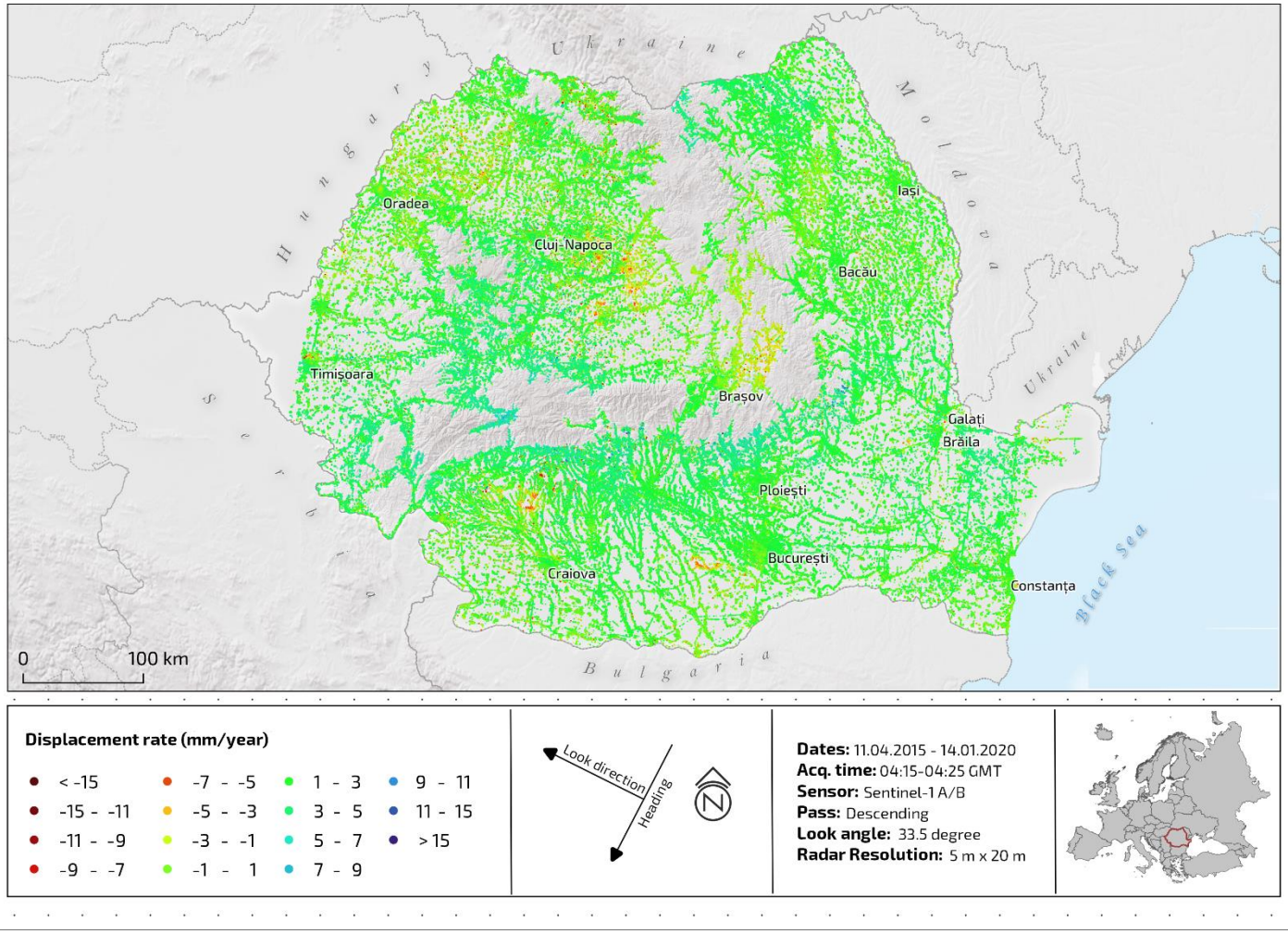
The wide-used color code in InSAR is the following:

- red color is used to symbolize an increase in distance along LOS from the ground pixel to the satellite, i.e. pixels which are e.g. subsiding/going down, having negative displacement rates;
- green color for relatively stable pixels,
- blue color for a decrease in distance along LOS from the ground pixel to the satellite, i.e. pixels which are e.g. lifted/going up, having positive displacement rates.

This color code is also used in all the maps presented in the book.

Displacement rate (mm/year)	
< -15	1 - 3
-15 - -11	3 - 5
-11 - -9	5 - 7
-9 - -7	7 - 9
-7 - -5	9 - 11
-5 - -3	11 - 15
-3 - -1	> 15
-1 - 1	

Romania



This is the first ever ground displacement map of Romania. It contains more than 21 million ground pixels, covering approximately 200.000 km^2 and it was obtained by PSI processing of around 1500 Sentinel-1 A/B datasets.

This map shows, with milimetric accuracy, stable and unstable areas in Romania during the last five years.

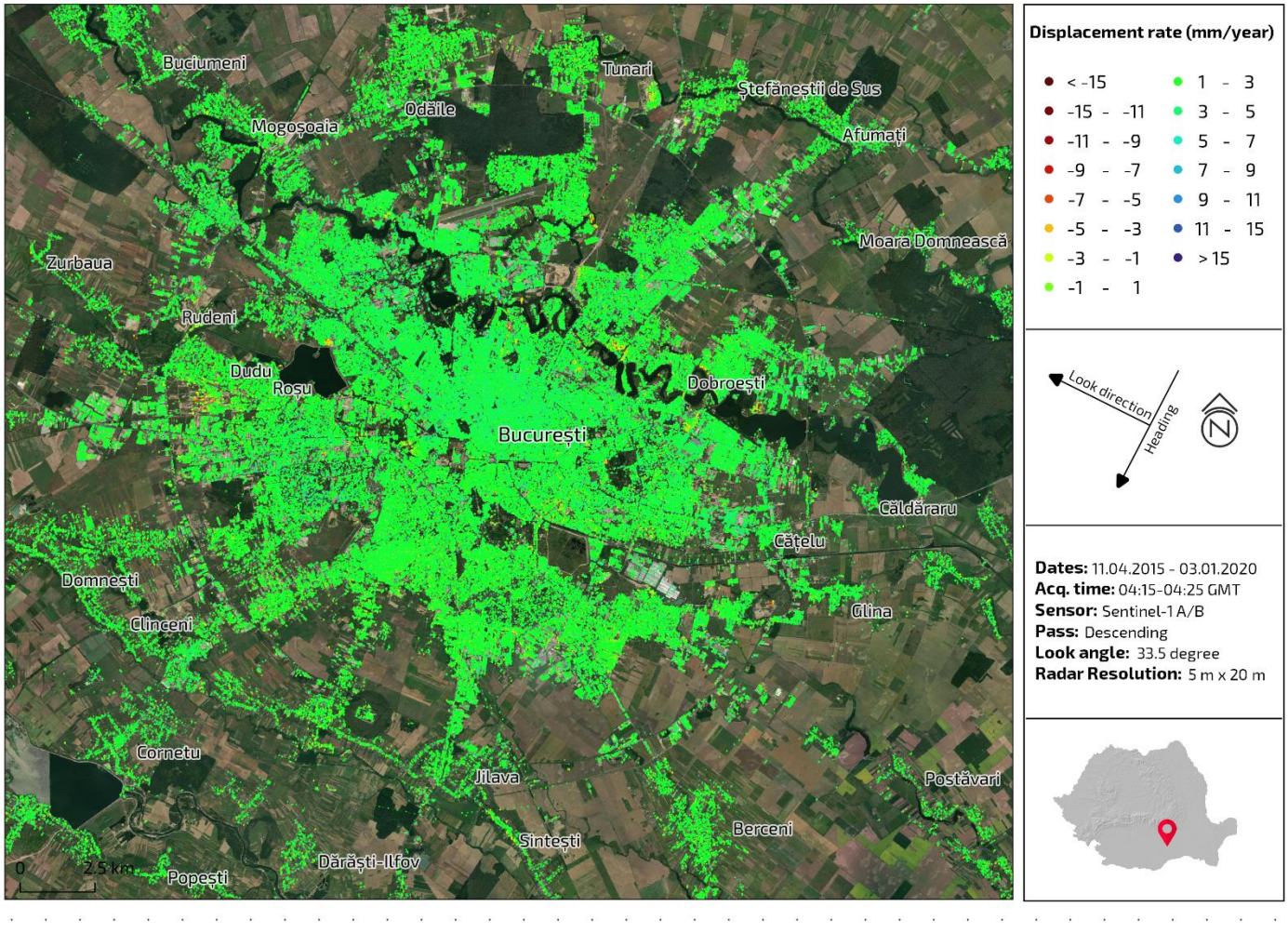
Most of the PSI measurement points are located around buildings and infrastructure units, like bridges, roads and highways and even power pillars or windmills.

In the following, local displacements maps are illustrated, grouped on main InSAR application areas found in Romania (urban areas, salt mining, oil&gas, nuclear power plant, landslides and thermal water areas).

Urban areas


Bucharest, Romania - Parliament House area
[mm/year]
6
-6
Displacement rate (2011 - 2014)

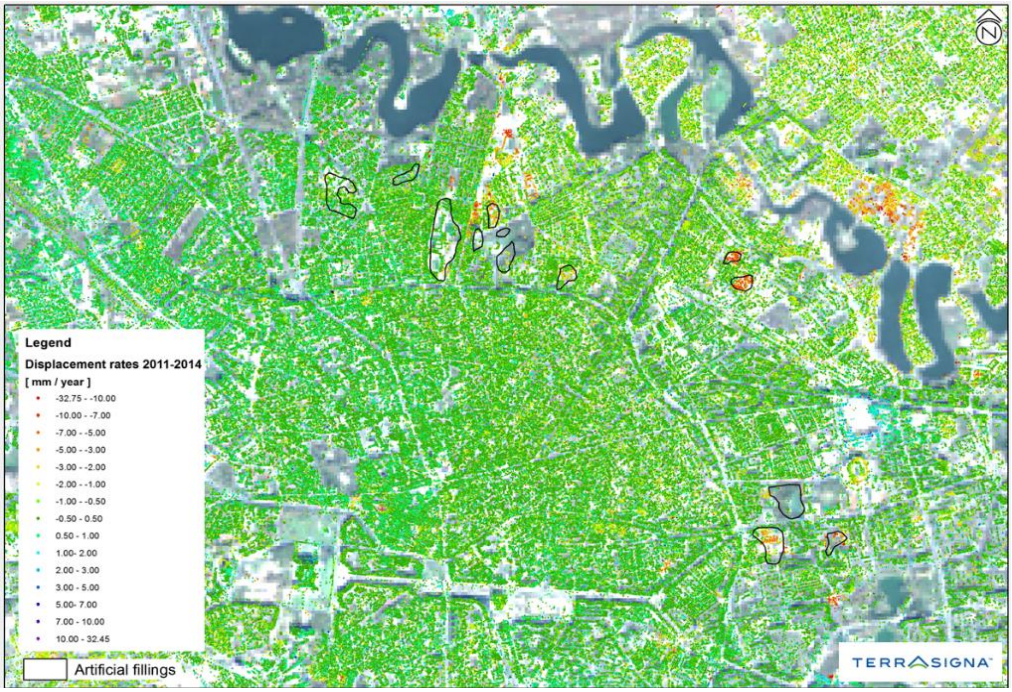
Bucharest



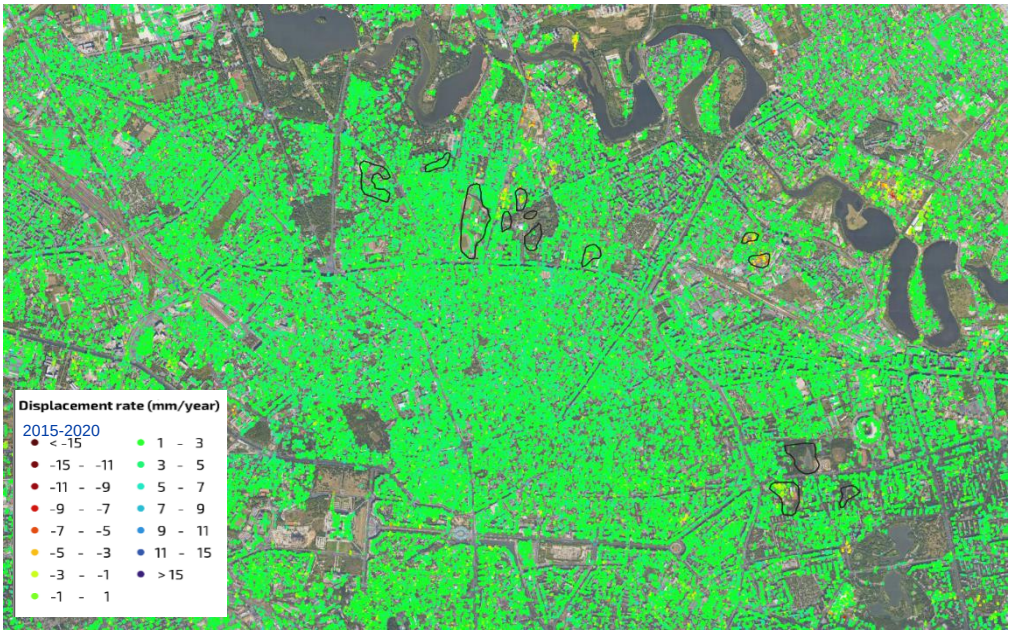
- Bucharest city is the capital and largest city of Romania, situated in the southeastern corner of the Romanian Plain, over sedimentary formations.
- Due to its position on the banks of Dambovita River and above a complex mix of underground infrastructure and aquifer systems, the risk of subsidence in the area is significant. Moreover, its closeness to Vrancea seismic area increases the risk of seismic induced soil liquefaction.

Bucharest

- Several local areas with well-delimited spatial extent showing ground compaction/subsidence with values between 3-10 mm/year can be identified. Most of them correlate very well with the position and extent of old artificial fillings found in a micro-zonation map of Bucharest dated in 60-70s.



Results using the TerraSAR-X mission 2011-2014

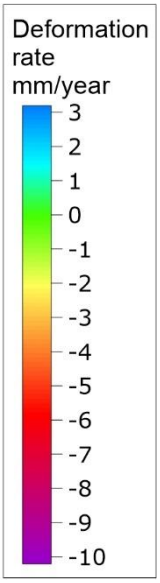


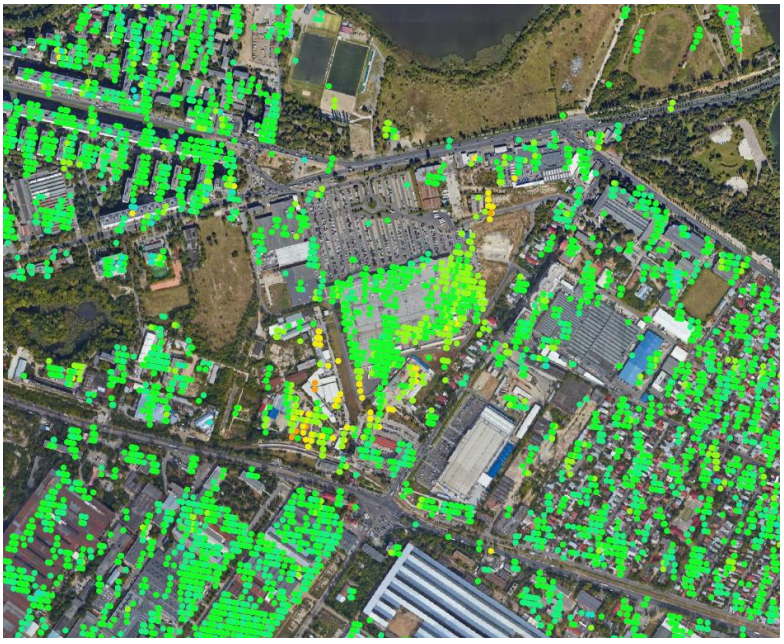
Results using the Sentinel-1 mission 2015-2020

Bucharest

- In the period between 2011-2014, a shopping mall areas was found to subside. From Sentinel-1 measurements it can be seen that subsidence continues at a slightly lower rate between 2015-2019.

TerraSAR-X results
2011-2014





Sentinel-1 results
2015-2019

Iași

Displacement rate near Iași, Iași county (Sentinel 1 A/B 2015 - 2020)

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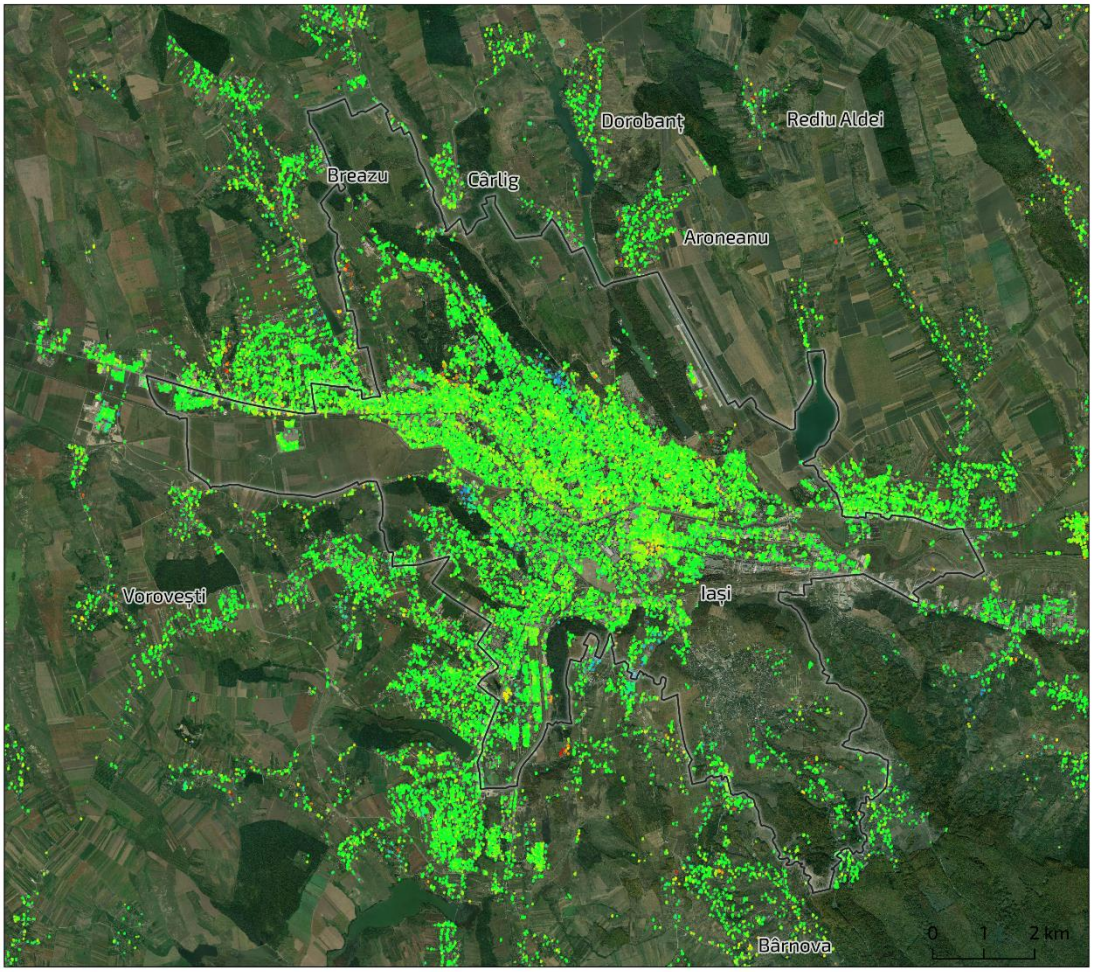
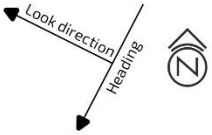


Displacement rate (mm/year)

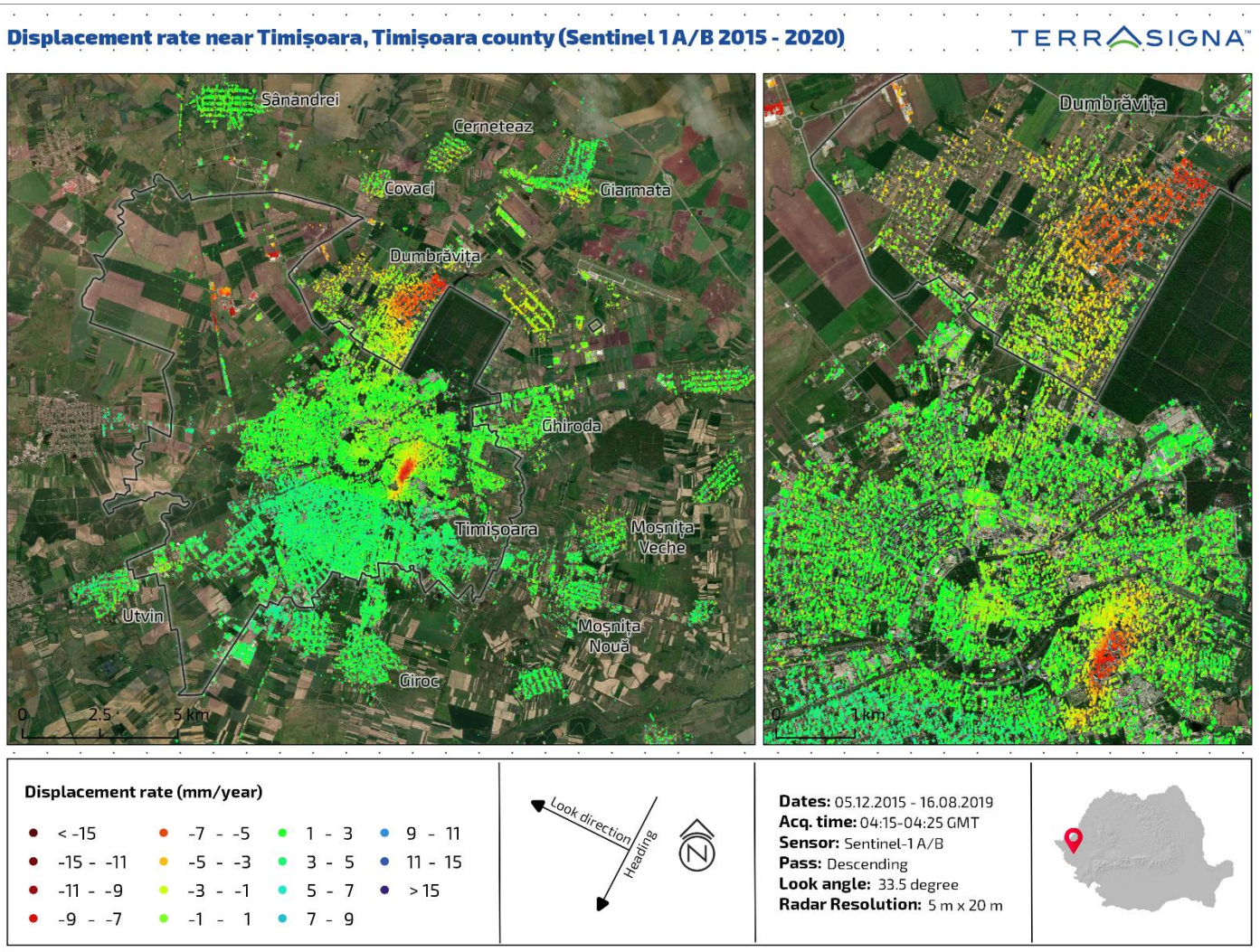
< -15	1 - 3
-15 - -11	3 - 5
-11 - -9	5 - 7
-9 - -7	7 - 9
-7 - -5	9 - 11
-5 - -3	11 - 15
-3 - -1	> 15
-1 - 1	



Dates: 11.04.2015 - 03.01.2020
Acq. time: 04:15-04:25 GMT
Sensor: Sentinel-1 A/B
Pass: Descending
Look angle: 33.5 degree
Radar Resolution: 5 m x 20 m

- With 376,180 residents (as of 2018), the Iași urban area is the second most populous in Romania.
- The city lies on the Bahlui River valley. The surrounding country is one of uplands and woods, featuring monasteries and parks. Iași itself stands amid vineyards and gardens, partly on hills, partly in the in-between valley. The central part of the city is located on the 35 m fluvial terrace of the Bahlui, the rest on hills up to 160 m.
- Some small areas were identified as unstable: Hilincea Monastery area (3-10 mm/year), “Baza 3” area (3-5 mm/year), some buildings in city center near Str. Modovei (3-5 mm/y) and Zimbrului (7-9 mm/y), Ticau district (5-7 mm/y) and an area South of Botanical Garden (5-12 mm/y).

Timișoara



- The 3rd largest city in Romania, Timișoara, lies at an altitude of 90 m in the Banat plain, near the divergence of the Timiș and Bega rivers. The waters of the two rivers form a wetland system with a floodplain in-between. Timișoara was developed on the floodplain, above sedimentary rocks. With time, the rivers were drained, dammed and diverted. However, the land across the city lies above a water table at a depth of only 0.5 to 5 m, thus being prone to instabilities.
- A large sinking area can be easily noticed on the East of the city center, the highest values of 12 mm/year being found in a zone with old houses and industrial fabrics.
- Dumbravita village, found in the North of the city, is also slowly subsiding, the highest values of 8-10 mm/year being found on a new residential park.

Cluj-Napoca

Displacement rate near Cluj-Napoca, Cluj county (Sentinel 1 A/B 2016 - 2020)

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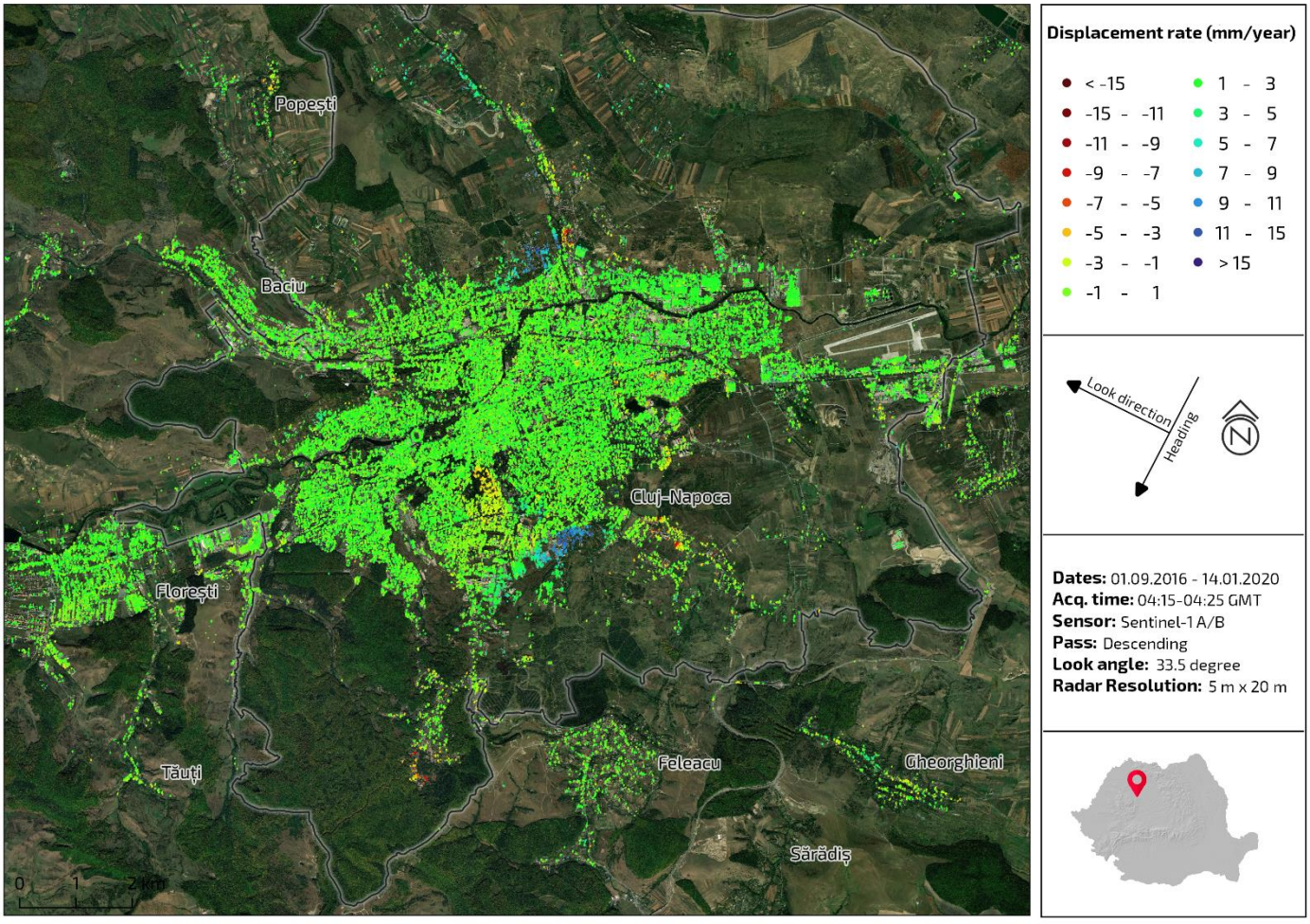
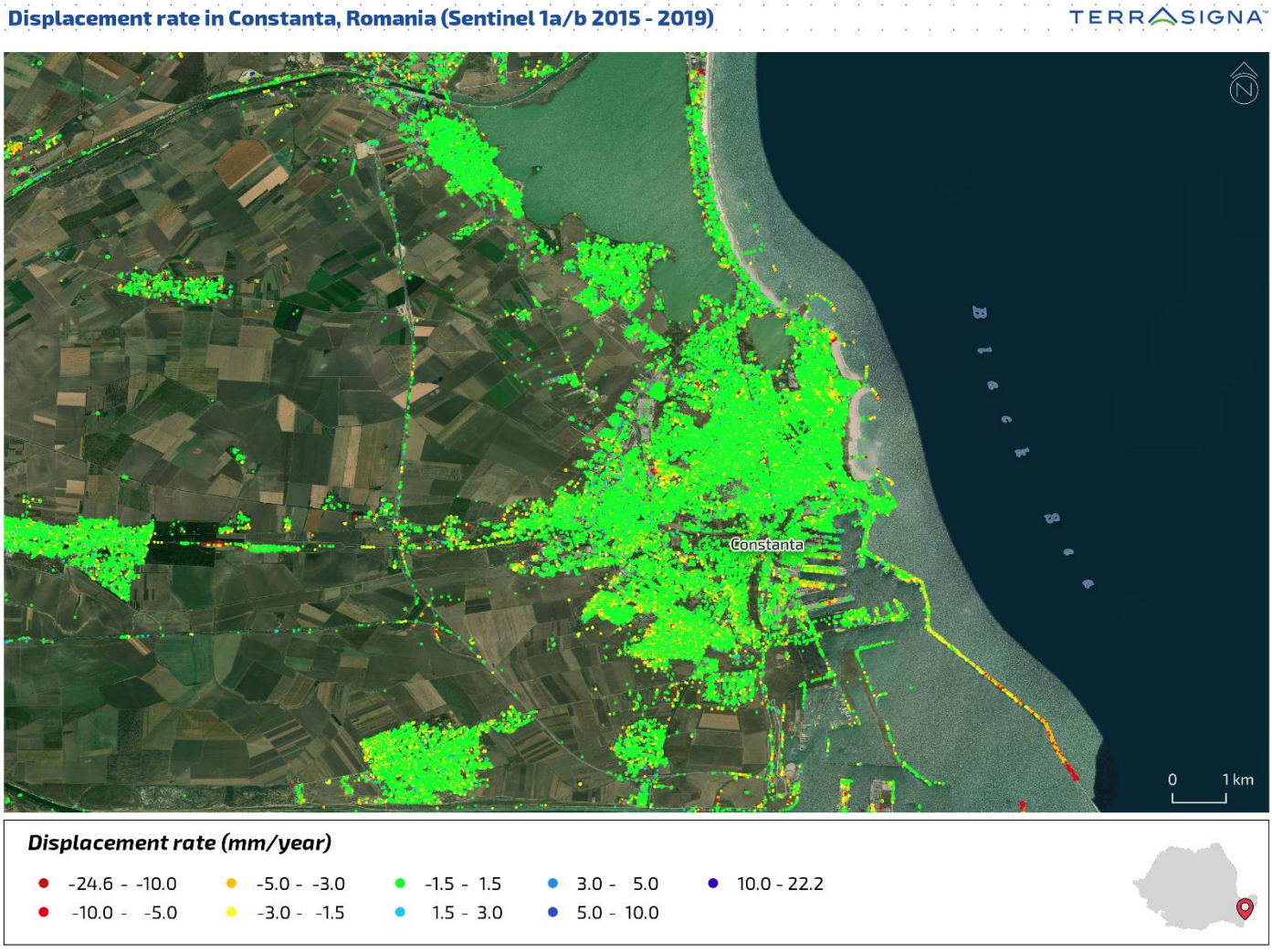


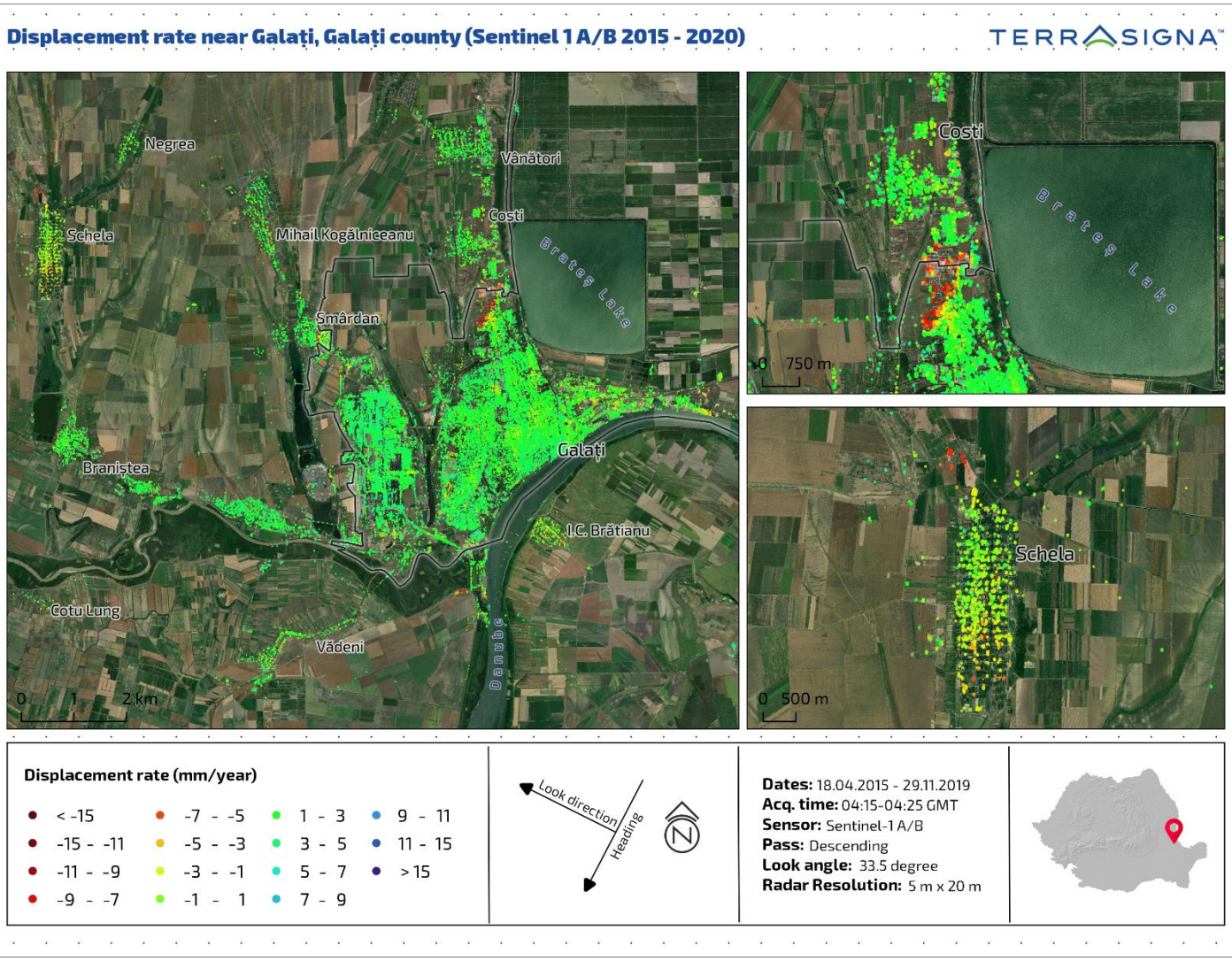
- Cluj-Napoca city, commonly known as Cluj, built on the banks of the river Someșul Mic, is considered the unofficial capital to the historical province of Transylvania. The southern part of the city occupies the upper terrace of the northern slope of Feleac Hill, and is surrounded on three sides by hills or mountains with heights between 500 m and 700 m. The hills of Calvaria and Cetățuia (Belvedere, 405 m) are located near the center of city.
- Several unstable slopes can be identified. For example, Buna-ziua district, which is well known for a rapid expansion of new residential buildings, shows displacements up to 12 mm/year and the slopes near Republicii street up to 6-8 mm/year.

Constanţa



- Constanţa, historically known as Tomis, is the oldest continuously inhabited city in Romania. It is located on the Black Sea coast, having a beach length of 13 km.
- Several unstable areas can be identified. A new residential district on the North Esplanade shows instabilities around 5 mm/year. Also some industrial areas and areas near the coast and in the harbour are slowly subsiding.
- The last 400 m of the seawall are subsiding with 5-8 mm/year.

Galaţi

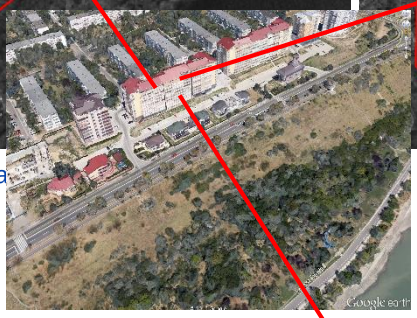


- Galați lies in the southern part of the Moldavian Plateau on the left (west) bank of the Danube river at the junction of the Siret River (west) and the Prut River (east), near Lake Brates. Galați is built on three geological terraces. One lies beneath "Valley City", with elevations between 5 and 7 m. The other two, which make a fan shape, have elevations of 20–25 m (the site of the old town, now the city centre) and 40 m (the site of the modern city) respectively.
- On the west side of Brates Lake, where there is a mixture of residential district and industrial constructions, subsidence up to 14 mm/year (dark red colour) can be detected. In Micro 17 district there are also buildings affected by subsidence of 10-15 mm/year.

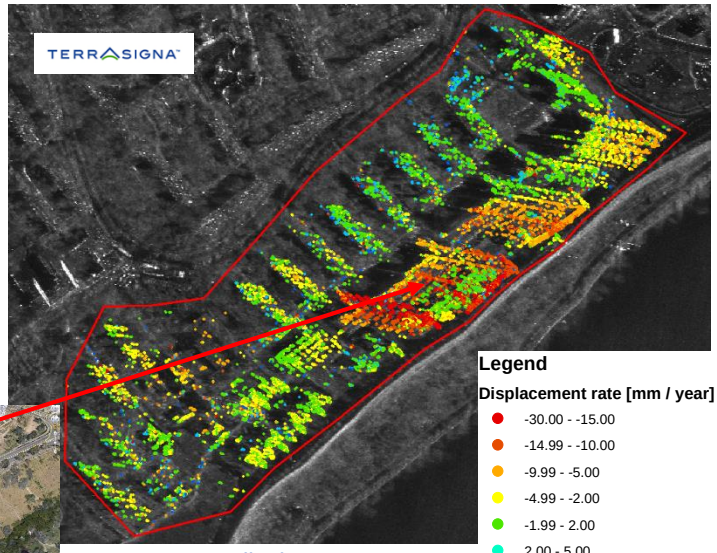
Galaţi

- A closer look at the Sentinel-1 results over two high-rise buildings located on the Danube cliff and known to be previously affected by subsidence in 2013-2015 from TerraSAR-X measurements shows a continuing subsidence of 6-8 mm/year.

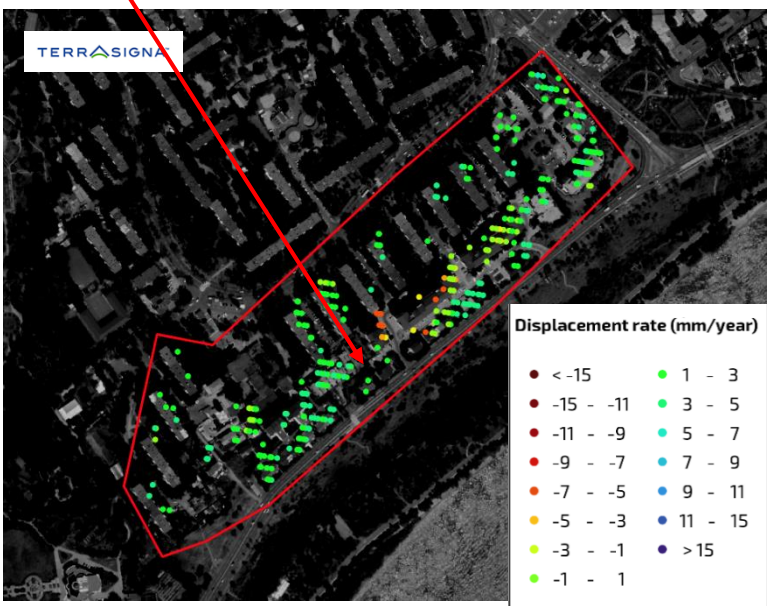
TerraSAR-X displacement ma
17.03.2013 – 09.06.2015



Buildings near the river bank in Galati city

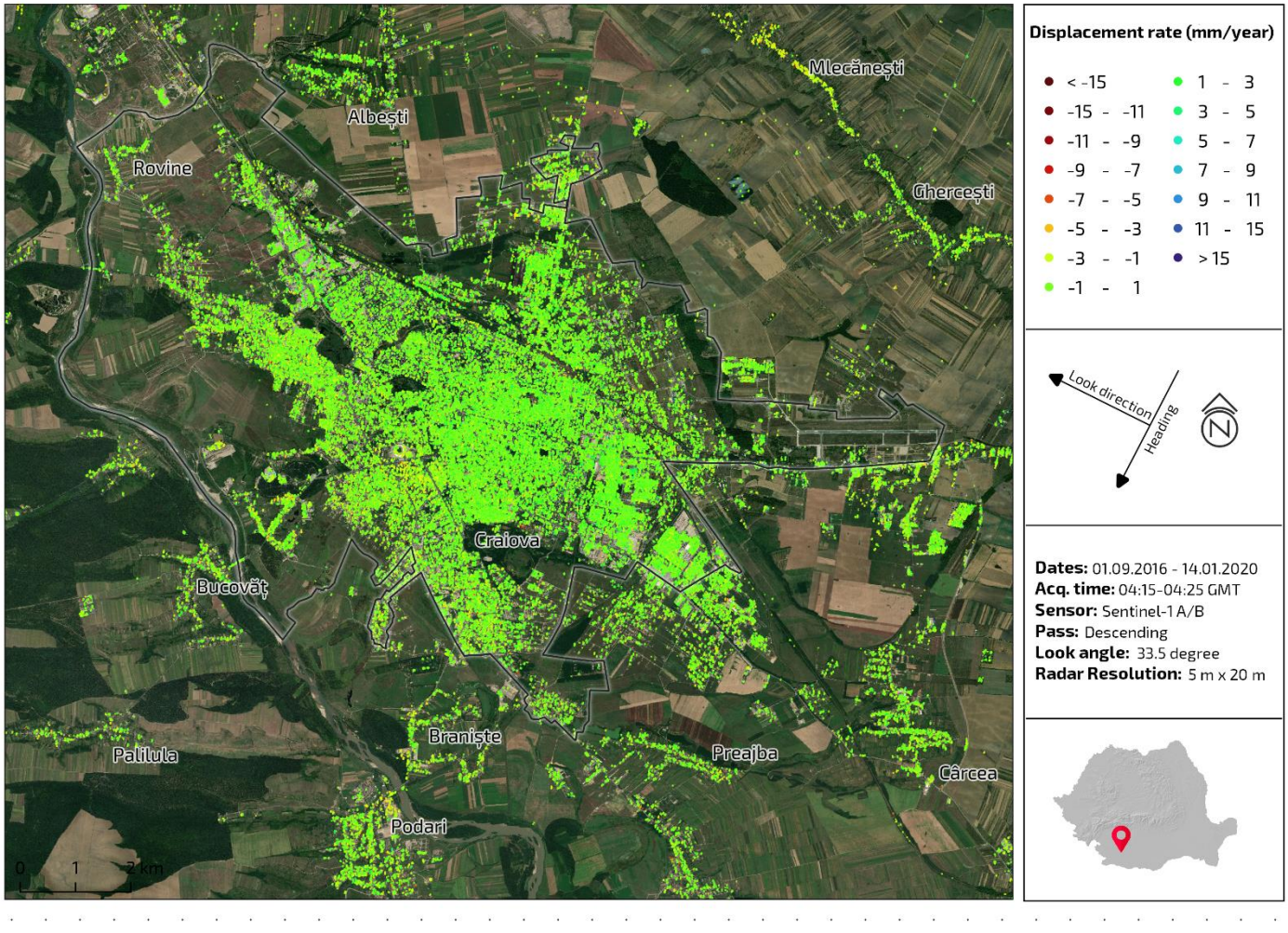


TerraSAR-X displacement map
30.06.2014 – 06.06.2015



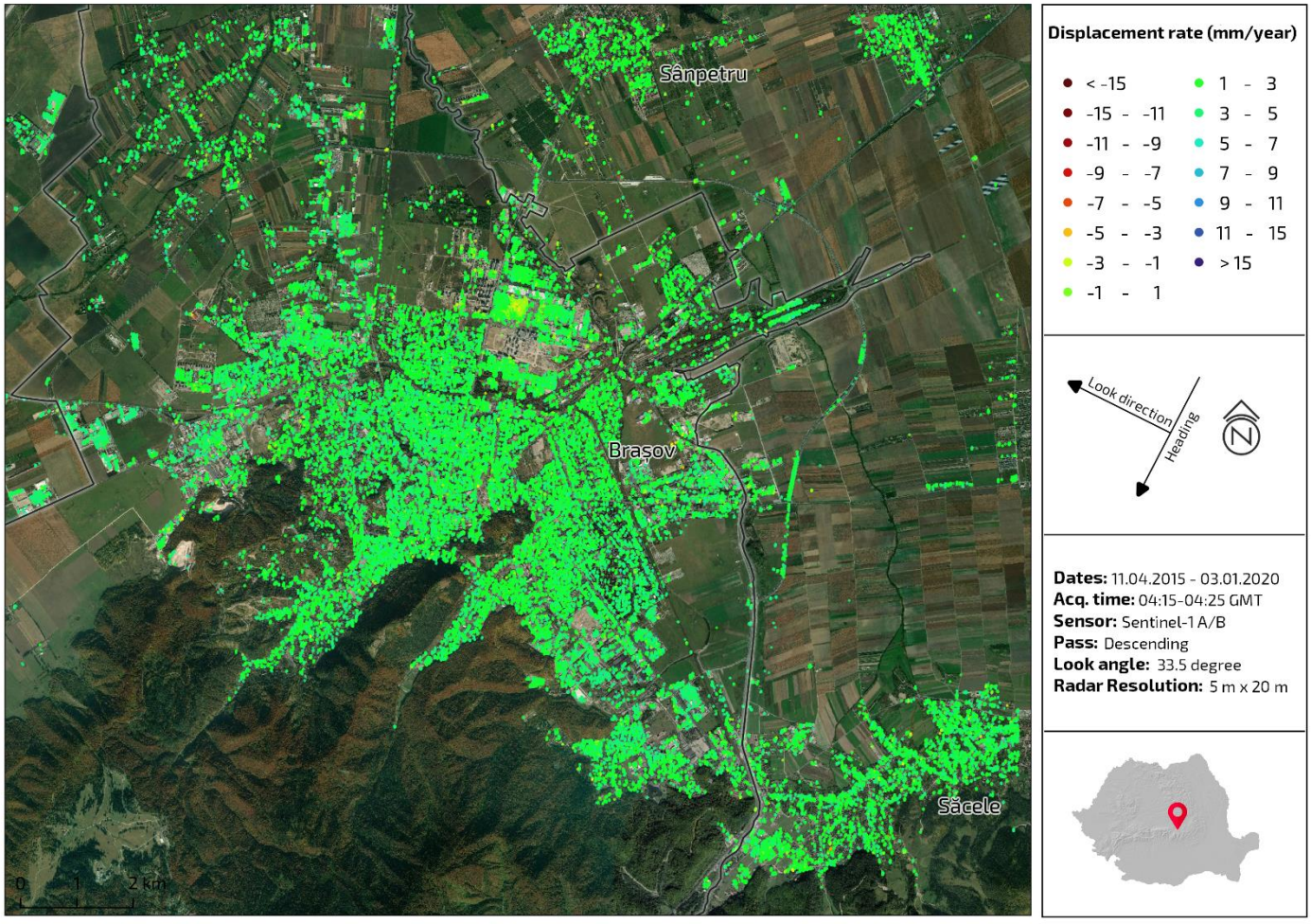
Sentinel-1 displacement map
18.04.2015 – 29.11.2019

Craiova



- Craiova, Romania's 6th largest city and capital of Dolj County, is situated near the east bank of the river Jiu. Built in a hilly region, its altitude varies between 75 m and 116 m.
- Measurements results reveal a quite stable city; only in a small area, the south of Stirbei Voda district, slow subsidence can be identified (3-5 mm/year). In the north of this area, the new stadium was built in 2017-2018.
- The dominant factor behind isolated detected ground motion seems to be new constructions.
- The north of Podari village, near the Jiu River, is also slowly subsiding.

Brașov



- Brașov is surrounded by the Southern Carpathians, being situated at an altitude of 625 m. In the southern part of the city, there is Tampa Mountain, part of the Postăvarul Peak, almost entirely surrounded by the city of Braşov. Its elevation is 960 m, ~ 400 m above the city.
- No predominant ground motion pattern was detected. There are some isolated unstable points spread over the city, also in the Prund-Schei district, which is known for landslides on its steep slopes, especially after a longer raining period.
- Small subsidence could be detected in a shopping area in the northern part of the city.

Ploiești

Displacement rate near Ploiesti, Prahova county (Sentinel 1 A/B 2015 - 2020)

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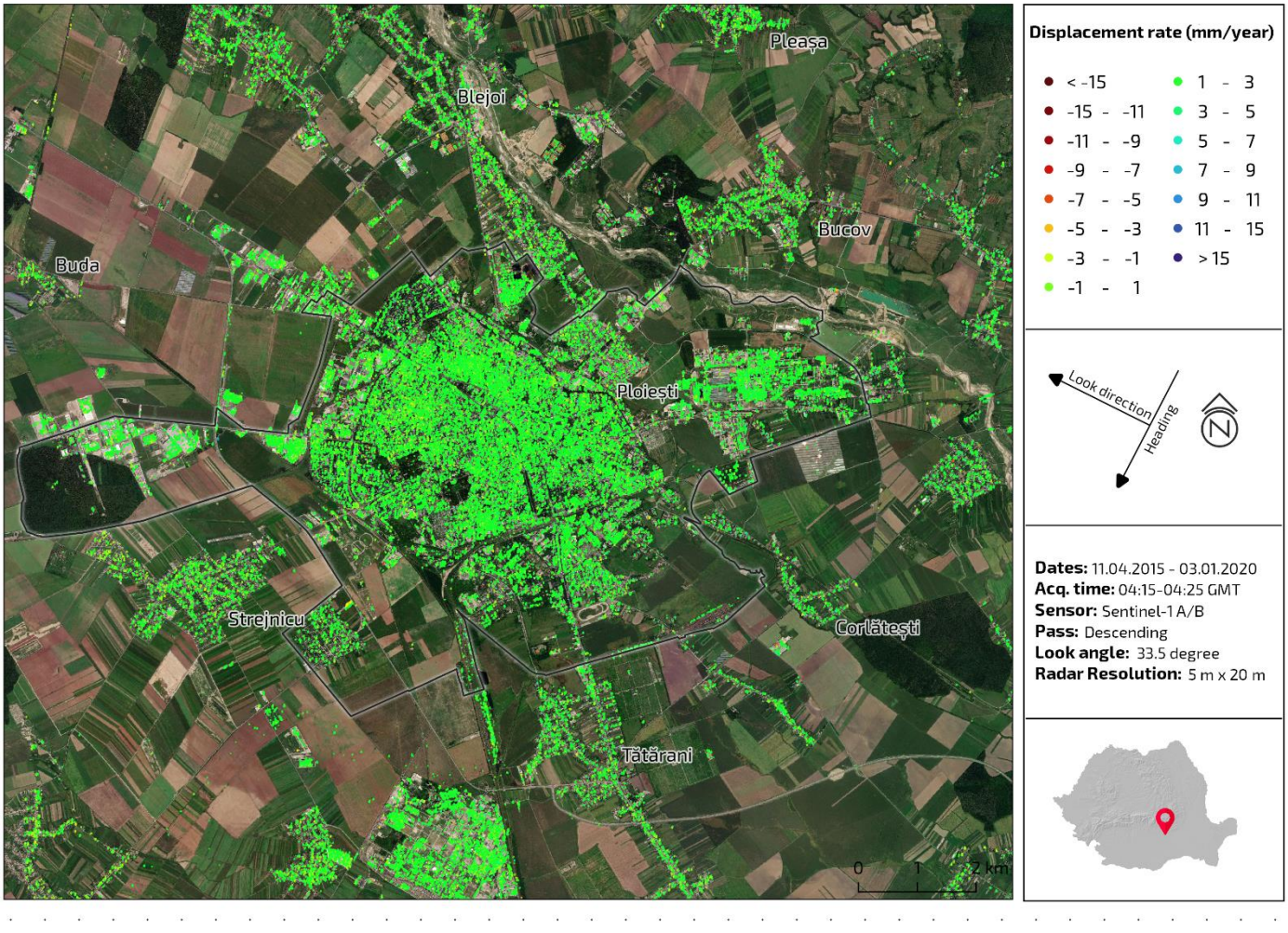
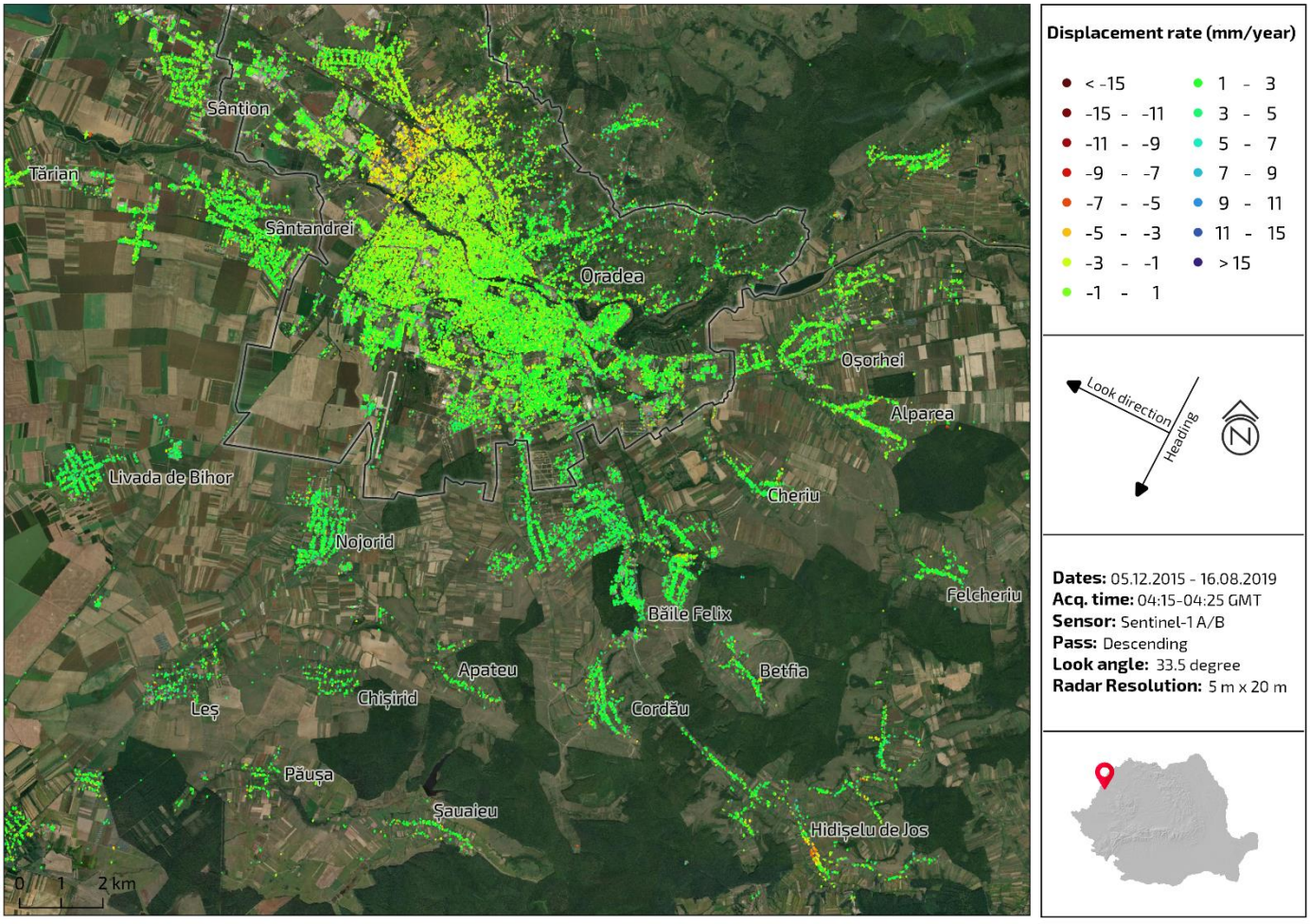


- Ploiești is located 56 km north of Bucharest, in the central-northern part of the Romanian Plain.
- There are 228,550 people living within the city of Ploiești, making it the 9th most populous in the country.
- No predominant ground motion pattern was detected In Ploiesti area.

Oradea

Displacement rate near Oradea, Bihor county (Sentinel 1 A/B 2015 - 2020)

TERRASIGNA

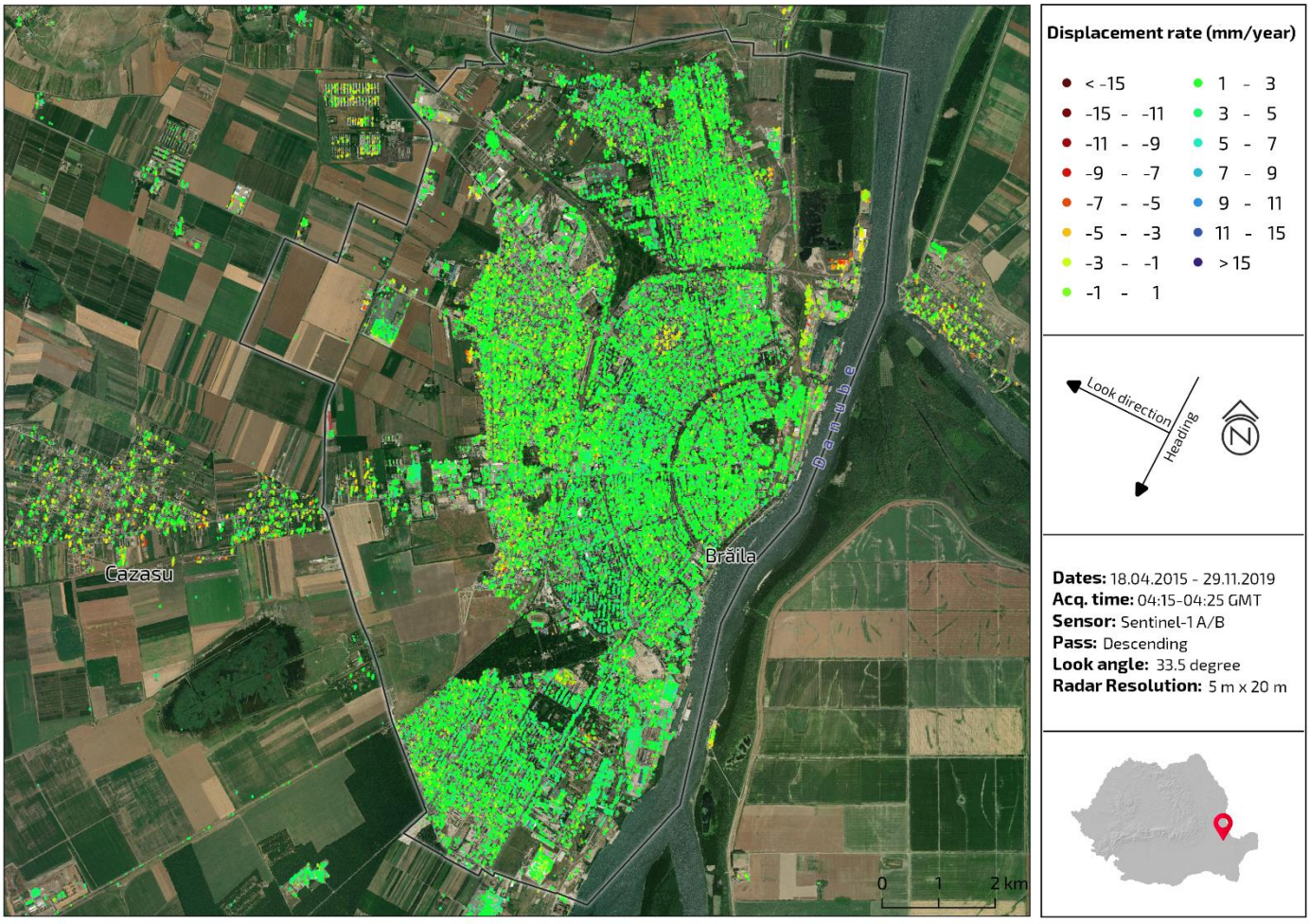


- The city is located in the north-west of the country, nestled between hills on the Crișana plain, 126 meters above sea level, on the banks of the Crișul Repede River, that divides the city into almost equal halves.
- In the North side of the city, there is an industrial zone which shows slow subsidence of 3-5 mm/year over entire area. Also in the Rogerius district, there is an area slowly sinking with 3-5 mm/year.
- At about 15 km of Oradea, in the Hidiselu de Sus village, the houses on both side of the national road DN76 on a length of about 600 m are subsiding with values between 5-9 mm/year, such that the road is currently higher than the windows level.

Brăila

Displacement rate near Brăila, Brăila county (Sentinel 1 A/B 2015 - 2020)

TERRASIGNA

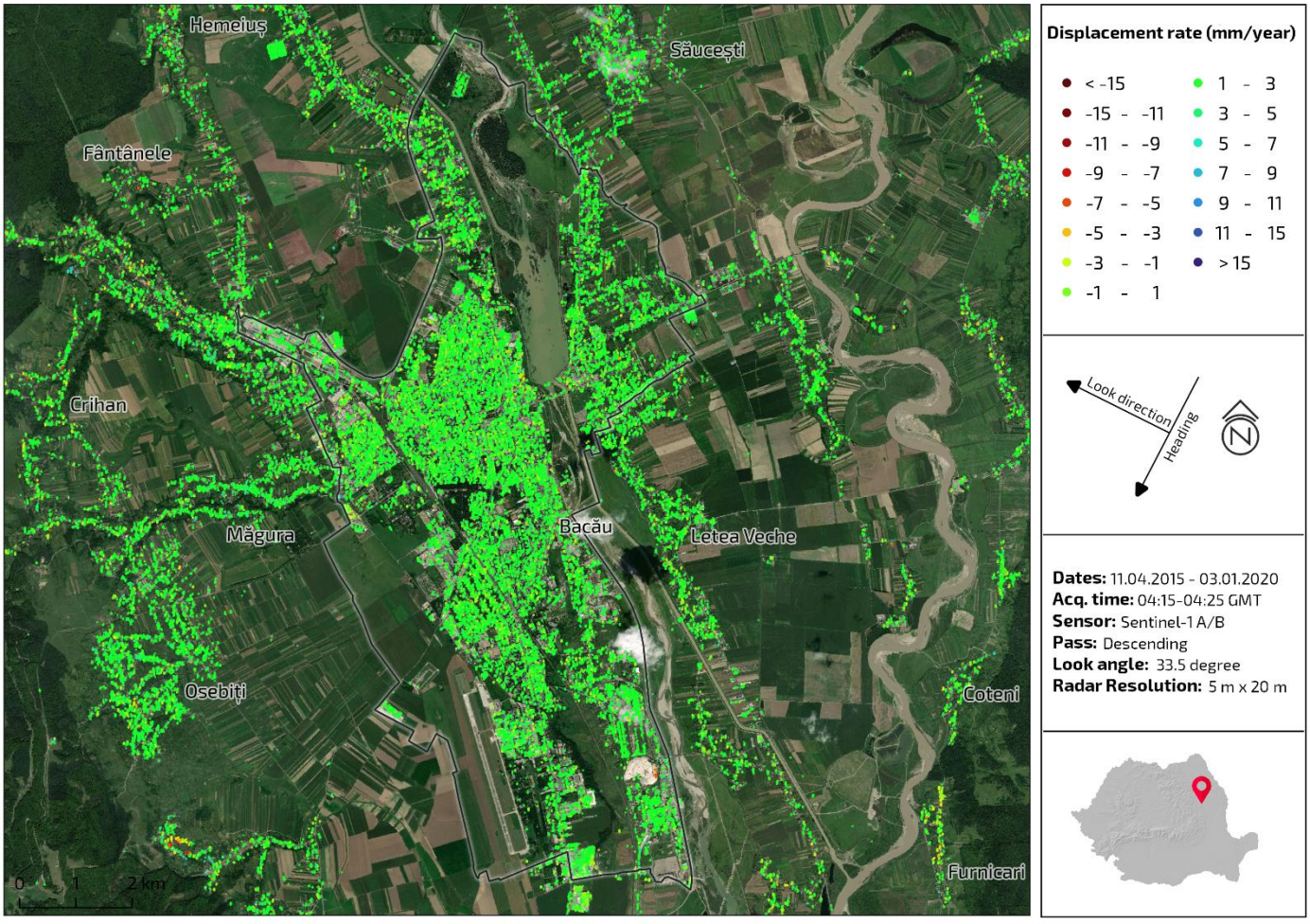


- Brăila is a city in the Romanian Plain, a port on the Danube.
- Streets radiating from near the port towards Brăila's center are crossed at symmetrical intervals by concentric streets, following the geometric design of the old Ottoman fortifications. The old center of the city has many 19th century buildings, some of them fully restored.
- A compact area affected by subsidence of 3-7 mm/year can be detected in Islaz district, near Bd. Dorobanti and Gratiei str., where the road crumbled in 2015 and 2016, when problems at the sewerage system occurred.
- Unstable areas can be find also in Viziriu III, Cazasu, Minerva, Lacu Dulce, and Chercea district and in the harbour area.

Bacău

Displacement rate near Bacău, Bacău county (Sentinel 1 A/B 2015 - 2020)

TERRASIGNA

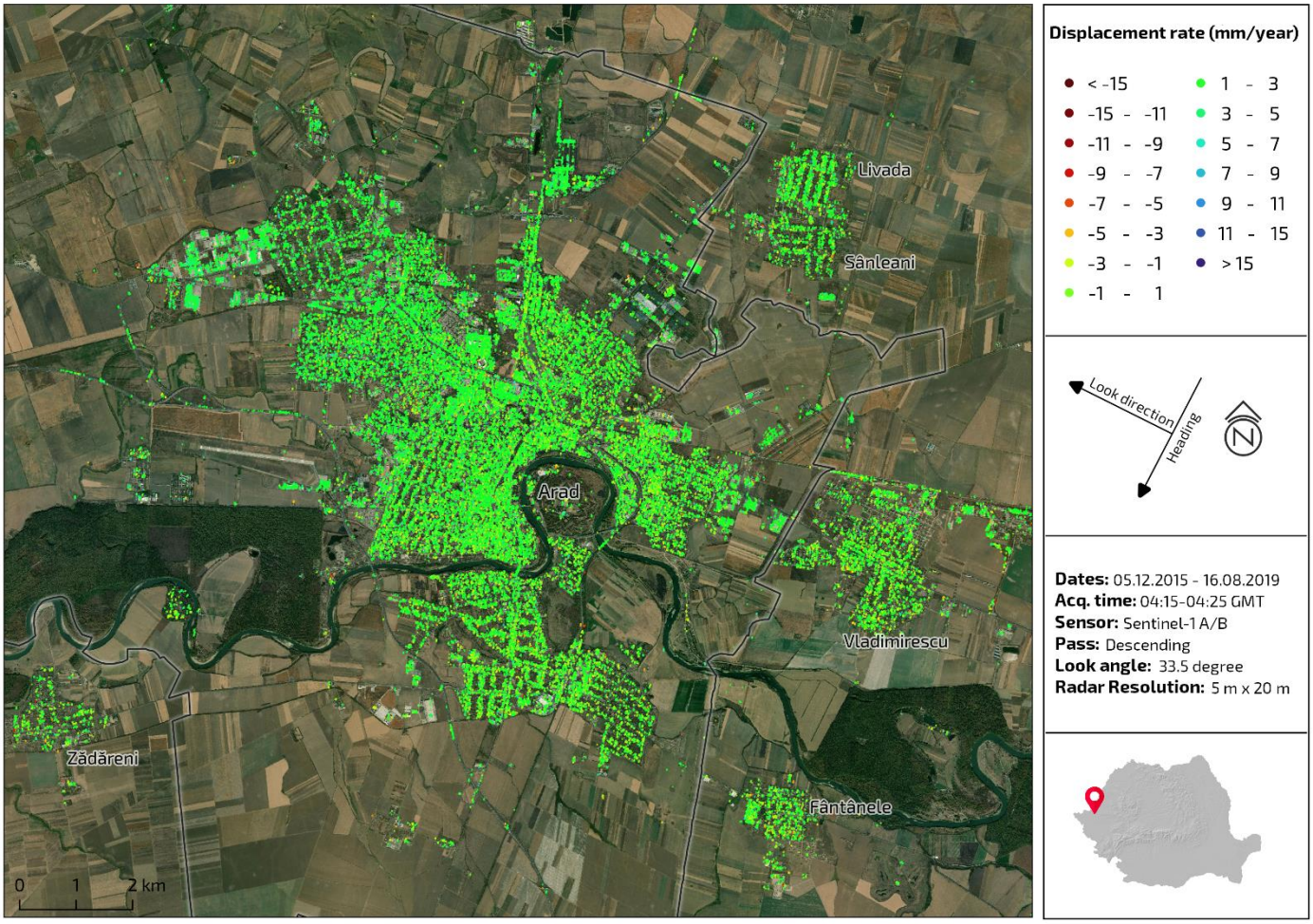


- Bacău is situated in the historical region of Moldavia, at the foothills of the Carpathian Mountains, and on the Bistrița River. Similarly to most urban centers in Moldavia, Bacău emerged on a ford that allowed water passage.
- No predominant ground motion pattern is detected in Bacău.
- A few isolated constructions show light instabilities (3-5 mm/y or 5-7 mm/y) in Serbănesti, Letea Veche, Cornisa and on Vantului Street, near the Barnat Dike.
- Outside the city, S-W, in Sărata Bai village, there are ground motions up to 15 mm/y on around 10 properties located on slopes.

Arad

Displacement rate near Arad, Arad county (Sentinel 1 A/B 2015 - 2020)

TERRASIGNA

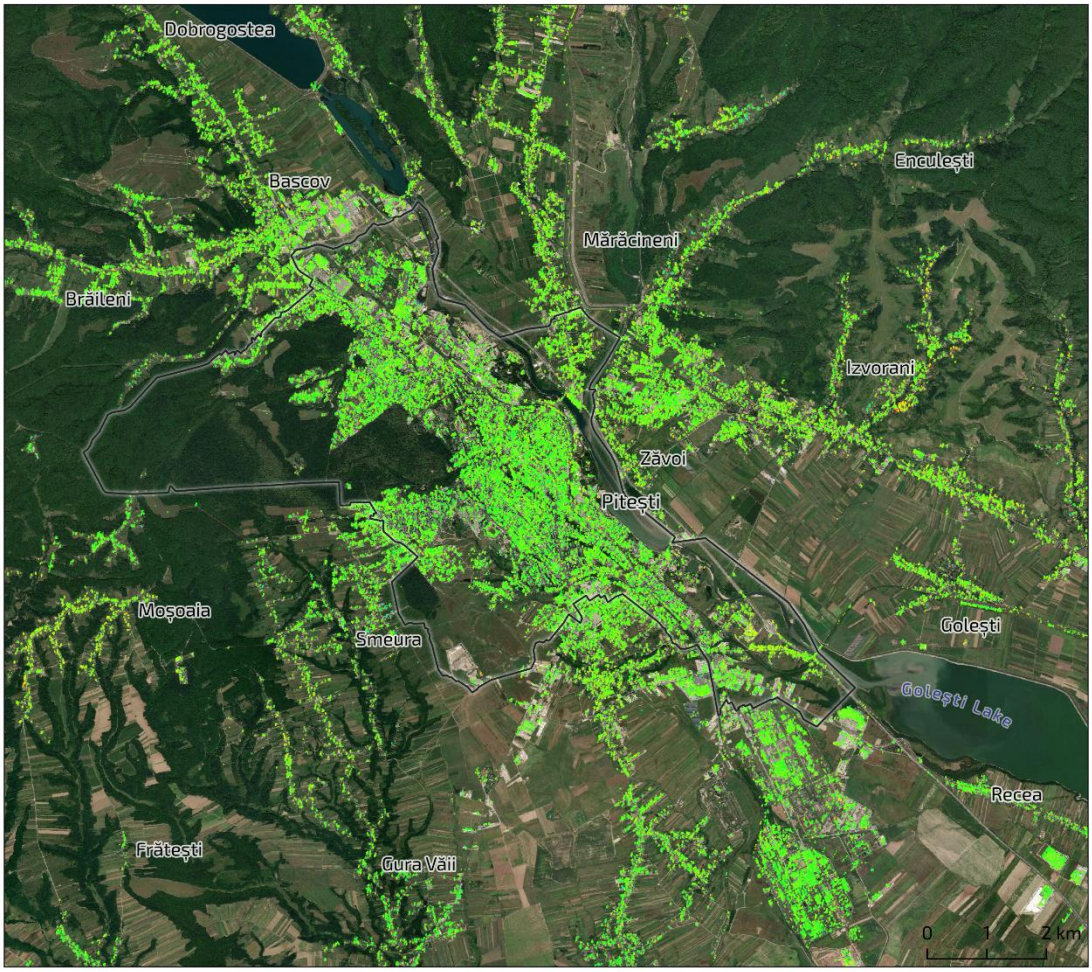


- Arad is located on the left bank of the Mures River, at an altitude of 107 m, in the Arad Plain.
- Even only 50 km away from Timisoara, Arad seems to be built on more stable ground, since only isolated points show small instabilities up to 5 mm/year.
- No predominant ground motion pattern was detected in Arad area.

Pitești

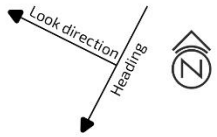
Displacement rate near Pitești, Argeș county (Sentinel 1 A/B 2016 - 2020)

TERRASIGNA



Displacement rate (mm/year)

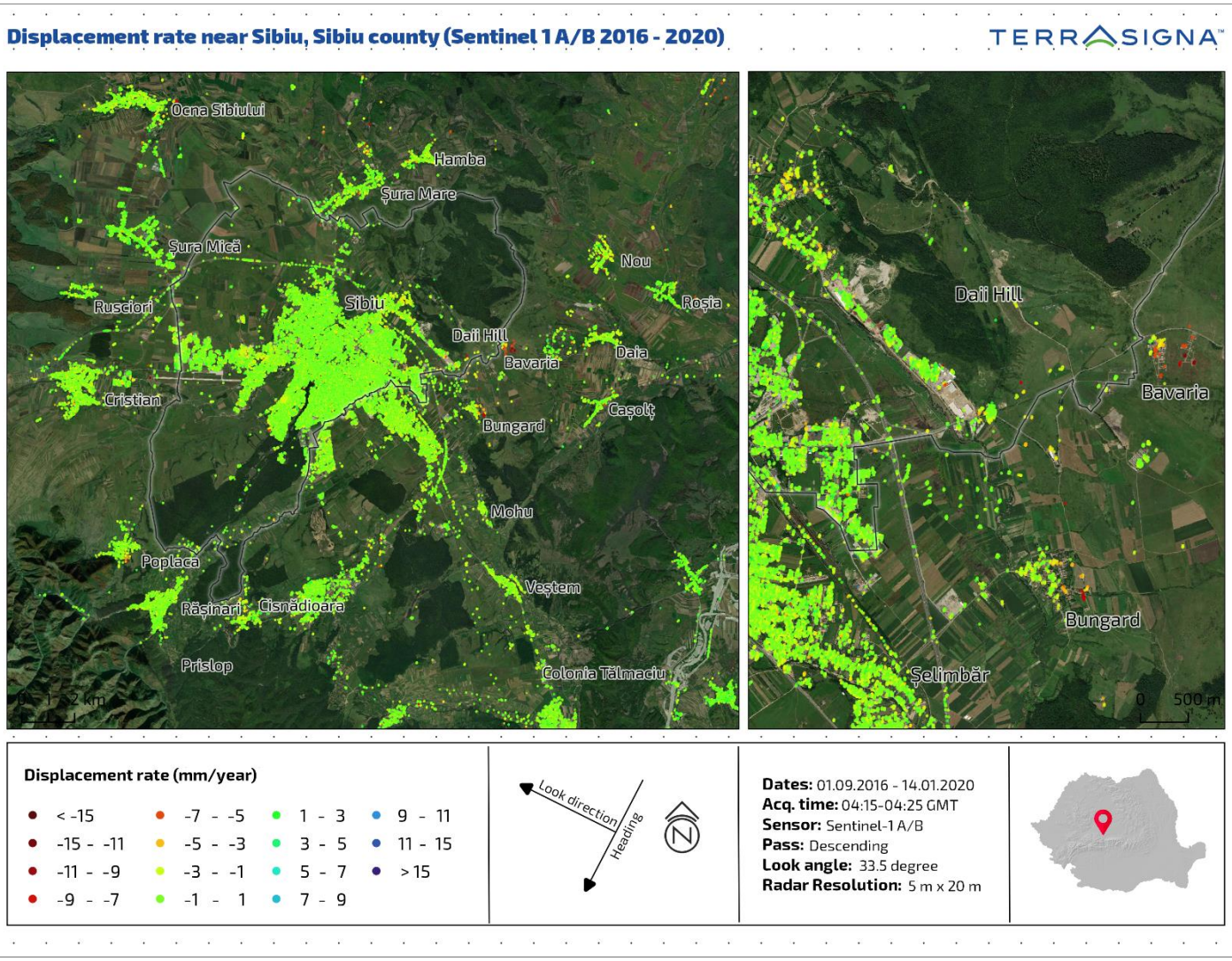
< -15	1 - 3
-15 - -11	3 - 5
-11 - -9	5 - 7
-9 - -7	7 - 9
-7 - -5	9 - 11
-5 - -3	11 - 15
-3 - -1	> 15
-1 - 1	



Dates: 01.09.2016 - 14.01.2020
Acq. time: 04:15-04:25 GMT
Sensor: Sentinel-1 A/B
Pass: Descending
Look angle: 33.5 degree
Radar Resolution: 5 m x 20 m

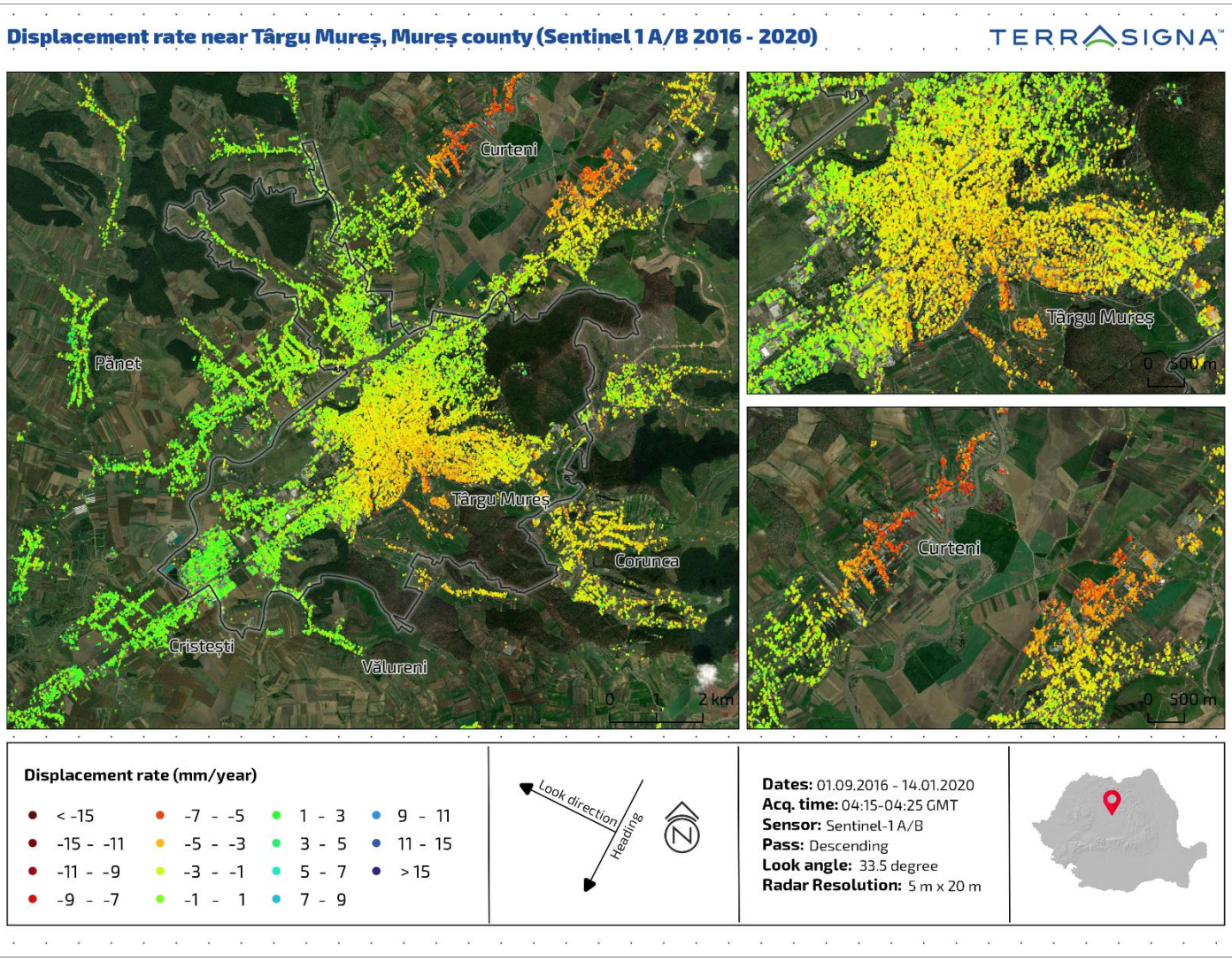
- Pitesti is a 300 years old city, located on Argeș River and inhabited by 155,383 people. It stands 280 m above sea level, on terraces formed by the river, and it belongs to the southernmost section of the Getic Plateau (an area of foothills leading up to the Southern Carpathians).
- The weak ground motion detected in the city in a few spots seems to be superficial construction.
- Unstable slopes are detected in Stefanesti / Izvorani and Hintesti / Smeura villages.

Sibiu



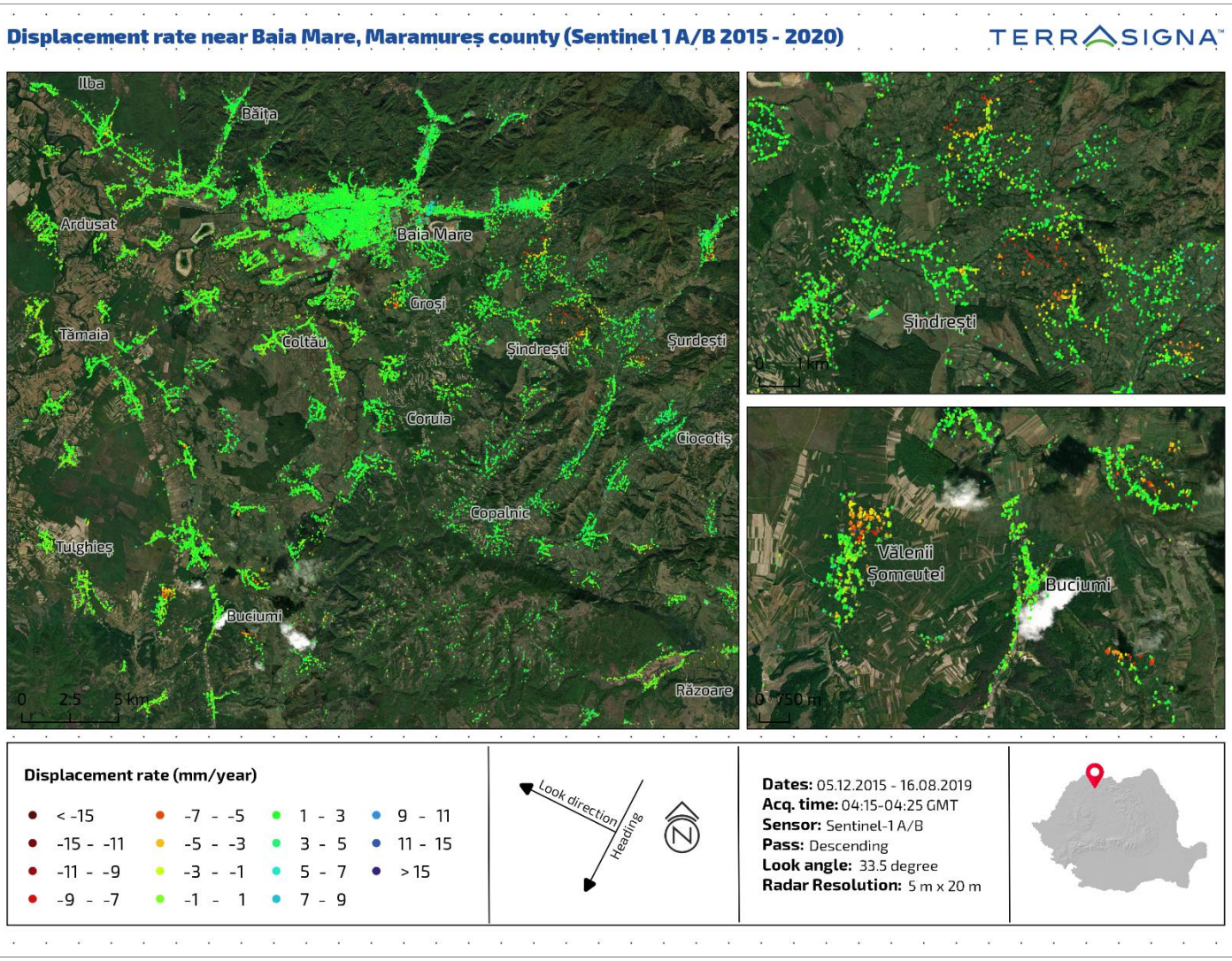
- Sibiu is located in the historical region of Transylvania, in the Cibin Depression, about 20 km from the Făgăraș Mountains. The Cibin river as well as some smaller streams runs through Sibiu. The geographical position of Sibiu makes it one of the most important transportation hubs in Romania with important roads and railway lines passing through it.
- It has a small altitude variation: 415 – 431 m.
- Slow subsidence can be detected in the Strand II, Turnisor and northern Gusterita district.
- Higher values (5-12 mm/year) can be found on the slopes of Daii Hill and in the Bavaria and Bungard villages, east of Sibiu.

Târgu Mureș



- Târgu Mureș is the 16th largest Romanian city, with 148,199 inhabitants in 2018. It lies on the Mureș river valley, at 330 m above sea level.
- Large areas of subsidence can be detected: in the main part of the city, highest values being in an old houses area along Valea Rece Street (5-7 mm/y), and in N-E of the city, extended along more villages: Curteni, Chinari, Sangeorgiu de Mures and Dumbravioara (5-11 mm/y).
- It needs further investigation if these ground motion patterns are related with the natural gas extraction/injection which takes place in Târgu Mures area or with the slopes on Belvedere Hill, Curteni or Chinari, or both.

Baia Mare



- Baia Mare is a municipality along the Săsar River, south of Igniș and Gutâi Mountains. Altitudes reach 1400 meters in some peaks. The precipitations in this area are quite high, the average rainfall being almost 1000 mm/year.
- Baia Mare region is a 2000 years old mining area, currently many of mine sites being closed. Thus there are plenty of artificial underground cavities, their exact locations are not public. There are also some known natural caves in the area.
- Many ground motion active areas can be detected, not only inside the city (highest values north of Sasar district), but also in the villages near, as e.g. Tautii de Sus, Grosi, north of Sisesti, Bontaieni, Plopis, Ferastrau, Valenii Somcutei, Ciolt and Hovrila. All of them are located at maximum 20 km of Baia Mare.

Buzău

Displacement rate near Buzău, Buzău county (Sentinel 1 A/B 2015 - 2020)

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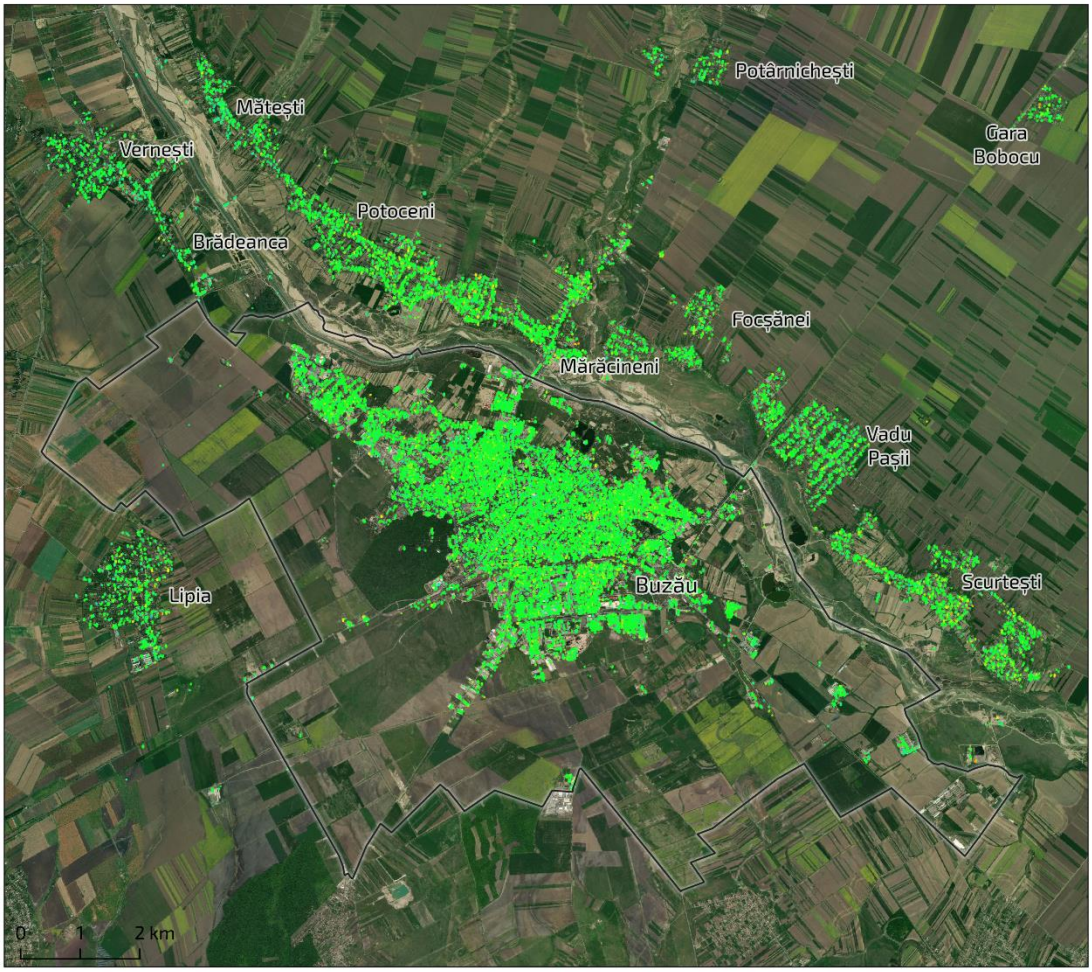
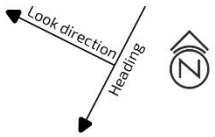


Displacement rate (mm/year)

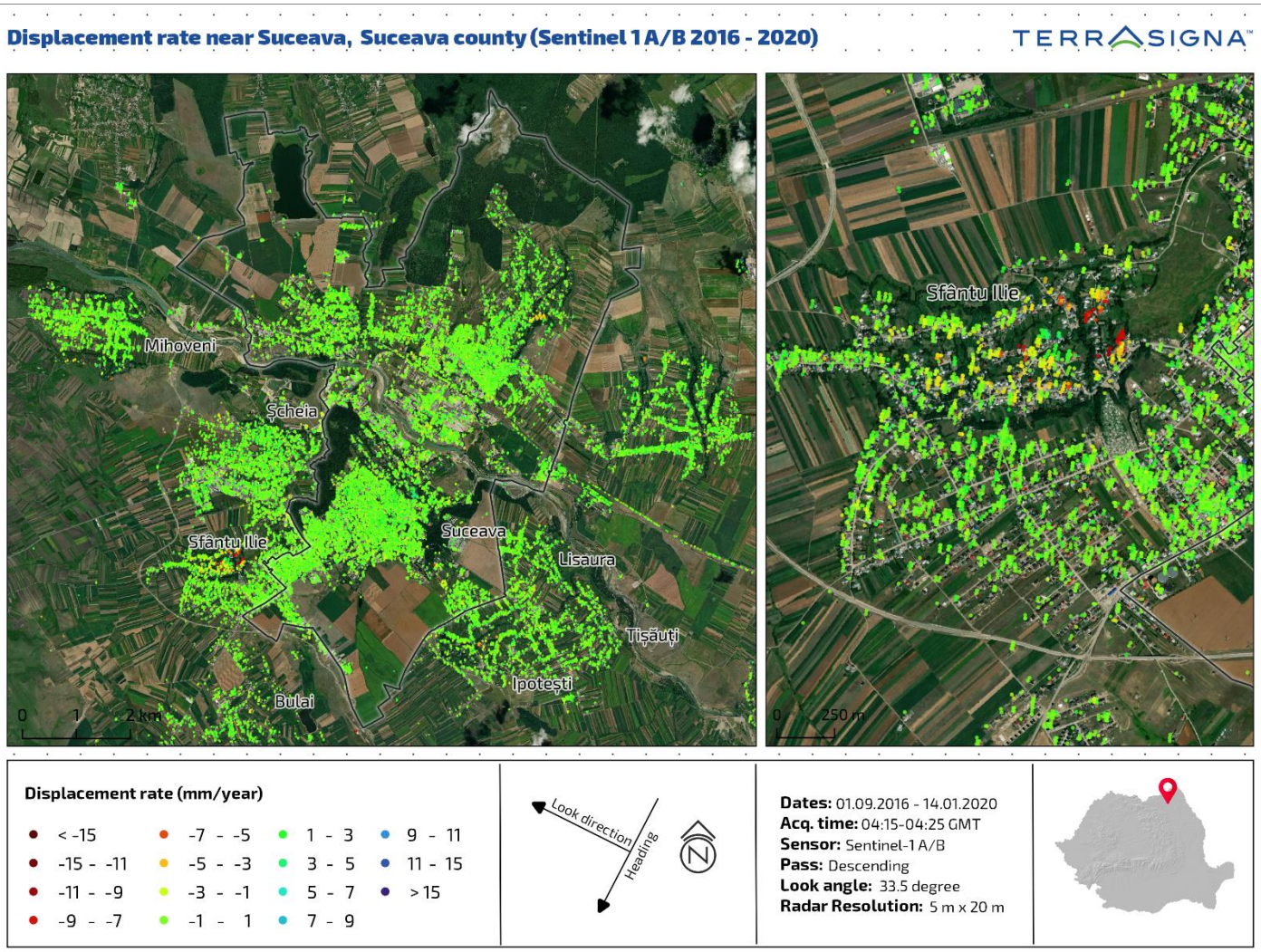
< -15	1 - 3
-15 - -11	3 - 5
-11 - -9	5 - 7
-9 - -7	7 - 9
-7 - -5	9 - 11
-5 - -3	11 - 15
-3 - -1	> 15
-1 - 1	



Dates: 11.04.2015 - 03.01.2020
Acq. time: 04:15-04:25 GMT
Sensor: Sentinel-1 A/B
Pass: Descending
Look angle: 33.5 degree
Radar Resolution: 5 m x 20 m

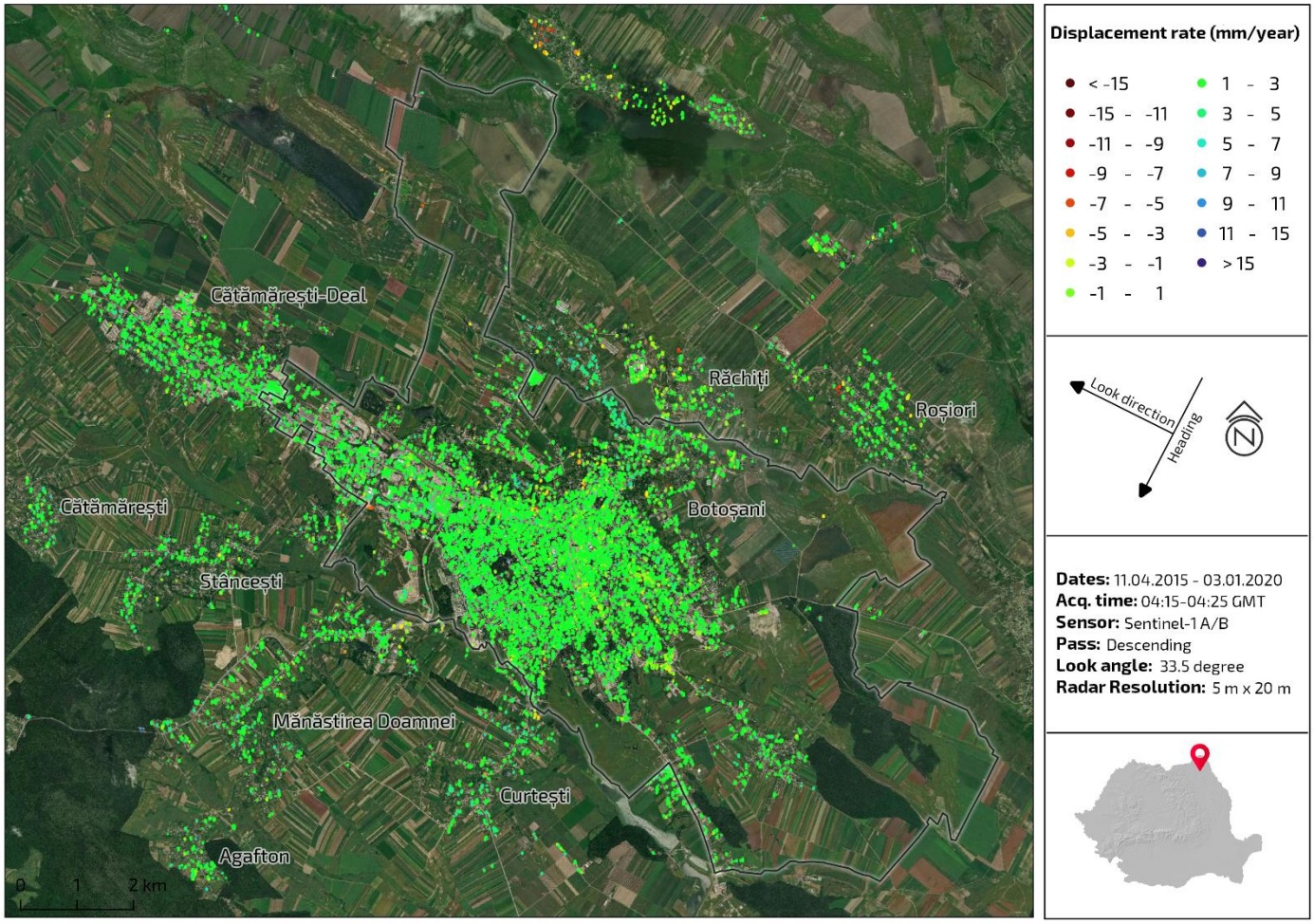
- Buzău lies near the right bank of the Buzău River, between the south-eastern curvature of the Carpathian Mountains and the lowlands of Bărăgan Plain. The city was, however, built away from its deep and wide valley, so the river never floods the city.
- It is placed in a flat area, with a height difference of just 10 meters along a 4 kilometer line. Average altitude is 95 m.
- There is no main ground motion pattern detected; overall the city can be found just a few constructions or ground affected by light instability.

Suceava



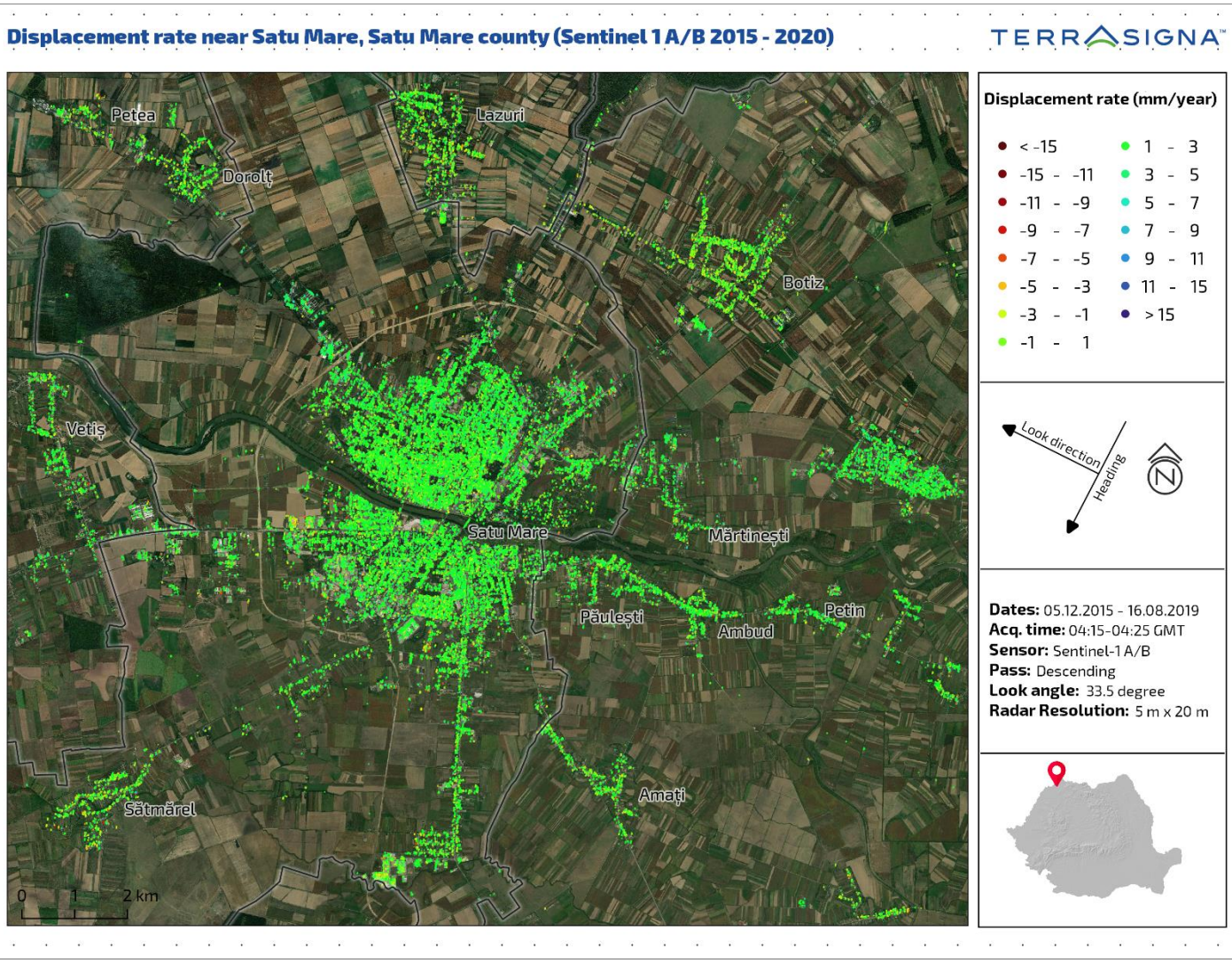
- Suceava covers two types of geographical areas, the hills (of which the highest is Zamca Hill, 385 m) and the meadows of the Suceava river valley. The ruins of the former medieval court are located in the city center of Suceava. In the 14th–17th centuries, in the proximity of the Princely Court there were built several churches that still exist today and attract tourists.
- The city is quite stable, with few exceptions: the St. Ilie district, where there are displacements up to 1 cm/year, the highest values being found near the St. Ilie church and the houses nearby. In the Burdujeni village, a 250 m sector of a road and the houses nearby are slowly moving up to 7 mm/year, a few pixels even with 11 mm/year.

Botoșani



- Botoșani lies between Sitna and Dresleuca Rivers, in a hilly region, at about 163 m above sea level. There are also a few artificial lakes near the city.
- There is no main ground motion pattern detected; overall the city can be found constructions or ground affected by light settlement (e.g. Pod de Piatra Str., Victoriei Str., Viorelelor Str. or Plopilor Str.), probably due to superficial construction or as a resultant of frequent flooding.
- Slow movement along the slopes can be detected in Cismea village.
- In Costești village, north of the city, instabilities up to 8 mm/y along LOS are found on the houses built on the slope of Ghidu lake. Affected area extends on ~ 0,25 km^2.

Satu Mare



- The city is located at an altitude of 126 m on the Lower Someș alluvial plain. From a geomorphologic point of view, the city is located on the Someș meadow on both sides of the river, which narrows in the vicinity of the city and widens upstream and downstream from it; flooded during heavy rainfall, the field has various geographical configurations at the edge of the city (sand banks, valleys, micro-depressions).
- There is no main ground motion pattern detected; overall the city can be found constructions or ground affected by light instability (near the river, minor subsidence and north and south of the city, frequent minor uplift), probably due to superficial construction or as a resultant of frequent flooding.

Piatra Neamț

Displacement rate near Piatra Neamț, Neamț county (Sentinel 1 A/B 2015 - 2020)

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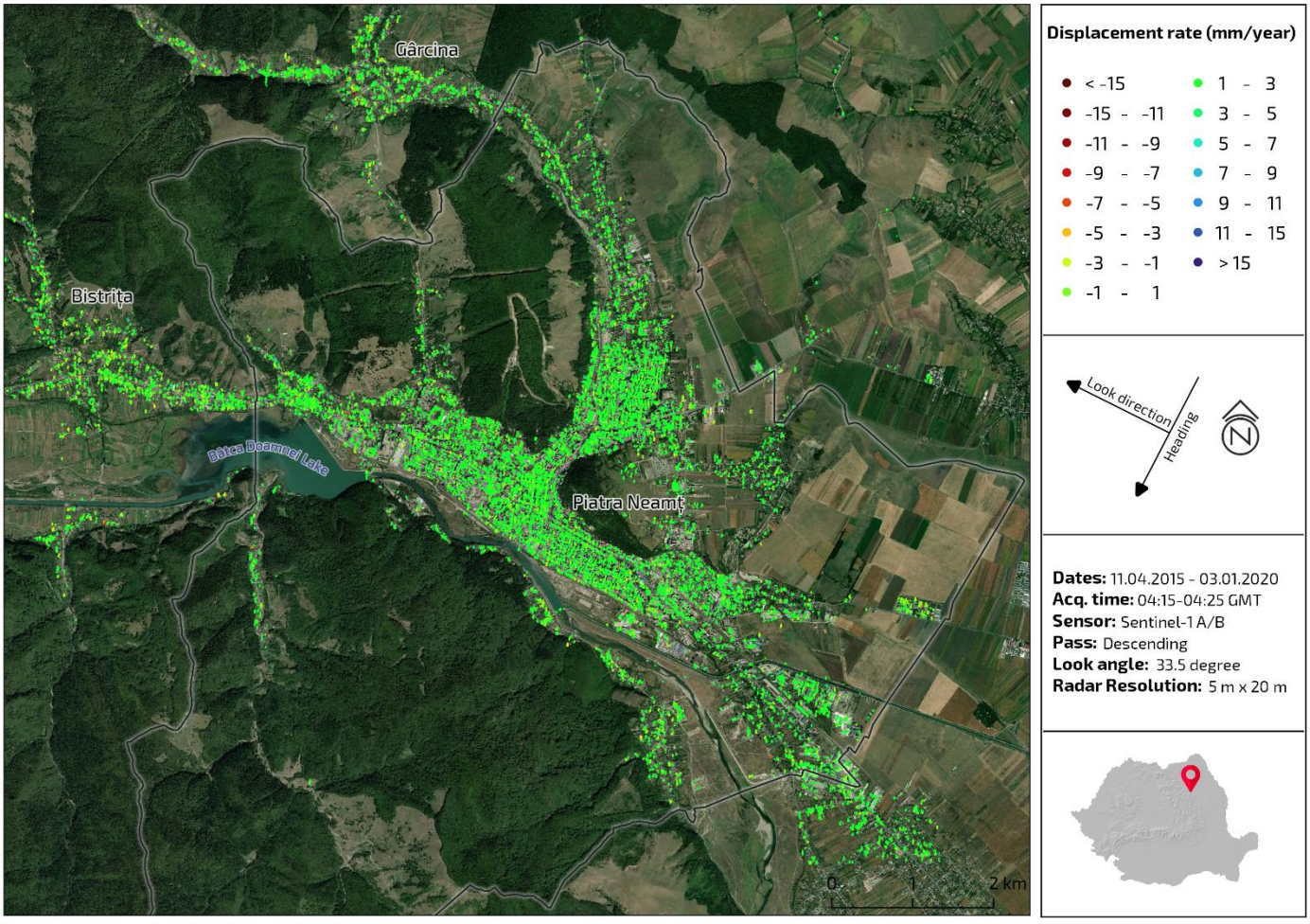
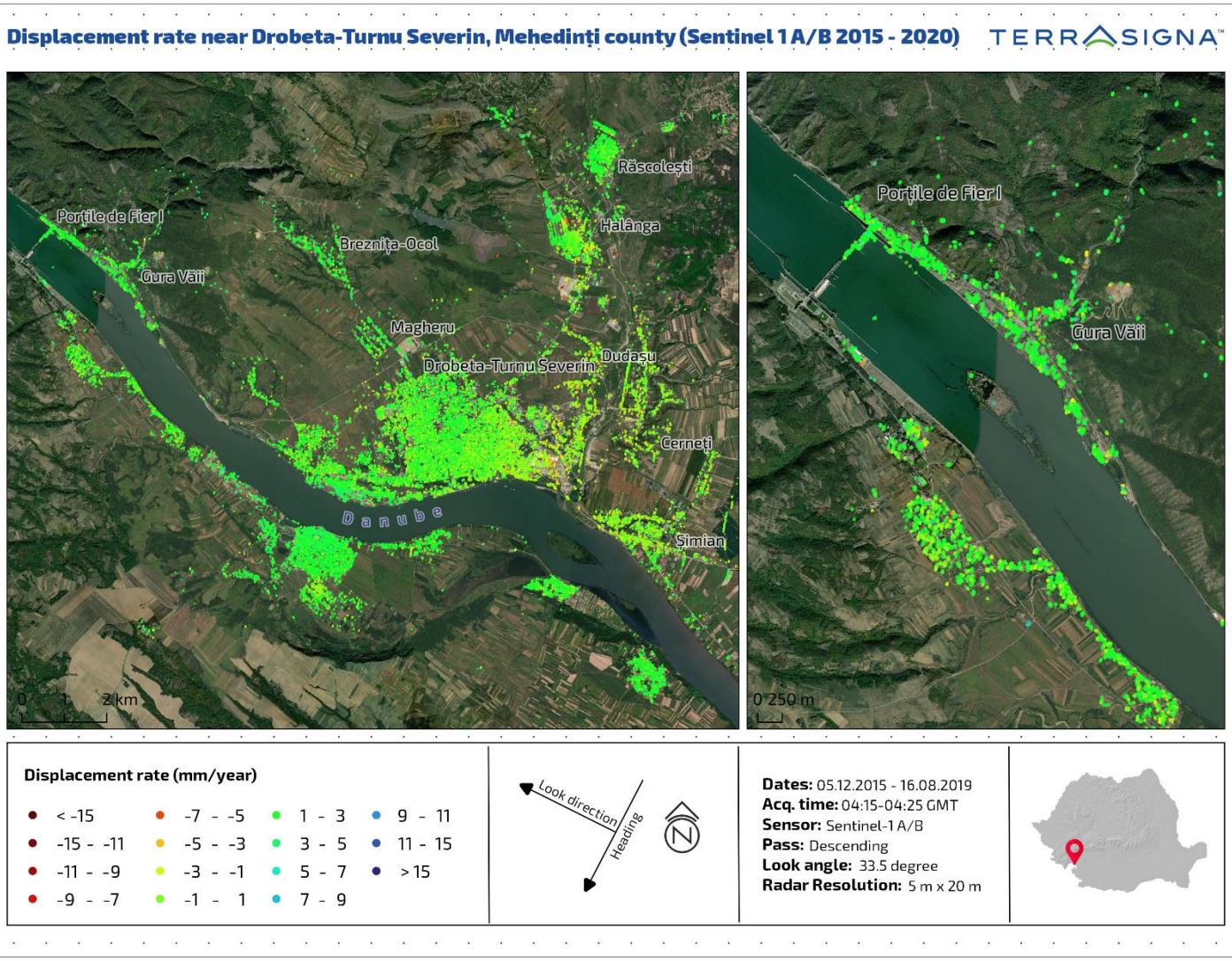


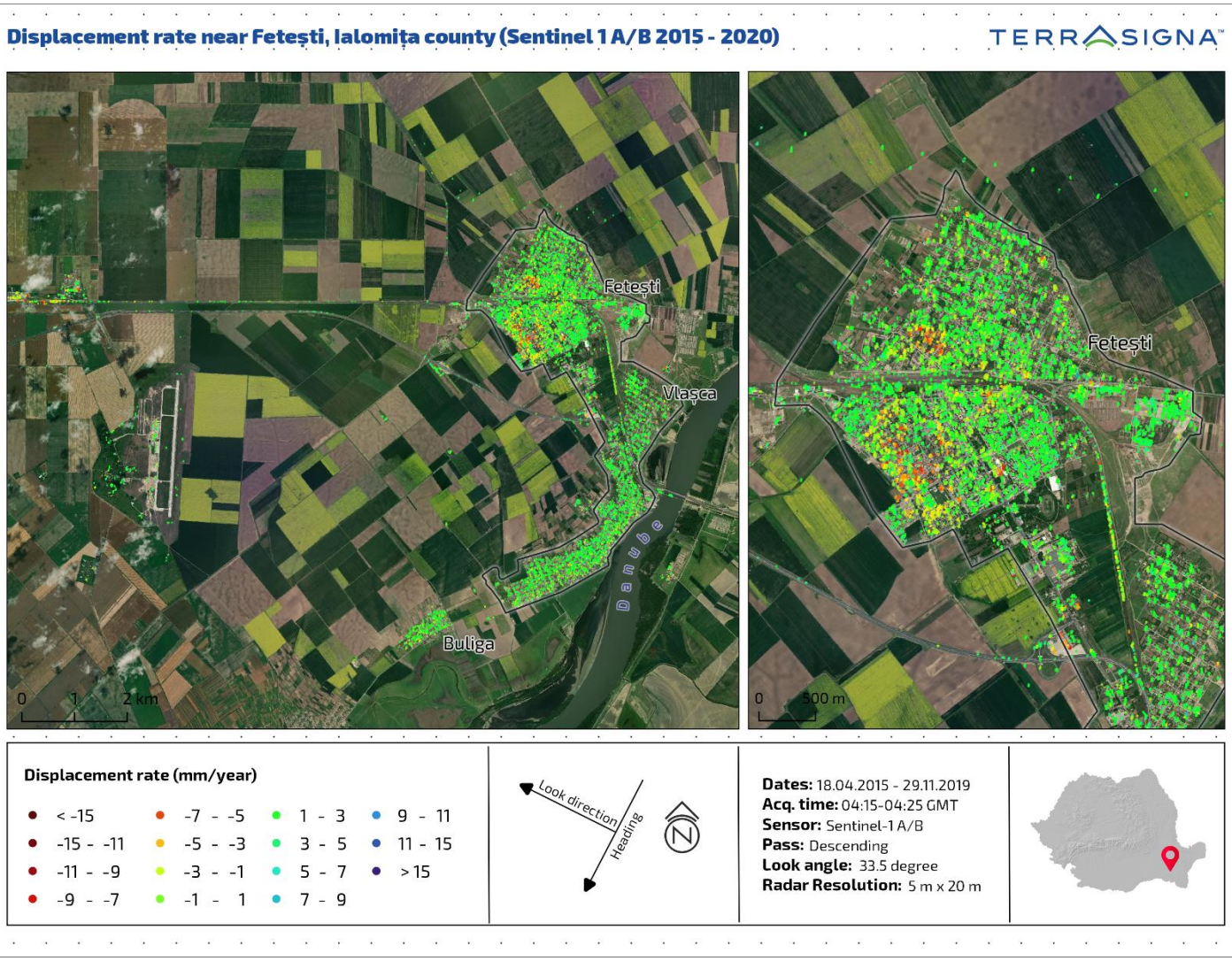
- Because of its privileged location in the Eastern Carpathian mountains, Piatra Neamț is considered one of the most picturesque cities in Romania. Piatra Neamț lies in the Bistrița River Valley, surrounded by mountains, at an average height of 345 m.
- There is no main ground motion pattern detected; overall the city can be found a few constructions or ground affected by light instability (near the river, minor subsidence).
- Unstable slopes can be found in Garcina and Bistrița villages.

Drobeta-Turnu Severin



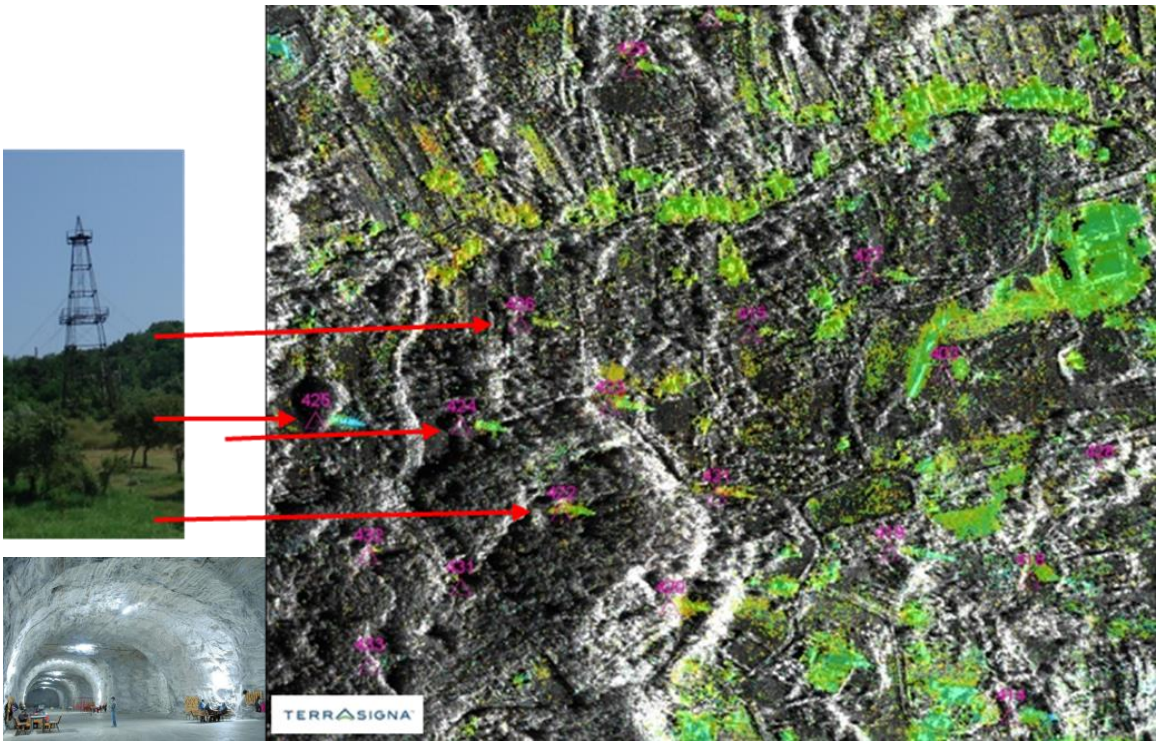
- Drobeta-Turnu Severin is a city on the left bank of the Danube, below the Iron Gates. It lies at the edge of the Topolnița depression.
- The Iron Gate I Hydroelectric Power Station is the largest dam on the Danube river and one of the largest hydro power plants in Europe. It is located on the Iron Gate gorge, between Romania and Serbia.
- The stability of Iron Gate dam and its neighbouring slopes can be detected.
- Extended subsidence up to 9 mm/y can be found mainly on the Industrial Platform East and Banovita district of Drobeta-Turnu Severin, but also in Dudasu, Cerneti or Halanga villages.

Fetești



- Fetești is a small town located in the Bărăgan plain, on the Borcea branch of the Danube, near Cernavoda.
- Large areas affected by subsidence of 3-12 mm/year are identified. They are inside the town, where there are residential houses and blocks.
- The cause seems to be loess settling especially where blocks were built during 1950-1960 without a proper foundation.

Salt Mining



Ocna Mureș

Displacement rate near Ocna Mureș, Mureș county (Sentinel 1 A/B 2016 - 2020)

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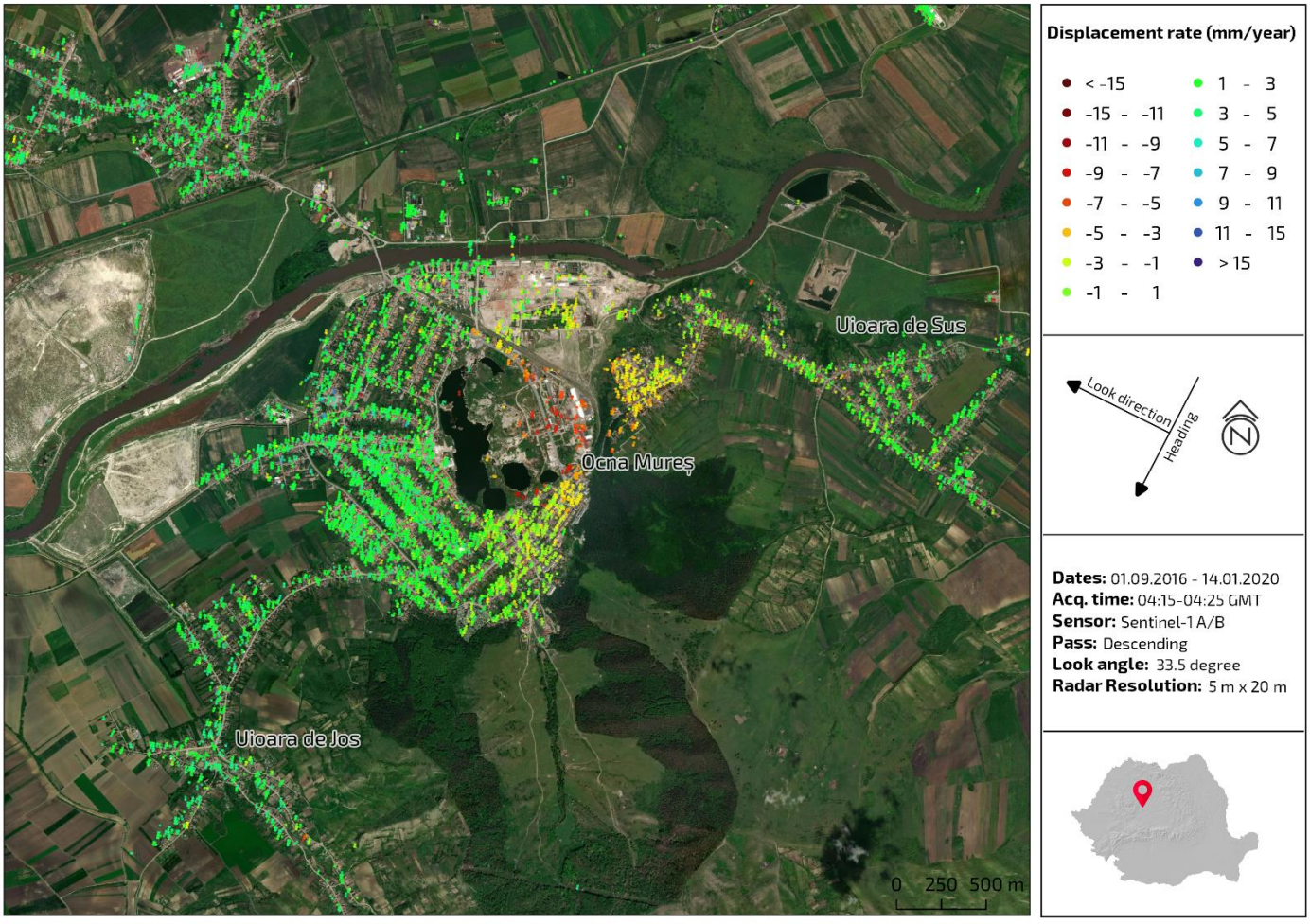
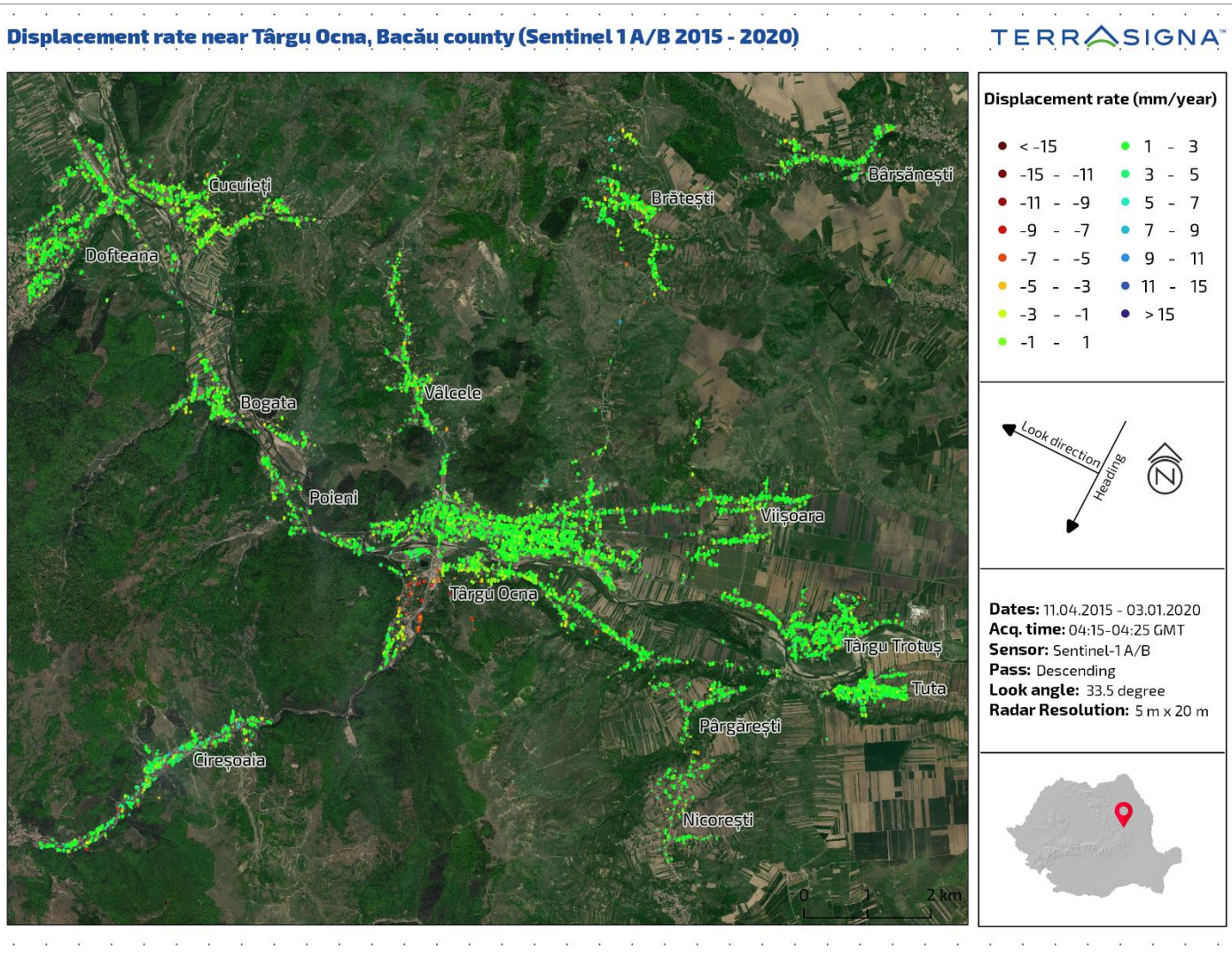


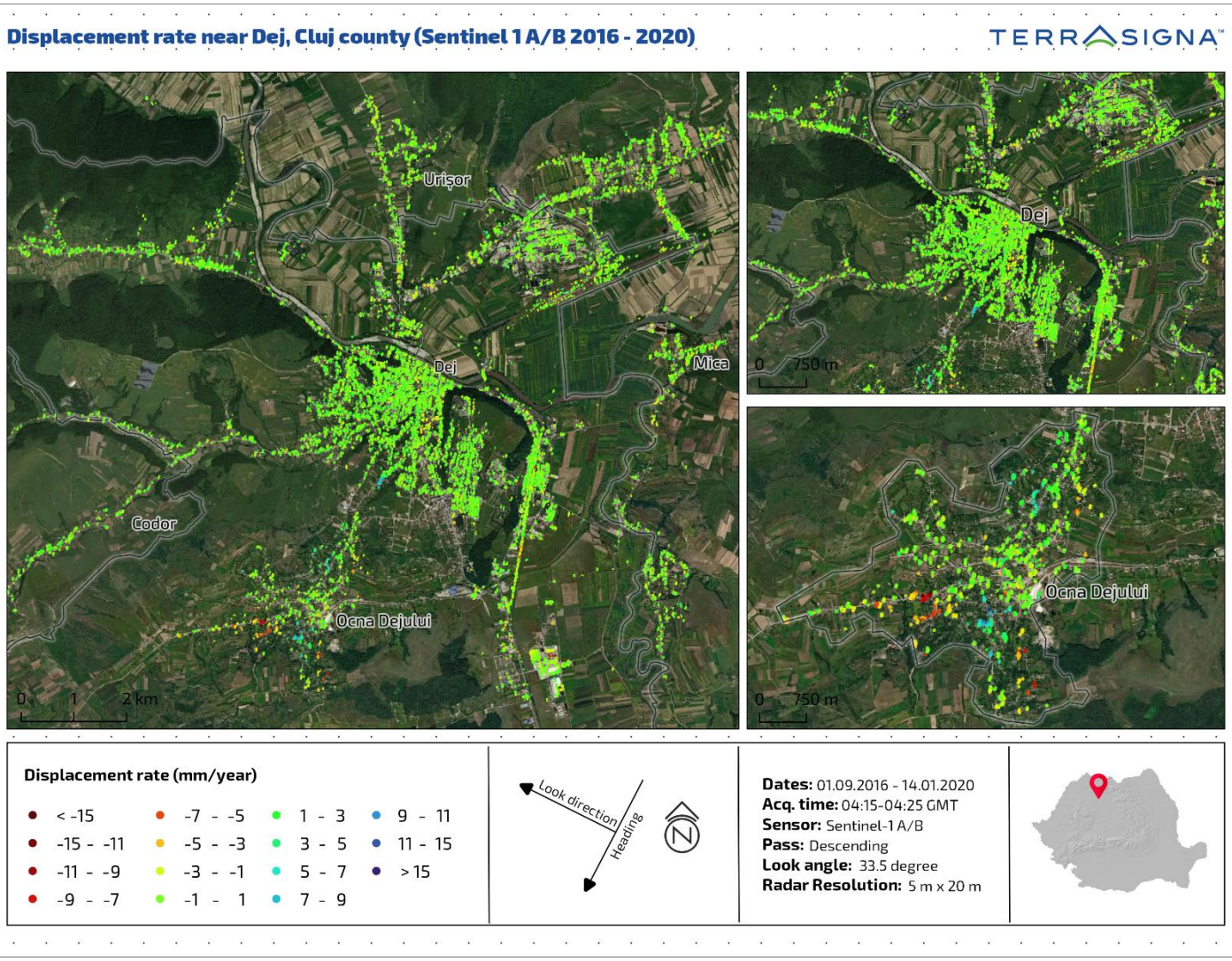
- Ocna Mureș, a small town near the Mureș River, is situated next to a large deposit of salt, mined in the past until the ceiling of the mines collapsed from water infiltration in 1978.
- The downtown was relocated after the mine was flooded as the ground became unstable. Now this area is filled with more than 4 large, very deep lakes. The center of town is now at the base of a large hill, the 'Bania.'
- The extent of the area affected by the instability of the former mine can be well seen in the map (yellow-orange-red areas, with increasing values up to 11 mm/y), east to the lakes.

Târgu Ocna



- Târgu Ocna is built among the Carpathian Mountains on bare hills formed of rock salt. In fact the English translation of Ocna is salt mine. Târgu Ocna's main industry is salt production, as it is the largest provider in Moldavia.
- Agas River and Slanic River cross the city.
- The instabilities are detected in the south part of the city, not in the north where the salt mine is located, on the slopes east of Magura Hill, near the Slanic River. Values are up to 7-9 mm/y along the LOS.

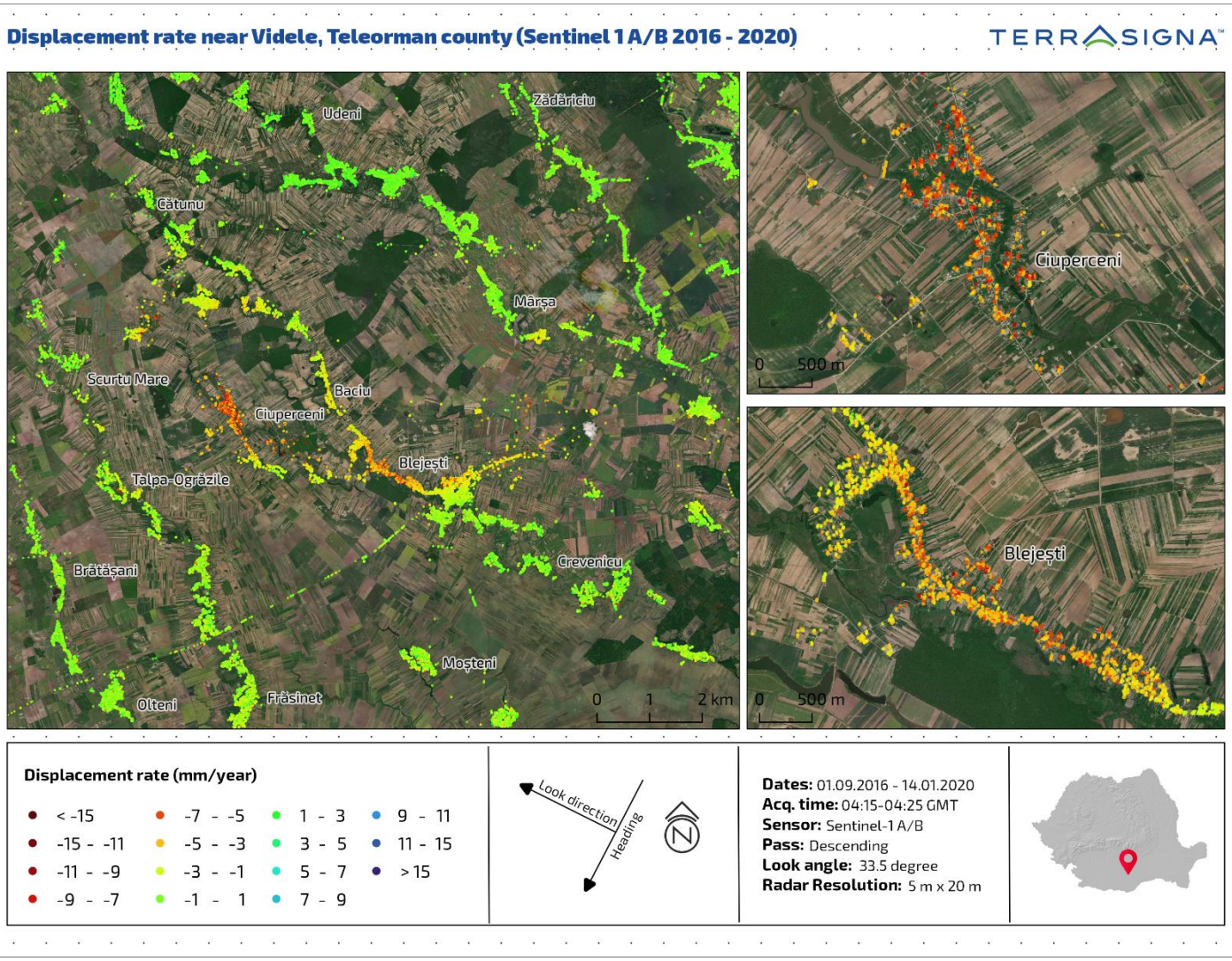
Dej



- Dej lies where the river Someșul Mic meets the river Someșul Mare, in Transylvania, between hills and has its altitude varies between 220 m and 420 m.
- 2 km south of Dej, lies Ocna Dejului – an ancient salt extraction mine.
- It is an area prone to landslides, floods and risks related to salt extraction.
- Medium subsidence (5-7 mm/y) can be found in the city near the Florilor Hill, between the Crangului Str. and the small lake (called “Balta”) in the south of Dej.
- Unstable slopes (up to 15 mm/y) can be found in Ocna Dejului, the area south and west of the salt mine.

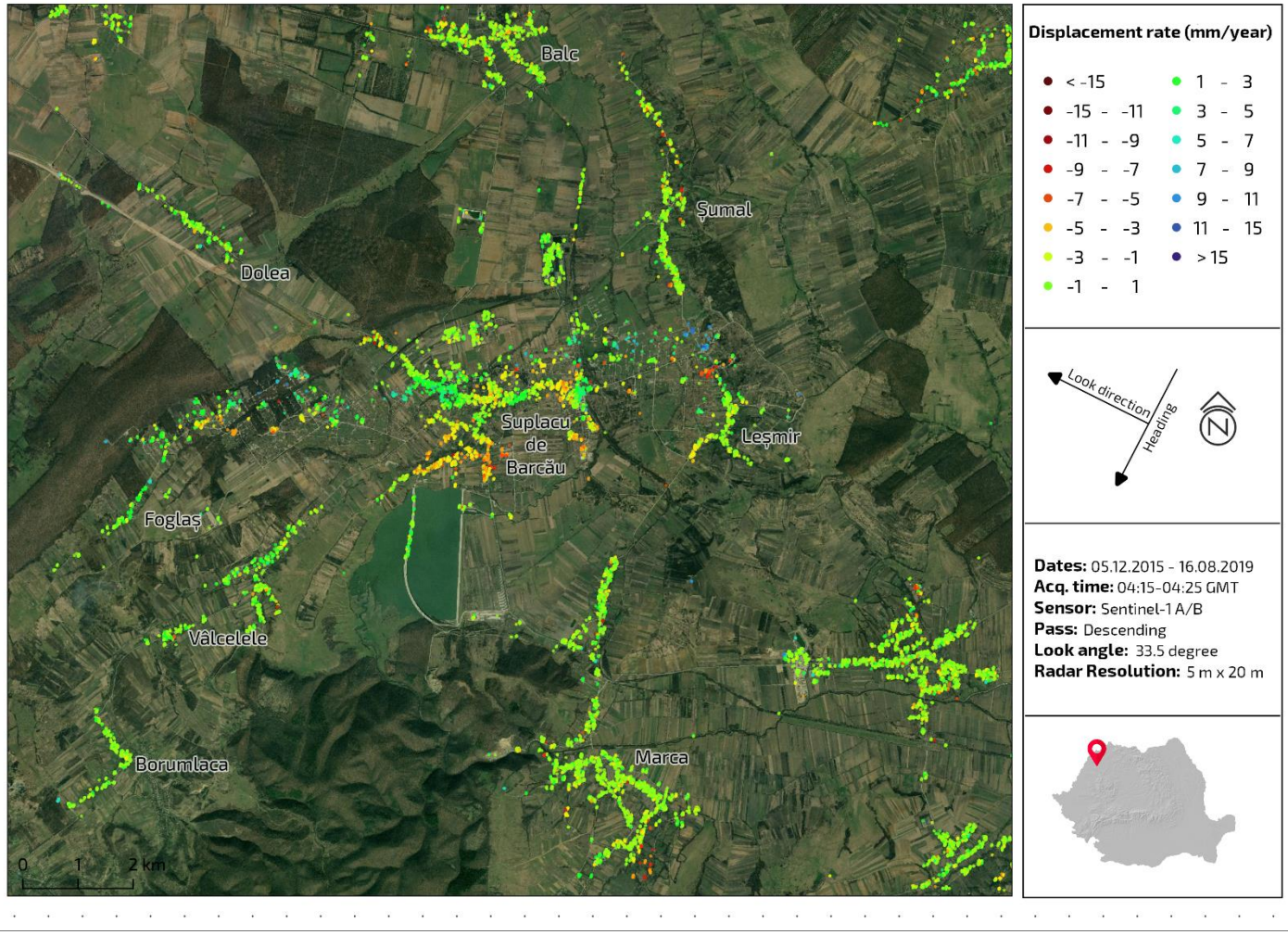
Oil & gas

Videle



- This area remarks itself through extended medium subsidence (3-9 mm/y), over an area of more than 20 km long and 5 km wide.
- Videle is a town with a population of 11,112 in 2011, S-E of Bucharest at ~ 48 km distance. It is known for oil and gas extraction.
- The subsidence pattern extent covers the north part of the town Videle and the villages Blejesti, Baciu, Ciuperceni and Puranii de Sus.

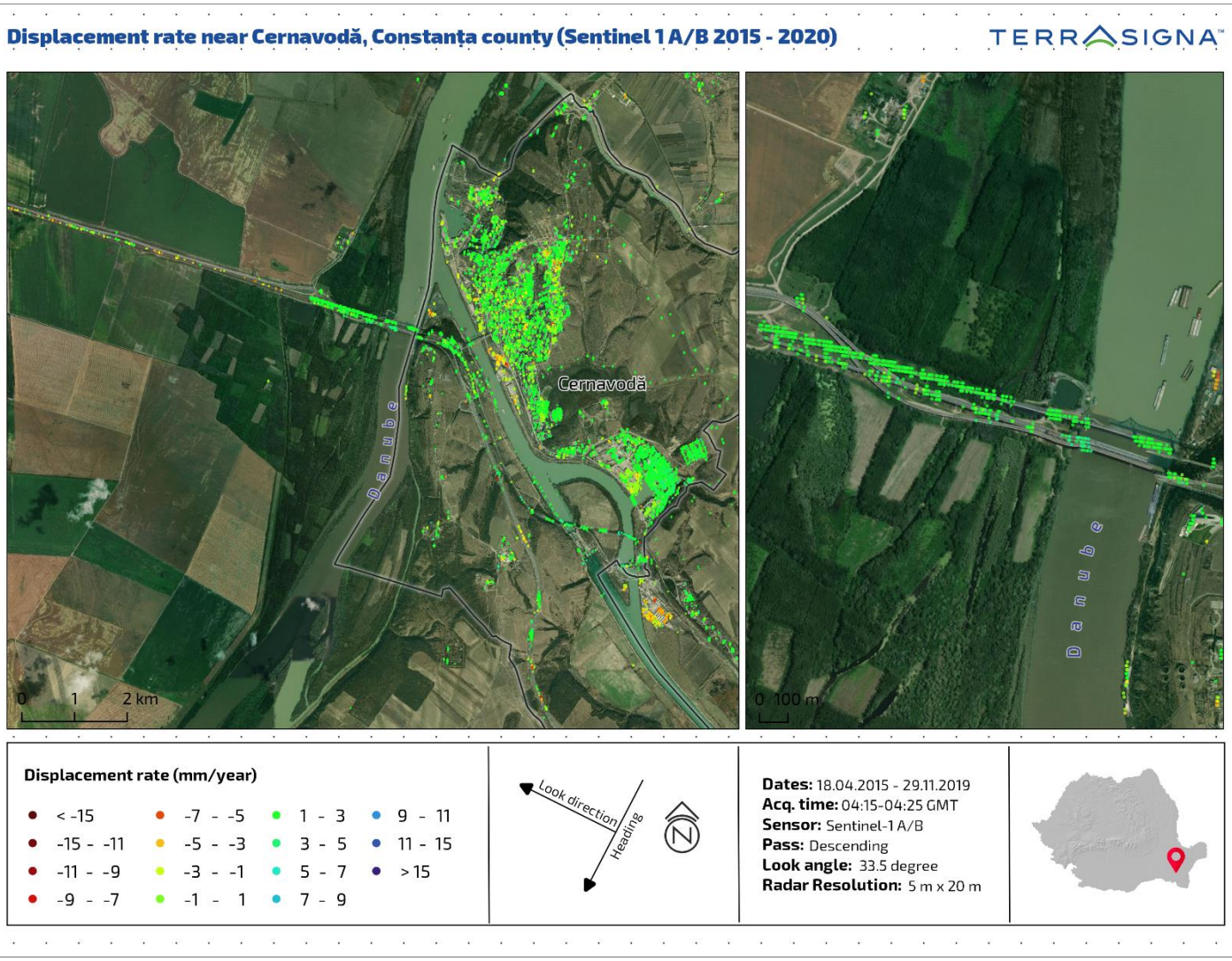
Suplacu de Barcău



- Suplacu de Barcău is a commune in Bihor county, which lies on an oil field discovered in 1956 and exploited since 1961.
- Extended medium subsidence combined with extended uplift can be detected with InSAR. The uplift pattern forms a long lane from West to East of ~ 6 km length, with a maximal average displacement rate of 10 mm/y north of Lesmir.
- Subsidence of variable intensity (3-10 mm/y) can be noticed in Suplacu de Barcau and on the oil fields nearby.

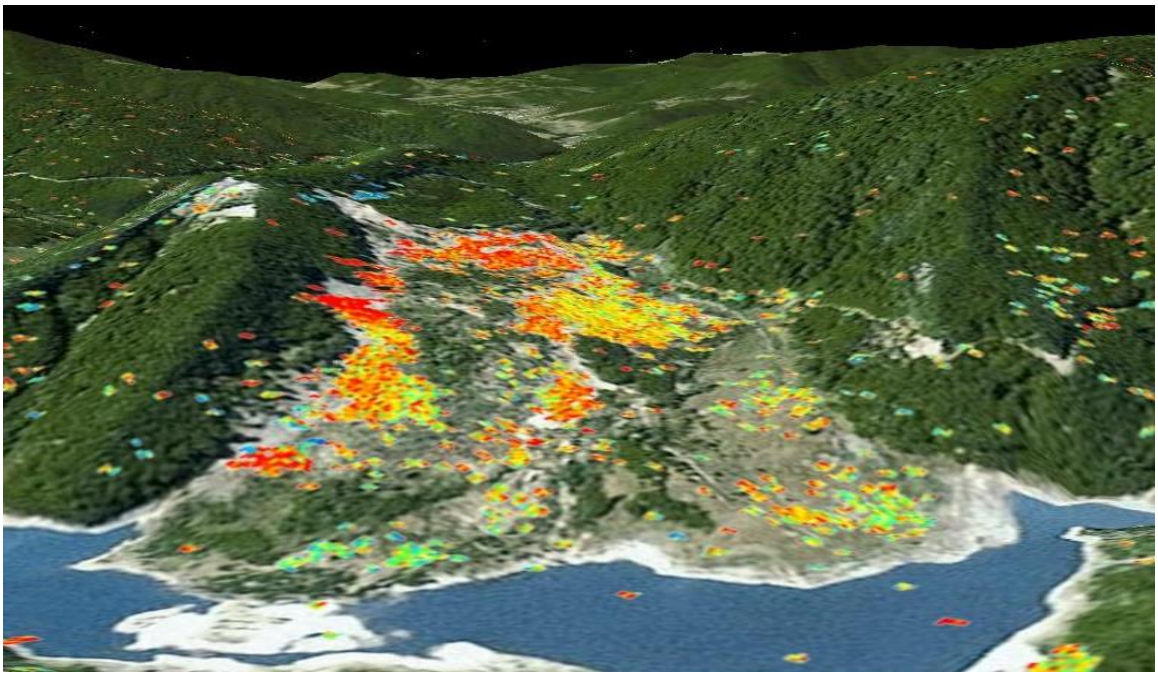
Nuclear power plant

Cernavodă

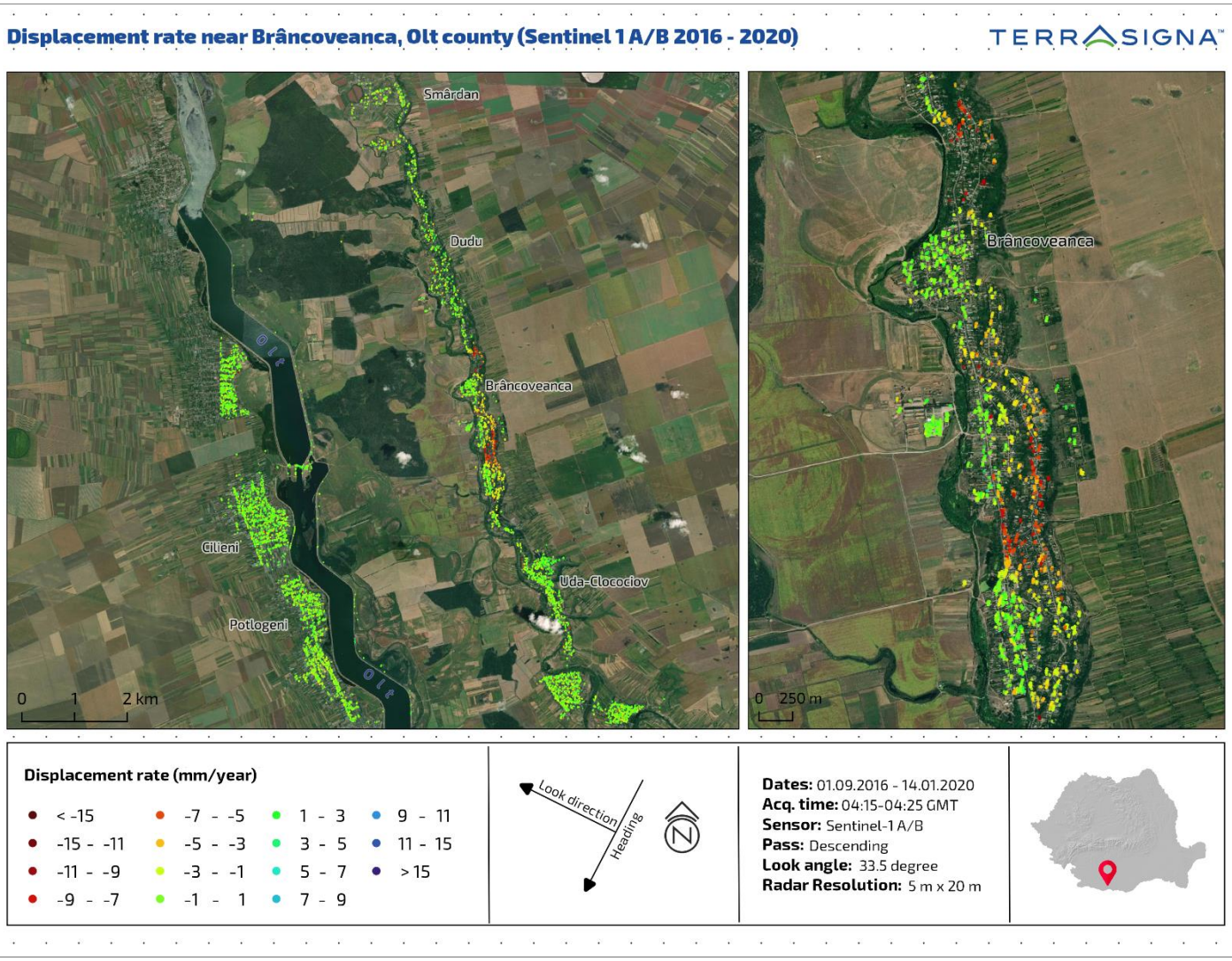


- Cernavodă, a fluvial port and a small town near Danube River, is important because it houses the Cernavodă Nuclear Power Plant (NPP).
- The Anghel Saligny Bridge, built between 1890 and 1895 over the Danube, shows stability even nowadays (right picture). Also the Nuclear Power Plant area shows stability.
- Two instable areas located in the immediate vicinity of the Danube River can be identified. They are slowly subsiding with 3-6 mm/year.
- Also in Cernavodă town there are some small areas which are slowly subsiding with 3-6 mm/year.

Landslides

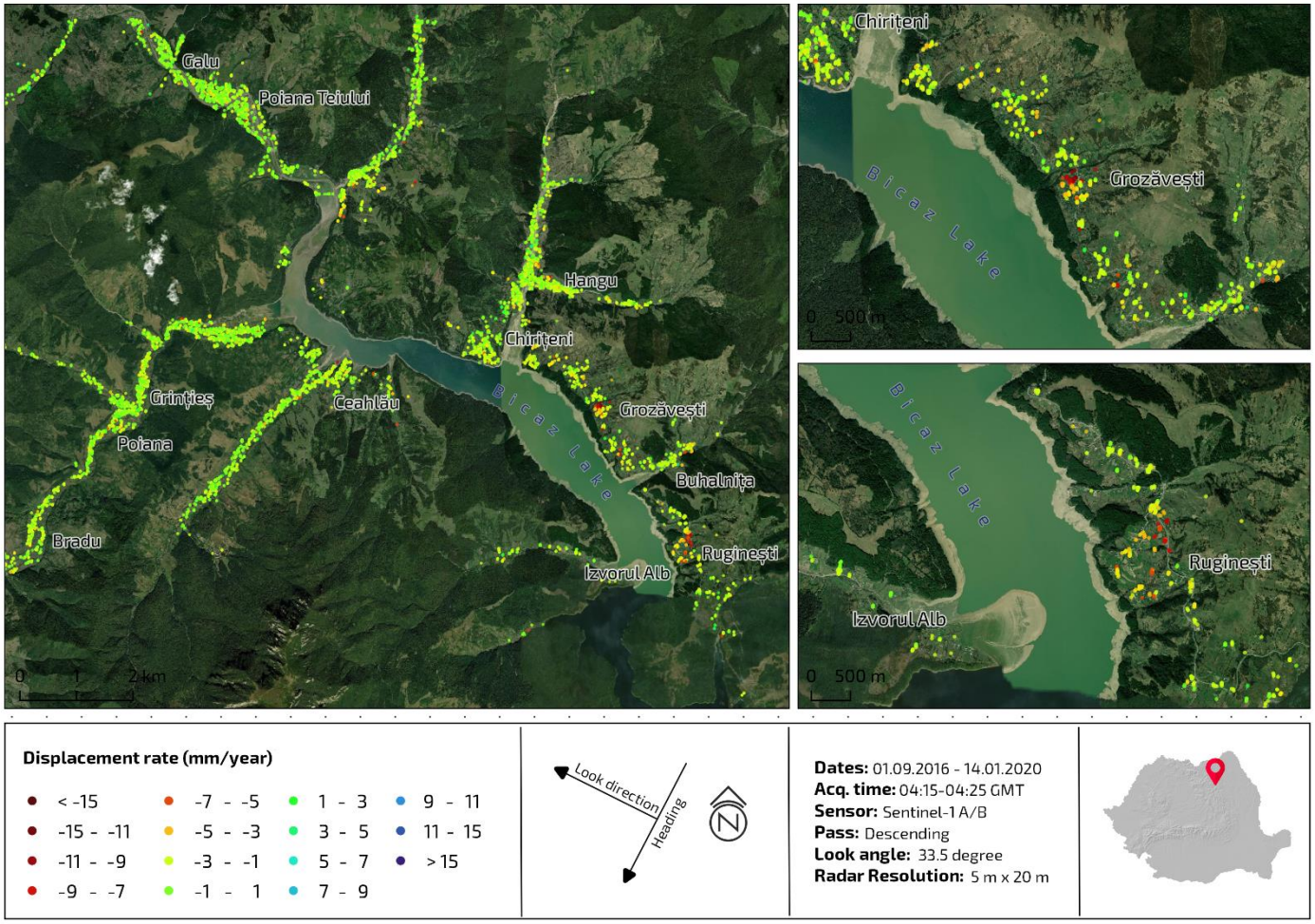


Brâncoveanca



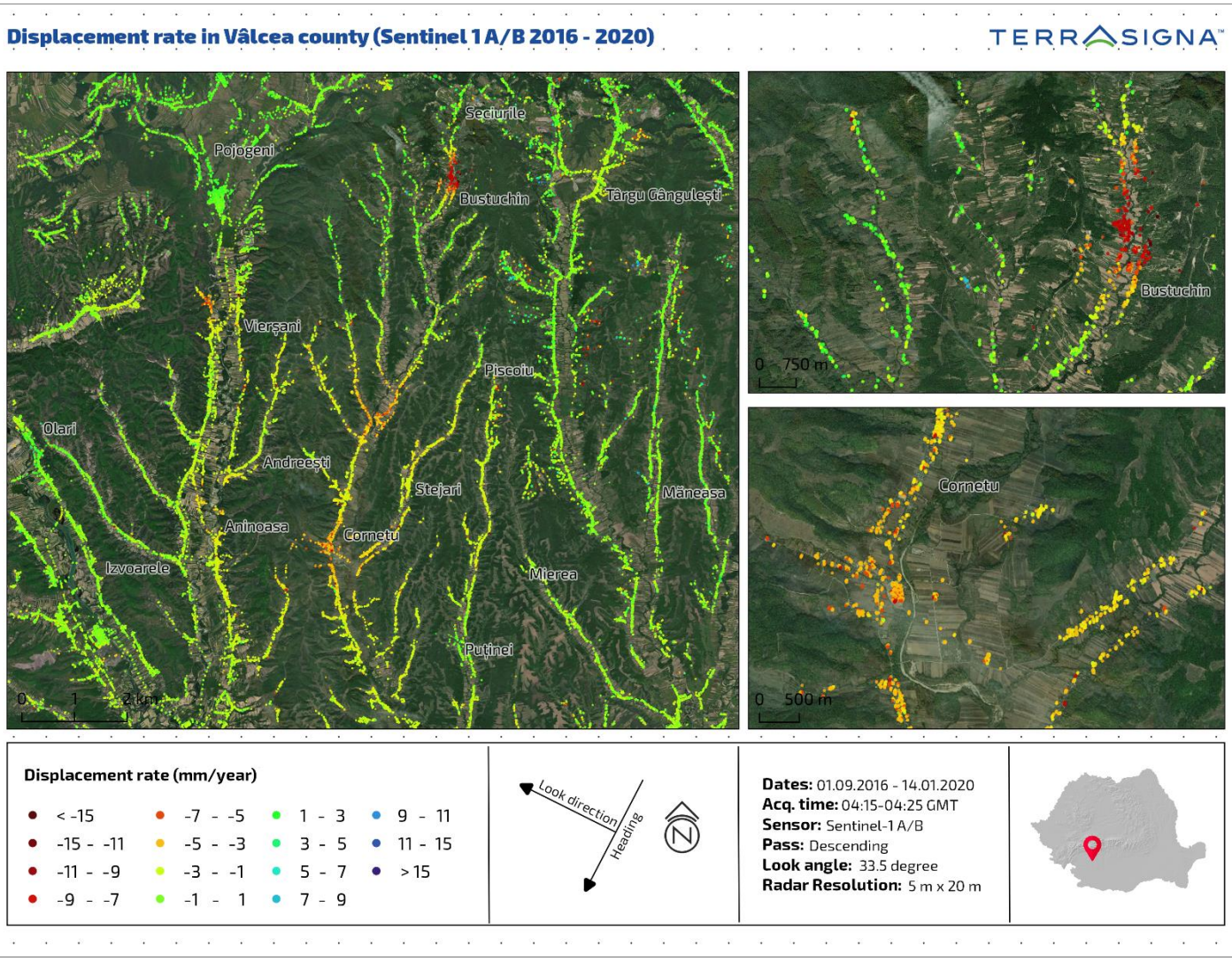
- Brâncoveanca and Slobozia Mândra are small villages in Teleorman County, developed on a slope between 2 terraces: the western terrace at 40 m above sea level, while the eastern one at 110 m altitude.
- The settlements, Uda Clocociov, Slobozia Mândra, Plopii Slăviteşti , Brâncoveanca and Beciu, along a strip of 15 km, are known to be prone to shallow (1-5 m depth) and very slow (< 6 cm/year) landslides, according to a public document issued 2010. The mentioned causes are cumulative effects of seismic movements with geological conditions.
- Using Sentinel-1, the extent and the intensity of the instabilities can be mapped. Ground motions of 7-15 mm/y along LOS are detected in the red areas of Slobozia, Mândra and Brâncoveanca.

Bicaz Lake



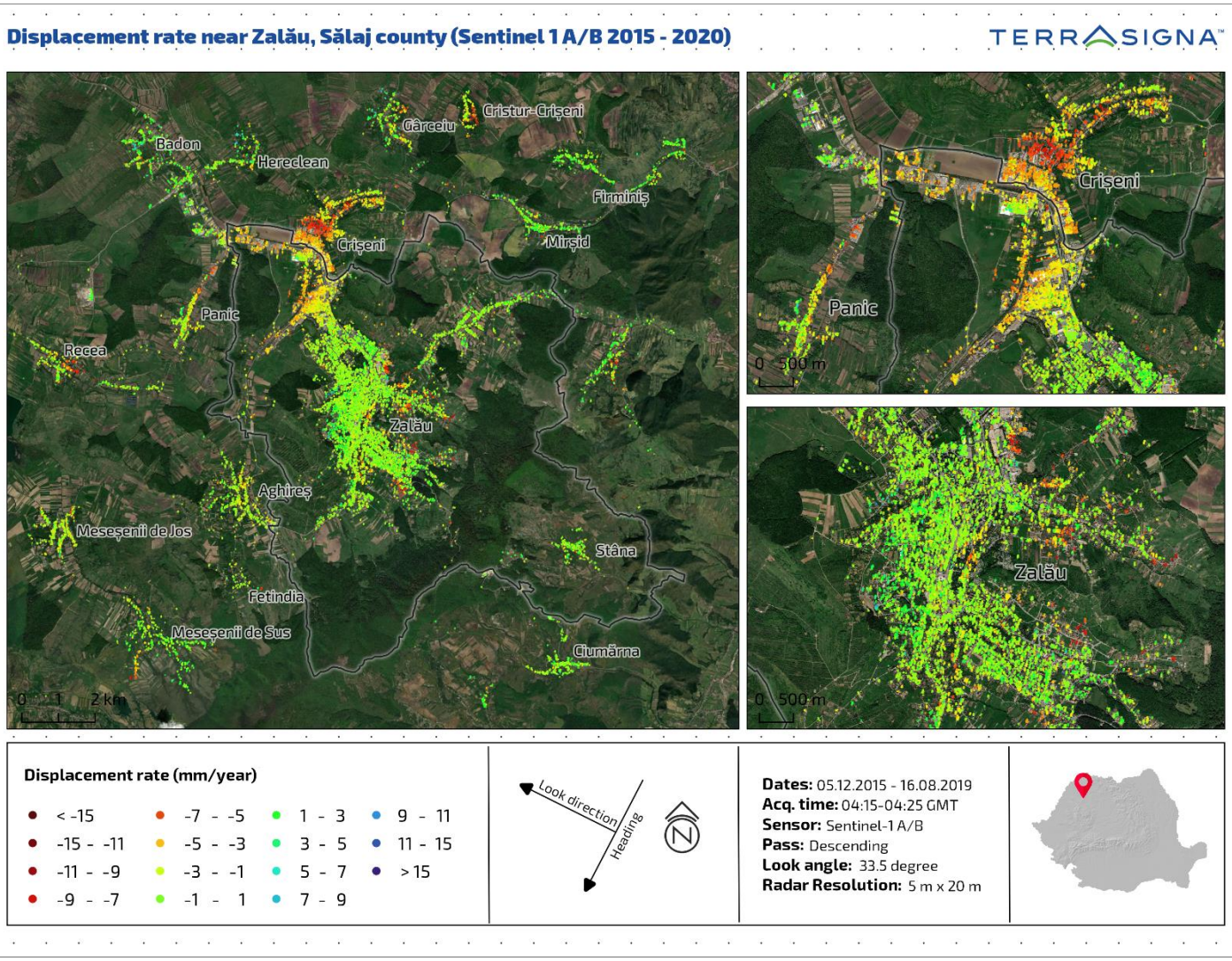
- The Lake Izvorul Muntelui, also known as Lake Bicaz, is the largest artificial lake in Romania; it was created after the completion of a dam built on the river Bistrița between 1950 and 1960 in order to generate hydroelectricity. The lake has a length of 40 km, an area of 31 km² and a maximum volume of 1,250 million m³. The lake is a tourist destination in the region, especially in summertime.
- Highest instabilities of 11 mm/y can be detected on properties from Grozavesti village over an inclined area of 0,2 km^2. Also in Ruginesti village, on a hill with altitude variation from 680 m to 520 m on a distance of approx. 750 m, there are displacements along LOS between 3-11 mm/y. In fact there are many instabilities on both slopes of the lake, as e.g in Hangu, Poiana Largului or Poiana Teiului villages, areas known for frequent landslides due to rockslides and mudslides.

Bustuchin / Valcea county



- Valcea County is a region known to be prone to landslides, due to relief and geological conditions, cumulated with industrial (mining, oil&gas, etc) activities.
- In Poiana Seciuri and Bustuchin villages (the red area in the above map) already important, damaging and repeated landslides took place in the past years, and the ground is not stabilized, since motions of more than 2 cm/y are measured with InSAR.
- Extended medium subsidence can be detected also in Cornetu, Hurezani, Socu, Tuturu, Parasusani and Turburea villages.
- Bustuchin and Hurezani are also known for oil&gas industry.

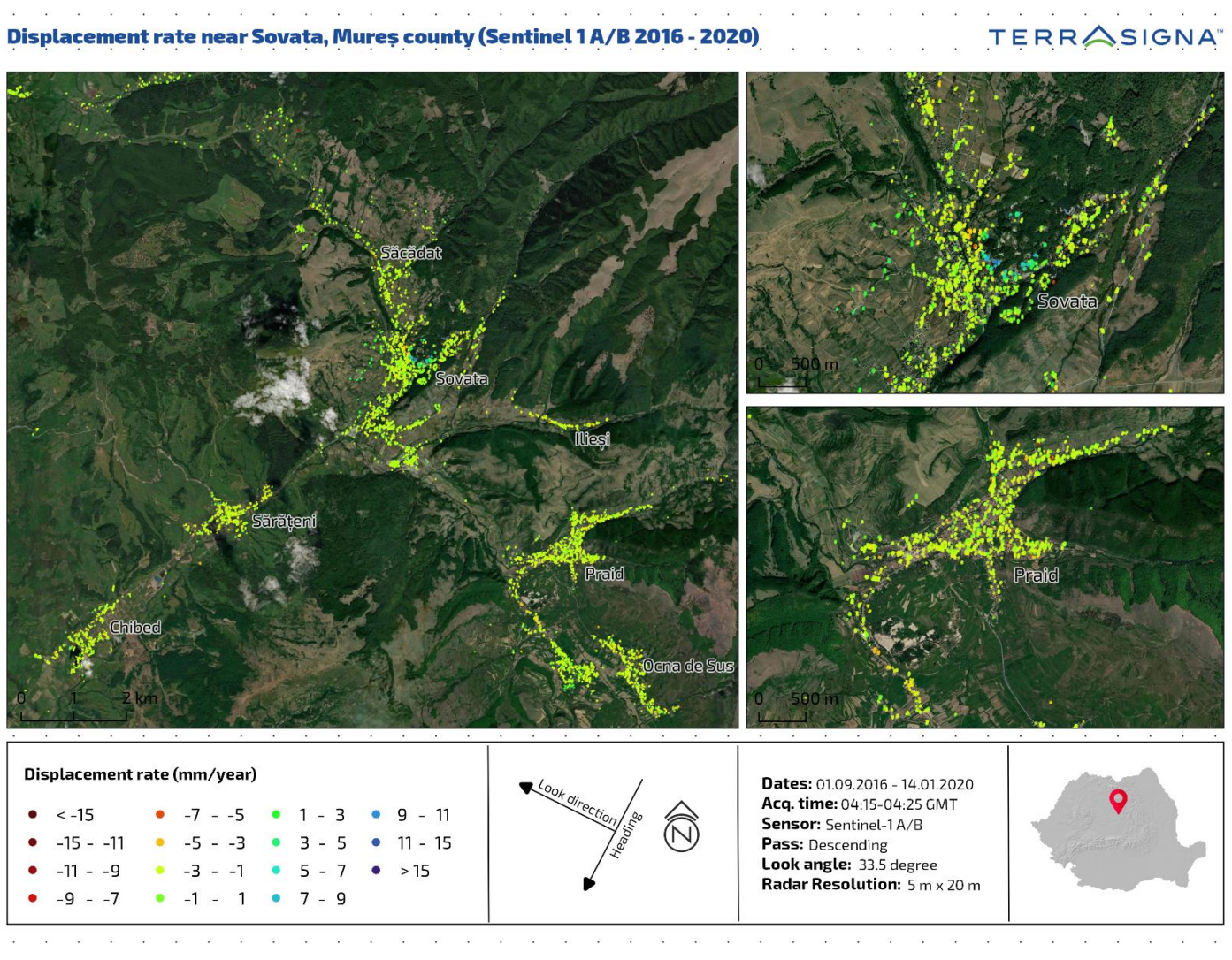
Zalău



- Zalău lies in the Zalău Valley, at the junction of the Apuseni mountains and the Eastern Carpathians, between 197 m and 345 m above sea level.
- Many active and large landslides can be detected in Zalău city, especially in the eastern part of the city, where the geomorphologic risk is high and it cumulates with anthropic causes. The most affected districts are: Citadin/Garii Str., Porolissum, Sarmas, Brădet, Stadion, Meses and city center.
- Extended medium subsidence is found in Criseni village, north of Zalău.
- Also the other settlements in the Zalău region, as e.g. Recea, Mesesenii de Sus si Jos, Moigrad-Porolissum, Cristur-Criseni or Garceiu, have unstable slopes.

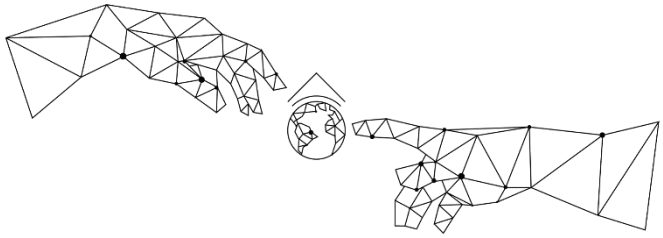
Thermal waters

Sovata & Praid



- Sovata is a small town situated between the river Corund and the valley of the Târnava Mică. The geological events in 1875 gave birth to the Bear Lake, which is unique in Europe, its water being helio-thermal and salty, with therapeutic effects.
- Praid is known for the salt mine that both provides salt for industry and attracts over 400,000 tourists every year.
- Instabilities up to 7 mm/y are found near the hill in N-E of Sovata and Lake Negru, above the Trandafirului and Stejarisului streets.
- In Praid, small instabilities up to 5 mm/y can be detected right near the Salt Hill Nature Reserve.

Afterword



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