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info@asrc.ro www.asrc.ro

Four-Dimensional Earth Observation: Space and Time

Scientific and Technical Subcommittee of COPUOS

Item 8. Disaster management support

February 2011, Vienna

Presentation Outline

- **Spatial Domains and Accuracy**
- **Automatic Change Detection Techniques in Satellite Imagery**
  - Fluctuation of the Water Extent (Danube Delta, Romania)
  - Black Sea Shore Evolution
  - Urban Growth Monitoring (Bucharest, Romania)
- **Interferometric Synthetic Aperture Radar (InSAR) Techniques**
  - Landslides Monitoring (Siriu, Ocnele Mari – Romania)
  - Glacier Movement (Imja Lake, Himalaya)
  - Environment Monitoring (Danube Delta, Romania)
  - Ground Stability Monitoring in Urban Areas (Bucharest, Romania)

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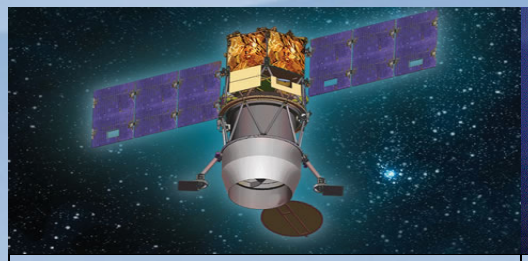
Spatial Domains and Accuracy



Remote sensing domain

0.5m - undefined

Photogrammetric domain

10cm – 1m

Interferometric domain

1mm – 20cm

↓ Macro-dynamics ↓ Time

↓ Mapping ↓ Space

↓ Micro-dynamics ↓ Time

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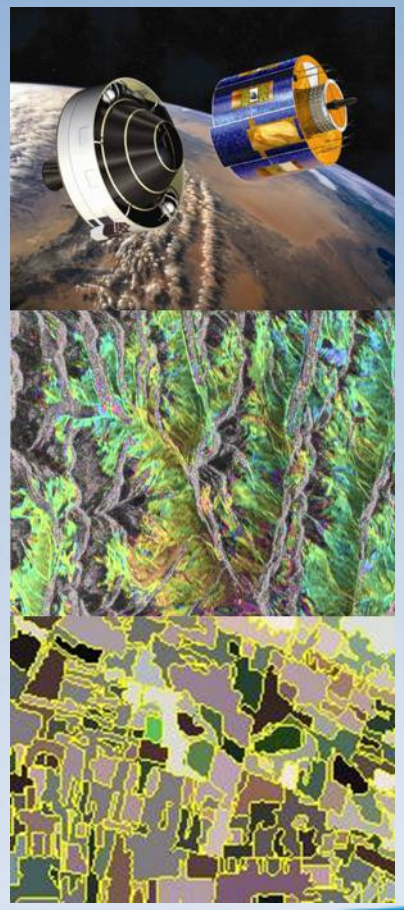
Automatic Change Detection Techniques In Satellite Imagery



- Adding a new dimension to classic cartographic products - **time**
- Using available airborne and space-borne optical imagery, urban and geomorphological changes can be **detected and estimated**.
- Improving classic cartographic products - increasing the density of the geodetical network by using radar targets that can be **accurately monitored from space** (similar to DGPS but without a ground segment).

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Applications

- Monitoring natural disasters:
  - Floods development and impact on the eco-systems (**e.g. Danube Delta**)
  - Soil erosion in high risk areas such as the **Black Sea** and Danube shore
  - Ground deformation due to mining, groundwater/oil/gas extraction, earthquakes and other
- Urban growth dynamics (**e.g. Bucharest**)
- Deforestation dynamics

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Fluctuation of the Water Extent Extracted from LANDSAT Imagery

Case Study: Danube Delta

Danube Delta

- The second largest Delta in Europe
- It represents an unique ecosystem, consisting of a network of river channels, shallow bays and hundreds of lakes, interspersed with extensive marshes, reed-beds, islands and flood-plains
- It is formed by the 3 channels of the Danube: Chilia, Sulina, and Sfântu Gheorghe

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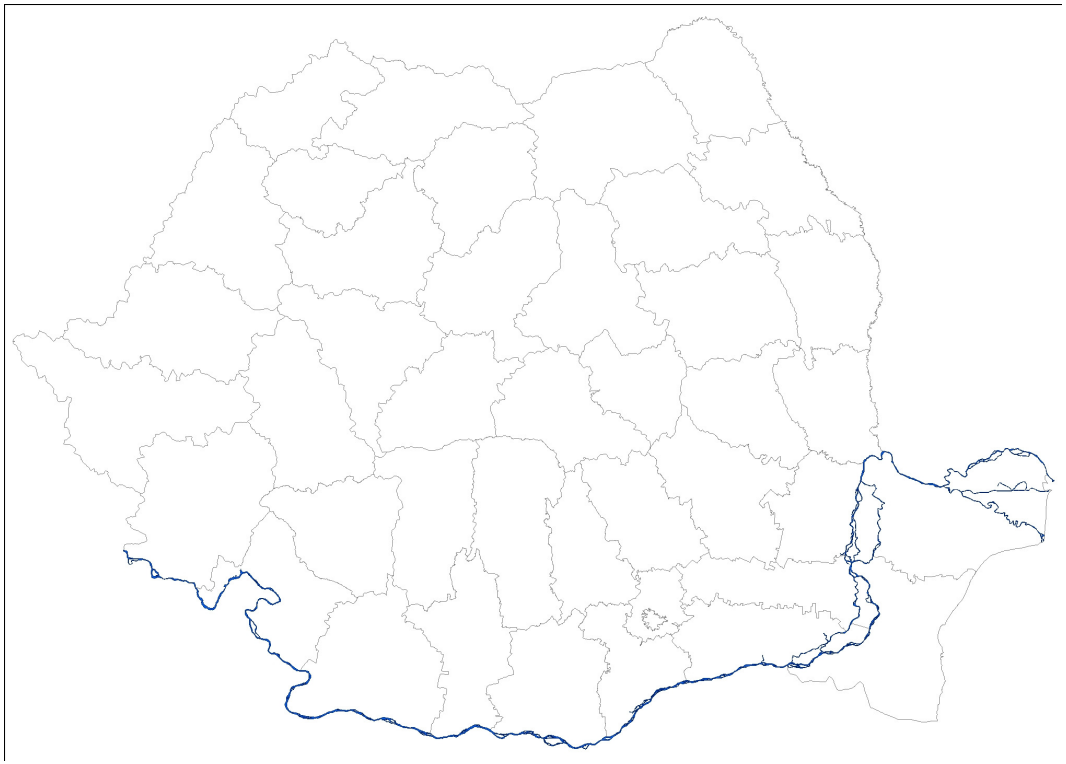

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Danube Delta

- It is the only delta in the world declared a reserve of Earth's biosphere and UNESCO World Heritage site

Danube Delta

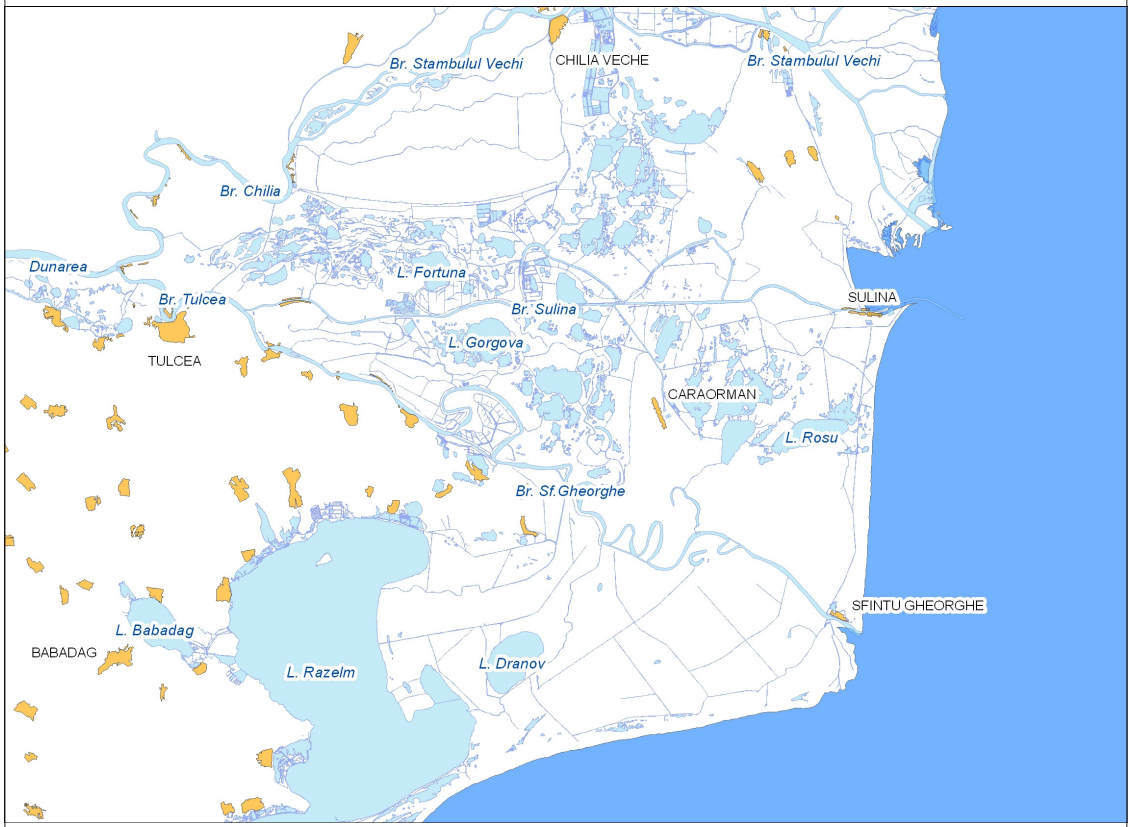
- It represents a natural open-air biodiversity museum, with 30 types of ecosystems

- It forms a valuable natural buffer zone, filtering out pollutants from the River Danube

The Area of Interest

- It covers more than 1300 sq.km.

- It is located in the central-southern part of the Danube Delta, South from Sulina channel



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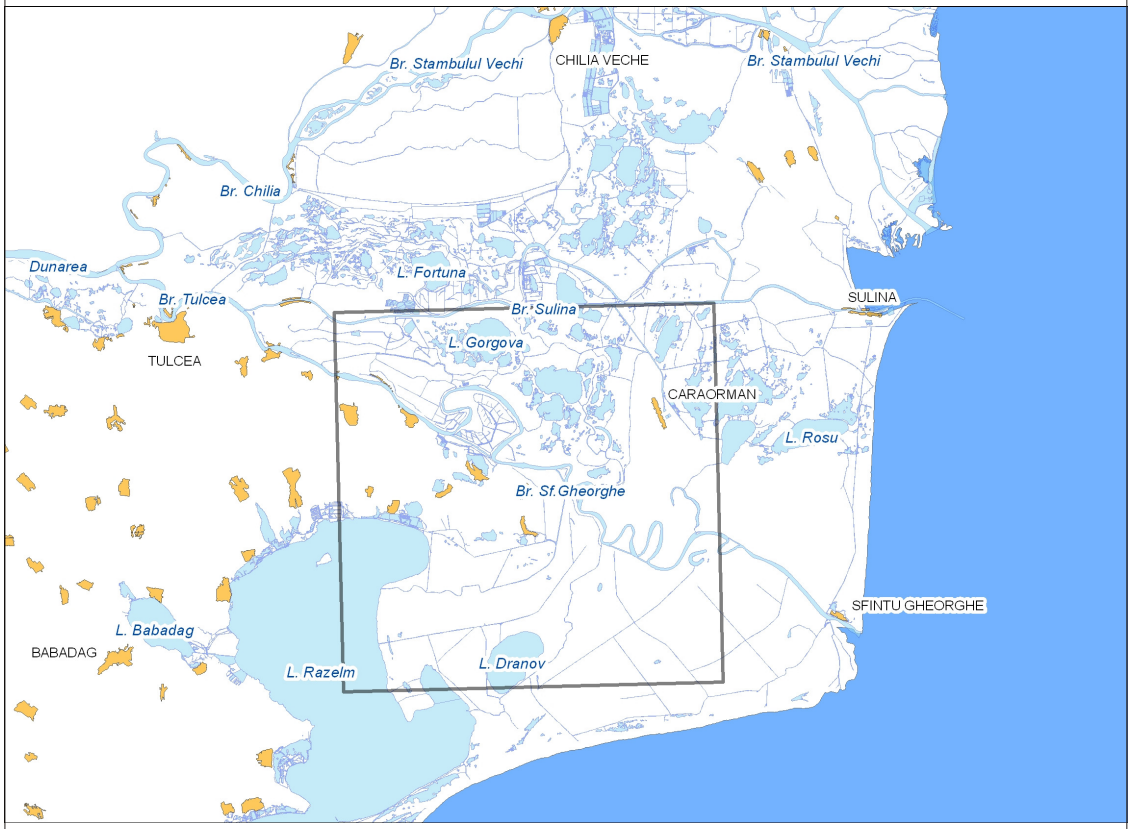

Fluctuation of the Water Extent Extracted from LANDSAT Imagery
Case Study: Danube Delta

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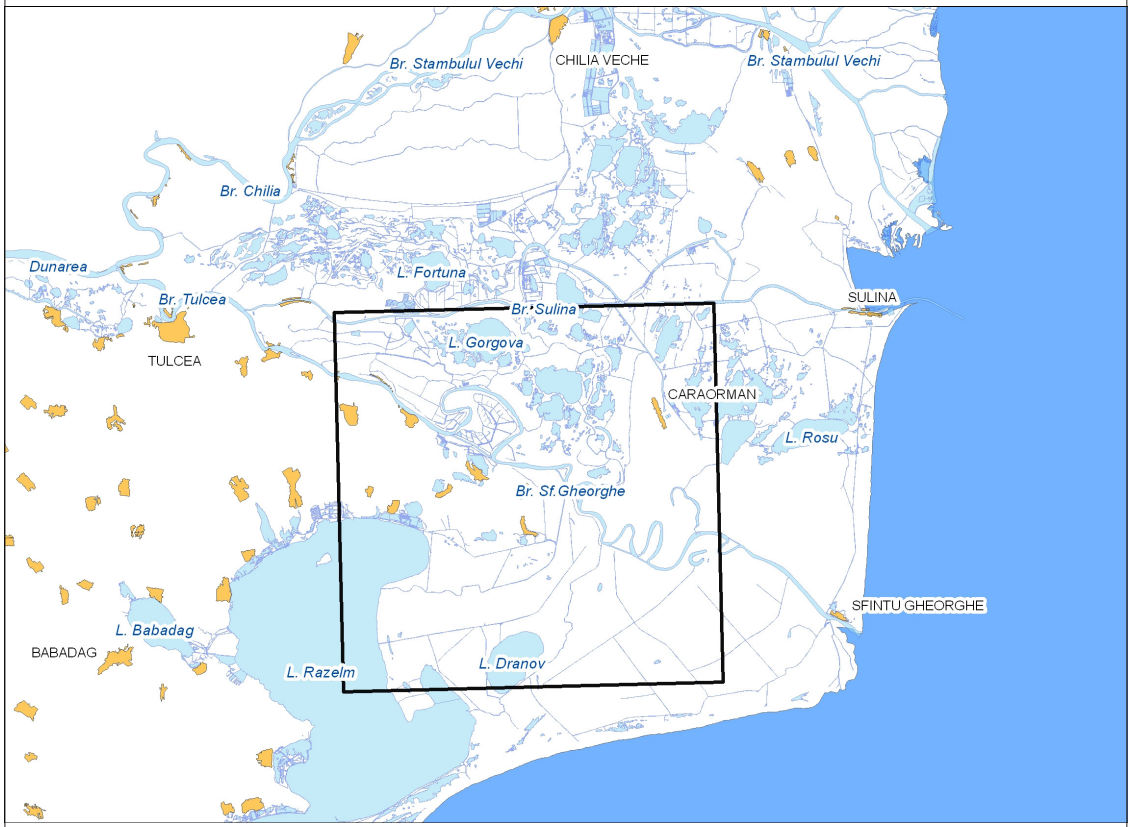

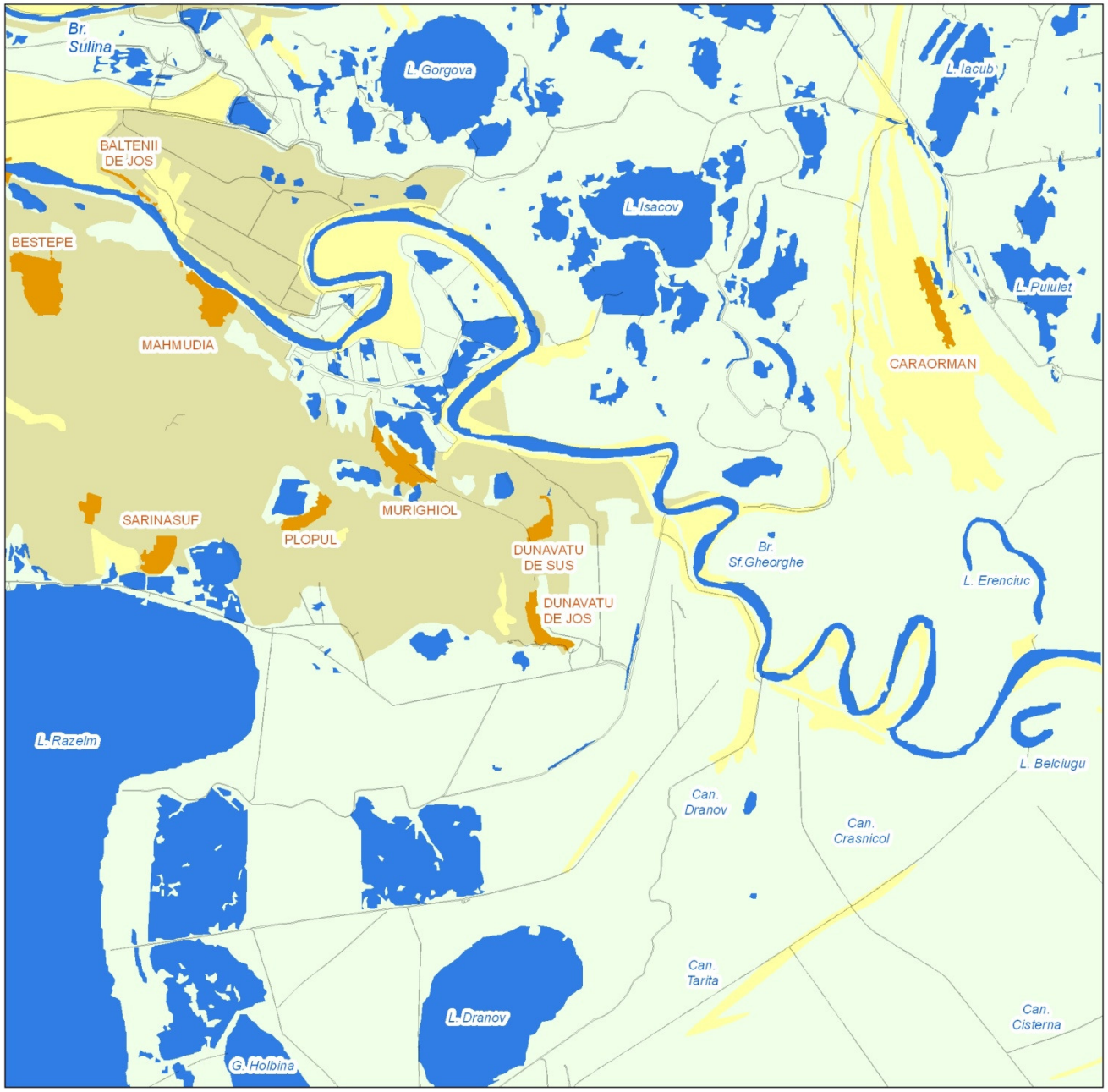

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year
2010

1984 **05.07.1984**

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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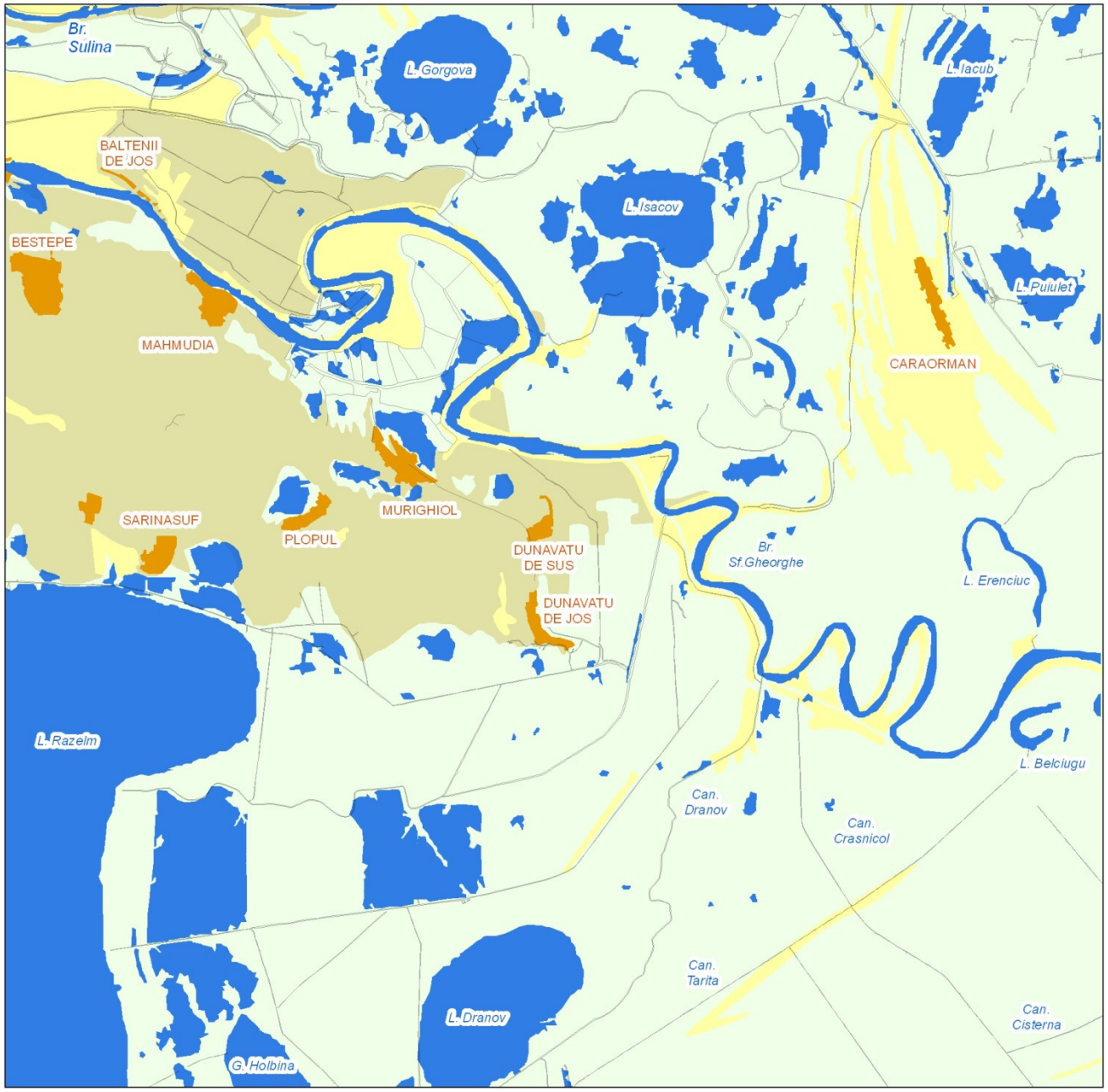

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year
2010

1984

06.07.1985

- Water
- Channels
- Localities
- Agricultural areas
- Semi natural areas, sand dunes.
- Wetlands

0 2.5 5 km

N

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Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year
2010
08.05.1986
1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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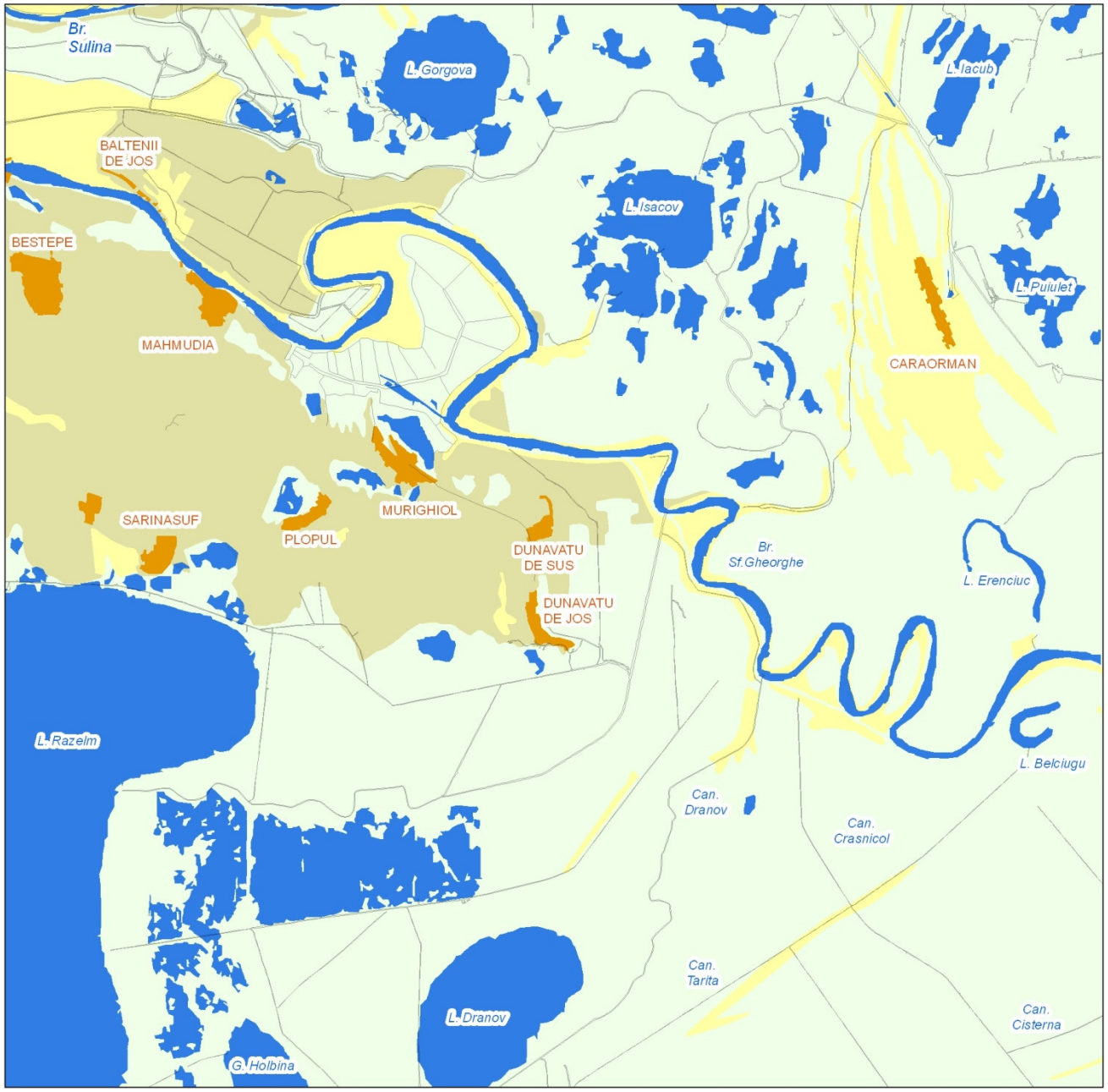

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year
2010
28.06.1987
1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year
2010
24.07.1988
1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year

2010

11.07.1989

1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year
2010
10.08.1991
1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year

2010

12.06.1993

1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

ASRC
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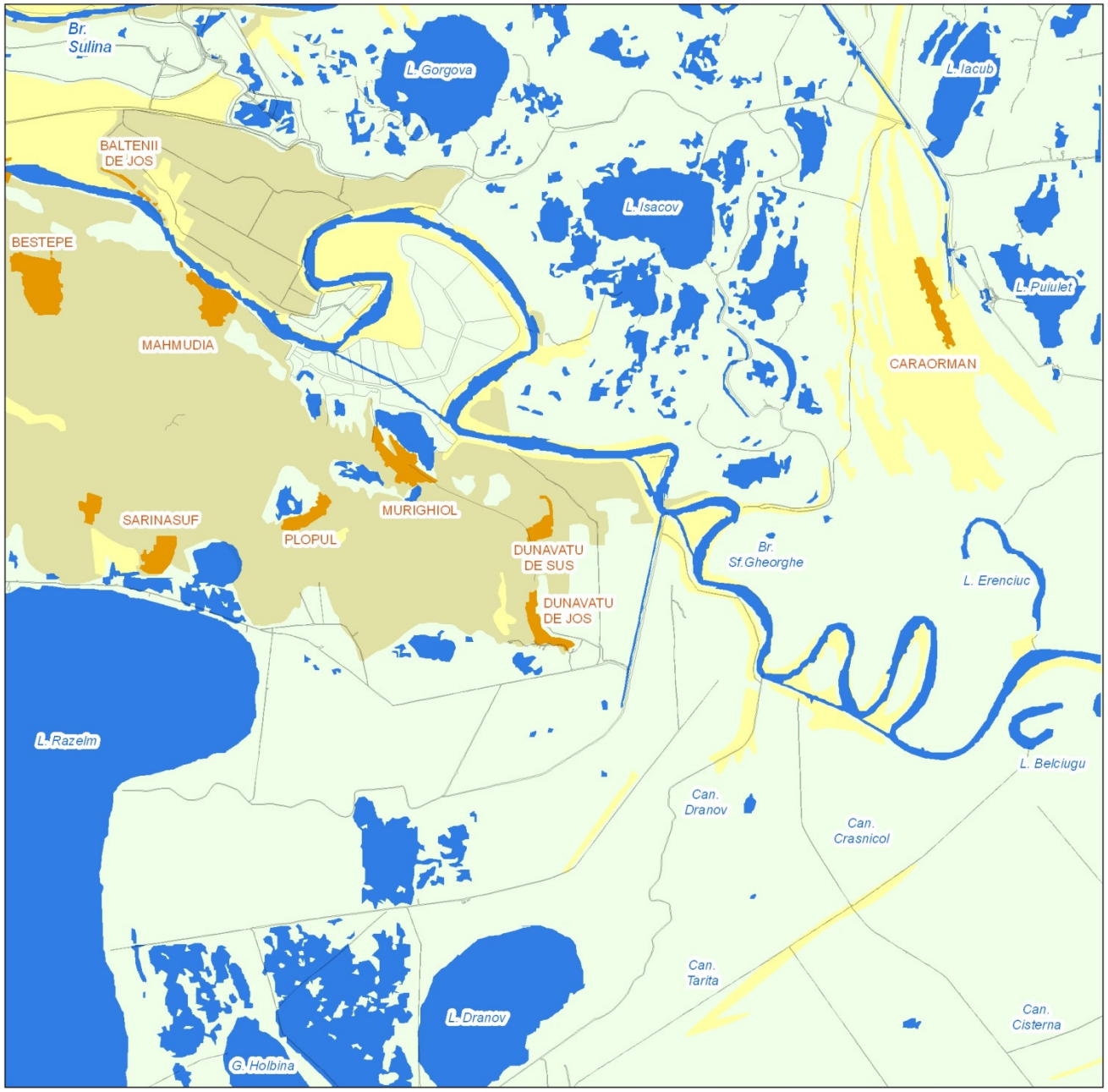

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year

2010

01.07.1994

1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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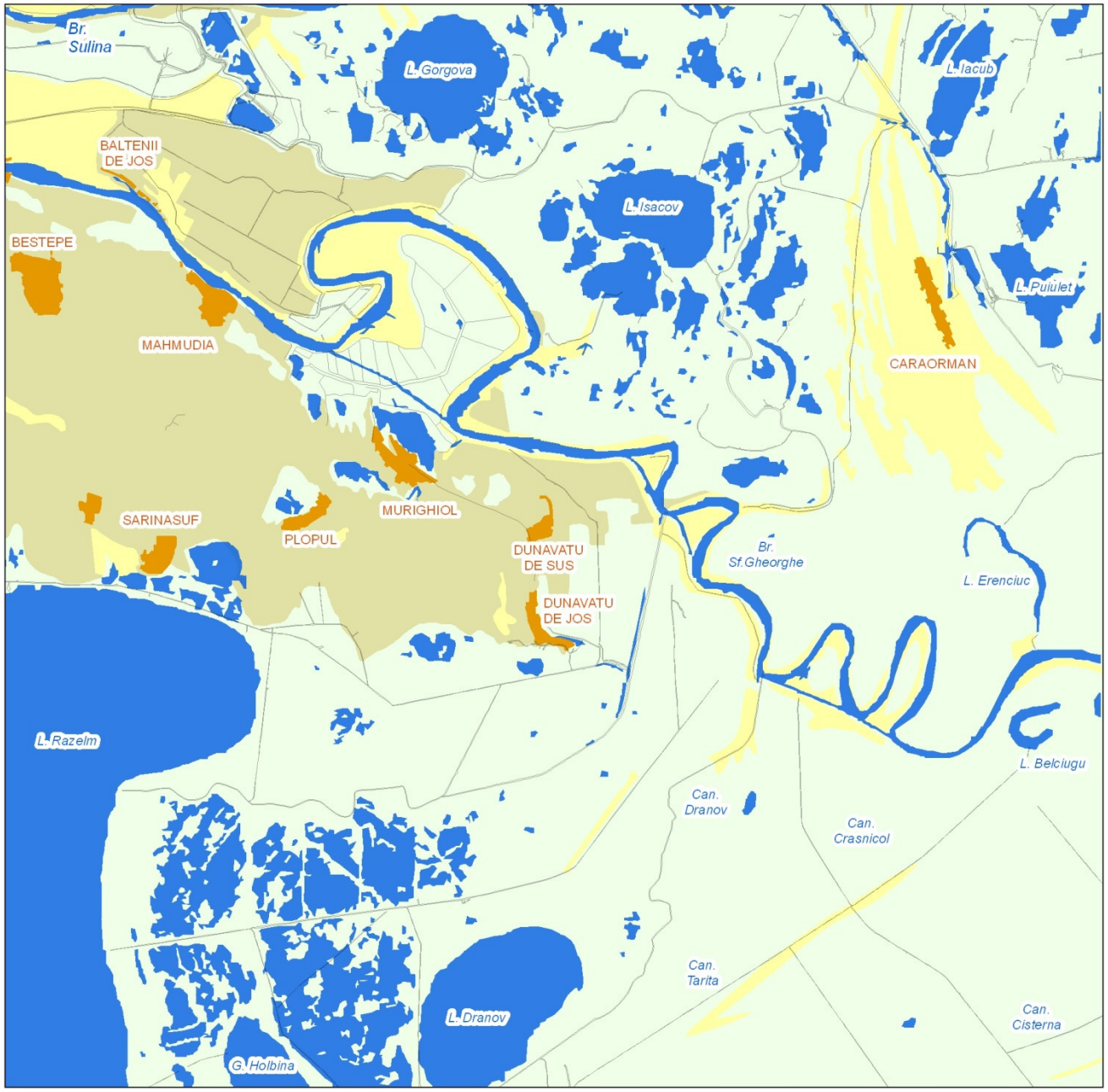

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year

2010

04.07.1995

1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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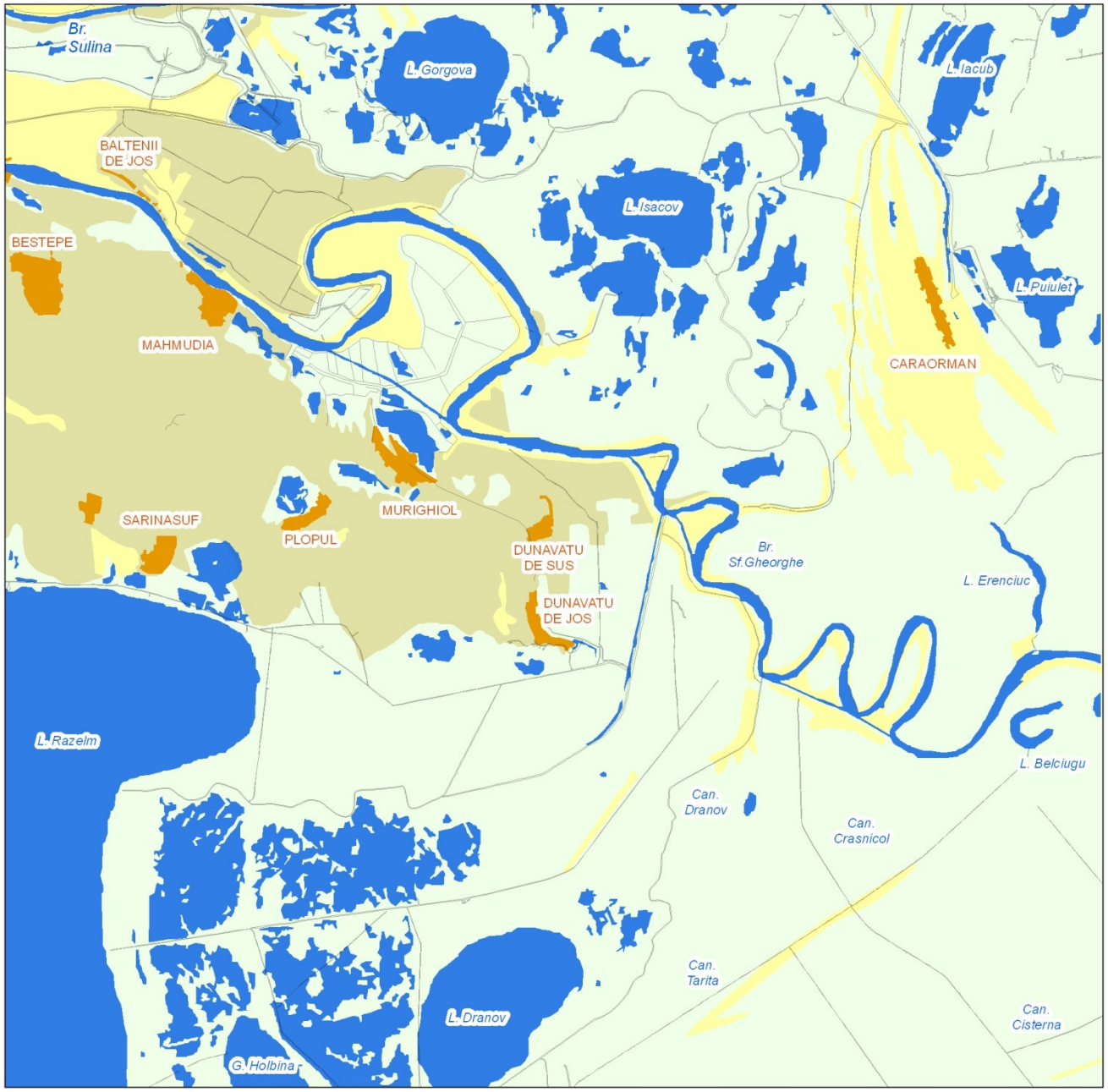

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year
2010
20.06.1996
1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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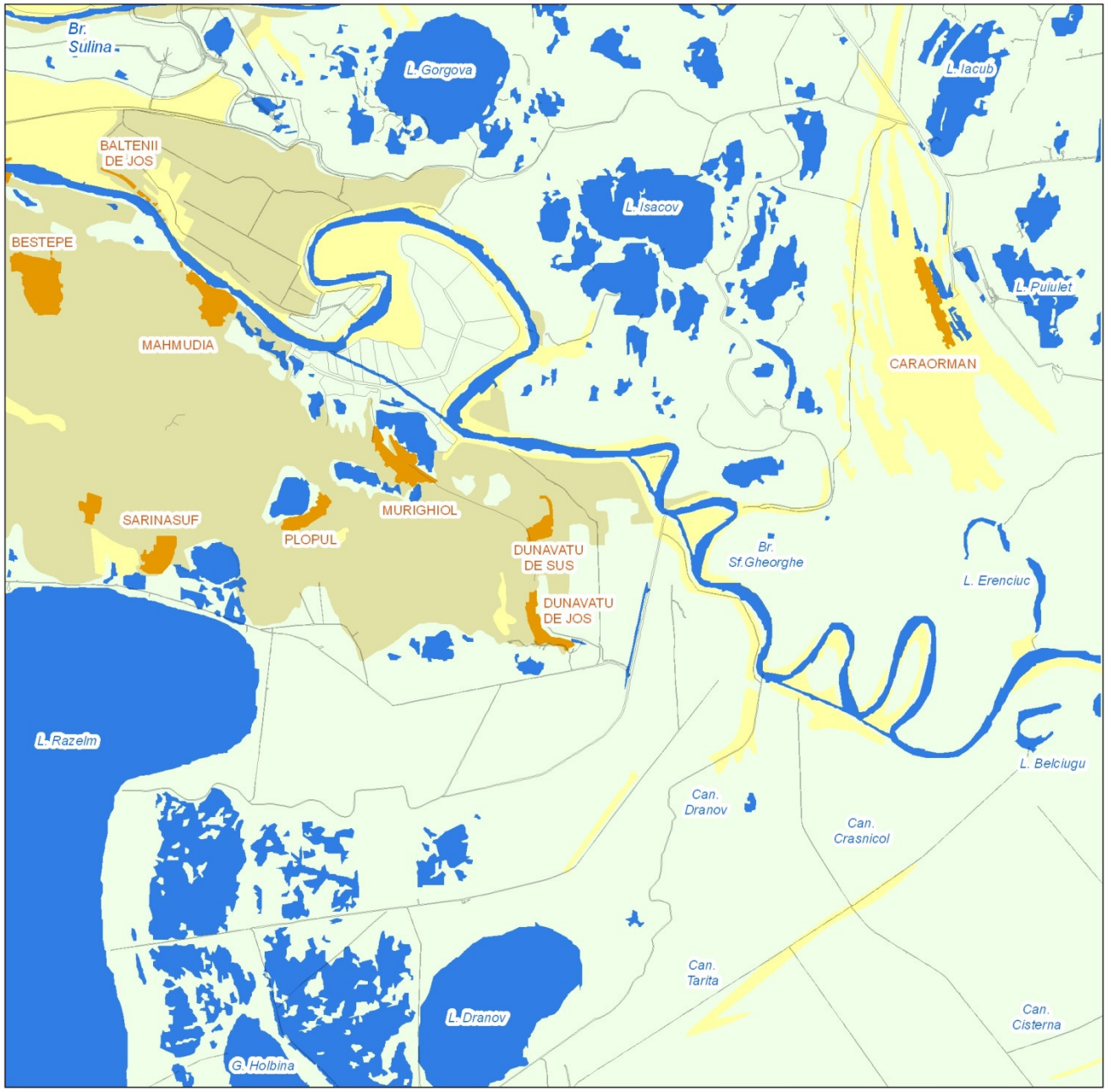

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year
2010
23.06.1997
1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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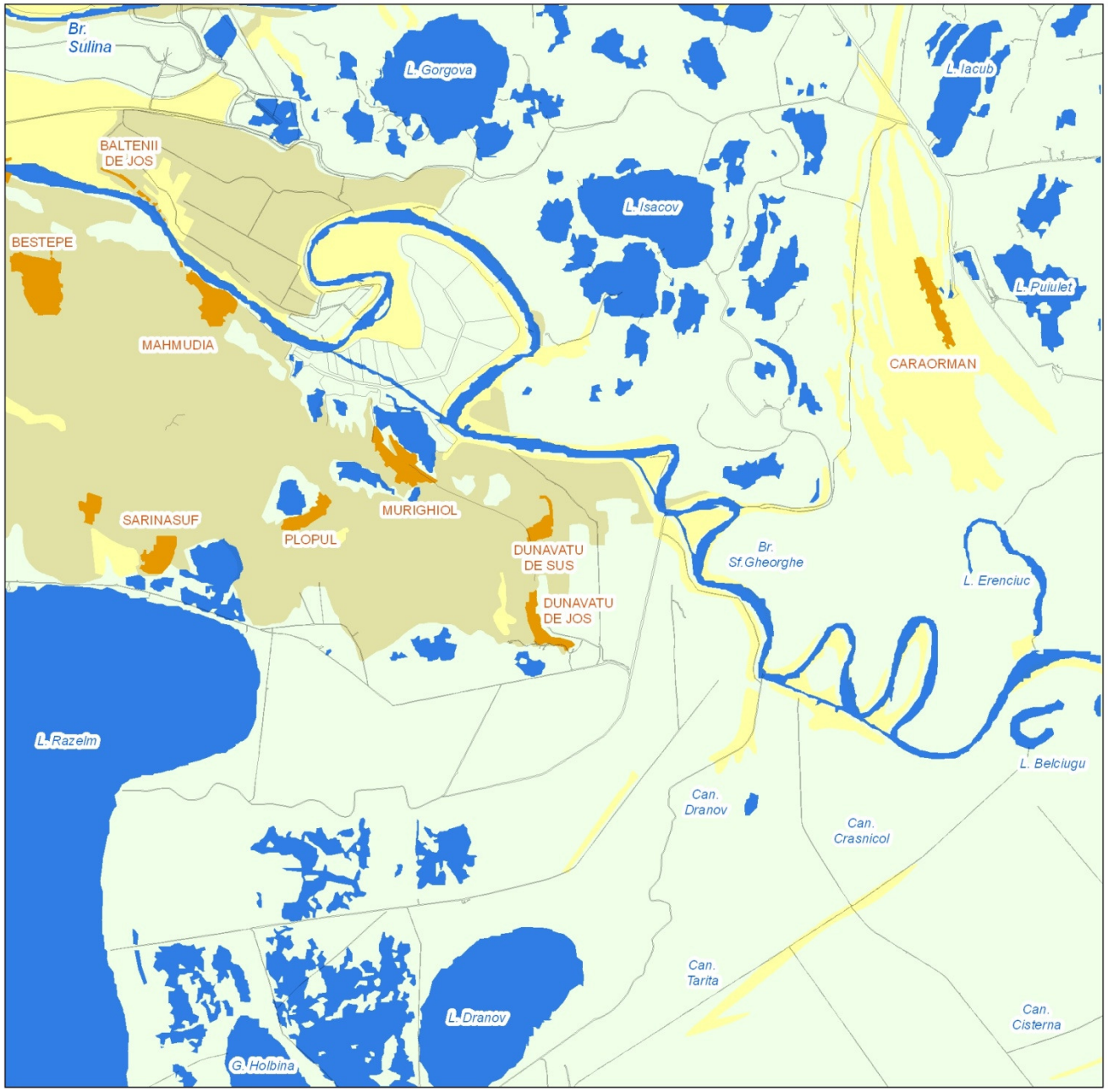

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year

2010

04.10.1999

1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year

2010

06.05.2000

1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year

2010

19.08.2000

1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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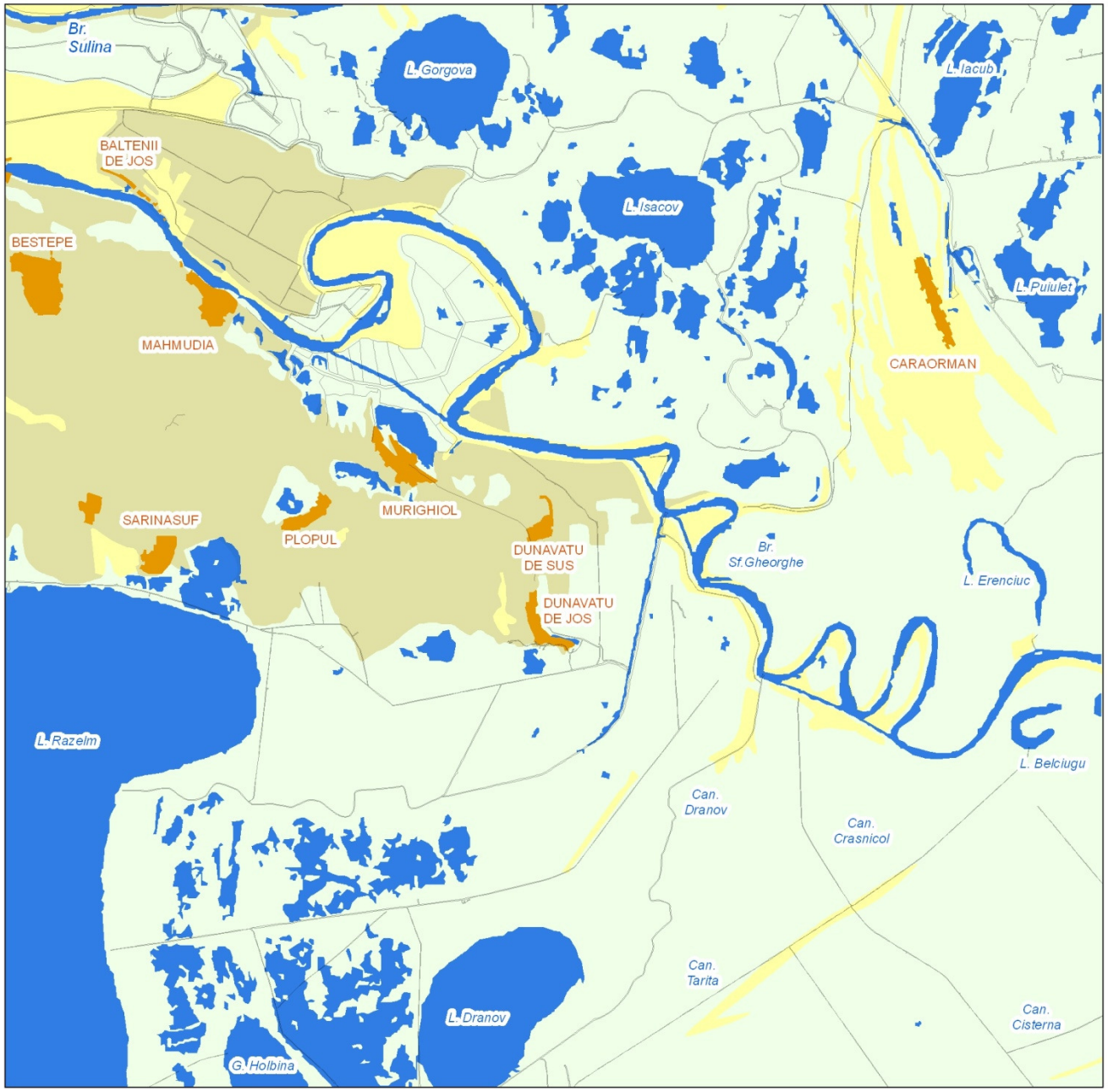

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year

2010

21.07.2001

1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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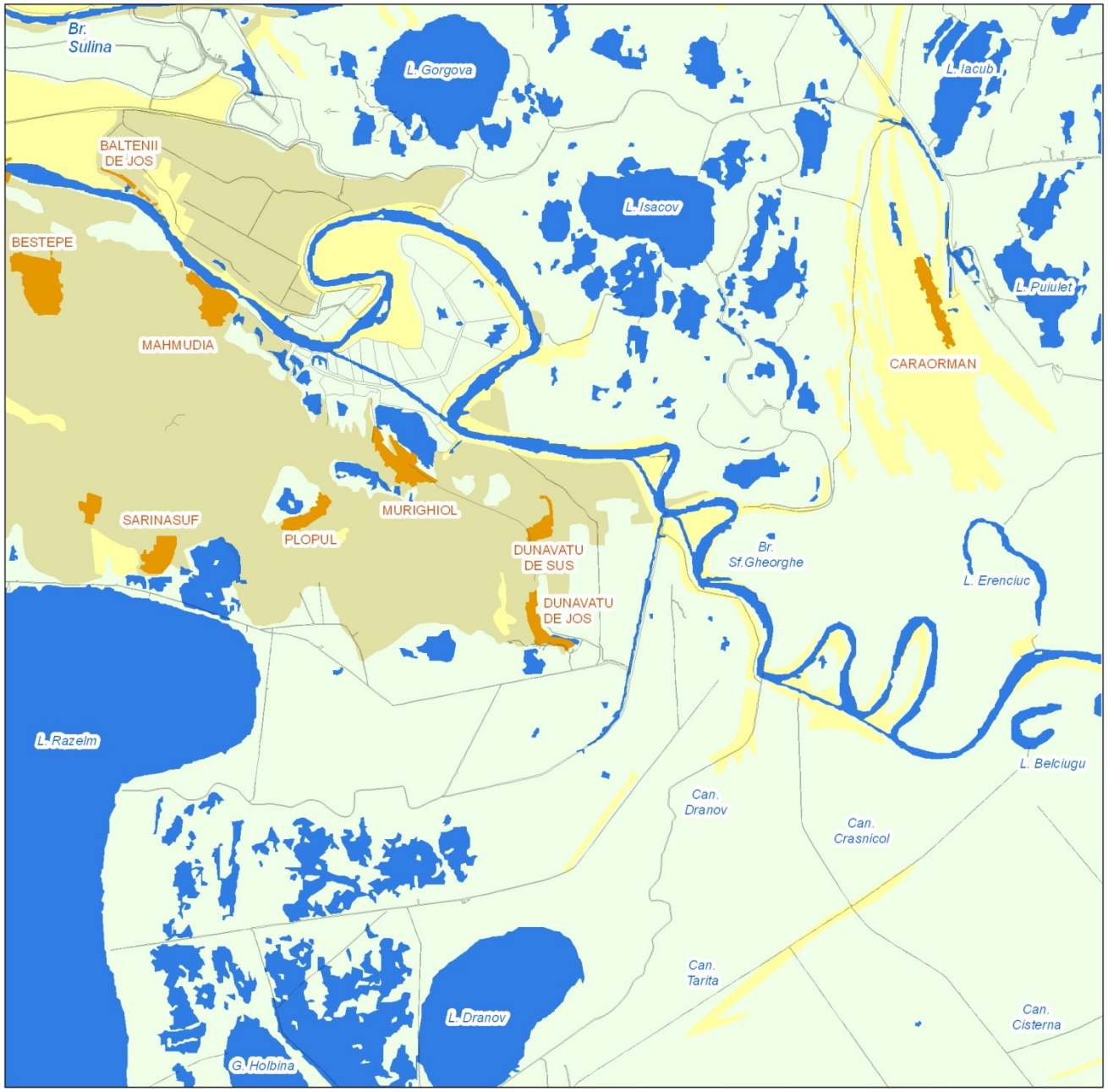

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year

2010

21.07.2001

1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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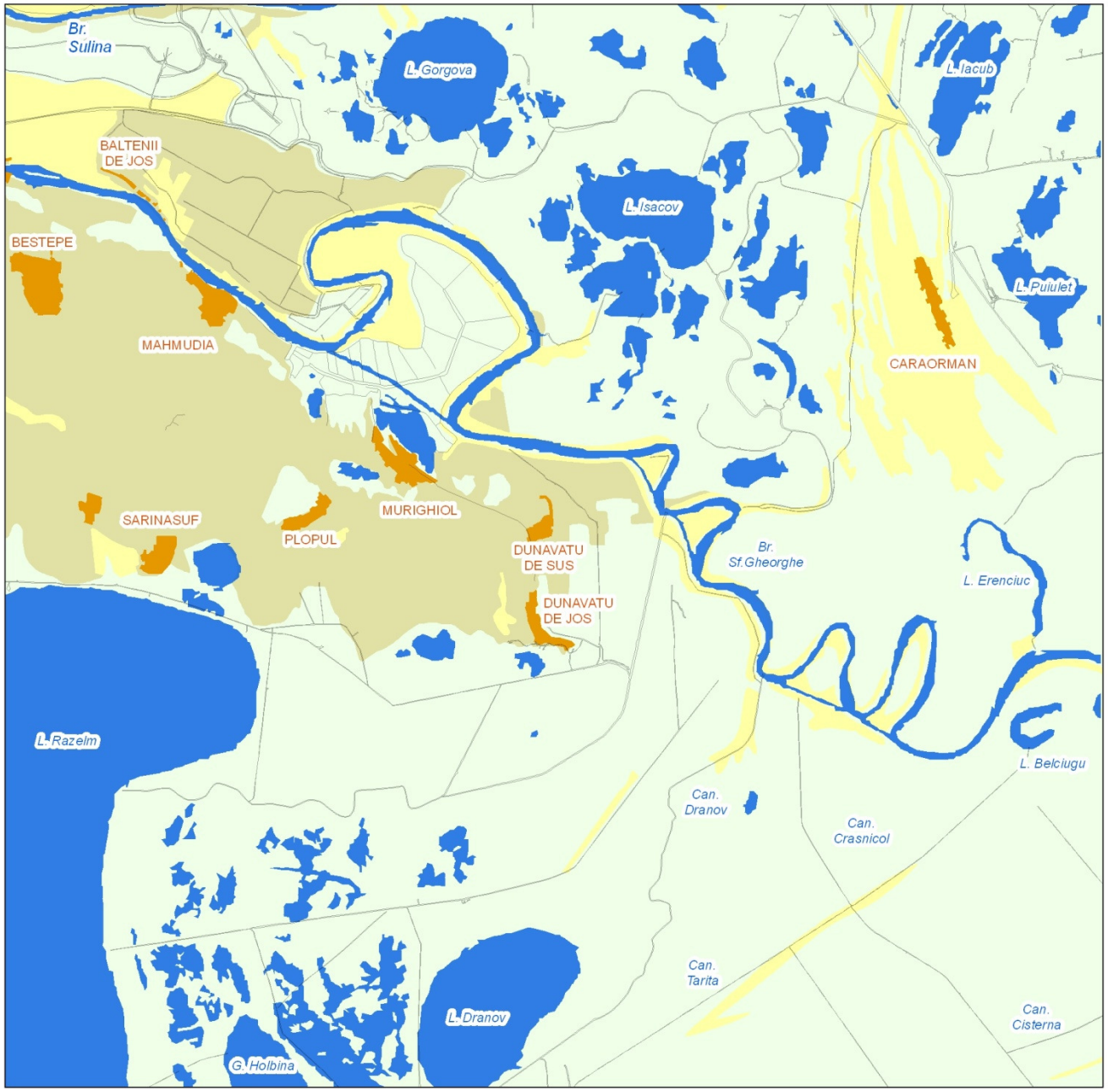

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year

2010

21.09.2003

1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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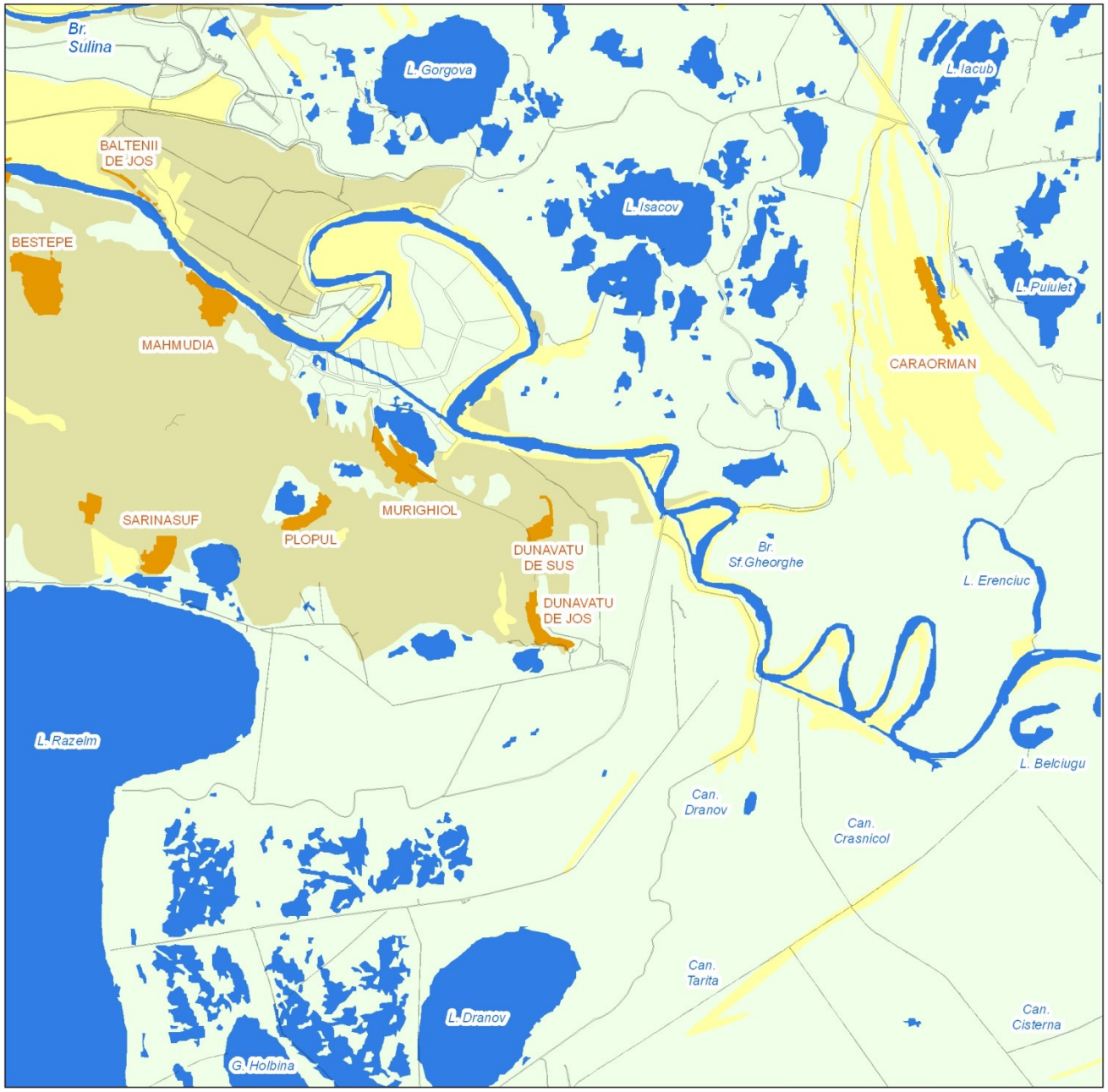

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year

2010

10.06.2004

1984

- Water
- Channels
- Localities
- Agricultural areas
- Semi natural areas, sand dunes.
- Wetlands

0 2.5 5 km

N

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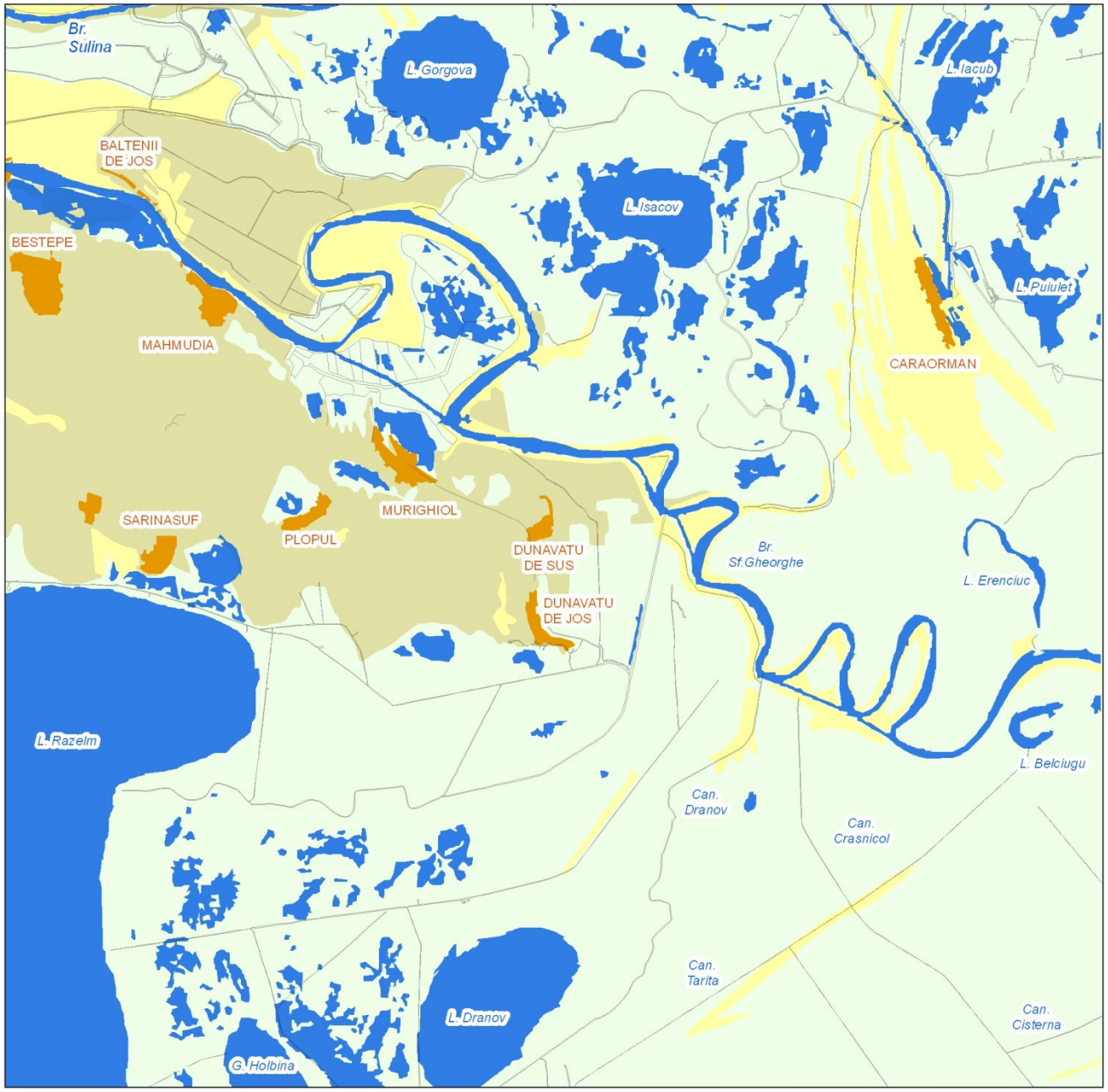

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year

2010

31.07.2005

1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

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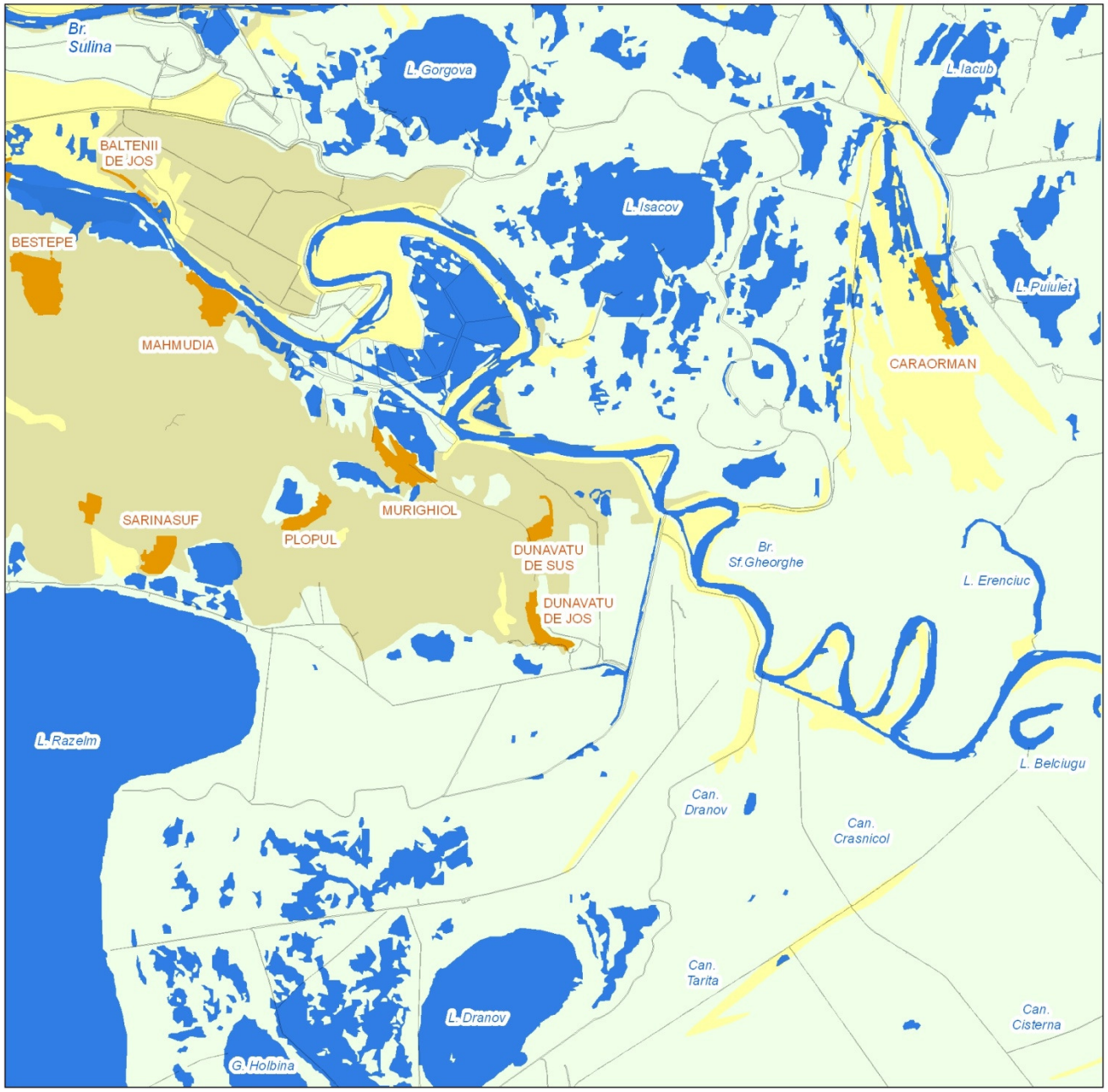

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year

2010

31.05.2006

1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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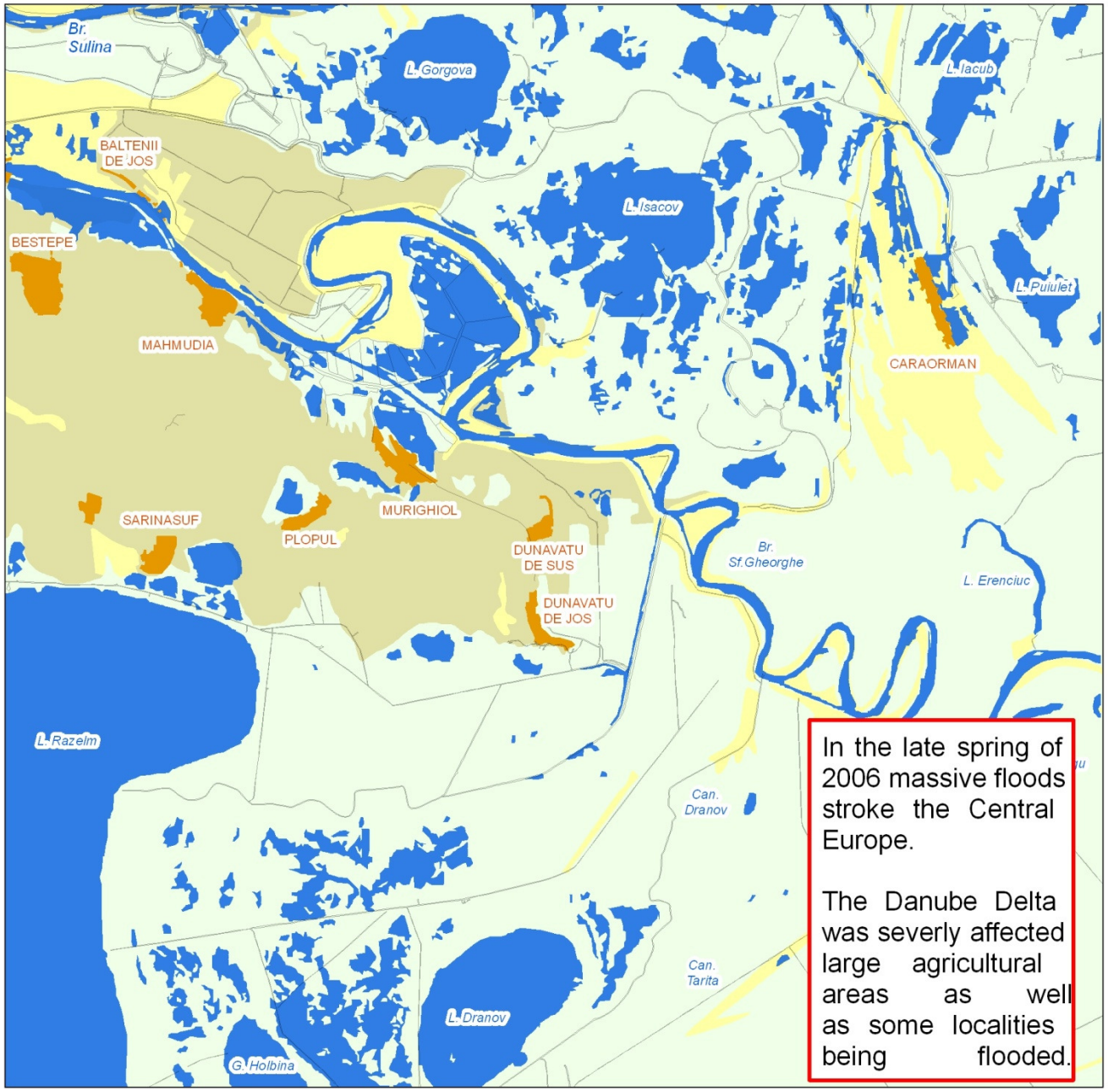

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year
2010
31.05.2006
1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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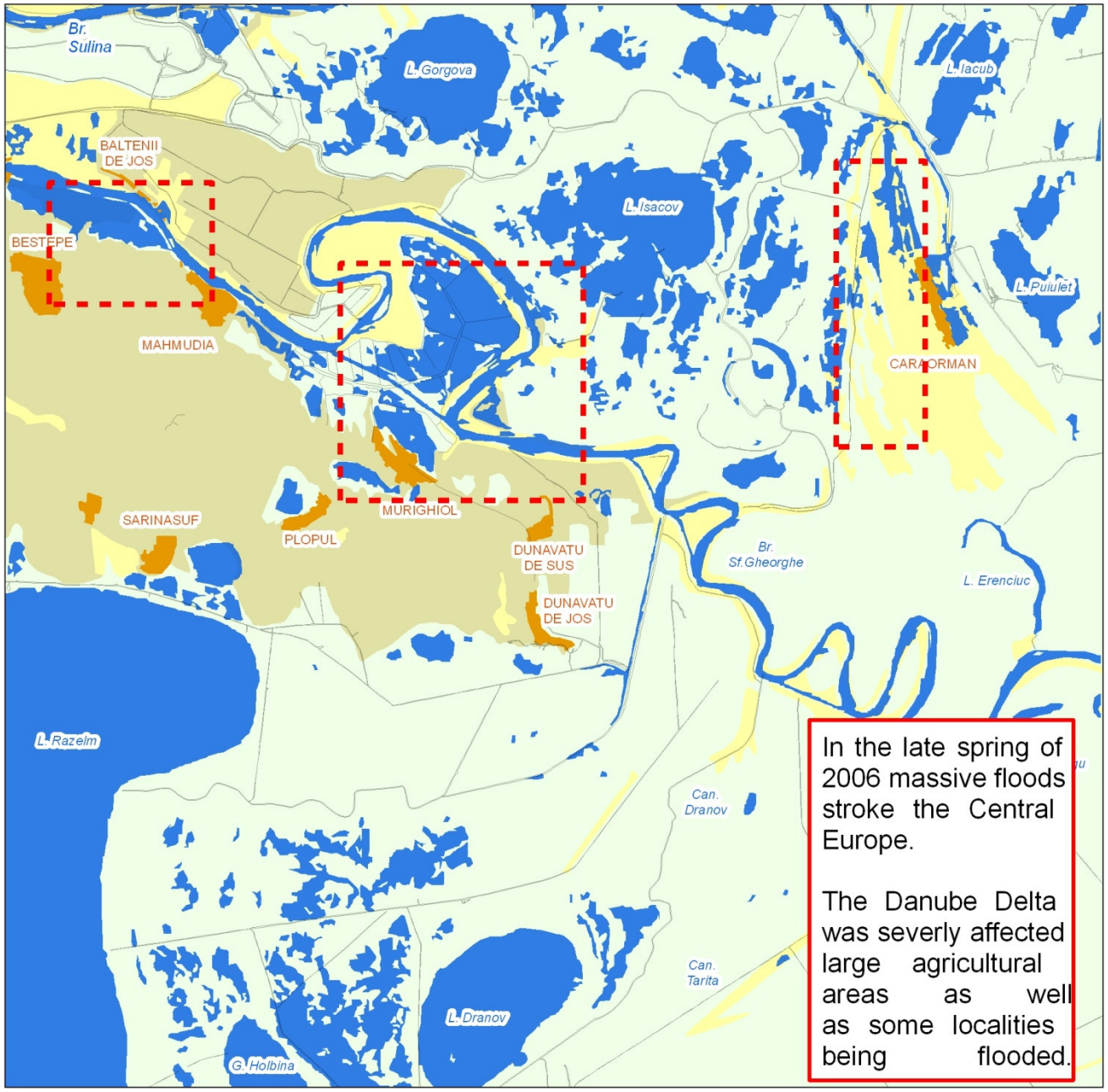

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year
2010
31.05.2006
1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

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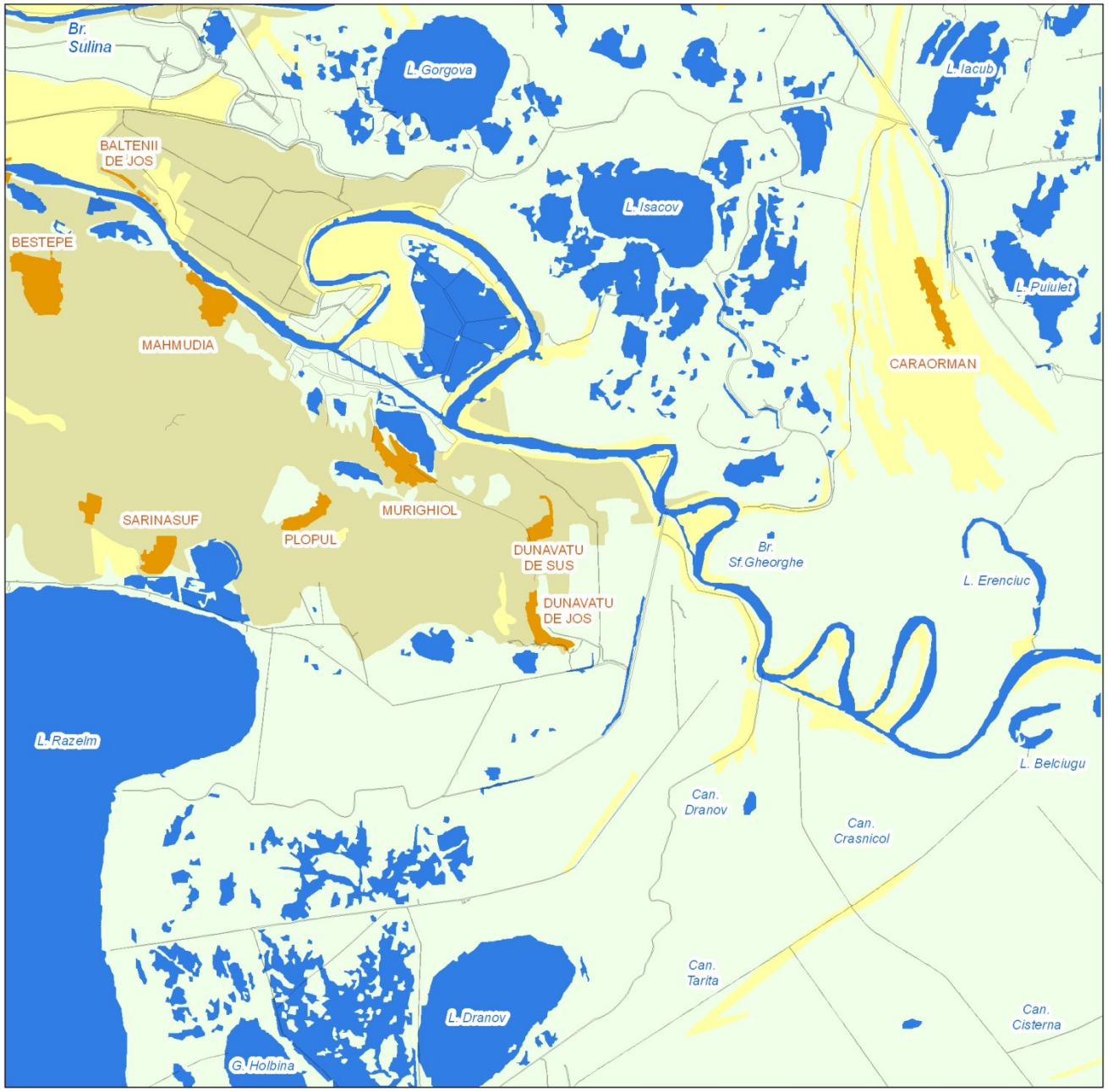

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year

2010

21.07.2007

1984

- Water
- Channels
- Localities
- Agricultural areas
- Semi natural areas, sand dunes.
- Wetlands

0 2.5 5 km

N

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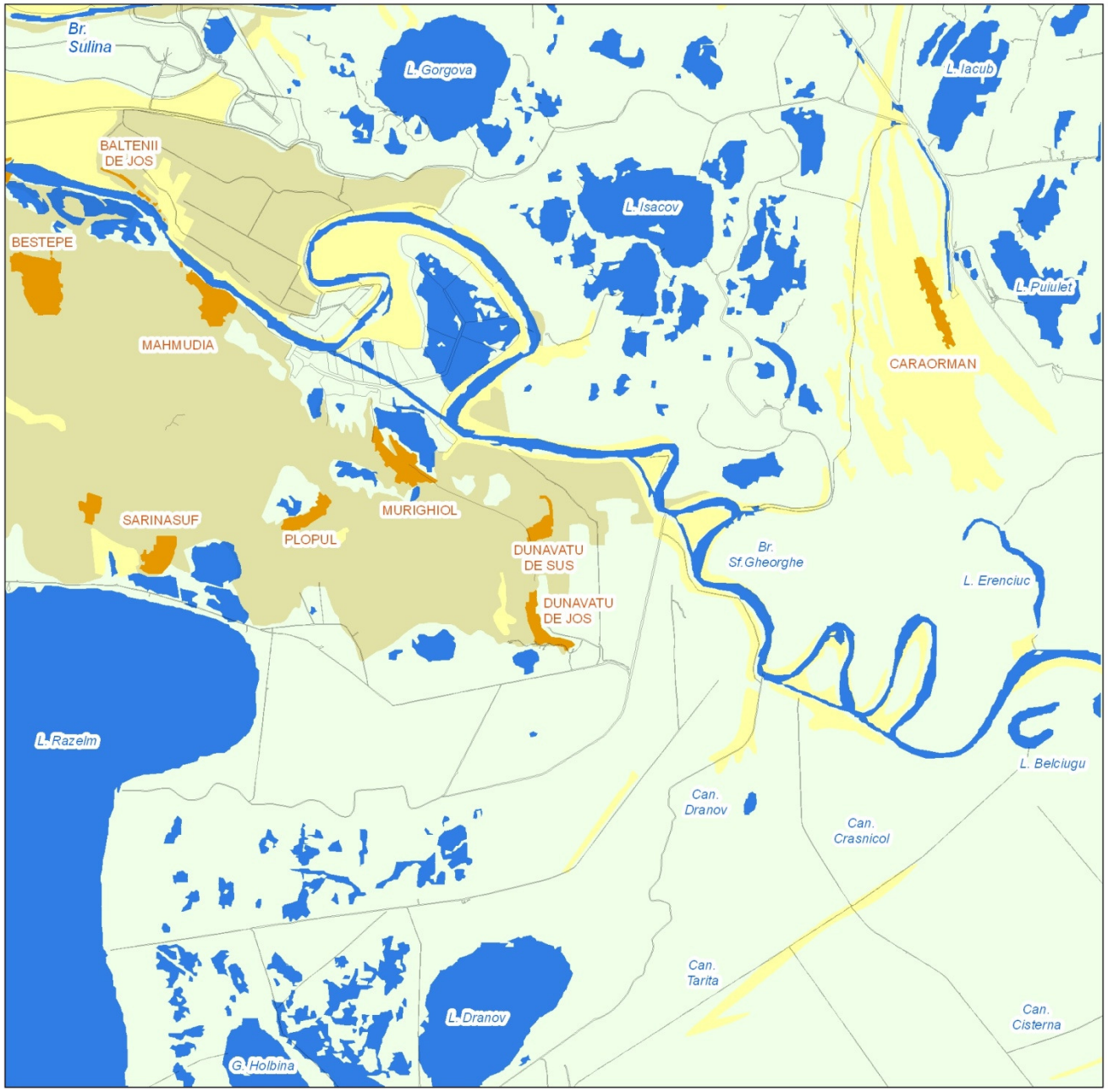

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year

2010

07.07.2008

1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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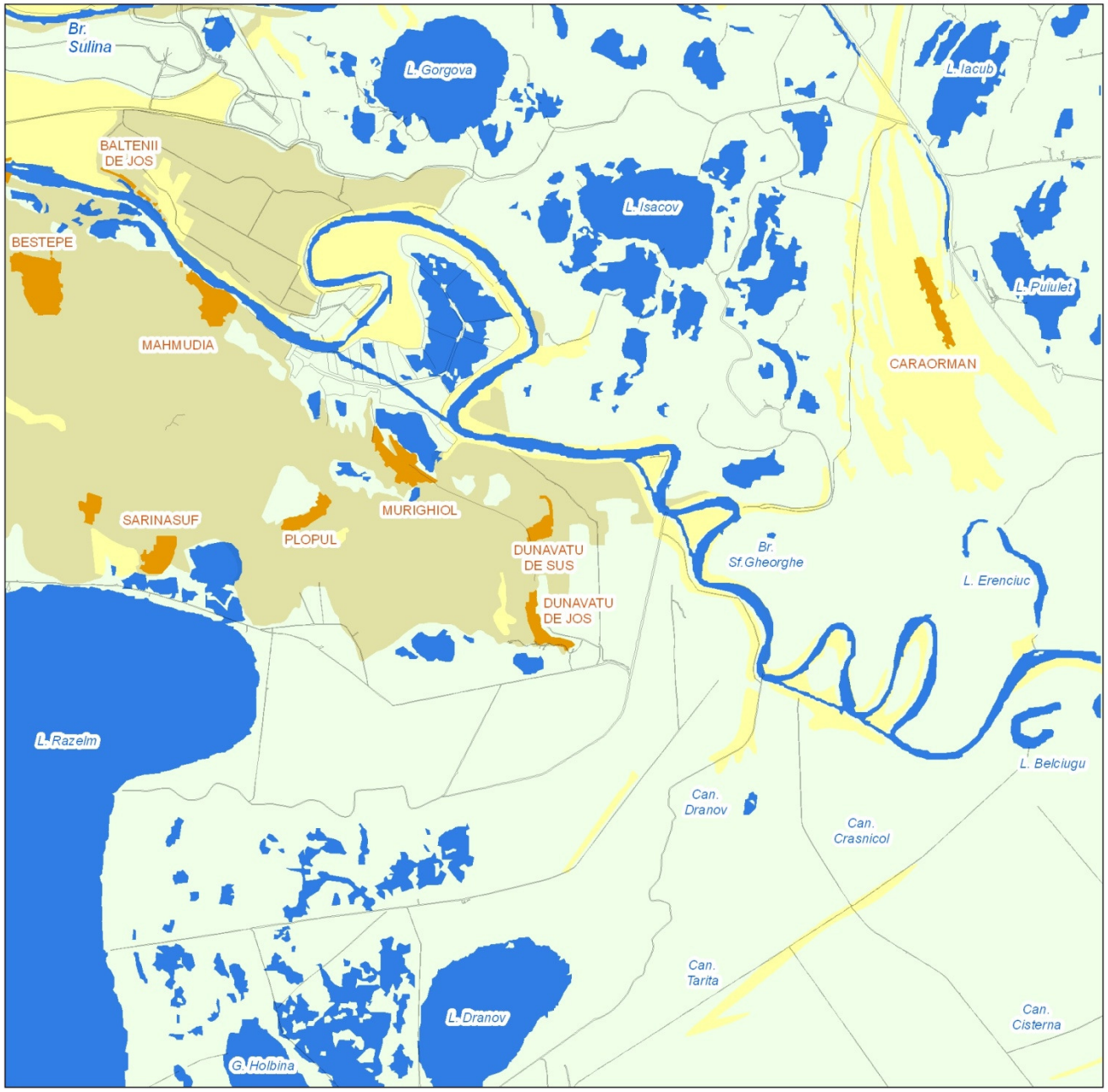

Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year

2010

19.07.2009

1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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Fluctuation of the water extent in the Danube Delta extracted from LANDSAT imagery in the period of 1984 - 2010

Year

2010

04.06.2010

1984

Water
Channels
Localities
Agricultural areas
Semi natural areas, sand dunes.
Wetlands

0 2.5 5 km

N

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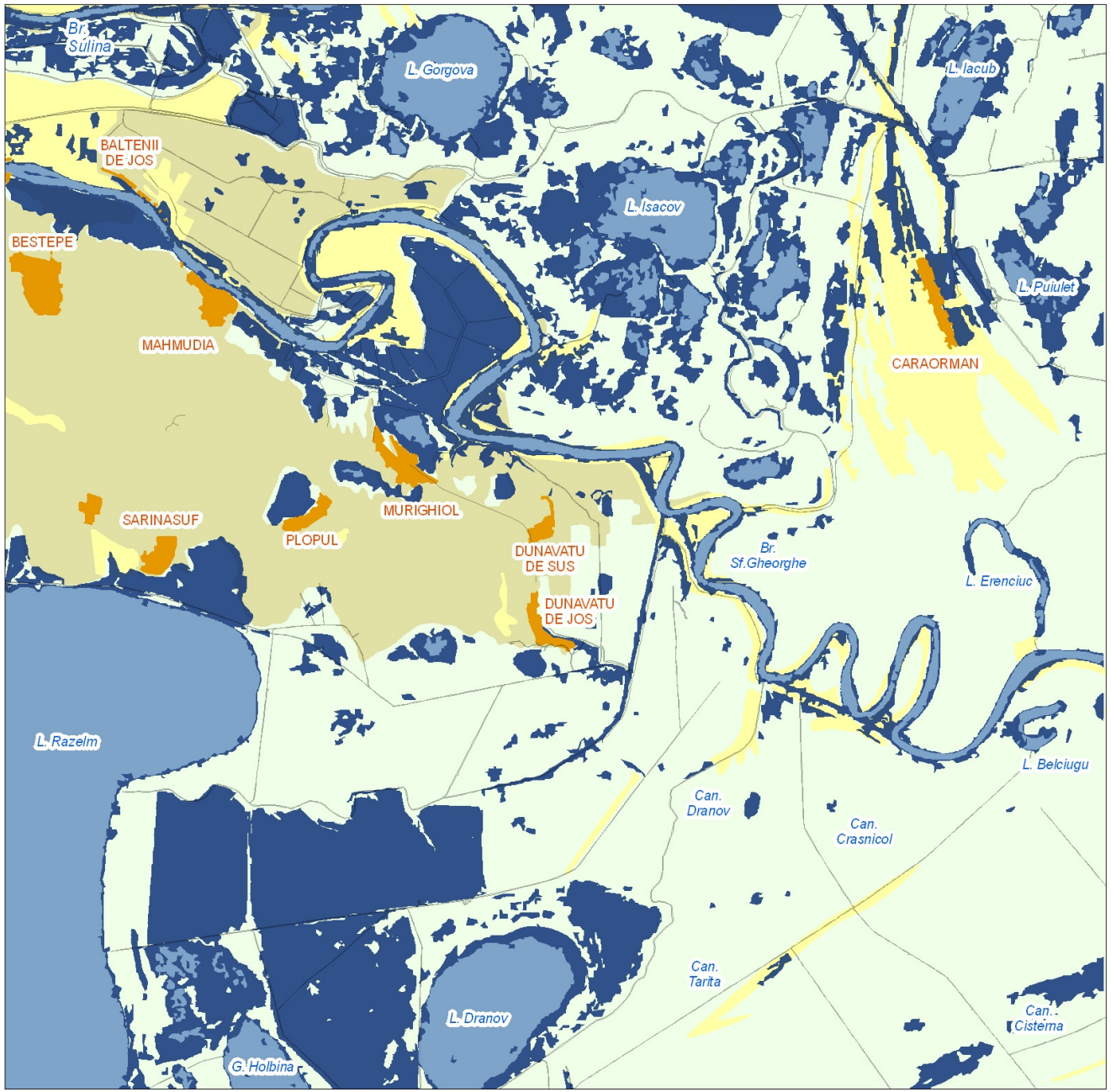

Map of the flood-risk areas

It was produced taking into account all the flooded areas during the 1984-2010 time series.

These areas are represented with dark blue.

Such a map provide essential information for flood risk assessment, land planning etc.

Permanent water bodies such as lakes or rivers are represented with pale blue.

- Permanent water bodies
- Areas with flooding risk
- Channels
- Localities
- Agricultural areas
- Semi natural areas, sand dunes.
- Wetlands

0 2.5 5 km

N

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Presentation Outline

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  - Fluctuation of the Water Extent (Danube Delta, Romania)
  - **Black Sea Shore Evolution**
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Black Sea Shore Evolution

- The Black Sea shore is a very sensitive area for monitoring, especially in its Northern part, adjacent to Danube Delta.
- The human activity as well as the natural factors (storms, marine currents etc.) lead to significant changes of the seashore line during the years.
- The changes were and still are very hard to estimate due to lack of consistent ground data.

Embankment activities on the Black Sea shore (Constanta, Romania)

Black Sea shore (Mamaia, Romania)

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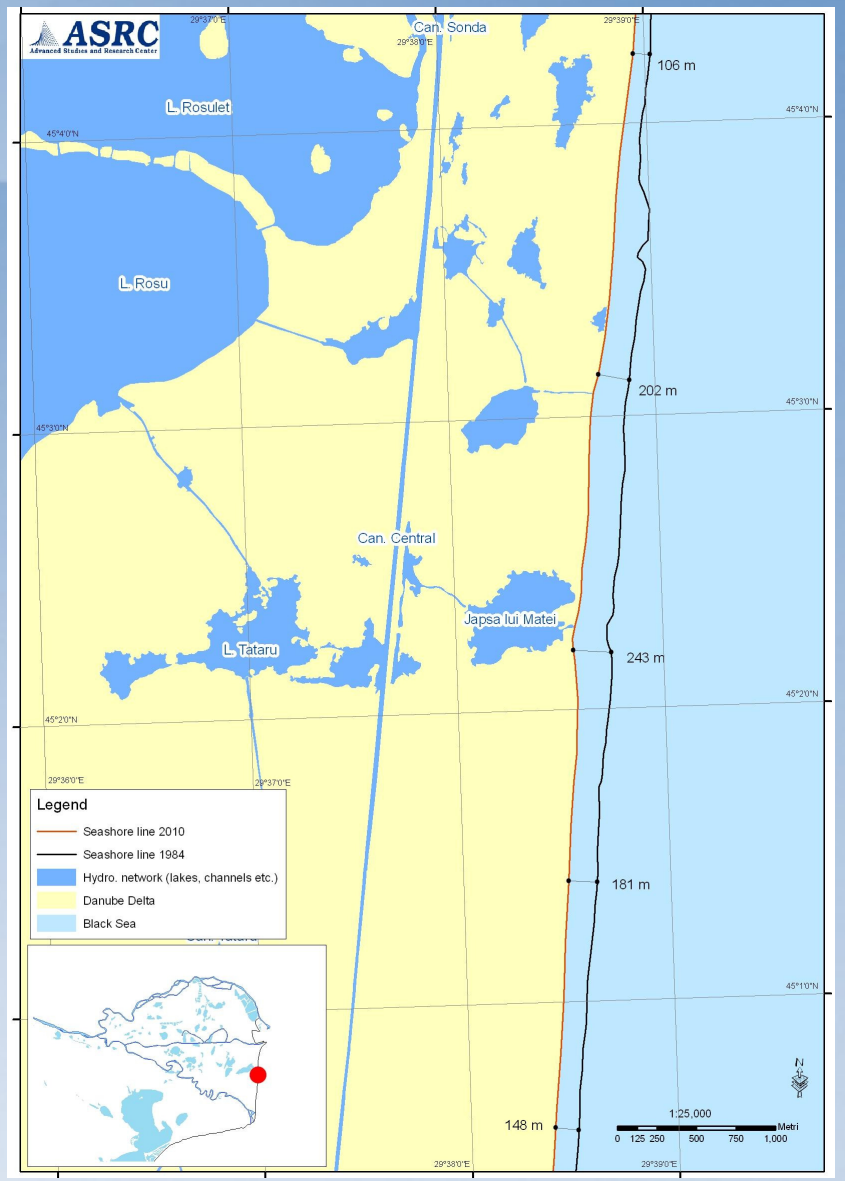
Black Sea Shore Evolution
1984 – 2010

- Due to Remote Sensing techniques, "snapshots" of the seashore line for every year or even every season can be obtained for studying the environmental impact of the seashore dynamics.

- This is how it can be determined that the seashore was reduced with about **100 – 250 meters** in the time interval 1984 - 2010.



***LANDSAT TM images were used - credit US Geological Survey**

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Urban Growth Monitoring Using Satellite Imagery

Case Study: Bucharest City

Bucharest City

- Bucharest is the capital city, the industrial and financial center of Romania

- It is the largest city in Romania, located in the southeast of the country, and lies on the banks of the Dâmboviţa River

Bucharest City

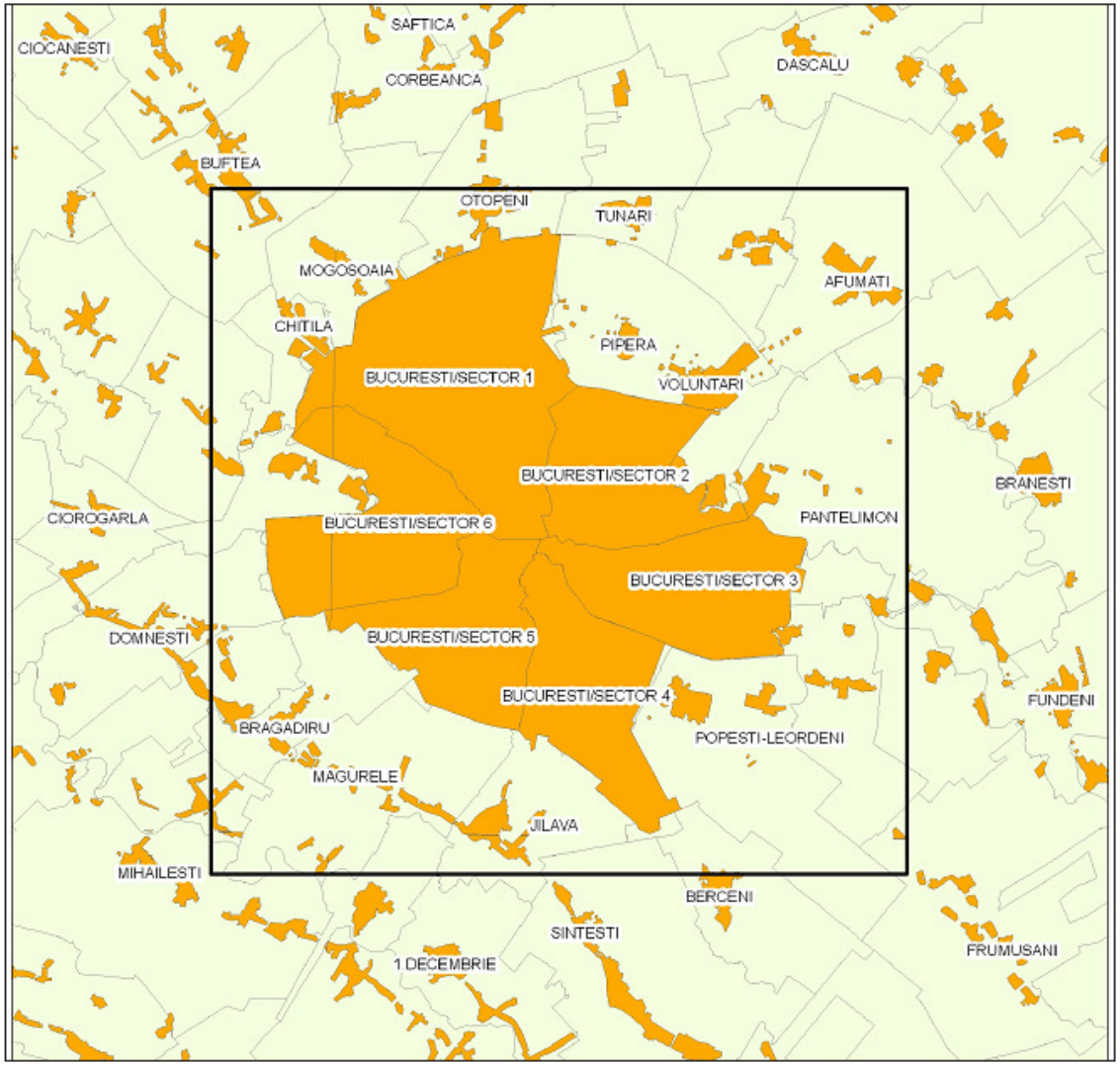
- There is a strong tendency of the urban area expansion

Bucharest City Urban Growth

- The regions surrounding Bucharest were mostly rural
- After 1989, new suburbs began to arise around the city
- Further urban consolidation took place during the last decade, when the Bucharest metropolitan area has expanded

The Area of Interest

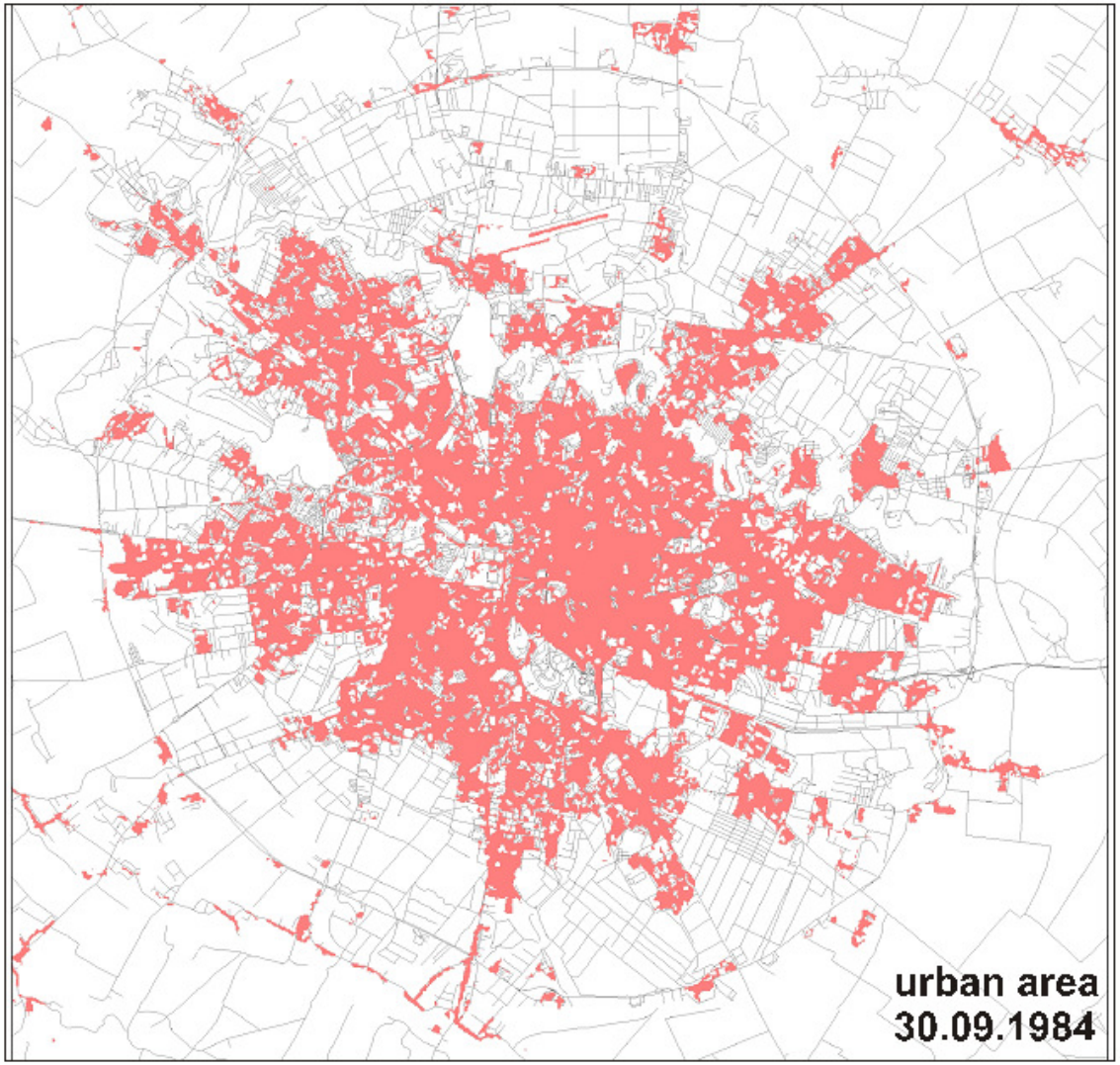
- It sumarizes 694 sq.km.
- It includes the entire administrative territory of Bucharest, as well as other 30 surrounding smaller towns or villages



Bucharest Urban Growth

- Prior to the year 1989 large areas within and outside the city limits had agricultural use. They were scarcely populated

- This was the ground for the urban development after the year 2000, when the city has grown especially to the West, East and Southeast



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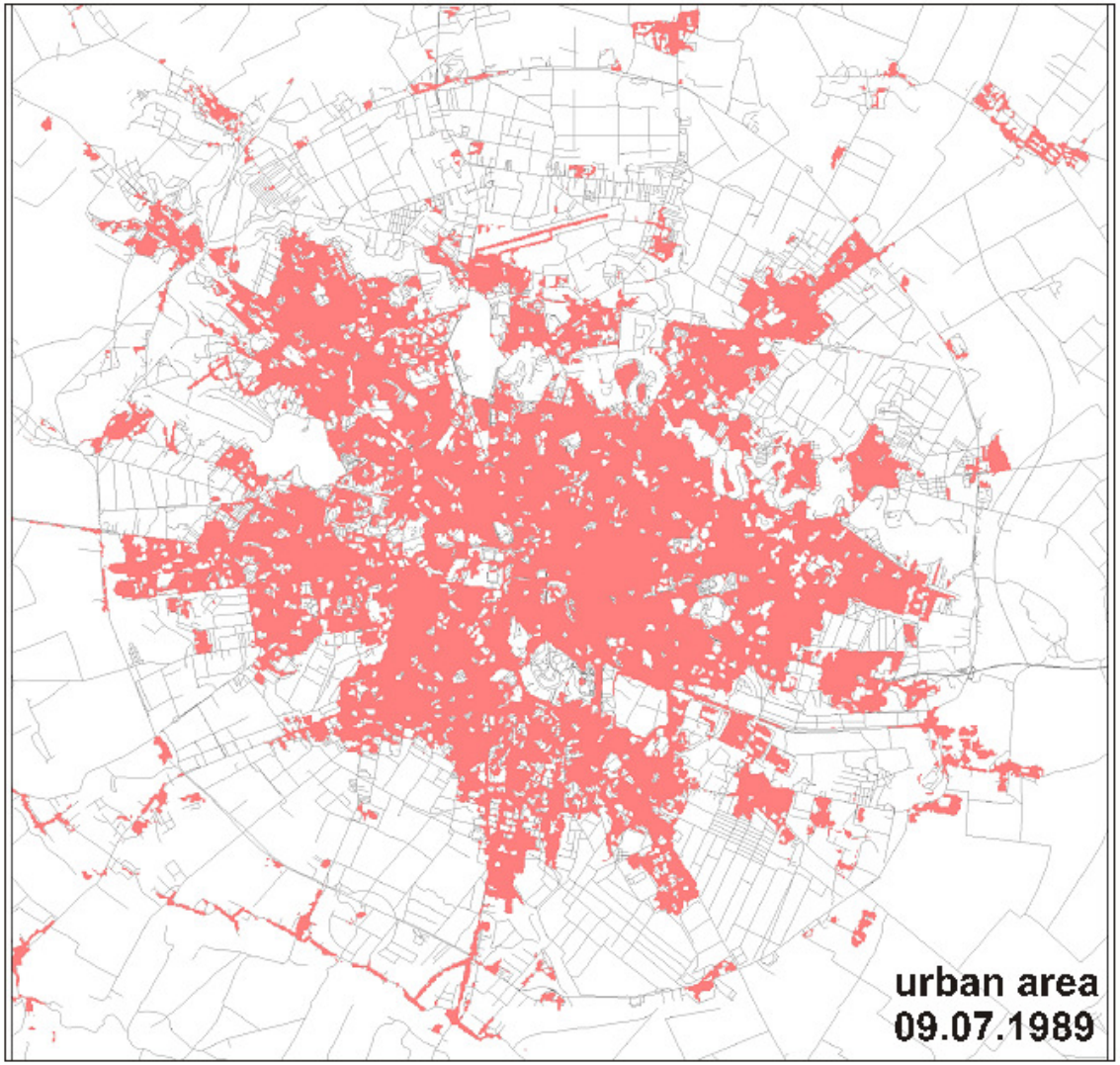

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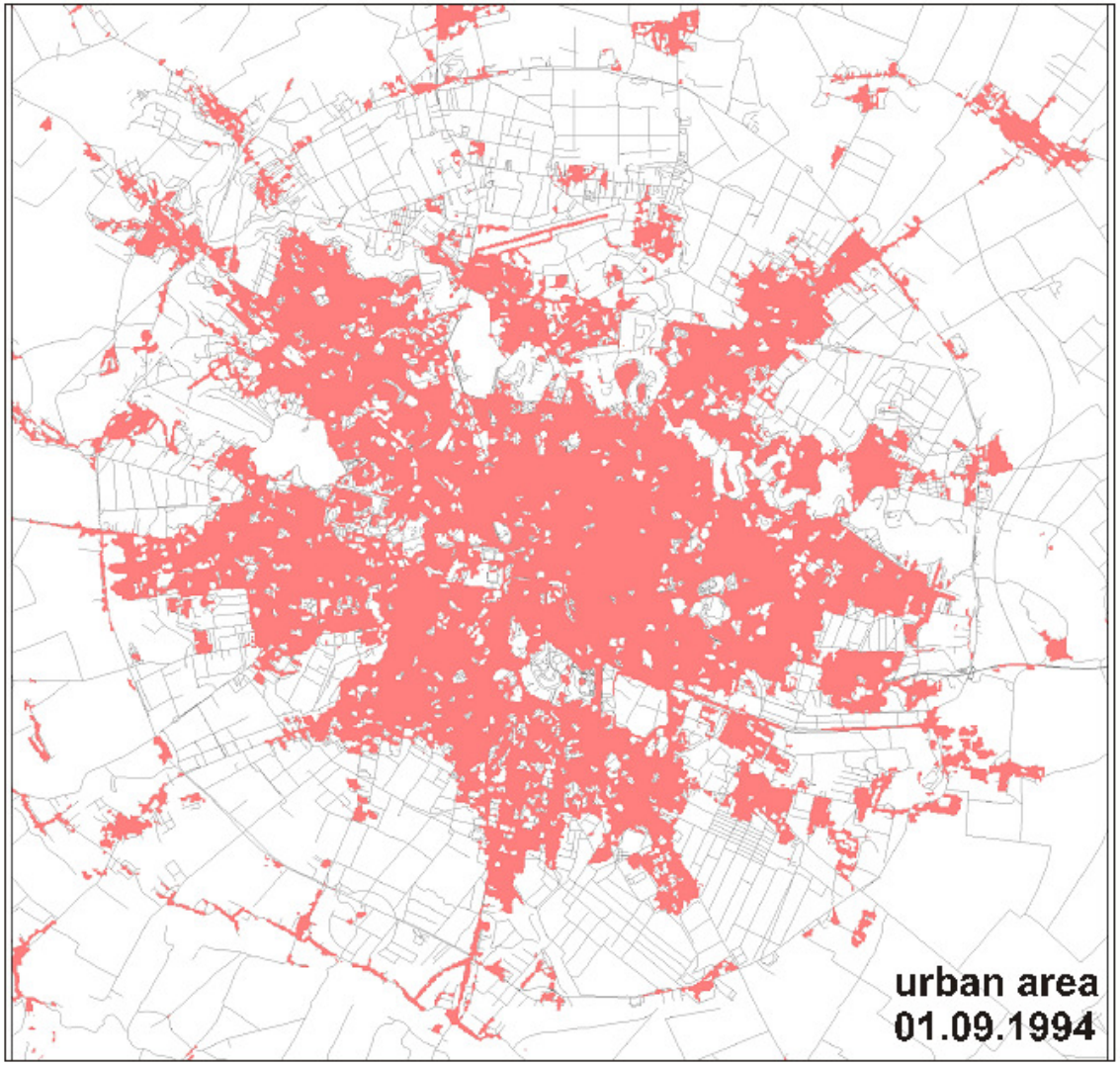

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Urban Growth Monitoring Using Satellite Imagery
Case Study: Bucharest City

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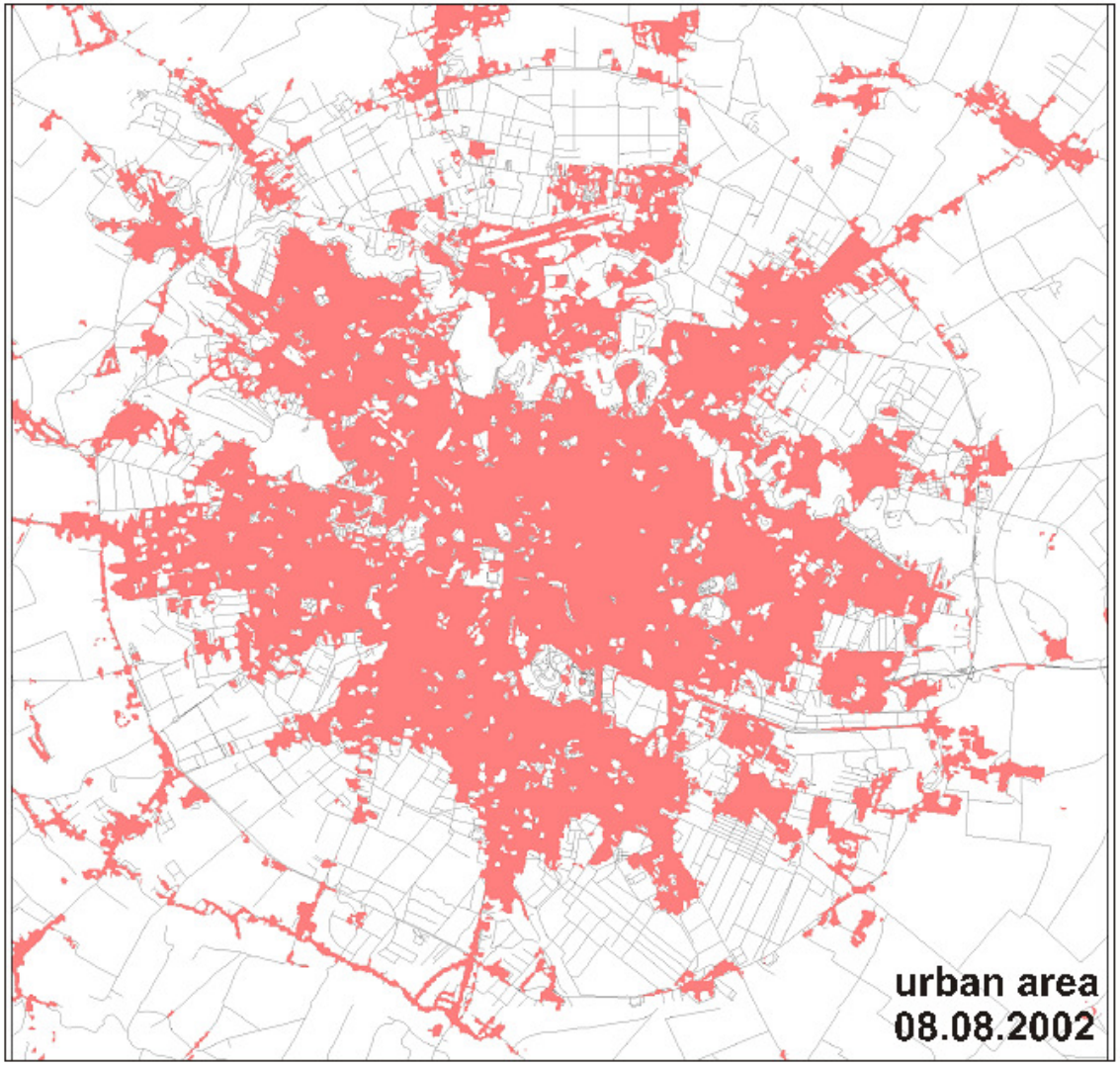

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Urban Growth Monitoring Using Satellite Imagery
Case Study: Bucharest City

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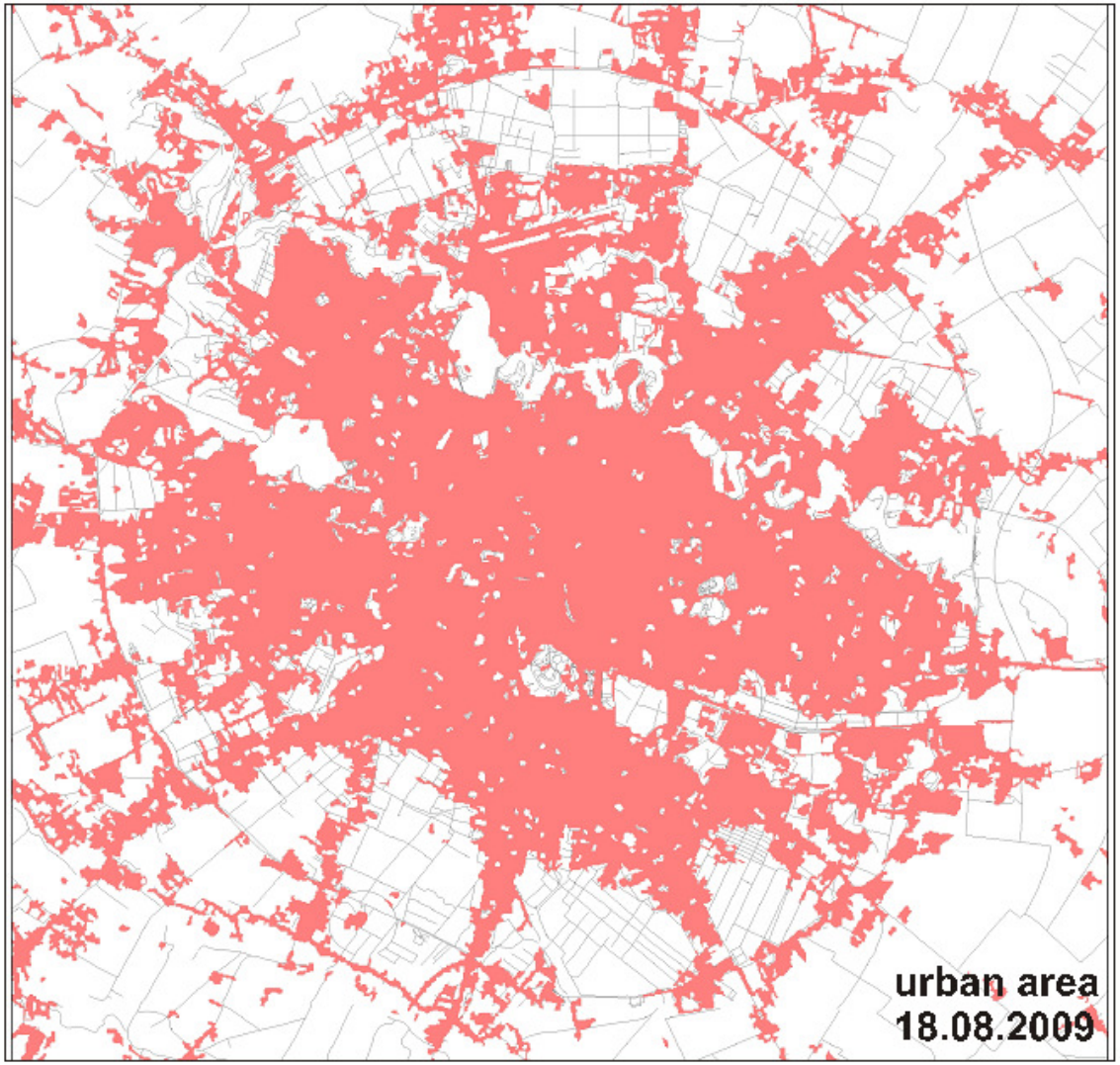

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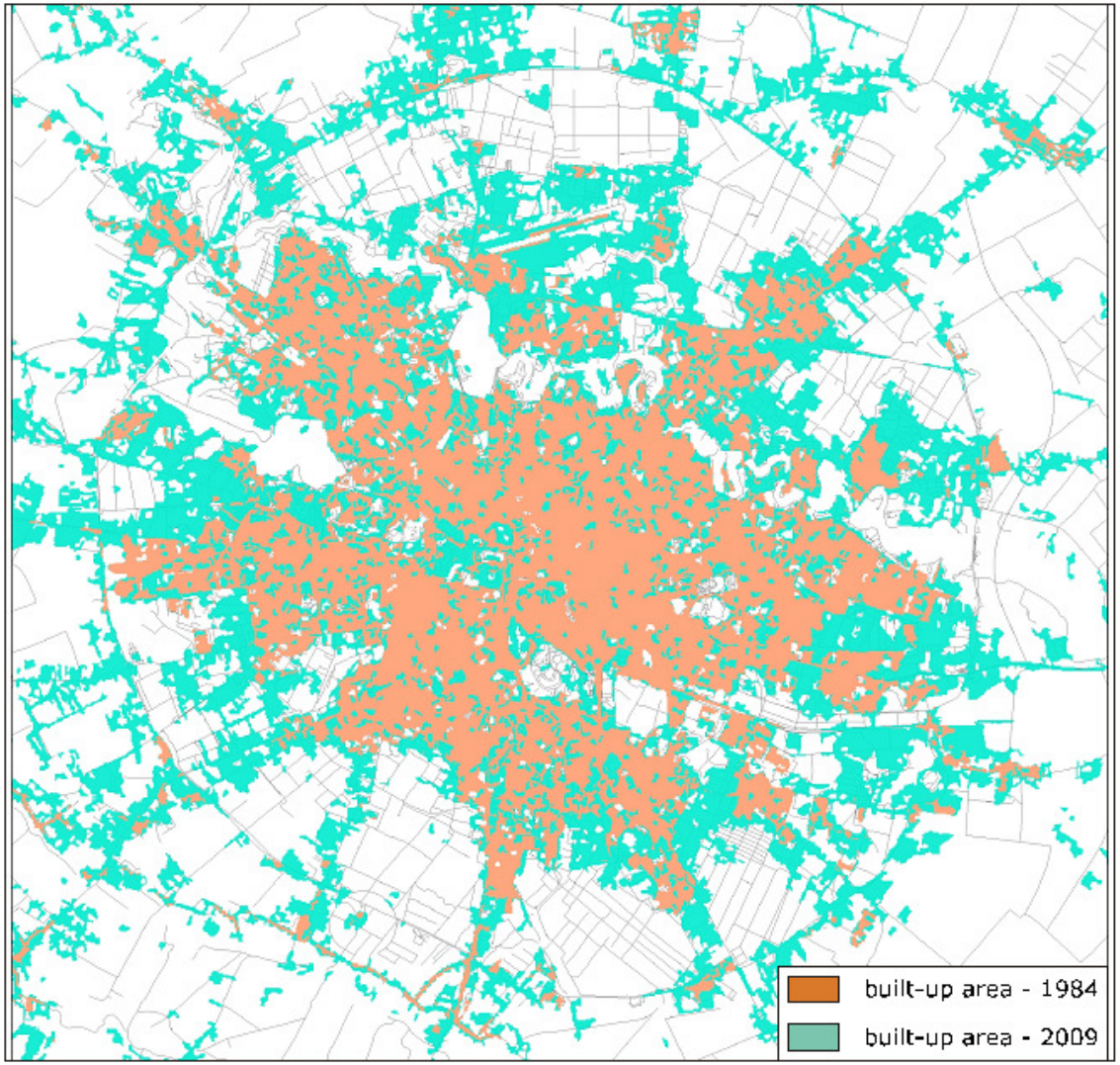
Urban Growth Monitoring Using Satellite Imagery

Case Study: Bucharest City

Bucharest Urban Growth

- After the year 2000, the city has grown especially to the West, East and Southeast

- The Southern side of the city can be an alternative for the future development of Bucharest



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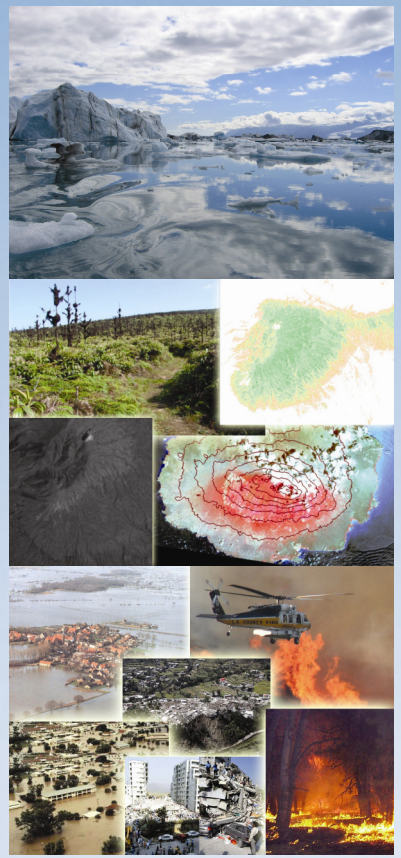
Interferometric Synthetic Aperture Radar (InSAR) techniques



- InSAR monitoring techniques from spaceborne SAR systems are a modern alternative to the traditional GPS or levelling techniques.
- InSAR techniques were successfully applied to monitor ground deformation processes at different scales:
  - medium to large scale deformation processes (e.g. the urban site of **Bucharest**, **Danube Delta**)
  - small scale deformation processes (e.g. the landslide sites of **Siriu water dam**, **Ocnele Mari**).

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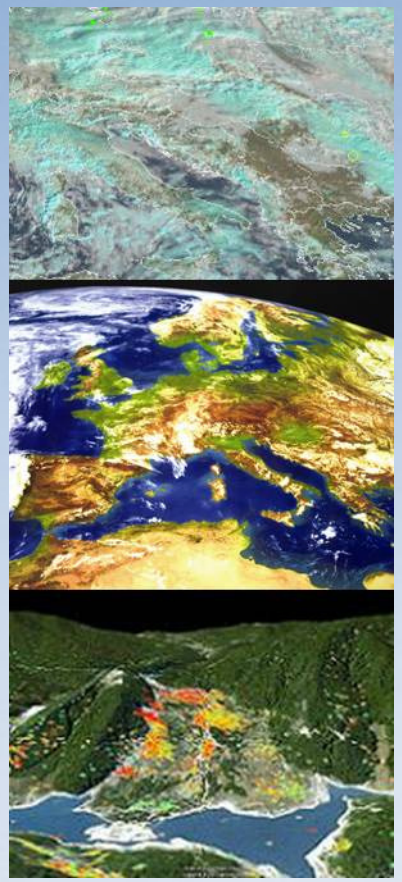

Applications

- Surface deformation measurements (landslides, earthquakes, motions of specific structures, e.g. water reservoirs, dams, bridges and other critical infrastructure assets)

- Environment monitoring (tracing global warming effects on the ground stability, glacier movement and groundwater extraction induced subsidence, fluctuation of the sea level effects on the habitat conditions of wildlife), etc.

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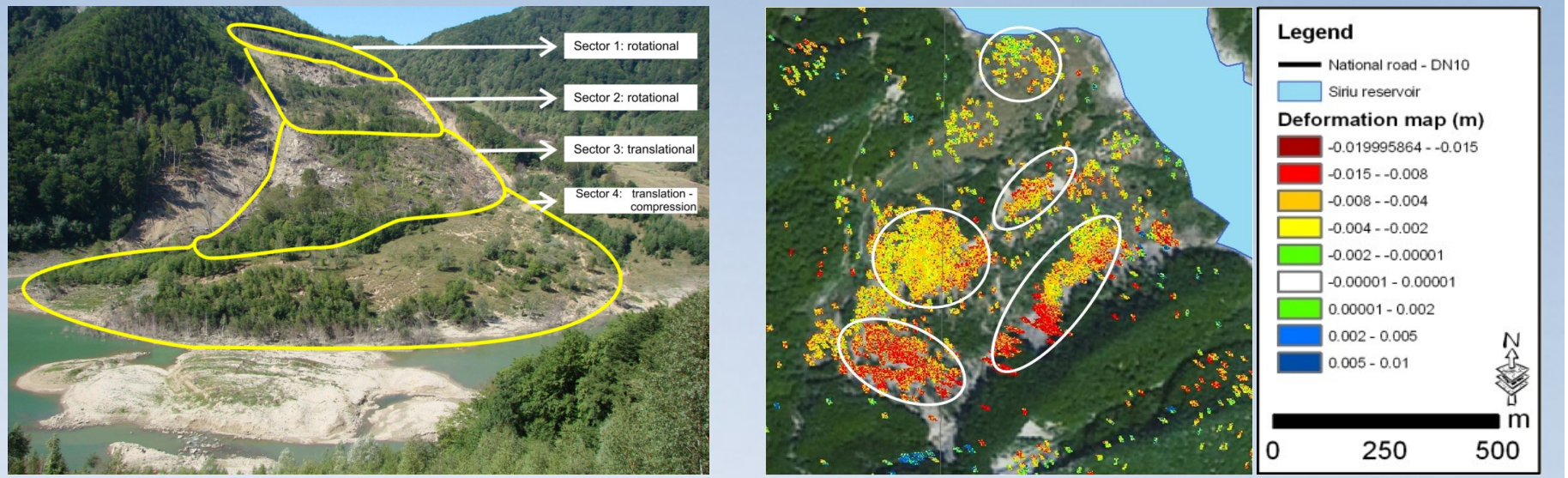
Landslides Monitoring
- Siriu -

●The Siriu area is affected by severe landslide, causing important damages on the water dam, the roads system and urban areas nearby.

●The interferometric measurements show that the landslide is still active in the present and indicate the velocity of the complex inner sectors of translational, rotational and compression movements.



Siriu water dam, "Groapa Vantului" landslide (left – photograph *, right - deformation map)

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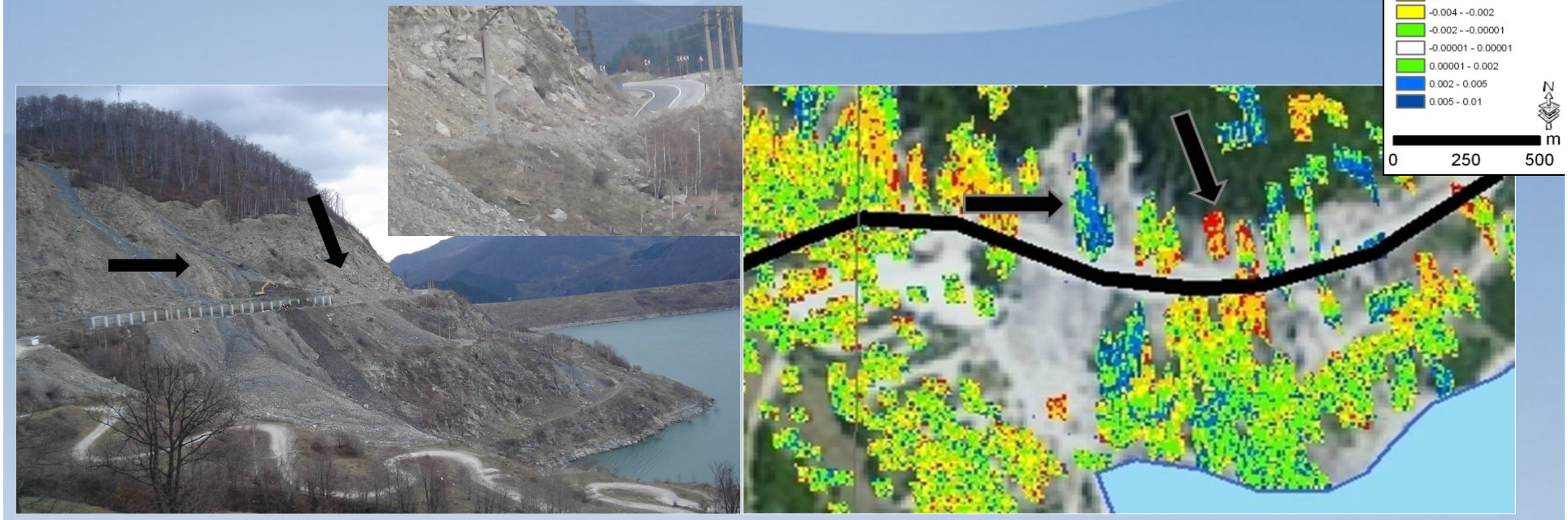

East bank landslide affecting DN10 (left - photograph, right – deformation map)

- The landslide is developing in two different stages: the slower motion (the one with the middle pointed out by the arrow) and two very active narrow landslides on each part of the arrow (grey color in the photograph).

- In the left side of the landslide there is less motion (orange color), in the middle of the landslide there is some motion towards the sensor (blue color), while in the right part of the landslide is quite active with the motion - about 2cm/11 days away from the sensor (red color).

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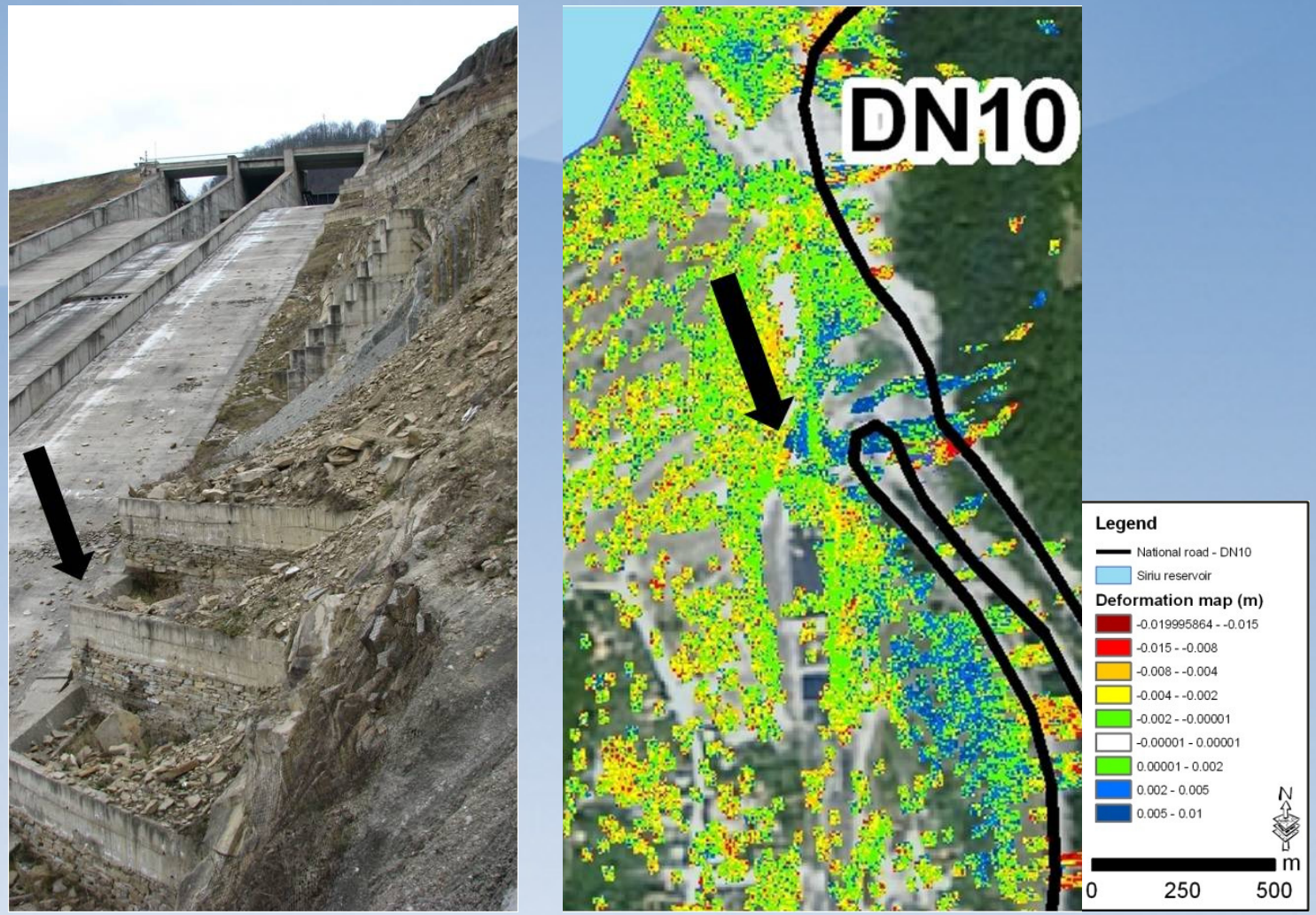

The spillway channel of the water dam (left) and deformation map (right)

- The concrete reinforcements put in place to stabilize the slope are also moving along the slide, putting pressure on the dam's spillway.

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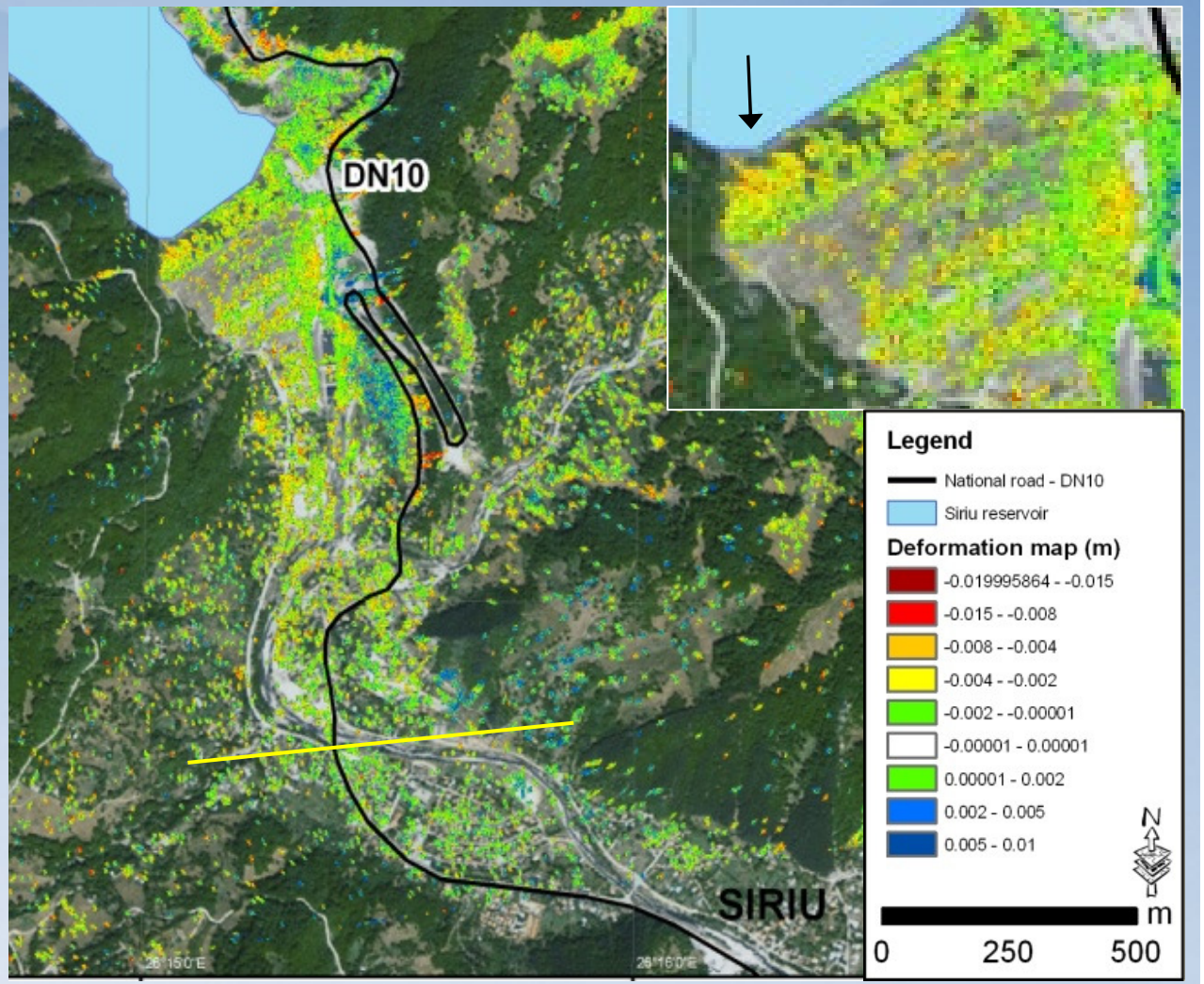
- The water dam is affected by a slow motion away from the sensor (5-6 mm/11 days), as expected.
- The upper right corner of the dam is more unstable than the rest of the dam.
- Motion of the whole Siriu colony (the urban infrastructure extending about 500 m down the water dam) is revealed in the deformation map, an aspect that was unknown before.



Deformation map of Siriu water dam and the urban area nearby

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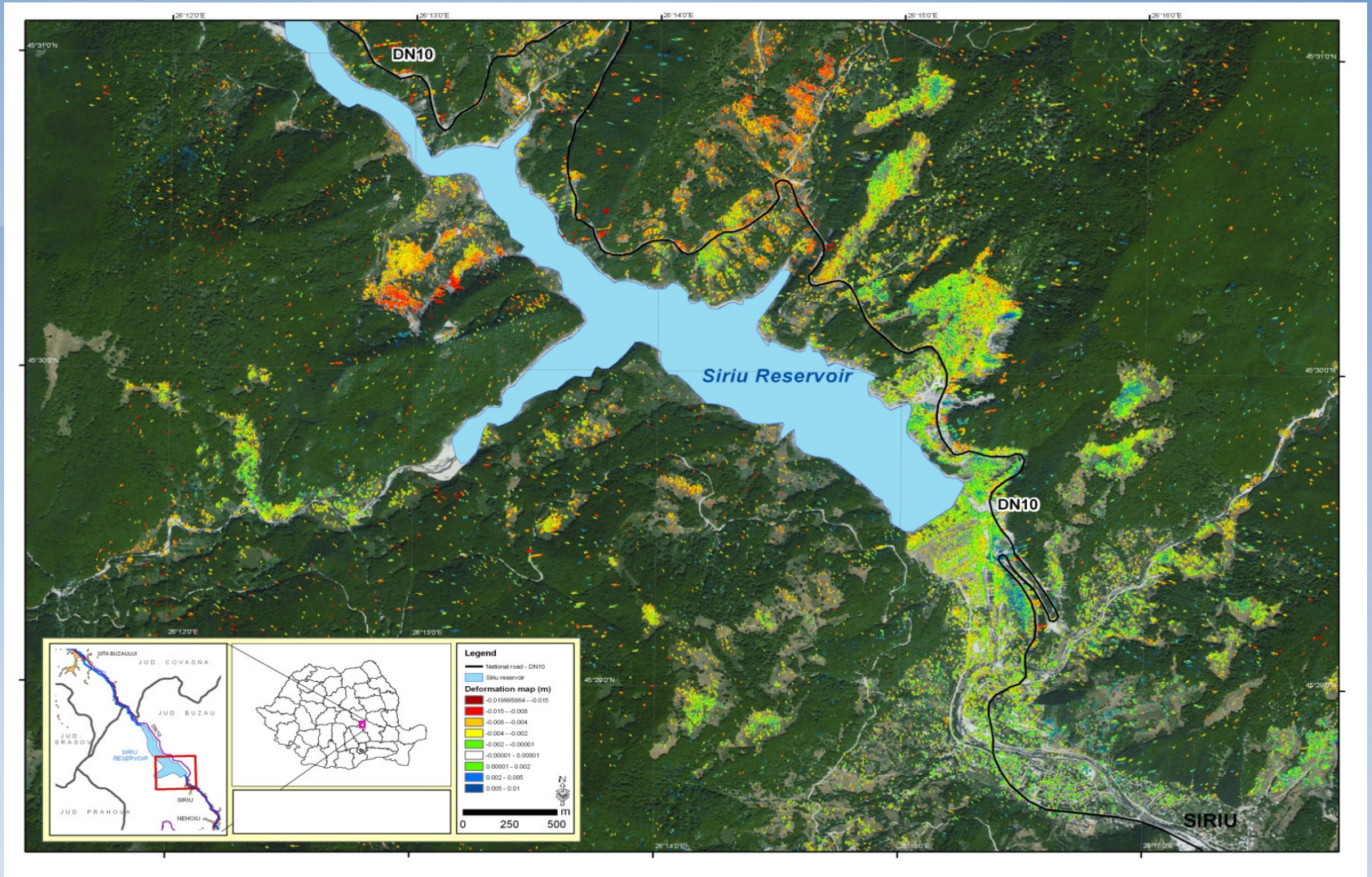

Deformation map of the Siriu area (31.10 – 11.11.2009)

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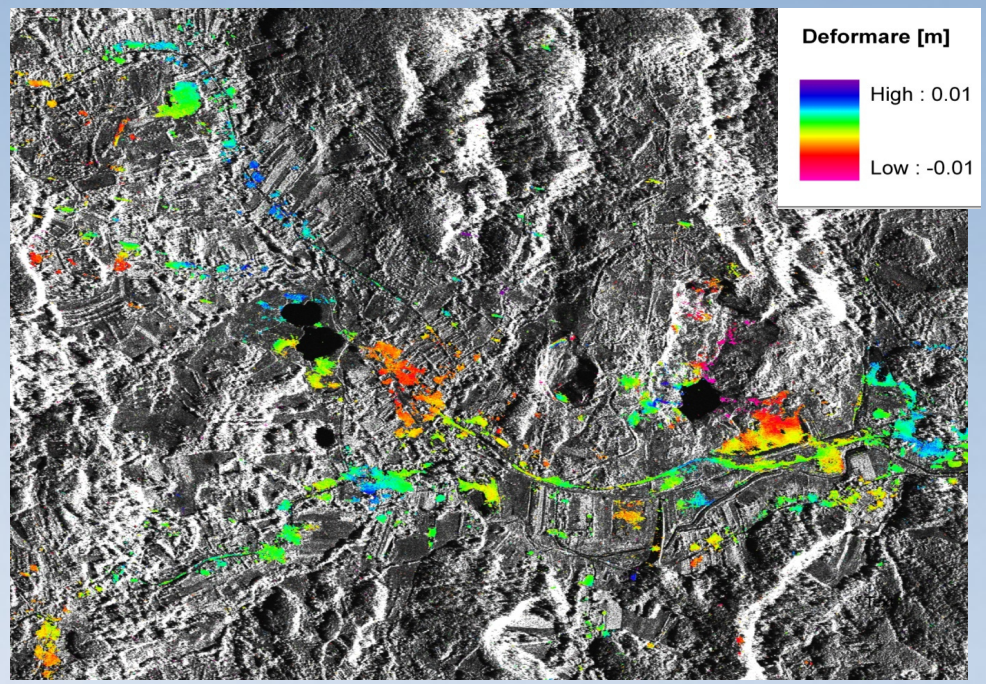
Landslides Monitoring in Mining Areas

- Ocnele Mari -

- In recent years, underground caverns created by salt mining have collapsed over an area of 50 hectares, causing many environmental and especially, social problems.



Google Earth photograph (left) and preliminary deformation map of Ocnele Mari region for 16.08.2010 – 07.09.2010, obtained with High Resolution TerraSAR-X data (right)

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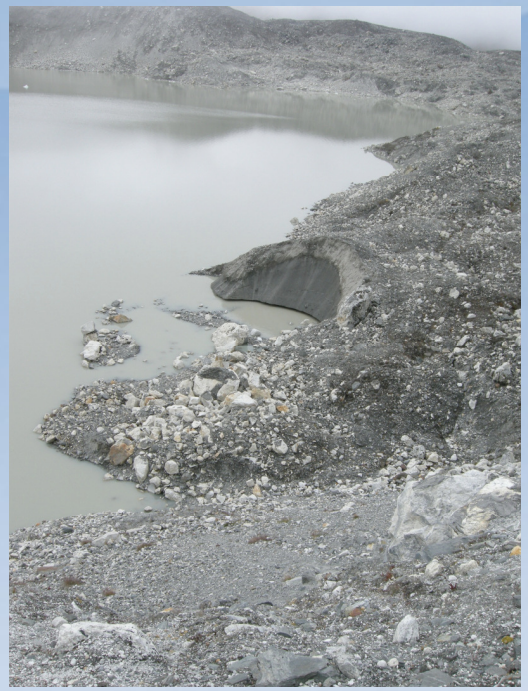
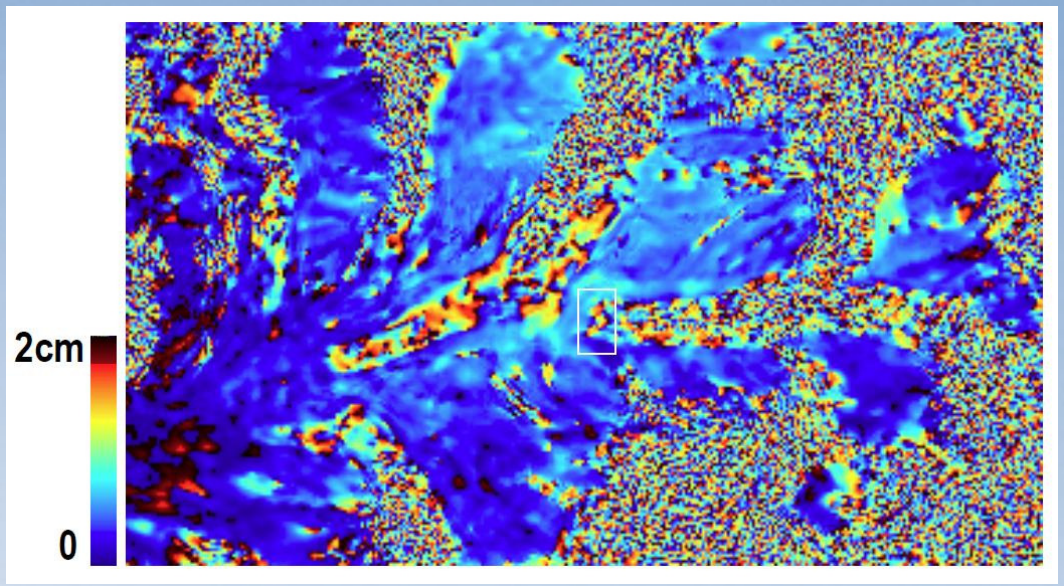
Glacier Movement
- Imja Lake (Himalaya) -



Ice covered by ground moraines at the Western end of the lake



Differential interferogram over the Himalayan glaciers around the Imja Lake, showing deformation rates up to 2 cm in 35 days

●The 2km long glacial lake of Imja at 5000 m altitude is a potential danger for people, animals and infrastructure down valley as the lake could produce a catastrophic flash flood.

●The steep side moraines are unstable and with an earthquake may collapse and provoke a tsunami.

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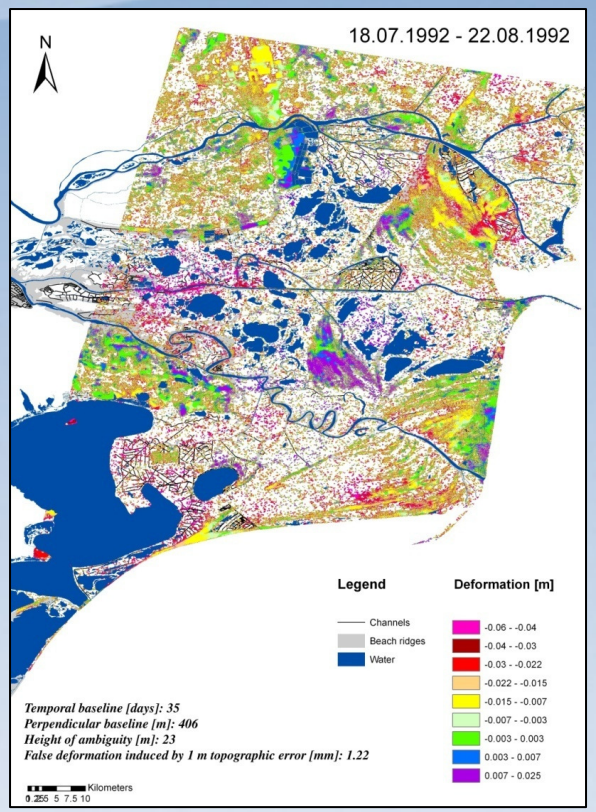
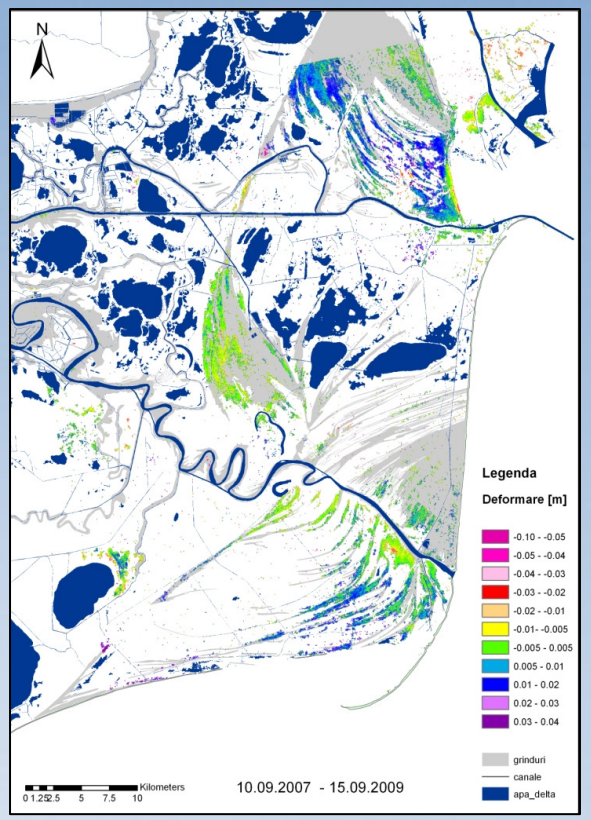
Environment Monitoring

- Danube Delta -



Deformation map over Danube Delta (18.07 – 22.08.1992)



Deformation map over Danube Delta (10.09.2007 – 15.09.2009)

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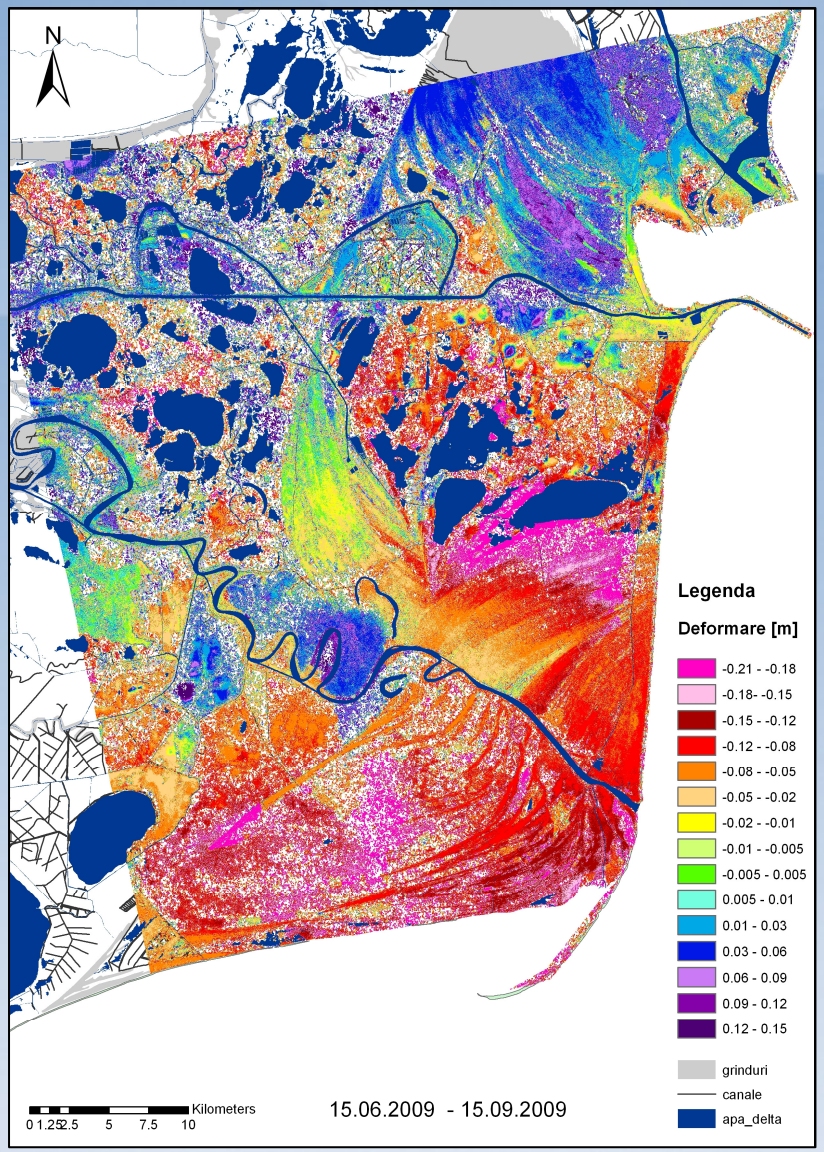

Deformation map over Danube Delta (15.06 – 15.09.2009)

- The Danube Delta proved to be a remarkably active area with complex dynamics driven by multiple factors.
- It consists of relatively stable areas and also of very dynamic, unstable areas.
- In the very dynamic areas, the so called “deformation” information may be related to variation in moisture and groundwater levels.
- The littoral part of the Delta (the beaches North and South of the town of Sulina) suffers from a continuous subsidence process.

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Ground Stability Monitoring Using Differential SAR Interferometry

Case Study: Bucharest City

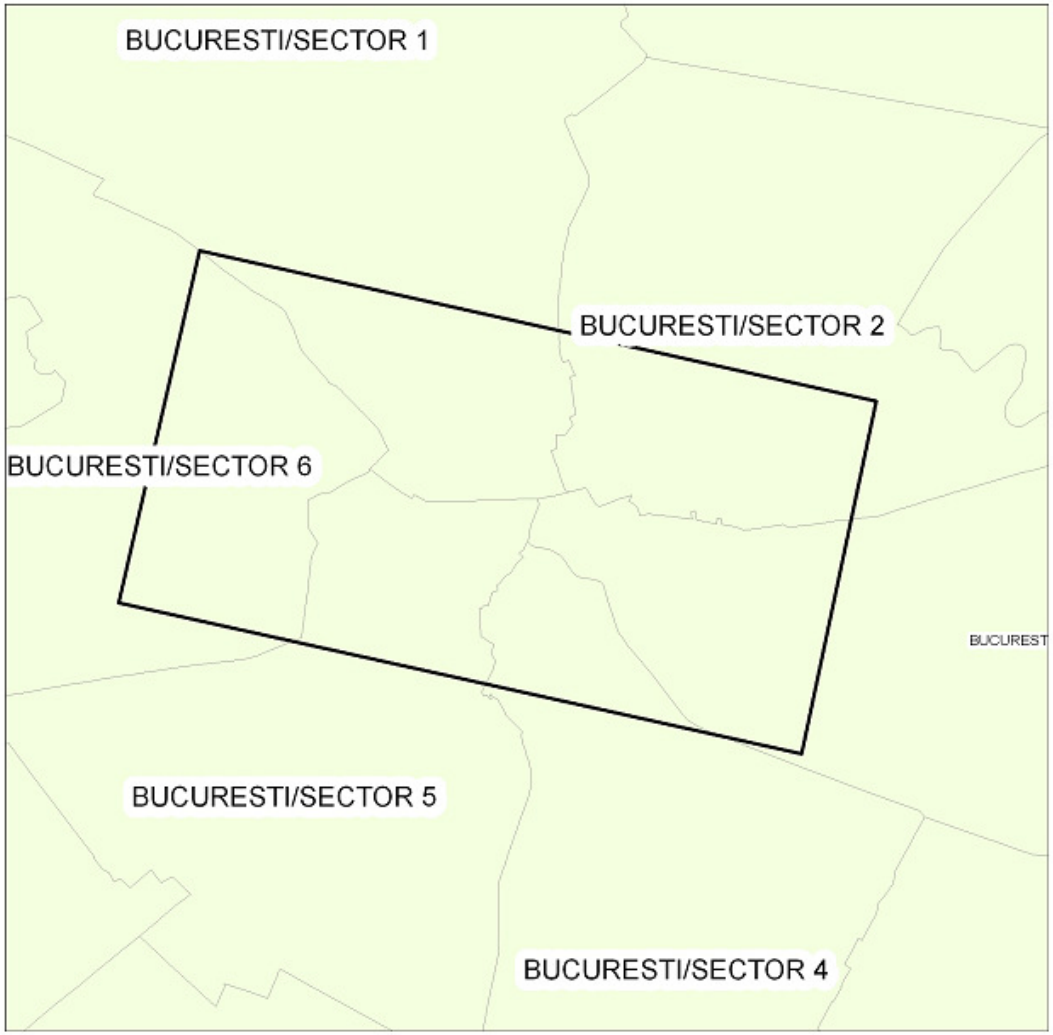
Bucharest City

- Bucharest is the capital city, the industrial and financial center of Romania

- It is the largest city in Romania, located in the southeast of the country, and lies on the banks of the Dâmboviţa River

The Area of Interest

- It summarizes 43 sq.km
- It includes the old center of the city, with many historical buildings and monuments



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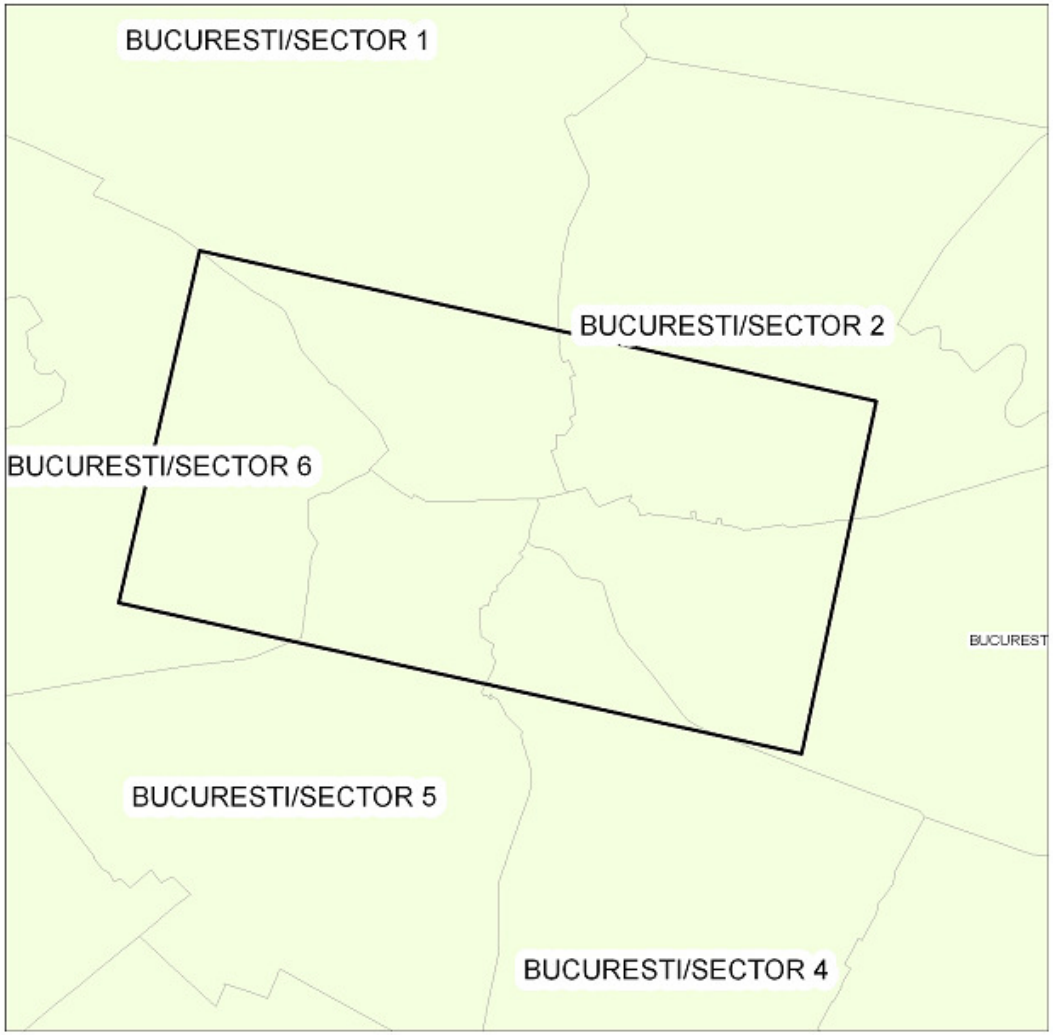

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Bucharest - Geology

- Bucharest is situated in a Molasse basin composed of thick, but poorly consolidated Tertiary and Quaternary sedimentary formations
- The shallow geology is dominated by large alluvial and diluvial deposits and anthropogenic landfill

Geological map of Bucharest area

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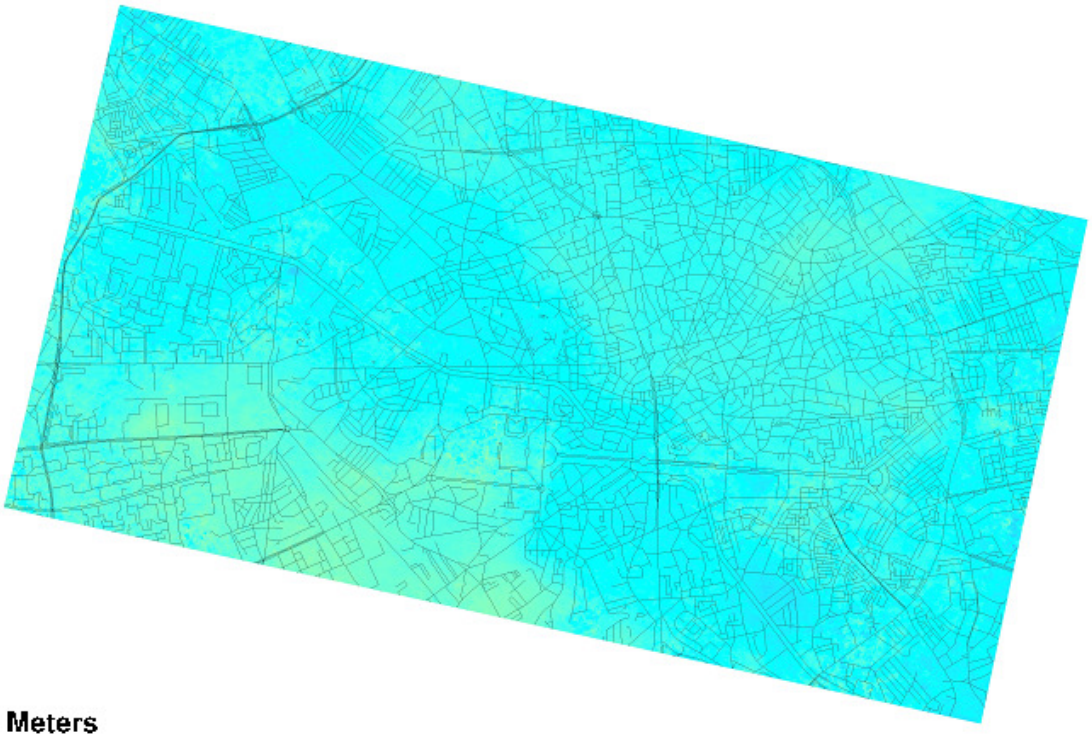
Ground Stability Monitoring Using Differential SAR Interferometry
Case Study: Bucharest City

Bucharest's Ground Displacement Map (1992 - 1998)

This map identifies large areas that are subsiding (red colored areas) with maximal 4 mm, or are uplifted (blue colored areas) with maximal 2 mm, during the time interval of 1992 – 1998

1992 - 1993



Meters

High : 0.002

Low : -0.004

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Ground Stability Monitoring Using Differential SAR Interferometry
Case Study: Bucharest City

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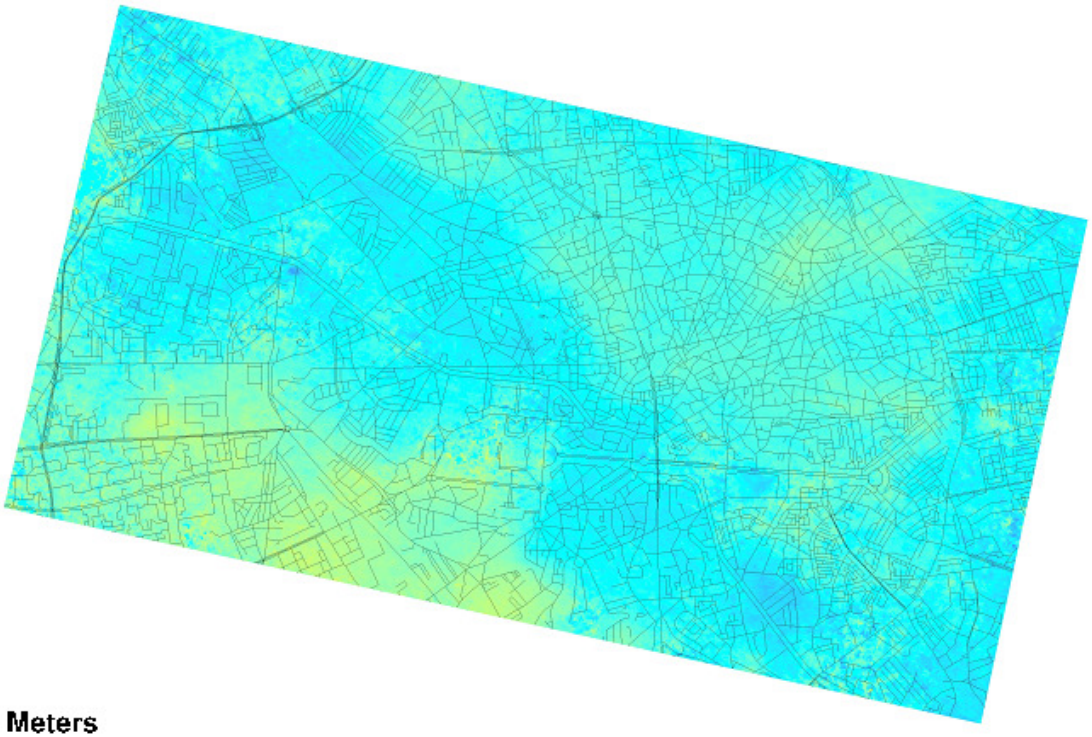
This map identifies large areas that are subsiding (red colored areas) with maximal 4 mm, or are uplifted (blue colored areas) with maximal 2 mm, during the time interval of 1992 – 1998

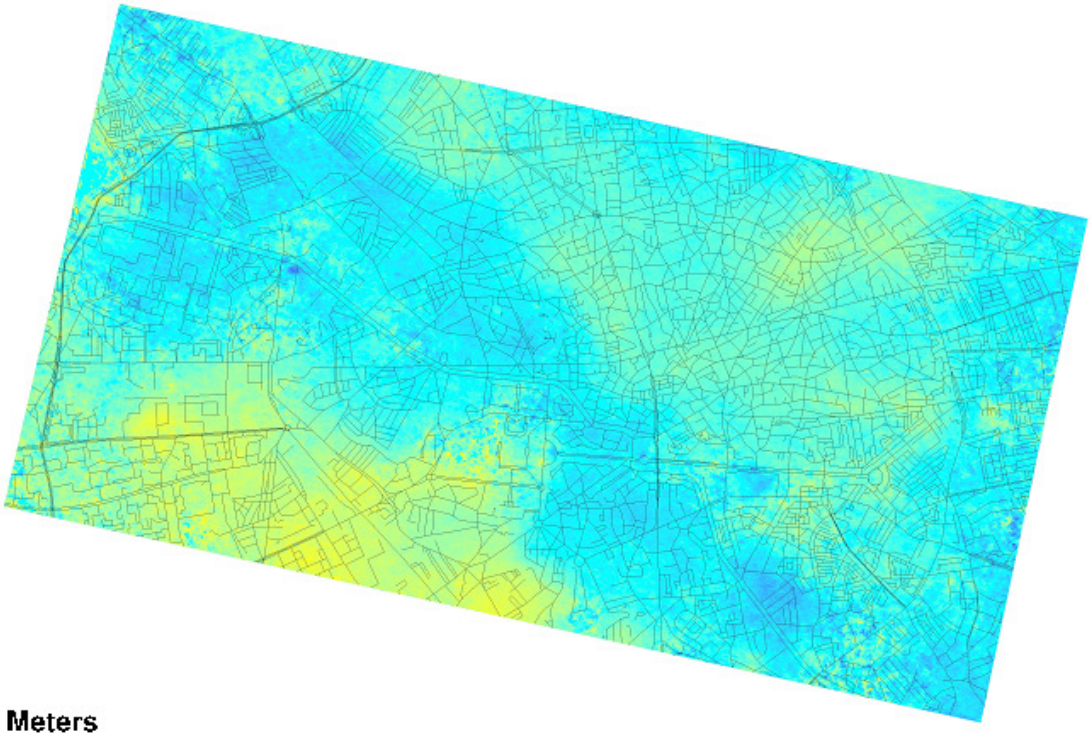
1992 - 1994



Bucharest's Ground Displacement Map (1992 - 1998)

This map identifies large areas that are subsiding (red colored areas) with maximal 4 mm, or are uplifted (blue colored areas) with maximal 2 mm, during the time interval of 1992 – 1998

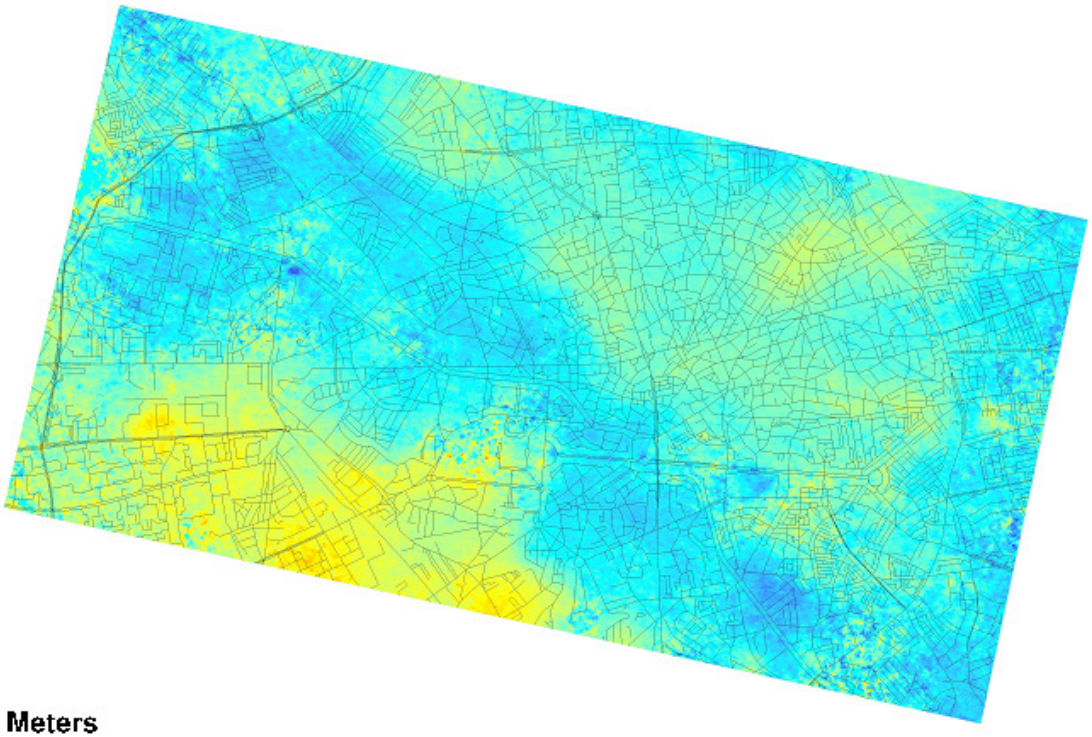
1992 - 1995



Bucharest's Ground Displacement Map (1992 - 1998)

This map identifies large areas that are subsiding (red colored areas) with maximal 4 mm, or are uplifted (blue colored areas) with maximal 2 mm, during the time interval of 1992 – 1998

1992 - 1996



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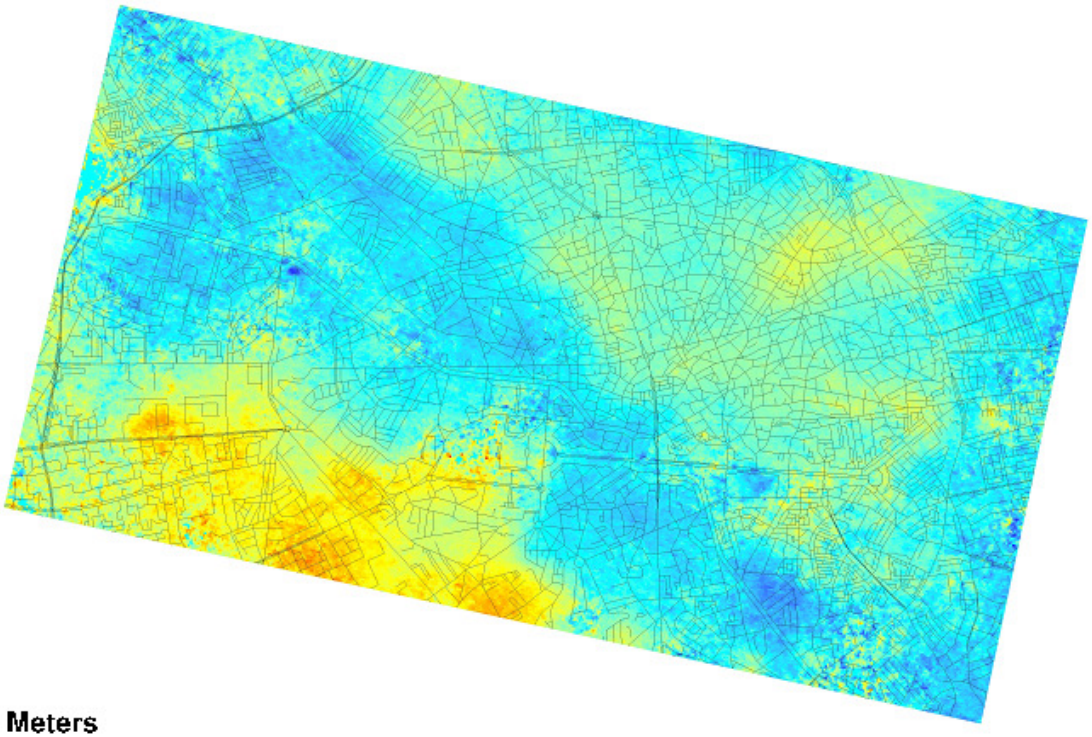

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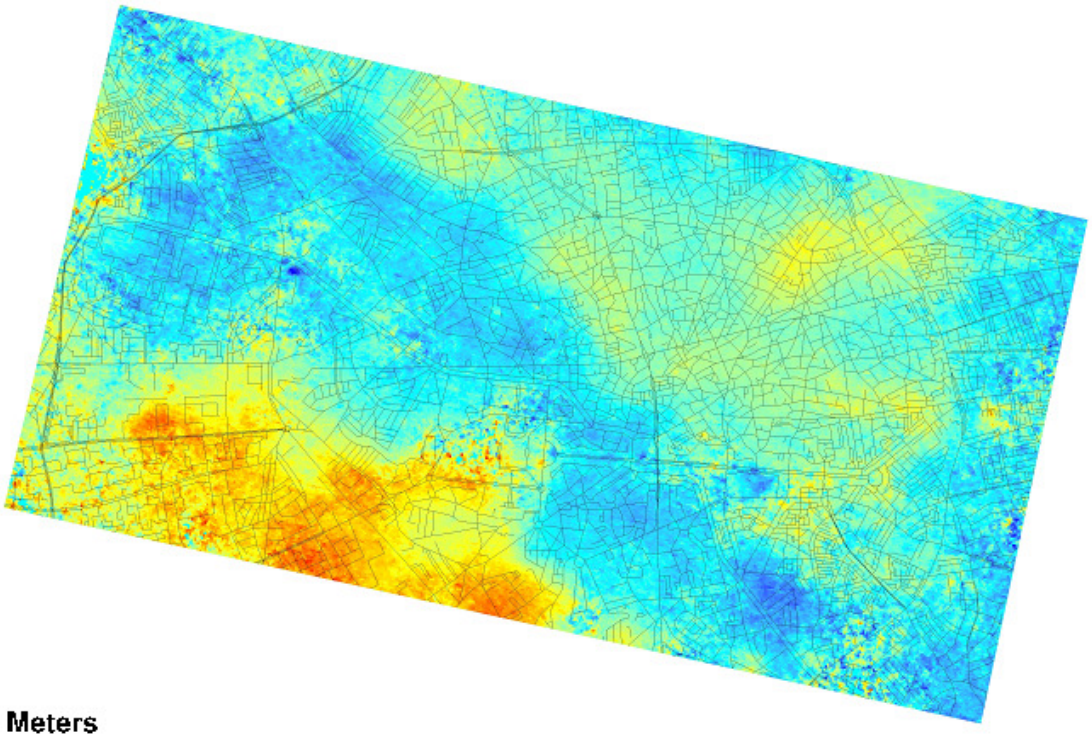
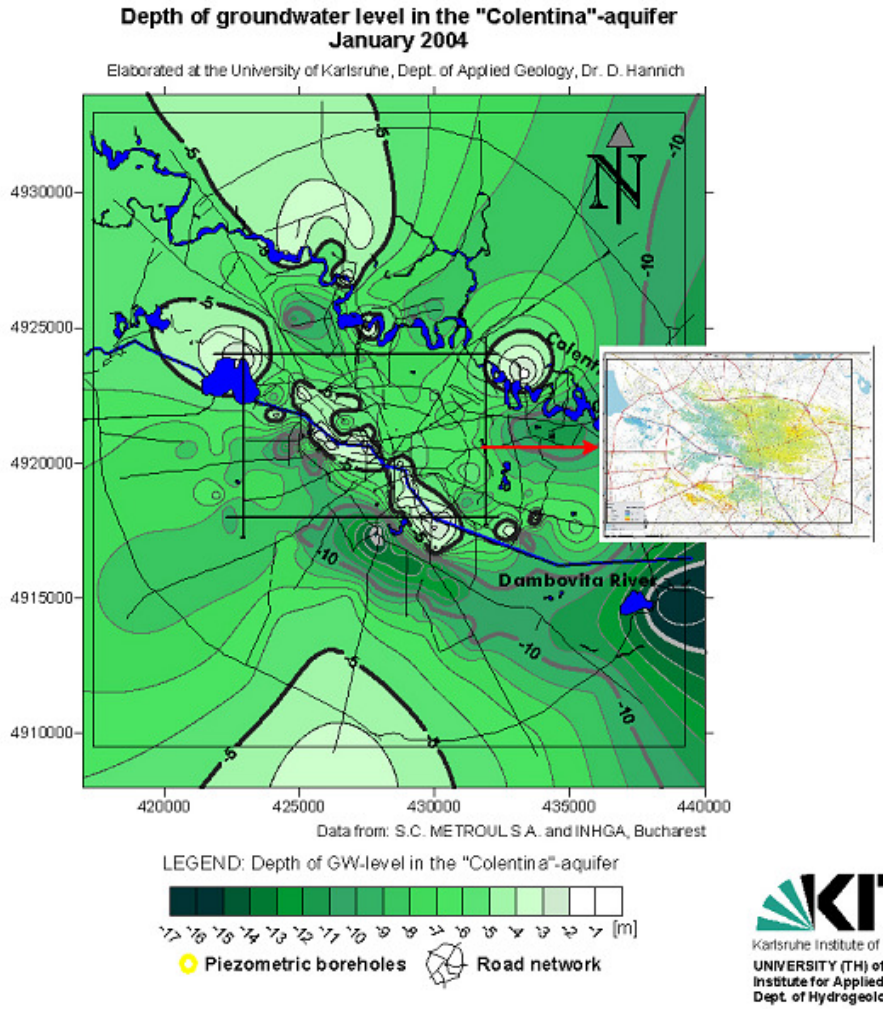


Bucharest's Ground Displacement Map (1992 - 1998)

- Uplift displacement areas in the deformation map correlate with areas of high groundwater level in Bucharest
- In Bucharest such areas are situated mainly in parts of the Dambovita River meadow



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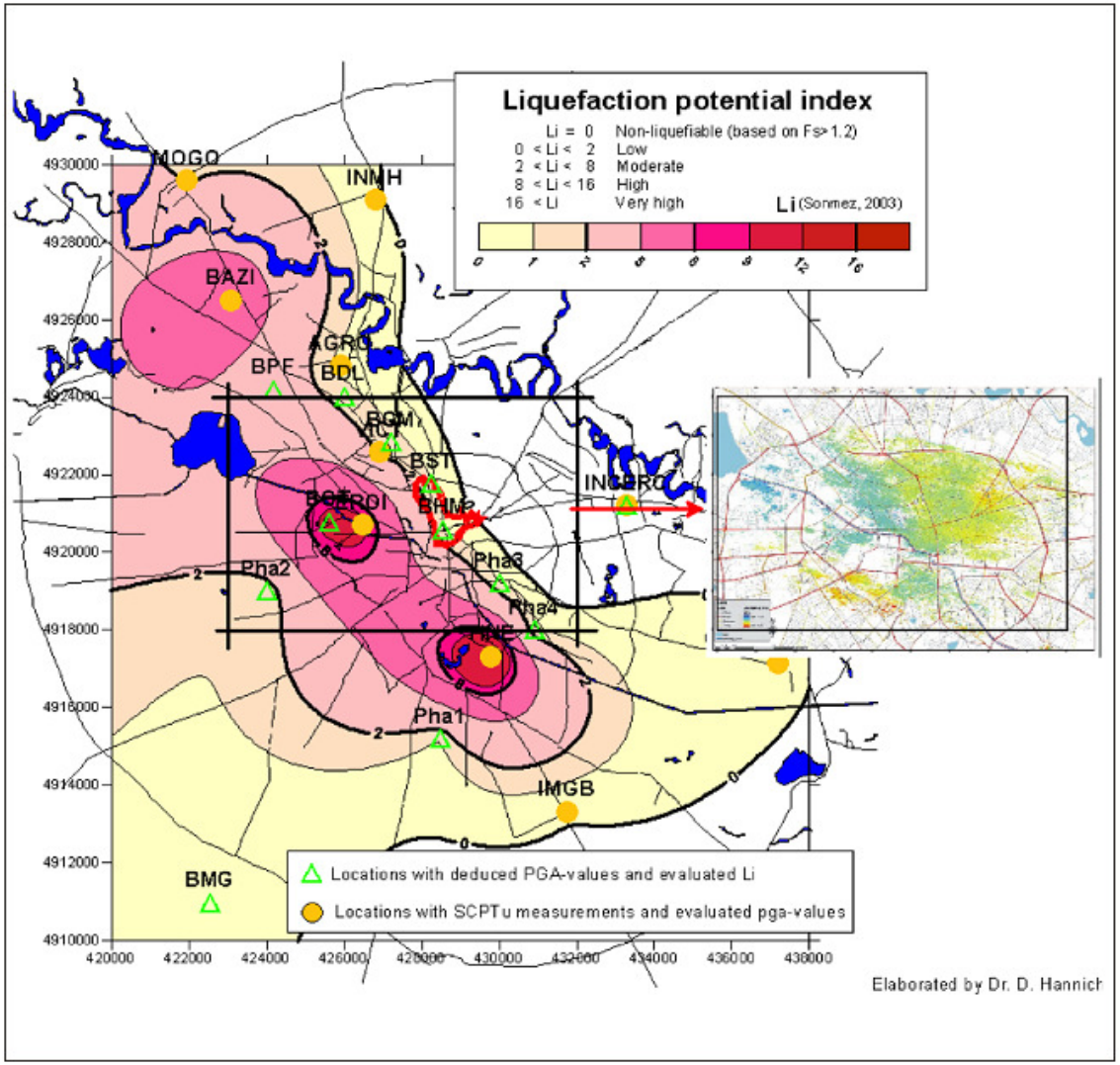

Conclusions

- A set of satellite images provides valuable information regarding the various phenomena dynamics in time.
- The access to large and/or remote areas is facilitated.
- The monitoring is performed both on the vertical and horizontal, with up to millimeters accuracy.

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Thank you!