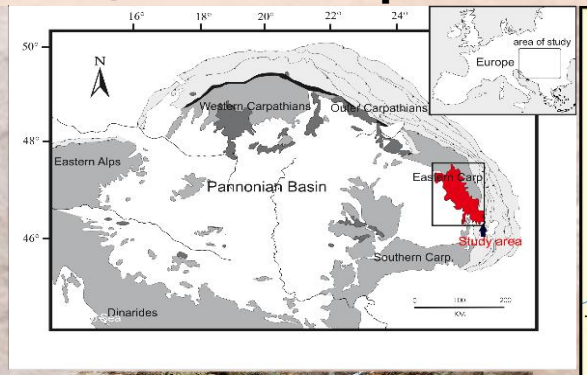
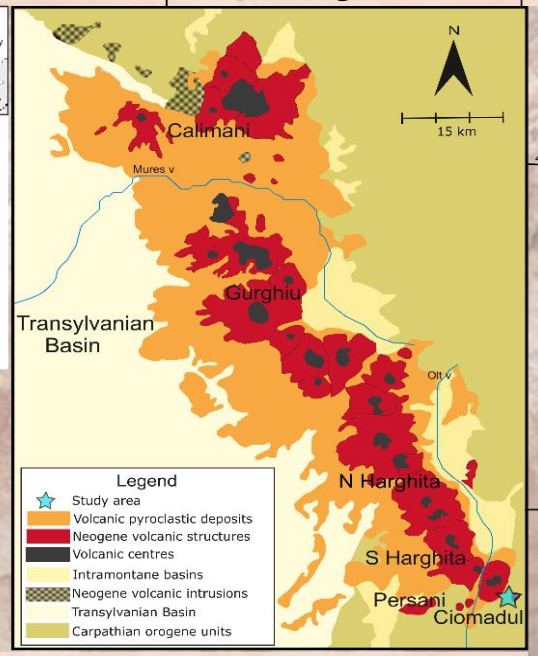
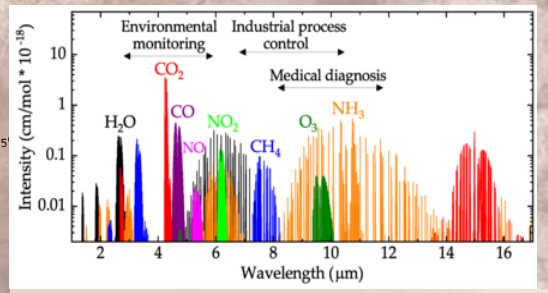
Using UAV-based Infrared Thermometry in the identification of gas seeps: a case study from Ciomadul, dormant volcano (Eastern Carpathians, Romania) –

Boglárka-Mercedesz Kis, Dan Mircea Tămaș, Alexandra Tămaș, Roland Szalay







- Ciomadul is a long-dormant volcanic area (Romanian Eastern Carpathians)
- Several caves are found here from which deep gases like CO_2 and H_2S escape.
- The Stinky Cave of Turia: opens on the southeast side of the Büdös/Puturosul volcanic dome
- Gas yield determination was performed by Kis et al., 2017. According to them, **1923 tons of CO_2 flows out of the cave every year.**

Remote surveillance of volcanic and geothermal areas can provide data even from hazardous areas, or places difficult to reach.

- **the Uncrewed Aerial Vehicles (UAV) or drones are equipped with Thermal Infrared (TIR) sensors, thus enabling the monitorization of large areas at high resolution.**
- **Structures from Motion (SfM) and UAV-based SfM have been increasingly used with the scope of creating 3D outcrop models or DOM and high-resolution DEM.**

- **we adopted a UAV-based IRT and Structure from Motion (SfM) for the identification of gas emission areas (hotspots).**
- **4 surveys in different environmental conditions**
- **The aim: to demonstrate the efficiency of the qualitative identification method, and to provide a concrete example from a case study in the Ciomadul volcanic area.**

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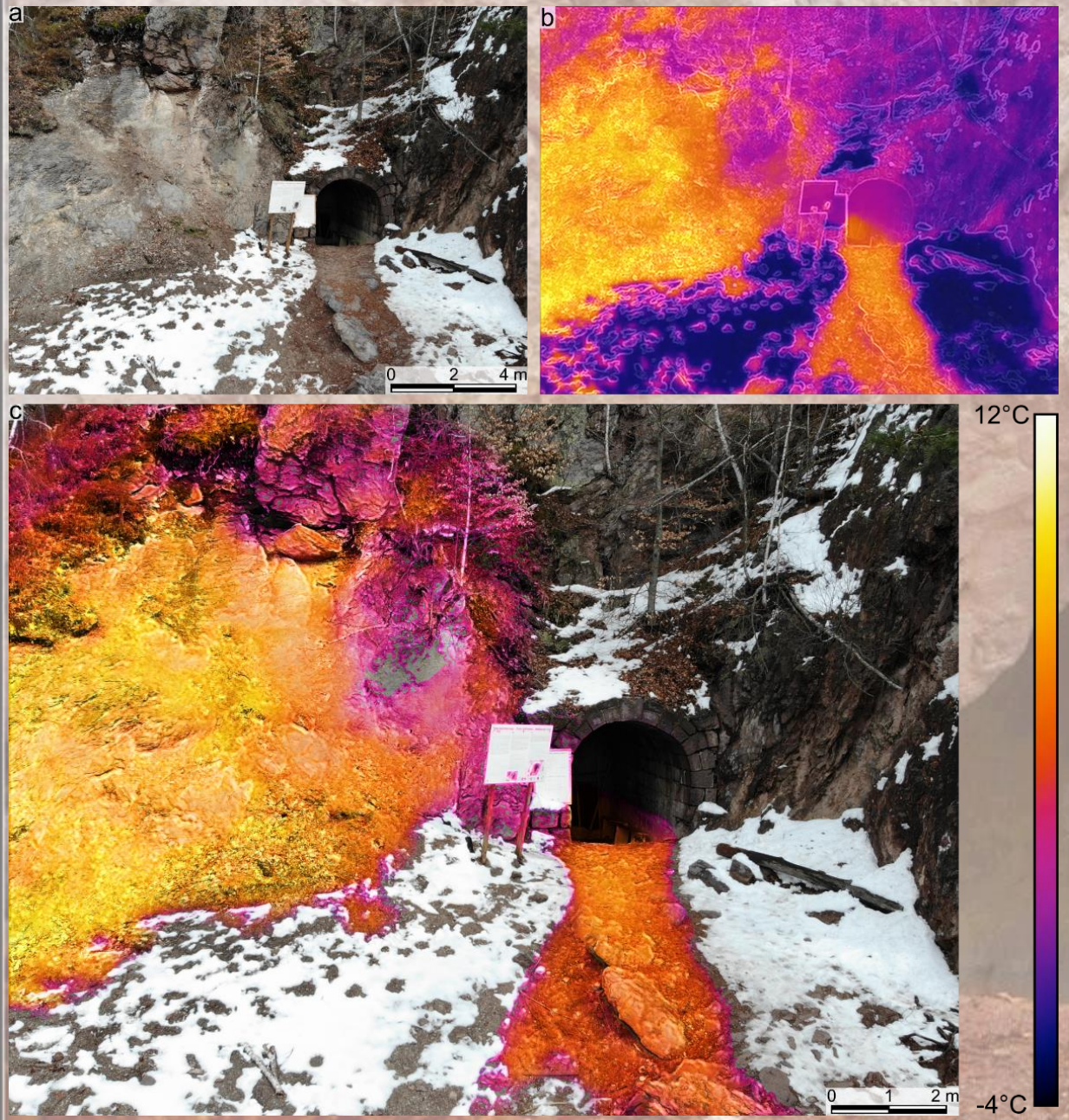

IRT survey 1

- **This survey was made during daylight when the studied outcrop and entrance of the cave were partially exposed to direct sunlight.**
- **The main scope of this survey was to acquire the RGB images for the successful construction of the RGB digital outcrop model. Still, the TIR images were recording warm thermal anomalies in the Sulphur Cave.**
- **The maximum recorded radiometric temperatures in the warm part of the cave interior were similar to those recorded in the area where the snow was melted by the warmer gases.**
- **Most of the warm thermal anomalies observed outside the cave could also be caused by exposure to sunlight and as a contrast to the snow cover.**

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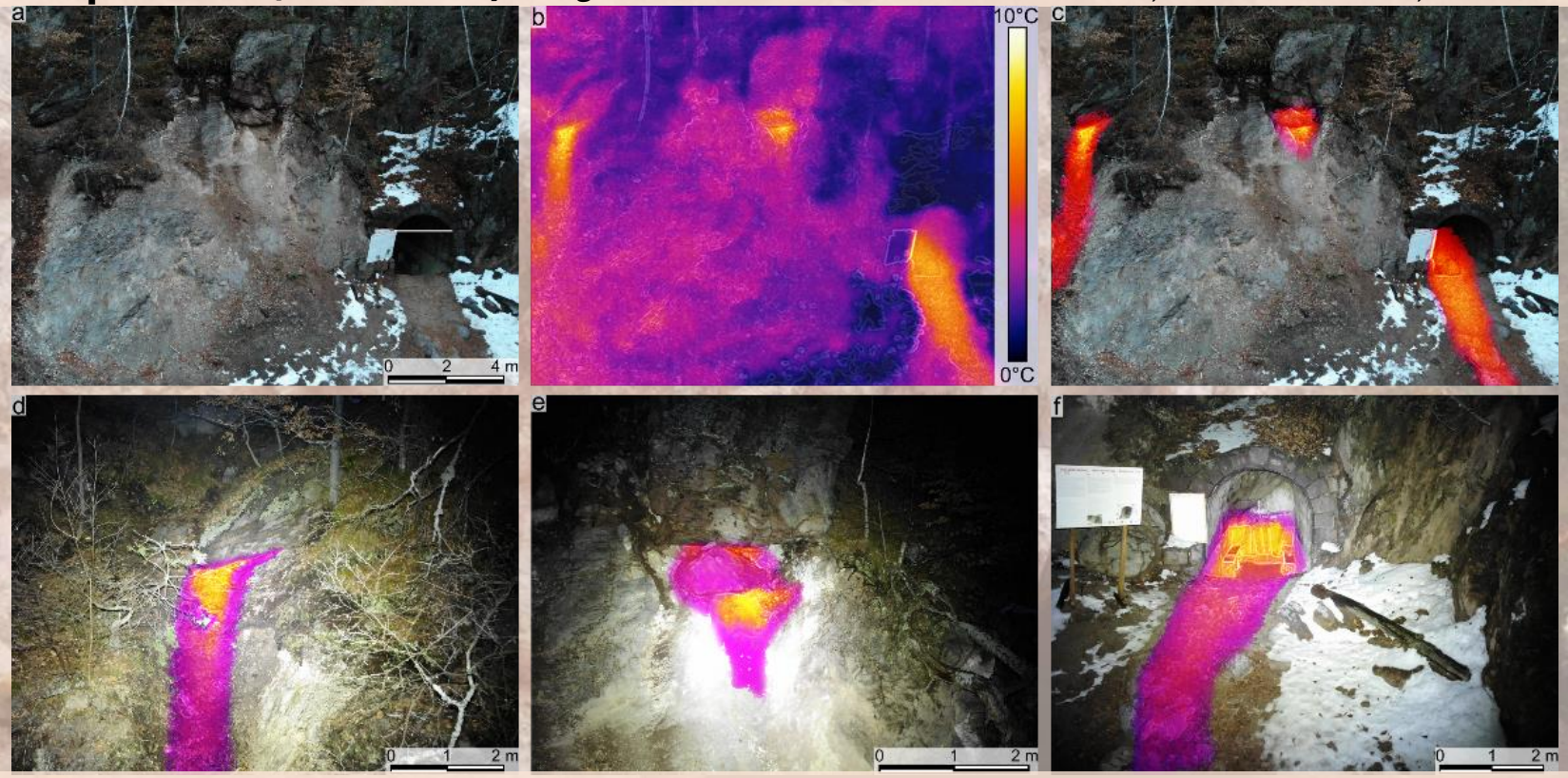

IRT survey 2

- **was acquired after sunset, when the ambient temperature has fallen below freezing**
- **3 significant warm thermal anomalies have been identified during this survey.**
- **the identified thermal anomalies present elongated shapes and were clearly visible even from a height of 70 meters (above the take-off altitude). The use of the spotlight during the acquisition aided us in distinguishing visible features on the thermal images (with FLIR MSX™).**
- **along with the clearly visible warm thermal anomalies, on the images acquired from a higher altitude (approximately 70 meters), we also identified several areas/patches with warm thermal anomalies, but not as significant as the main three.**

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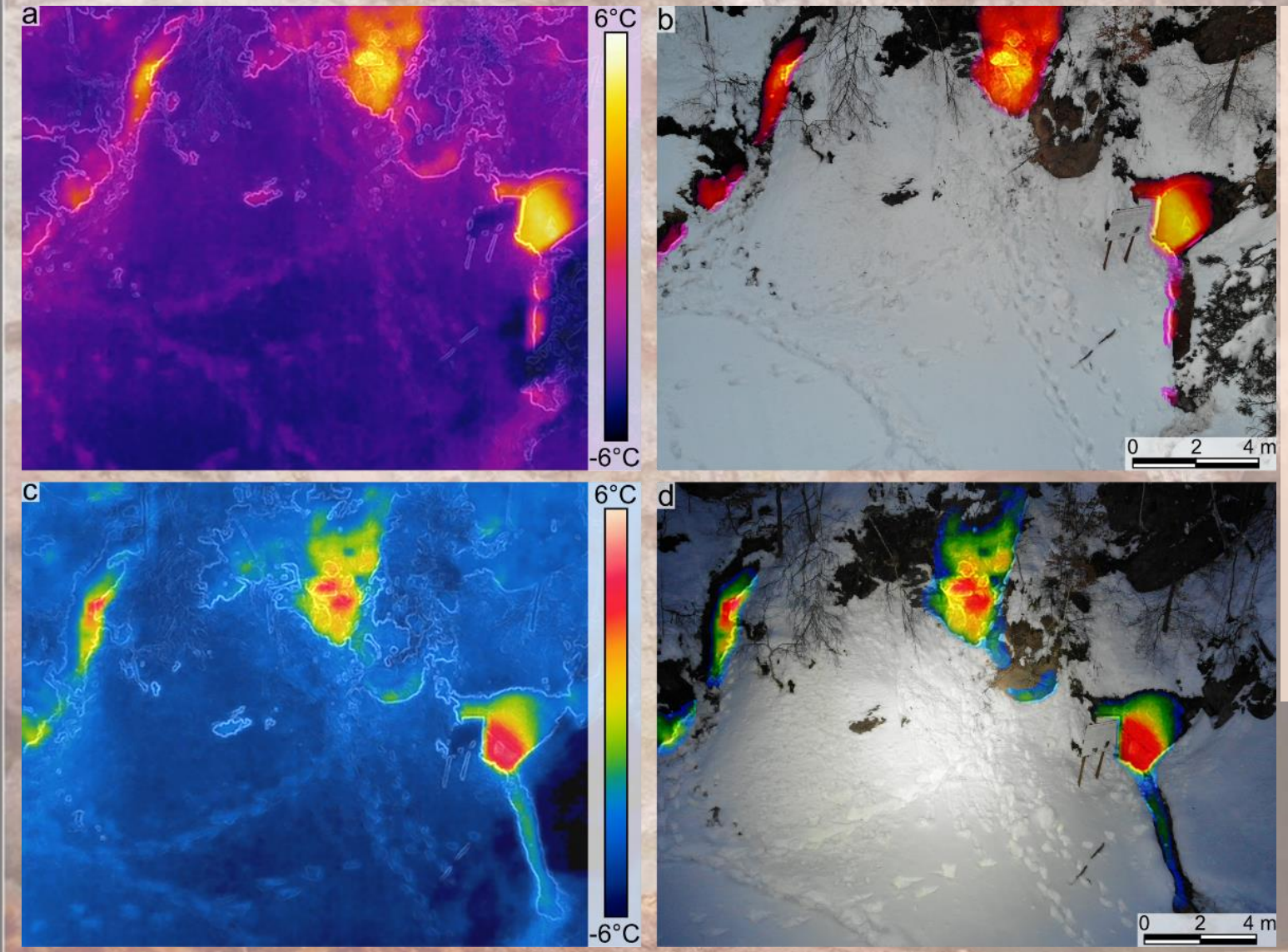

ITR survey 3 and 4

- During IRT survey 4 the ambient temperature, as well as that of the cliff face and vegetation was slightly cooler compared with IRT survey 3 (0.5-1°C).
- The main difference between the two surveys is the thermal palette used for acquisition (HotMetal for IRT survey 3 and Rainbow for IRT survey 4).
- The scope of the change in the thermal palette was to evaluate which of them would provide better SfM model results.
- During this campaign, several other (smaller) hotspots have been identified. The three main ones were still providing strong warm thermal anomalies.

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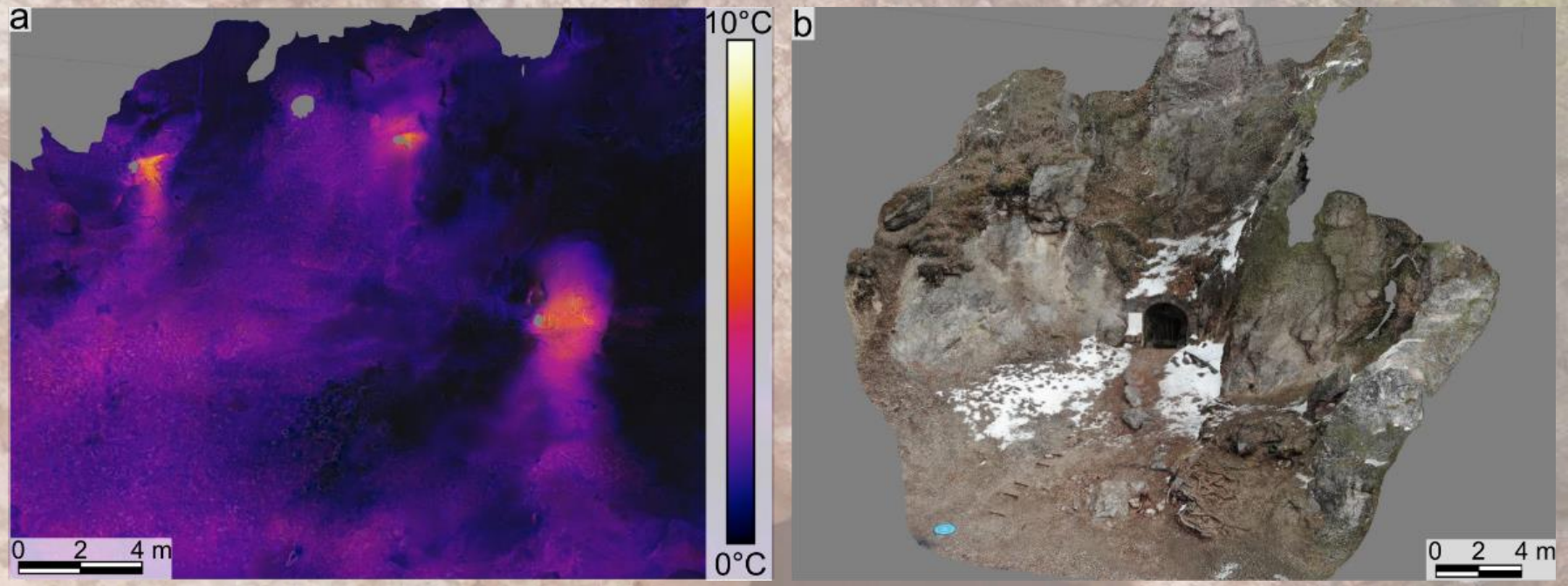

- **The TIR SfM models as well as the orthomosaics provide a clear and integrated view of all the warm thermal anomalies.**
- **Models based on IRT surveys 3 and 4 we identified several smaller anomalies.**
- **The location of the two main newly identified hotspots have been cross-correlated between the TIR and RGB SfM models. They originate from areas in the outcrop that are intensively fractured (fracture/fault orientations show two main trends of ~65/355 and ~80/60).**
- **Further work: UAV-based mapping for a better understanding and quantification of the total CO_2 emissions and a future regional rollout of the TIR mapping and identification of CO_2 emissions in the area.**

This work was supported by a grant of the Romanian Ministry of Education and Research, CNCS - UEFISCDI, project number PN-III-P1-1.1-TE-2019-1908, within PNCDI III and Grant for Young Researchers of Babes-Bolyai University, GTC 32144 and GTC 35275.