Monitoring of thermal regime of municipal solid waste landfill using airborne data

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Motivation

Landfilling is a relatively low demanding and prevalent method of **municipal solid waste** (**MSW**) disposal in most European countries. More MSW is disposed of in landfills than is recycled. Landfilling raises a number of issues harmful for the environment, such as discharge of leachate from the landfill body, release of methane from the ground surface, settling and instability of landfill body, and spreading of invasive species (Kuraš et al. 2014, Vinti et al. 2021).

MSW landfills currently contribute around one third of the European methane emissions (Malinauskaite et al. 2017). Methan is an important greenhouse gas which is around twenty-five times more harmful relative to CO_2. On MSW landfill, when anaerobic conditions are established, a methane-producing bacteria begin to decompose the waste and generate methane. Methane should not escape from the sealed stage, but it often does. In addition, methane can be formed under the top layer of waste under favorable conditions for its formation, such as MSW humidity higher than 20-30% and temperature 25-40 °C. Methane is a flammable gas, and methane spots on the landfill surface are places of potential burning.

Landfills can exhibit variations in surface temperature due to various factors such as the decomposition of waste materials, the presence of landfill gases, and the interaction with environmental conditions. Monitoring surface temperature contrasts within a landfill can help identify areas of active decomposition and potential methane "hotspots". **Landfill surface temperature** can be an indicator, according to which we can potentially infer the course of biomethanation process and explore the relationship between landfill surface temperature and **methane release on the surface** (Brovkina et al. 2023). The high accuracy and easy interpretation of airborne thermal data make it a powerful tool for mapping surface temperature on relatively large areas (aircraft) or in small focused missions (dron).

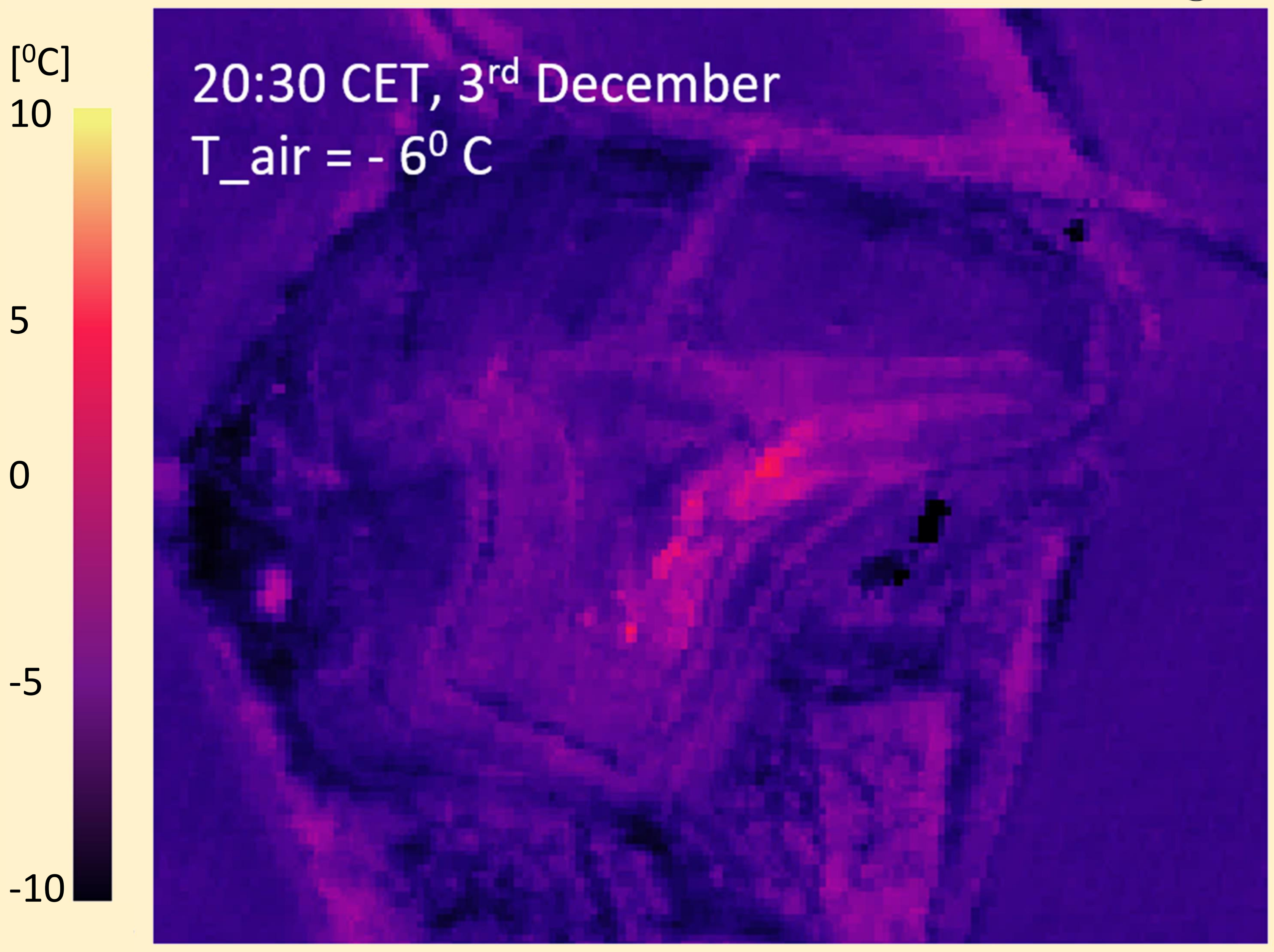
Data and Methods

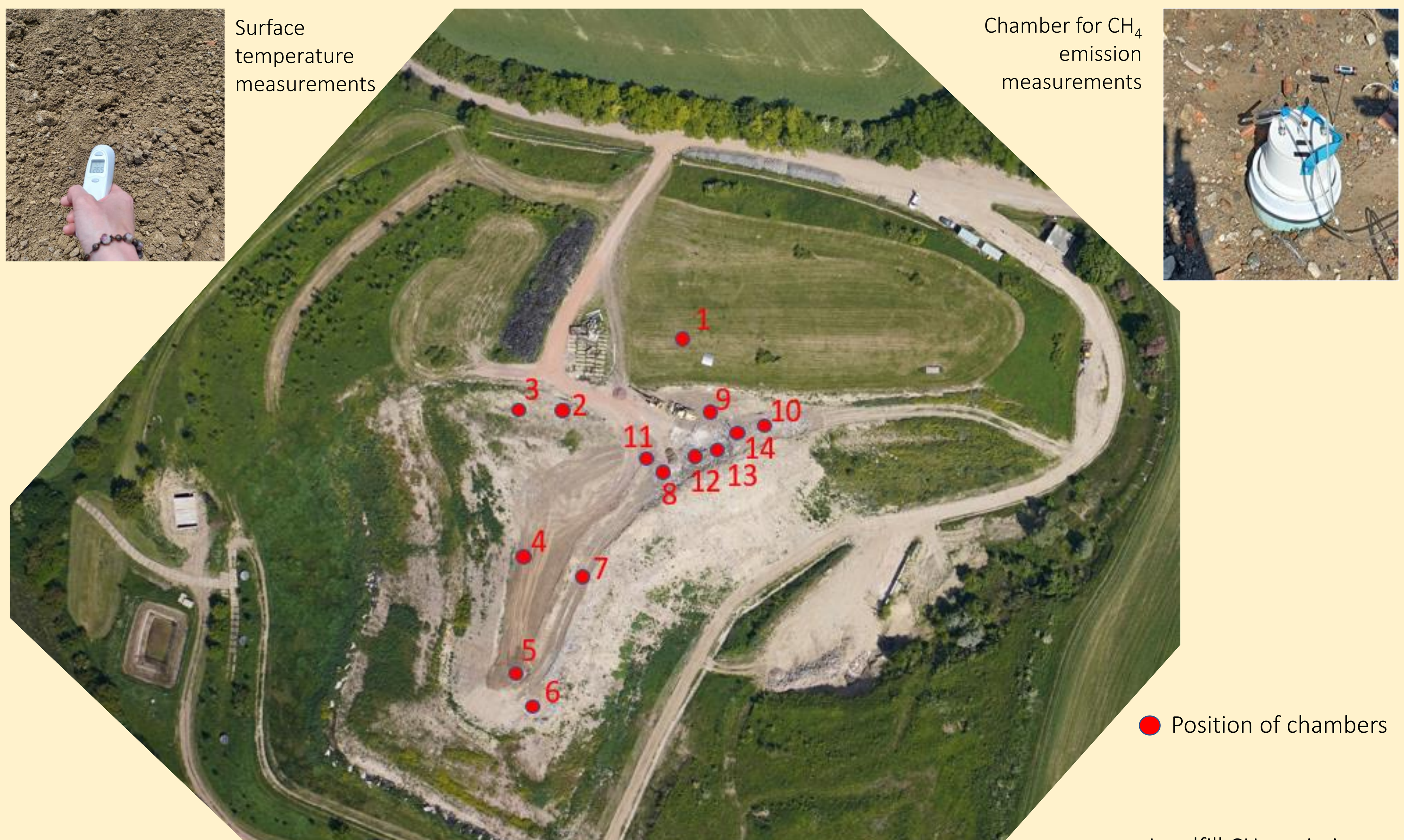
SWIR and LWIR hyperspectral (HS) data of Flight Laboratory of Imaging Systems (FLIS, https://olc.czechglobe.cz/en) were acquired 31.8.2022 at 10:00 CET, 3.12.2022 at 20:30 CET, and 31.5.2023 at 10:00 CET for the municipal solid waste landfill close to Brno city. LWIR data from DJI Matrix 600 Pro hexacopter were acquired 31.5.2023 at 4:00 CET. Landfill objects surface temperature using a portable handheld infrared thermometer and concentration and fluxes of CH_4 using a soil chamber connected to a portable greenhouse gas analyser (Picarro GasScouter G4301, Picarro, CA, USA) were measured simultaneously with airborne data acquisition (31.8.2022, 31.5.2023). *Data processing*. The spectra profile from airborne SWIR HS data were analysed to detect CH_4 absorption features in several landfill parts. Methane indices (Xiao et al., 2020; Thorpe et al., 2021) incorporating specific narrow spectral SWIR regions (1630 - 1690 nm, 2100 – 2300 nm) were calculated to indicate the presence of CH_4 "hot spots" on the landfill. The surface temperature of the landfill from aircraft and dron LWIR data was validated with surface temperature measurements on the landfill and mapped to identify locations with extremely high surface temperature. The CH_4 emissions from landfill based on soil chamber measurements were calculated using a linear fit of the CH_4 concentration change over time (3 min) for all chamber positions, and used for validation of CH_4 "hot spots" from airborne SWIR data.

Parameters of data acquisition

Sensor	Aircraft		Dron
	TASI-600	SASI-600	WorksWell WIRIS Pro
Spectral domain	LWIR	SWIR	LWIR
Spectral range	8000 – 11000	950 – 2450	7500 - 13500
Number of spatial pixels	600	600	640 × 512
Max. spectral resolution	110	15	-
FOV [^{0}]	40	40	6.9 – 58.2
Spatial resolution [m]	1.25 - 5.0	1.25 - 5.0	From 0.01

Aircraft, drone, and field data acquisition





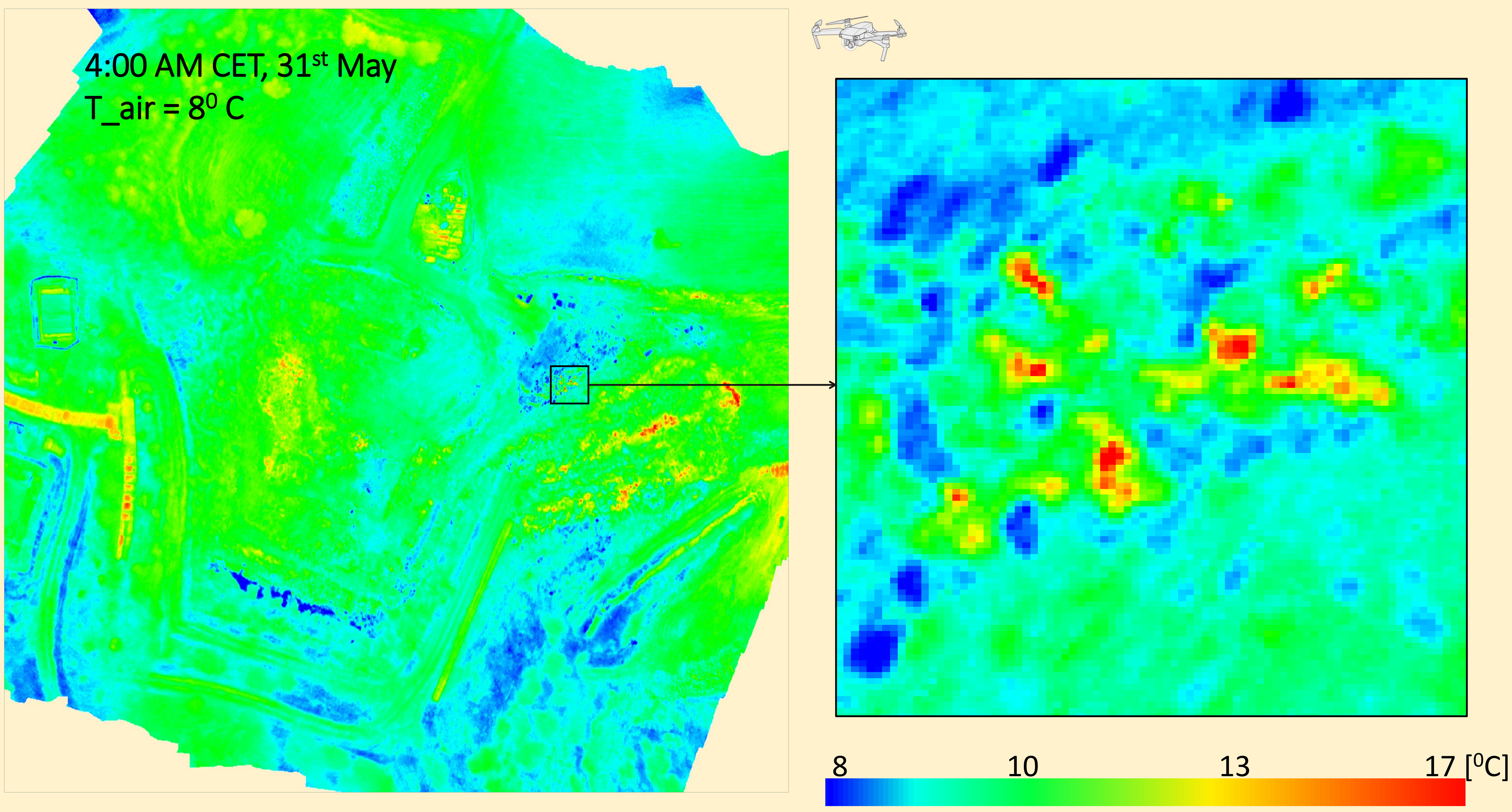
Landfill CH_4 emission

Position	Flux [mgCH4 m-2 d-1]
1	-1.89
2	63.93
3	-36.61
4	54.93
5	0.00
6	551.28
7	52.79
8	20522.05
9	3125.15
10	1015.20
11	14886.55
12	12609.74
13	38511.87
14	37329.28

Surface temperature of landfill objects*

Object	Temperature [^{0}C]
asphalt	13.4
stones	9.8
tires	8.7
leachate	12.8
soil mixture	9.7
iron fragments	8.0
waste with soil	10.7
green grass	9.9
dry grass	8.7
concrete	12.6

* Measured 31.5.2023 at 4:00 AM CET



Results

The surface temperature "hot spots" in several locations of the landfill body were more than two times higher than surface temperature of the surrounding vegetation (a proxy of "background temperature"). Maximum CH_4 concentrations and emissions were around 200 ppm and 40 g m^{-2} d^{-1}, respectively, in several locations of the landfill which spatially coincided with the locations of surface temperature "hot spots" on the landfill thermal map. Airborne thermal data can help identify locations on MSW landfill that may require attention in terms of waste management practices or gas collection systems.

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References: Brovkina et al. 2023. Application of airborne data to monitor urban infrastructure objects, Int. Arch. Potogramm. Remote Sens. XLVIII-5/W2-2023, 25-29. **Kuras,** M. 2014. Odpady a jejich zpracovani. ISBN: 978-80-86832-80-7, 344 p. **Malinauskaite**, J., et al. 2017. Municipal solid waste management and waste-to-energy in the context of a circular economy and energy recycling in Europe. Energy 141, 2013–2044. **Thorpe**, A. K., et al. 2021. Improved methane emission estimates using AVIRIS-NG and an Airborne Doppler Wind Lidar, *Remote Sensing of Environment*, 266. **Vinti,** G., et al. 2021. Municipal solid waste management and adverse health outcomes: a systematic review. Int J Environ Res public Health 18 (8). **Xiao,** C., B. et al.2020. Detecting the sources of methane emission from oil shale mining and processing using airborne hyperspectral data. *Remote Sensing*, 12 (3): 537.