

# UNDERGROUND TEMPERATURE EVOLUTION DURING SUMMER TOURISM SEASON IN ȘUGĂU CAVE HARGHITA COUNTY, ROMANIA

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**Abstract.** *Underground temperature evolution during summer tourism season in Șugău Cave (Harghita county, Romania).* This paper presents a preliminary report on the diurnal temperature evolution in Șugău Cave (located in the southwest part of Giurgeu Mountains, Suseni village, Harghita county, Romania), during summer tourism season. Hourly frequency of data covers the period of July 6 - August 31 2017, with highest tourist flows. Gemini Data logger sensors was set on the touristic gallery from the Entrance to the Music Hall (Sala Muzicii), which was designated as the main climatic alignment. In opposition, the sensor from the Great Hall (Sala Mare) is meant to capture the topoclimatic features unchanged by mass tourism. It is noted that the average daily temperature in Music Hall (7.32 °C) is a little bit higher than that recorded in Great Hall (7.231 °C) a difference due to the presence of tourist activity. Daily temperature values from Music Hall show multiple and non - periodical variation, with daily mean amplitude reaching at 0.21 °C. Despite this, the high resilience of the system does not allow cumulative effects.

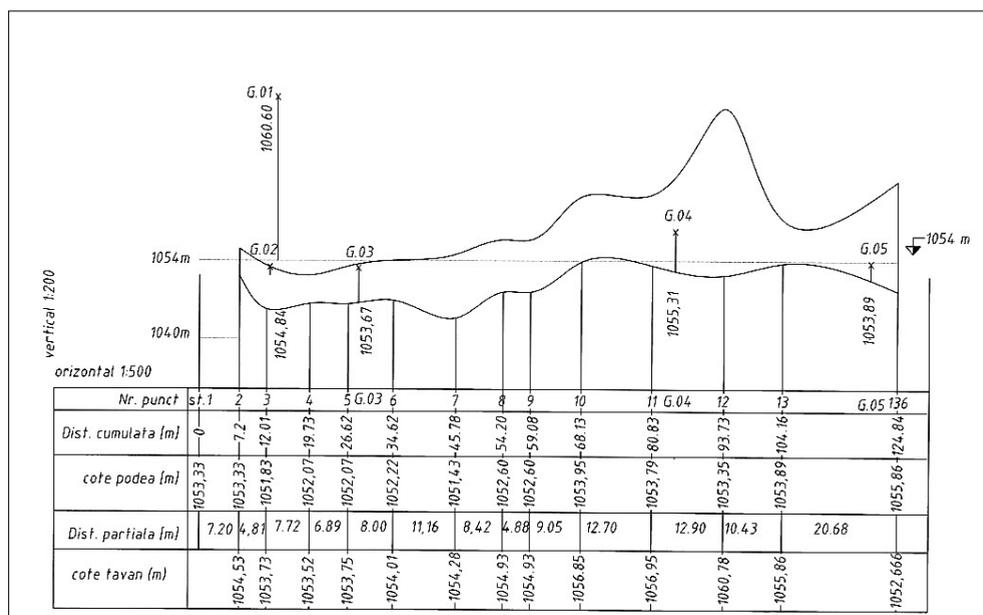
**Key words:** temperature, data logger, amplitude, resilience, cumulative effects

## 1. INTRODUCTION

From climatic point of view, in summer there are important thermal contrasts between the outer and underground atmosphere, which is reflected in the intensification of the energy exchanges through thermal convection. The phenomenon is amplified by the volume of underground voids, underground morphology, and by the number and positioning of the openings. Given the fact that Șugău Cave has three openings at different altitudes and the altimetric difference between the upper and the lower openings is 40 m, the system resilience is high. Theoretically, any anthropogenic influence on climatic parameters - in this case air temperature - should be quickly removed without recording any cumulative effects. The foundation lies in the fact that the tourist gallery corresponding to Branch no. 1 Dry (Ramura nr. 1 Uscată) is connected with the opening of the active via the Linking Arm (Brațul de Legătură). Resurgence is the

lowest openness of the cavernicol system, the summer energetic output of seasonal unidirectional thermocyclation.

The configuration of underground morphology gives tourist galleries, to a greater extent, the role of a transfer corridor from the energy point of view. There is only one exception - the Music Hall (Sala Muzicii) - that closes in the "bottom of the bag" („Fund de sac”) (Fig. 1).



**Fig. 1** Longitudinal profile (Entrance - Music Hall) with sensor position rendering, topological alignment G01-G05

This is why the convection is much diminished, as the "thermal footprint" of the tourists' presence can be noticed.

## 2. DATA AND METHODS

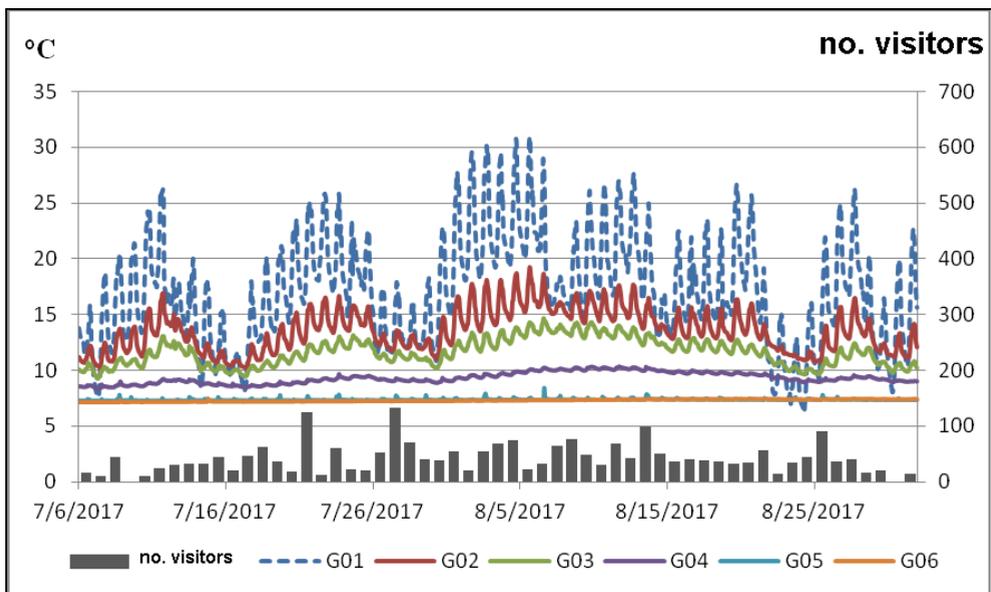
The sensors used in the study come from Gemini Data Loggers in the United Kingdom and are designed for relative humidity and air temperature measurements. Tinytag TGP 4500 sensors with a moisture-, dust- and condensing-resistant housing (-25 ... + 85°C, 0-100% UR) were used.

They were set to measure the two parameters for one hour for one year. For the present study, data for the official duration of the tourist season was taken from 6 July to 31 August 2017. The data was processed in Microsoft Office Excel 2007.

From a meroclimatic point of view, the TE24, G05 and G06 sensors are meant to capture stability meroclimate, stating that the G05 station in the Music Hall may record short-term, non-periodic fluctuations of the thermal regime due to large groups of visitors.

### 3. RESULTS AND DISCUSSIONS

External thermal oscillations, recorded by G01 station, are obviously propagated through the thermal convection mechanism, up to 78.2 m away from the entrance, near the G04 station. Any influence of the presence of tourists on the underground temperature is masked on this cave section, the inflections of the variation curves correlating to the outer ones. In G05 (Music Hall) and G06 (Great Hall) stations, the reduced amplitudes of the thermal variations and the impossibility to relate them to the outer ones in the short term place this cave sector in the stability meridian sector (Fig. 2).



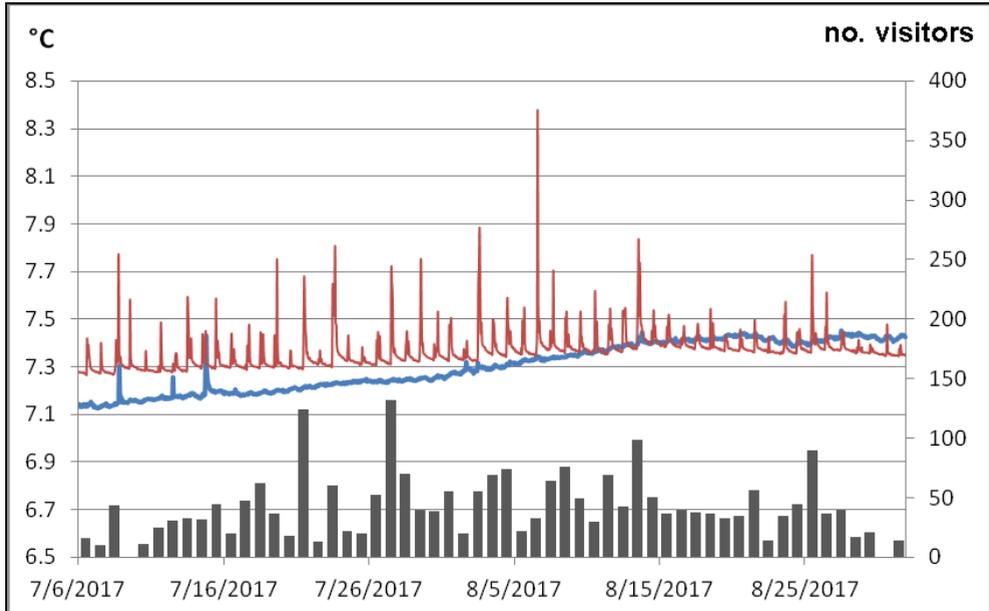
**Fig. 2** The evolution of the temperature (°C) along the alignment G02-G05 underground topoclimatic, in the outer station (G01) and the stability meridian (station G06), and the number of registered tourists (July 6 - August 31, 2017)

The temperature variation line stored by the G05 sensor shows more pronounced apexes than those recorded by G06 station, the diurnal amplitude being

on average of 0.21°C, unlike the G06 station where the average daily amplitudes of 0.03°C.

The absolute diurnal thermal amplitude reveals even more pronounced contrasts, so in the Music Hall the highest value was 1.03°C and the highest value in the Great Hall was 0.06°C.

All these non-periodic variations are associated with the presence of tourists, as shown in Figure 3.



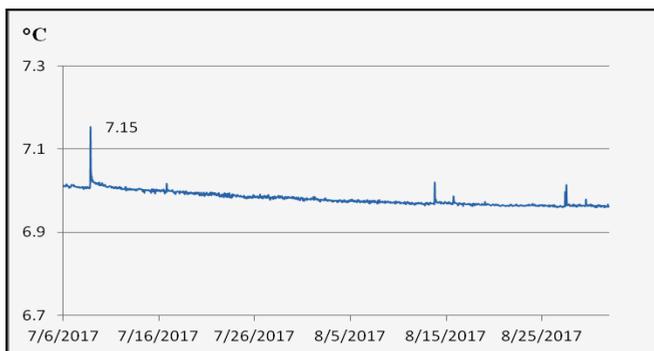
**Fig. 3** Evolution of the temperature in the Music Hall (the thin line) and the Great Hall (thickened line) and the daily number of visitors (6 July - 31 August 2017)

The total number of tourists in the time span is 2408 (source: Gyilkosto Adventure Association). The most pronounced apex of the thermal variations in the Music Hall (G05 sensor) reveals a 1.03°C daytime thermal amplitude on August 6, 2017. Although the number of visitors was lower, 33 tourists, the pronounced thermal increase can be put on the tourists' long standing in the auditorium, that is known for its excellent acoustics, classical music concerts being organized here (<http://www.sugo.ro>).

With the decrease of the number of tourists at the end of the season - the official closing of the season is 31 August 2017 (source: Gyilkosto Adventure Association), the temperature variation curve in the Music Hall closely follows the oscillations in the Great Hall (G06 station).

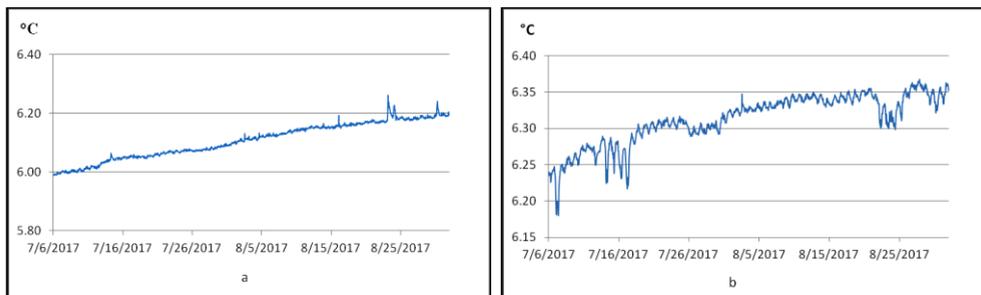
In the long run, energy exchanges with the external atmosphere manifest themselves in the temperature variation curve from the stability meroclimate sector (G05 and G06). This curve shows a steady increase in the first part of the time taken into account, with outdoor peak temperatures culminating in the beginning of August, with values above 30°C.

In the TE24 station, from the deep part of the protected sector, the temperature flow suggests energy exchanges with the exterior, predominantly through thermal conductivity, with an inverse ratio between the thermal underground and external oscillations (Fig. 4).



**Fig. 4** Daily temperature evolution for the TE24 sensor (Wonderful Hall) (Sala Minunată)

On the active gallery, temperatures are steadily rising, with average daily amplitudes higher for the G08 sensor. This station is at the junction of the Active Gallery with the Linking Arm where the ventilation is greatly enhanced by the downward configuration of the underground voids. The thermo-dynamic equilibrium is reached in front of the G07 sensor, proof being the low air temperature oscillations (Fig. 5).



**Fig. 5** Daily temperature evolution recorded on the active gallery, sensors G07 (a) and G08 (b)

Comparing the graphs of the thermal oscillations associated with the sensors G04 (Currents Hall - Sala Curenților), the TE23(junction between the Linking Arm and the Branch no. 2 Dry – joncțiunea Brațului de Legătură cu Ramura nr. 2 Uscată) and the G08 it is noted that this passage takes over the main flow of the thermo-circulation in the Șugău Cave, the correlation with the external temperature being obvious.

#### 4. CONCLUSIONS

The main flow of the underground thermo-circulation in the Șugău Cave follows the route traced by the sensors G02, G03, G04, TE23, G08 and G07, the unidirectional summer ventilation orienting the vectors of the currents from the main entrance to the karstic spring. The accentuated thermo dynamics mask the anthropic influence on the thermal oscillations, the presence of the tourists being felt only on the sectors that close in "bottom of the bag", such as the Music Hall (the G05 sensor). The isolation of the Music Hall from the main flow of thermo-circulation increases the sensitivity of the topoclimate to the anthropic stress factors, materialized in the nonperiodic thermal oscillations mentioned above.

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