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# Thermic characterization of the Underground Superficial Compartment near Pugnetto cave system

## Lanzo Valley, Western Alps

Luigi Motta, Michele Motta
Earth Sciences Department
Università degli Studi
Turin, Italy
michele.motta@unito.it
luigi.motta@unito.it

***Abstract*—This paper shows the thermic characterization of Underground Superficial Compartment (MSS) near Borna Maggiore di Pugnetto, a cave rich in subterranean fauna. We have found evidences that the thermic behavior of MSS is not similar to that of a true soil or that of a cave, even though MSS is closely linked to both.**

***Keywords- Temperature; Subterranean climate; Thermal dynamics; Cave habitat; Alps***

## I. The study area

The site of study is the hill of Truc d'le Tampe, in Western Alps (Lanzo Valley, Italy). This is a unique karst landscape, in a sector of the Alps without other karstlands, without glaciers even during the glaciations [8] and [9]. The hill is made of calcschist with marble lenses. Within of this rock, the fractures enlargement by dissolution, together to processes of cave breakdown has created four caves: the well-known Borna Maggiore (1501 Pi/TO, 375551E 5014621N, 820 m a.s.l.), which was intensively studied since very long time; Tana del Lupo (1502 Pi/TO), Creusa d'le Tampe or Borna Minore (1503 Pi/TO), Tana della Volpe (1504 Pi/TO).

Karst breccia made of marble and calcschist fragments, with large interstices and voids, partially covers the lower part of slopes of Truc d'le Tampe. Soil with a thick epipedon covers in turn the breccia (fig. 1). Ref. [4] has described ecologically this interstitial habitat as Milieu Souterrain Superficiel or Underground Superficial Compartment (MSS), and [5] has reported this habitat also in karst breccia.

The Truc d'le Tampe represents an important spot of hypogean biodiversity in the Western Italian Alps. It hosts several caves protected by law (European Habitat Directive 43/92, S.C.I. IT 1110048), because they are the winter shelter of several species of bats, such as *Myotis emarginatus*, *M. myotis*, *Rhinolophus ferrumequinum*, *R. hipposideros*. These caves host many important endemic invertebrates also. Among these, it's worth to mention the coleopterans *Dellabeffaella roccai*, the most specialized Leptodirinae in Piedmont [1], and *Sphodropsis ghilianii ghilianii*; the orthopteran *Dolichopoda ligustica septentrionalis*; the isopod *Alpioniscus feneriensis caprae*; *Troglohyphantes bornensis*, a cryophilic, steno-endemic spider.

This study born as part of the CaveLab project "From microclimate to climate change: caves as a laboratory for the study of the effects of temperature on ecosystems and biodiversity", funded by the University of Turin and Compagnia di San Paolo (Progetti di Ateneo 2011 - ORTO11T92F).

This study is funded by University of Turin project "Contrasti termici e umidità in microclimi di grotte di particolare interesse naturalistico" (MOTMRIL013).

## II. Aims of work

In interdisciplinary project CaveLab [3] traps and data logger with temperature probe have worked both in caves, and both in MSS. The traps have captured many species (including those highly specialised) both in caves, and both in MSS. So, the thermic characterization of these habitats is necessary for understanding of subterranean ecology. Ref. [7] describes the internal climate of the Borna Maggiore; the aim of this paper is the completion of work, with the thermic characterization of MSS.


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Figure 1. The excavation for recovering of a trap shows the aspect of MSS and overlying soil, near to station 1, on the slope lower down of Borna Maggiore.

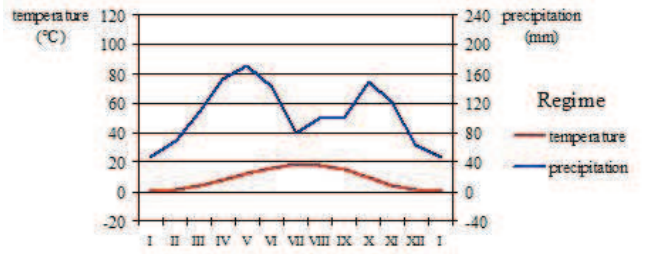


Figure 2. Ombrothermic diagram of Pugnetto, from data of [2].

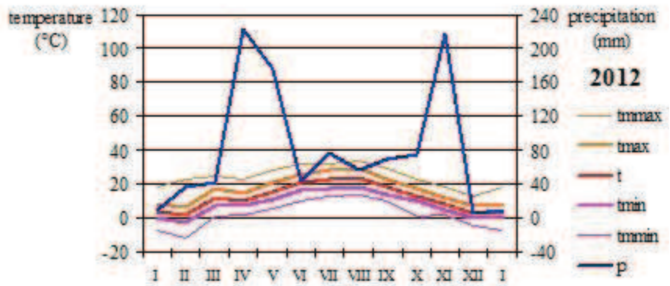


Figure 3. Temperature and precipitation distribution at Lanzo Torinese in 2012 (ARPA data).

## III. The Climate

The climate is that one typical of low altitude in the Piedmontese Alps. The regime is hypomesaxeric (fig. 2). The thermic regime of soils is mesic; the moisture condition is almost anywhere udic.

The nearest station is Lanzo Torinese (ARPA Piedmont). The 2012, year of measurements, has been normal, except for rainfall, bigger and concentrated in April and November (fig. 3).

## IV. Data Collection

The CaveLab members had placed within the MSS, at several depth, 10 I-buttons Hygrochron - DS1923 (nominal accuracy of 0.0625 °C; measurement every 3 hours): 4 in two stations (1 and 2) lower down of Borna Maggiore, at a distance of about 100 m from the cave entrance; 4 at the foot of the small crag of cave entrance (30 meters from the entrance; 3 and 4 stations); 2 at the 5 station, near the Borna Minore. We have validated the data of the period 27 May 2012 - 6 February 2013, and then we have gathered the data at monthly level.

## V. Data Analysis

### A. Average values

Monthly average temperature and standard deviation (both calculated from daily data) at several measuring depth for July 2012 and January 2013 are in tab. 1. The average between January and July of T° and of the standard deviations, to the depth of 60 cm (where the thermic condition is quite stable), is the best representative datum of the annual average (not available for the short time of measurement).

TABLE I.

| **Station** | | **Average of January** | | | **Average of July** | | | **Average of Jan.-Jul.** |
|---|---|---|---|---|---|---|---|---|
| *N°* | *Depth Position* | *40 cm* | *60 cm* | *80 cm* | *40 cm* | *60 cm* | *80 cm* | *60 cm* |
| *1* | *wooded slope* | | 1.5 | 2.3 | | 15.5 | 15.1 | 8.5 |
| *2* | *wooded slope* | 4.6 | 5.0 | | 14.0 | 13.7 | | 9.3 |
| *3* | *foot of crag* | | 6.4 | | | 15.5 | | 10.9 |
| *4* | *foot of crag* | 3.3 | 4.2 | 5.1 | 16.0 | 14.8 | 13.7 | 9.5 |
| *5* | *foot of crag* | | 4.5 | 5.8 | | 16.1 | 14.8 | 10.3 |
| **Station** | | **Standard deviation of January** | | | **Standard deviation of July** | | | **Average of Jan.-Jul.** |
| *N°* | *Depth Position* | *40 cm* | *60 cm* | *80 cm* | *40 cm* | *60 cm* | *80 cm* | *60 cm* |
| *1* | *wooded slope* | | 1.01 | 0.82 | | 0.84 | 0.54 | 0.93 |
| *2* | *wooded slope* | 0.74 | 0.68 | | 0.29 | 0.25 | | 0.47 |
| *3* | *foot of crag* | | 0.50 | | | 0.54 | | 0.52 |
| *4* | *foot of crag* | 1.23 | 0.89 | 0.63 | 0.70 | 0.33 | 0.22 | 0.61 |
| *5* | *foot of crag* | | 1.05 | 0.66 | | 0.63 | 0.26 | 0.84 |

Monthly average temperature and standard deviation (both calculated from daily data) at several measuring depth for July 2012 and January 2013 are in tab. 1. The average between January and July of T° and of the standard deviations, to the depth of 60 cm (where the thermic condition is quite stable), is the best representative datum of the annual average (not available for the short time of measurement).

In all stations, with increasing depth °T in January grows, in July decreases. January and July have a gradient quite similar in value and opposite as sign. For example, in 4 station, between 40 and 80 cm depth, in January the temperature rises of 1.8 °C, in July decreases of 2.3 °C; in 5, from 60 to 80 cm in January, °T rises of 1.3 °C, in July decreases of 1.3 °C.

The standard deviations of daily values of January and July decrease significantly with increasing depth, i.e. to greater depths the temperature remains more constant during the month.

### B. Annual excursions

The monthly averages of daily maximum, minimum, and medium temperatures of each sensor are in figures 4-7. The three curves are almost perfectly overlapping for each depth.

On the slope below the Borna Maggiore, at all depths the curves are very similar to each other. In station 1 (fig. 4), the maximum of difference between 60 and 80 cm is 1.4° C; in 2 (fig. 5), this maximum between 40 and 60 cm (i.e. at an even lower depth) is only 0.6 °C. Altitude and exposure of the two stations are very similar, but in 1 steepness and grain size of the


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MSS are lower. The temperatures distribution is significantly different in the two stations. In station 1, in August °T > 16 °C, and in January T ≈ 2 °C, i.e. an excursion of about 14 °C; in 2, the excursion is lower (15 °C in August and 5 °C in January).

In other stations, the lowering of the annual thermic excursion with the depth is significant. This is normal also in any soil, but in the latter the excursion is less.

In station 4 (fig. 6), from 40 to 80 cm of depth the difference between August and January changes from almost 14 °C at about 9 °C. Close to autumn equinox °T ≈ 13.5 °C at all depths. The station 5 (fig. 7) is similar to 4, with a difference between August and January of about 13.5° at 60 cm of depth, 10° at 80 cm. Close to autumn equinox °T ≈ 14,7 °C both at 60, and both at 80 cm of depth.

The comparison of average monthly temperatures of the various stations at 60 cm of depth is in fig. 8. The maximums are always in August (17.0 °C - 14.3 °C). The minimums in 5 and 1 are in January (in the others perhaps also in February, because in this month the measurement ends). In January, 1.5 °C < °T < 6.5 °C. The thermic excursion is between, 15° C (1) and about 12° C (5); the excursion varies greatly from station to station, particularly at the foot of the crag. All have the same value (almost 14° C) close to autumn equinox.

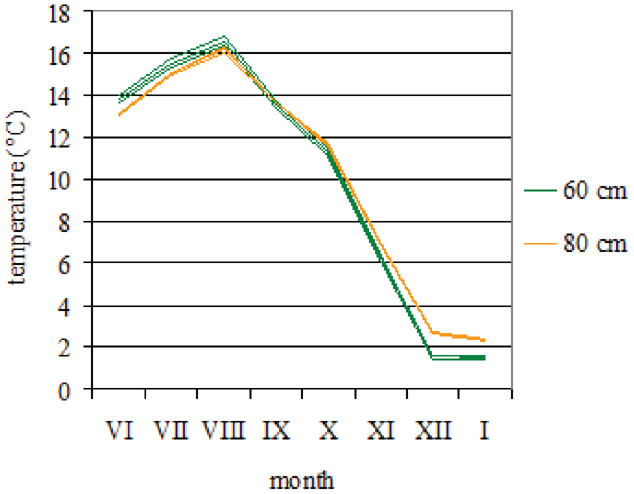


Figure 4. Station 1: average value, for each month, of daily maximum, minimum and medium temperatures.

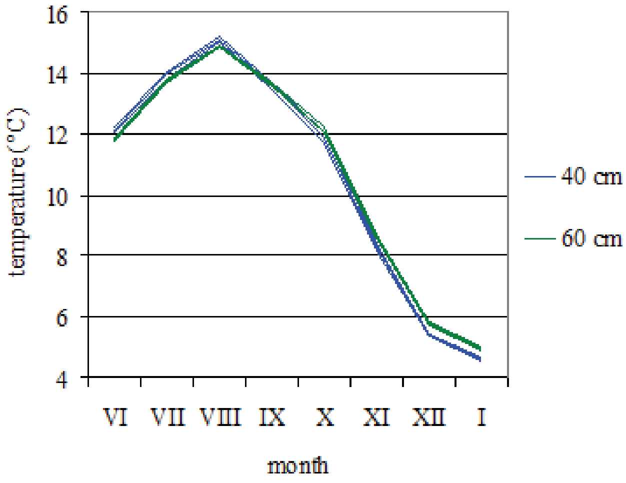


Figure 5. Station 2: average value, for each month, of daily maximum, minimum and medium temperatures.

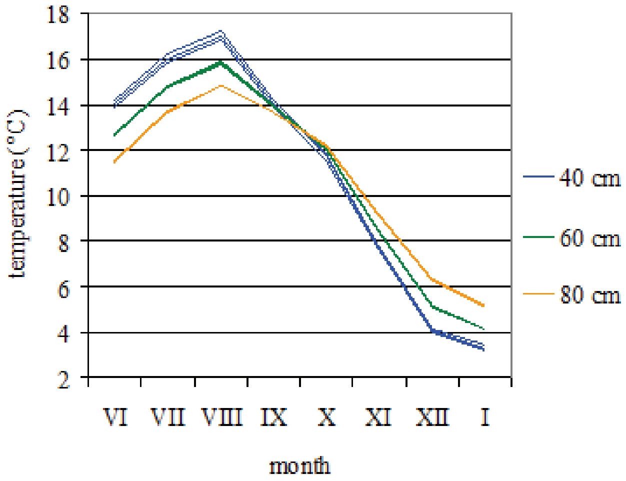


Figure 6. Station 4: average value, for each month, of daily maximum, minimum and medium temperatures.

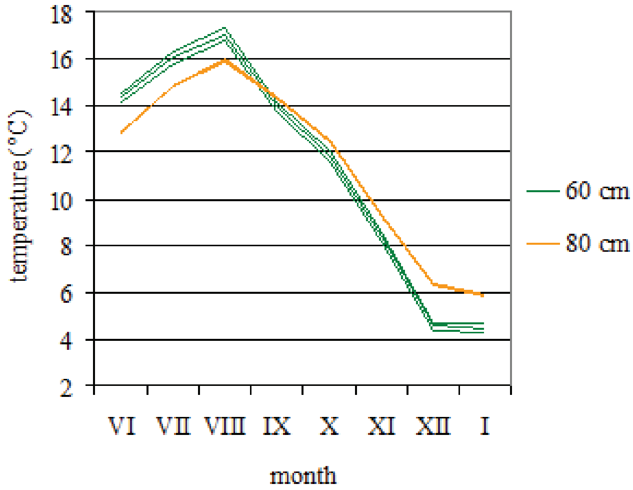


Figure 7. Station 5: average value, for each month, of daily maximum, minimum and medium temperatures.


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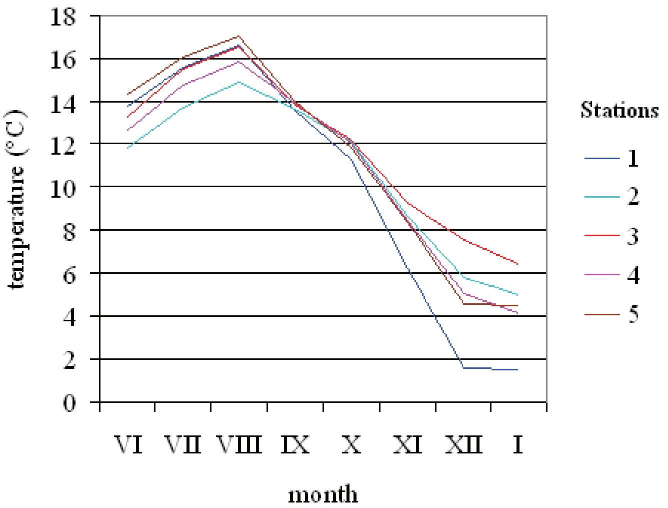


Figure 8. Temperature at 60 cm depth.

*C. Daily excursions*

There is only one common feature in graphs of monthly average of daily excursions of each sensor (fig. 9-12): the thermic excursion decreases with the depth.

In 1 (fig. 9), at 60 cm the thermic excursion decreases from July (almost 0.5 °C) to December (< 0.2 °C). At 80 cm, the daily excursions show small seasonal variations, from 0.2 °C (October) to 0.1 °C (already in November).

In 2, the daily excursion at 40 and 60 cm is similar (fig. 10), with a maximum in October (0.35 °C at 40 cm, < 0.2 °C at 60), and with no obvious seasonal variations.

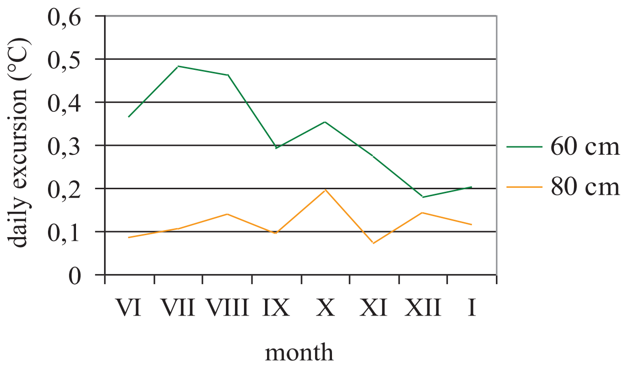


Figure 9. Daily excursions in station 1.

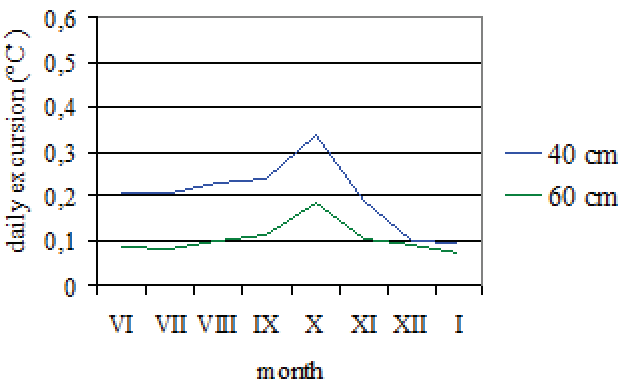


Figure 10. Daily excursions in station 2.

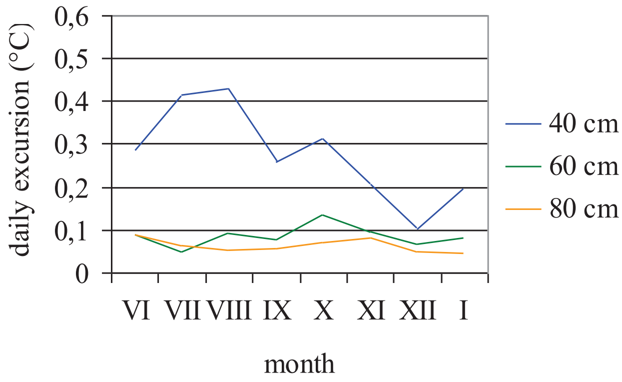


Figure 11. Daily excursions in station 4.

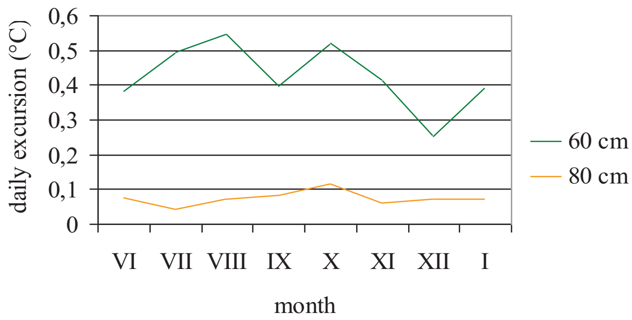


Figure 12. Daily excursions in station 5.

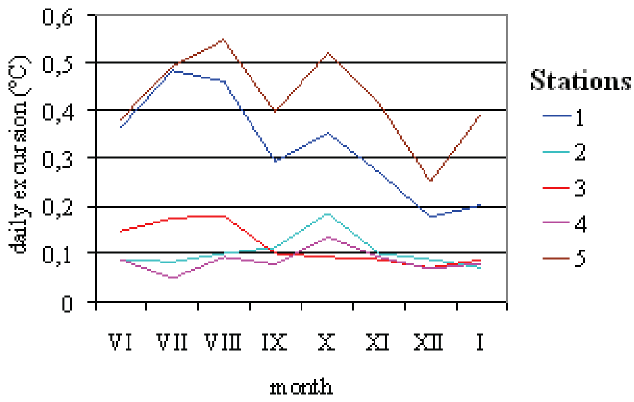


Figure 13. Daily excursions at 60 cm depth.

In 3, at 60 cm the daily excursions are very low, between < 0.18 °C in August and 0.07 °C in January.

In station 4 the curve changes at the different depths (fig. 11). At 40 cm descend by 0.43 °C in August to 0.10 °C in December; at 60 cm the values are much lower, with a maximum in June to 0.14 °C and two minima in July and December; at 80 cm the variations range is minimal, with a maximum in November of just 0.08 °C, and two minima in August and December of about 0.05 °C.

Also station 5 has several curves at different depths (fig. 12). The probe at 60 cm depth measures about 0.55 °C in August, a bit more than 0.25 °C in December. The curve of 80


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cm depth is different, with maximum in October of only 0.12 °C and minimum in July (0.05 °C).

The comparison of monthly averages of daily excursions at 60 cm depth is in fig. 13. The excursions are very variable even at the same depth, both as values and both as aspect.

By comparing the data with those of pluviometric station (Lanzo Torinese), we note that the influence of the rainfall is very important. In 1, at 60 cm depth the thermic excursion reached a maximum of 3.27 °C, a value some six times the seasonal variation, in a rainy day (10/28/2012), when it rained in Lanzo 8.4 mm. With heavier rains the effect is probably greater than: in example above mentioned, the temperature fell by 10.83° C at 5:14 (solar time) of 10/27/2012, to 5.62° C at 10:14 of 10/30/2012. In the same period, with a precipitation at Lanzo of 31.4 mm, the air not was become greatly cold, only 2.4 °C of cooling.

This suggests that the rain water can percolate quickly and easily in the MSS, causing a sudden lowering of temperature, and an irregularity of daily thermic cycle, both in the days of precipitation, and both in those immediately following.

## VI. Comparison with the thermic data of adjacent caves

Tab. 2 gives thermic data of caves, detected in same time periods of MSS stations.

The mean values are very different from those of the MSS. The difference between July and January, proves that the annual excursion of cave climate is always much lower than that of MSS climate. About the daily temperature excursion: in winter, when in the caves near the entrance is maximum (0.3-0.6 °C), in the MSS is minimal (0.2 °C at only 40 cm deep); in summer, when the daily excursion in the caves is generally < 0.05 °C, in the MSS is so low only at 80 cm depth, while already at 60 cm is > 0.5 °C.

Obviously, in both environments, as increases the depth and isolation with the outside, °T variation is less and less, like the annual and daily excursions [6]. However, the data suggest that existing thermic processes in these environments are very different. For instance, in MSS the monthly standard deviation at daily level (i.e. the value uniformity) is proportional to daily excursion (fig. 14): the values of the same month, of all stations and all depths, are aligned along a straight line. For different months, as January and July, the values are aligned on different lines. The same happens in Borna Maggiore (fig. 14), but the angle between the lines of January and July is less, and the line of January is over that of July instead of under.

The comparison between the daily excursion in open air, in MSS (at 60 cm depth) and in caves, is in Fig. 15. The three environments differ not only because of the characteristic width of thermic excursion, but also for variations of excursion width in hot and cold months.

## VII. Conclusions

The MSS environments have a reduced thermic variability in the annual and daily cycles. The fig. 15 suggests that the thermal dynamics of each environment is very different from that of others. The annual excursions of MSS at the foot of crag are different than on the slopes. The MSS has thermal characteristics different from both caves and true soils, although genetically it is linked and contiguous to both.

Obviously, the main factors that determine MSS temperature are air temperature, solar radiation, and precipitations. The rains influence the climate of MSS studied more quickly and much more intensely than a soil climate.

The MSS seems an optimal refuge for cold-sensitive invertebrates. At the foot of the crag, the MSS temperature is even better than at the entrance of a cave.

TABLE II. Thermic data of Borna Maggiore [7] and Borna Minore (unpublished).

| Probe position | Average (°C) | | Standard deviation | | Daily excursion (°C) | |
|---|---|---|---|---|---|---|
| | *Jan* | *Jul* | *Jan* | *Jul* | *Jan* | *Jul* |
| **Borna Maggiore** | | | | | | |
| ***Entrance tunnel*** | 3.0 | 7.8 | 1.13 | 0.16 | 0.41 | 0.05 |
| ***Before first chamber*** | 5.4 | 7.1 | 0.39 | 0.06 | 0.14 | 0.01 |
| ***After siphon narrow*** | 6.5 | 7.5 | 0.21 | 0.04 | 0.03 | 0.00 |
| ***Breakdown chamber*** | 8.2 | 8.4 | 0.04 | 0.00 | 0.02 | 0.00 |
| ***End of Madonna Branch*** | 9.3 | 9.4 | 0.00 | 0.00 | 0.00 | 0.00 |
| ***Spring (Fountain Branch)*** | 9.2 | 9.3 | 0.02 | 0.04 | 0.01 | 0.01 |
| **Borna Minore** | | | | | | |
| ***Entrance*** | 3.5 | 8.7 | 1.10 | 0.13 | 0.30 | 0.01 |
| ***Entrance*** | 2.7 | 8.4 | 1.32 | 0.12 | 0.38 | 0.01 |
| ***Entrance*** | 2.6 | 8.2 | 1.33 | 0.10 | 0.57 | 0.01 |
| ***Inside*** | 8.7 | 8.7 | 0.18 | 0.05 | 0.02 | 0.01 |

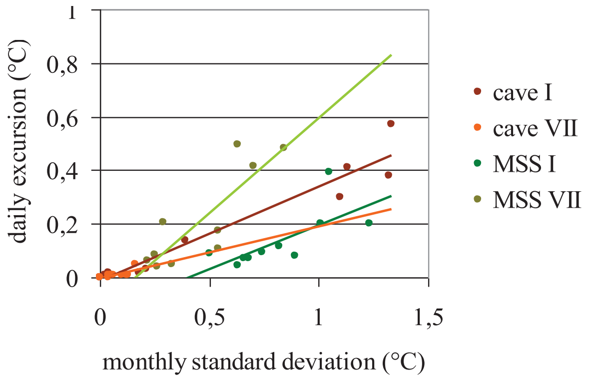


Figure 14. Daily excursion versus monthly standard deviation in January (cave and MSS I) and July (cave and MSS VII).

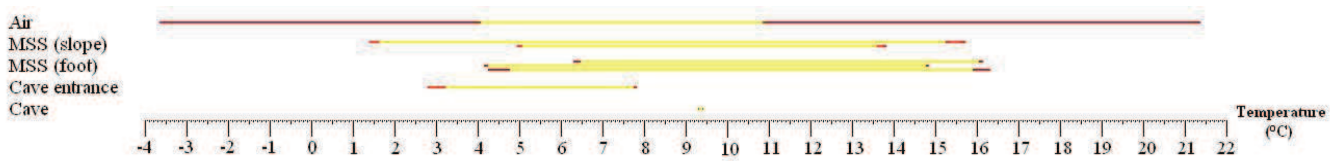


Figure 15. Daily excursions in the coldest month and warmer. Air: open air; MSS slope: 1 and 2 stations; MSS foot: 3 and 4 stations; cave entrance: stairway of entrance tunnel in Borna Maggiore. Cave: end of the branch of Madonna of Borna Maggiore.

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