3.1. Temperature

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3.1.1. Mean Temperatures over a 12 Month Time-Span

Regular recordings started on the first October 1991 and stopped on the 30th September 1994 which corresponds to a 3 year time-span; bad data (generally due to a faulty Rotronic sensor) have been interpolated where necessary. The contiguous good Rotronic data from station 4 are too sparse to give meaningful averages over a complete 12 month period. As the Hamster logger started recording on 5th May 1993, we nevertheless have a reliable picture for station 4 from that day on to September 1994.

The results of temperature measurements (in °C), rounded to the first decimal can be seen in table 3.1.1.

Several conclusions can be drawn from this table:

1. The mean deep-cave temperature is 9.4 °C; this is 1.6 °C higher than the temperature given by Choppy's law [Choppy, 1990], which expresses deep-cave temperature (including ice-caves!) as a function of latitude and altitude :

$$\begin{aligned} T &= 54.3 - 0.9 * latitude - 0.006 * altitude \\ &= 54.3 - 0.9 * 50 - 0.006 * 250 \\ &= 7.8\ °C \end{aligned} \qquad \text{[eq. 3.1.1]}$$

2. The differences between the yearly maximum and minimum temperatures at a given location decrease rapidly with increasing distance: an exponential fit on the maxima and minima of the 8760 hourly data from Jan.1993 to Dec.1993 gives the following result:

$$dT = 43.9 * e^{-0.099*x} \qquad \text{[eq. 3.1.2]}$$

   where 0.099 represents the damping factor leading to a temperature relaxation length of 1/0.099=10 m for the cave air.

3. In 1993 there is a delay of about 45 days before the maximum outside temperature (06 Aug. 93) has reached station 4 (20 Sep. 93); the corresponding delay, before the following outside minimum (21 Feb. 94) can be first detected at station 4 (06 May. 94), is 74 days; no such clear-cut delays can be found for stations 2 and 3.

Table 3.1.1.

Station	***Sensor***	***Period***	***Mean +/- Std***	***Max. and Date***	***Min. and Date***
station1	***Rotronic***	*Oct91-->Sep92*	9.5 +/- 6.4	31.7	-6.3
(x=0m)				09 Aug 92	15 Dec 91
This is the outside reference		*Oct92-->Sep93*	9.7 +/- 6.5	36.1	-7.8
station				06 Aug 93	04 Jan 93
.		*Oct93-->Sep94*	10.3 +/- 7.4	39.8	-7.8
				03 Aug 94	21 Feb 94
		Oct91-->Sep94	9.9 +/- 6.8	39.8	-6.3
				03 Aug 94	15 Dec 91
station2	***Rotronic***	*Oct91-->Sep92*	10.7 +/- 2.3	18.5	5.1
(x=12m)				27 Jul 92	20 Dec 91
		Oct92-->Sep93	9.7 +/- 1.9	17.6	4.1
				16 Jul 93	06 Apr 93
		Oct93-->Sep94	10.4 +/- 3.0	18.8	2.9
				28 Jul 94	24 Dec 93
		Oct91-->Sep94	10.2 +/- 2.5	18.8	2.9
				28 Jul 94	24 Dec 93
station3	*Rotronic*	*Oct91-->Sep92*	9.8 +/- 0.6	10.9	8.8
(x=31m)					
no dates given, as max. and		*Oct92-->Sep93*	9.5 +/- 0.4	10.6	8.6
min. are so close					
		Oct93-->Sep94	9.0 +/- 0.2	9.4	8.2
		Oct91-->Sep94	9.4 +/- 0.5	10.9	8.2
station4	***Hamster***	*May93-->Sep93*	9.4 +/- 0.1	9.6	9.4
(x=50m)					
no dates given, as max. and		*Oct93-->Sep94*	9.4 +/- 0.1	9.6	9.3
min. are so close					

4. Curiously at the timescale of 1 hour, the maximum temperatures at station 2 (x=12 m) do occur prior to the outside maxima, the lead time being 13, 21 and 6 days for the years 1992, 1993 and 1994. During this summer period, the wind always blows into the cave, so one should expect that the cave maxima would follow the outside ones. This is indeed the case in 1993 and 1994 (but not in 1992) if the analysis is done on the daily mean temperatures, which are not so strongly influenced by the momentary outside wind pattern.

   If dry outside air enters the cave, it evaporates a greater quantity of water than does a more humid air. The latent heat needed for condensation is higher for dry air, so dry air induces near the entrance a stronger cooling effect than humid air.As a consequence, at periods of hot and dry weather, temperatures near the entrance may be lower than they are at periods of rainfall. Alas, the mean outside humidities in July and August are very similar, so this hypothesis could not be confirmed by our data.

The convective heat transfer seems to be rather negligible for station 4, contrary to what happens for the other two stations at x=12 m and x=31 m. The main heat transfer mechanism into the deepest cave locations is pure conduction.

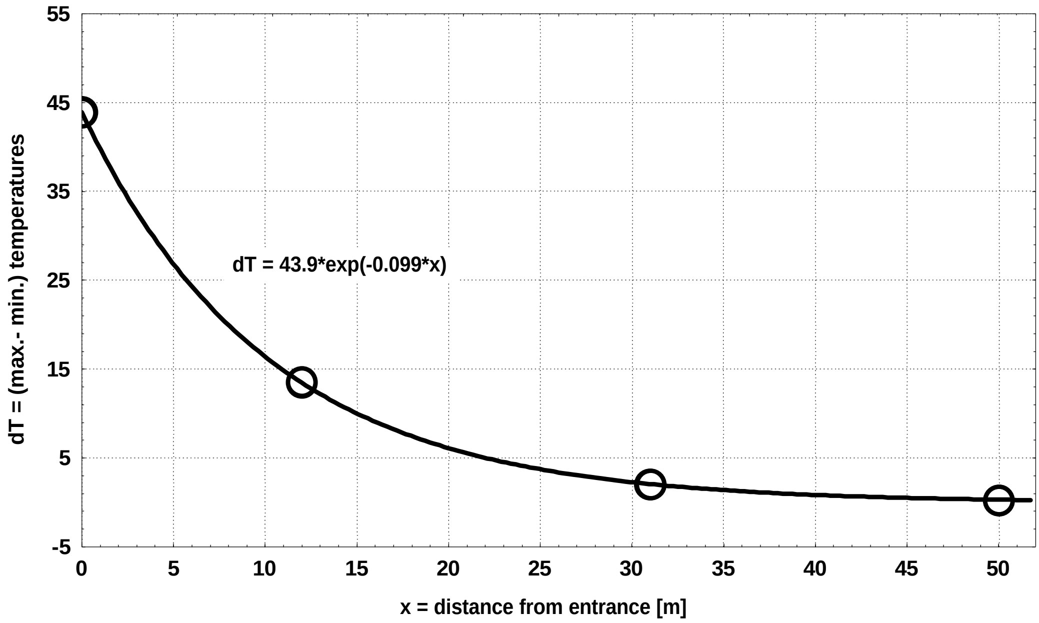

Fig.3.1.1. Difference of yearly maximum and minimum temperatures versus distance from entrance (year 1993

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3.1.4. Instant Temperature Variations

It seems obvious that we cannot detect anymore the influence of rapid outside temperature variations at locations situated deep in the cave; let us look in this paragraph at what distance from the entrance the daily or hourly variations of the outside temperature can still be detected. Fig. 3.1.5 of the mean daily temperatures shows that the overall seasonal outside pattern can readily be observed at station 2 (one should note that during winter months, the temperature at station 2 often anti-correlates with the outside temperature; as will be seen later, this is due to a different air flow direction).

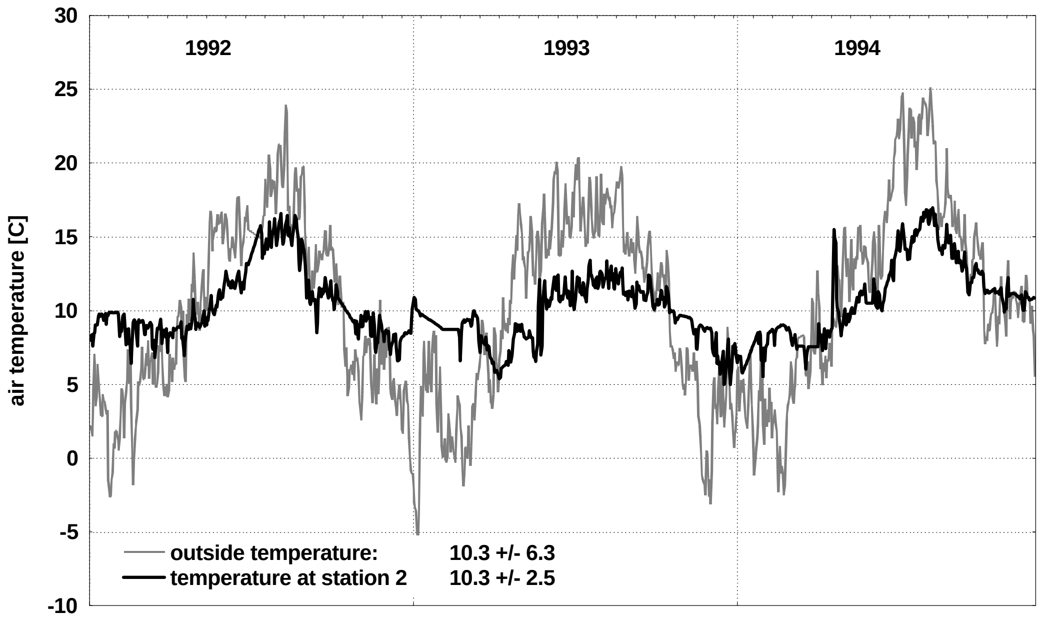

Fig. 3.1.5. Daily mean temperatures at station 1 and 2 from January 92 to November 94

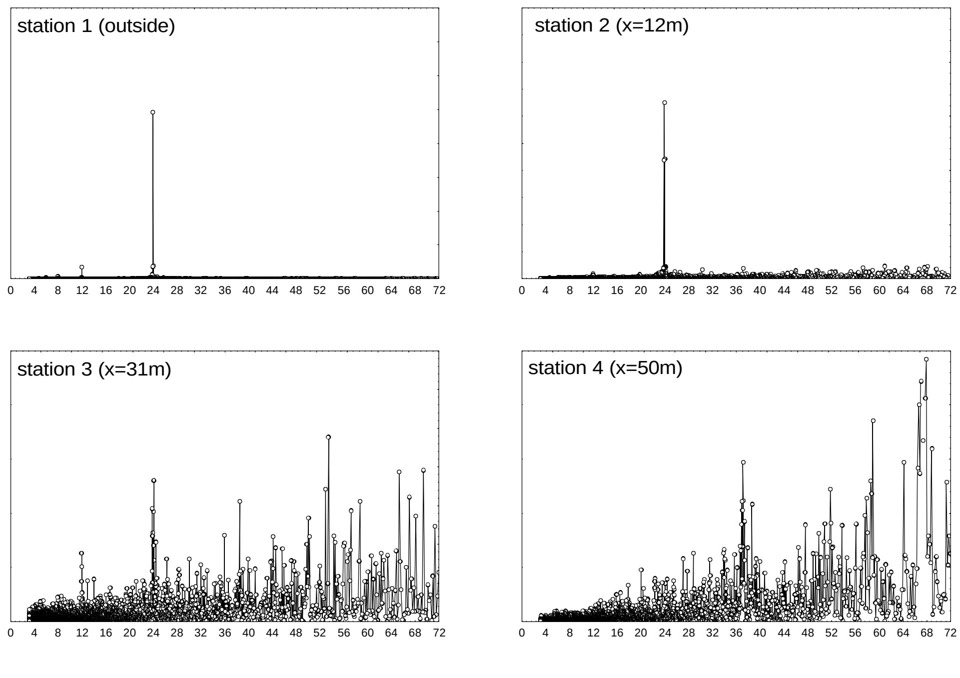

Fig. 3.1.6. Spectral analysis of temperature records from January 92 to November 92 (25 560 data)

The diurnal variations ca be detected up to station 3 (x = 31 m), but are lost at station 4 (x = 50 m): this can be shown by a spectral analysis on the same data set as above (fig.3.1.6, 25560 data points). There is a very clear cut 24h spectral peak at station 2, and a much smaller, but still detectable one at station 3. All diurnal patterns are lost at station 4.

In the successive plots, the different vertical axes have increasingly smaller scales.