Caves and global change

Carbon dioxide, temperature and vegetation rise

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Abstract

In several Belgian caves, the CO_2 air content is rising for eight years at least and probably much more. We think it is related to the present-day vigorous increase of vegetation, particularly trees. The CO_2 measured in caves is an organic gas displaying the same $\delta\ ^{13}C$ as the surrounding soil CO_2. This evolution results from the present climate change.

Résumé

Karst et réchauffement climatique. Augmentation du dioxyde de carbone, de la température et de la végétation.

Dans plusieurs grottes de Belgique, la teneur en CO_2 de l'air est en augmentation constante depuis au moins huit ans et très probablement beaucoup plus. Nous pensons que cela est relié au développement actuel vigoureux de la végétation, et en particulier de la végétation arborescente. Le CO_2 que nous dosons dans les grottes est en effet un gaz d'origine organique : il a le même $\delta\ ^{13}C$ que le celui du sol environnant. Ceci nous paraît en relation avec le changement climatique.

1. Introduction

Cave air is much richer in CO_2 than the outside atmosphere. The CO_2 content in cave air varies drastically from one site to another and can sometimes change according to the weather, displays seasonal variations and evolves throughout the decades (Atkinson, 1977; Renault, 1979). Our first measurements date back to 1966 (Ek et al., 1968; Delecour et al., 1968). At that time, we had already noticed a significant variability of the underground air CO_2 content. In 1985, in Saint-Anne Cave (Esneux) we noticed that the air in ceiling cracks was sometimes richer in CO_2 than in the cave halls and galleries bulk.
And, in 2009, we recorded a significant CO_2 rise in some Belgian caves (Ek & Godissart, 2009). Our study included twelve caves, but in the present paper we only take into account five of them (Fig. 1).

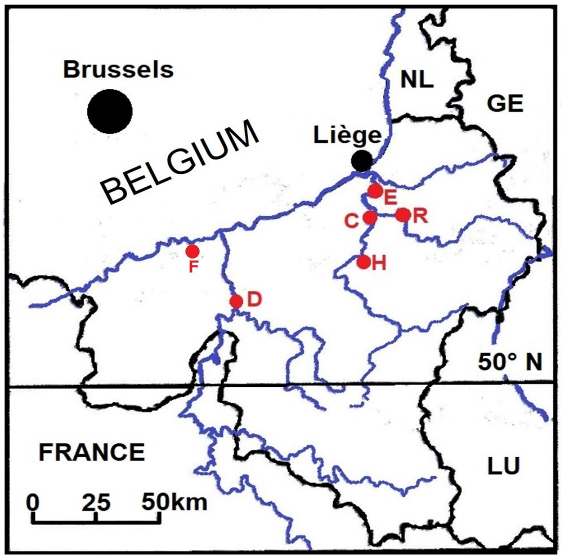

Figure 1: Location of the studied caves. C. Comblain-au-Pont. D. Dinant. E. Esneux. F. Floreffe. H. Hamoir. R. Remouchamps.

2. Instruments

Our first measurements were carried out with an electrolytic device invented by H. Koepf in 1952 (Delecour et al., 1968; Ek et al., 1968). It was heavy (15 kg) and fragile, but accurate and precise. From 1981, we have also used the Bendix-Gastec pump, a colorimetric instrument in which carbon dioxide reacts with hydrazine, and where the CO_2 concentration is given by a direct reading on a graduated tube. This device was described in Ek & Gewelt, 1985 and in Ek & Godissart, 2009. Since 2008, we have used a Draeger X-am 7000 device, equipped with an I.R. probe (Godissart & Ek, 2013) in addition to a Vaisala MI 70 carbon dioxide meter and data logger, operating with I.R. absorption too (Ek & Godissart, 2020).

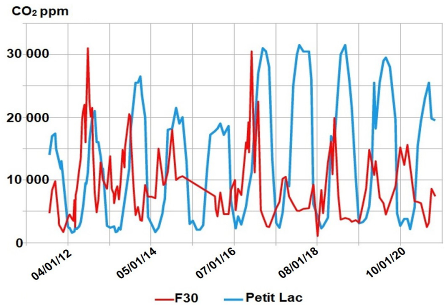

Figure 2: Variations of the air CO_2 content in a wooded soil at 30 cm depth (red curve) and in the Petit Lac Hall in Comblain-au-Pont Cave (blue curve).

3. Results

3.1. A seasonal rhythm

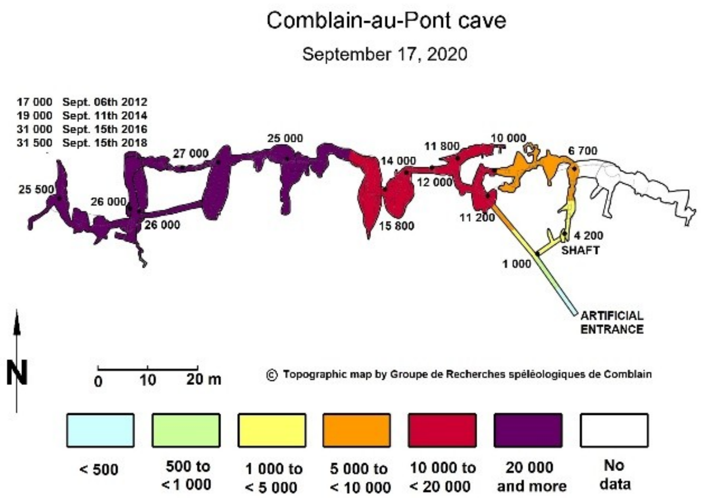

Figure 3: Comblain-au-Pont Cave. CO_2 content (ppm) on September 17, 2020 and comparison with some previous years at the far end of the cave.

Belgium is subject to oceanic temperate climate: precipitations occur all year round, but summer and winter cause a rhythmic alternation of temperatures. The high CO_2 content of the caves always happens in summer, whereas winter brings low temperatures and CO_2 values (Fig. 2). The highest CO_2 contents are observed near the far end of the Comblain-au-Pont cave like in several studied caves in Belgium, both in summer and winter.

3.2. A long-term rise of CO_2

The CO_2 in cave air has gradually been rising over the years (Ek & Godissart, 2009; Ek & Godissart, 2014) (Fig. 4). Seasonal changes affect vegetation and soil bacterial activity. Every spring, there is an increase of CO_2 in the soil atmosphere. Underlying cave-air pCO_2 starts increasing a few weeks later, suggesting that cave CO_2 comes from the soil and the epikarst (Fig. 3).

The $\delta\,^{13}C$ analyses of the soil CO_2 and cave CO_2 confirm this statement. The $\delta\,^{13}C$ of the free atmosphere is around -8,5 ‰. As the vegetation uses more ^{12}C and less ^{13}C than the atmospheric standard, its $\delta\,^{13}C$ value is lower.

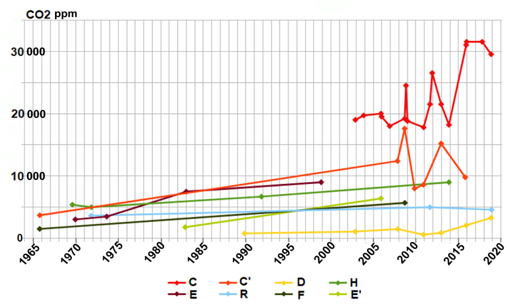

Figure 4: Evolution of the summertime air CO_2 content of a few Belgian caves between 1966 and 2020. C : Comblain-au-Pont cave. C': Trou Joney. D : Dinant, grotte Merveilleuse. H : Hamoir, grotte de Fontaine de rivîre. E : Esneux, grotte Sainte-Anne. R : grotte de Remouchamps. F : grotte de Floreffe. E' : Esneux, grotte de Brialmont.

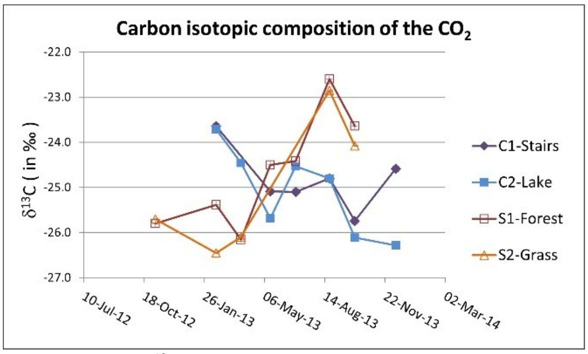

Figure 5: CO_2 δ ^{13}C of the air of Comblain-au-Pont Cave and of a wooded soil at 30 cm depth. C1: Waterfall Hall, in the cave. C2: Petit Lac Hall, in the cave. S1: in wooded soil (30 cm depth). S2: in grassland soil (30 cm depth).

In our temperate climate zone, the CO_2 δ ^{13}C issued from vegetation breathing and from organic material decay is between – 21 ‰ and – 27 ‰ VPDB. In Comblain-au-Pont Cave, the δ ^{13}C values range between -23 ‰ and -27 ‰ VPDB (Fig. 5). We may induce that air CO_2 in this cave is mainly pedogenic.

3.3. A rise of temperatures

In 1975, a measurement campaign was carried out in fifty caves in Belgium (Godissart, 1975).

Only subhorizontal caves were taken into account in order to avoid the trapped air and the chimney effects. We found that the temperature in these caves was 9,5°C.

Since 2016, annual measurements have been carried out in some of these caves and we observed that the temperature had risen up to 10,2°C while the mean temperature at the Bierset weather station in 2019 was 11,5°C. Bierset weather station lies at 186m.asl, 50,65°N-5,45°E. So underground temperatures follow surface temperatures with some delay.

4. Discussion

In the caves we investigated in Belgium, the CO_2 of cave air comes from the soil and the underlying ground. We have been persuaded of that for a long time because we know that the seasonal maximum of CO_2 in the caves generally follows the seasonal maximum in the soil (Fig. 2). The analysis of the δ ^{13}C in Comblain-au-Pont Cave and in the surrounding soils definitely confirms that idea (Fig. 5).

On the other hand, it is well known that atmospheric CO_2 and air temperature are clearly rising nowadays. These two phenomena favour the vegetation growth. The result is that the trees, and probably many other plants, grow more rapidly than before. This is confirmed by dozens of photographs in the study area. We have chosen two of these sets of two pictures (Fig. 6).

5. Conclusion

Figure 6: Comparison of scenery in the studied karstic area, the Condroz (Belgium). Left: XXth century postcards. Right: Present-day photographs by Vincent de Waleffe (2014 or 2017). a-a': Comblain-au-Pont, Thier Pirard Rocks – Postcard, beginning of the XXth century and present-day view, 2014 (photograph by Vincent de Waleffe). b-b': Esneux, Fêchereux hamlet, left side of the Ourthe River – Postcard, beginning of the XXth century and present-day view, 2014 (photograph by Vincent de Waleffe). Strong rise of vegetation during the XXth century.

In the free air, the CO_2 rise was of 33 % during the XXth century: from 300 ppm in 1900 to 400 ppm in 2000.
In most of the caves we study, the rise is much steeper (Fig. 4). The origin of this discrepancy lies first in the very various morphologies of the caves, with large or narrow entrance, with one or several entrances, with or without underground river, etc. And second in the very large variability of the influences of the vegetation: woods, pastures, cultivations, the use or not of fertilizers, etc.
The huge growth of the trees is particularly impressive (Fig. 6). This expansion deserves much interest from the European foresters (Chmielewski & Rötzer, 2001; Claessens et al., 2017). This development, whether natural or not – this is not the question – is responsible for the increase of the CO_2 production by the roots and soil microfauna, etc. Soil may be a tremendous source or sink of CO_2 (Trumbore et al., 1996; Baldini et al., 2018).
An increase of temperature induces a rise of CO_2, and a rise of CO_2 causes an increase of heating through greenhouse effect (Ek & Godissart, 2009). This is a fine example of positive feedback loop.
We are surprised of the absence of similar observations in many recent studies on CO_2, although we notice that Fornos et al. (2018) show a similar CO_2 rise in two caves in the Balearic Island (Spain) in their figures 2 and 3.

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