Dear Referee,

Thank you very much for reviewing our manuscript.

Response to the comments:

(Referee comments are repeated in red)

1)

“Is there really no interannual change (ablation or formation) in the cave ice volume? i.e. can you be sure that the cave ice is fossil and that no water infiltrates into the cave throughout the year? If so, where is the water from the catchment area above the cave being directed to? How do these water fluxes affect heat exchanges at the system’s boundaries?”

Water and ice are in dynamic equilibrium state. Water infiltrates into the cave throughout the year, and forms ice; Ice at the bottom of Ningwu ice cave is thawed under geothermal flow, and the water infiltrates into the deeper place. Ice stalactites, ice stalagmites (Fig. 1d) can be seen in all part of Ningwu ice cave. This can verify the former process; No directly observational evidences support the latter process which is our supposition. It is difficult to consider these water fluxes in our models, because we could not fix several parameters (porosity, permeability, rainfalls, etc).

2)

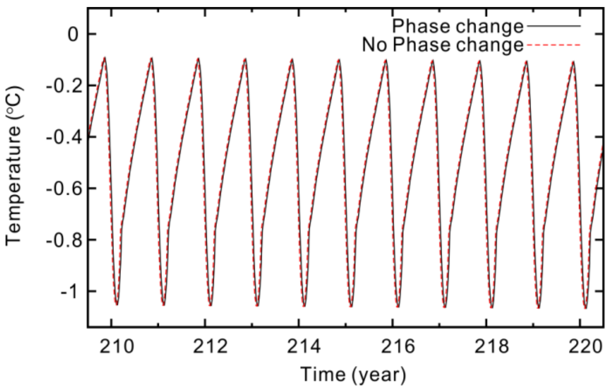
“How would a change in the infiltration regime (i.e. timing and recharge) affect the ice build-up, resp. the preservation of the cave ice?”

The ice build-up process is a self-regulating process. If too much ice was accumulated in Ningwu ice cave, the cavity will become small. Thus, Ra number and Nu number will be reduced. That means the freezing efficiency become low. Some of the cave ice will be thawed, and the cavity will become large. Ra number and Nu number will be increased. That means the freezing efficiency become high. More ice will be accumulated in Ningwu ice cave. This process is always happening.

3)

“Based on the sensitivity study, what would be the minimum climatic conditions required to form the ice cave?”

Based on the current climatic environment, Ningwu ice cave can form when the mean annual temperature increases 3.5 ◦C. We consider this is the minimum climatic condition required to form Ningwu ice cave. The figure shows the ice cave temperature annual fluctuations when the process has lasted two centuries, long enough to be evolved to a stable cyclic state. We can see the temperature ceiling is -0.1 ◦C.



Here are some clarifications

2370 l.18-21 edit or delete sentence as the formation of hoar frost (i.e. snow crystals) is not a process relevant to your system

We planned to verify that little humidity enters Ningwu ice cave. So these lines should not be deleted.

2372 l.14 please rephrase: do you mean that cold air is trapped inside the cave and leads to a thermal stratification which is not affected by natural convection during summer?

Natural convection occurs due to temperature differences which affect the density. Cold air in Ningwu ice cave is heavier than the environment air during summer and thus will not produce natural thermal convection.

2372 l.27 this assumes an equilibrated energy balance without considering any new formation or ablation of cave ice. Is this true (cf. also general comment)

This question includes two parts: energy and mass (ice or water). As Figure 4 of our paper showed, it takes relative long time to reach a stable cyclic state. The energy could not balance until the cave temperature reaches the stable cyclic state. As mentioned in question 1), water and ice are in dynamic equilibrium state.

2373 l.25 what about the cave ice mass balance? is the formation/ablation strictly limited to the cave entrance zone (l. 10)? If so, does this mean the cave ice in the deeper cave is completely "fossil"? when would it have formed?

As mentioned in question 1), it is difficult to consider these water fluxes in our models. In our numerical model, when the air temperature of Ningwu ice cave is below -0.1◦C (cf 2376 l.5 of our paper), the air will become ice at numerical simulation. We consider the cave ice in the deeper cave is not completely “fossil”. In further study, we will try to model the water fluxes.

2375 l.8-9 Eq. 3 and 4 are not necessary but Ts, Tl and T need to be better defined

The (Ts, Tl) is phase change range. Water (or ice) phase change occurs at 0 ◦C. But in numerical model, it is necessary to give a phase change range, for example, (-0.01, 0.01). T is temperature, unknown number.

2378 l. 7 a gradient of 2◦C/100m would be surprisingly high for a mature karst system surrounding the ice cave. A gradient of ca. 0.5◦C/100m would probably be more realistic; cf discussion in Luetscher and Jeannin (2004).

Fig. 4 in Luetscher and Jeannin (2004) showed the temperature in a borehole of the Swiss Jura Mountains. We can see the observed gradient of the main karst conduits is 0.55

◦C/100m. However, in our model, the temperature boundary conditions are assigned to both sides of the model. The both sides of the model are about 150m away from the cave ice (Figure. 3 in our paper). Therefore, we use the normal temperature gradient.

2379 l.11 “increasing rate” do you mean the “positive trend”?

The heat conduction in spring, summer and fall is much less efficient than convective heat transfer in winter. Therefore, the air temperature of Ningwu ice cave will decrease more rapidly in winter than in spring, summer and fall.

Sincerely,
S. Yang and Y. Shi

References

Luetscher M., Jeannin P.-Y., 2004. Temperature distribution in karst systems: the role of air and water fluxes. Terra Nova, 16, 344-350. doi: 10.1111/j.1365-3121.2004.00572.x