Responses to reviewer 1 comments 20160414

Ref: nhess-2017-222

We hope that the editor and reviewer 1 agreed with our assessment that the paper has been substantively improved

Dear editor and authors, this is also my first time with this review process type, I found it interesting while I expect to find a new version of the manuscript and not an answer to what can be do (I have not found the new version of the manuscript, then I cannot evaluate it or if the suggested changes and suggestions have been incorporated in the article).

I am very sorry that I thought the new version of the manuscript had been uploaded at 12 April but in fact the upload is failed because the modification file is too large. Then I uploaded the new version of the manuscript again on April 14th.

About the answer to my previous comments, manuscript is entitled with “early warning”, that require a monitoring technique that permits to evaluate indicators that can be used for alert about a collapse that can appear. In this sense, I understand the parts that make reference to evaluate the susceptibility, conceptually some of the proposed monitoring techniques can sound clear, but I am not sure that as presented and described can be used as an early warning. Solution is a long process (fast in C1 NHESSD Interactive comment Printer-friendly version Discussion paper geological terms), possibly the main part of the cavities can be present, or they change through long periods of time.

In the karst area, the bedrock collapse is that the bedrocks sink along the cavities and pipes under gravity. The soil collapse is that the overlying materials comprised mainly of the quaternary loose deposits over the carbonate rocks sink under gravity. According to the statistics for the karst collapse of ten southern provinces in China, the soil collapse accounted for 96.7 percent of the total. The karst collapse in this paper is the soil collapse, which is a phenomenon that the quaternary overlying materials collapse along the pipes to the cavities due to the effect of natural and human factors since there are cavities beneath the overlying strata and the pipes connecting the both of them. It’s showed as Figure 1.

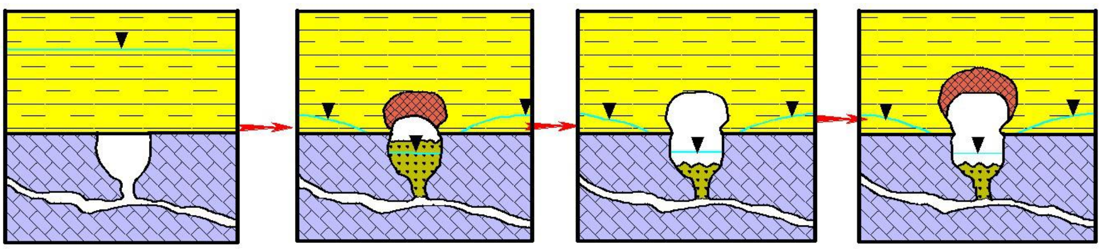

Figure 1 The process of karst collapse

Yellow: quaternary loose deposits light blue: bedrock green: groundwater table

Sometimes the speed of the karst collapse can be very fast. For example, the water inrush occurred in 2171 working faces of the Fangezhuang Mine of Kailuan (Group) Limited Liability Corporation at 10:20 am on June 2nd, 1984 and the entire mine was submerged after only about 21 hours. Moreover, 4 large-scale mines were damaged in different degree and the direct economic loss amounted to RMB 0.56 billion. In about 50 minutes after the water inrush occurred in the Fangezhuang Mine, the covered karst area from the Pengjiatatuo to the Linxi factory, about 3~7 km north of the water inrush point, collapsed due to sharp decline of the karst water table. There were 17 sinkholes with general diameters of 10 m and depths of 3~12 m, and then four of the sinkholes were connected together. (Source: Wei Fenghua: Study in the Mechanism of Karst Collapse in Tangshan City, Chinese Journal of Geology and Prospecting, 2006,4(2), 86-89.)

The evaluation of water as a factor can produce the development of collapses due to the rheological changes related to water pressure change, weight, etc.
Then this subject is of interest for monitoring but I am not sure if this is an early warning measurement as presented (e.g. about the evaluation of the rheological properties of the materials in a static manner).

Three conditions needed to form a karst collapse are as follows:
(1) The cavities beneath the overlying strata and the pipes connecting both of them.
(2) The overlying materials comprised mainly of the loose deposits with a certain thickness.
(3) The hydrodynamic condition of the karst groundwater is easy to change.

The soil collapse is the most common karst collapse in Wuhan city. There is a close connection for surface water, phreatic groundwater and karst groundwater in the study area and the water exchange among them is completed by groundwater runoff. The hydrodynamic pressure induced by groundwater runoff is proportional to the hydraulic gradient. The hydraulic gradient increases due to the change of the water level in Yangtze River and the groundwater exploitation, which makes the groundwater flow faster and the hydrodynamic pressure increase. The hydrodynamic pressure will be greater than the cohesion and the friction of the soils, and the soils are carried away by the seepage which results in the formation of soil cavities in the overlying strata. The surface collapse occurs when the soil cavities expand to a certain stage.

Based on an investigation for the statistical relation between karst collapse and water-level fluctuation and change of hydraulic gradient, an early warning for karst collapse can be realized by using these two indexes.

There are some formation mechanisms of karst collapse, such as suffosion erosion theory, vacuum suction erosion theory, vibration theory, liquefaction theory and gas explosion theory et al. Furthermore, some scholars proposed the mechanism of soil rheology. At present, the suffosion erosion theory and vacuum suction erosion theory are recognized widely.

For the suffosion erosion theory, the overlying loose deposits and fillings in gaps are eroded and hollowed along pipes in bedrock by groundwater flow, which leads to the formation of soil cavities and the collapse of roof.

For the vacuum suction erosion theory, in some shallow covered karst area with impermeable overlying strata, the pipes remain closed. Thus, a vacuum is formed between groundwater level and pipes when groundwater level falls fast below the bottom of soil. The overlying soil will be sucked by the vacuum which leads to a karst collapse. (source: Xu Weiguo, Zhao Guirong: The Implication of Suction Action for Ground Subsidence in Karst Mining Areas, Chinese Journal of Geological Review, 1981,27(2): 174-180.)

For the soil rheology theory, shear failure occurs easily inside saturated plastic-flowing soil due to pressure difference induced due to gravity and tension after groundwater level falls when the overlying stratum are mucky soil and soft clay. The cavities of soil expand continuously due to the soil erosion and the new relaxation zone formed continuously in a certain region of roof. As the cavities expand, the roof will finally collapse when the gravity of overlying strata is greater than the friction of surrounding soils. (source: Li Qianyin: Further study on formation mechanism of karst collapse, Chinese Journal of Geological Hazard and Control, 2009, 20,3, 52-55.)

In some cases the topographical surficial change can be used as predictor for collapse, but it does not exclude that collapses can be used for this subject.

Indeed, the monitoring programs for the karst collapse in Wuhan city involve the topographical surficial change. However, the topographical surficial change is not suitable to be a criterion for the karst collapse because the influencing factors of the topographical surficial change are too many.

GPR, for example, can be used to locate cavities, and to evaluate in time how it progress to surface, but the way to evaluate data does not permit to identify an early warning.

Indeed, the time that cavities progress to surface can be obtained by short period GPR. Because of the high cost of GPR, the monitoring period of GPR is 6 months in the monitoring programs for the karst collapse in Wuhan city, which is a kind of medium and long-term monitoring.

All in all, my main concern is still the same related to the early warning, that is the main objective of the manuscript, being the rest of subject more related to susceptibility to karst processes that can be used in urban planning for example, I want to say, measurements to avoid the exposition to the hazard, not to live over it.

With the economic development, the scale of Wuhan city is expanding fast. It is inevitable to construct in the covered karst area because the area of land is limited.

The monitoring infrastructure that permits to avoid the hazard by early warnings is difficult to evaluate in the proposed manner because some of them requires to be continuously measured.

Indeed, an early warning for karst collapse is on the basis of the continuous measure. So far, the

monitoring network for karst collapse in Wuhan city has been in operation for 8 years and the water-level fluctuation has been obtained successfully before the karst collapses occurred. Since 2009, the abrupt changes of water level have been monitored around the occurrence of 5 karst collapses. The water levels of monitoring holes (MT-1, CK13) in Maotangang increased abnormally in March, 2013. The water level of hole MT-1 increased abruptly on March 3, 5 and 7-12 and the maximal increase was 5.28 m as shown in Figure 2, which indicated that the karst collapses would occur in this area. A warning report was submitted in time to the Wuhan land resources and planning bureau from the Hubei Province geological environment Terminus and then 3 karst collapses occurred in this area from April 18th to 24th.
(source: http://www.chinatesting.com.cn/0hyzx/b/2015047493.html)

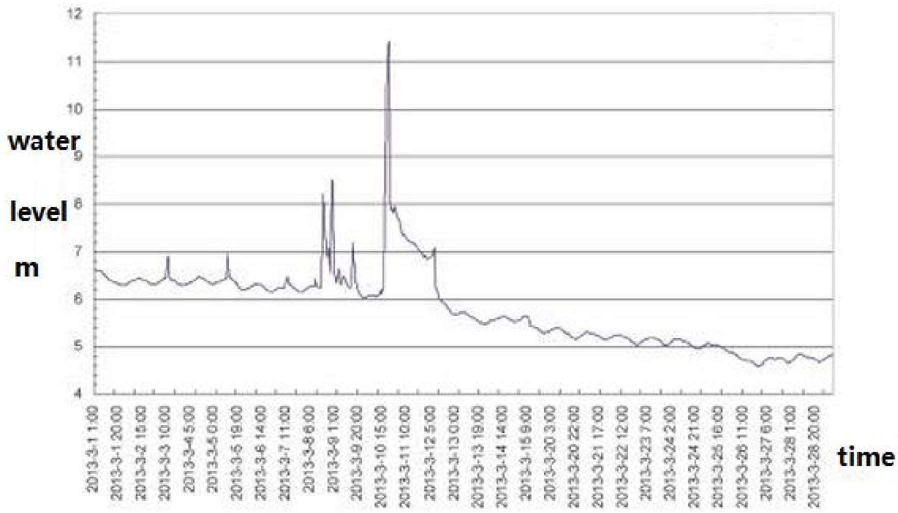

Figure 2 Time trend of M1-1 monitoring hole