1. Major results of Project

Progresses of project IGCP513 achieved in the year 2009 could be summarized in line with the 4 objectives of the Project.

1) Relation of hydrology to the function and health of karst ecosystems:

Guo Fang (2009) discussed the heterogeneity of water resources in a typical peak cluster depression karst area, Mumei subterranean stream catchment, in Yunnan, China. Its catchment area is 308 km², in which the carbonate area covers 297 km², accounting for 96 percent of the total. The strata are Permian, Carboniferous and Devonian with lithology of limestone, dolomite and sandstone. The mean annual karst water resources in Mumei catchment is 172 million m³, with a maximum of 211 million and a minimum of 136 million m³ according to long period hydrological data. The water resources include precipitation, surface water, phreatic zone water, and vadose zone water. For the purpose of water exploitation and utilization, the characteristics of heterogeneity of water resource in the studied area could be specified in four parts: (a)The precipitation which is asymmetric through the year due to monsoon climate. The annual average rainfall is 1410 mm according to observation data in Mumei weather station from 1986 to 1991 and 2001, but it mainly occurs between May and October, accounting for 83 percent of the total; (b)The surface water resource is nonuniform too. There are perennial allogenic water near the clastic rock areas with an average discharge of 100 l/s, while it is absent in peak cluster area. There are only several short seasonal streams or karst lakes emerging after heavy storm. Such seasonal streams distribute mainly in six karst depressions with a total length of 6 kilometer; (c) The groundwater resource in phreatic zone is also uneven. Complicated dissolutional conduits with a total length of 78 kilometer are main channels for water flow, and they are very difficult to investigate due to the thickness of the vadose zone which is usually more than one hundred meters. Along conduits there are 13 karst windows with plentiful water resources, but only 2 have been exploited due to complicated conditions. (d) Water resource in the vadose zone is in general poor. Some perched springs developed because of aquifuge in Devonian dolomitic limestone, such as the Shidongping Spring which enjoys a maximum discharge of 4.46 l/s and a minimum of 0.24 l/s. Its annual variation coefficient makes
The ideas of the heterogeneity of water resource was not the same as the heterogeneity of carbonate rock dissolution, nevertheless there are close relationships. Methods to evaluate and exploit karst water resource should be based on the four characters of heterogeneity as discussed above correspondingly.

Land use results in a series of variations of soil physicalchemical property, furthermore influencing on karstification direction and intensity. Taking two spring basins at different elevation in Jinfo Mountain, Chongqing as an example, Zhang Cheng(2009) analyzed the soil water and CO2 variation, soil water characteristics, solution rates in soil and their driving factors etc. The results showed that solution of tablets mainly occurs during the rainy season, with the mean weight loss in soil account for 65.5% and 71.9% of annual loss in Bitan and Shuifang spring respectively. It was also proved that soil CO2 is an important driving factor for the ground carbonate rock denudation. Soil CO2 and the residence time of the water are two major controlling factors which influence the weight loss in tablets placed in the soil. The intension of soil water transmission might be the decisive factor of solution rate in soil in dry season.

He Qiuang, Yang Pingheng(2009) explored the conduits of underground water medium and the recharge of underground water in a typical karst valley in Chongqing, China using chemical and microbiological indicators. High resolution tracer tests of two times with uranine have been conducted to find out the conduits of underground water medium and its recharge. Classification with Cl- concentration and discharge of the water in different sampling sites were used to divide the rainy reason and dry season specifically. With the results of classification, the correlation coefficient of nitrobacteria, denitrifying bacteria, which were the microbe indicator and NO2-, NO3- in different season, were analyzed. Using the chemical indicator tracking curves, which had only one peak without any tale, the recycle ration of uranine was calculated to be 93.94% and 27%, and the ration between the maximum apparent velocity and the average apparent velocity was 1.26 and 1.12. Therefore, chemical tracking implied that there was a big conduit underground river without big ribbon or byroad. Classification showed a rainy season lasting from May to September, the rest of the year was a dry season. In the dry season, at the output (site S2) of the underground river, the correlative coefficient of nitrobacteria and NO3- was 0.929. The correlative coefficient of denitrifying bacteria and NO2- was 0.811, but such relation has not been found in the rainy season when the correlative coefficients were 0.153 and -0.311. On the other hand, at the income (D1) of underground rivers, the relation of microbe and NO2-, NO3- has been found neither in the dry season nor in the rainy season. In a word, microbiological tracking implied the main recharge of the underground river in a dry season was the soil penetrative water through the fissures in karst, but in a rain season, the main recharge was surface water flow through swallow holes.

2) Water supply in karst regions:

Water resources of epikarst spring in dry season are not as much as that in rainy season. So a small reservoir is needed to keep the water resources. The volume of
reservoir, daily-consumed water resources and total consumed water resources in a period are related with each other. The problem to be solved is how to determine them. It can be considered as a problem of optimal water resources management, and can be solved with the genetic algorithm program. This special genetic algorithm (GA) was used for the Nongla epikarst spring (Jiang Guanghui, et al. 2009). The max daily-consumed water resources and related volume of reservoir were obtained for the spring. It also indicated that the initial water resources in the reservoir and discharge of the spring had important impact on the optimal result. Three advices were provided based on the study: (1) The reservoir should be built in rainy season; (2) There should be water resources as much as possible in the reservoir before consuming; (3) The volume of reservoir could also be gotten from actual daily consumed water resources according to the linear relationship between them.

Pu Junbing and Yuan Daoxian (2009) studied the spatial distribution of underground river streams and water resource in the Chongqing Municipality. Karst rocks in the Chongqing Municipality in southwestern China covers about $3.0 \times 10^4$ km$^2$, accounting for approximately 36.49% of the total area of Chongqing. The 1/200 000 hydrogeological map of Chongqing and the relevant reports show that there are approximately 380 underground streams with a total length of about 1898.43 km, with a total mean discharge of more than 144.20 m$^3$/s and water resources of more than $4.547 \times 10^9$ m$^3$/a. The underground streams, in general, exist mostly in the southeast and northeast of Chongqing. The distribution of the underground rivers is consistent with the occurrence of the carbonate rocks in Chongqing. Three indicators, i.e., the development density, runoff modulus and multi-year average precipitation, are used to judge distribution of the underground streams in Chongqing. The coefficient of development density of the underground streams varies between $12.25$ m/km$^2$ and $263.37$ m/km$^2$, and the coefficient of runoff modulus of the underground streams, between $0.10L/(s\cdot km^2)$ and $22.89L/(s\cdot km^2)$. It appears that variation exists from region to region. The high development zones occur in the west and southeast of Chongqing. The high runoff modulus zones concentrate in the northeast, southeast and west of Chongqing. In Chongqing, it is also found that the high-density zone of underground streams is not necessarily the high runoff modulus zone, and the high rainfall zone is not necessarily the high runoff modulus zone.

3) Water-related environmental problems in karst regions:

Karst groundwater is one of the important water resources for people in the world. There is an estimate that by 2028 karst groundwater will supply more than 80% of people in the world. However, several areas in the world are characterized by high nitrate concentrations in karst aquifers. In China, karst groundwater is also threatened by extensive use of fertilizer and pesticides, industry waste, septic systems and poultry, hog or cattle manure.

In order to understand the water quality of a subterranean river in south China, especially the dynamic variation of nitrate, nitrogen input and output were determined via auto-monitored apparatus, manual observation and samples from 2004 to 2008 in Guancun subterranean river drainage area (Fang Guo and Guanghui Jiang, 2009).
Land use and anthropogenic activities were also investigated frequently. The results showed the range of nitrate variation was 2.56–15.40 mg/L, with an average value of 6.60 mg/L. Spatial variation of nitrate concentrations showed nitrate rose where there were villages and agriculture distribution. Long series of nitrate and discharge monitoring revealed there was a nitrate peak in spring just before the beginning of rainy season. Three rainfall events were selected for analysis of relations among hydrological process, water chemistry, and nitrate of the spring. The flood processes of the spring were divided into three or four phases according to change of water level and water chemistry. They were dominated by initial condition of aquifer, piston flow in soil and vadose, piston flow in conduit, diffuse recharge, and bypass recharge. The original condition of aquifer and rainfall pulse controlled recharge flow and changes of nitrate and hydro-chemical graphs of the spring. The quantity of nitrogen input in a year was 66.61 t, and the output was 21.24 t. Nitrogen leaching loss in base flow accounted for 76.11% in a year. Some measures should be taken to protect karst water in the very near future, so that health risks to the local people can be decreased.

Zhang Meiliang et al.(2009) reported cave dripping water and carbon isotopic records of modern carbonate (CaCO₃) deposits: stalagmite in Panlong cave of Guilin and its environmental significance. The trend monitoring of cave dripping water and modern carbonate deposits at 13 monitoring points of dripping water in Panlong Cave of Guilin during the pre-phase (1995~2000) and nearly two hydrological years reveal that there exist two types of modern carbonate (CaCO₃) deposits: the first is the modern carbonate (CaCO₃) deposit of the perennial dripping water in the cave whose δ¹³C values have recorded climate change characteristics of the whole year, and the second is the modern carbonate (CaCO₃) deposit of the seasonal dripping water in the cave with the seasonal change characteristics of δ¹³C values. The monitoring and isotope analysis of modern carbonate (CaCO₃) deposits show that the exterior mountain peaks of the Panlong cave in Guilin are mainly C₃ plants (with almost no C₄ plants), and the δ¹³C records of modern carbonate (CaCO₃) indicate that the summer monsoon is strong, the rainwater is relatively rich, the biologic activities are strong, and the modern carbonate deposits are fairly well developed in the half year of summer, and the average δ¹³C value is −13.13‰ in the half year of summer. The δ¹³C values of the modern carbonate (CaCO₃) deposits are somewhat negative, with the annual average δ¹³C value being −12.23‰ and the maximum negative value being −14.5‰ for the whole year. The δ¹³C values of the modern carbonate (CaCO₃) deposits are somewhat positive (−10‰—11‰) due to less rainwater in the half year of winter. In addition, the δ¹³C values of modern carbonate (CaCO₃) formed by dripping water with a lag of one month or half a month show a sudden negative trend and mainly reflect the influence of the CO₂ effect, which results in the effect of meteoric precipitation when heavy rain falls or rainstorm occurs no matter whether in the half year of summer or in the half year of winter.

4) Aqueous geochemistry of karst aquifer/landscape systems.

In normal days of no rainfall, the hydrochemical variation of the exit of a karst
ground river system has a remarkable diurnal periodicity on a short time scale (about 10 days) and the periodicity can be identified using continuous power spectrum analysis and cross spectrum analysis. Zeng Cheng and Liu Zaihua et al. (2009) studied the short-time scale variation in hydrochemistry of a karst ground river based on spectrum analysis taking the outlet of the Banzhai karst ground river system in the Maolan Nature Reserve as an example, the authors investigate the data of meteorological factors and hydrochemistry which were continuously monitored for about ten days of no rainfall in the middle October in 2007. The results indicate that the hydrochemical variation of outlet of the karst ground river system covered with virgin forest shows a remarkable diurnal periodicity. The water pH rose, whereas CO₂ partial pressure, electric conductivity and calcite saturation index drop during daytime when the air temperature rose. The response of water pH to meteorological factors and the response of CO₂ partial pressure to water temperature are most sensitive.

An attempt was made to distinguish the natural and anthropogenic processes and factors responsible for groundwater quality (Jiang Yongjun et al. 2009). R-mode factor analysis was applied for the sets of chemical data, i.e. pH, EC, HCO₃⁻, Ca²⁺, Mg²⁺, Na⁺, K⁺, SO₄²⁻, NO₃⁻ and Cl⁻ in the Nandong underground river system. Groundwater samples and surface water samples were collected at 42 and 15 locations in 2008, respectively. Analytical results of these groundwater samples show that the Nandong underground river system has very variable chemical compositions and spatial variability. By applying the R-mode factor analysis, three factors were obtained, which explained the characterization of groundwater quality and identified the sources for the presence of ions and their geochemical processes. It was found that the anthropogenic contribution is responsible for Cl⁻, NO₃⁻, SO₄²⁻, Na⁺ and K⁺ in groundwater. The natural dissolution of existing rocks of carbonate is the common influencing source for Ca²⁺ groundwater. However, the anthropogenic contribution is also responsible for Ca²⁺ in groundwater. The natural and human-influenced processes are responsible for pH, EC of groundwater. Mg²⁺, HCO₃⁻ are influenced by the factors of soil and water-rock interactions, respectively. The concentrations of CO₂ in soil and the water-rock interactions are responsible for Mg²⁺, HCO₃⁻ in the groundwater. The anthropogenic processes are the most important influencing factors for groundwater quality in the Nandong underground river system.

In order to grasp the hydrologic regime of underground river, a case study on the Qingmuguan subterranean stream in Chongqing was carried out (Xian Liu et al. 2009). During May 2007 to June 2008, a water table gauge (WGZ-1 photoelectric figure flaviograph monitor) and water quality monitoring site were set up to record the water level, temperature, pH and conductivity. Hydrology dynamic method was adopted to analyze the response of hydrologic dynamic of the subterranean stream to the rainfall in this paper. The result showed, during the rainfall, water table and discharge increased with the rain, especially on July 17, 2007, some peaks appeared in the large storm, the highest water level was 1.175m, and the response lagged for 6h10min after the largest rainfall intensity with the highest discharge being 2.5781m³/s and the smallest only 0.0189m³/s. It was found that there was a significant correlation between the water table regime and rainfall event, which indicated the Qingmuguan
subterranean stream is developed intensity in tensity with single conduit and weak water-storing ability. Conductivity, pH and water temperature also responded to the rainstorm rapidly. Conductivity fell down from 602.7 to 462.09µs/cm, pH fell down from 7.23 to 7.01, and water temperature risen from 18.9°C to 19.5°C, all these indexes lagged shorter than 15 hours. The results showed that the hydrochemical response of the subterranean river system, where a well-developed and connected conduit system existed for underground flow, to rainfall is very fast. The water level varies abruptly following the rainfall and electrical conductivity, water temperature, pH, calcite saturation index and carbon dioxide partial pressure also response rapidly to the change of environment. The acid rain probably causes the pH reduction and increase of electrical conductivity of spring water. The turbidity of spring water increases due to the surface soil erosion scoured by the rainfall. It indicates that the water is polluted by microorganism.

2. Scientific activities

Members from China national working group of IGCP513 are involved in 6 activities in 2009. One is the annual meeting of IGCP513 during the 15th International Congress of Speleology which was held in the University of Schreiner situated in Kerrville town of Texas, US, during July 19 to 26, 2009.

The others are International Symposium on Efficient Groundwater Resources Management (IGS-TH 2009) from February 16 to February 21 in Bangkok, Thailand; an excursion on karst environmental geological problems in northern Guangdong Province from 7-12, April, 2009; “Training Course on Resource Management Methods and Standards of Karst Region” in Kunming, Yunnan Province, China, from August 11-13, 2009; the Conference of Sustainability of the Karst Environment – Dinaric Karst and other Karst Regions in Plitvice, Croatia on September 23 to 36, 2009; International Seminar of Hydrology and Geohazards Management, Wuhan, China from November 2 to November 4, 2009.

1) Texas, US: 19-26 July 2009

Prof. Zhang Cheng and others attended the 15th International Congress of Speleology (ICS) and the annual meeting of IGCP 513 international working group held in the University of Schreiner situated in Kerrville town of Texas, US, during July 19 to 26, 2009.

Researchers of IRCK/Institute of Karst Geology (IKG) of CAGS, had submitted five academic papers before the congress. Prof. Zhang Cheng gave a presentation titled as “Different Land Use of Soil and Karst Process”.

During the congress, he distributed IRCK brochures to participants present, and introduced its significance, objectives and activities in 2009. At the same time, he communicated with representatives from different countries, and invited experts in karst research fields to join the lecturer group for the training course to be held in 2009.
2) Bangkok, Thailand | 16-21 February 2009


The IGS-TH 2009 International Symposium was held from February 16-21 in Bangkok, Thailand. Research fellow Li Qiang and Wang Jinliang of China working group took part in the Symposium. They introduced IRCK, IKG and the Key Laboratory of Karst Dynamics (KLD) to the meeting and the scholars and popularized the “Training Course on Karst Hydrogeology and Karst Ecosystem” to be held in Guilin.

During the Symposium, up-to-date information about groundwater exploitation, usage and protection were given by 513 group members, especially groundwater quality and efficient way of groundwater management. It was declared that we should pay more attention to the further development of groundwater. More communication with the Southeast Asian karst countries was made by the IRCK introduction during this Symposium. As a result, the related research institutions of Thailand and Viet Nam etc., hope to conduct cooperation and exchange of researchers.

3) Northern Guangdong | 7-12 April 2009

Combination with China Geological Survey Project: study on key geo-environmental problems and their countermeasure, an excursion was carried out in northern Guangdong karst area from April 7-12, 2009. Several underground streams and springs were investigated, including Yangshan Taiping underground stream, Xingzi and Sanyang underground streams, karst spring in Zhang Town, Dabaoshan underground stream (seriously polluted by mine tailings). More than 50 participants from provincial geological department of Guangdong, Guangxi, Yunnan, Guizhou and Hunan, China Geosciences University (Wuhan), Guangxi University, Southwest University etc. attended the excursion and investigation. 3 reports from China Central Television are also involved in the investigation.

4) Kunming, Yunnan: August 11-13, 2009

“Training Course on Resource Management Methods and Standards of Karst Region” and “Consulting Seminar of Major Geological Environment Problems and Countermeasure Study of Karst Rock Mountainous Areas in Southwest China” were jointly held by IRCK, the Institute of Karst Geology (IKG) and the Western Kentucky University in Kunming, Yunnan Province, China, from August 11-13, 2009. Experts from IRCK, IKG, the Western Kentucky University, the Karst Institute of Slovenia gave lectures and made discussions on karst resources management and karst environmental protection.

After the training course, the "Consulting Seminar of Southwest Mines and Water Environment Problems", which focused on human activities, especially karst groundwater environment problems that caused by mining, was held. The following suggestions were provided:

(1) Strengthening further investigation to prepare a classification map of major
geological environment problems of southwest karst region, which was listed in the work plan of 2010.

(2) Intensifying the popularity of karst ecological environment structure characteristics and karst groundwater vulnerability to enhance people’s awareness of water environmental protection in karst area.

(3) Learning from the up-to-date ideas, measures and mechanism on karst groundwater resources protection of the US and other western countries so as to bring in new technology, methods and ideas on the basis of the combination of geological investigation and scientific research.

5) Plitvice, Croatia: 23-36 September, 2009

The Conference of Sustainability of the Karst Environment – Dinaric Karst and other Karst Regions, organized by the Centre for Karst from Gospic, Croatia, was held in Plitvice (World Heritage), Croatia on September 23 to 36, 2009. Four 513 China working group representatives: Prof. Yuan, Prof. Jiang Zhongcheng, Associate Prof. Jiang Guanghui and Meng Yan attended this conference and gave presentations. Besides, Prof. Yuan hosted a session in the afternoon of September 24. Jiang Guanghui as the co-chairman of IAH Karst Commission(KC) took part in judging Young Research Prize. KC had the first meeting during the conference organized by the elected new chairman. Prof. Yuan and Dr. Jiang attended the KC meeting. One member of Chin working group was appointed as co-chairman of KC and two others as the member.

6) Wuhan, China: 2-4 November, 2009

During November 2 to 4, 2009, the International Seminar of Hydrology and Geohazards Management was held in Wuhan, China, which was sponsored by Jakarta Office of UNESCO, China’s national commission of the International Hydrological Programme (IHP) and Hydrological Bureau of the Ministry of Water Resources.

The purpose of the seminar is to communicate and share the knowledge, information and technology in the field of hydrology and water resources based on the five key domains of IHP-VII 2008~2013. Bilateral and multilateral cooperation was encouraged.

Prof. Yuan, Associate Prof. Jiang and Guo Fang attended this seminar and gave presentations about the particularity of karst environment and mechanism of karst waterlogging and flood.

Mr. Giuseppe Arduino from the Jakarta Office of UNESCO invited IRCK representatives to introduce IRCK briefly. After the seminar, Mr. Giuseppe Arduino and IRCK representatives exchange ideas about how to join the IHP. The IRCK representatives met Mr. R. Jayakumar from the Beijing Office of UNESCO, who concerned much with the development of IRCK and promised to keep contact with IRCK and take part into its activities.

3. Work plan of year 2009
1. Carry out Sino-USA, Sino-Austria, Sino-Slovenia and Sino-Indonesia bilateral cooperation projects continuously.

2. Combination with China Geological Survey Project: study on key geo-environmental problems and their countermeasure, to investigate the actual pollution status of the subterranean rivers in southwest China karst areas, including the distribution features, water quality and quantity variations during the past 2 decades and their controlling factors, contaminations and relationship with human activities, et al. A draft karst environmental map with underground river database will be established and aquifer vulnerability mapping will be carried out in typical underground river basins of southwest China in the year 2010.

3. Take part in IGCP513 international working group meeting at the 4th International Conference on Karst in Malaga University, Spain and post conference excursion on April 27-30, 2009. The project will be summarized; a new karst related IGCP proposal will be discussed and outlined during the meeting.

4. Organizing the International training course on carbon cycle monitoring of karst dynamics system scheduled in October 2009 in Guilin Institute of Karst Geology, CAGS.

4. List of important publications


(7) He Qufang, Yang Pingheng. 2009. Using Chemical and Microbiological Indicators to Track the Recharge of Underground Rivers in a Karst Valley.
Hydrogeology and Engineering Geology. 36(3): 33-38


