ON THE MYSTERIES OF SUMMER ICING AND WINTER WARMING IN THE ICE VALLEY AT MIRYANG, KOREA

H. R. Byun[1] – H. L. Tanaka[2] – D. Azzaya[3]

[1] Dept. of Environmental Atmospheric Sciences Pukyong National University, Daeyeon Namku 608-737 Republic of Korea; hrbyun@pknu.ac.kr.

[2] Center for Computational Sciences University of Tsukuba, Tsukuba 305-8577 Japan; tanaka@sakura.cc.tsukuba.ac.jp.

[3] Institute of Meteorology and Hydrology, Juulchny gudamj-5, Ulaanbaatar-46, 210646, Mongolia; azzaya23@yahoo.com.

Abstract: The mysteries of the Ice Valley, Miryang, Korea are introduced. In the summertime, icing occurs, with many icicles standing upward, a continuous cold wind emanates from cold wind holes (CWH), and cold-water streams are found just below the CWH. On the contrary, in the wintertime there is a continuous warm wind, no ice in the CWH, and no freezing streams are seen. This has been an unsolved mystery for a long time. The mechanisms of these mysteries are explained herein along the results of long observations and investigations. Finally, it is imagined that Ice Valley may provide a model for a refrigerating engine that lasts a long time without a power supply.

Key words: mystery, summer icing, icicle, cold wind hole, Ice Valley, refrigerating engine

INTRODUCTION

The Ice Valley in Miryang, Korea, designated as a Natural monument (No. 224) by the Korean government, has been a mysterious place in the world though not well known yet. Much ice and many icicles form in the late spring when nearby ice melts away. Many icicles stand upward in talus in the valley. These icicles change to ice plates and persist until summer. Moreover, in midsummer, when outside air temperature reaches to 35 °C, small ice is still forming. From several holes called cold wind holes (CWH), cold wind flows out continuously throughout the year. Also in the lower part of the CWH, streams of much colder water than is found nearby persist through the summer.

Contrary to this, in the winter it is very hard to see ice or icicles in or near the CWH. Moreover, in several holes in the talus, warm wind flows out throughout the entire winter and the CWH are then known as has named as the warm wind holes (WWH). Also, stream water coming out from the talus is much warmer than the air temperature and never freezes during winter though other nearby streams do freeze.

Since 1968, several studies have tried to solve the mysterious nature of Ice Valley. However, most of them have focused only on the origin of the cold air and ice formation during the summer. Kim (1968) thought that the cold air forms through Adiabatic Expansion (AE) of underground air (Then named 'AE theory'), as Poison's equation explains. It means that the rapid decrease of pressure, if it gets through the multi-step AE can reduce the air temperature during outflow from the underground. However, the AE theory is contested by many studies. To decrease temperature from 30 °C to 0 °C by AE theory, a large pressure differential between the in and out flowing parts of talus is needed. However, a large enough pressure difference has not been found in anywhere in the valley.

Moon and Whang (1977) made more observations than Kim (1968) and proposed that the cooling and icing processes progress through the evaporation of water. However, this theory has since been withdrawn. Whang (2005) who was a co-author of Moon and Whang (1977) does not mention this theory anymore. Moon (1997) is also pessimistic on this theory. Bae (1990) noticed the fact that water flowing out from the Valley is relatively warm in winter and very cold in summer (known as 'temperature inversion'). However, neither Bae's observations nor analyses were sufficient to make accurate conclusions, due to the poor efficacy of the observation tools at the time.

Jung (1992) was the first to observe the CWH regularly once a day for more than three months. He guessed that there are numerous large ice formations underground and that these are the origin of the cold air and icing in summer. He also tried to find and explain the origin of the warm water and warm wind in winter but was not successful.

Song (1994) coined the term 'the regenerator effect' to explain the mystery of Ice Valley. But this name has since changed to 'the natural convection theory'. By both of the regenerator effect and the natural convection theory, it has been hypothesized that the cold air stored in the talus during winter flows out during summer and the warm air and heat stored in the talus during summer flows out during winter. However, based on this theory,

Jung (1992) said that the energy (cold or warm) stored in the talus could not persist more than 7 days.

On the other hand, Tanaka et al. (2002) tried to express the whole system in Ice Valley through a numerical model. He proposed many things in numerical data with the name of "thermal filter", hypothesizing that only the cold air could penetrate into the talus while warm air was filtered out, and that this filtering took place in a short time. This study, however, did not consider the water in the valley that had been known to be cold in summer and warm in winter.

A rumor that the summer CWH changes to winter WWH persisted among the citizens of Miryang City until the year 2003. However, Jung (1992) found that CWH did not change to WWH, though he did not successfully find any WWHs. In 2003, Byun (2003) found several WWHs where warm air flowed out during the winter that they were located apart from CWH. Byun (2003) also found that the ice of Ice Valley does not form during the summer but rather in late spring and early summer, when all other ice around the valley melts. Again Whang et al. (2005) proposed that during throughout the winter cold air had been accumulated in the CWH. That was similar to Song (1996) but opposite to Tanaka et al. (2002) and Jung (1992) in time scale of convection. But Whang et al. (2005) did not comment on the water temperature and WWH.

The present study includes meteorological observations every one or three hours for more than three years. With these results, the whole mysteries of the Ice Valley, CWHs, WWHs, strange water temperatures, and other particular phenomena are introduced. Also, this study tries to explain the reasons behind all of these mysteries. Importantly, this is the first study to examine the mystery of why ice forms at late spring and little ice exists in winter.

TOPOGRAPHY OF THE ICE VALLEY AND OBSERVATION

Ice Valley is located in the mountain of Yeong-Nam Alps (Fig. 1) in the southern part of Korea. The ridge-line of the mountain over 1,000 m lies continuously for more than 4 km, and prevents the southerlies from penetrating into the valley. Under the northward side of Jae-Yak Mountain there is a deep and narrow valley; Ice Valley. The administrative district is Kyeongsangnam-do Miryang-si Sannae-myeon Nammyeong-ri. In August, Miryang (the nearest meteorological station located in 35° 29' N, 128° 45' E with 12.5 m elevation), has a monthly mean daily temperature is 25.7 °C, a minimum daily temperature of 21.6 °C, and a maximum of 30.8 °C. The record high temperature is 38.5 °C.

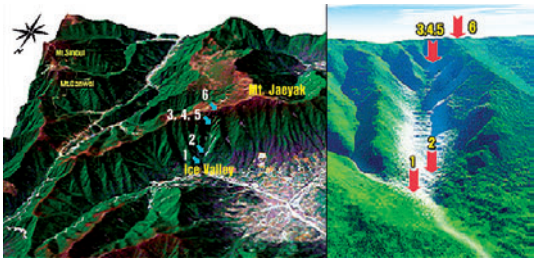

Fig. 1. Topography of the ice valley. Left panel is from satellite image. Right panel is an afternoon figure of the ice valley simulated by contours. From Byun et al. (2004a).

Geological characteristics are as follows, described by Yun (2004). At the end of the Cretaceous period there was much volcanic activity and became the center of the Unmoonsa Caldera. The Unmoonsa Caldera was estimated to be a shallow lake 69,000,000 years ago. Through the shallow sedimentary layer volcanic ashes spewed out and the Yeong-Nam Alps were made. The fault activity that developed in a NNE direction inter-locked with these volcanic activities, and formed a northward wall named Ice Valley. A trace of volcanic ash flowed slowly southward with 25~30 degree incline and is found near the summit of the mountain. After this volcanic activity, the vacant area underground was made and the surface upheaval subsided. Then, walls with clipped rocks were formed. These rocks were weathered by wind and water during the 4th glacier epoch and inter-glacier epoch, and are hypothesized to have become the talus of Ice Valley.

The observation equipment for this research were installed in approximately 40 locations, but only some of them will be introduced (Tables 1 and 3; thermometers for water temperatures in the bottom of the valley). Some data collection was started in September of 2003 and has continued to recent days (September, 2006).

Table. 1. The geographic information of Ice Valley. Numbers denote observation locations.

S No.	S Name	Latitude	Longitude	Altitude
1	Lower valley	35°34'22.2"	128°59'11.7"	377 m
2	CWH	35°34'18.2"	128°59'10.8"	401 m
3	WWH_OUT			
4	WWH_IN1	35°33'54.4"	128°59'05.7"	759 m
5	WWH_IN2	35°33'54.4"	128°59'05.7"	759 m
6	Mt._Top	35°33'42.8"	128°59'00.9"	1,062 m

THE CAUSES OF THE MYSTERIES OF ICE VALLEY

Fig. 2 illustrates part of the observed data. The Annual maximum temperature of CWH1 (green line) and CWH2 (blue line) are less than 10 °C. CWH2 is positioned in a slightly isolated place and shows a warmer temperature than CWH1. Abrupt increases of temperature in CWH1 appeared twice in 2003. The first temperature increase was caused by the typhoon Maemi, with heavy rain. The cause of the second temperature increase is not known. From October 2003 until early April 2004, the temperature of CWH rapidly drops only when the temperature

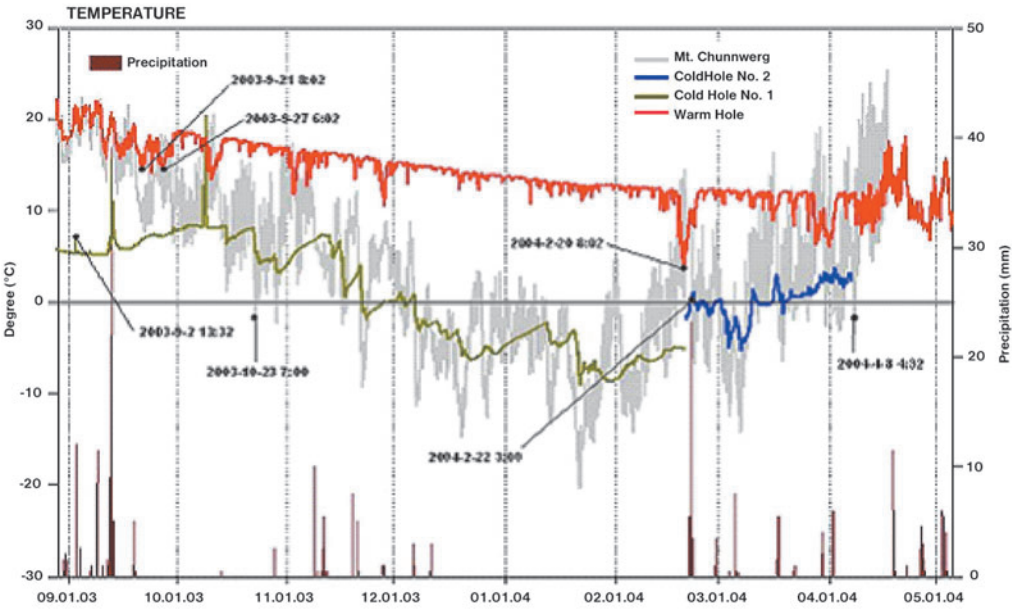

Fig. 2. Air temperature variation at the top of the mountain (TMT, 6 in Fig. 1, gray line with the largest fluctuation), CWH (2, blue and green line with small fluctuation) and WWH (3, upper red line) from May 01, 2003 to August 25, 2005. Bars denote precipitation. Temperatures were checked at 3 hour intervals

of the mountain top (MT) drops, as seen in October 23, 2003. This means that the source of the cold air in CWH is a cold wave from the Siberian or Artic regions. Generally, the temperature of the CWH1 gradually increased from April to October (not shown).

From October 2003 to March 2004, the temperature of WWH was much warmer than the MT and gradually decreased. Even though the temperature of the MT was -20 °C, the temperature of WWH did not drop. When the MT is warm, the temperature of WWH decreases temporally, as in February 20, 2004. It is not clear whether the rain has any correlation with the temperatures of CWH and WWH. Several mysteries and their causes are explained as follows.

1. THE MYSTERY OF THE LACK OF ICE IN WINTER

In the talus, there is no water to freeze in winter because all rainwater penetrates into the deep talus. Immediately following a snowfall, we observed small icicles over the surface of the talus that persisted for a little while. But these icicles disappeared within a few days not by melting but by sublimation.

2. THE MYSTERY OF THE FORMATION OF ICE IN THE LATE SPRING

In spring, when most ice melts, ice located in the upper part of Ice Valley melts also. The water runoff from this melting ice flows down. However, it does not penetrate into the talus but rather floats over ice plates and freezes again at a lower part of these ice plates. Continuously with this process, ice flows down from the upper part of the valley and finally reaches to the CWH and supply water to freeze.

Late spring is the season when the path of water to CWH is opened and there is enough water in talus to freeze. However, in CWH more cold air is needed in order to freeze the water. Melting processes can produce only air near 0 °C, not enough to cause water to freeze. If the air is warmer than the ice, ice does not sublimate but melt.

If air temperature is colder than ice, even though the underground air is almost saturated, ice sublimates. And the colder air produced by sublimation flows down along the inclined talus and is stored in CWH. This cold air can make more ice when it meets water.

If air is cold enough at the first stage, that is, colder than the ice, the colder air is produced continuously through the positive feedback mechanism of sublimation, as long as there is enough ice to sublimate in the inclined talus. Actually, in Ice Valley at late spring it is easy to find ice that is drying rather than melting. And large ice plates form only one time in late spring, when much colder air than 0 °C exists.

In Ice valley, cold air that can initiate the sublimation process is stored in the talus until late spring. This is the most important aspect contributing to the strange behavior of ice in Ice Valley. Particular topography that protects the valley from the invasion of outside warm air, special rocks that insulate the solar heat and warmed air etc. are necessary environments not only to keep the valley cold but also to initiate the sublimation process.

3. THE MYSTERY OF THE FORMATION OF ICE AT MIDSUMMER

In midsummer two kinds of ice are found in Ice Valley, though very rare. One is small icicles that can be seen from the outside of the talus. The other is thin ice plates attached to the rock in deep talus, and can only be seen using a special tool such as an endoscope. Because air cooled by melting ice is not cold enough to make water freeze, ice forming in midsummer needs another explanation as to the source of cold air.

In some vacancies in talus, cold air is trapped in winter not only by rock walls but also by ice walls. Midsummer icicles are formed due to the trapped cold air in talus by ice walls. In summer, when the ice walls are melting away, a path is opened for the cold air. At this time cold air flows downwards, and makes ice when it meets water. However the amount of cold air is so small that summer icicles are not big.

4. THE MYSTERY OF ICICLES GROWING UPWARD

It has been observed that some icicles in the ice valley grow upward. This is caused by the colder air positioned in the lower part of the underground region. In talus, the lower is the location, the colder the temperature. Sometimes, only the lower part of the talus is below zero. That is the case here. The origin of water for the icicles is the water dropping from melting ice. This is different from the ice spike that shows the upward growth of ice without a falling drop of water (Byun et al., 2004b).

However, most of icicles in Ice Valley do not grow upward. At first they grow downward like other icicles. Later, they form a pillar. Upper parts and parts nearer to surface melt earlier than lower parts, because the lower region is colder than the upper region. At this point the icicles look like bars standing upward.

5. THE MYSTERY OF COLD AIR PERSISTING UNTIL SUMMER

In the talus, coldness is stored during winter not only in the form of sensible heat (cooled rocks) but also in the form of latent heat (ice). This means that there is a lot of ice in the deep talus. How is this ice stored in the deep talus? First, there is enough vacant space in the talus because the rocks underground are big enough. Second, there is a continuous water supply from the several waterfalls located over Ice Valley. Third, the topography of Ice Valley with its bottle-necked shape opened to the north and surrounded by big mountains, etc., makes it easy to keep cold air and ice underground. Fourth, because all of the rocks (Dacite welded ash flow tuff) in the valley are good insulators, it is difficult for heat from warmed air to penetrate into the talus. So, cold air and ice easily persist underground.

If there is no ice in the valley, then cold air can persist for only about 10 days because the heat capacity of the rocks is small. Evidence was seen in early November 2003, illustrated in Fig. 2, that the outside air temperature was warmer than the freezing temperature.

6. THE MYSTERY OF WARM WIND IN WWH

WWH in talus are not easy to find. But they are easily found after a snowy day. Though all surfaces are covered by snow, no snow is stored over WWH. In some WWH, snow melts away much earlier than in other regions. One WWH located 800 m above mean sea level was the most distinct, because it was just below the big rock wall where the warm air from underground cannot go upward. On the origin of heat sustained continuously in WWH, two causes were deduced. One is the heat stored during summer; another is latent heat produced by condensation. Because the heat capacity of the rock is not great enough, the latter cause is more persuasive. Throughout the winter, WWH are always humid and dewy. Near WWH, mosses grow not in summer but in winter. Stream water below CWH provides other evidence of condensation, as explained below.

7. WARM WATER IN WINTER AND COLD IN SUMMER

In winter water under the CWH is not ice-melt water but saturated water of the underground vapor. We analyzed the ingredients of water. In water that flows into the Valley, densities of minerals were high. However in water that flows out from the Valley they were low like distillate. It means that the water passed through the evaporating process in talus. Stored minerals during winter are guessed to be washed away with flush flood every summer.

Once penetrate into the deep talus, water evaporates, rises and finally condenses again. Then it is imagined that condensed water flows down not through CWH but through the other routes nearby, though warmed air by the latent heat of condensation rises and flows out through WWH.

Another evidence is seen at the water temperature. In winter just below CWH, never ending stream with never freezing water flows out. Also several waterfalls upper valley provide cold water to the valley continuously. Water flows out below CWH is much warmer than the water flows into the valley.

As the warm air of WWH is not only from the heat stored during summer but also from the latent heat by the condensation, warm water flows out is heated not only by ground heat but also by latent heat. However, the precise calculation says that the vapor evaporated in the talus is not enough to sustain the heat of the WWH and warm water. Then a possibility of existence of spa underground that provide more vapor is carefully proposed.

On the other hand, water flowing out from Ice Valley is very cold in summer. However, through extensive observation, it was found that the water temperature in Ice Valley (not shown) has the same annual variation as a natural season, so to speak; cold in winter and warm in summer. But this variation is so small that the water feels the cold in summer and warm in winter. In winter, the water temperature is near 3~4 °C and in summer 6~8 °C.

SUMMARY AND DISCUSSION

Several mysteries of Ice Valley were addressed in this study and causes and mechanisms for each were proposed. The key aspects of Ice Valley are summarized into three points. The first is that there are enough cavities underground in the talus that for the storage of cold air and ice. The second is that there is a large enough supply of water and vapor through waterfalls over the valley and a spa underground. The third is the fact that very cold air that can initiate the sublimation process of ice formation remains underground until late spring or summer. Because air produced by melting ice cannot make water freeze again, the sublimation process and its positive feedback is the most important mechanism for spring and summer icing. This mechanism gives us a clue to the

development of long-lasting refrigeration without electric power. Ice Valley constitutes a natural example and actual evidence of this. Someday, human beings will be able to use this mechanism to improve day to day life.

Acknowledgments

This work was funded by the Korea Meteorological Administration Research and Development Program under Grant CATER 2006 – 2306.

REFERENCES

BAE, S. G. 1990. Hydrological Study on the summer icing of the Ice Valley. J. of Korean Hydrological Society (In Korean with English abstract). 23(4), 459–466.

BYUN, H. R. 2003. The underground convection on the winter warm wind and summer icing of the Ice Valley (In Korean). 'The Atmosphere' edited by Korean Meteorological Society. 13(1), 230–233.

_____ - CHOI, K. S. – KIM, K. H. – TANAKA, H. L. 2004a. The characteristics and thermal mechanism of the WWH found at the Ice valley in Mt. Jae-Yak. (In Korean with English abstract). J. of Korean Meteorological Society, 40–4, 453–465.

_____ - SEO, D. I. – LIM, B. H. 2004b. The observation of the naturally formed ice spikes and their inductive inferences. J. of Korean Meteorological Society, 40–2, 203–216.

JANG, K. S. 1989. Study on the summer icing of the Gumsu Mountain, Chungbook Jaewon-gun (In Korean). Ms. Thesis of the Kongju College of Education, 33pp.

JUNG, C. H. 1992. The research study on the Ice Valley Miryang Namyeong-ri (Natural monument 224) (In Korean). The inspection report on the natural monument and the put-step of the dinosaurs, Korean Geological Society. 61–84. 200pp.

KIM, S. S. 1968. On the cause of the Summer Icing in the Ice Valley (Miryang) (In Korean with English Abstract). J. Korean. Meteorological Soc., 4(1), 13–18.

KIM, Y. I. 2003. The research of the Ice Valley- Ice Valley and stony ice storage (In Korean). Digitaldio (LTD), 101pp.

Miryang Cultural Center. 1987. Miryangji (In Korean). 382–383, 500pp.

MOON, S. Y. – WHANG, S. J. 1977. The study on the summer icing of the Miryang ice valley. Collection of the research papers of the College of Education Busan University (In Korean), Vol. 4, part of natural sciences. 47–57.

NOHARA, D. – NURA, N. – TANAKA, H.L. 2002. WWH in winter at Nakayama. *Tenki*, 49, 745–746.

SASAKI, H. 1986. Geographical distribution of wind holes in Tohoku district. *Tohoku Chiri*, 38, 34–35 (in Japanese).

_____ - YOKOI, M. – NOHARA, D. 2000. Observational study of Summertime Ice at the Nakayama Wind-Hole in Shimogo, Fukushima. *Sci. Rep.,* Inst. Geosci., Univ. Tsukuba, 21, 1–21.

OHATA, T. – FURUKAWA, T. – HIGUCHI, K. 1994a. Glacio-climatological study of perennial ice in the Fuji Ice Cave, Japan. Part 1. Seasonal variation and mechanism of maintenance. *Arctic and Alpine Research*, 26, 227–237.

_____ - _____ - OSADA, K. 1994b. Glacio-climatological study of perennial ice in the Fuji Ice Cave, Japan. Part 2. Interannual variation and relation to climate. *Arctic and Alpine Research*, 26, 238–244.

PARK, Y. S. 2004. The geological study on the wind hole of Haenam Gowndu Mountain. Environmental geological research information center (In Korean).

SONG, T. H. 1994. Numerical simulation of seasonal convection in an inclined talus, Proceedings of the 10th international heat transfer conference, 2, 455–460.

TANAKA, H. L. 1997. The numerical experiment on the summer icing on the Miryang Korea. Jirihak-Pyeongron (in Japanese), 70A-1, 1–14.

TANAKA, H. L. – NOHARA, D. – YOKOI, M. 2000. Numerical simulation of the wind hole circulation and summertime ice formation at Ice Valley in Korea and Nakayama in Fukushima, Japan. *J. Meteor. Soc. Jap*, 78, 611–630.