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Temporal Variation of Air Temperature in Ice-Valley at Milyang in Association with Ice Formation

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Abstract: A long-term in situ observation was carried out in the Ice-valley at Milyang in order to explain the factors and processes associated with the summertime ice formation. The variation of temperature inside Ice-valley in relation with ice formation in summer time was found to depend on precipitation rate in spring and cold air sinking in autumn and winter. The rate of temperature rising tends to correspond to sensible heat release depending on the precipitation amount at the freezing location. The reason of the cold air accumulation in a talus in the Ice-valley is the cold air sinking over the surface of talus due to the occurrence of outside clod air mass and the accumulated cold air from autumn to spring flow outside at the bottom of talus. The out-flowing cold air can result in the ice formation in the hot summer.

Keywords: Summertime ice, Ice valley, cold air sink, ice formation environment

Introduction

The Ice-valley at Milyang is one of the most famous natural monuments in Korea because of the unusual freezing even during hot summer. The formation of ice is found as early as April and disappears in the late October in the Ice-valley, and it found that the more ice appear in the hot summer. Fig.1 shows ice formed in the Ice-valley. This unusual summer time ice formation and cold drainage in this area are essential characteristics in this Ice-valley. This odd phenomenon has been well known for many years as a natural refrigerator, and investigation of geographical environment in this area has also been carried out. However, the precise cause and the mechanism of the summertime ice formation in this mountainous area are not yet fully understood (Lee et al., 2004a and b).

Hwang and Moon (1981) and Tanaka et al. (1998) proposed the evaporation theory, in which the structure of the Ice-valley was divided into two parts, named as the saturation belt and the capillary belt. According to this theory, evaporation becomes active at the upper capillary belt in summer, and the latent heat released from this evaporation drops the air temperature. However, it is doubtful that the evaporation is the only cause of dropping air temperature.

Based on another theory devised by Bae and Kayane (1986) argued that the water in underground of the Ice-valley is the cause of the ice formation in summer. They explained that the water freezing for the summer resulted from air temperature delay caused by advection and conduction in the underground water. However, observational data supporting the theory is scarce without any analysis of the internal air current important for freezing. Song (1994) showed Ice-valley's role as a cooler with numerical analysis; Ice-valley stores cold and hot air alternately for summer and winter, respectively. However, storage of hot air was not observed, and the reason for rising mechanisms is obscure. Thus it seems that all theories presented to date have some drawbacks with the lack of long term observations to explain the mechanism of summertime ice formation.

We conducted in situ observation of air temperature in the Ice-valley for a long time in order to provide the explanation of summertime ice formation. This study is hence intended to analyze the reasons for and processes of freezing phenomenon with meteorological data collected for five years.

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Fig. 1. Photography of ice during summer season with 20 cm length in the Ice-Valley.

Observation

The geographical features of Ice-valley are shown as follows. Ice-valley (128°59'E, 35°34'N) is located at the upper reaches of the Milyang river near Milyang city, south-western part of the Korean Peninsula. Surface of Ice-valley have much air tube and space constructed by accumulation of big and hard rocks crumbled from steep cliff. Such slope with accumulated debris is called talus especially andecite rock talus. The slope of the valley is 15-20 degrees and andesite rock talus is 250 m width by 750 m length. Much of the Ice-valley is almost covered with andesite rock talus with about 50 cm diameter, and freezing occurs 400 m above the sea level (Fig. 2). In addition, underground water is close to the basin of Milyang under 750 m from top of the mountain, so it is hardly observed near talus.

We conduced in situ observation in Ice-valley for 5 years from October 1999 to May 2005, and intensive observations were also carried out twice at April 1997 and May 2003. We mainly measured the meteorological elements of the nearby area of the freezing location with Automatic Weather System (AWS) and a 6 m-high iron. We measured temperature, humidity, solar radiation, and net radiation at 1.8 m height, and wind direction and speed at the top of the tower. We also installed thermocouples on the surface, and buried 50 cm and 170 cm deep under the ground to measure the internal temperature. In addition, a temperature-humidity sensor was separately installed at freezing location, and measured temperature and humidity until June 2004. Precipitation was measured with the rain gauge set up at the parking lot in the mouth of the Ice-valley. The measurement data is stored in the data logger and then is transferred to a computer.

Results

Fig. 3 shows air temperature measured at the

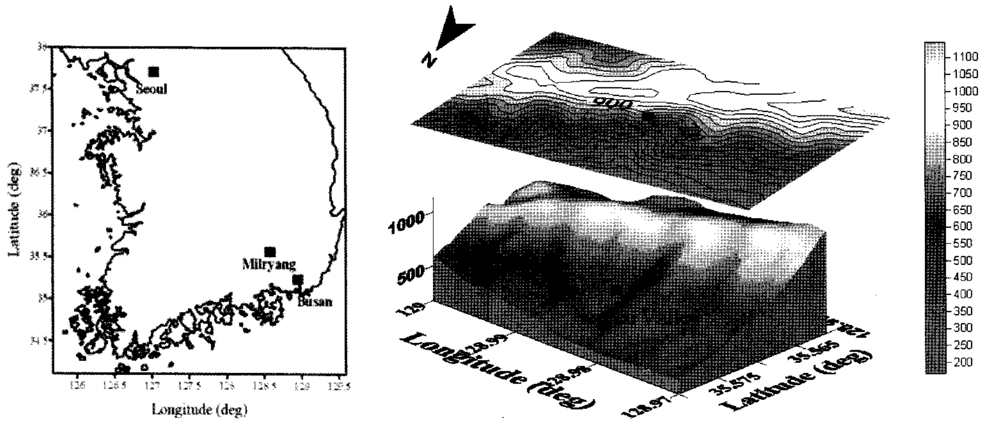

Fig. 2. Topography around Ice Valley in Milyang, Korea. The freezing point of Ice Valley is located at the bottom of the talus with 400 m high.

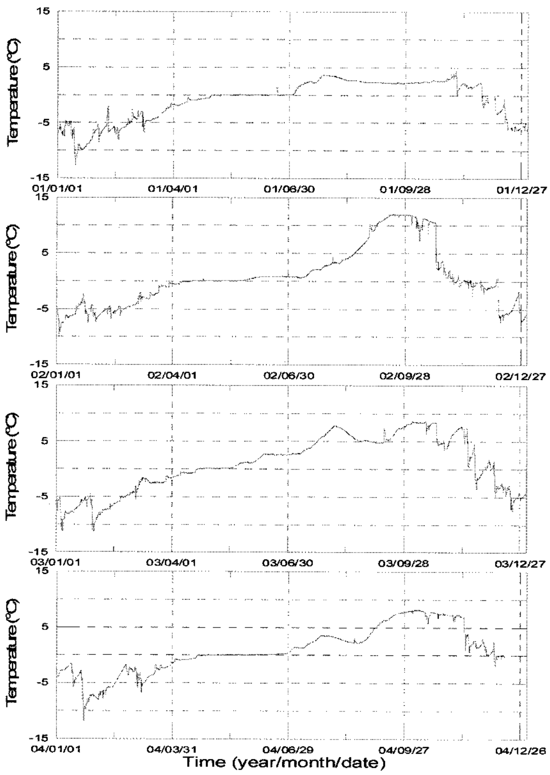

Fig. 3. Annual temperature variation observed at freezing point in the Ice Valley during four years from 2001 to 2004.

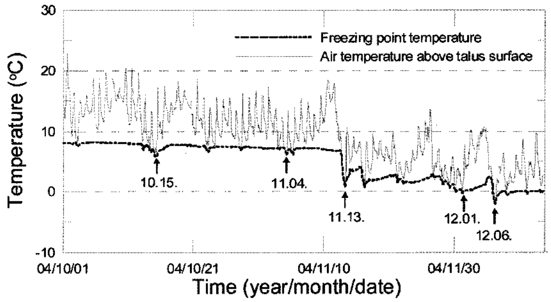

Fig. 4. Air temperature variation on talus surface and freezing point from Oct. 2004 to Dec. 2004. Solid line and dashed lines represents air and freezing point temperature, respectively. Arrows and date indicate sudden decreasing of air temperature.

freezing location in the Ice-valley from 2001 to 2004. Temperature at the freezing location was the lowest in January and 0 degree in spring. It remained 0 degree throughout summer and the highest in fall. In the early winter the temperature started to drop. Such tendency of temperature change appears in all observation data and although maximum temperature in 2002 rose to the 13.8, maximum temperature of summer season tends not to be over 10 degree in the Ice-valley.

We can find two features in this variation of temperature. While the temperature rose slowly and continuously from spring to summer, it changed discontinuously from the end of winter to early in spring; the temperature dropped discontinuously like a step function. The mechanism of the discontinuity in temperature was studied.

Fig. 4. shows the temperatures inside and outside of the freezing location from October to December 2004. An arrow points at the sudden temperature change at the freezing location and this means that the synoptic-scale cold air mass appear over Ice-valley at that time. It is consistent with the sudden change in outside temperature due to the appearance of synoptic-scale cold air mass. While the external temperature bounced back quickly after a cold wave, the temperature at freezing location did not bounce back but stayed at the lower temperature. The temperature at freezing location dropped further by the next cold wave. With this, the cold air could be stored in the interior of talus for a long time. The great amount of cold air was continuously accumulated as following time before summer season.

Fig. 5. shows the air temperature and precipitation in talus during spring. It shows that the temperature rises in Ice-valley matched with the days of precipitation until June 2004. It can be explained as warm latent heat from rain raised the temperature. The effect of latent heat from rain disappeared after April 19th. It is probably caused by that temperature inside rose above zero already. Therefore, the rate of temperature rise depends on the amount of precipitation at the freezing location. The steep rise in temperature in 2001 could be viewed as a result of latent heat from the abundant precipitation that year had.

In summary, the mechanism which we found from the above experiments is as below. Because of the surrounding geographical features of the Ice-valley,

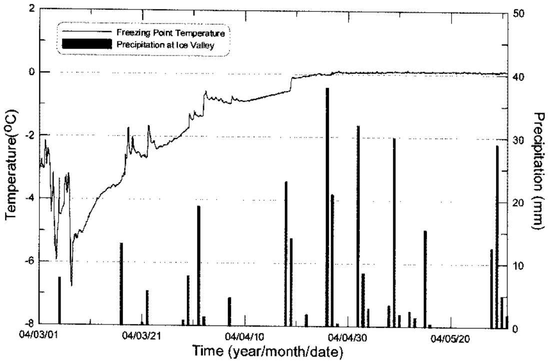

Fig. 5. Time variation of temperature at freezing point and precipitation amount two months from 1 March 2004.

solar radiation is little but radiative cooling is considerable in a season when solar altitude is low. Then the surface temperature of talus is lower than the air temperature. The air above the surface of talus begins to cool and sink, and this cold air makes internal air and debris of talus cooler. And also, the effect of cold waves at the beginning of winter cools talus down. In this case, a sudden drop of air temperature by a cold wave makes air temperature is lower than the internal talus. As air temperature above the surface of talus is lower than the one of the internal talus, the cold air sinks into the internal talus; the higher the temperature is, the less dense the density is.

The rise of air temperature in the exterior talus suppresses the outflow of cold air through the surface talus, and thus the cold air is stored in the talus. This is because a stable layer is formed along the surface of talus. When the air temperature of internal talus is lower than the one of external talus, air outflows slowly through the bottom of talus, because the air density of internal talus is greater than that of external talus. Therefore the convection along the opposite direction does not occur as season changes. That is, the cold air sinking through the surface of talus and outflowing at the bottom of talus allowed by the mechanism mentioned above is the only airflow in talus. So to speak, the circulation in the talus does not reverse its course as season changes, but only sinking occurs.

Conclusion

The mechanism of ice formation known as freezing phenomenon is as follows. When a cold wave comes in the early winter, the external cold air flows into the internal talus by difference of density. Because cold air flows inside is more stable than external warm air, it does not flow out but is accumulated inside. Although external temperature rises slowly after winter, convection does not happen due to the small amount of solar radiation. The temperature in the talus remains constant.

However, spring precipitation supplies warm latent heat to internal talus, which raises temperature in the talus. Internal temperature of talus rises discontinuously like step function by latent heat. When internal temperature of talus reaches above zero, effect of latent heat disappears and the temperature rises continuously. Therefore the ice formation mechanism of internal talus is not related to the convection but to the one way circulation of cold air. In the next study, we want to install anemometers to observe variations of wind speed and verify this conclusion.

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References

Bae, S.-K. and Kayane, I., 1986, Hydrological study of Ice Valley, Korea. Annual Report of Institute of Geoscience, University of Tsukuba, 12, 15-20.

Hwang, S.-J. and Moon, S.-E., 1981, On the summertime ice formation at Ice-valley in Milyang, Korea. Abstracts in Spring Conference, Geophysics Society of Japan, 19, 218-219.

Lee, S.-H., Seo, K.-S., Kim, D.-H., and Hwang, S.-J., 2004a, Numerical Study on warming effect due to green house gas in moicroscale atmospheric domain. Journal of Korean Society of Atmospheric Environment, 20, 303-315. (in Korean)

Lee, S.-H., Seo, K.-S., and Hwang, S.-J., 2004b, Study on variation of local atmospheric circulation due to road development in mountain area. Journal of Korean Earth

Science Society, 25, 94-108. (in Korean)
Song, T.-H., 1994, Numerical simulation of seasonal convection in an inclines talus. Proceeding of the 10th International Heat Transfer Conference, 2, 455-460.
Tanaka, H.L., Hwang, S.-J., and Moon, S.-E., 1998, Mysterious Ice-valley in Korea where ice grows during the hottest season. Tenki, 45, 3-4. (in Japanese)

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