Climatological study of the wind hole in Shodoshima Island

*Masaki HORIUCHI[1], Takako YAMAGUCHI[2]

1. Hosei University, Graduate School of Humanities, 2. Hosei University

1.Introduction
A windhole is a place where cold wind blows out of a mountain slope in summer and such a phenomenon (Shimizu et al., 2015).
An example of application in Japan is the storage of silkworm species. Overseas, in Europe, such as the Swiss and Northern Alps, the use of milk in a refrigerated hut can be seen (Sato, 2008).
In recent years, due to growing interest in natural energy, the value of windhole as a natural cold source has been re-recognized, and many windhole have become cool spots for sightseeing and tours. In some areas, practical refrigerators are used to store seedlings, vegetables, pickles, fruits, etc., and demand is increasing.
It is indispensable to clarify the nature of such windholes, and many studies have been conducted over the fields of climate, topography, geology, and vegetation since the Meiji era. In Tanaka et al. (2004), convection caused by the relatively low temperature inside the talus in summer compared to the outside air caused cool air to blow out from the lower windhole, and the inside of the talus was relatively hot in winter. This reveals that warm air blows out from the upper windhole. In this paper, the windhole that blow cold air in summer are called “cold windhole”, and the windhole that blow hot air in winter are called “warm windhole”.
Many examples of such air hole research have been reported in cold regions such as the Tohoku-Hokkaido region and high altitude regions. However, the temperature rarely drops below 0 ˚C, and warm regions where ice does not form inside the windhole. Although there are Hagi (Mori and Sone, 2009) and Kozushima (Suzuki, 2019), there are not many research cases.
In the future, it is considered that the thermal environment of the ground surface will be affected by the rise in temperature due to global warming (Bogdan et al., 2012), and the thermal environment of the windhole may change in the same way. Therefore, conducting a survey in a warm region at the present time is considered important in considering the effects of global warming on the flora and fauna and flora inhabiting the flora.

2.Method
In this study, a windhole (100m above sea level) located on Shodoshima, Kagawa Prefecture, facing the Seto Inland Sea and having a mild climate. A thermometer (TandD: RTR-502, measured at 10-minute intervals) was installed at the windhole and the surrounding area, and the long-term temperature fluctuation was recorded.
A hot-wire anemometer (CUSTOM: WS-03SD) was installed in the windhole from August to November to observe daily changes in wind speed.

3.Result
From the start of the observation (June 8, 2019) to the beginning of October, the temperature of the cold windhole was around 11-14 ˚C, and gradually increased while keeping the temperature lower than the outside temperature. In addition, a temporary rise in the temperature of the cold windhole was observed during a mass precipitation event. This is probably because warm rainwater flowed into the cold windhole, causing the temperature inside to rise temporarily.
Comparing the cold windhole temperature between 11:00 on June 9 (11.3 ˚C) and 11:00 on October

1(14.1 ˚C), the effect of precipitation and outside air intrusion was small and it seems that cold wind was blowing stably. The temperature difference was 2.8 ℃, and the temperature rise rate of the cold windhole during this period was 0.025 ℃ day^{-1}.
According to the wind speed observation results, a relatively good correlation was found between the cold windhole wind speed and the temperature difference inside and outside the cold windhole, and it was found that the wind speed increased as the temperature difference increased. This supports the mechanism (Takahashi et al., 1991) that the wind in the windhole is caused by the density difference between the outside air and the air inside the windhole.
Later, from mid-October, the number of days when the difference between the cold windhole air temperature and the outside air temperature became small at night increased, and in early November, the nighttime temperature difference almost every day became very small. During the winter, the heat stored in the talus in the summer creates an upward air current inside the turf, and the wind blown out of the cool windhole turns into a suction in the summer. Synchronization is considered to capture this suction phenomenon. In addition, in the survey conducted in December, the wind direction of the windhole was actually replaced by suction, which proved that the air temperature was synchronized with the outside temperature.
In addition, the hot windhole was discovered by measuring the surrounding ground surface temperature with a radiation thermometer in winter (December 27, 2019), and observation was started.

Keywords: Windhole, Warm region, air circulation, Observation

