Observational Analyses of Nocturnal Temperature Inversions in Haean Basin

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Abstract: In this research we analyzed nocturnal temperature inversions in Haean Basin. Inversions are important phenomena for understanding meteorological and hydrological character of the basin region. Three automatic weather station data and tethered balloon soundings were used to analyze inversion strength, depth, and occurrence of inversions. Stronger and deep inversion was found during early summer while weaker but frequent inversions occurred during late September and early October. A significant influence of fog layer was found. The fog layer acts as a break during a cooling process. The fog appears usually in early mornings. During our experiment, average potential temperature change at the surface was -1.08 K/h without fog presence. When the fog appeared six hours average decreased to -0.23K/h. The most deep and strongest inversion of the studied period was 0.19 ℃/m temperature gradient.

Keywords: *nocturnal temperature inversion, radiation fog, basin climate*

1. Introduction

Strong nocturnal inversions are common during good weather conditions especially in deep valleys and basins. During the night when the air in contact with ground is cooled, a nocturnal inversion is formed (Lee, 1985). Kondo et al. (1989) describes the importance of cold air advection from the basin sideslopes in the cooling process of the basin bottom layer. As the air temperature decreases during the night the heavy cold air settles to topographic depression. The air is then trapped by surrounding terrain and creates cold air pool. Thus, very low temperatures can be found over the basin floor compare to the temperatures measured at higher altitudes. Several researches has studied and described inversion formation and breakup in mountainous basins (Clements et al., 2002) valleys in Colorado (Whiteman, 1981) etc. has been done This research is focusing on Haean Basin located in North-East part of the Kangwon-do province in South Korea. The basin is specific by its symmetric feature and steep slopes with significant soil erosion. The elevation of the basin floor is about 420m MSL. Perimeter of the basin ridge is 31.2km with maximal diameter of 11.7 km. The maximal height of ridge is 844.3m over the basin floor (Figure 1). The land is typical rural area mostly used for agriculture especially cultivation of rice, radish, cabbage and potatoes. The topographic characteristics of Haean suggest a high probability of frequent and strong temperature inversion presence during spring and autumn nights. The main goals of this study were survey and analyze the occurrence and structure of the nighttime temperature inversions in Haean Basin.

2. Methodology

The entire meteorological research in Haean basin is supported by data from several instruments including eighteen HOBO Pendant temperature data loggers, fourteen automatic weather stations, tethered balloon sonde and one Eddy flux tower consisting ultrasonic anemometer, net radiometer and LI-7500 CO_2/H_2O analyzer. In this research data from three of the automatic weather stations has been used to determine the inversion strength and depth. AWS14, AWS10, and AWS2 represent measurements at different elevation (Figure 1a). AWS 14 represents the lowest level at 451 m, AWS 10 is located on west slope at 633m and AWS2 is placed on the mountains crest at 977 m. Thus, the elevation difference between AWS14 and AWS10 is 182 m and 526 m between AWS14 and AWS2. Inversion strength during selected period was analyzed using method used by Wendler (1974) where inversion strength is estimated simply by temperature difference (Δt) between two sites.

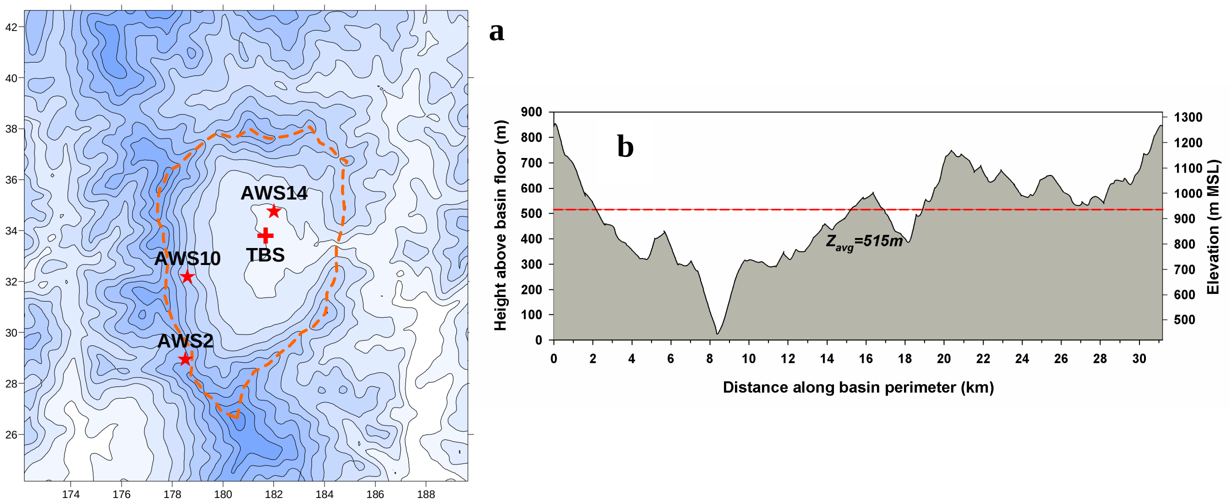

*Figure 1. **(a) Location** of three automatic weather stations AWS14 (451m), AWS10 (633m), AWS2 (977m), and location of tethered balloon soundings (TBS). (b) Ridgeline elevations as function counter clockwise distance around Haean Basin. The average elevation is 936 m and 515 m over the basin floor (red dashed line).*

Results of Δt were categorized into 23 categories of 1.0 C intervals. Using this method 30 minutes average data were analyzed beginning on June 6th 2010 19:30, finishing on October 10th 2010 10:30 Korean Standard time (KST). The tethered balloon sounding experiments were performed approximately in the middle of the basin with starting altitude 430m. The experiments were divided on two parts, spring observation (before monsoon season) and autumn observation. The spring tethered balloon experiment took place during relatively good weather condition from 4th June to 6th June 2010. Measurements were performed in 2 hour intervals from 5:00PM until 9:00AM. The autumn experiments were performed twice (24th -28th September) in 1hour intervals.

3. Results

In our previous research monthly occurrence of nocturnal inversions has been analyzed using different data set where temperature measured at 677m elevation were compared with temperature observed at 577m elevation (AWS9, not shown). The results are shown in Figure 2. The maximal number of inversion 21 cases was found in early June and 18 cases in October. Note, that the inversion case means the night when the inversion was present. In this research data from the AWS14 with the lowest altitude was analyzed and each 30 minutes of observation was compared. Unfortunately, the data for early June are not available. Therefore, the most frequent inversion sequence is not seen in Figure 3. However, absence of inversion during the July and August is obvious from the diagram. In July, number of cases rapidly decreased which is mostly caused by worse weather condition during summer monsoons. The frequent inversions were again present during September and October. Interesting finding was that inversions during the fall season last until late morning (around 10:00 AM). We found that this is mainly caused by fog layer which appeared during early morning and last almost until the noon. Thus, shallow fog layer absorbed and scattered sunlight and protect the low altitudes from the direct sun light, while slopes were fully insolated. Since, we focused on nocturnal inversion this daytime inversions which are not based on nighttime cooling were excluded in next analyses. In this research the night-time period refers to data from 6:00 until 20:00 during summer and from 7:00 until 19:00 during fall season. Frequency of classified night-time temperature difference between three sites is plotted in Figure 5. The positive value simply means that the temperature at higher altitude was higher than the temperature at the basin floor, thus can be consider as temperature inversion. In contrary, the negative values refer to no-inversion

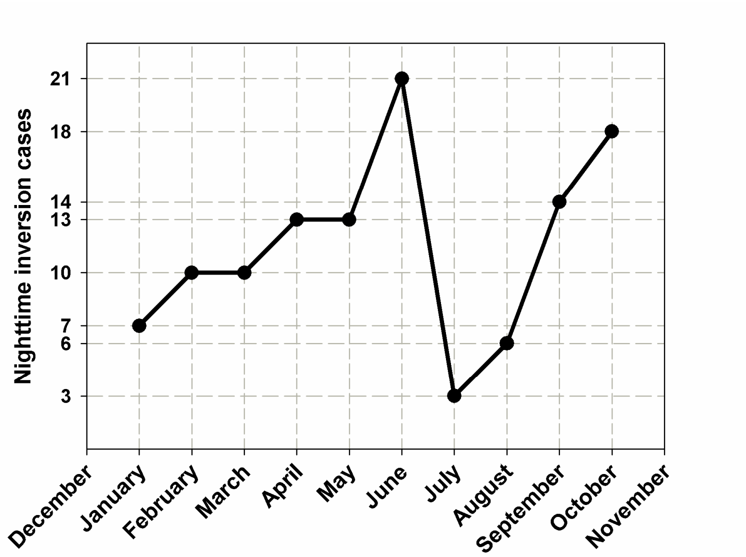

*Figure 2. **Occurrence** of nocturnal inversion during 2010 (based on AWS10- AWS09 data)*

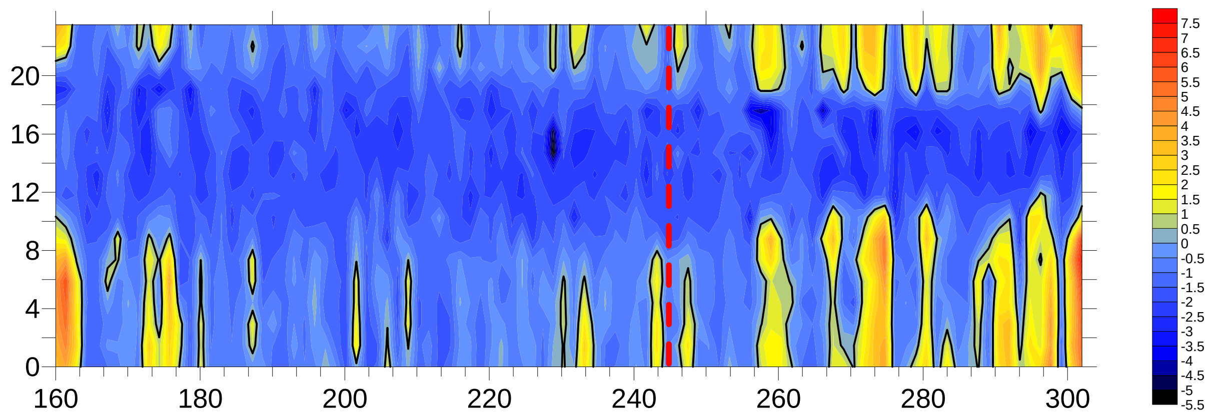

Figure 3. Temperature difference between 451m and 633m

cases. Two altitude differences can give some basic information about inversion depth. Four cases are included in the class of 10 °C for summer season at 526m distance. This data refers to the strongest inversion of studied period on June 6th 2010. The inversion between 526m reached 9.87 °C and 0.19 °C/m temperature gradient. No evidence of such strong deep inversion is for fall season, however many weaker inversions (1-2°C) appeared (Figure 5. b). The relation between relative humidity and temperature is plotted in Figure 6. From the scatter diagram it is seen that most of the weaker inversion cases are followed by high relative humidity reaching 100% while during the strongest inversion cases the relative humidity is less (around 90%). We can assume that a mist or a fog layer appeared when relative humidity reached the 100%. Since no visibility sensor or fog sampler was used for observation of fog we do not have any prove of the fog presence. However, we have notes of weather condition during tethered balloon soundings. Thus, we can report which sounding were performed during fog event. The potential temperature profiles are plotted in Figure 7 and are divided on sounding without fog and with fog evidence. The first sounding starts on September 24th at 18:00 PM and last until September 25th 9:00 AM. The potential temperature follows basic inversion patterns until 0:00 when the fog layer appeared in the basin. The six hours average potential temperature change at the surface was -1.08 K/h. The second part of sounding during fog event shows significant difference. The six hours average has decreased to -0.23K/h. A change can be seen on potential temperature profiles shape as well. Profiles with no fog evidence are mostly straight from the surface until the inversion top, while profiles with fog evidence have significant arcs over the basin floor. It is obvious that the arcs are caused by fog layer and the top of the shape is approximately equal to fog layers top. Since the fog is present often during the autumn it plays important role in nocturnal inversion formation and break up in Haean Basin.

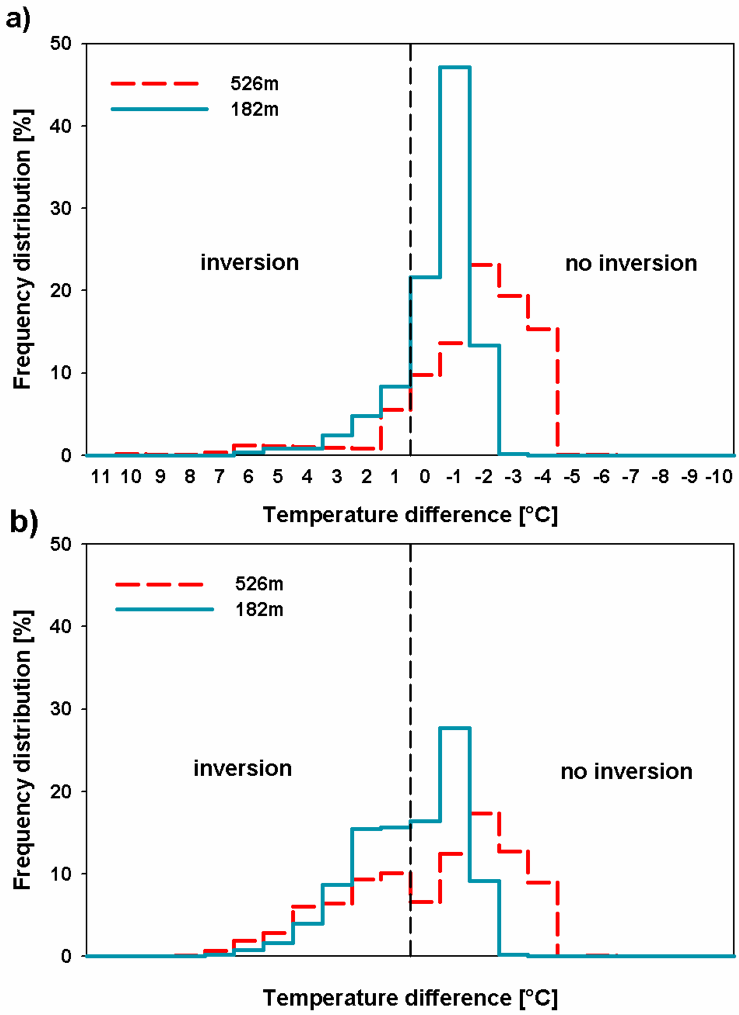

Figure 4. Frequency distribution of inversion strength for different altitude difference a) summer b) fall

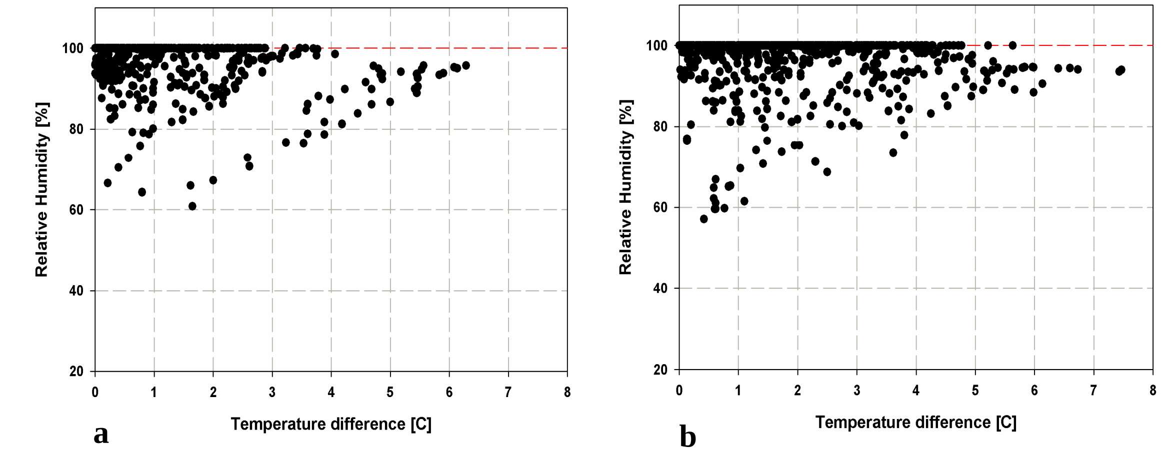

Figure 5. Relation between relative humidity (at the bottom of basin) and temperature difference (182m). a) during summer season, b) during fall season

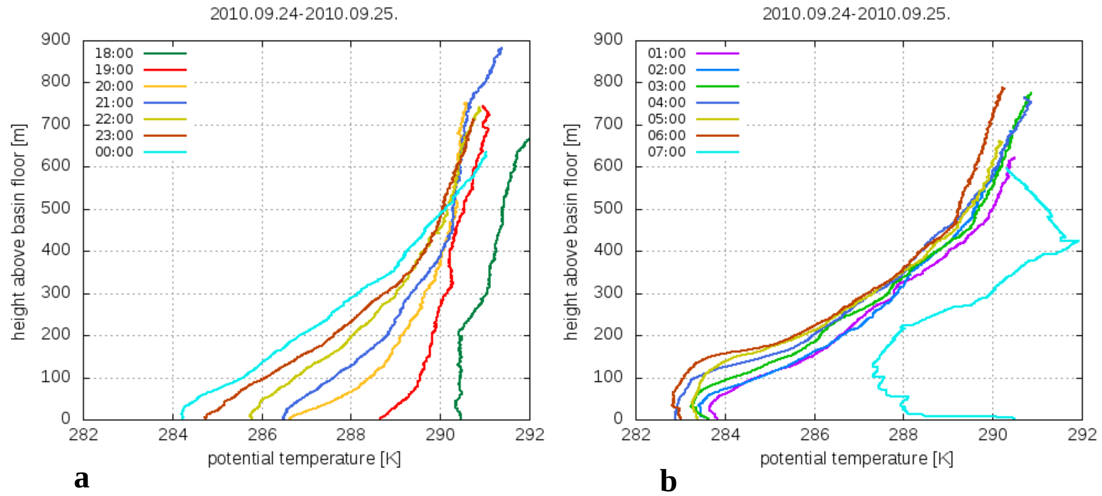

Figure 6. Change of potential temperature profiles. a) without fog evidence b) with fog evidence

4. Conclusion

In this research we studied about nocturnal inversions in basin, rural area, where strong nocturnal inversions was expected. We found that the stronger temperature inversions are present during early summer (June). The weaker but frequent inversions can be found during fall season. We found that the weakness of nighttime temperature inversions is caused by presence of radiation fog layer which appears usually between midnight and early morning. The fog layer appears in lower layer as the humid air is cooled during temperature inversion and become saturated. Thus, the fog is concomitant phenomena of nighttime inversion and acts as a feedback to inversion formation, and negatively affects the inversion strength and inversion time length. However strong temperature difference at different altitude can be caused by fog during later mornings when the slopes are insolated by sun beams while the basin floor is isolated mainly by scattered sunlight. For better understanding of nighttime inversions in Haean Basin, a more detailed research of fog layer is desirable.

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