

PASSIVE AND FAN-ASPIRATED RADIATION SHIELDS IN HIGH-ELEVATION OPEN AND CLOSED-FORESTED ENVIRONMENTS: A COMPARATIVE STUDY

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**ABSTRACT:** This study investigates the differences between a passive radiation shield in a relatively closed-forest setting (Timberline Campus Weather Station), and a fan-aspirated radiation shield in an open-forested setting (Leadville Airport Weather Station). Both weather stations are located at approximately 10,000 feet (3048 meters) above sea level, between the Sawatch and Mosquito Mountain Ranges in central Colorado and are subject to similar microscale weather, given the proximity and similar topographic setting. Daily maximum temperature differences between the two stations averaged a 3° Fahrenheit (1.67°C); however, daily minimum temperatures were nearly identical.

**KEYWORDS:** temperature differentiation, forest edge, radiation shield, wind run

## 1. INTRODUCTION

In November 2014, the Timberline Campus of Colorado Mountain College (CMC) in Leadville, Colorado, installed a research-grade weather station for inclusion in the academic instruction of students and collection of long-term, high-elevation climate data. The Timberline Campus is situated in a high-mountain valley, above 10,000 feet (3048 meters) above mean sea level (AMSL).

The CMC Timberline Campus Station (TCS) is located in an approximate 0.5-acre (0.2 hectare) forest clearing at 10,032 ft. (3058 meters) AMSL, surrounded by continuous lodgepole pine forest. Instrumentation for the campus station is located in the center of the forest clearing on a 32.8-foot (10-meter) aluminum tower. Temperature readings are measured from a passive radiation shield, mounted six feet (1.83 meters) above the ground. Whereas, wind measurements are recorded from the 32.8-foot (10-meter) tower apex.

Prior to the TCS, the National Weather Service Automated Surface Observing System (ASOS) Station at the Leadville Airport was the closest automated weather station available to the public from the Timberline Campus (Fig. 1). The Leadville Airport ASOS Station (LAAS) is located 4085 feet (1245 meters) to the west-southwest of



Fig. 1: Map of weather station locations showing local topography.

of the TCS. Both stations are positioned on a ridge above multiple cold air drainages. Though the topographic surroundings are similar

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between the two stations, the environmental surroundings of each station are different (Fig. 2).

edge. Wind directions with the closest forest edge would be those from the northeast (105 feet; 32 meters) through southeast (138 feet; 42 meters).

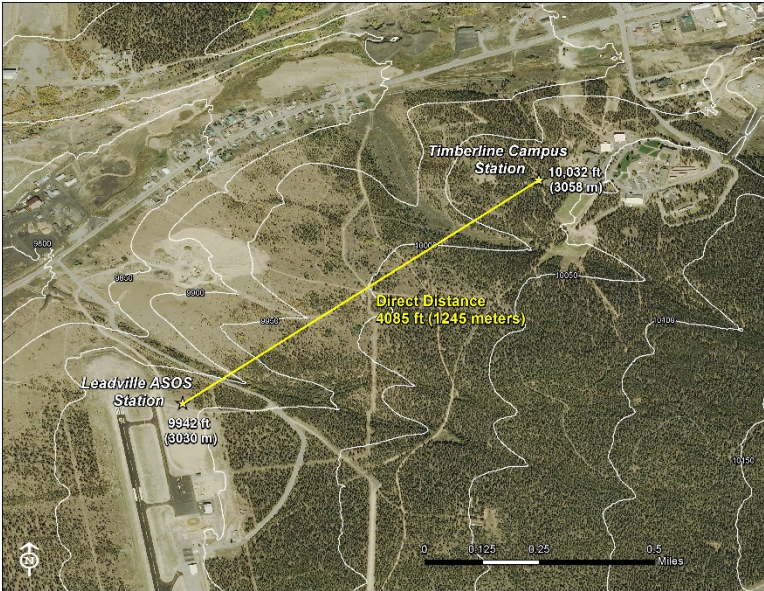


Fig. 2: Separation distance and elevation of weather stations.

The LAAS is located on the edge of a forest clearing, at 9942 feet (3030 meters) AMSL, with a greater exposure to predominant north (WRCC 2002) and northwesterly winds (Fig.3). On the north side of the weather station is a sparse stand of lodgepole pine, whereas there is no definitive forest edge following along a northwest transect.

Instrumentation location on the LAAS is identical to that of the TCS. The LAAS anemometer is also mounted at a height of 32.8 feet (10 meters) and the temperature/humidity sensors are mounted at 6 feet (1.83 meters) above the ground. Unlike the TCS radiation shield, the radiation shield on the LAAS is fan-aspirated which allows the constant movement of ambient air to pass across the temperature and humidity probes regardless of wind speed.

Forest edge distances are far reduced at the TCS compared to the values of the LAAS (Fig. 4). Nevertheless distances to forest edges at the TCS are rather uniform, with a range of 53-120 feet (16-37 meters).

Several trees on the forest edge are only minimally shorter than the height of the aluminum tower at 32.8 feet (10 meters). The result is a greater coefficient of friction for wind measurements at the TCS. However, the temperature readings are taken at a height of six feet (1.83 meters), where the winds are greatly reduced from those measured on the anemometer at 32.8 feet (10 meters).



Fig. 3: Distances between Leadville ASOS Station and forest edge.

Southwest winds are also well represented with a distance of 1345 feet (410 meters) to the forest

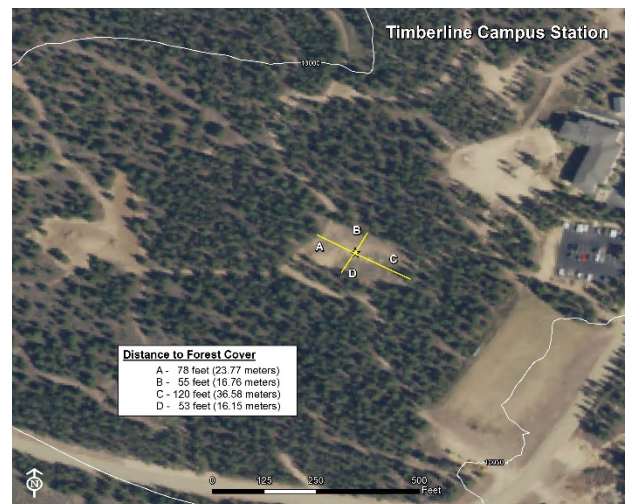


Fig. 4: Distances between Timberline Campus Station and forest edge.

The wind-dissipating effect of the relatively close forest edge reveals artificial warming under certain

atmospheric conditions with the passive radiation shield.

## 2. METHODS

The TCS data for analysis was collected from the weather station datalogger and was continually written to a computer server. This study investigates the collected 24-hour data tables for 513 consecutive days, spanning 12 December 2014 through 9 April 2016. For comparison, the data for the identical time period has been ascertained from the National Weather Service for the LAAS (NCEI 2016). Meteorological variables used for comparison were: wind speed, ambient air temperature, liquid precipitation from all-weather precipitation gauges, and relative humidity.

The gathered data were input and analyzed in spreadsheet software for calculations between the two weather stations. Due to the integer rounding in maximum and minimum temperatures recorded by the National Weather Service ASOS station (LAAS), the recorded temperature values from the TCS have been rounded to the nearest integer for standardization.

## 3. RESULTS

Wind data revealed from the TCS show reduced wind values as compared to the LAAS wind data. Nevertheless, there is a correlation in average wind speed between the TCS and the LAAS ( $r=0.86$ ). Though the average wind speed at TCS over the investigated timeframe was 2.73 miles per hour (1.22 meters per second) as compared to 7.29 miles per hour (3.26 meters per second) at the LAAS. The maximum temperature differential had no correlation to wind run ( $r=-.02$ ), or daily distance of wind passing the station. The average wind run for the zero-degree differential days was 12.07 miles (19.42 kilometers); whereas, with the  $\geq 3^\circ\text{F}$  ( $1.67^\circ\text{C}$ ),  $\geq 4^\circ$  ( $2.2^\circ\text{C}$ ), and  $\geq 5^\circ$  ( $2.78^\circ\text{C}$ ) differential occurrences averaged 12.73 mi (20.49 km), 13.04 mi (20.99 km), and 12.27 mi (19.75 km), respectively (Tbl. 1). This finding reaffirms the recommendation of proper spacing between the instrument tower and trees or buildings; a distance recommended to be ten times the height of the tower (EPA 1987).

In comparison, the temperature data between the two stations also has distinct patterns. The TCS averages  $3^\circ$  Fahrenheit

( $1.67^\circ\text{Celsius}$ ) warmer for a daily maximum temperature as compared to the LAAS. Whereas the daily minimum temperature differential indicates a zero-degree differential between the TCS and the LAAS.

Further analyzing the patterns of daily maximum temperatures differentials between the two weather stations show there were 35 occurrences (6.8% of the total 513 days) with a zero-degree differential, 251 occurrences (48.9%) where the daily maximum temperatures were  $\geq 3^\circ\text{F}$  ( $1.67^\circ\text{C}$ ), 148 occurrences (28.8%) of  $\geq 4^\circ$  ( $2.2^\circ\text{C}$ ), and 76 occurrences (14.8%) of  $\geq 5^\circ$  ( $2.78^\circ\text{C}$ ) (Tbl. 1).

Precipitation patterns between the two stations show the strongest correlation ( $r=0.95$ ) when evaluating the daily precipitation values. Though the stations are 4085 feet (1245 meters) apart, precipitation appears to be rather uniform. Additionally, the total precipitation during the 513-day period recorded 20.41 inches (518.41 millimeters) at the TCS and 20.23 inches (513.84 millimeters) at the LAAS.

Relative humidity (RH) also appears to have a role in the relationship of the maximum temperature differential. When evaluating the average of the minimum and average RH values at the TCS during the days which had zero-degree differential as compared to the LAAS, both had greater values as compared to those of each of the  $\geq 3^\circ\text{F}$  ( $1.67^\circ\text{C}$ ),  $\geq 4^\circ$  ( $2.2^\circ\text{C}$ ), and  $\geq 5^\circ$  ( $2.78^\circ\text{C}$ ) occurrences. The average minimum RH for the zero-degree differential days was 30.82%; whereas, with the  $\geq 3^\circ\text{F}$  ( $1.67^\circ\text{C}$ ),  $\geq 4^\circ$  ( $2.2^\circ\text{C}$ ), and  $\geq 5^\circ$  ( $2.78^\circ\text{C}$ ) occurrences averaged 23.84%, 22.81%, and 23.63%, respectively (Tbl. 1). Likewise, the daily average RH for the zero-degree differential days was 65.06%; however, with the  $\geq 3^\circ\text{F}$  ( $1.67^\circ\text{C}$ ),  $\geq 4^\circ$  ( $2.2^\circ\text{C}$ ), and  $\geq 5^\circ$  ( $2.78^\circ\text{C}$ ) occurrences averaged 56.34%, 55.58%, and 57.80%, respectively (Tbl. 1). Though there appears to be a weak relationship between temperature differential and RH, the relationship between temperature differential and

Table 1. Summary of Data for TCS.

Max. Temp. Differential	Avg. Wind Run (mi/km)	Frequency of Occurrence	Avg. Min. RH	Avg. RH	Avg. Precip. (in/mm)
Total Record	12.95/20.84	513 (100%)	24.91%	57.52%	0.04/1.02
0° Differential	12.07/19.42	35 (6.8%)	30.82%	65.06%	0.06/1.52
$\geq 3.0^\circ\text{F}/1.67^\circ\text{C}$	12.73/20.49	251 (48.8%)	23.84%	56.34%	0.04/1.02
$\geq 4.0^\circ\text{F}/2.2^\circ\text{C}$	13.04/20.99	148 (28.9%)	22.81%	55.58%	0.04/1.02
$\geq 5.0^\circ\text{F}/2.78^\circ\text{C}$	12.27/19.75	76 (18.8%)	23.63%	57.80%	0.05/1.27

daily precipitation shows no correlation ( $r=-0.05$ ). Average precipitation on days with zero-degree differential was 0.06 in (1.52 mm) and the  $\geq 3^{\circ}\text{F}$  ( $1.67^{\circ}\text{C}$ ),  $\geq 4^{\circ}$  ( $2.2^{\circ}\text{C}$ ), and  $\geq 5^{\circ}$  ( $2.78^{\circ}\text{C}$ ) occurrences averaged 0.04 in (1.02 mm), 0.04 in (1.02 mm), and 0.05 in (1.27 mm), respectively.

#### 4. CONCLUSION

The daily maximum temperature differential of  $3^{\circ}\text{F}$  ( $1.67^{\circ}\text{C}$ ) and the zero-degree minimum differential, illustrate a strong likelihood the effects of incoming solar radiation during the daytime hours are creating artificially higher recorded temperatures. However, during the nighttime hours when there is no artificial warming of the passive radiation shield temperatures appear to be nearly identical at the two stations. Though the relationship between wind and maximum temperature differential appear to be minimally impacted, the installation of an anemometer adjacent to the passive radiation shield may reveal more conclusive data.

Inferences from the data warrant future research comparing and contrasting passive and fan-aspirated radiation shield need to address several factors. First, the TCS needs to incorporate a fan-aspirated radiation shield with an identical temperature and humidity probe mounted at the same height as the current passive radiation shield. Secondly, an additional anemometer should be installed to quantify the wind speeds at the six-foot (1.83-meter) height of the temperature and humidity measurements. Thirdly, the impacts of the closed-forest environment of the TCS should be further investigated, though it should be noted that clear-cutting a 656-foot (200-meter) diameter patch in the current lodgepole pine stand to satisfy the EPA proper siting recommendation is not realistic or feasible. Lastly, an examination of the thermal effects, e.g. thermal inertia, of the concrete in the vicinity of the LAAS is worth mentioning and could warrant a more in-depth study as compared to the natural forest floor surrounding the TCS.

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