College of Earth, Ocean, and Atmospheric Sciences (CEOAS)

ON THE SEASONALITY OF COLD AIR POOLING DYNAMICS ACROSS SCALES

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Lookingbill, T., and Urban, D., 2004

ABSTRACT

The dynamics of the cold air pooling phenomenon was investigated at local and regional scales at the HJA Experimental Forest in Central Oregon during winter and summer of 2014. Two different experimental methods were used to assess the stability of the boundary layers at both local and regional scales. At the local scale (Primet and Vanmet), the main contributing variables to the stability of the boundary layer were incoming shortwave radiation and the mean wind speed whereas at the regional scale (the HJA Forest), the hourly lapse rate was the main contributing variable to the stability of the boundary layer. The result show that the incoming shortwave radiation, mean wind speed, relative humidity, and vapor pressure deficit (VPD) follow a diurnal pattern during July 15, 20, and 25 whereas they follow a non-diurnal pattern during December 15, 20, and 25 in 2014. It is concluded that the main reason for observing this behavior during the mentioned days in December is the effect of synoptic forcing on the local weather condition.

INTRODUCTION

The dynamics of cold air pooling refers to the cycle of formation and dissipation of stable cold air which forms in valley depressions due to radiative cooling of the ground. The physical mechanisms responsible for describing the phenomenon across scales are hypothesized to be radiative cooling, along-valley and cross-valley flows, and stability of the boundary layer. Since the mechanisms are affected by topography and seasonality (Daley, 2010), therefore the dynamics of cold air pooling should be different at different topographic settings throughout a year. According to Daley *et al*.,(2010), the effect of topography becomes less important than the effect of synoptic forcing (cyclonic condition) in the formation of cold air pooling during winter while the effect reverses during the summer when the Anticyclonic condition exists. Radiative cooling is a mechanism by which a surface loses heat by emitting long wave radiation to the sky. The underlying physical law is described by Stephan-Boltzman equation. Along-valley winds are categorized as topographically induced winds which blow parallel to the valley axis from higher to lower elevations as mountain winds (drainage flow) during calm nights and from lower to higher elevations as valley winds during daytime (AMS). Cross-valley winds blow perpendicular to the valley axis from the less heated sidewall towards the more heated sidewall. This wind is categorized as a thermally driven flow (anabatic or katabatic) (AMS). Stability refers to the characteristics of a system if a small disturbance occurs, the system reacts either by decreasing the intensity of the disturbance or by oscillating periodically (AMS). The objective of this study was studying the dynamics of cold air pooling at local (Primet and Vanmet) versus regional scales (the HJA forest) during different seasons.

Study site: Established in 1948, the Andrews Forest is an experimental site in Oregon's western Cascades Mountains. It is part of a long-term ecological research (LTER) network supported by NSF. It is a 6475 hectare- site with complex topography including V-shaped and U-shaped valleys, alluvial fans, fluvial terraces, hillslopes, and vegetated floodplains. The Primet and Vanmet are two meteorological stations which are located at 450 meters and 1250 meters above sea level respectively. The first is located on a fluvial terrace whereas the latter is close to a ridge. *Data:* The hourly mean temperature, wind speed, wind direction, incoming shortwave radiation, vapor pressure deficit, and relative humidity for Primet and Vanmet were acquired for three days (15, 20, 25) in July and December 2014.

METHODS

*Experimentation_* Primet and Vanmet (local scale): A value of 300 Wm^-2 for the incoming shortwave radiation in July 2014 was used as a threshold for determining the stability of the boundary layer. Any value less than 300 Wm^-2 contributes to the stability of the boundary layer whereas values equal or greater than 300 Wm^-2 contributes to the instability of the boundary layer. A value of 0.37 m/s was determined as a threshold for the mean wind speed too. These values were determined based on trial and errors and also comparing them with other values including hourly mean temperatures and saturation vapor pressure from 8:00 am to 4:00 pm on July 15,20, and 25, 2014. For December 2014, the threshold values of 1Wm^-2 and 1 m/s were determined for the hourly mean incoming shortwave radiation wind speed from 8:00 am to 4:00 pm respectively.

HJA Forest (regional scale): The underlying assumption here is that the weather data from Primet and Vanmet could be used as representatives of the whole HJA Forest weather condition. To assess the stability of the boundary layer at the scale of the HJA Forest, the hourly environmental lapse rates were calculated based on the hourly deficit of mean temperatures between Vanmet and Primet. Positive values mean temperature increases with altitude, therefor the boundary layer is stable and inversion has occurred whereas negative values mean temperature decreases with altitude, therefore the boundary layer is instable or mixed. The stability of the boundary layer was assessed on an hourly basis for 15,20, and 25 of July and December 2014.

RESULTS

July pattern_ Primet: According to figure 1 the mean wind speed and mean incoming shortwave radiation follow relatively same diel pattern on July 15,20, and 25, 2014. The figure shows that the hourly relative humidity and mean wind speed have opposite diurnal pattern. *July pattern_ Vanmet:* According to figure 2, the hourly mean wind speed shows a multimodal pattern for all three days with highest variability on July 15th. The minimum and maximum values occur at 7:00 am and 10:00 am on July25th and 20th respectively. The hourly mean shortwave radiation shows multimodal pattern on July 20th as well. *December pattern_ Primet:* According to figure 3 the maximum value of the hourly mean shortwave radiation occurs at 1:00pm on December 15, 2014. In terms of hourly mean wind speed, the minimum and maximum values occur at 11:00pm and 8:00pm on December 15 and 20 respectively. The figure shows that the maximum value of the VPD occurs at 1:00pm on December 25 while the minimum value occurs during the most part of the three days. *December pattern_ Vanmet:* According to figure 4 the maximum value of the hourly mean shortwave radiation occurs at 12:00 pm on December 15. In addition, the minimum and maximum values of hourly mean wind speed occur between 3:00am to 12:00pm on December 25 and December 20 respectively. The maximum value of VPD occurs at 2:00pm on December 15 whereas the minimum value occurs on the entire December 20 and 25. *July pattern_ HJA Forest:* According to figure 5, the minimum and maximum values of the hourly deficits of the mean incoming shortwave radiation between Vanmet and Primet are -202.5 Wm^-2 and 358 Wm^-2 which occur on the 25th at 8:00am and 5:00pm respectively. In terms of lapse rate, the minimum and maximum values are -7.7 degrees C/km and 5.3 degrees C/km which occur on 20th at 11:00am and 15th at 9:00am respectively. *December pattern_ HJA Forest:* According to figure 6, the minimum and maximum values of the hourly deficits of the mean incoming shortwave radiation between Vanmet and Primet are -152.98 Wm^-2 and 31.51 Wm^-2 which occur at 1:00pm on 25th and 1:00pm on 15th. In terms of lapse rate, the minimum and maximum values are -6.6 degrees C/km and -0.4 degrees C/km which occur at 5:00 pm and 6:00 pm on 25th and 20th respectively.

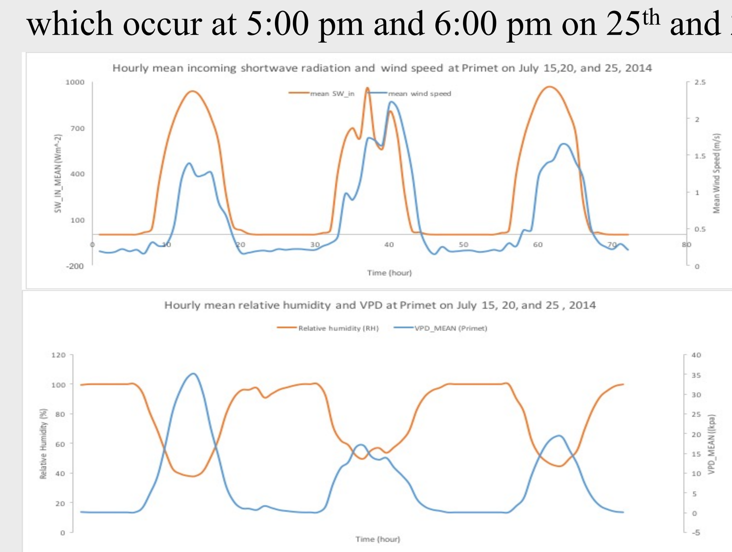

Figure 1_Primet JULY

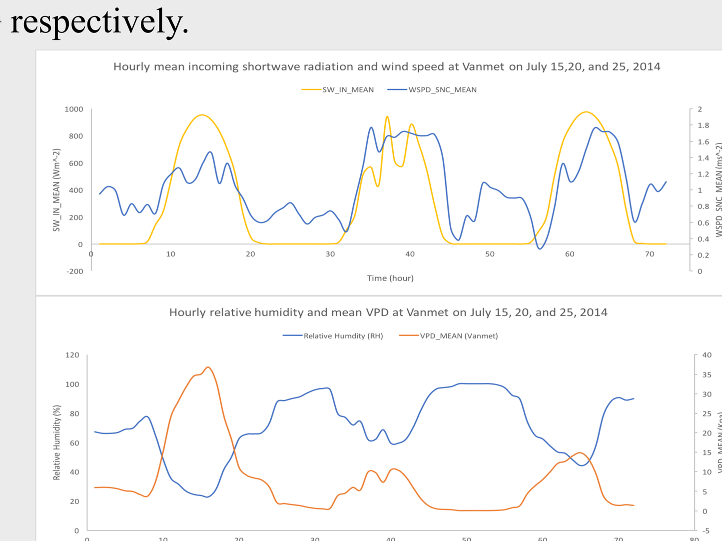

Figure 2_Vanmet JULY

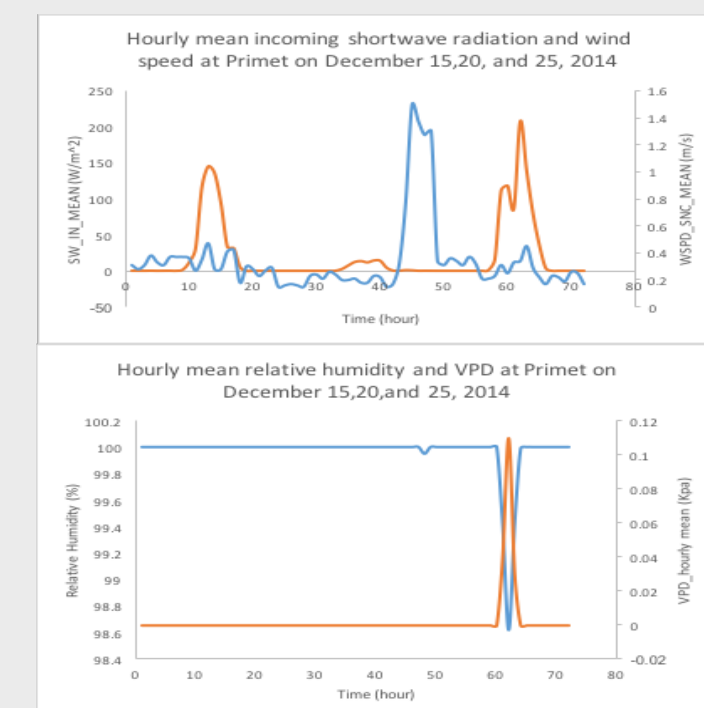

Figure3_Primet DECEMBER

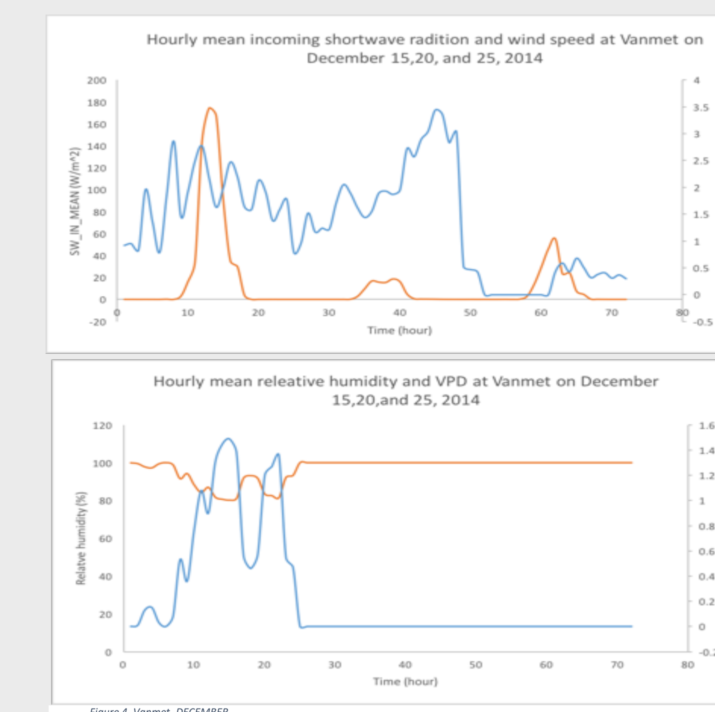

Figure 4_Vanmet DECEMBER

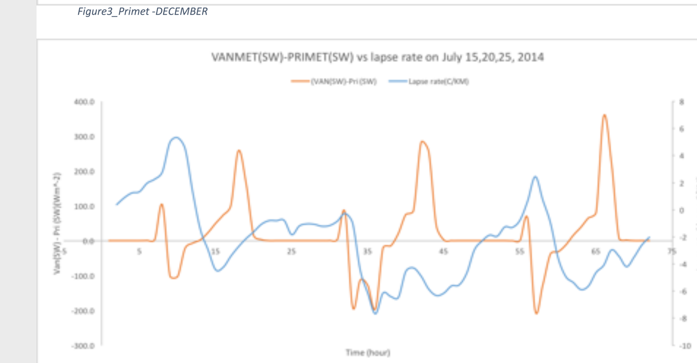

Figure 5_HJA_JULY

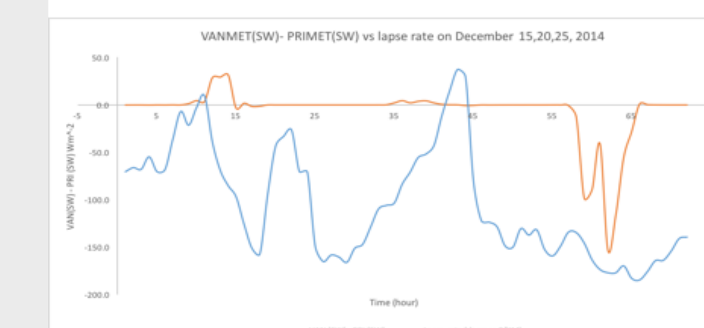

Figure 6_HJA_DECEMBER

DISCUSSION

As Dobrowski *et al.* (2009) has mentioned the physiographic factors are the most important ones in the formation of cold air pools in stable condition while in instable condition, lapse rate is more important. This finding is consistent with Pepin *et al.*, (2011) findings regarding the influence of synoptic condition on decoupling and the resultant cold air pool formation. They claim that the synoptic weather pattern during winter has more influence on decoupling than physiography. The findings of this research is consistent with the findings from the aforementioned studies as well.

CONCLUSION

In summary, this study was motivated by an urge to understand how cold air pooling events form and dissipate across scales during different times of a year. One of the most important limitations of this study was lack of data availability. The use of suggested method is recommended on multiple years of data in future studies. In addition, studying the contribution of the cross-valley flows to the along-valley flow between Vanmet and Primet is highly recommended for the future studies.

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