ON THE SEASONALITY OF COLD AIR POOLING DYNAMICS ACROSS SCALES

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ABSTRACT

The dynamics of the cold air pool 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 layer at both local and regional scales. At the local scale (Primet and Vannet), 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 shows 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-Boltzmann 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 to study the dynamics of cold air pooling at local (Primet and Vannet) 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 Cascade 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 Vannet 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 Vannet were acquired for three days (15, 20, 25) in July and December 2014.

METHODS

Experimental Primet and Vannet (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. For December 2014, the threshold values of 1 Wm$^{-2}$ and 1 m/s were determined for the hourly mean incoming shortwave radiation wind speed from 8:00 am to 4:00 pm respectively.

RESULTS

July pattern: Primet: According to figure 1 the mean wind speed and mean incoming shortwave radiation follow relatively same daily 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: Vannet: 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 July 25th 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 1:00 pm on December 15th. In terms of hourly mean wind speed, the minimum and maximum values occur at 11:00 pm and 8:00 pm on December 15 and 20 respectively. The figure shows that the maximum value of the VPD occurs at 12:00 pm on December 20th while the maximum value occurs during the most part of the three days December pattern: Vannet: According to figure 4 the maximum value of the hourly mean shortwave radiation occurs at 12:00 pm on December 15th. In addition, the minimum and maximum values of hourly mean wind speed occur between 3:00 am and 12:00 pm on December 25 and December 20 respectively. The maximum value of VPD occurs at 2:00 pm 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 mean shortwave radiation between Vannet and Primet are 0.025 Wm$^{-2}$ and 0.058 Wm$^{-2}$ which occur on the 25th at 8:00 am and 5:00 pm 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 11:00 am and 15th at 9:00 am respectively. December pattern: HJA Forest: According to figure 6, the minimum and maximum values of the hourly mean shortwave radiation between Vannet and Primet are -0.588 Wm$^{-2}$ and 31.5 Wm$^{-2}$ which occur at 1:00 pm on 25th and 10:00 pm 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.

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 unstable 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 disperse 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 Vannet and Primet is highly recommended for the future studies.

REFERENCES


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