Utah Winter Inversion Optical Air Quality Study

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Introduction & Background

Atmospheric pollution is one of the greatest obstacles humans face today. Atmospheric scientists have a variety of ways to measure air pollution, most of which being expensive, and often unavailable to the general public. This study attempts to measure air pollution by analyzing the luminance of images during a winter inversion in the Ogden area taken from two camera systems. One is a flight camera system looking at images with altitudes cycling between ground and 500 feet above ground, while the other is a stationary all-sky camera.

Procedure

The proposed method in this study involves the optical resolution of images. We have analyzed the change in luminance over a high contrast line. The steepness of this slope indicates the optical resolution of that line. A highly polluted atmosphere contains more particles, scattering light off air particulates, creating a shallow sloped line. In this study we focus on the analyses of these slopes using the following methods:

- Data were compared to other flight hardware making simultaneous measurements of altitude, time, and *in situ* air quality. A GT-526 particle counter was used as to provide the PM measurements from 0.3 to 10µm.

- Comparison of flight camera image resolution between a background target, the ground, and foreground target (an industrial building). All-sky camera selected objects were the atmosphere and a stationary target (in this case, a nearby building).

- NASA's Spotlight 16 software was used to obtain line profiles of pixel intensity to analyze the contrast across a sharp edge. The slope of this contrast was used as a proxy to try and determine a value for air quality.

- Slope is calculated for the respective line profile, and then normalized. The normalization accounts for images that may altogether be brighter or more dim by subtracting the low luminance value, then scaling the maximum luminance value to 1, shown in the following equation:

$$L_{\text{normalized}} = (L_{\text{pixel}} - L_{\text{Dim,Avg}})\left(\frac{1}{L_{\text{Bright,Avg}} - L_{\text{Dim,Avg}}}\right)$$

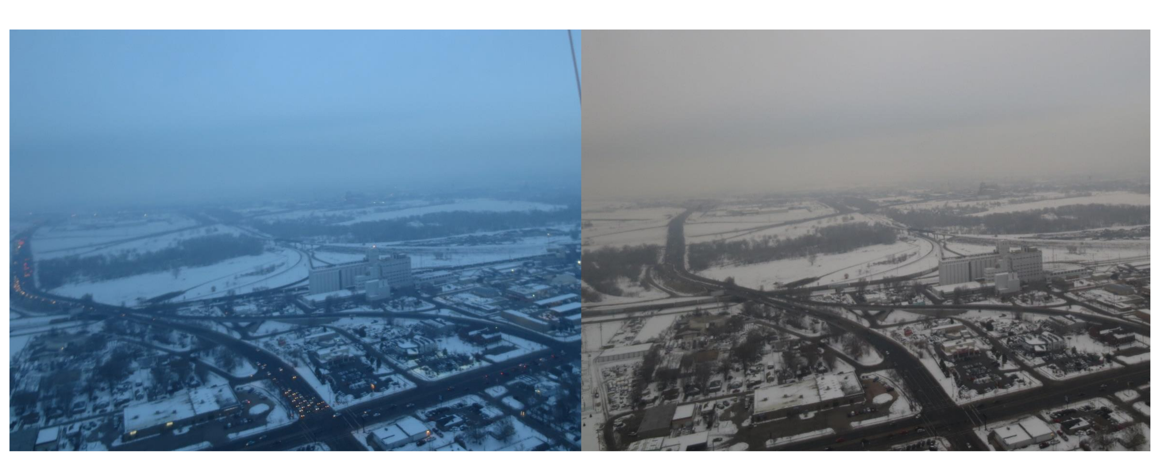

Figure 1. Very similar landscape showing the change in overall brightness and color of an image. Normalization accounts for images that may altogether be brighter or more dim.

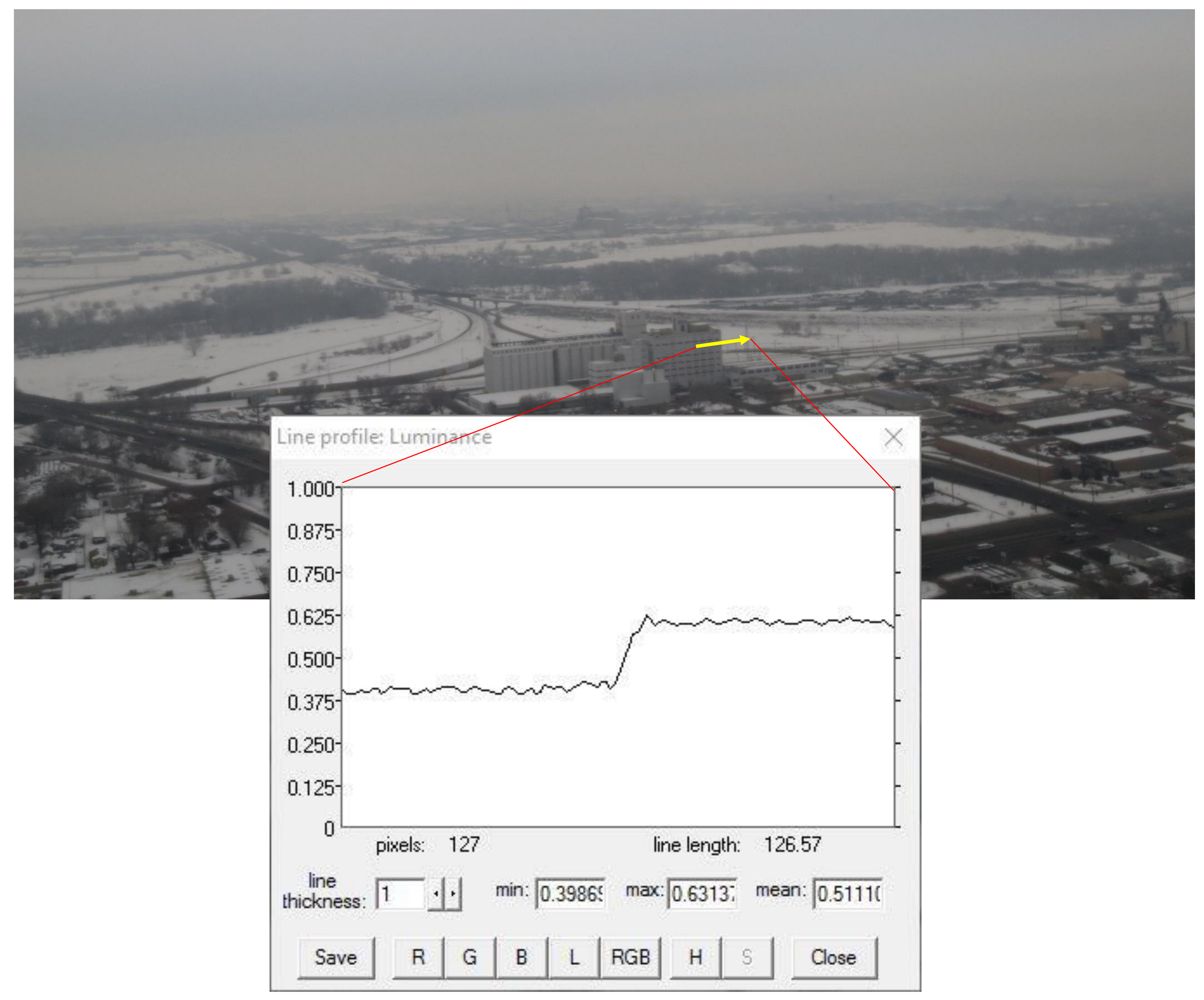

Figure 2. Snapshot of Spotlight 16 software taking a line profile of the indicated high contrast line. The image was taken on February 2, 2017 during a minor inversion.

- A general sense of the trend was determined by plotting each individual slope point as a function of altitude, and time. An inverse relationship is expected between air quality and luminance slope method.

Results and Conclusions

The flight imaging system yielded a limited set of usable data. Figure 3 shows the luminance slope values, plotted with the respective $PM_{0.3}$ data. The amount of fine particulate matter is higher at the ground, and decreases as we rise in altitude. With this reference, the luminance slope values should then start from a low value, and increase to represent the building edge becoming more crisp. This is not the trend that occurs. In fact it is difficult to make a cohesive conclusion for several reasons, the main being that we cannot get images with the proper parameters at low elevations.

The all sky camera produced mixed results. While some days did produce obvious trends in the evolution of luminance slopes, others produced rather weak fit lines. Using ground-based $PM_{2.5}$ data[1] to proxy air quality, slope values had very little consistent correlation with the trend of luminance slopes. Even for days tested that had expected trends, there was no mathematical correlation between the $PM_{2.5}$ slopes and luminance slopes as a function of time.

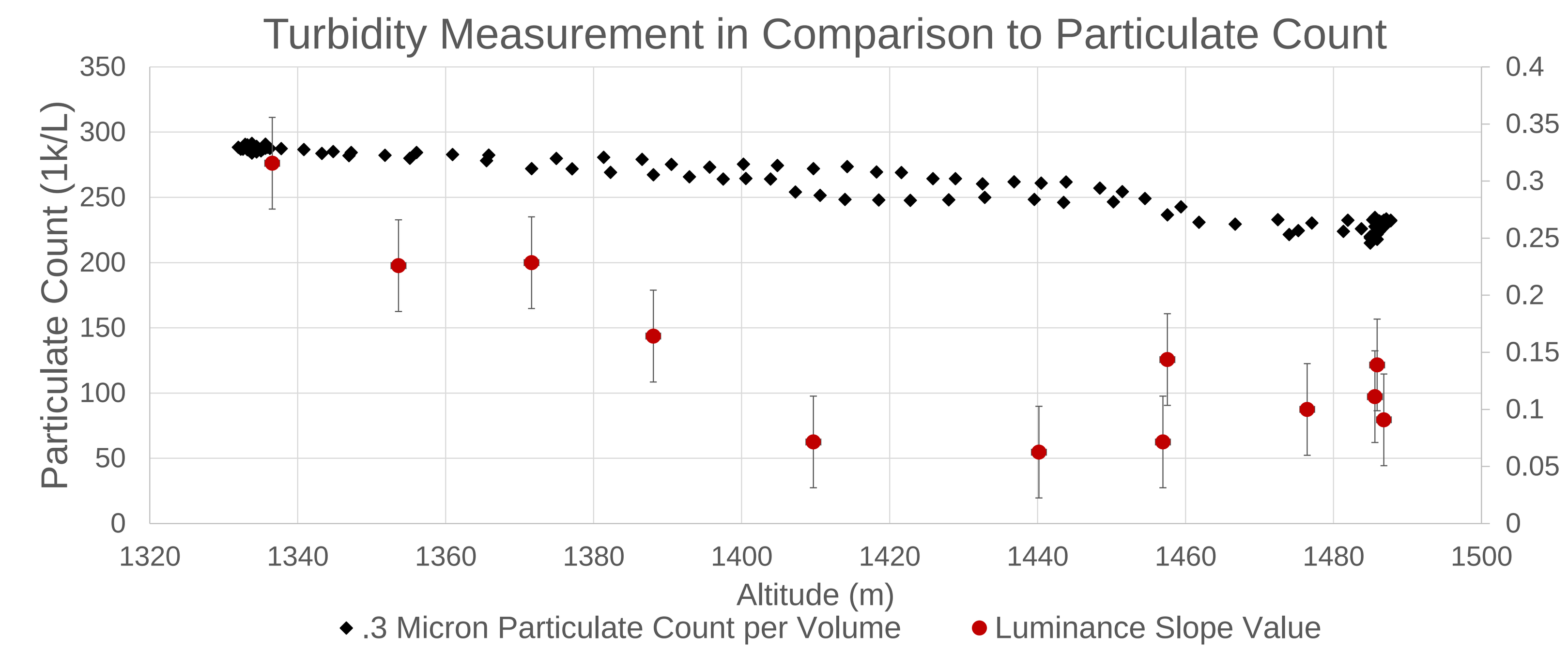

Figure 3. Flight camera resolution compared to $PM_{0.3\text{-}10}$ data taken by the GT-526 PM counter, we expected the opposite trend. Images were taken on 2/2/17 in Ogden, UT.

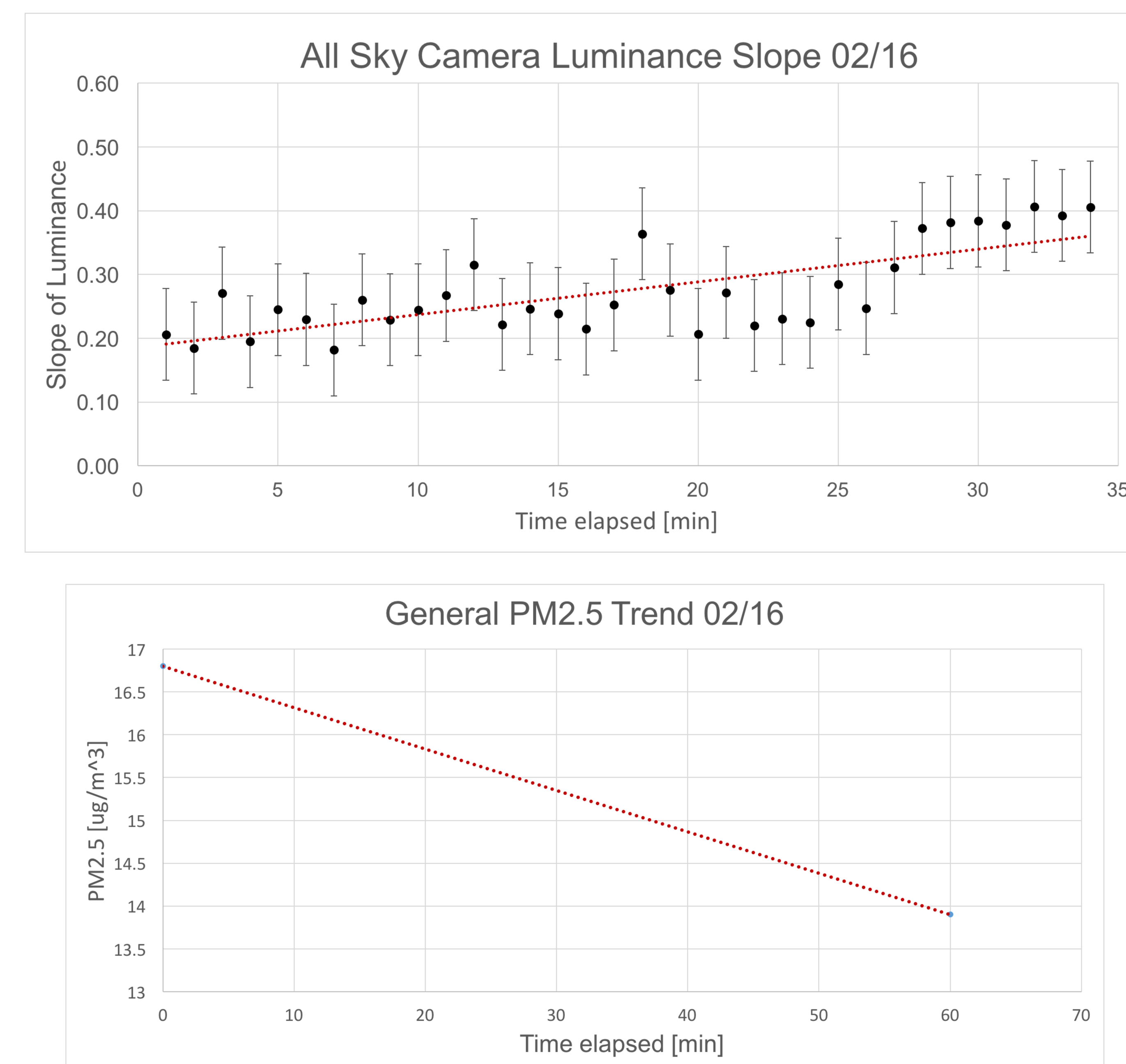

Figure 4. All sky camera picture analysis for afternoon during mild inversion. Comparison to 24-hour average $PM_{2.5}$ data[1] during the same time show an anticorrelation between luminance slope and amount of $PM_{2.5}$ as expected.

Overall, the luminance-differential method lacked a consistent correlation between luminance-slope trends and air quality which suggests more parameters need to be analyzed. Further work on this topic would also suggest a more technical approach. The use of RGB channels would help better correlate data, as studies[2] have shown that some colors are more correlated to air quality data than others. Another method could be using a ratio of contrasts between two selected targets, rather than one. This method also involves using the Lambert-Beer Law to determine the atmospheric transmission coefficient, τ: [3] [4]

$$C = C_0 e^{-\tau x} \quad .$$

Works Cited

1. Utah Division of Air Quality 2017
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3. "*Atmospheric Visibility and Angstrom Exponent Measurements Through Digital Photography*" Filipe Carritas *et al. Measurement* Volume 64, March 2015, Pages 147–156
4. "*Determination of Aerosol Concentration using an Internet Protocol Camera*" C.J. Wong *et al.* IEEE 2009