Ozone Source Partitioning and Data Analysis Between Valparaiso University, IN, and Pierce Cedar Creek Institute, MI

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Abstract

Five ozonesondes were launched at Pierce Cedar Creek Institute near Hastings, Michigan, during the summer of 2007. A launch was also conducted at Valparaiso University in Valparaiso, Indiana, before the PCCI launches, and another was conducted after. We combined these two Valparaiso profiles with profiles from Valparaiso acquired the year prior in a separate study. We wished to determine the difference between the Valparaiso average and the PCCI average. We wanted to prove that regional sources such as Gary, IN, and Chicago, IL, play at least a minor role in ozone levels at Valparaiso as it is much closer to these places than PCCI. We were expecting the remote location of PCCI to display a significantly lower level of ozone in at least the lower levels, if not throughout the entire vertical profile. However, what we found was that the overall profile displayed little variation, except for at a layer aloft where the PCCI mean profile was actually higher than the Valparaiso mean profile. This is most likely due to the fact that we sampled from the same air mass for most of the study, leading to an exaggeration of this higher level of ozone. It was determined that we cannot truly determine this to be a regional variation without further years of study to be compiled to the average.

I. Introduction

It has been shown that ozone precursors such as Hydrocarbons (HC), Volatile organic compounds (VOCs), and Nitrogen Oxides (NOx) have a detrimental effect on the air quality downwind of the given location. Because of these trends, it was our goal to observe the conditions in a ‘control’ setting, away from large cities and local larger sources of pollution. The purpose of this was to see what, if any, effect distant large cities have on a rural location. We also compared the profiles of our ‘control’ area of Pierce Cedar Creek Institute, MI (PCCI) to the average Valparaiso, IN, profile for late July and early August, paying particular attention to the lowest 5km. The reason for this distinction is that between the surface and 5km is where there should be more difference in the profiles due to the relatively short temporal scale of our study.

Five balloons were launched at PCCI in the period between July 24, 2007 and August 4, 2007 and two balloons in Valparaiso on July 22, 2007 and August 7, 2007. On August 1, 2007, while at PCCI, we performed an intensive launch, launching once at 12Z and again at 18Z. This was to observe the diurnal cycle of ozone and determine the residual and the produced and advected levels of ozone over the region.

The reason that we launched at Pierce Cedar Creek in late July and early August is due to ozone’s reliance upon sun light. Since the more incident light upon the ozone precursors yields more ozone, performing this study in the late summer will yield the highest possible ozone levels, creating the most dynamic profiles.

The motivation to launch at PCCI over other locations was based on the fact that it is a remote location. We wished to treat this location as a control mechanism in regards to local producers of pollution such as Chicago, IL, and Gary, IN, are for Valparaiso, IN.

II. Procedure

Data collection was carried out by launching a 350g weather balloon with our instrument and various safety items attached beneath it. On the balloon train was our ozonesonde in its protective case, a payout reel and a parachute.

The ozonesonde is the most crucial component of our equipment. Via an intake tube, it pumps in ambient air as it ascends through the atmosphere and pumps it into a chemical cell. In this cathode cell is a 0.5% of Potassium Iodide (KI) solution with a wire leading to an anode cell of saturated KI solution. The imported ozone will react in the cathode cell leading to an induced current between the cathode and anode cells. This current is then recorded and sent back to our listening station on the ground via a Viasala-88D radiosonde attached to the side of its packaging. The packaging is Styrofoam which serves two purposes; the first serves to insulate the electronics from the possible -70˚C ambient temperature, keeping them around 25˚C, and the second is to protect the instrument from the potential 30mph fall (if the parachute fails) when it lands.

The other sections of the balloon train include the pay-out reel, the parachute, and the balloon itself. The pay out reel is a metal spool of string that distances the ozonesonde packaging from the parachute, ensuring that the package doesn’t entangle the parachute, guaranteeing that the parachute opens. The balloon is a standard 350g weather balloon which rises to a height of 80,000feet ± 5,000feet when filled with a final weigh-off of 2100g ± 1,000g.

III. Data Analysis

Upon analysis of the total overall averages, (Fig. 1) we see that the two averages are not remarkably different, being 85.9% correlated. However, there are minor variations present between the data sets, prominently seen between 9km and 16km. This is most likely due to minor variations in the prevailing meteorological variables present during the respective launches. The PCCI launches were conducted during the same week, increasing the ozone levels’ temporal dependence upon each other. The Valparaiso profiles, however, were a collection of the July 22nd, August 7th, and the profiles from 2006 conducted during the same late-July and early-August time frame.

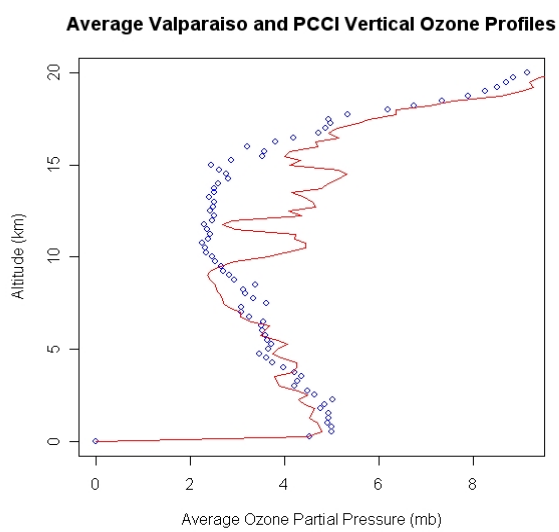

Fig. 1: Comparison of mean vertical ozone profiles. Valparaiso data is the blue, dotted data points and the PCCI data is the red line.

The layer of 9km to 16km was of interest, as it was very statistically different. Being only 8.5% correlated, this region was remarkably different between Valparaiso and PCCI. This is most likely due to the fact that the PCCI average is highly dependent temporally, as we performed the four launches within five days of each other. This will skew the average, as we were sampling the same general air masses and meteorological conditions. It should be noted that to properly analyze this anomaly, we will need to acquire more years' data from both Valparaiso and PCCI to truly judge if this difference was simply a phenomenon found this year or if it is truly a regional difference mean difference.

We decided to focus upon the lowest 5km of the ozone profile in this study to maintain our focus on the residual levels of the surface ozone and the implications of regional sources – both of these can be seen best in the lowest 5km of the profile.

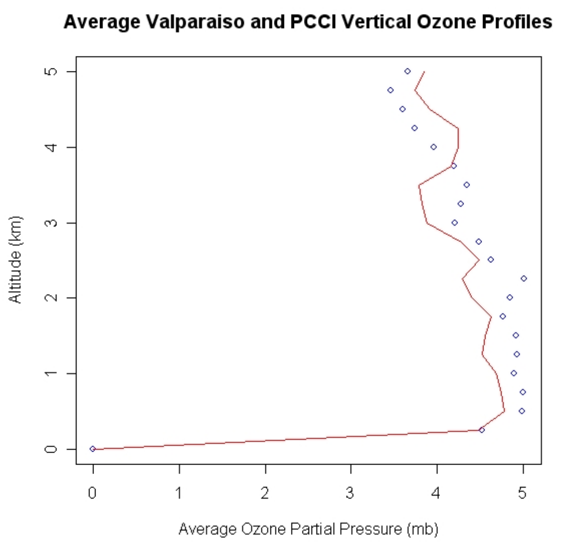

Fig. 2: Examination of the lowest 5km of both vertical profiles. Valparaiso data is the blue data points, PCCI data is the red line.

Looking at Figure 2, we can clearly see the variations in the lowest 5km. While being minor variations, we see that overall the PCCI average is slightly lower than the Valparaiso composite profile beneath 4km. This difference is marginal, with a mean difference of -0.14mb between the PCCI and the Valparaiso profiles (Figure 3). This minimal difference is indicative of no statistical difference between the 2007 PCCI high ozone season and the temporal mean of the 2006 and 2007 Valparaiso high ozone season in the lower levels.

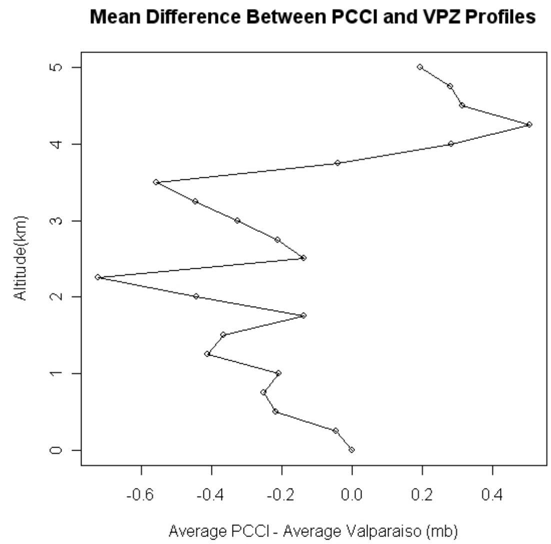

Fig. 3: Difference between the PCCI vertical profile and the Valparaiso vertical profile.

IV. Intensive Launch

Wednesday, August 1, was forecasted to have the conditions required for an unhealthy ozone day. As such, we launched twice on that day to help determine the residual levels of ozone over the southwest Michigan region of early August.

During the day, ozone levels slowly rise until it reaches its peak concentration around 3pm. However, as the sun sets, ozone levels near the surface slowly decrease as ozone is no longer being produced. Ozone is allowed to deposit itself onto plants, bodies of water, or even is allowed to be advected away by the wind during the night.

The morning surface level of ozone is expected to be very close to zero since it has all been deposited or advected away during the night hours. The above surface amounts of ozone in the lower 5km, however, are the residual amounts that can be found naturally in the region given the conditions over the region at the time.

The afternoon launch then indicates how much ozone has been either advected into the region, locally produced, or a combination of these two since the morning launch, showing how much influence regional factors have on that location given those meteorological conditions.

As observed in Figure 4, the meteorological conditions were conducive to high levels of surface ozone. The calm to light winds and abundant sunshine associated with the center of high pressure focused over eastern Michigan helped to build the unhealthy levels of ozone that were observed.

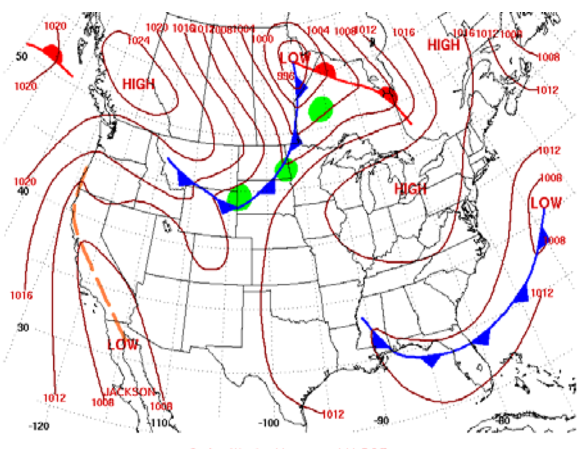

Fig. 4: The surface weather analysis of August 1, 2007.

During the week, this High was formed in south western Canada. It propagated west, then slowly made its way south into Minnesota and then southwest into Michigan. Ahead of this high pressure system was a moderate cold front which, due to its denser air, pushed the previous air mass away with its passing. Thus, on the day that we launched we were observing ozone levels that were due almost solely to local production, regional low-level transport, or some level of pollution transported with the air mass associated with the high pressure system. This is supported by analysis of Hysplit regressional models.

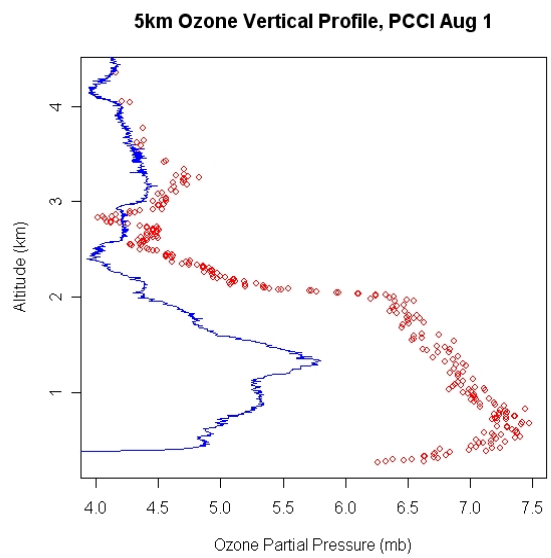

Fig. 5: The 5km comparison between the 12Z profile and the 18Z profile. The 12Z data is the blue solid line and the 18Z data is the red data points.

As seen in Fig. 5, there is a striking disparity between the morning (12Z) and afternoon (18Z) profiles between the surface and 5km. Above 5km, however, there is little difference between these profiles. This means that there is continuous advection from a polluted region and local production taking place.

The first feature seen in this comparison is the intense vertical gradient of the morning launch. This is to be expected as the surface ozone has been reduced throughout the night via deposition and advection. As such, the

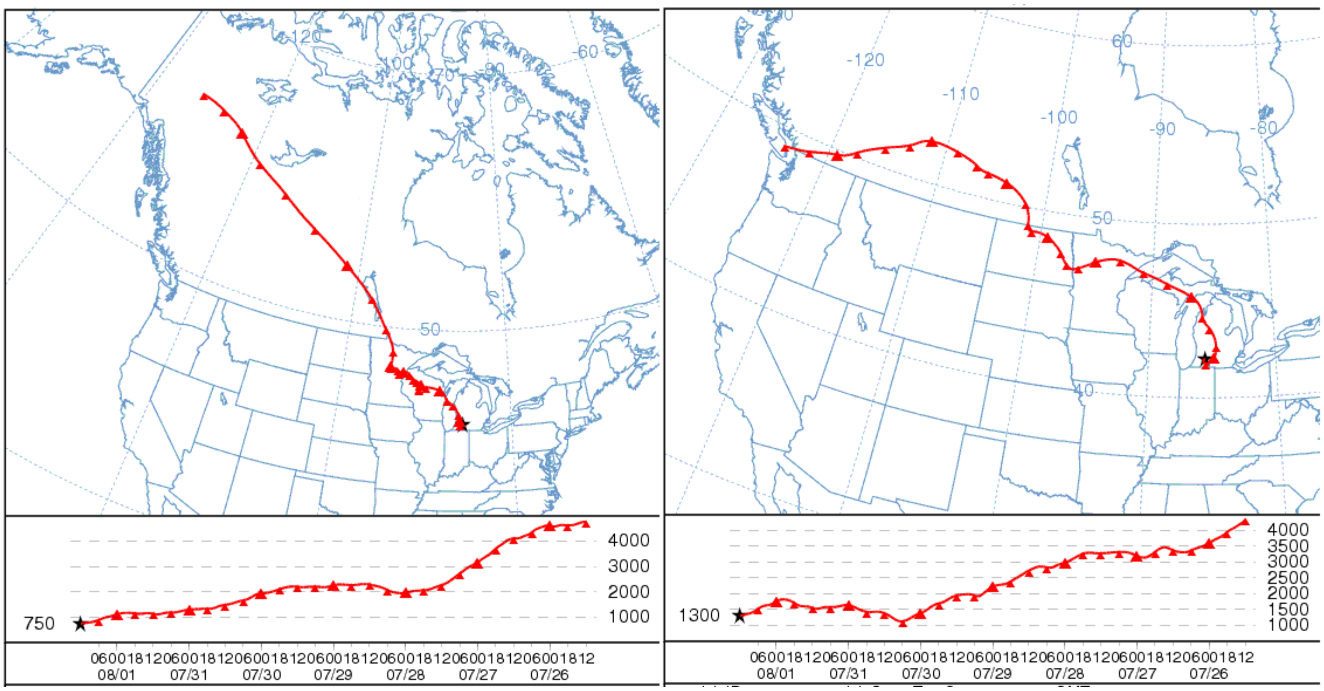

Fig. 6: : NOAA's Hysplit Air-Mass Regression model done at the two levels of interest – 750m on the right and 1300m on the left. These model outputs display a run time of one week prior to launch.

surface partial pressure was only 0.72mb – well beneath any level of significance, indicative that the diurnal cycle was functioning properly. However, as we approach 750m the ozone levels rise to just beneath 5mb of partial pressure. This is a modest level of ozone, reaching just beneath the upper bounds of a healthy level of ozone, usually thought to have an upper limit of 6mb.

There are two distinct protuberances seen in the lower 5km of the morning profile – the first seen at 0.75km and the second at 1.3km. As seen in Figure 6, these two air masses have slightly different origins. The 0.75km air mass, which has ozone levels around 5.25mb, followed the Canadian high pressure system down into Michigan. The 1.3km air mass, however, originates much further south, but is carried into the region through the High. These air masses follow similar trajectories, especially as they approach PCCI, but what especially differentiates these air masses from each other are the conditions of their origins.

The 750m air mass originates over central western Yukon, traveling southeast almost directly to Michigan. The question was presented as to what might induce the observed higher levels of ozone in this air mass, since it is traveling over relatively unpopulated regions that aren't overly industrial. Upon examination of July 2007 wildfire data from Canada, presented in Figure 7, we see that the path of the air parcel depicted from the regression model coincides well with the line of wildfires present at the same time. As was observed by Morris et. Al, 2006 (Journal of Geophysical Research), wildfire smoke is a strong precursor for ozone.

At the 1300m level, however, the cause for the increase in ozone is less certain. The parcel doesn't travel nearly north enough to be impacted by the Canadian wildfires, but it does pass directly over Lansing at 18Z the day prior. With a significant population of just under a half million people, this 1300m parcel is most likely transporting rush hour pollution into the PCCI region.

Fig. 7: Canadian wildfires that were in place on July 25th, 2007. Each red data point is a separate forest fire of at least 2500 square acres. Source: US National Climatic Data Center.

The afternoon profile, however, has only one main region of enhanced ozone located centrally at 1.25km. Upon Hysplit analysis (Fig. 8), these high levels are also suspected to be from the Canadian wildfires. The air parcel path is the same from 700m to 1.5km.

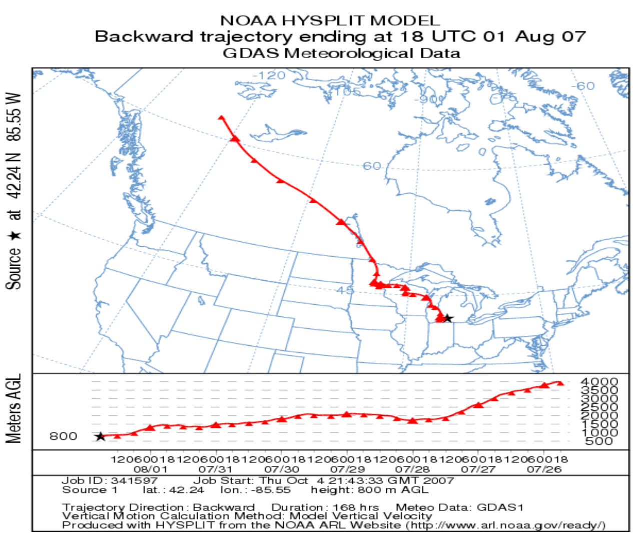

Fig. 8: NOAA's Hysplit Air-Mass Regression model performed at the base of the level of elevated ozone observed at the 18Z launch.

Above this level, the ozone amounts steadily depletes as the concentration returns to its residual amounts in the upper regions of this 5km layer and becomes similar to the morning profile.

V. Conclusions and Acknowledgements

We see that PCCI is locally similar to the Valparaiso profiles during late July and early August, but have some disparities between them. Further launches need to be conducted at PCCI to obtain a multi-year temporal average to see if the 9-16km variation is just indicative of the week of study or if it is truly a regional variation.

The intensive launch day revealed that it was actually long range transport associated with the high pressure system that moved into Michigan that impacted PCCI's low level ozone levels the most. This was not expected, as we did not take into account the possibility of widespread wildfires, or the advection of their smoke into the region. However, other factors also impacted the region, as pollution from Lansing also was advected over the region, leading to a region of elevated ozone in the morning profile.

Overall, this data indicates that regional sources play a minor role in vertical profiles of ozone. The largest variation in the low levels is due to long range transport from Canada. The upper level variation would most likely then be much smaller if we launched at Valparaiso at the same time as we did at PCCI. Again, if we performed more launches in the year to come we can asses this variation with more certainty.

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Reference:

Gary Morris, Scott Hersey, Anne M. Thompson, Steven Pawson, J. Eric Nielsen, Peter R. Colarco, W. Wallace McMillan, Andreas Stohl, Solene Turquety, Juying Warner, Bryan J. Johnson, Tom L. Kucsera, David E. Larko, Samuel J. Oltmans, Jacquelyn C. White; Alaskan and Canadian forest fires exacerbate ozone pollution over Houston, Texas, on 19 and 20 July 2004; Journal of Geophysical Research, Vol. III, 2006