Unmanned Aerial System Utilized to Characterize Low Altitude Ozone Measurements in a Northern Wisconsin Forest

RADTKE, JOSIE[1], B. KIES[1], P. CLEARY[1], W. MOTTISHAW[1], G. PETTY[2], M. VERMEUEL[3], T. BERTRAM[3]

[1]Department of Chemistry, University of Wisconsin-Eau Claire, 105 Garfield Avenue, Eau Claire, WI
[1]Department of Atmospheric Science, University of Wisconsin-Madison, Madison, WI
[1]Department of Chemistry, University of Wisconsin-Madison, Madison, WI

University of Wisconsin Eau Claire

INTRODUCTION

The CHEESEHEAD19 campaign studied measurements of ozone depositions that were taken at a very tall tower at two different heights (30 meters and 120 meters) and compared to measurements from an unmanned aerial system, UAS, equipped with meteorological sensors. Ozone is a pollutant formed in the atmosphere by photochemical processes involving nitrogen oxides and volatile organic compounds when exposed to sunlight. The ozone rich atmospheric layer is mixed with the ground level ozone formation to produce the gradients. The hexacopter UAS was flown with a portable ozone monitor (POM) and a meteorological temperature and humidity sensor, InterMet system (iMet). The hexacopter UAS was hovered at specific altitudes to determine ozone concentration gradients. The gradients observed will be discussed in context of the very tall tower ozone concentration measurements and other meteorological parameters. From this campaign, there has been better understanding of how the equipment performs to improve the quality of future campaigns.

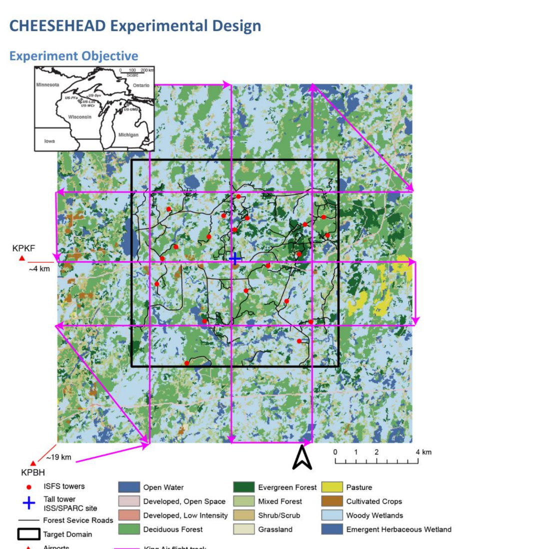

Figure 1 Landcover (National Land Cover Data 2011) map of the surrounding region, 10x10 km study domain (black box), WLEF very tall tower, ISS, SPARC instruments (blue cross), 20 tower locations (red dots), airports (red triangle), and proposed flight pattern for UW King Air (purple lines and arrows), based at KPBH. Flight pattern for the UW ultralight varies, but generally follows the edges of the target domain, flying in from KPKF.

CHEESEHEAD19

The CHEESEHEAD19 campaign was an intensive multi-platform field campaign that took place from May 2019 to October 2019. The University of Wisconsin-Eau Claire's team looked at the ozone gradients that were present in this forested area in July 2019.

UNMANNED AERIAL SYSTEM

The hexacopter UAS was flown by Dr. Patricia Cleary, a University of Wisconsin-Eau Claire Chemistry Professor, throughout the CHEESEHEAD19 campaign. Before the Cheesehead19 campaign, numerous test flights were needed to work out any kinks and to devise a feasible flight plan. A flight plan was formulated to maintain consistency in all documentation and flight practices.

Figure 2. Typhoon H with POM and iMET attached.

The hexacopter UAS was equipped with the POM for each flight at the very tall tower, while the iMet sensor was only used for the last day's flight. The hexacopter UAS was flown in different patterns at the heights of 30 meters and 120 meters. The hexacopter UAS allowed the team to collect ozone gradient measurements. The data collected from the flights was used to examine the ozone concentration trends each day. The goal of using the hexacopter UAS was for method validation for the gradient measurements compared to the tower measurements.

OZONE MEASUREMENTS

The POM data was compared to the ozone concentration measurements taken at the very tall tower. The ozone concentration measurements from the POM via the hexacopter UAS were very noisy. The typical relative standard deviation for the ozone concentration measurements were between 15-35% which is large compared to the relative standard deviation of 1-4% for each calibration.

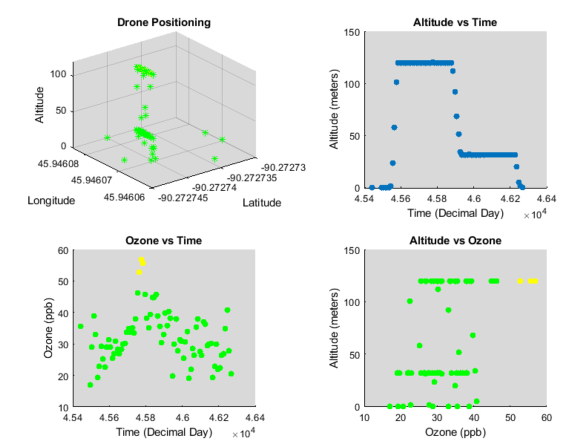

Figure 3. Matlab rendering of one of the flights with POM and drone data merged.

	ΔO_3 (ppb) 120m-30m	
	POM UAS	Tower
8-Jul	-5.9	1.2
11-Jul	11.9	8.9
12-Jul	16.1	9.1
16-Jul	-6.0	-5.7

Table 1. Ozone gradient, ΔO_3, calculated as measured O_3 at 122 m – O_3 at 30 m.

The POM measurements were not in agreement with the tower measurements which hinders the comparability of the POM and tower. **Table 1** shows the ozone concentration gradients collected from 3 of the 4 sampling times with the approximate overall magnitude of the ozone gradients.

METEOROLOGICAL MEASUREMENTS

The iMet-XF sensor measures temperature, humidity, and pressure along with records GPS data. The iMet sensor was flown on July 16, 2019 for all flights taken.

The data from the iMet sensor was used to recognize the saturated and dry adiabatic lapse rate for that day. The saturated and dry adiabatic lapse rate can be seen in **Figure 4**.

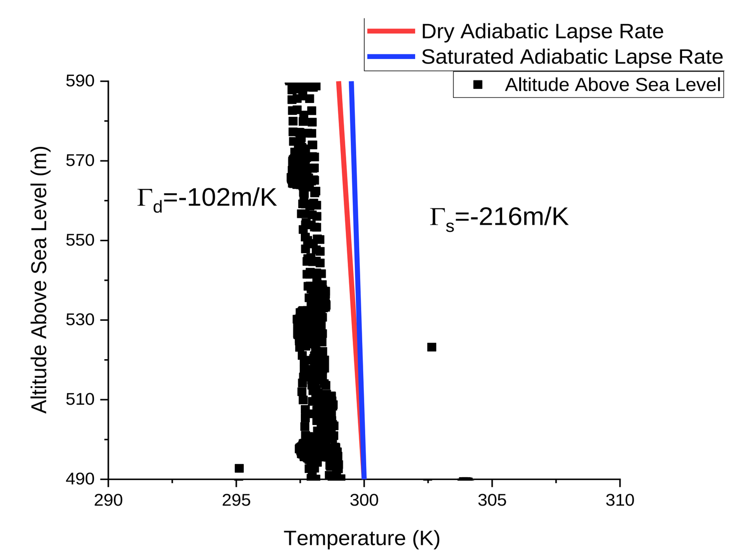

Figure 4. Saturated and Dry Adiabatic Lapse Rate plotted next to iMet temperature and altitude data.

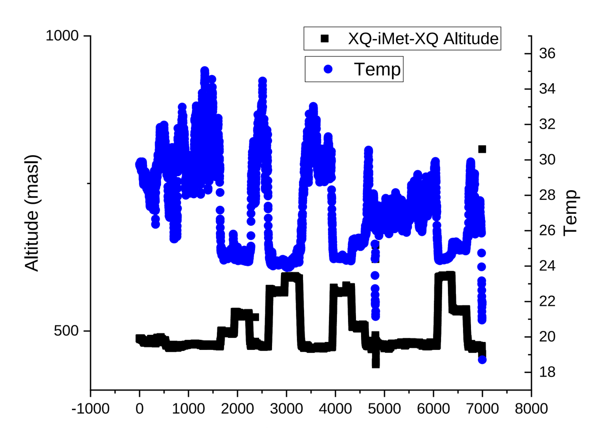

Figure 5. Altitude and temperature data from the iMET-XQ on July 16, 2019.

The flight data of altitude vs. temperature along with the adiabatic lapse rates. The ddry Adiabatic Lapse Rate is a constant, while the saturated adiabatic lapse rate is calculated from the data to give the relationship as it exists given the humidity during the time of the flight.

Figure 6. Image taken from the hexacopter UAS during a practice flight with the camera of the tall tower at 120 meters.

CONCLUSION

The POM ozone measurements that were taken while attached to the hexacopter UAS were shown to be noisy. The noise in the POM ozone concentration data resulted in a unreliable comparison to the tower ozone concentration measurements. This realization ensued our team to understand that there is a need to investigate different circumstances to have more meaningful measurements from the POM. The iMet-XF sensor was deemed suitable to begin to comprehend the atmospheric stability while attached to the hexacopter UAS.

FUTURE WORK

In order to better understand the performance of the POM while attached to the hexacopter UAS, more testing is needed to investigate how well the POM performs with respect to:

- Changing humidity
- Changing speed
- Changing temperature conditions
- Understand the POM's zero drift with calibration techniques
- Use the meteorological data to determine the lapse rate
- Interferences in air sampling from propeller motions

The data from the campaign will be used to define how long the POM needs at a given altitude to obtain representative measurements.

ACKNOWLEDGEMENTS

I would like to acknowledge Caitie Hedberg, Sydney Zeuli, and Marissa Zaleski for their contributions to this project. I would like to thank the following for funding this project: UWEC Office f Research and Sponsored Programs Faculty/Student Research Collaboration Grants and the National Science Foundation Grant AGS-1918850. I would also like to thank Ankur Desai and CHEESEHEAD19 campaign contributors for providing infrastructure for this project.

REFERENCES

1. Bertram, et al. *Atmos. Meas. Tech.*, 4, 1471-1479, 2011
2. Novak, G., M. Vermeuel, T. Bertram *Atmos. Meas. Tech. Discuss.*, amt-2019-445, in review, 2019

We thank the Office of Research and Sponsored Programs for supporting this research, and Learning & Technology Services for printing this poster.