Understanding the Lake Breeze Front in Eastern WI Through Remote Sensing and Aircraft Measurements

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Introduction

Abstract

The lake breeze is a meteorological phenomenon which factors into the air quality near the shorelines of Lake Michigan with significant impacts in studies of meteorology, chemistry, atmospheric physics, and more. Using high resolution radar imagery of base reflectivity on days with ozone levels greater than 70ppb, we were able to categorize near-shore and inland lake breeze events from the historic ground-based monitoring data sets, to better quantify the correlation between lake breeze events with ozone episodes. During the Lake Michigan Ozone Study of 2017, an aircraft flew spirals above and within the marine inversion layer. One such day captured spirals above the lake breeze front at a shoreline site, with unique signatures of small spatial gradients in ozone and wind direction in the spiral. We intend to use the data collected from the aircraft platform to understand the low altitude meteorology and air quality relationships near this lake breeze front.

Lake Breezes

Lake breezes are natural phenomena that occur when the air above land becomes warmer than the air over the water-in this case, Lake Michigan. The warmer air decreases in density which decreases localized atmospheric pressure. This produces a pressure gradient between the land and water's air, and makes a breeze moving inland. These lake breezes not only bring cooler air to the land, but can also transport substances in the air, such as ozone, from one location to another. Lake breezes are further classified as near-shore lake breezes-where the lake breeze does not permeate far onto land- and inland lake breezes-where the lake breeze can be monitored several miles away from the lake shore.

Radar Imagery

This research utilized radar imagery to confirm the lake breeze's existence in conjunction with data collected from the aircraft. An analysis was developed to identify lake breeze fronts through a combination of radar, satellite, and ground measurements to classify lake breezes as near-shore (Figure 1) or inland (Figure 2). This process correlated with ozone events (O_3>70ppb) for a large majority of ozone exceedances since 2013 in Eastern Wisconsin

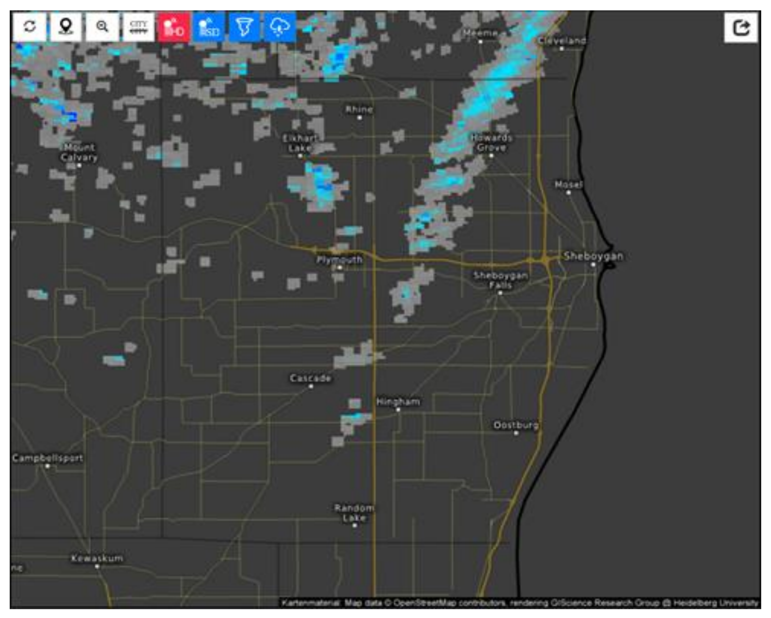

Figure 1: Image of near-shore lake breeze event
Sheboygan, 05/02/2014 2:44:19PM

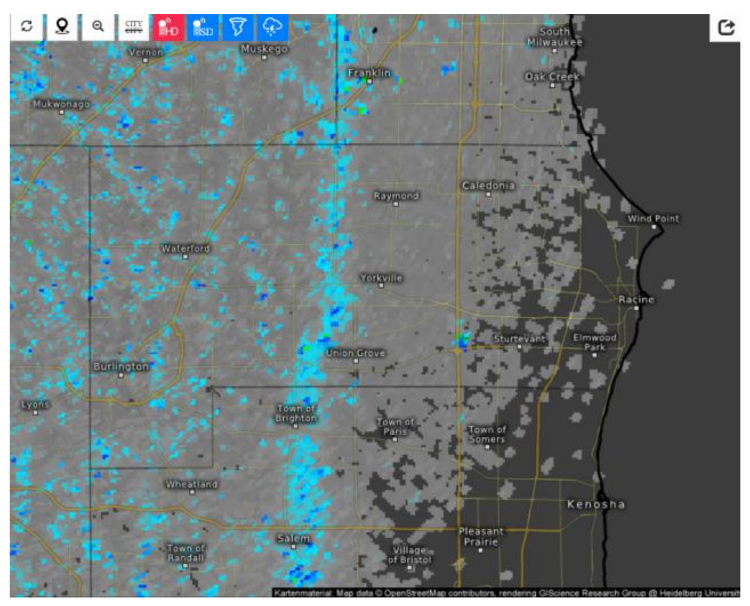

Figure 2: Image of inland lake breeze event
Kenosha, 05/01/2013 2:34:59PM

Lake Michigan Ozone Study 2017 (LMOS)

The Lake Michigan Ozone Study of 2017 was a collaborative, multi-agency field campaign that Employed a family of various ground and automobile platforms, ships, and two aircraft measurement platforms to better understand the ozone production chemistry and precursor emissions in the region along the Wisconsin and Northern Illinois coastline of Lake Michigan. This study ran from May 22, 2017 through June 22, 2017, with this project assessing data pulled from June 12, 2017.

Acknowledgements

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References

1. Doak JAWMA 2021 (in press)
2. Stanier BAMS (2021 submitted)

Near-Shore Lake Breeze Example June 12, 2017

These graphs are created from data of Scientific Aviation flights on June 12, 2017 during the LMOS study when there was an observed near-shore lake breeze confirmed by satellite, radar, and ground station observations. The x, y, and z-coordinates are longitude, latitude, and altitude, respectively. The coloring system is determined by different variables for each graph: temperature in Celsius (Figure 3), ozone in ppb (Figure 4) , East-West wind direction (Figure 5), and North-South wind direction (Figure 6), following the flight path of the aircraft near the on-shore and off-shore Zion flights, marked on Figure 7. We compare these two sites to understand how these variable differ over land and water. Note that the altitude flown over water reaches lower than it does over land.

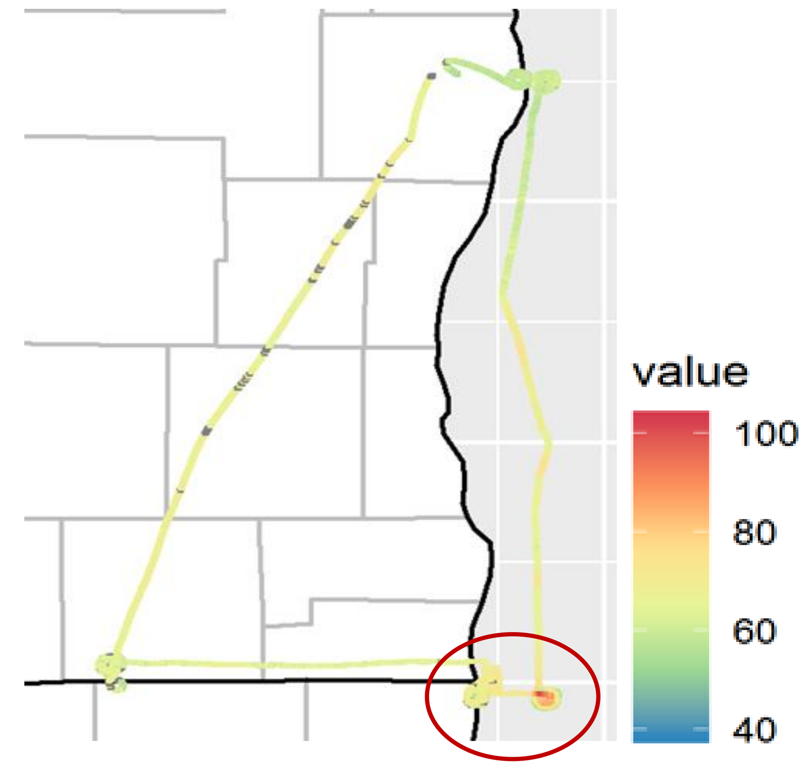

Figure 7: Map view of data collection sites along Lake Michigan
Cleary et al 2021 in preparation

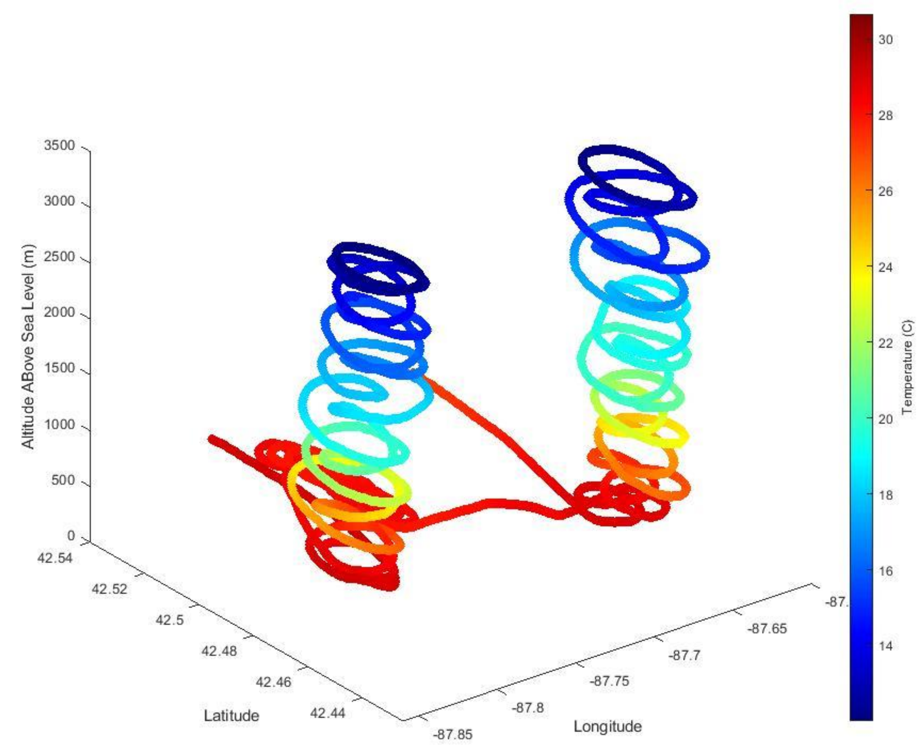

Figure 3: Graph of Longitude, Latitude, Altitude, and Temperature in Celsius

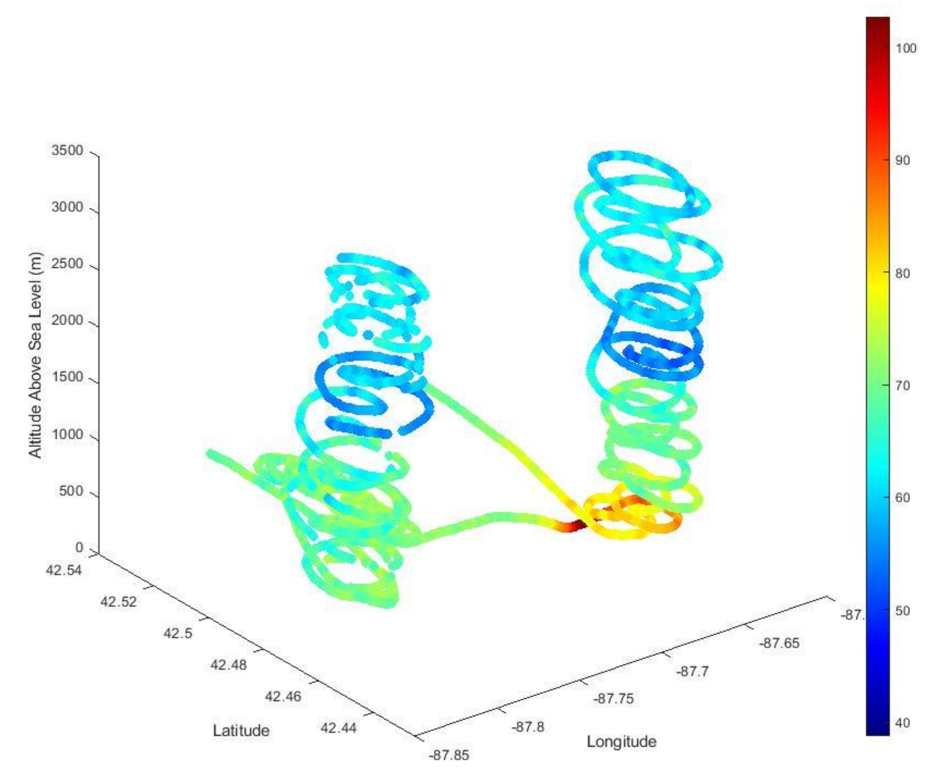

Figure 4: Graph of Longitude, Latitude, Altitude, and Ozone (ppb)

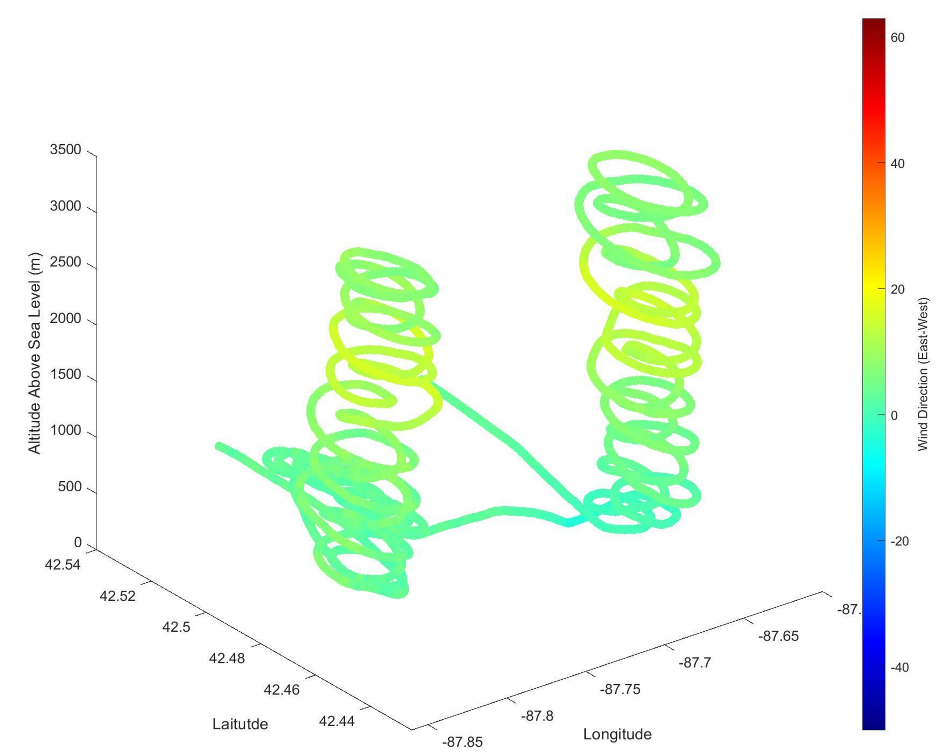

Figure 5: Graph of Longitude, Latitude, Altitude, and Wind Direction (East-West)

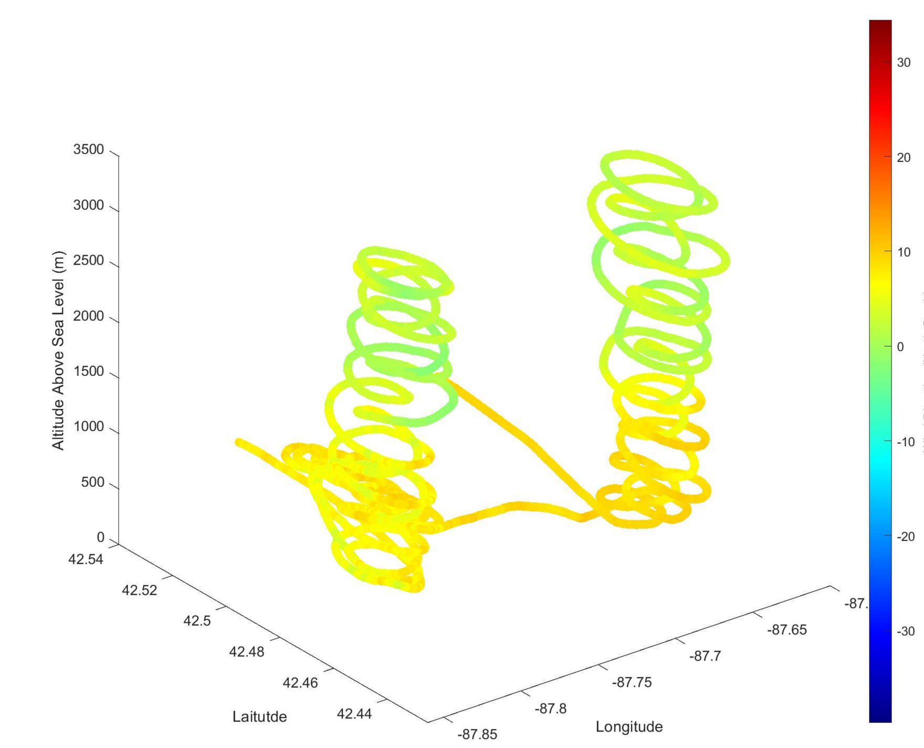

Figure 6: Graph of Longitude, Latitude, Altitude, and Wind Direction (North-South)

Discussion

In Figure 3, there is a slight lowering of temperature at low altitudes consistent with high ozone concentrations present in Figure 4. Note in Figures 5 and 6, the data indicates a largely Western wind component. Combined, this is in indication that the flight path crossed into the Marine Layer which contains enhanced ozone levels.

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