Spring 5-11-2016

Comparison of Combustion Efficiency to In-Situ Atmospheric Ammonia Measurements from a Miniature Chemical Ionization Mass Spectrometer in the LA Basin

Taylor Krause
Chapman University, kraus119@mail.chapman.edu

Barry L. Lefer
NASA Student Airborne Research Program

Timothy H. Betram
NASA Student Airborne Research Program

Steven R. Schill
NASA Student Airborne Research Program

Comparison of combustion efficiency to in-situ atmospheric ammonia measurements from a miniature chemical ionization mass spectrometer in the LA Basin

Taylor Krause, Barry L. Lefer, Timothy H. Betram, Steven R. Schill
National Suborbital Education and Research Center, the University of North Dakota, NASA Student Airborne Research Program

Abstract:

Atmospheric ammonia (NH_3) has been shown to impact the environmental and threaten both human and animal health, especially in heavily populated urban areas, yet to date there remains a paucity of direct measurements. Recent studies have suggested that ammonia may be generated as a byproduct of fossil fuel emissions due to highly active catalytic converters in light-duty gasoline vehicles. To investigate this relationship, an airborne miniature Chemical Ionization Mass Spectrometer (miniCIMS) was used to directly measure atmospheric ammonia and combustion reaction products in the Southern California LA Basin, during the 2015 NASA Student Airborne Research Program (SARP). The temporal variability in measured ammonia, and the relationship to combustion efficiency will be compared to mobile ground-based measurements from the NASA DISCOVER-AQ campaign, and implications of the findings will be discussed.

Introduction:

NASA offers an airborne science research opportunity for undergraduates for their NASA Student Airborne Research Program (SARP). This opportunity allows undergraduates a real graduate research experience with hands-on research in multiple aspects of atmospheric science. Students work in multi-disciplinary teams to study terrestrial, atmospheric, and oceanographic region throughout California. This research project was conducted under the advisory of the Los Angeles Air Quality team with the Los Angeles Basin as the area of interest.

The research program utilizes a NASA DC-8 aircraft from NASA Armstrong Flight Research Center to facilitate its sample and data collection. The instruments of interest for this research project are a novel airborne miniature Chemical Ionization Mass Spectrometer (miniCIMS) to detect atmospheric ammonia (NH_3) and an Atmospheric Vertical Observations of CO2 in the Earth's Troposphere (AVOCET) to detect CO_2 (g) and CO.

Methods

SARP conducted data collection for the airborne research campaign aboard the NASA DC-8, a highly specialized research aircraft used for studying Earth system processes. The area of interest for this study is the LA Basin, which SARP conducted flights through the Los Angeles International Airport known as, "missed approaches". The analytical methods used to analyze the whole air samples collected during the flights were accomplished in the UCI Department of Chemistry Rowland-Blake Lab. However, the analytical methods of interests for this research project are from in-situ data taken from inflight instruments utilized aboard the DC-8. The instruments utilized to detect the species interest for this research project are a *novel* airborne miniature Chemical Ionization Mass Spectrometer (miniCIMS) to $NH_{3\,(g)}$ and an Atmospheric Vertical Observations of CO_2 in the Earth's Troposphere (AVOCET) to detect $CO_{(g)}$, and $CO_{2\,(g)}$. The emphasis of the *novel* aspect of the miniCIMS is due its miniature size. Its compact dimensions are so that it may more easily be integrated onto an aircraft to thus facilitate airborne research.

Results

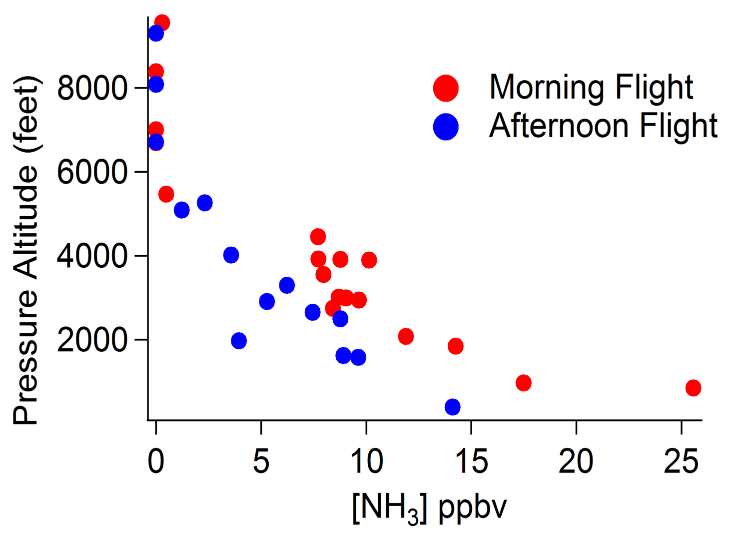

Figure 3: Comparison of NH_3 at varying altitudes between, "Morning Flights" and "Afternoon Flights" SARP 2015 June 23rd flights through LAX.

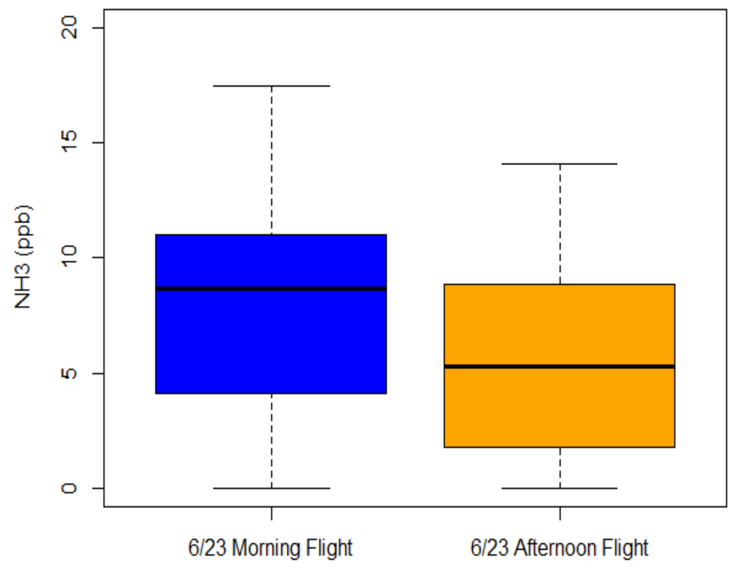

Figure 4: $[NH_3]$ Mean comparison between 2015 SARP "Morning" Flight at 9:39 am – 10:00 am and "Afternoon" Flight at 2:18 pm – 2:30 pm on June 23 through Los Angeles Basin. The respective mean concentrations were found to be 6.0465 ppb for the "Morning" Flight and 3.8282 ppb for the "Afternoon" Flight.

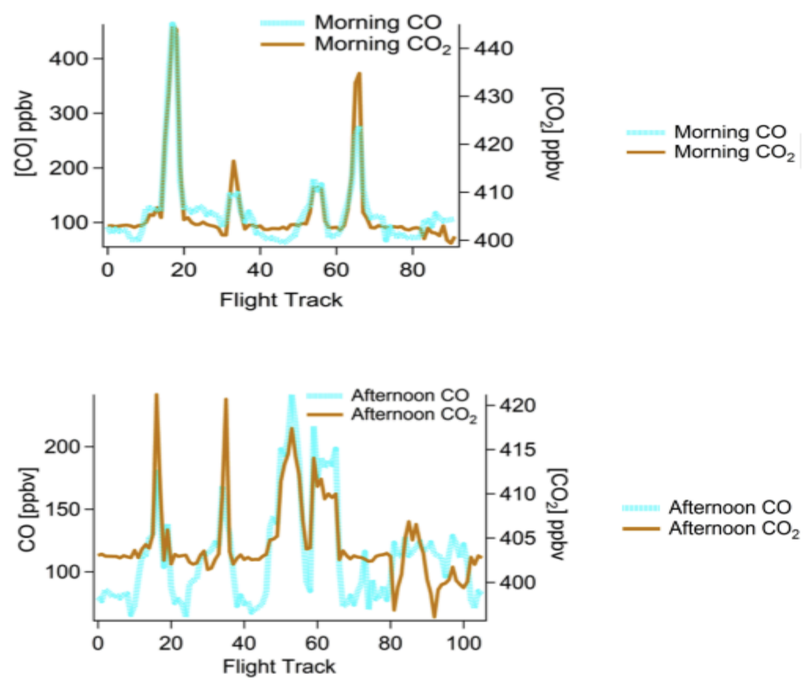

Figure 5: Comparison of $[CO_2]/[CO]$ (combustion efficiency) for 2015 SARP on June 23rd through LAX.

Conclusions:

During the SARP 2015, novel miniCIMS was able to detect elevated ambient ammonia during these two missed approaches through Los Angeles International Airport. The "Morning" Flight was conducted at 9:39 am – 10:00 am and "Afternoon" Flight was conduced at 2:18 pm – 2:30 pm on June 23rd had respective mean concentrations of 6.0465 $[NH_3]$ ppbv for the "Morning" Flight and 3.8282 $[NH_3]$ ppbv for the "Afternoon" Flight.

Both flights, which flew similar tracks and at similar pressure altitude, but experienced different concentrations of NH_3; The max 25.56 $[NH_3]$ ppbv "Morning" Flight compared to the max 14.11$[NH_3]$ ppbv for the "Afternoon" Flight.

NASA DISCOVER-AQ

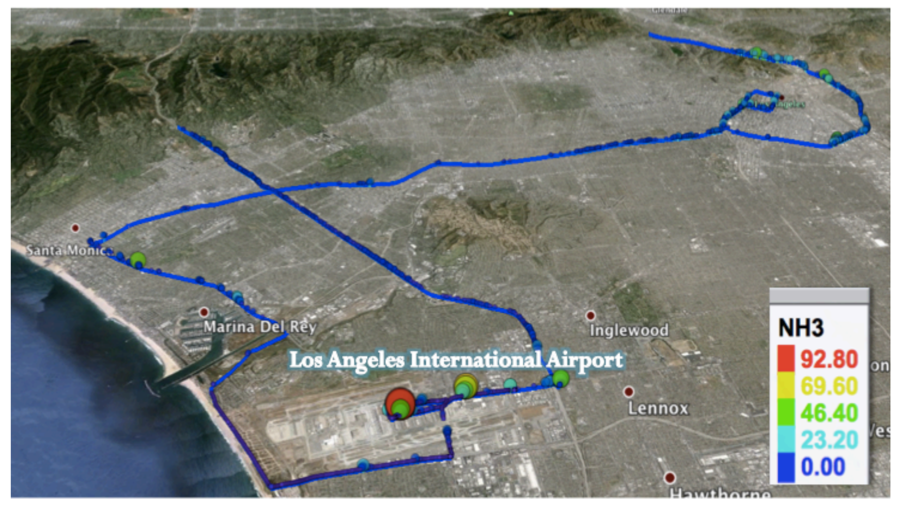

Figure 1: 2014 NASA DISCOVER-AQ mobile track through the Los Angeles Basin, which detected elevated levels of NH_3 with a max of 92.8 $[NH_3]$ ppb.

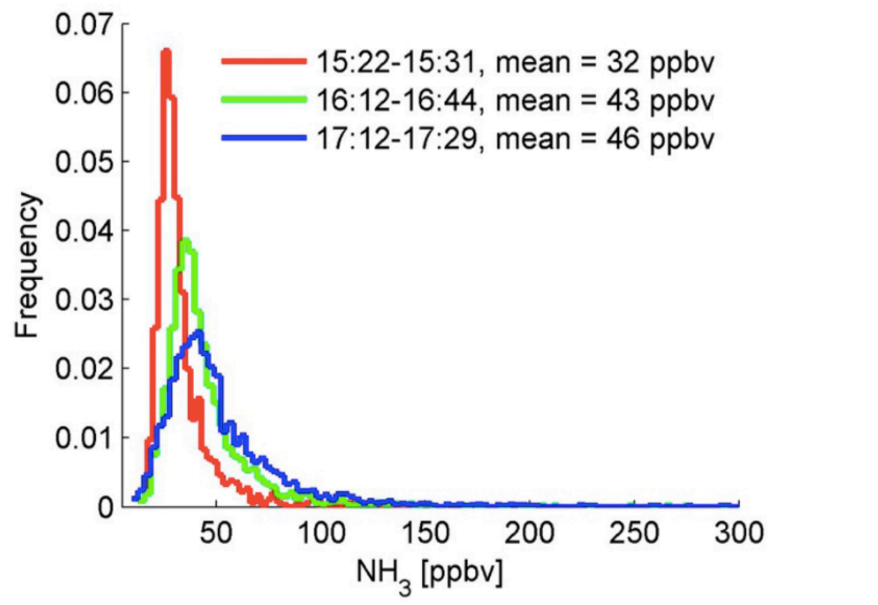

Figure 6: The relative frequency and time evolution of on-road $[NH_3]$ distribution of U.S. 1 conducted by for Mark Zondlo for *On-Road Ammonia Emissions Characterized by Moblie, Open-Path Measurements, 2014*.

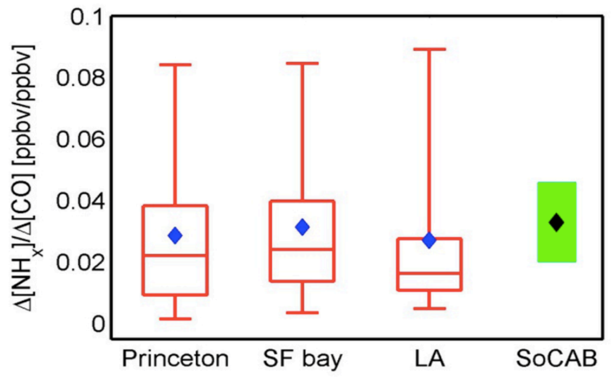

Figure 8: $[NH_3]/[CO]$ mean conducted by Mark Zondlo for *On-Road Ammonia Emissions Characterized by Mobile, Open-Path Measurements, 2014* for NASA DISCOVER-AQ mobile platform. $[NH_3]/[CO]$ were calculated for routes through New Jersey, San Francisco, and Los Angeles compared to the standard set for the Southern, CA Air Quality Board. In Los Angeles the mean was found to be $[NH_3]/[CO]$ = 0.027 ppbv/ppbv.

NASA SARP

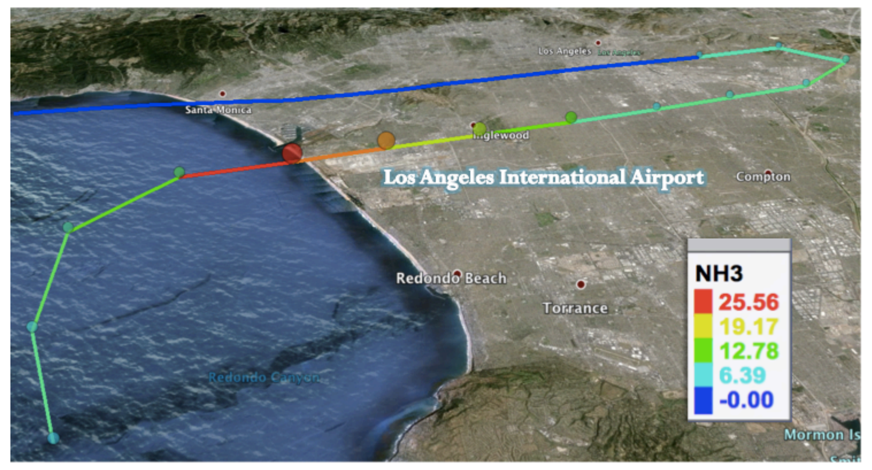

Figure 1: 2015 SARP on June 23, "Morning" Flight at 9:39 am – 10:00 am; "Missed approach", through LAX. The max amount of NH_3 was detected during the "Morning" Flight was 25.56 $[NH_3]$ ppbv.

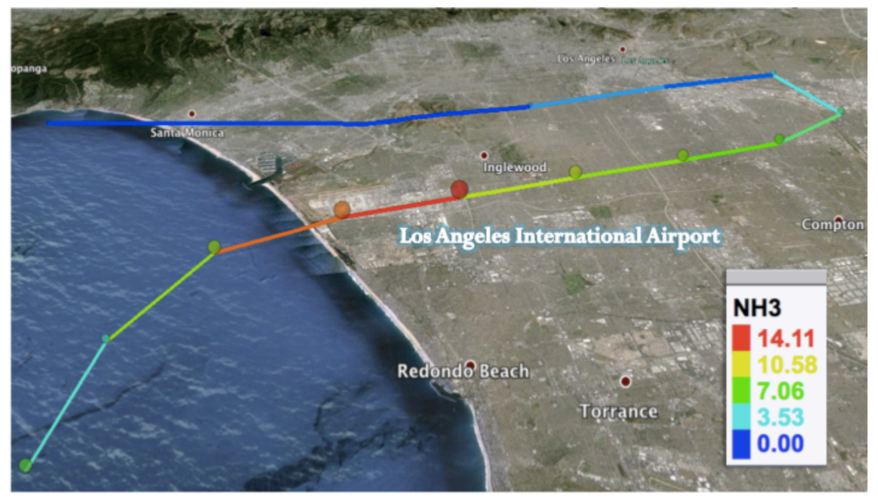

Figure 2: 2015 SARP on June 23, "Afternoon" Flight at 2:18 pm – 2:30 pm "Missed approach", through LAX. The max amount of NH_3 was detected during the "Afternoon" Flight was 14.11 $[NH_3]$ ppbv.

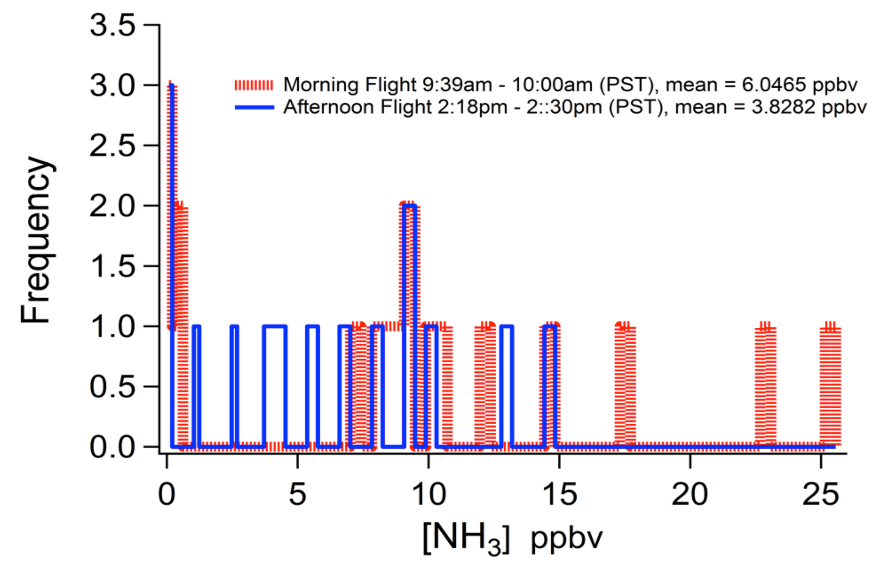

Figure 7: Comparison of relative frequency of airborne ammonia NH3 (g) on June 23rd 2015 SARP through LAX.

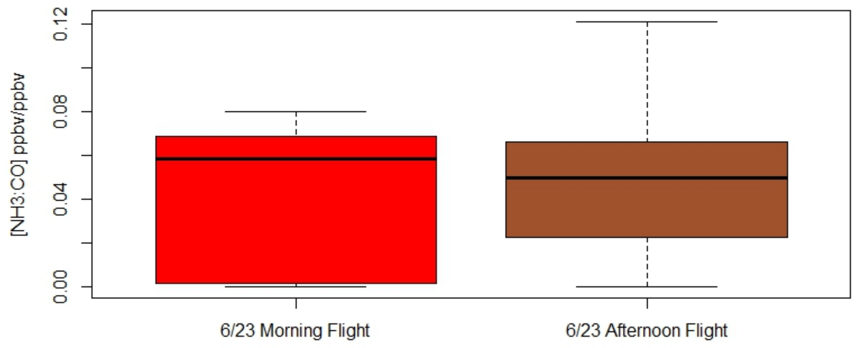

Figure 9: Comparison of $[NH_3/CO]$ Mean 2015 SARP on June 23rd through Los Angeles International Airport. $[NH_3/CO]$ Mean was 0.0466 ppbv/ppbv for the "Morning" flight and 0.0308 ppbv/ppbv for the "Afternoon" flight.