



Evaluation of Small Sensor Technology for Criteria Pollutants at Ground-based Sites and a Citizen Science Network

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- Background information
 - Next Generation Air Monitoring
 - DISCOVER-AQ Study
- Houston, TX deployment (CairClip Sensors)
 - Citizen science-based sensor network
 - Educational Outreach
 - Results from sensor network
- EPA RTP, NC AIRS (AQMesh Sensor)
- Current and future work



Next Generation Air Monitoring

- Small sensors are a rapidly emerging technology for measuring air pollutants
- Growing interest in understanding the capability of sensors to accurately measure criteria pollutants in ambient air
- Potential to use these devices for various applications



DISCOVER-AQ

DISCOVER-AQ (Deriving Information on Surface Conditions from Column and VERTically Resolved Observations Relevant to Air Quality)

- NASA earth science suborbital venture mission
- Science Question:
 - Under what conditions can ambient air quality be reliably informed using satellite remote sensing?
- Multi-Year Mission
 - Baltimore, MD – Washington, DC (June-July 2011)
 - San Joaquin Valley, CA (January-February 2013)
 - **Houston, TX (September 2013)**
 - Denver, CO (July-August 2014)



DISCOVER-AQ

Observational Components

NASA King Air (Remote sensing)

Continuous mapping of aerosols with HSRL and trace gas columns with ACAM



NASA P-3B (in situ measurements)

In situ profiling of aerosols and trace gases over surface measurement sites.



Ground Sites

- Ambient trace gases and aerosols (based on EPA FRM/FEM)
- Remote sensing of trace gas and aerosol columns
- Aerosol and Ozone profiles

EPA, State, Local, and temporary Ground sites





EPA Collaboration with DISCOVER-AQ

- Conducting research in Federal Reference and Equivalent methods (FRM/FEM) used for NAAQS compliance
 - Direct measurement methods for nitrogen dioxide (NO_2) and oxides of nitrogen (NO_x)
 - New ozone (O_3) FRM
- Changing the paradigm of air pollution monitoring
 - Remote sensing technology
 - Small sensor technology



EPA Federal Reference and Equivalent Methods Program

- Federal Reference Methods (FRM)
 - Method, sampler, or analyzer that utilizes measurement principles and calibration procedure specified in 40 CFR* Part 50
- Federal Equivalent Methods (FEM)
 - Method that has been tested under 40 CFR Part 53 and designated by EPA as an FEM under Part 53
- FRM/FEM provide a specified, definitive method for measuring criteria pollutants for comparison to the National Ambient Air Quality Standards (NAAQS)

* CFR = Code of Federal Regulations



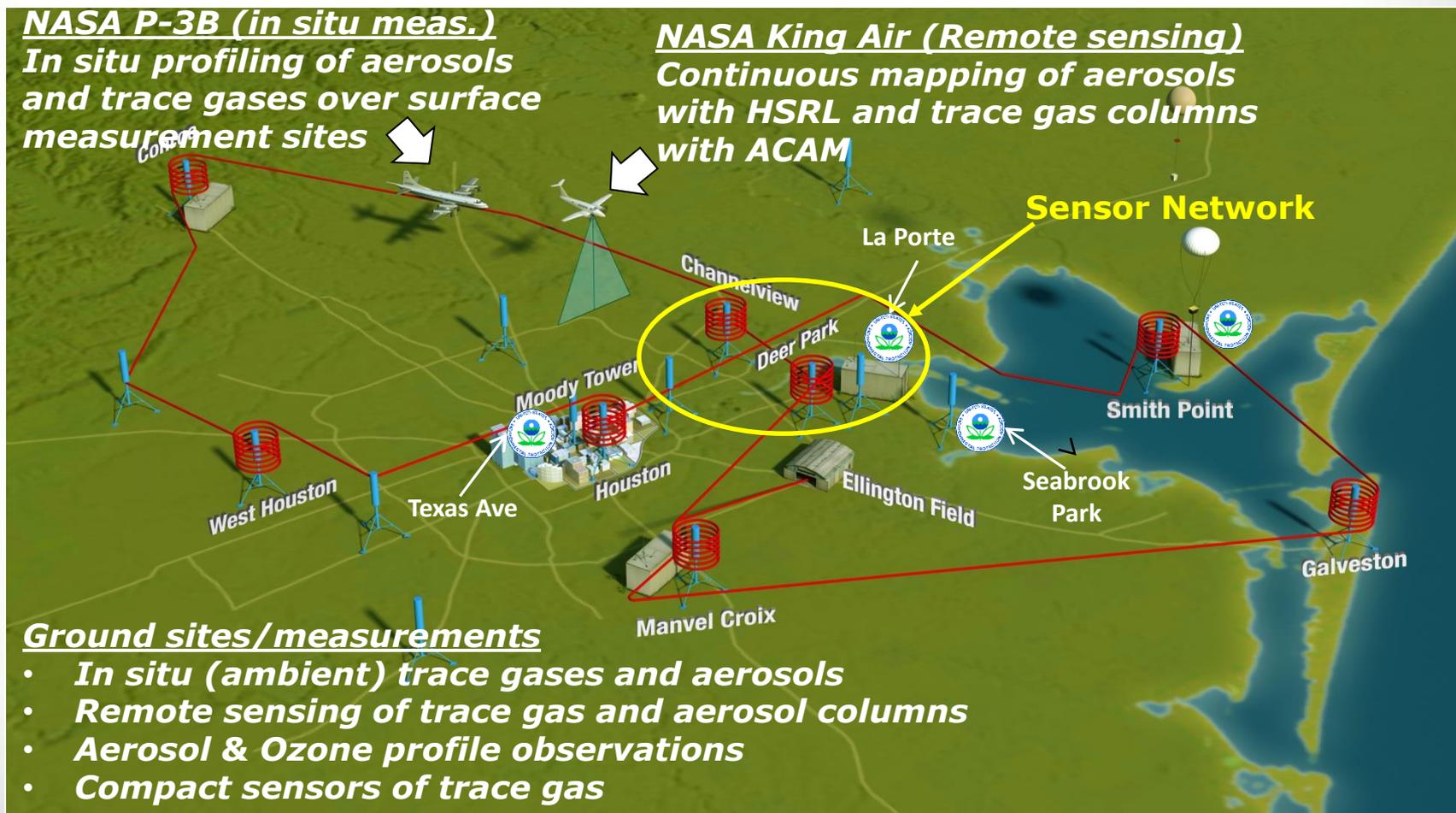
DISCOVER-AQ Houston September 4-28, 2013





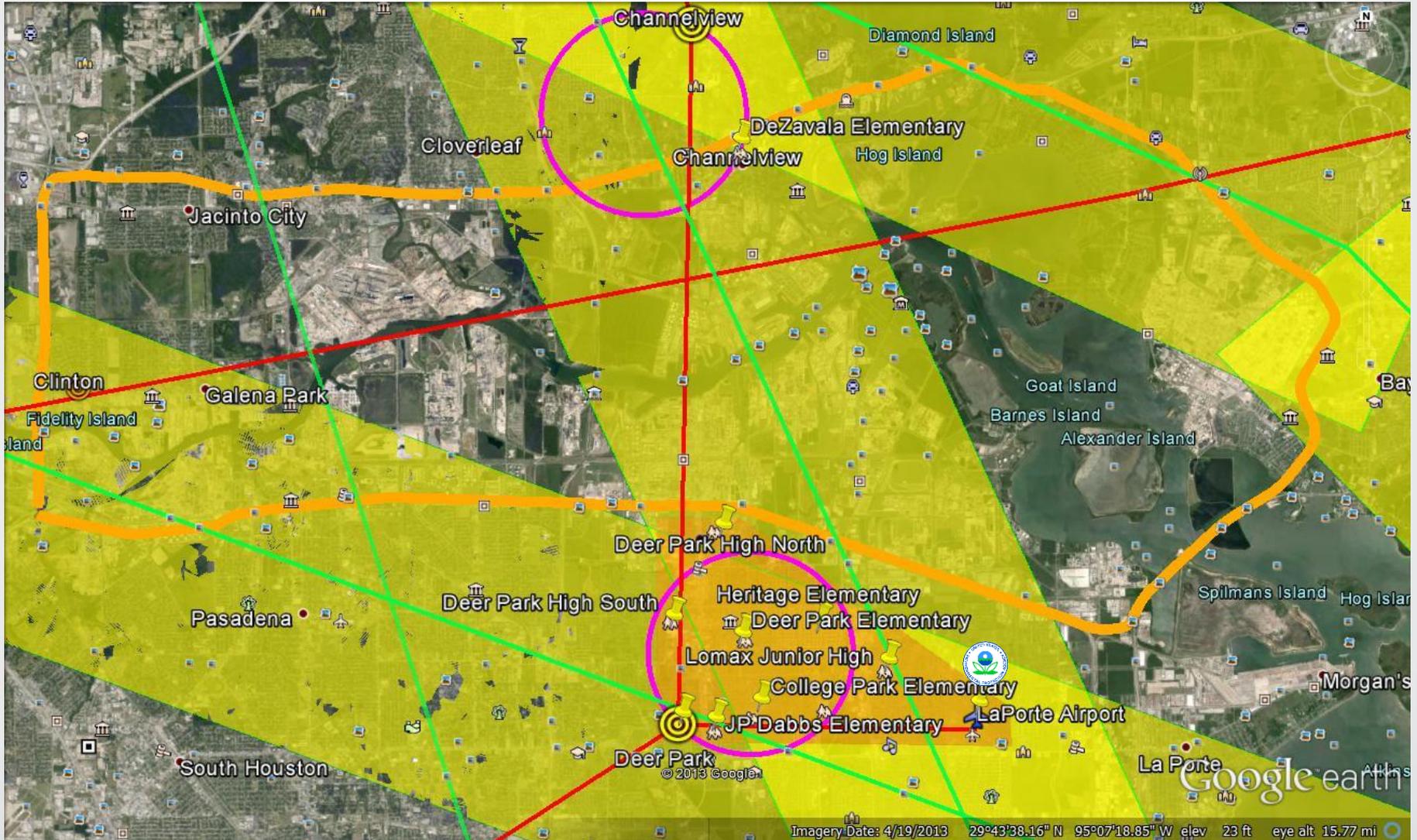
Houston Observation Strategy (Sept 2013)

Field measurements were located at 4 sites. A small sensor network was deployed at local schools.





EPA-NASA Sensor Network





Sensor Network Citizen Science Based

- 8 schools participated (elementary, junior high, and high school)
- Teachers trained on how to operate sensors
- Teachers/students collected data and incorporated activities into lesson plans
- EPA scientists visited schools and conducted educational outreach activities



CairClip Sensor

- Electrochemical sensor
 - Measures current between working electrode and counter electrode
 - Gas reacts at working electrode and generates a measurable difference in electrical potential between electrodes
 - Difference proportional to target gas concentration
- Contains micro fan to allow for dynamic air sampling
- Includes air filter to remove particles from sample
- Sensor components enclosed in aluminum-based casing cylinder (32 X 62mm)



CairClip Sensor



- 2 versions: NO₂ and combined O₃+NO₂
- Detection Range: 0-250 ppb
- Weight: 55 grams (0.12 pounds)
- Dimensions: 32 mm wide, 63 mm long
- Battery life: ≥ 24 hours
- Recharging battery: 4-6 hours to charge
- Data storage: 28,800 data points (20 days of 1 minute averaged data)
- Data retrieval: Cairsoft software



Sensor Network

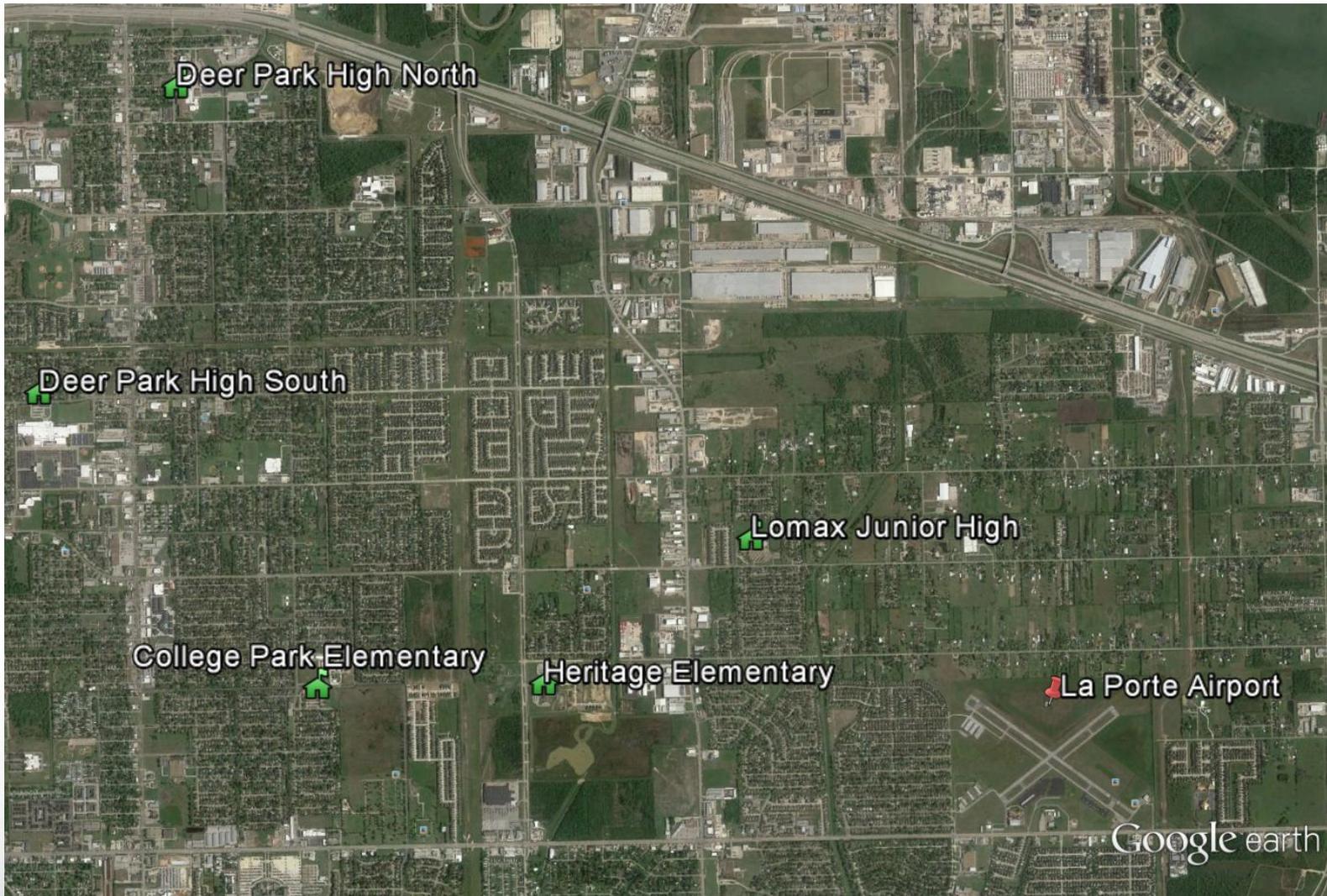
School	Sensor Type		
	AQMesh*	CairClip NO ₂	CairClip O ₃ +NO ₂
Lomax Junior High	X	X	X
College Park Elementary	X		X
Heritage Elementary	X	X	X
Deer Park High South	X	X	X
Deer Park High North	X	X	X
Deer Park Elementary	X		
JP Dabbs Elementary	X	X	
DeZavela Elementary	X		X
LaPorte Airport (Ground site)	X	X	X

* Sensor deployed by NASA; measures NO₂, NO, O₃, SO₂, and CO



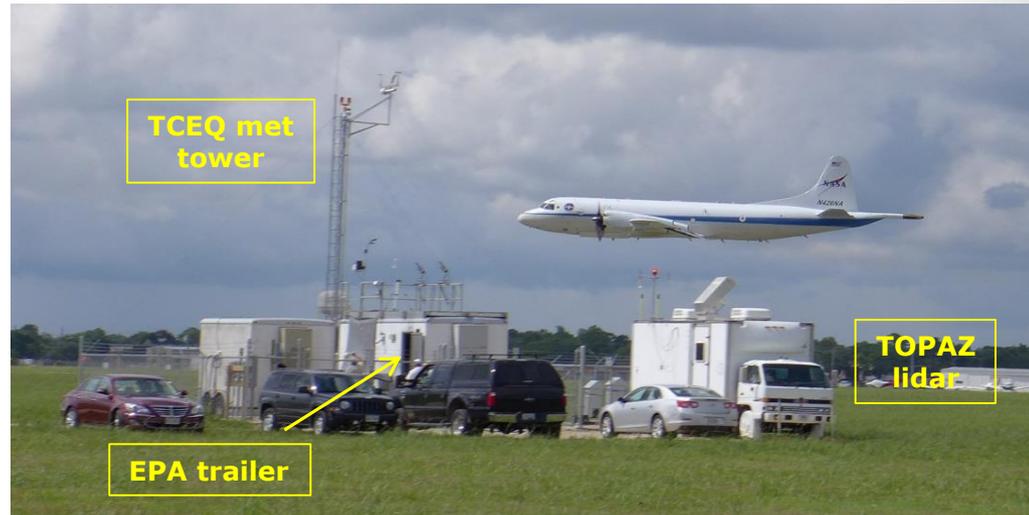
Sensor Network Results

Sensor data will be shown for these schools only





La Porte Airport (La Porte, TX) EPA Ground-Based Site

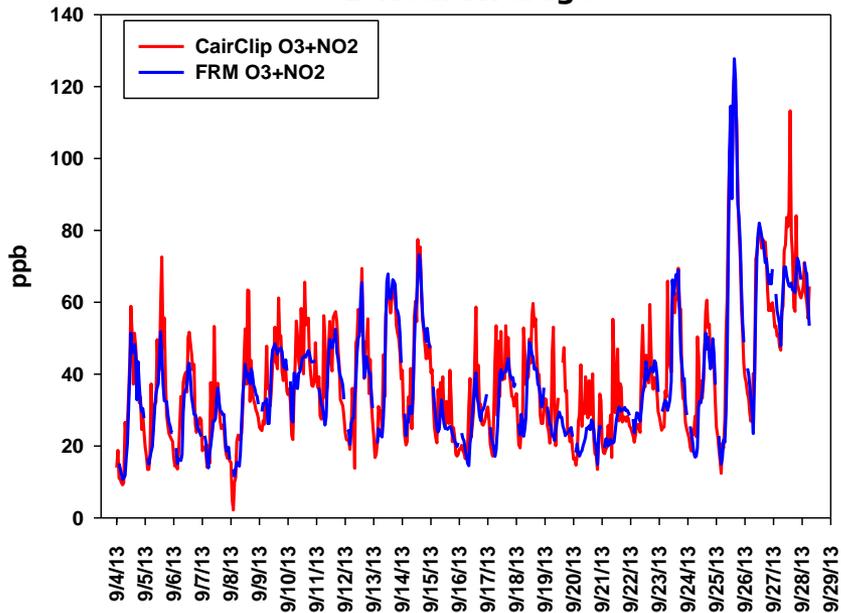


- CairClip sensors collocated with O_3 and NO_2/NO_x FRM/FEM measurements
- Missed approach site for NASA-P3B Aircraft

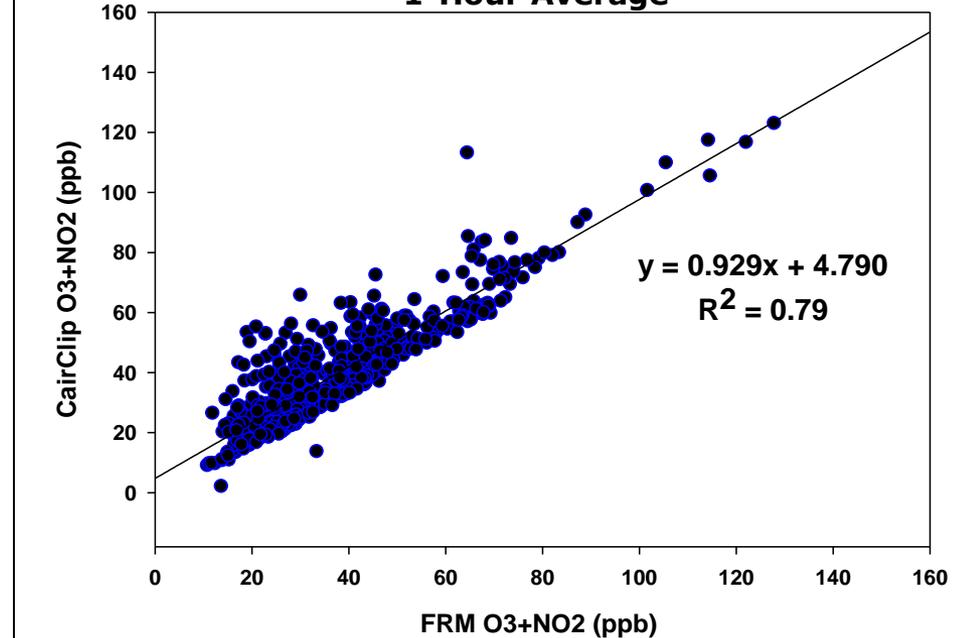


La Porte Airport (La Porte, TX) EPA Ground-Based Site

September 4-28, 2013
1-Hour Average



September 4-28, 2013
1-Hour Average

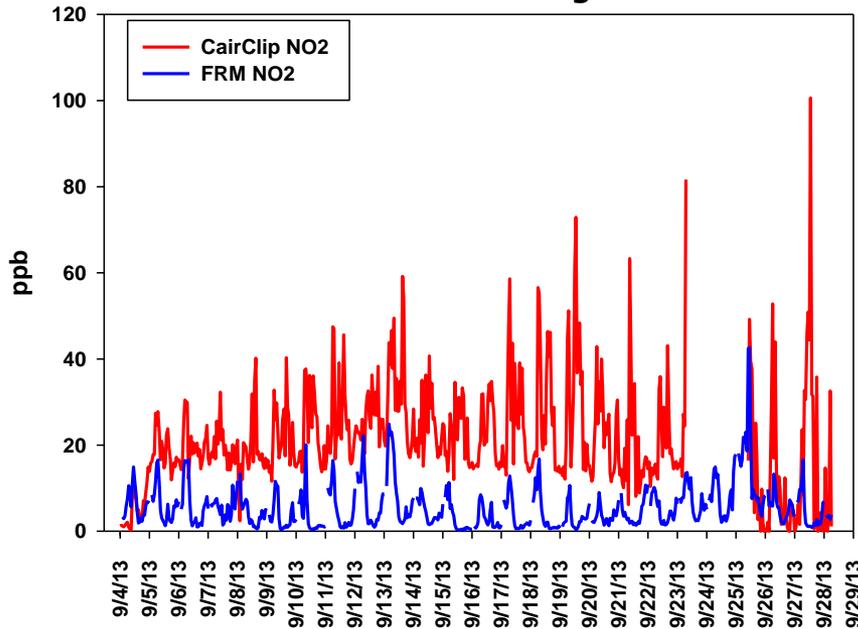


- Very good agreement between CairClip and FRM measurements
- Ozone NAAQS (75 ppb, 8hrs) exceeded on September 25, 2013

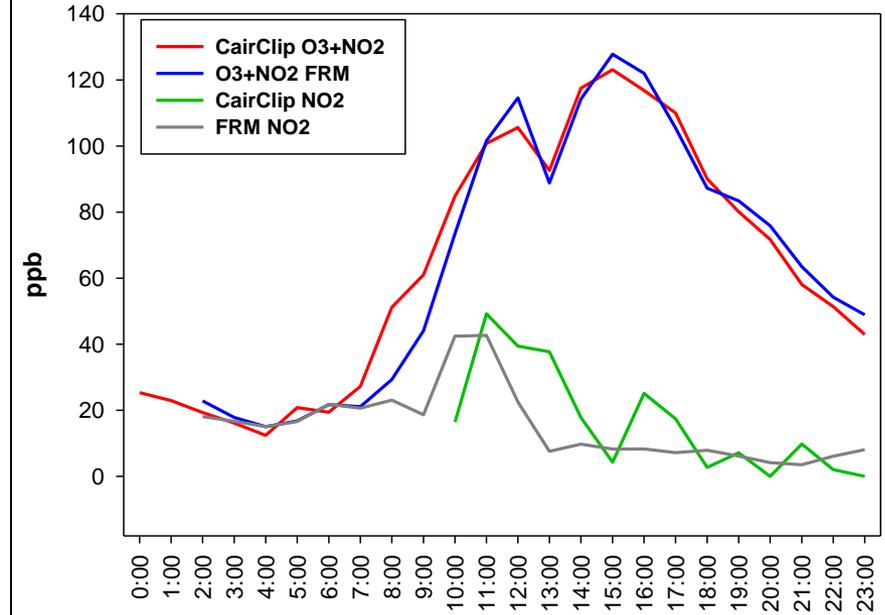


La Porte Airport (La Porte, TX) EPA Ground-Based Site

September 4-28, 2013
1-Hour Average



September 25, 2013
1-hour Average



- CairClip reported much higher NO₂ measurements
- Ozone NAAQS exceedance day on September 25, 2013
 - Good agreement between Cairclip O₃+NO₂ and FRM



Citizen Science Network

Sensor Placement and Data Collection

- Identified secure areas at each school to place sensors
 - Flag poles or sturdy columns
- Avoided placing sensors near high pollution spots
 - Bus lanes
 - Student drop off/pick up
- Teachers/students deployed sensors in morning and collected them at the end of the day
- Teachers/students able to track flight days and asked to deploy sensors on flight days
 - 10-12 flight days total





Lomax Junior High (La Porte, TX) ~ 1 mile from La Porte Airport



**CairClip
Sensor**

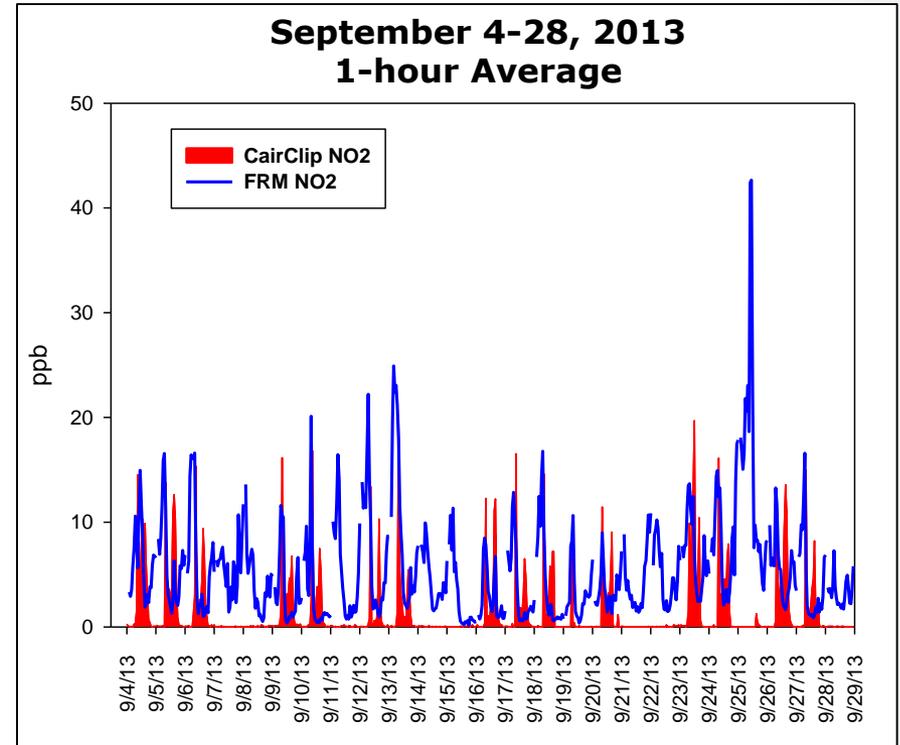
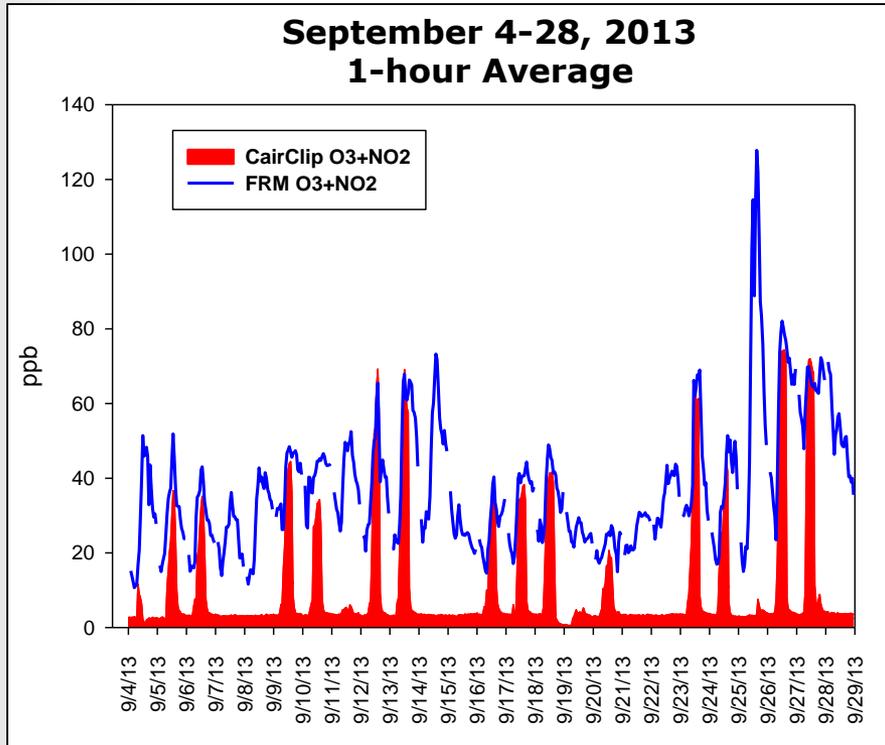


**AQMesh
Sensor**





Lomax Junior High (La Porte, TX) ~ 1 mile from La Porte Airport



- Sensors normally deployed on NASA P-3B flight days
- CairClip O₃+NO₂ sensor performed well



Heritage Elementary (La Porte, TX)

~ 2 miles from La Porte Airport



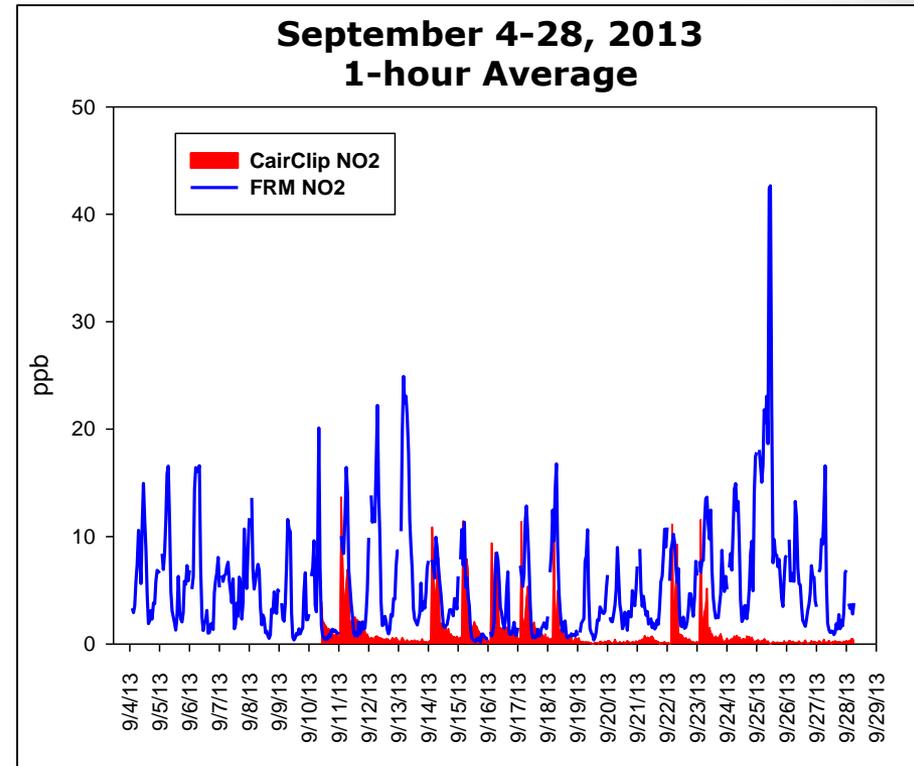
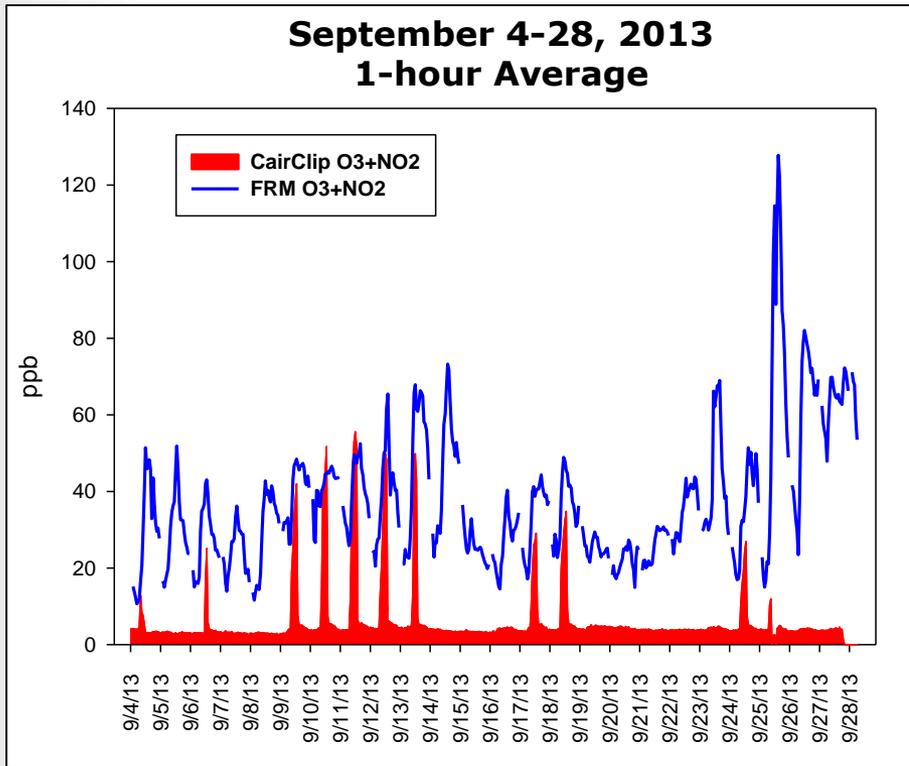
**AQMesh
Sensor**

**CairClip
Sensor**





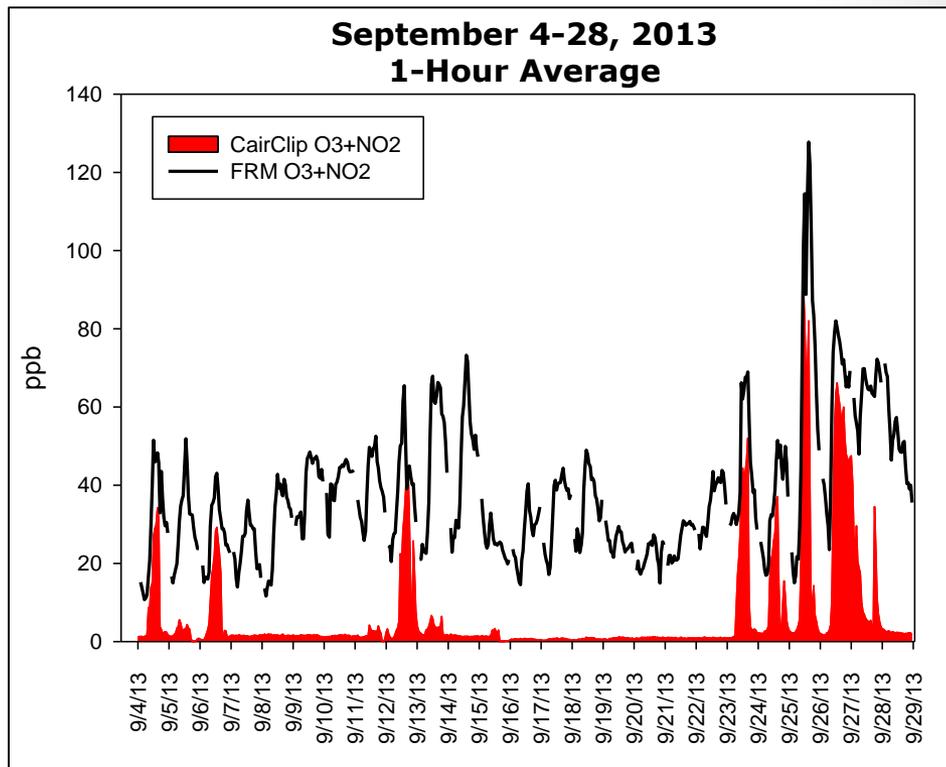
Heritage Elementary (La Porte, TX) ~ 2 miles from La Porte Airport



- CairClip O₃+NO₂ sensor performed well



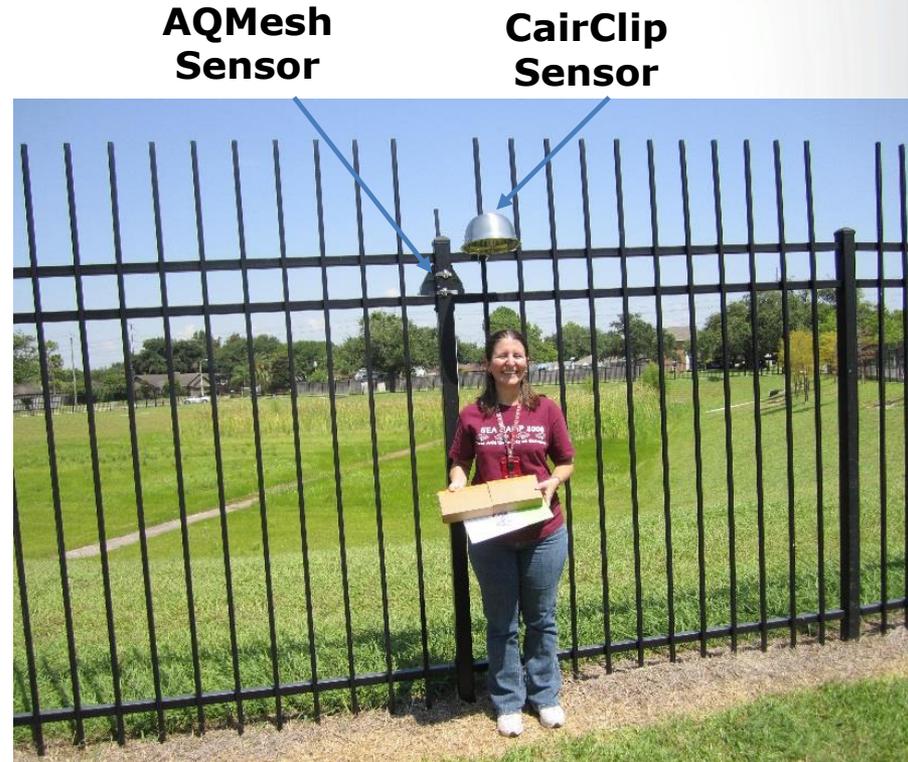
College Park Elementary (La Porte, TX) ~ 3 miles from La Porte Airport



- Low cost sensor performed well



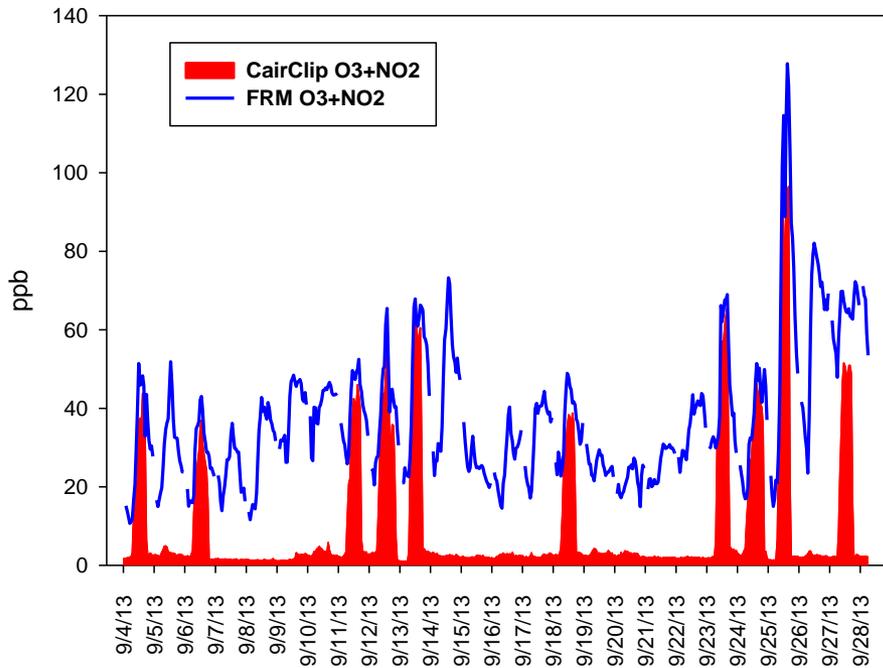
Deer Park High South (Deer Park, TX) ~ 4.5 miles from La Porte Airport



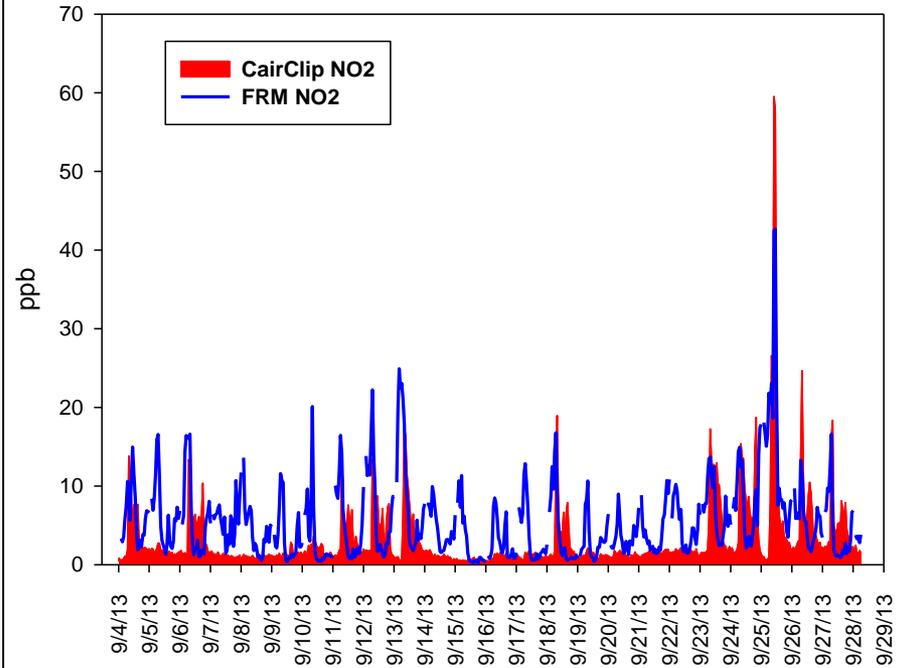


Deer Park High South (Deer Park, TX) ~ 4.5 miles from La Porte Airport

September 4-28, 2013
1-hour Average



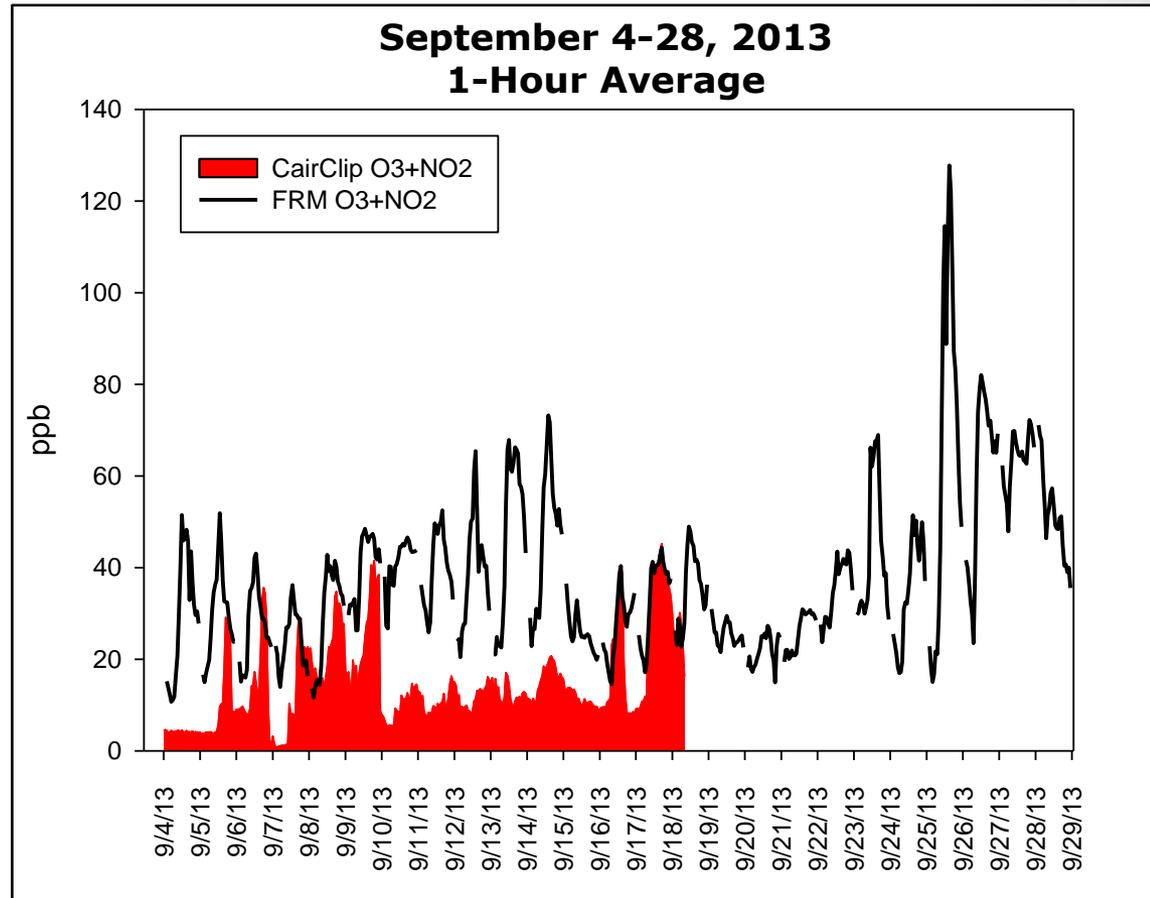
September 4-28, 2013
1-hour Average



- CairClip O₃+NO₂ sensor performed well



Deer Park High North (Deer Park, TX) ~ 6 miles from La Porte Airport



- Low cost sensor performed well



EPA Outreach and Citizen Science Feedback from Schools

"The students and I have loved being involved in this project, and I know they have a better understanding of air quality, the effects of pollution, the science processes, and what being a scientist entails in general." Katy Jordan, 5th Grade Science Teacher, Heritage Elementary School

"Thank you for including us in this study! " Kristen Knoedler, Science Department, Deer Park High School South

"There is no way for us to express our gratitude to the EPA and NASA for the experience given to the Dabbs students. Everyone's willingness to contribute in all the ways they have has been unbelievable. We have enjoyed the chatting, the question and answer session, and the field trip (which I am so sorry I couldn't attend). These opportunities provided our children experiences they will never forget, have motivated many, and has peaked their interest in science. Thank you again for allowing Dabbs to participate in the research study and we look forward to hearing from you!" Becky Turner, Amy Etchberger 5th Grade Science Teachers, JP Dabbs Elementary School

"Thank you so much for including us. The students learned so much and had a blast while learning! We also really enjoyed the presentation Friday. All grade levels told me that they loved it!" Elaine Finnen, 5th Grade Science Teacher, College Park Elementary School



Summary of Sensor Network in Houston, TX

- Pilot sensor study proved to be successful
- CairClip O₃+NO₂ sensors performed very well throughout sensor network
 - Data compared well to FRM/FEM measurements
- NO₂ CairClip sensor data showed less agreement
 - NO₂ concentrations more localized
- Sensor technology capable of filling in spatial gaps along aircraft path



EPA-RTP AIRS Site

AQMesh Evaluation





AQMesh Sensor

- Multi-pollutant Sensor (**NO₂**, **NO**, **O₃**, **SO₂**, **CO**) and met measurements (**RH**, **temp**, **pressure**)
- Electrochemical sensors
- Weight: < 4 lbs
- Size: 4.6 x 7.0 x 5.5 inches
- Battery powered (lifetime ~ 2 years*)
- Built in wireless GPRS communications
- Reading Intervals: 1 min, 15 min, 30 min

Pollutant	Range Accuracy (ppb)	Lower Detectable Limit (ppb)
NO	0-20,000	< 3ppb
NO ₂	0-200	< 5 ppb
O ₃	0-200	< 5ppb
CO	0-50,000	< 5ppb
SO ₂	0-100,000	< 5ppb



* Depends on reading interval



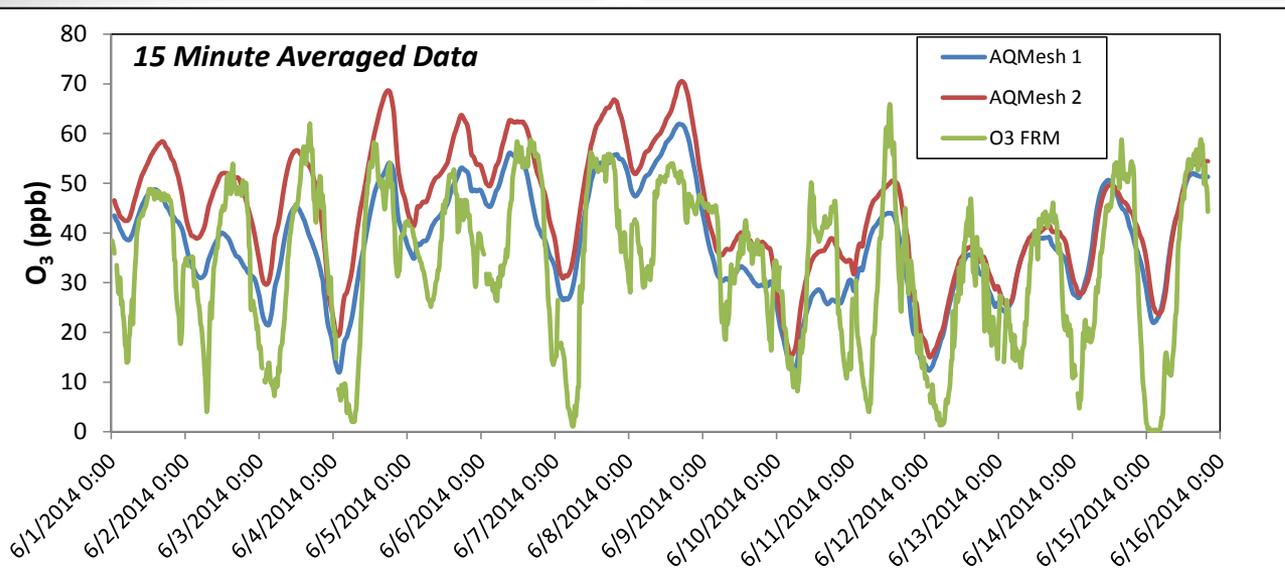
AQMesh Sensor Ambient Evaluation

- AIRS site on EPA-RTP Campus
- 16 days of data
 - June 1-16, 2014
- AQMesh collocated with FRM/FEM measurements
- Focus: NO₂, NO, O₃, and SO₂
- 2 pods installed to evaluate precision and comparability to FRM/FEM measurements

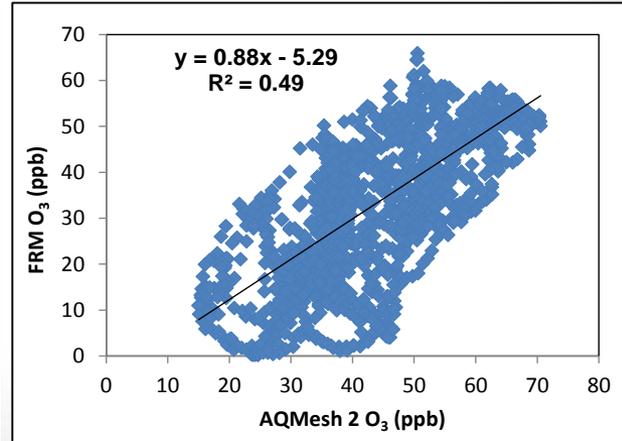
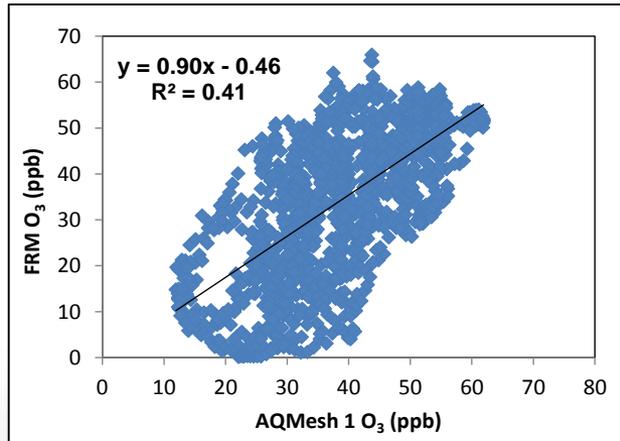
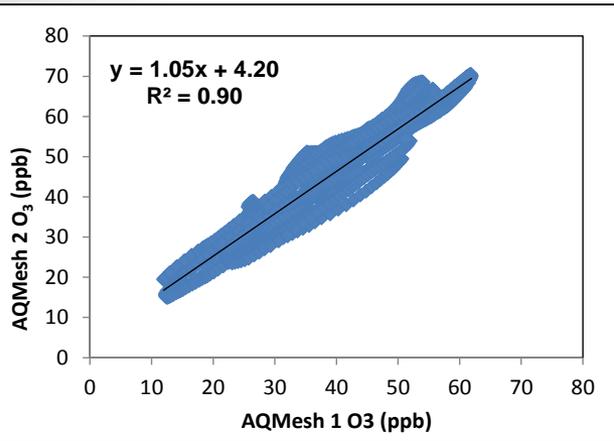




AQMesh Preliminary O₃ Data

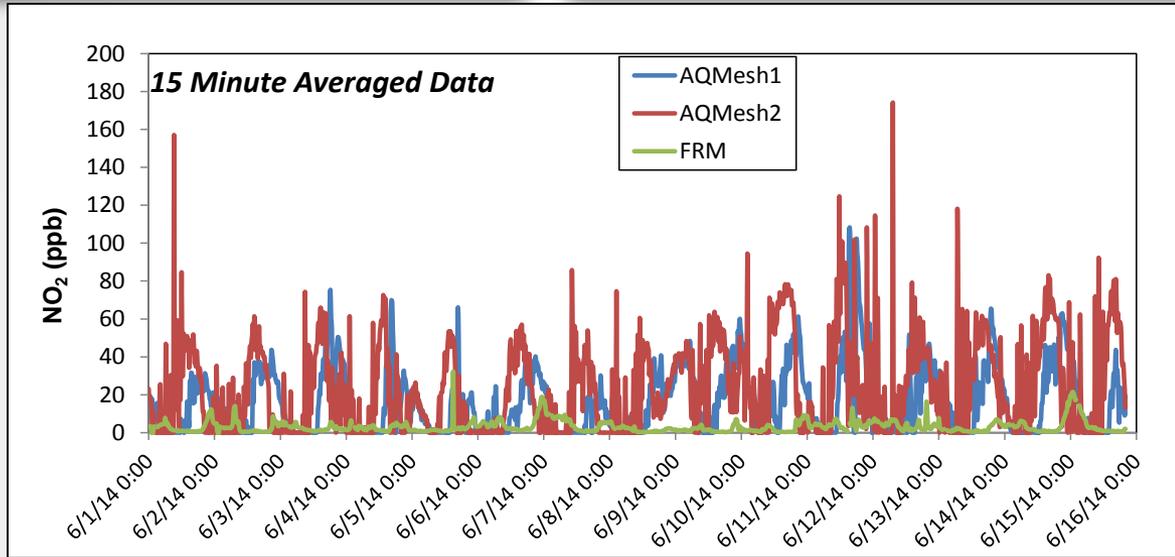


- Fair agreement between AQMesh and FRM measurements
- AQMesh pods agree well with each other
- Moderate to fair agreement between AQMesh and FRM

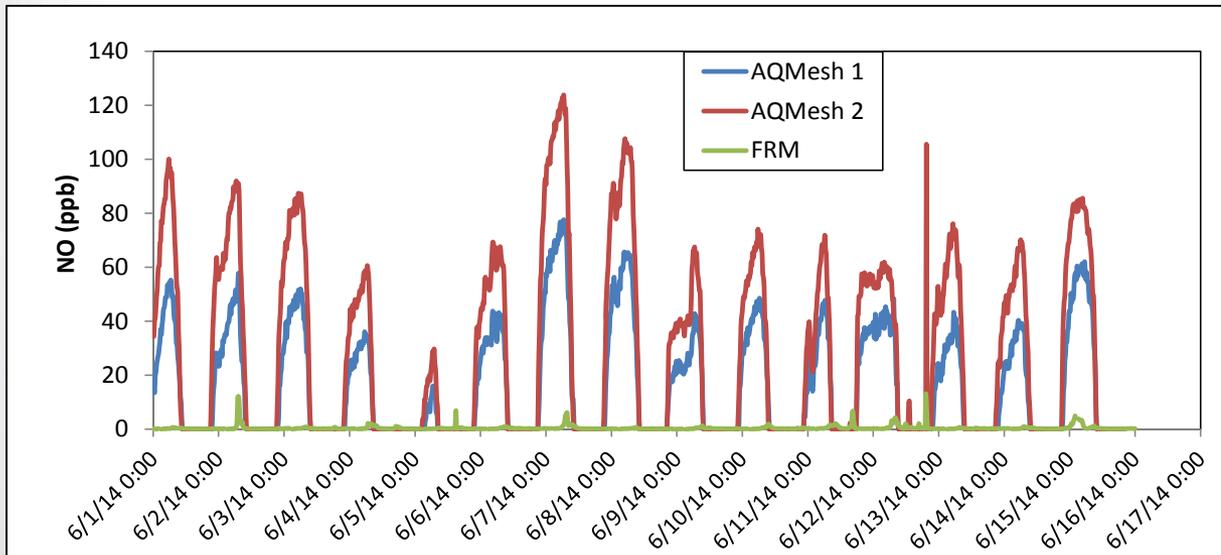




AQMesh Preliminary NO₂ and NO Data

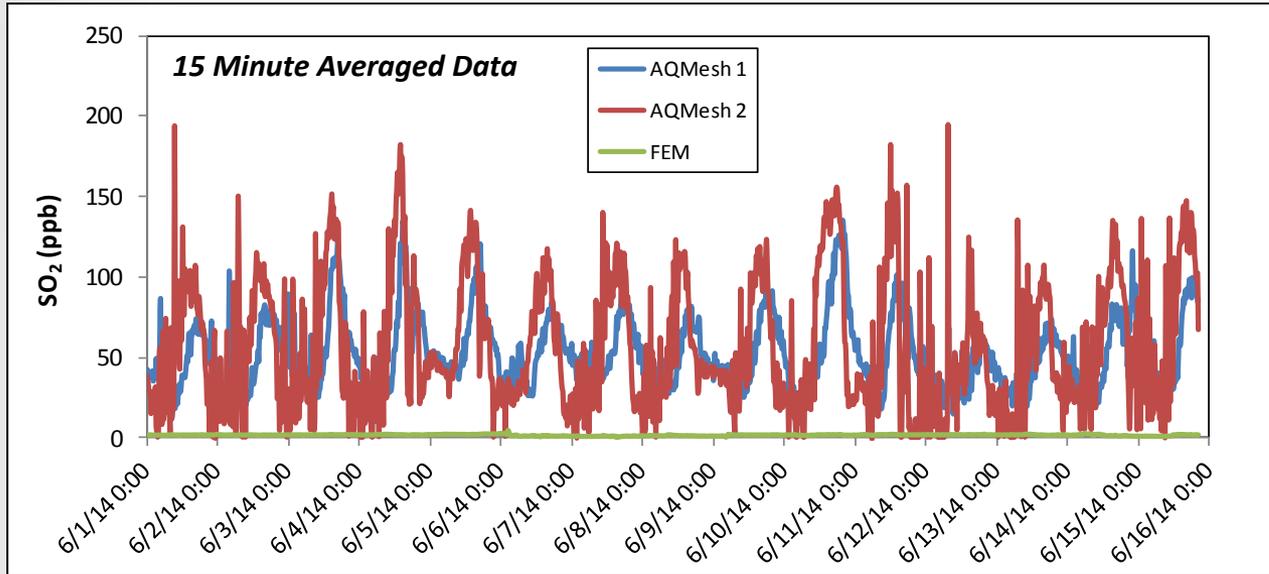


- Poor agreement between AQMesh and FRM measurements
- AQMesh readings significantly higher
- Issues discovered with NO₂ sensors which required replacement

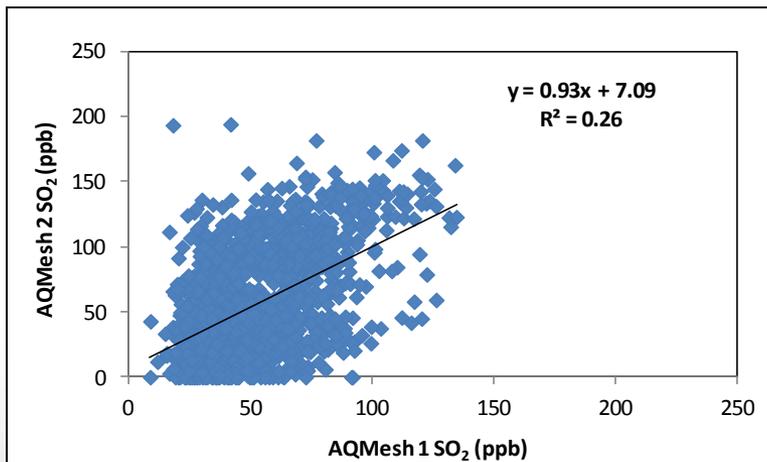




AQMesh Preliminary SO₂ Data



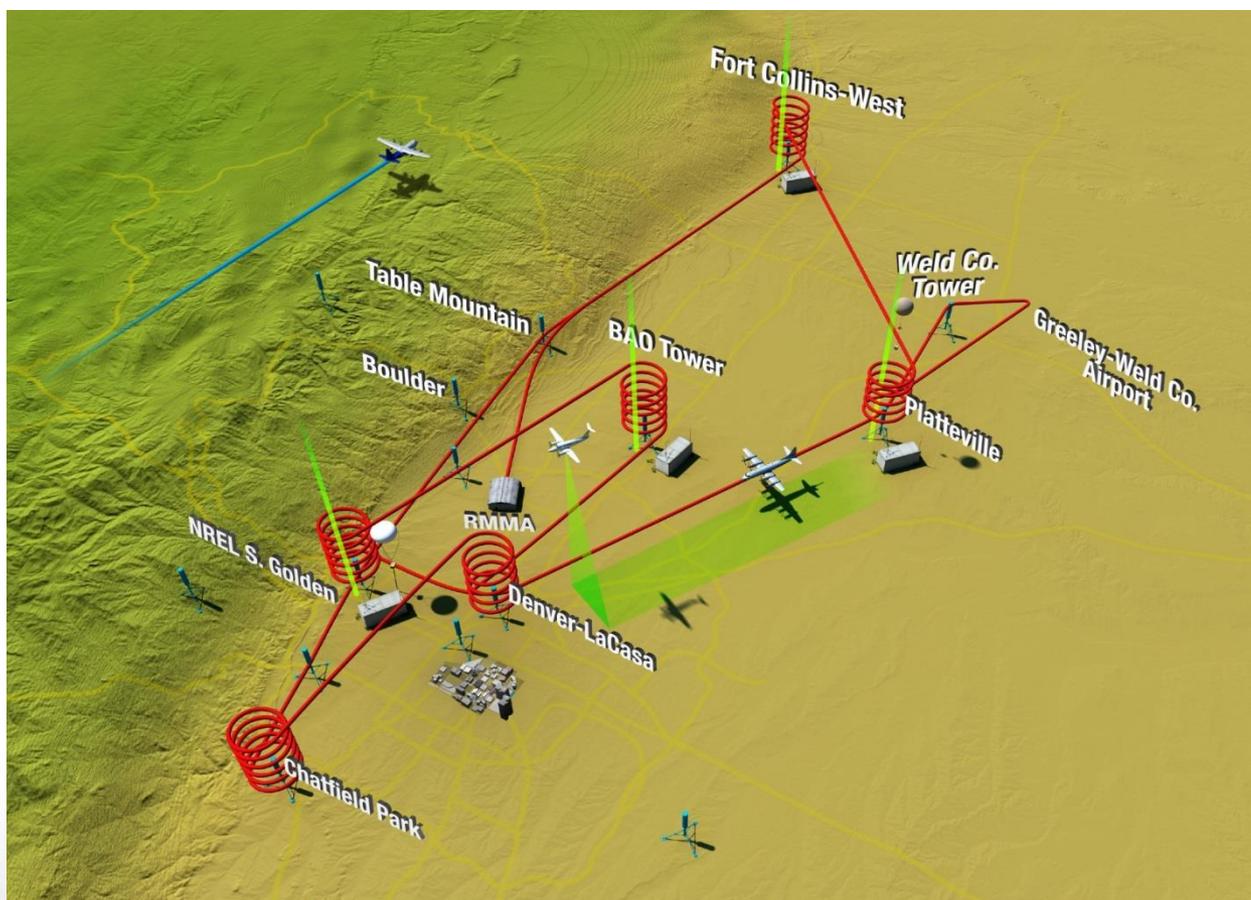
- Poor agreement between AQMesh and FRM measurements
- AQMesh readings significantly higher
- Poor agreement between both pods





Current Work

Final DISCOVER-AQ deployment in Denver, CO July 16-Aug 11, 2014

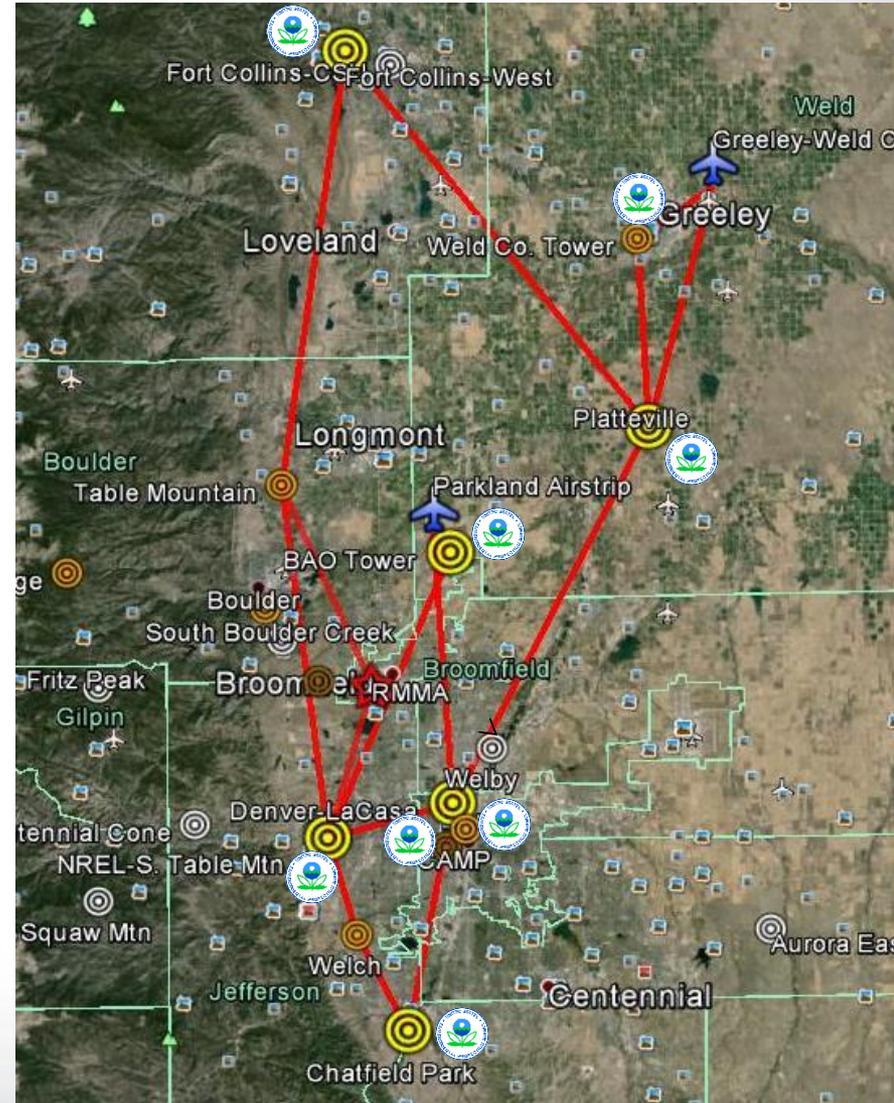


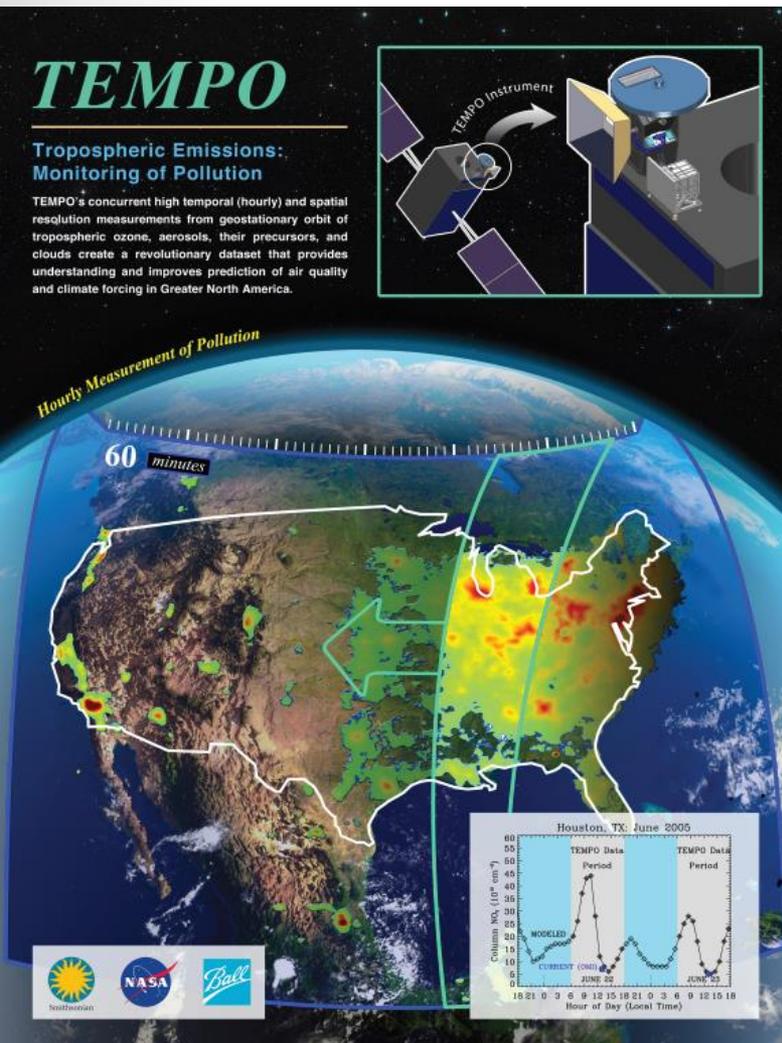


Current Work

DISCOVER-AQ Denver, CO

- Continuing to evaluate small sensor technology
 - Expanding network with new sensor technologies
 - Collocating sensors with FRM/FEM measurements
 - Understanding vertical distribution of pollutants (ground level to 300 meters)
- Citizen science and educational outreach
 - Citizens host sensors
 - Visiting local museums





TEMPO

- NASA's first Earth Venture Instrument expected to launch in 2018
- Provides hourly daylight observations to capture rapidly varying emissions & chemistry important for air quality
- Potential to use small sensor technology at ground-based sites



Acknowledgements

- Alion Science and Technology
- NASA – Jim Crawford, Mary Kleb, Luci Crittenden
- Landtec/Geotech – Angelo Bianchi
- Texas Commission on Environmental Quality – Raj Nadkarni, Mark Estes
- Citizen Scientists
 - Lomax Junior High, College Park Elementary, Heritage Elementary, Deer Park High South, Deer Park High North, DeZavela Elementary, JP Dabbs Elementary
- US EPA – Ron Williams, Neelson Watkins



**Thank You
Questions?**



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