Observations of greenhouse gases and short-lived pollutants over the Mid Atlantic States: Insight into emissions and photochemistry

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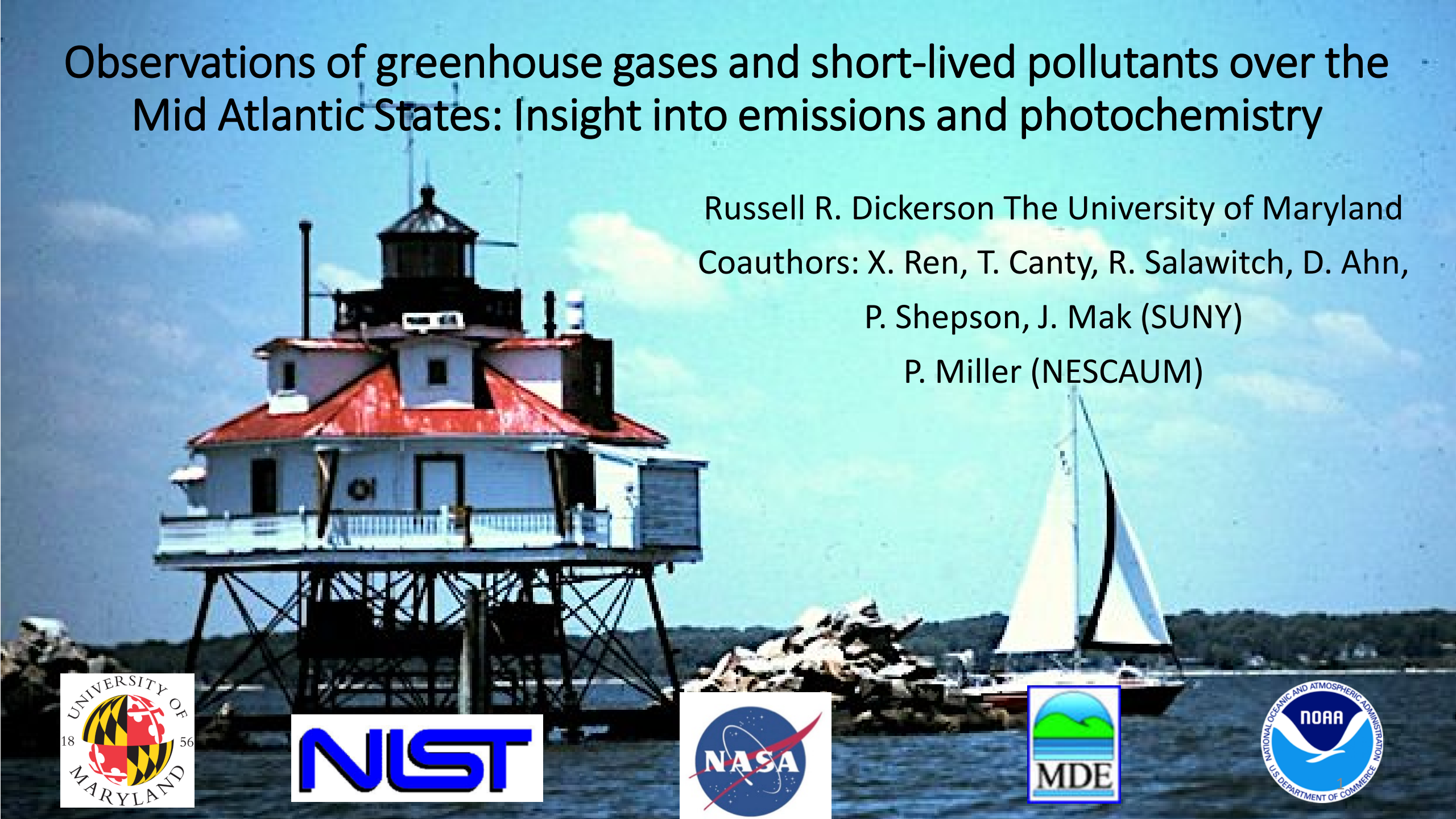
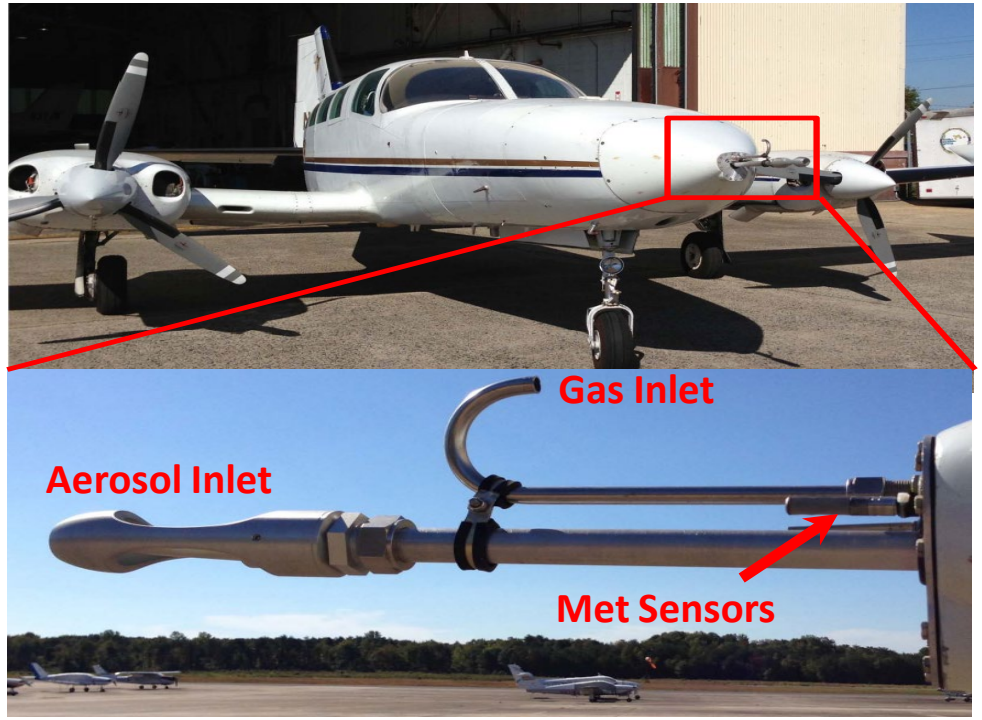


The Guilty Parties

UMD Cessna 402B Research Aircraft



GPS Position (Lat, Long, Altitude)

Met (T, RH, P, wind speed/direction)

Trace gases:

- O_3: UV Absorption, modified TECO
- SO_2: Pulsed Fluorescence, modified TECO
- $CH_4/CO_2/CO/H_2O$: Cavity Ringdown, Picarro
- NO_2: Cavity Ring Down, Los Gatos
- NO: Chemiluminescence, modified TECO
- VOCs: whole air samples

Aerosol Optical Properties:

- Scattering: b_{scat} (@450, 550, 700 nm), Nephelometer
- Absorption: b_{ap} (565 nm), PSAP

Aerosol Chemistry:

- Black/Brown Carbon: Aethalometer (370-950nm)
- Major ions and SOA: filter samples

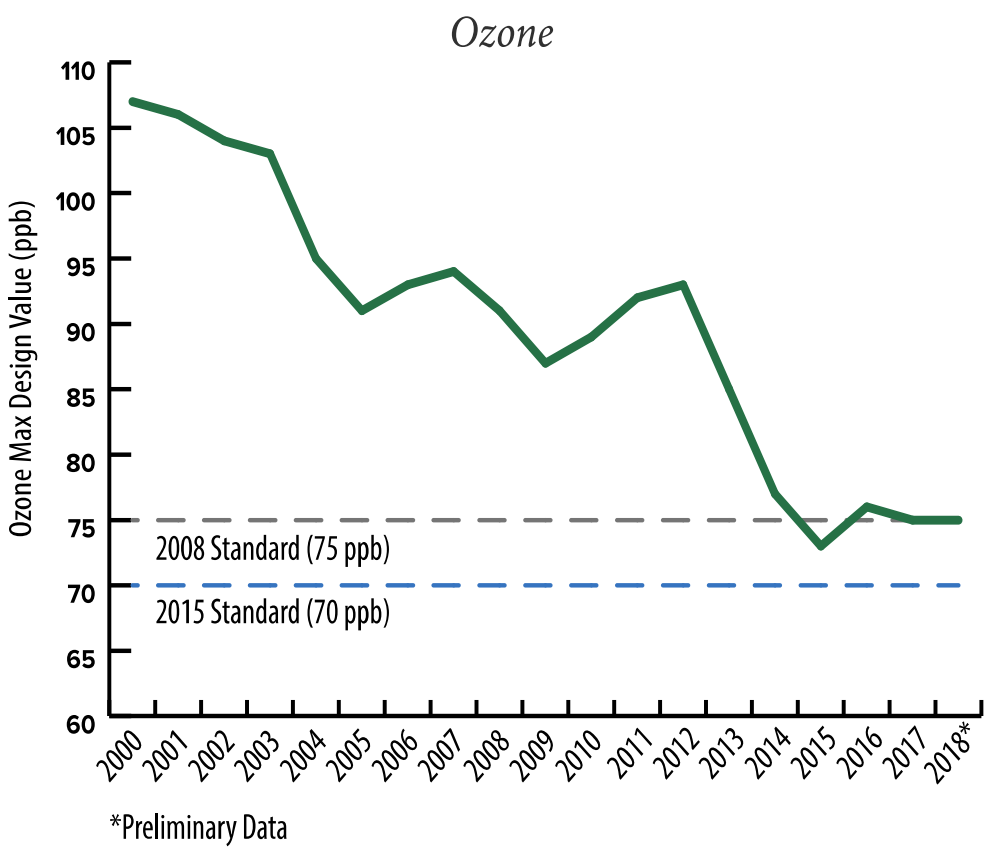
Charge

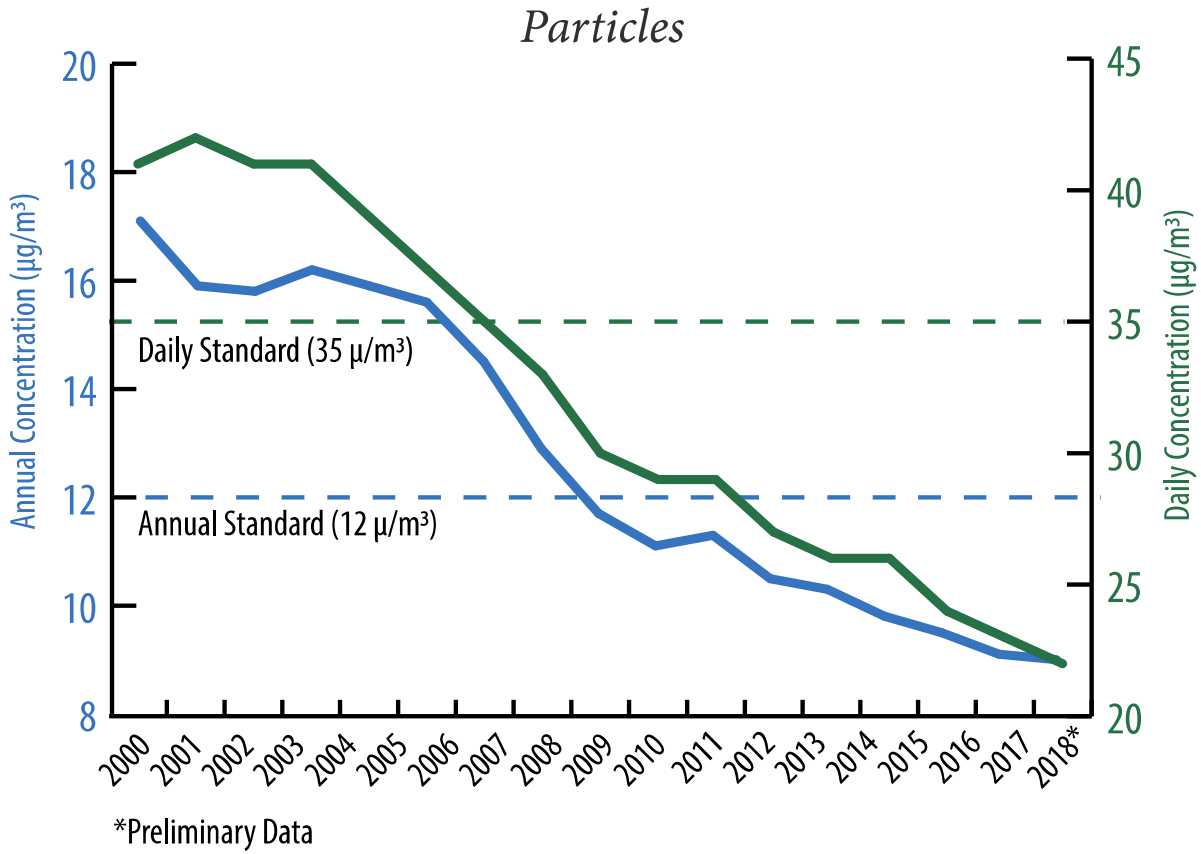
- What are the key remaining unanswered scientific questions in your area of expertise to be addressed (observational or modeling) by a future large study on wintertime western US air quality?
- How does your specific topic area tie into the big picture? What are the interrelationships between your topic area and others?
- What recommendations do you have for designing a future wintertime air quality observational or modeling study in the Western US?

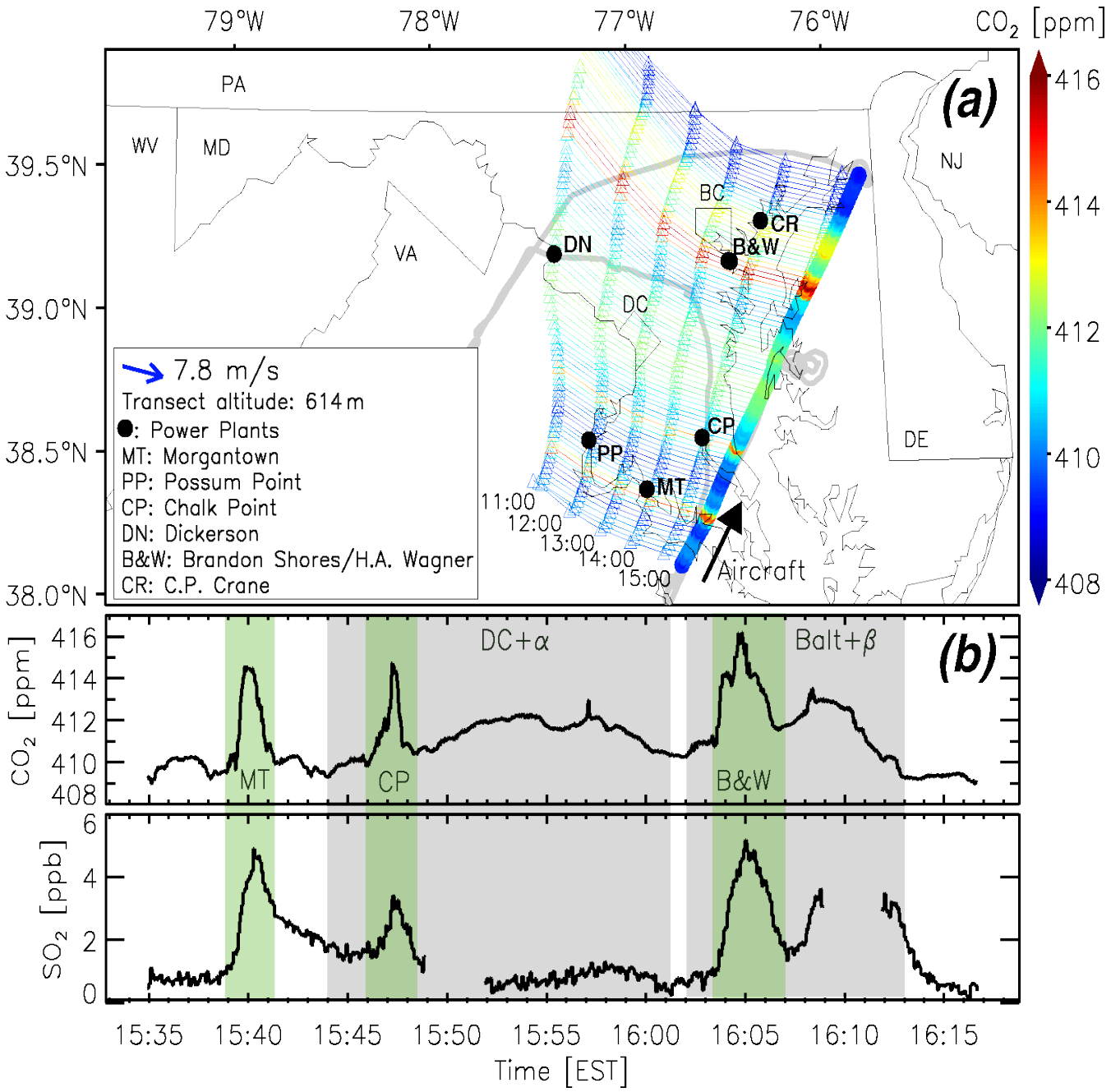
Charge

- What are the key remaining unanswered scientific questions in your area of expertise to be addressed (observational or modeling) by a future large study on wintertime western US air quality?
  - How do emissions change summer/winter?
  - Multiphase NOx chemistry?
  - Unique boundary layer meteorology – Lake breeze.
- How does your specific topic area tie into the big picture? What are the interrelationships between your topic area and others?
  - **We need a deeper understanding of the meteorology and chemistry to inform policy.**
  - Objective: to reduce ozone, PM, and N deposition.
  - Improve budgets of GHGs and short lived pollutants.
  - Calibration and measurement of Black Carbon.
- What recommendations do you have for designing a future wintertime air quality observational or modeling study in the Western US?
  - Leverage GHG measurements to understand better NOx and VOC emissions.
  - Recycling NOx on aerosols and snow.
  - Emissions from oil and natural gas operations

Air Quality Trends in Maryland





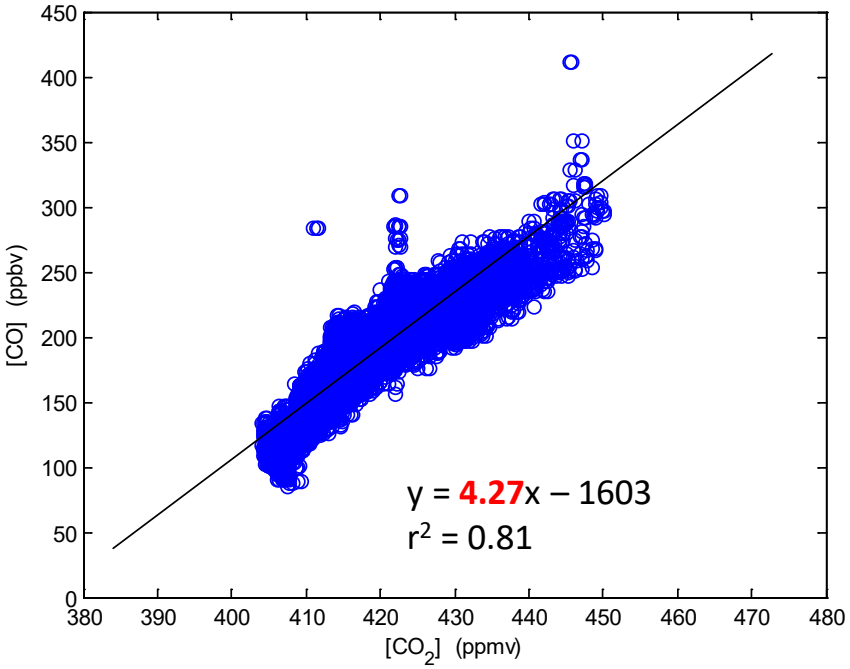


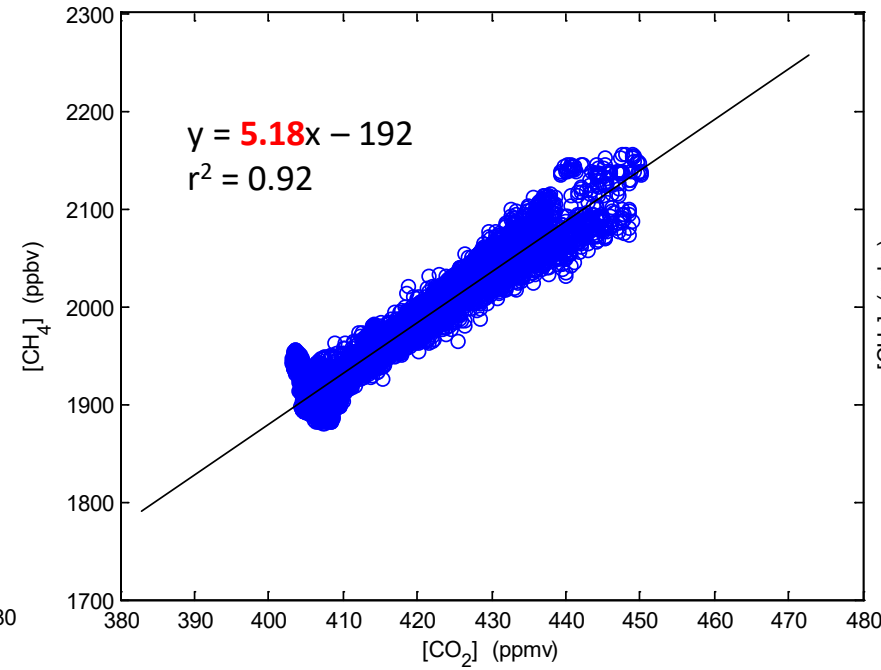
Example transect

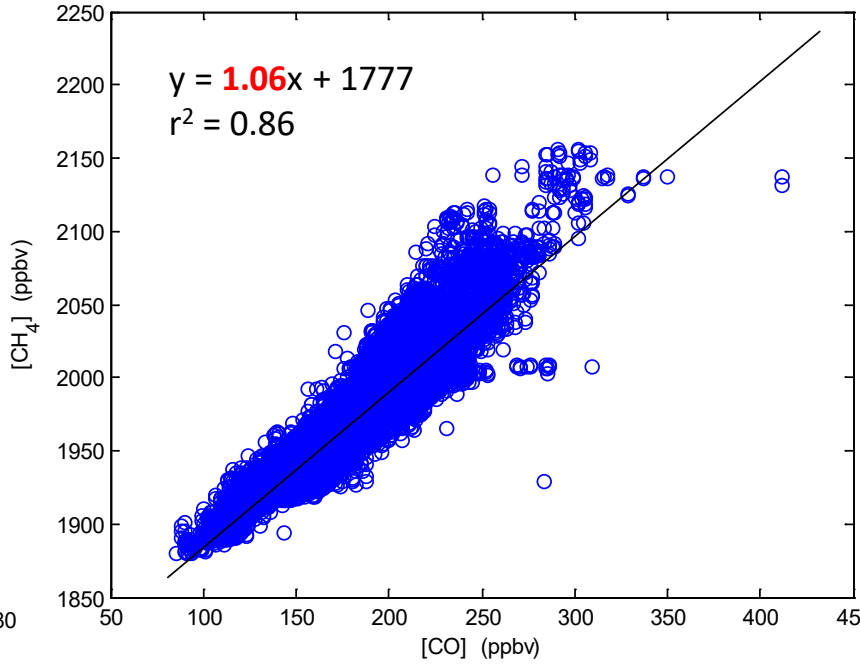
Constant altitude(s) downwind.
Spikes from point sources.
Broad plumes from urban areas.
Integrate flux through plane.
Using wings for background.

Correlation among CO, CO_2 and CH_4 over NYC

Afternoon Flight on May 18, 2017



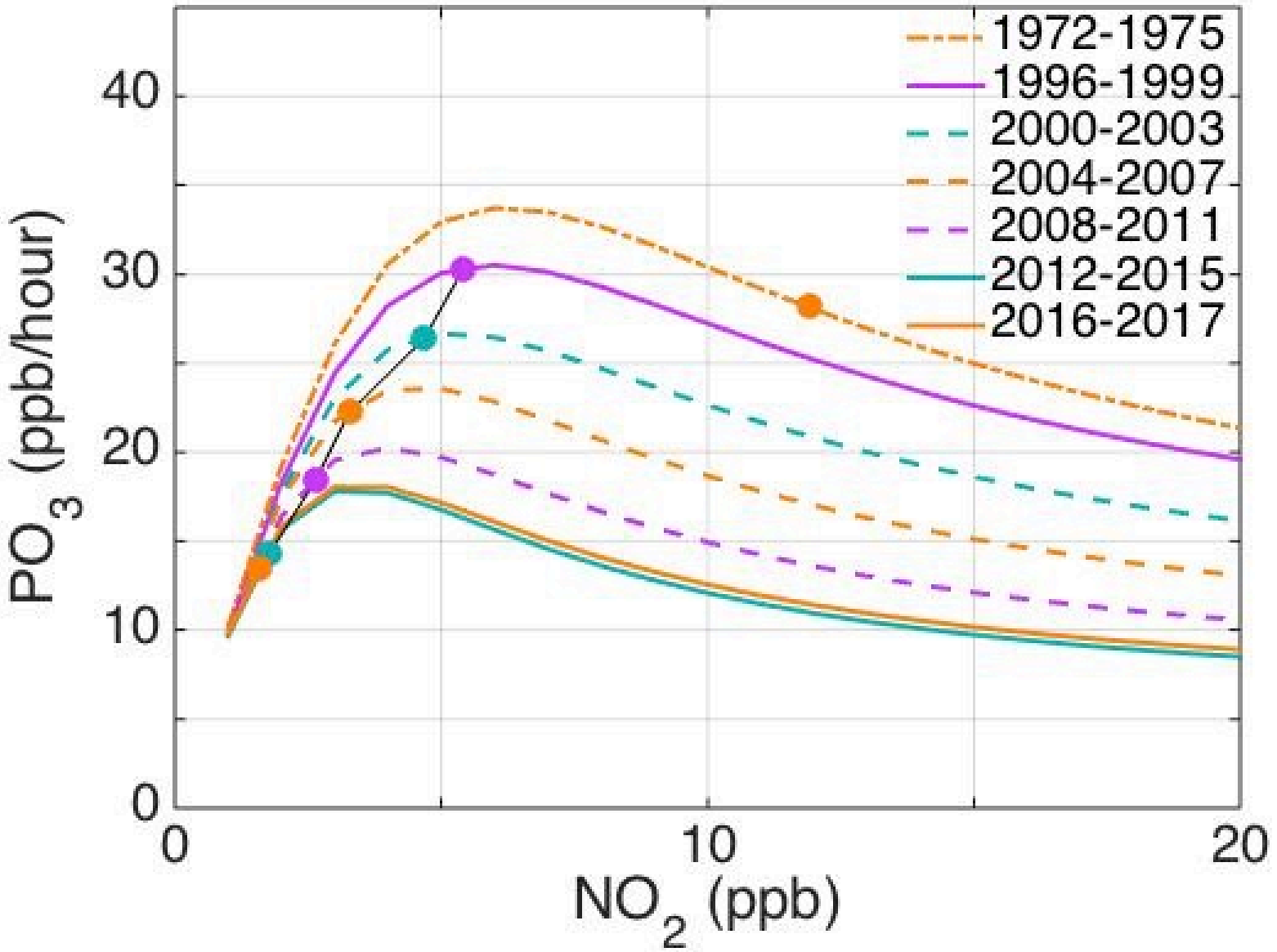




Observed CO and CO_2 , CH_4 and CO_2 as well as CH_4 and CO are well correlated.

CO and CO_2 emissions look good,

but CH_4 emissions may be underestimated by a factor of 2-3.

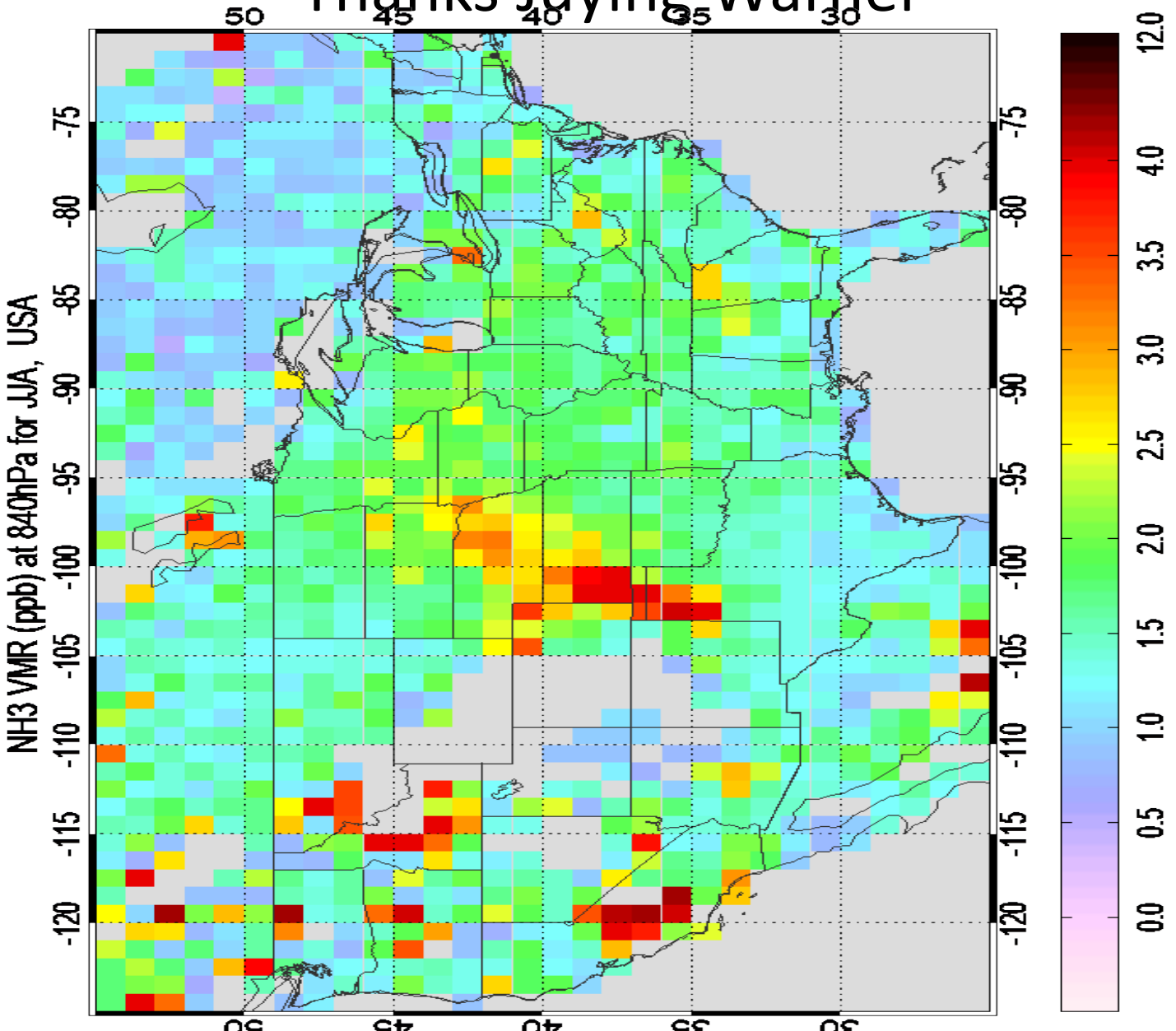


Using surface obs and a box model, calculated rate of production of ozone in the Balt/Wash area went up before it went down.

Region-wide NOx controls worked.

From Sandra Roberts' preprint.

AIRS NH_3 - maybe. Ag and fires
Thanks Juying Warner



Recent Findings

- Field experiments indicate that NOx emissions inventories are about right in **winter**, but overestimated in **summer** (Salmon et al., 2018; Hall et al. in prep., 2019).
- Mass balance flights improve understanding of GHG emissions in Balt/Wash/NYC and Marcellus.
    - Urban CO_2 emissions inventories are pretty close, but CH_4 underestimated (Ren et al. 2018, 2019; Plant et al., 2019)
    - Losses of CH_4 from natural gas operations may be (Vinciguerra et al., 2015; Ren et al., 2019; Barkley et al. 2019).
- Needed policy relevant science,
    - Relative strength of NOx sources:
    - Understand land/sea interface
    - Emissions: Identify key VOC species & source: isoprene dominates.
    - Ozone got worse before it got better.

Recent Findings

- Commercial “NOx” analyzers must be used with caution (Dickerson et al., *Atmos. Environ.,* 2019)
- CMAQ with CB05 underestimates RO_2 + HO_2 (ratio NO_2:NO) (Hembeck et al., 2019) perhaps due to H_2CO or consumer VOCs (McDonald).
- Improvements in Black Carbon standards and measurements (Zangmeister (NIST) et al. *AST*, 2019).
- Mesoscale meteorology (sea or bay breeze) can create ozone events (Mazzuca et al., 2017; 2019; Martin et al., 2019).
- Low cost sensors can measure CO_2 to better than 2 ppm (Martin et al 2017).
- AIRS measures NH_3 at 920 hPa (Warner et al. 2016;17); good for Utah?

The End

Fear the Turtle!

Reprints can be found at http://www.atmos.umd.edu/~russ/recent_pubs.html

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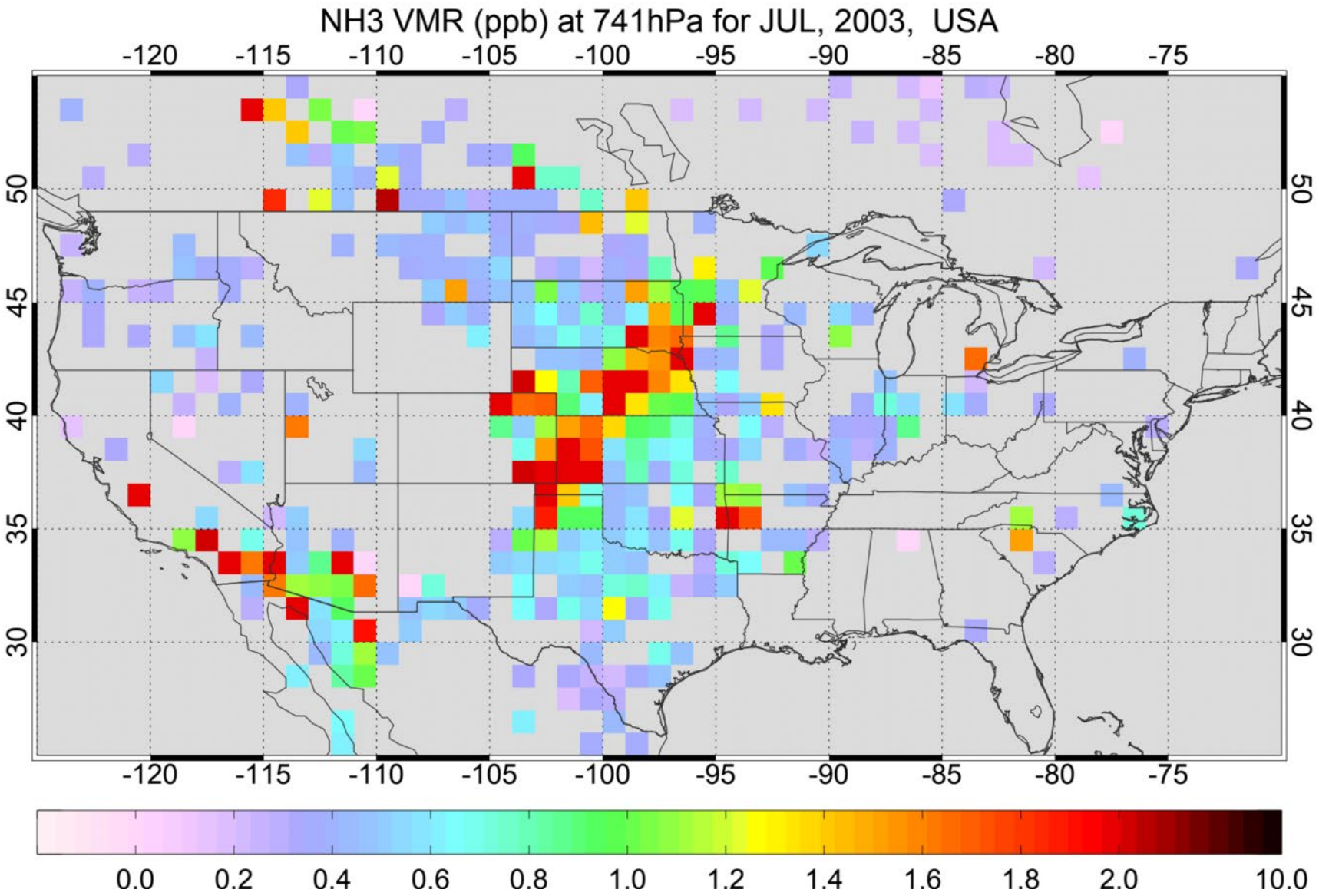
AIRS NH_3 - maybe. Thanks Juying Warner



Local transport

More ozone over the Bay

Fair weather cumulus (humilis) often form over the warm land but not over the Bay.

Abatement of regional ozone allows us to tailor new measures see Ring's et al., 2019; Hembeck et al., 2019.

Stauffer et al., 2012; Goldberg et al. 2014; Loughner et al., 2014; Mazzuca et al., 2017, 2018.

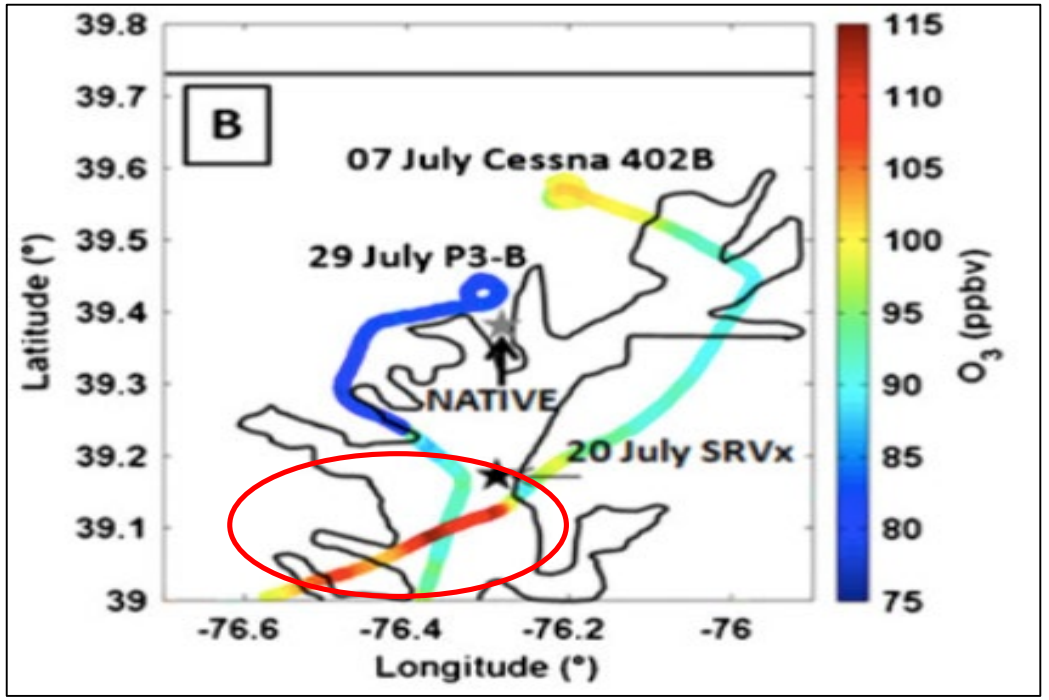
Fig. 13. Visible image from the MODIS satellite at 1610Z (2:10 PM local time) on July 20, 2011 showing the presence of low-level cumulus clouds only over the land.

Coastal areas are subject to sea/bay breezes as a result of the land-water temperature contrast

- Higher O_3 concentrations over water than the adjacent land (Goldberg et al., 2014)
- Bay breezes can advect high O_3 from water to land (Stauffer et al., 2012, Loughner et al., 2014)
- Thunderstorms interact the Bay breezes and don't always kill ozone events (Mazzuca et al., 2018).
- Baltimore NOx emissions (CEMS) highest on ozone days at Hart-Miller Island (Dreessen et al., AGU 2018).

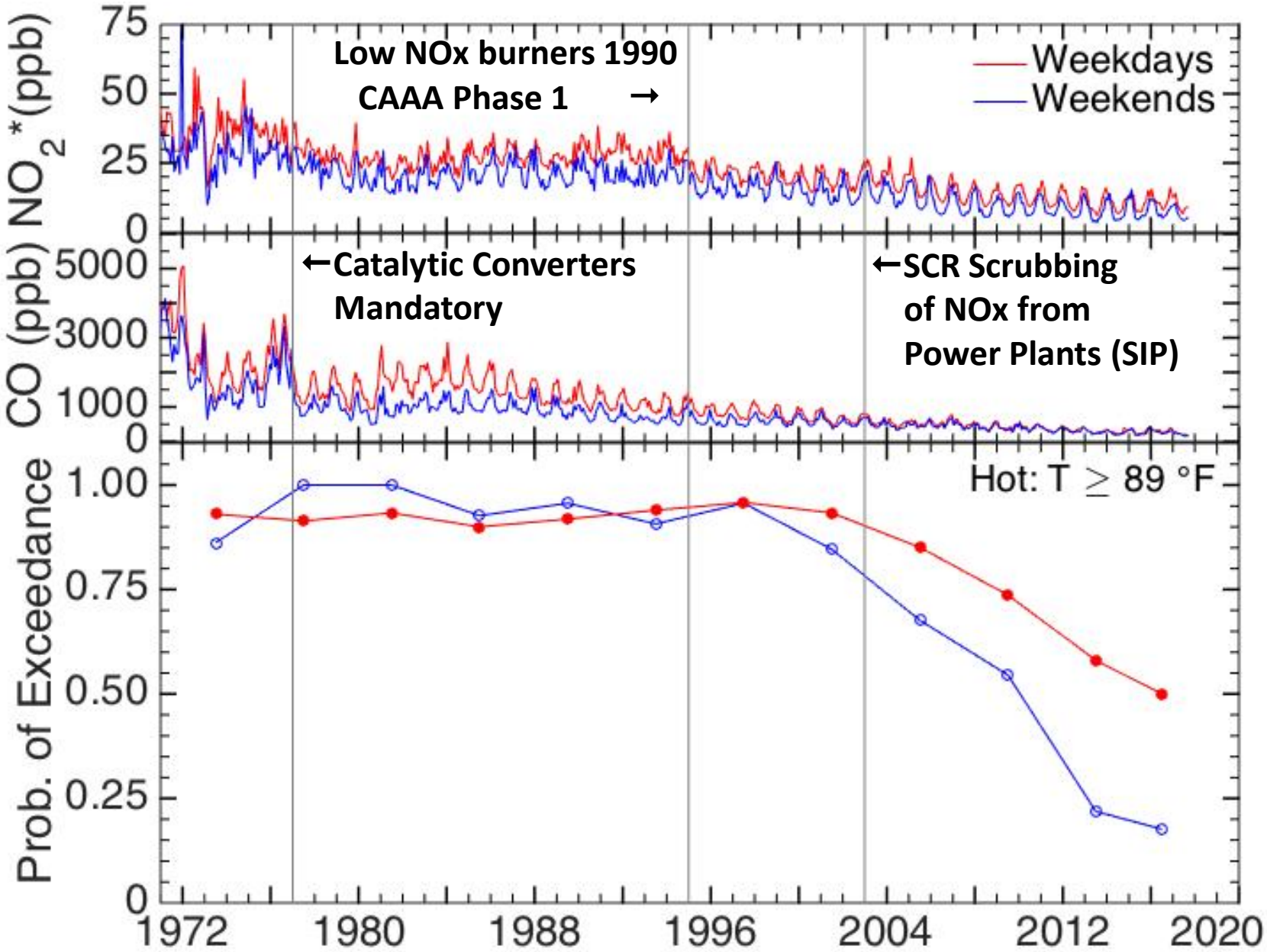
Goldberg et al., 2014 *Atmos Envi.*

MODIS vis. image of Shallow-cu along the Chesapeake bay breeze front



Stauffer et al., 2012 *J. Atmos Chem*

Higher O_3 conc. observed by the UMD Cessna over the Chesapeake Bay at low altitudes.



Surface obs from the Baltimore/Washington region – suffered severe ozone for decades.

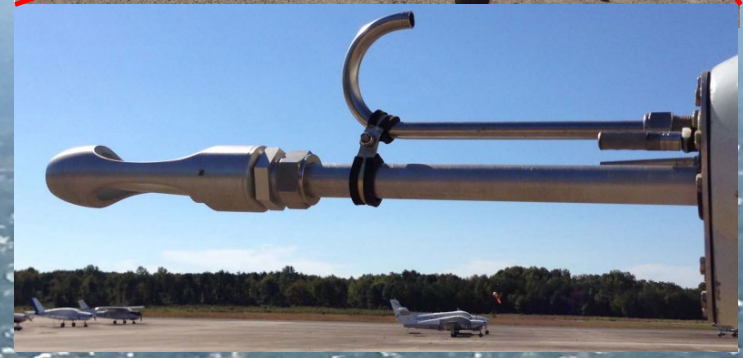
Initial VOC & CO controls had little effect.

Region-wide NOx controls worked.

From Sandra Roberts' preprint.

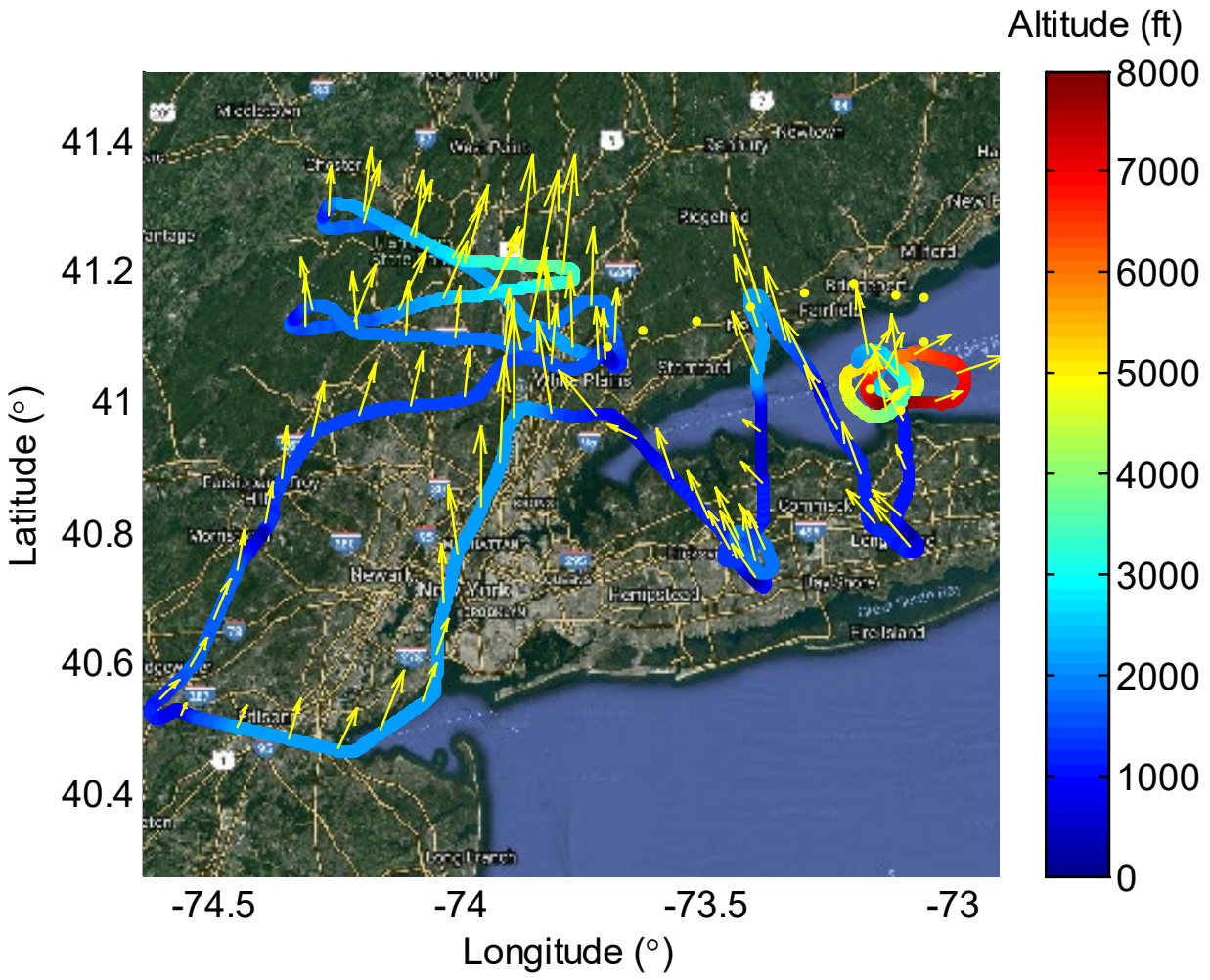
Connecticut Coast

Xinrong Ren photo 2017

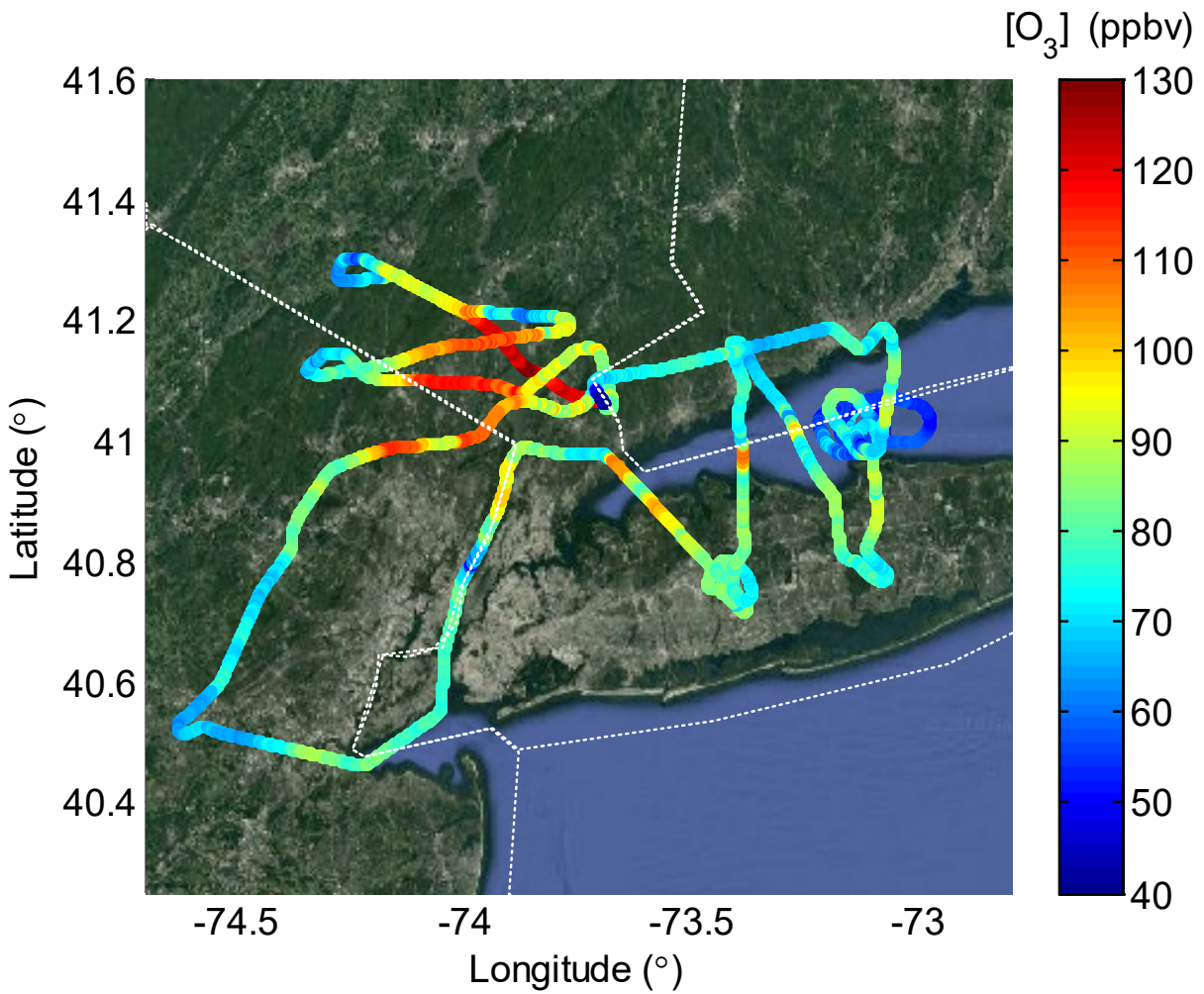


UMD Cessna LISTOS Flights on Monday, 7/2/2018

Morning Flight (~9:00-12:30 EDT)



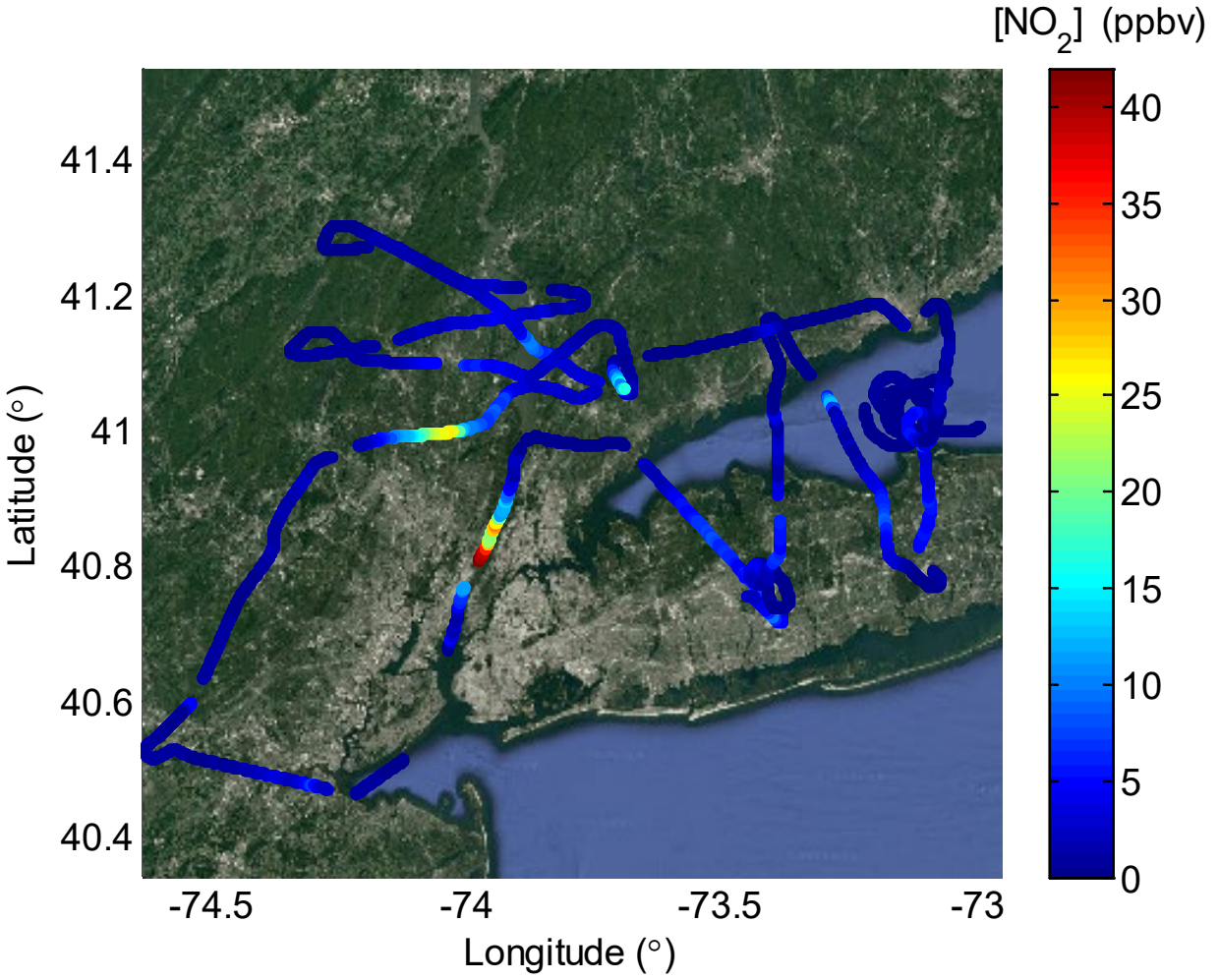
Yellow arrows show WD (generally S) and relative WS.



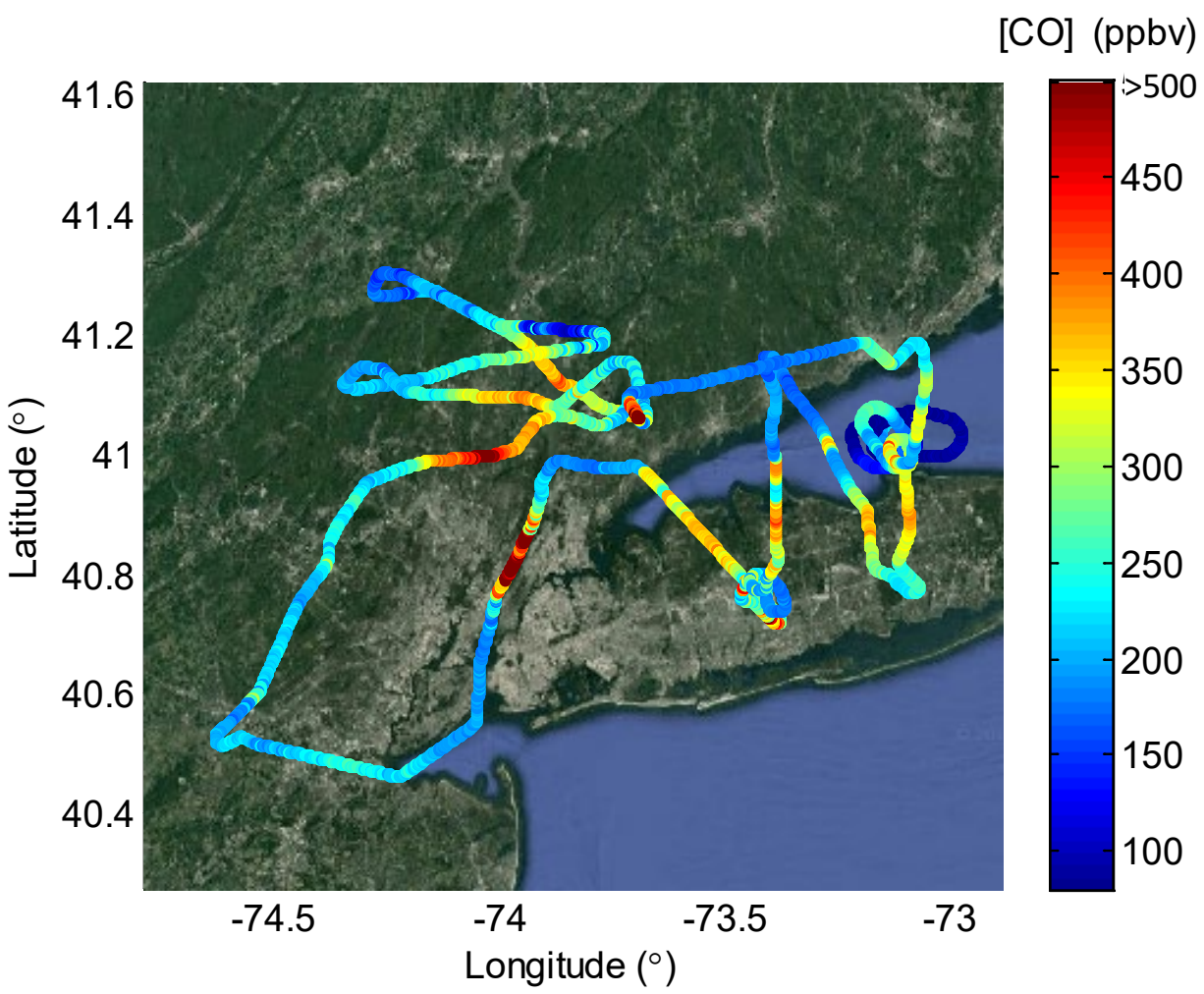
High O_3 was already produced north of NYC in the late morning.

UMD Cessna LISTOS Flights on Monday, 7/2/2018 **heavy** primary **pollution**

Morning Flight (~9:00-12:30 EDT)



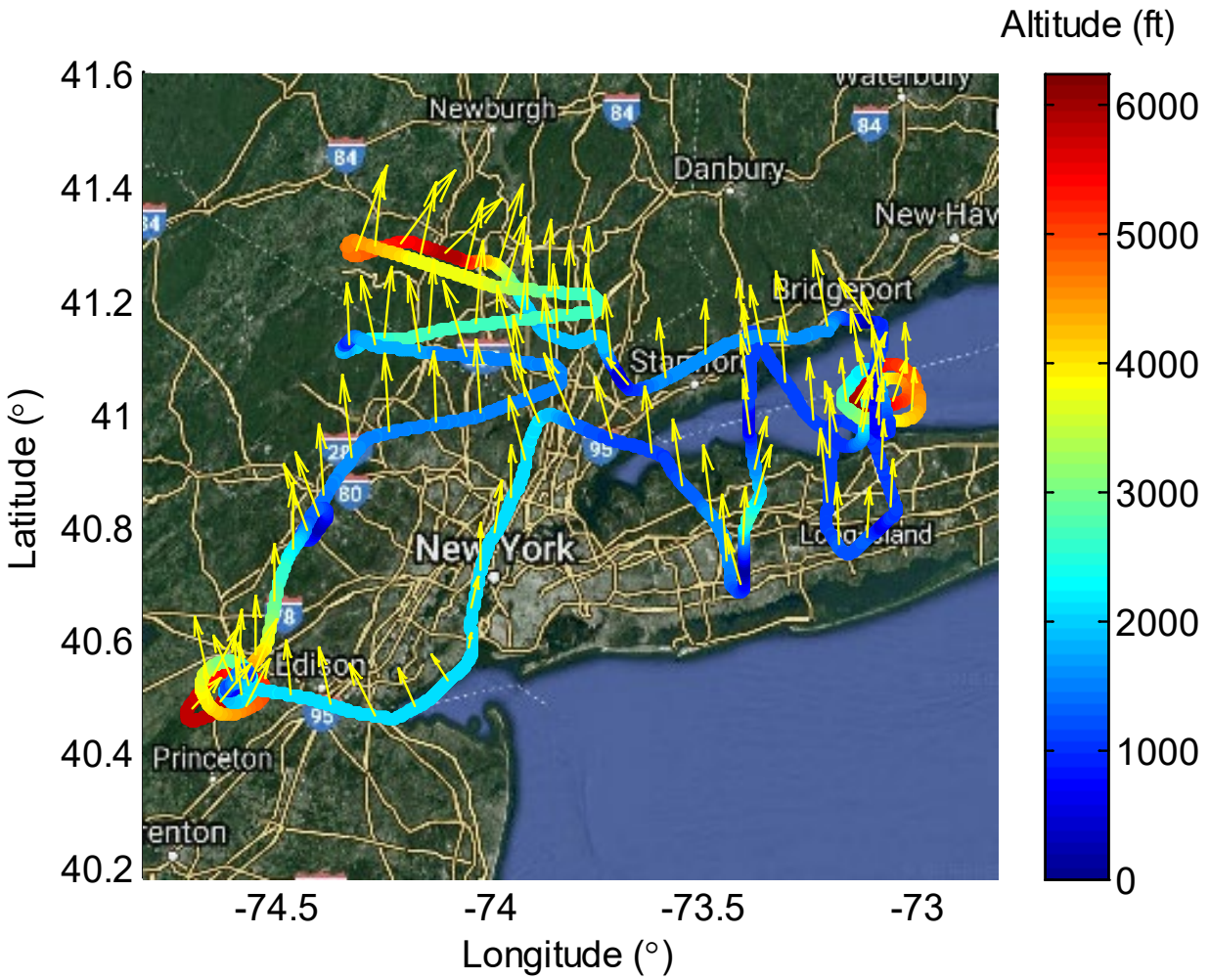
- Max. [NO_2]~42 ppb observed over Hudson River at 650 m altitude.



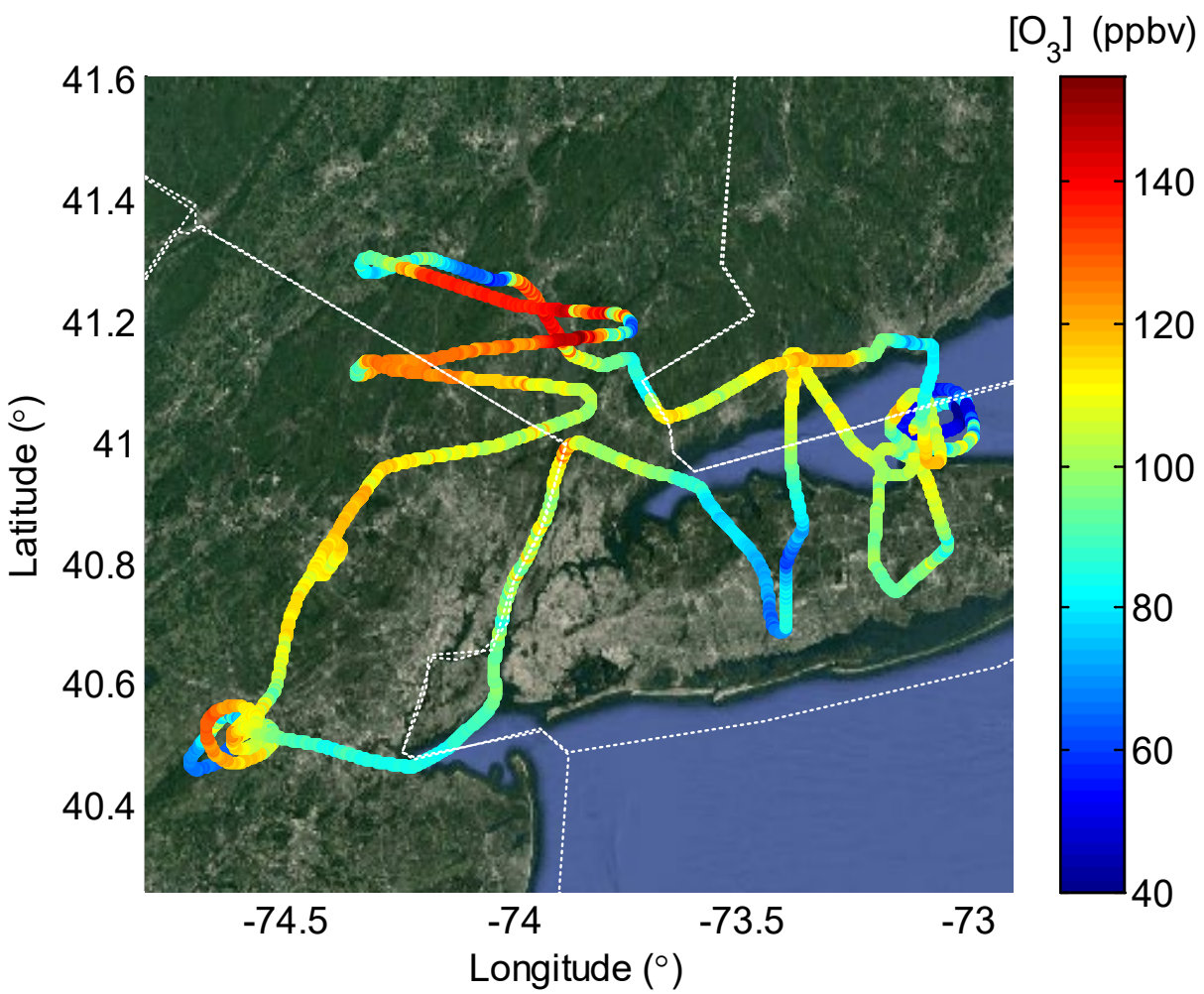
- 800-900 ppbv CO over Hudson River @ 650 m
- ~500 ppbv CO downwind of NYC at ~350m.

UMD Cessna LISTOS Flights on Monday, 7/2/2018

Afternoon Flight (~3:00-6:30 PM EDT)



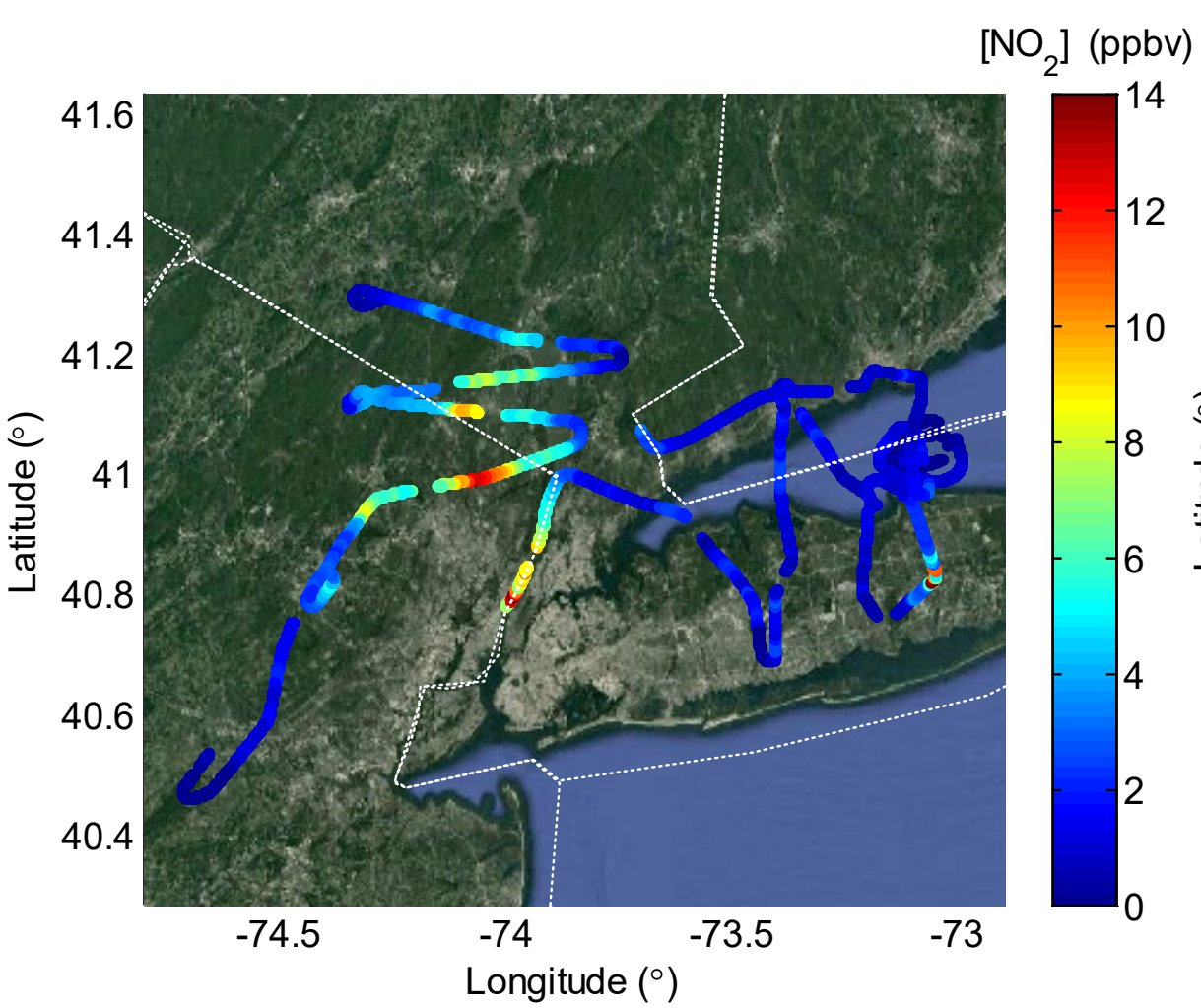
Yellow arrows show WD (southerly) and relative WS.
Spirals near Flax Pond and the Rutgers site.

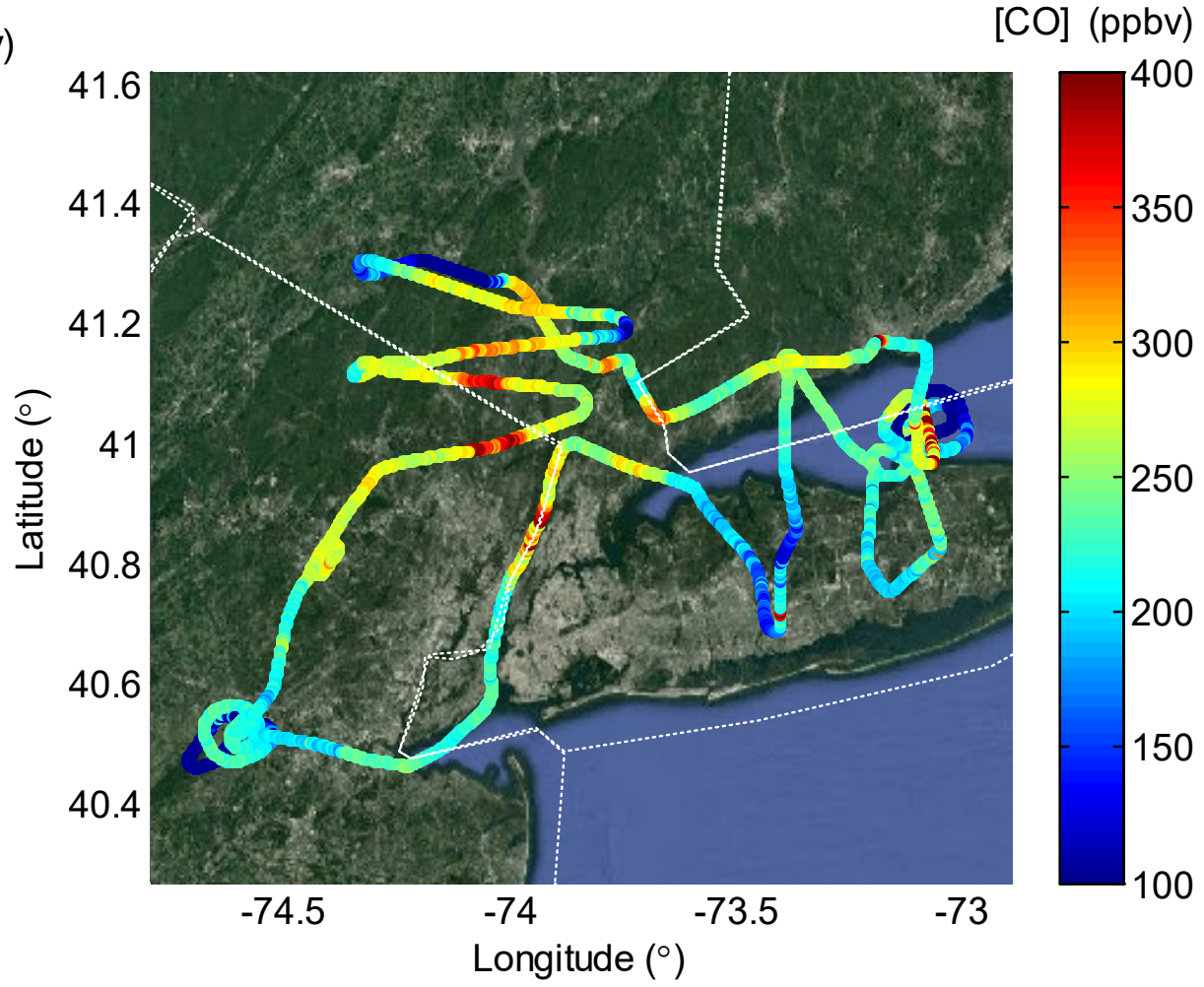


Max. 1 min [O_3] **~ 150 ppb** to the north of NYC.

UMD Cessna LISTOS Flights on Monday, 7/2/2018

Afternoon Flight (~3:00-6:30 PM)





- Still high NO_2 and CO concentrations in the NYC outflow