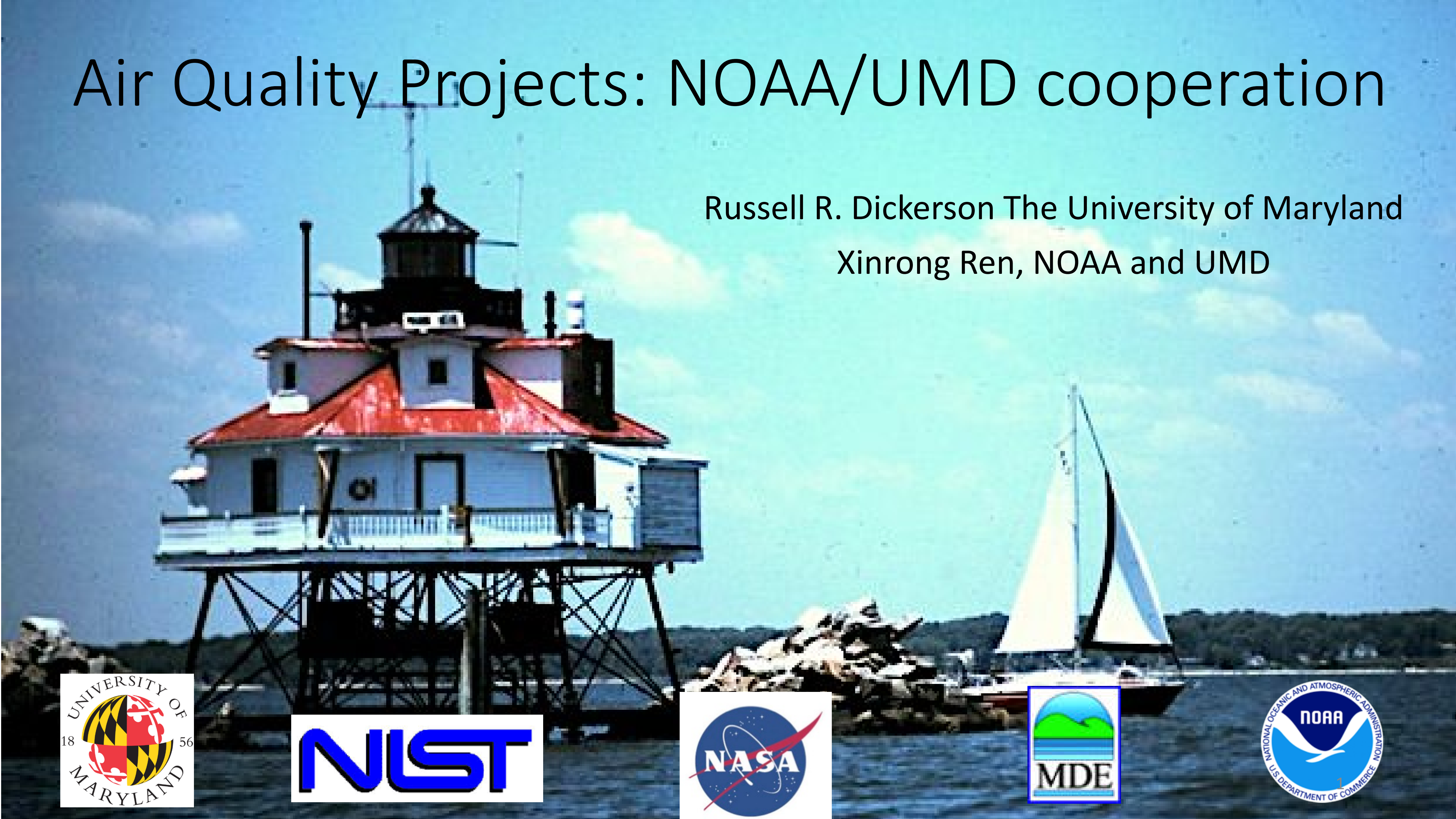
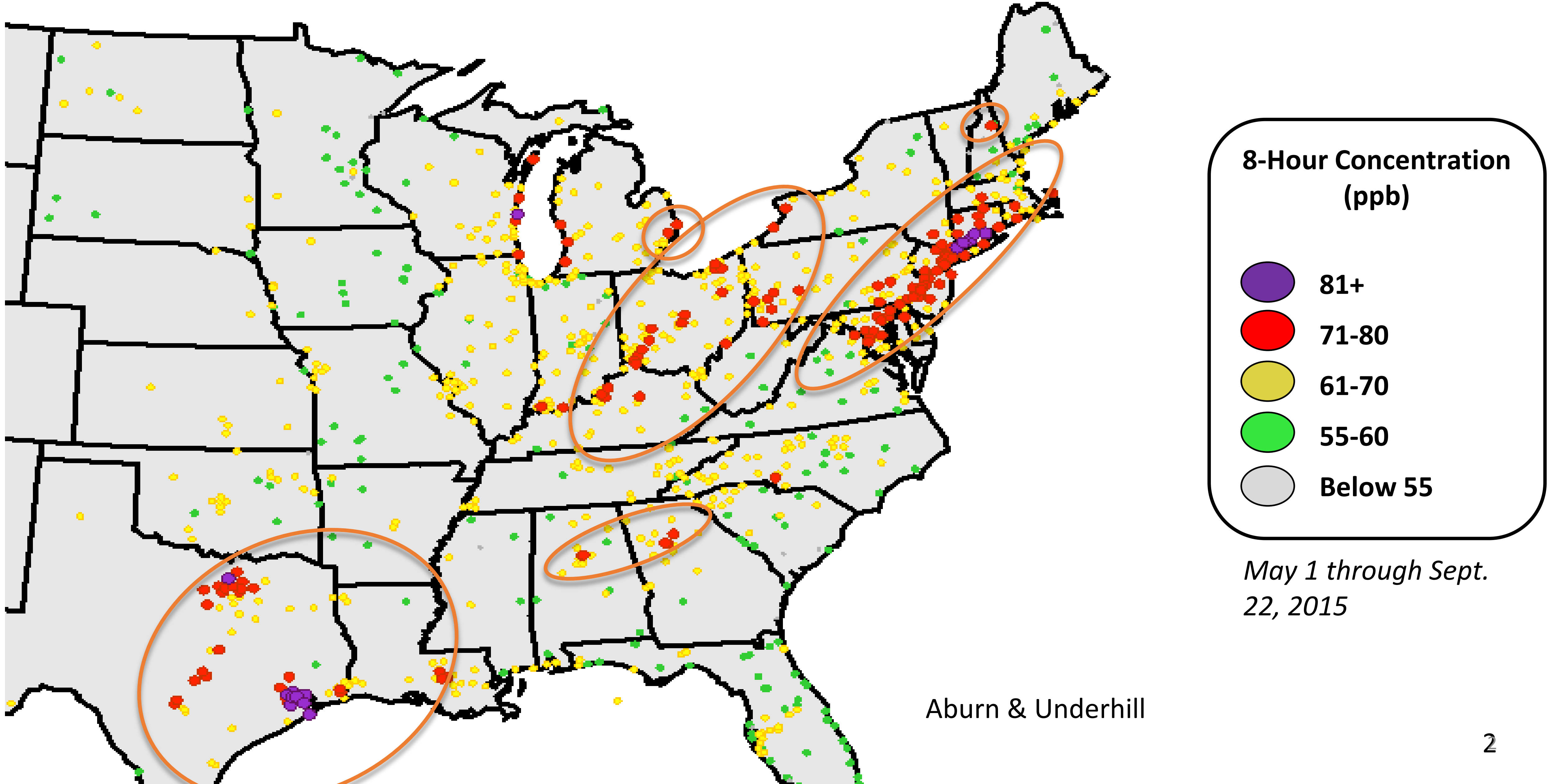
Air Quality Projects: NOAA/UMD cooperation

Russell R. Dickerson The University of Maryland

Xinrong Ren, NOAA and UMD



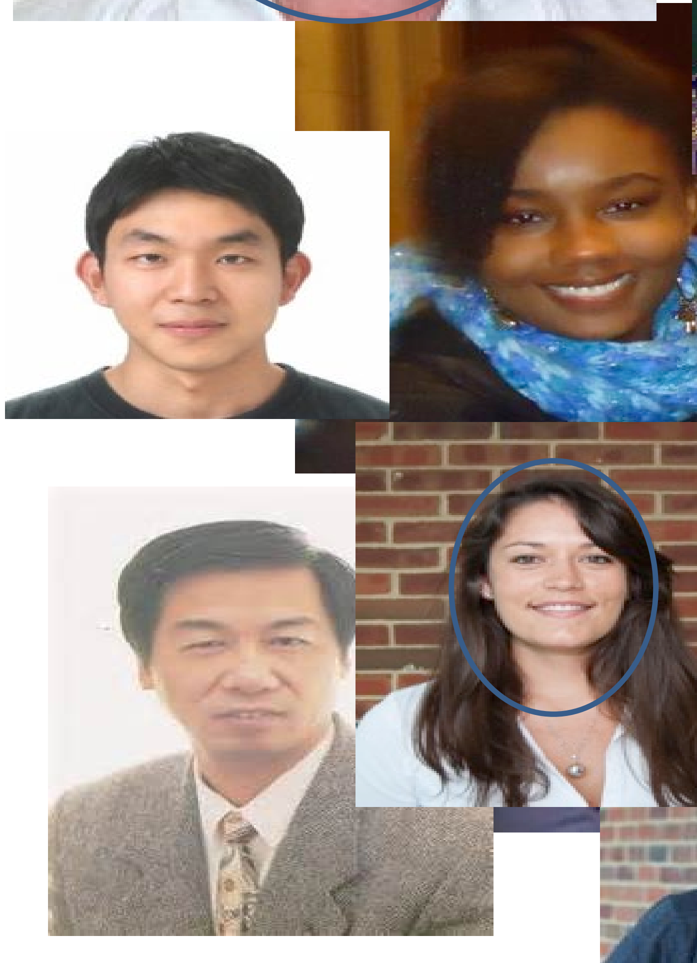
The crime.

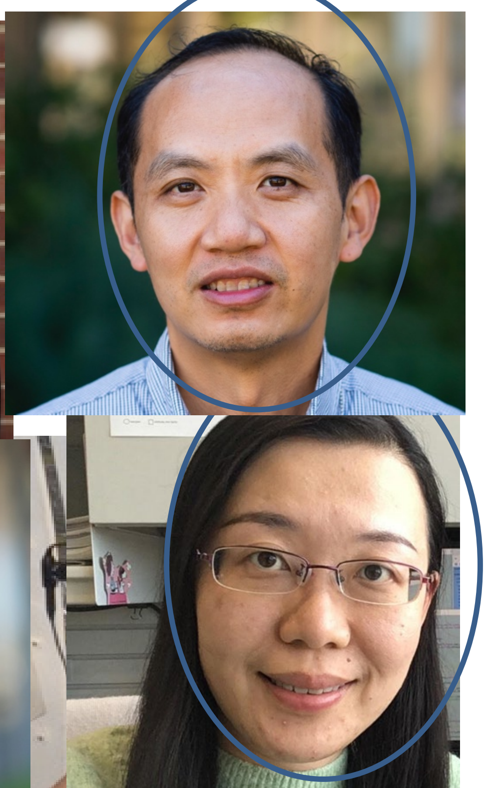


May 1 through Sept. 22, 2015

Aburn & Underhill

The Guilty Parties





ARL and UMD work together to identify the gaps in our knowledge of the fundamental meteorology and chemistry that impede our ability to attain the Air Quality Standards, then to put this new knowledge into practice.

We are drowning in information, while starving for wisdom. The world henceforth will be run by synthesizers, people able to put together the right information at the right time, think critically about it, and make important choices wisely.

E. O. Wilson

I. Development of NOAA HYSPLIT (HYbrid Single Particle Lagrangian Integrated Trajectory) Inverse Modeling System;

Task Leader: Dr. Tianfeng Chai.

II. Field measurements of mercury and related variables.

Task Leader: Mr. Paul Kelley

III. Top-down estimation of natural and anthropogenic emissions.

Task Leader: Dr. Hyun Cheol Kim

IV. Support for dispersion modeling at the Air Resources Laboratory.

Task Leader: Dr. Fong "Fantine" Ngan

V. Trace gases and HYSPLIT.

Task Leader Dr. Xinrong Ren

VI. AOSC JPSS Initiative for Improving Volcanic Hazard Monitoring and Forecasting

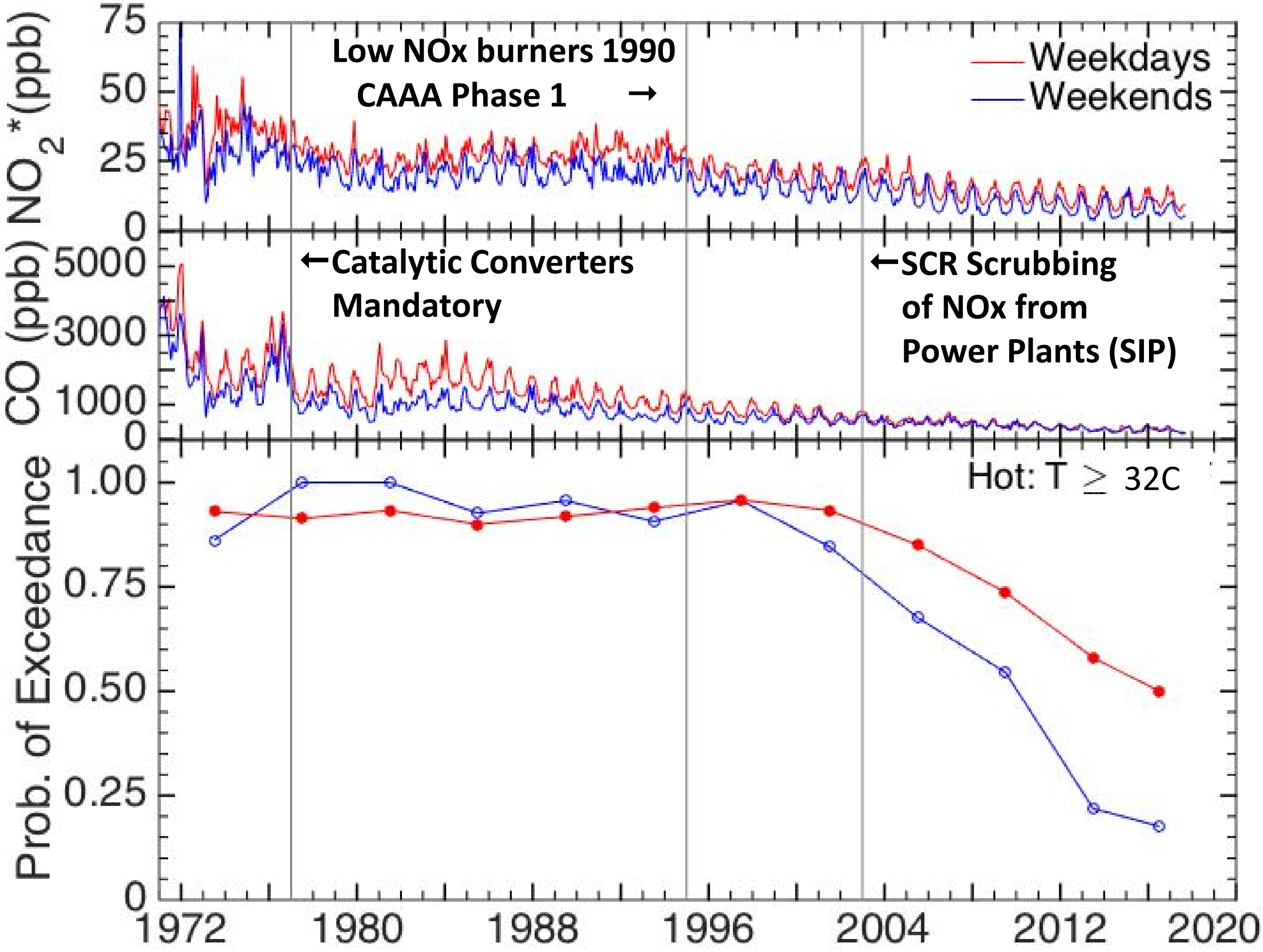
Task Leader Dr. Allison Ring

VII. Air Quality Prediction Improvement, Data Assimilation and Emission Development

Task Leader Dr. Youhua Tang

Outline

- Air Quality
  - Forecast. Fly/nofly. (Pius Lee)
  - SIP (State Implementation Plan), MDE (Maryland Dept. Environment)
  - OWLETS and LISTOS (NASA and NESCAUM; New York)
  - NASA AQAST AND HAQAST
- Trajectories and dispersion (HYSPLIT)
  - Power Plant Plumes
  - Tracing sources; Actionable intelligence
  - Sea and bay breeze (micrometeorology)
- Greenhouse Gases and NIST
  - Emissions of natural gas twice as high as in inventory
  - GHG Reduction Act.



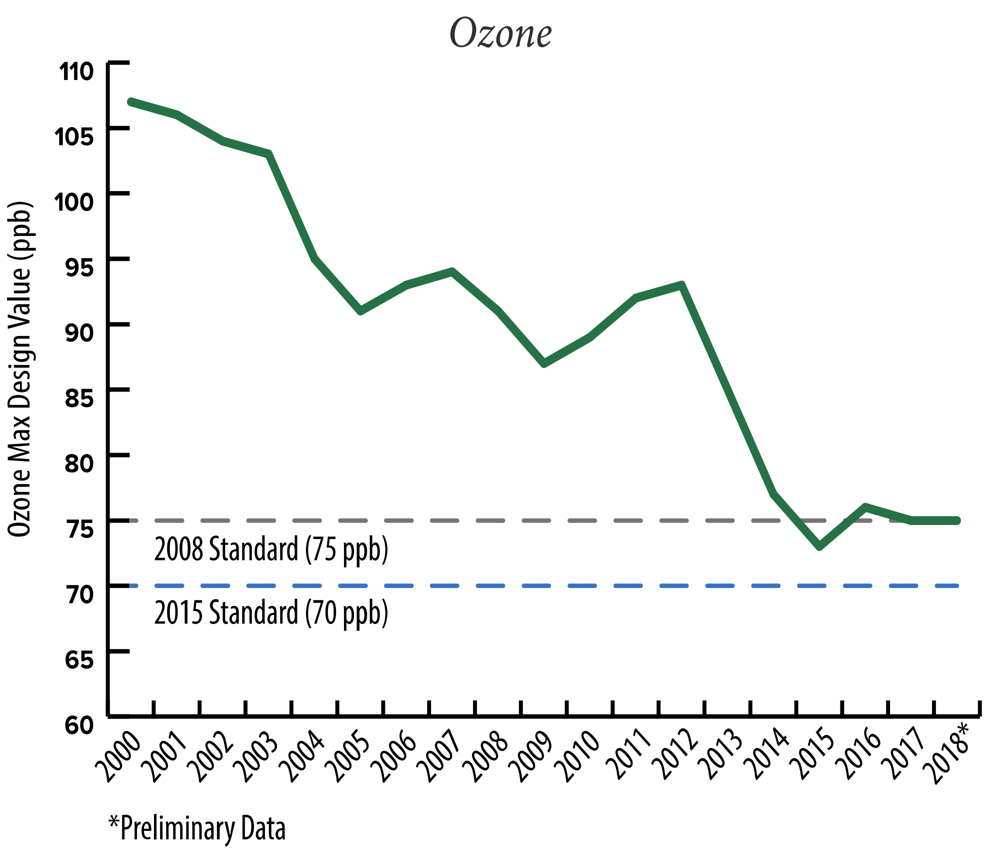
Surface obs from the Baltimore/Washington region – suffered severe ozone for decades.

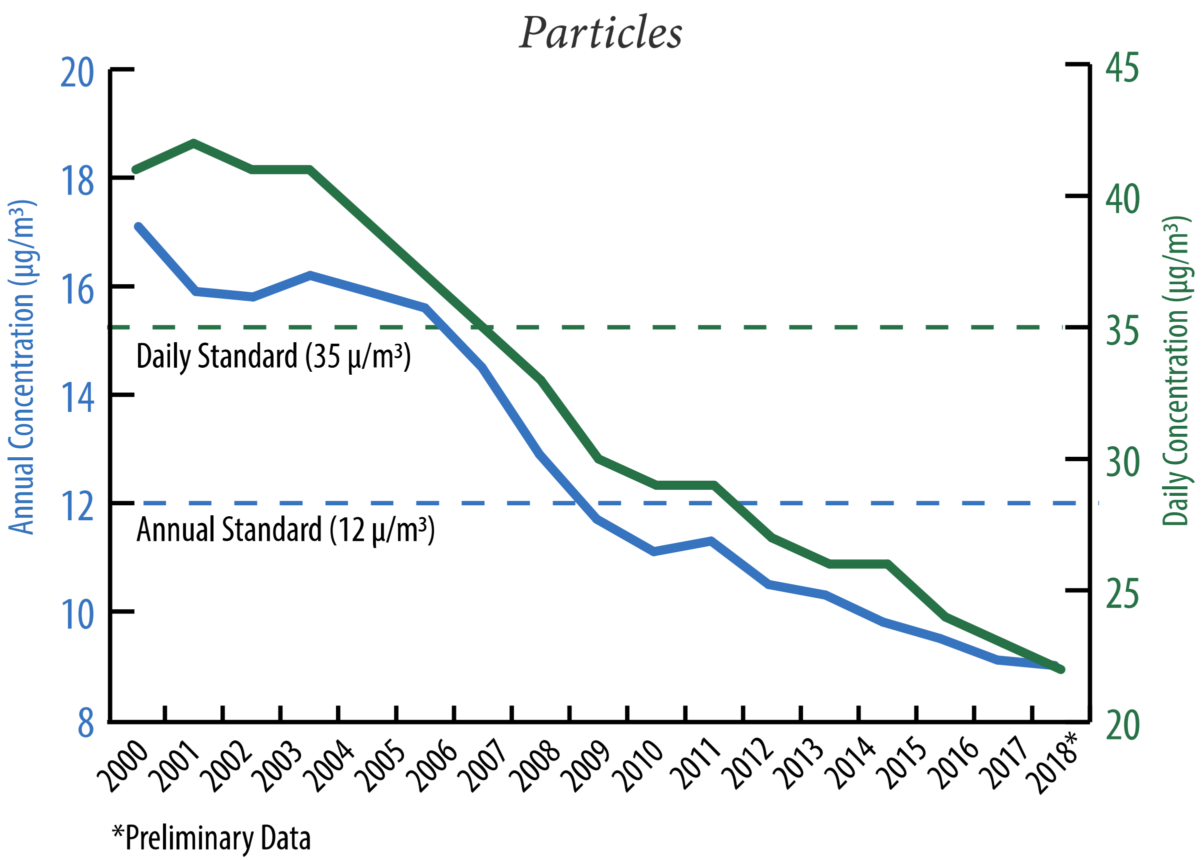
Initial VOC & CO controls had little effect.

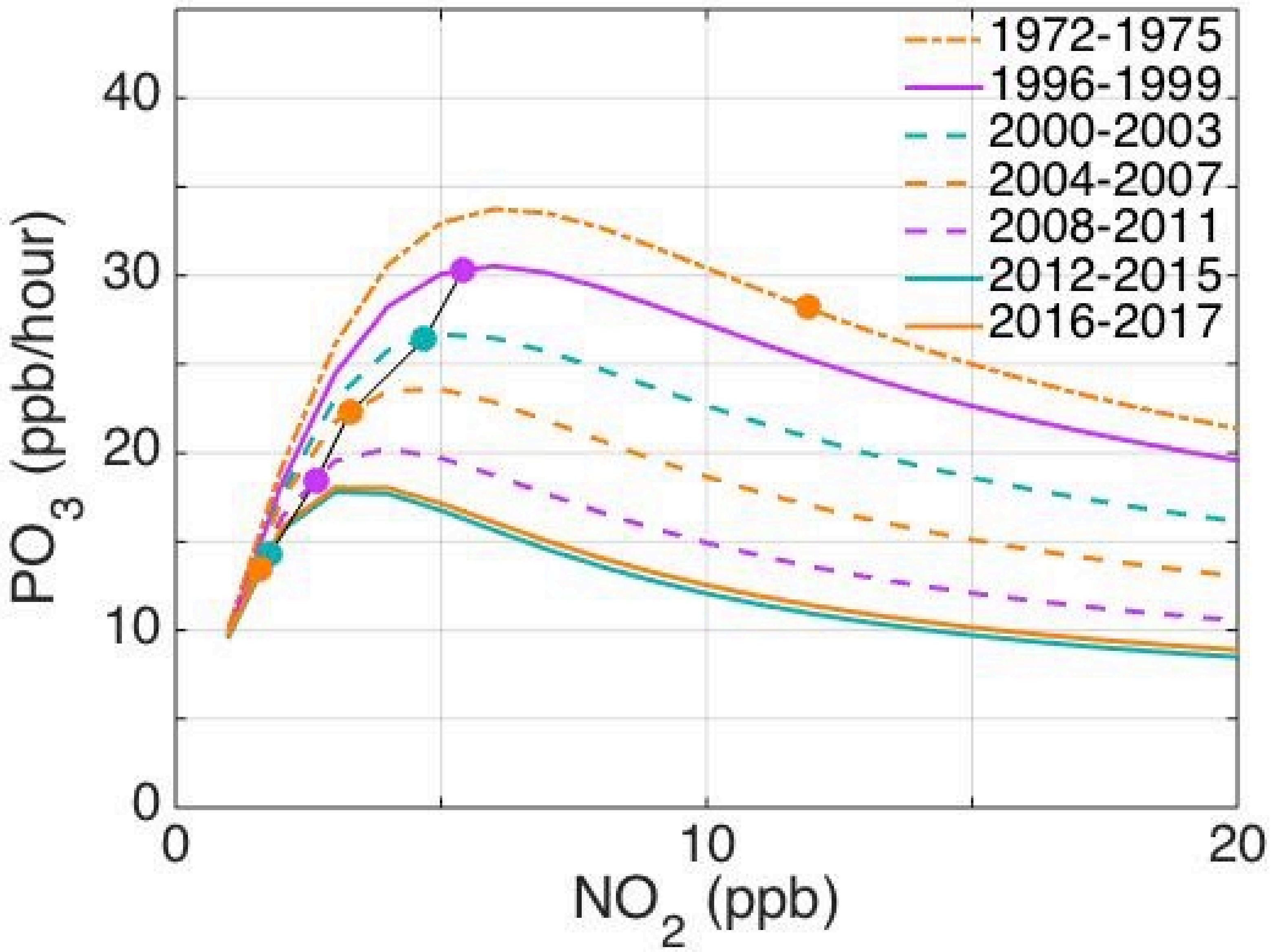
Region-wide NOx controls worked.

From Sandra Roberts' preprint.

Air Quality Trends in **Maryland**





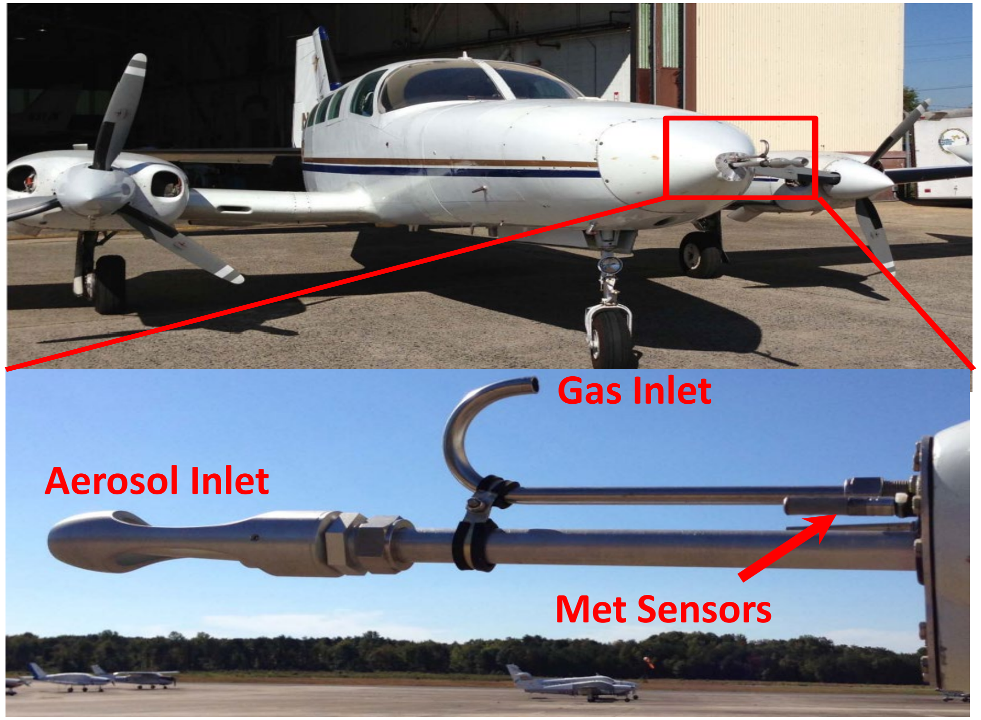


Using surface obs and a box model, calculated rate of production of ozone in the Balt/Wash area went up before it went down.

Region-wide NOx controls worked.

From Sandra Roberts' preprint.

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
- HCHO: Fluorescence (Hanisco)

Aerosol Optical Properties:

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

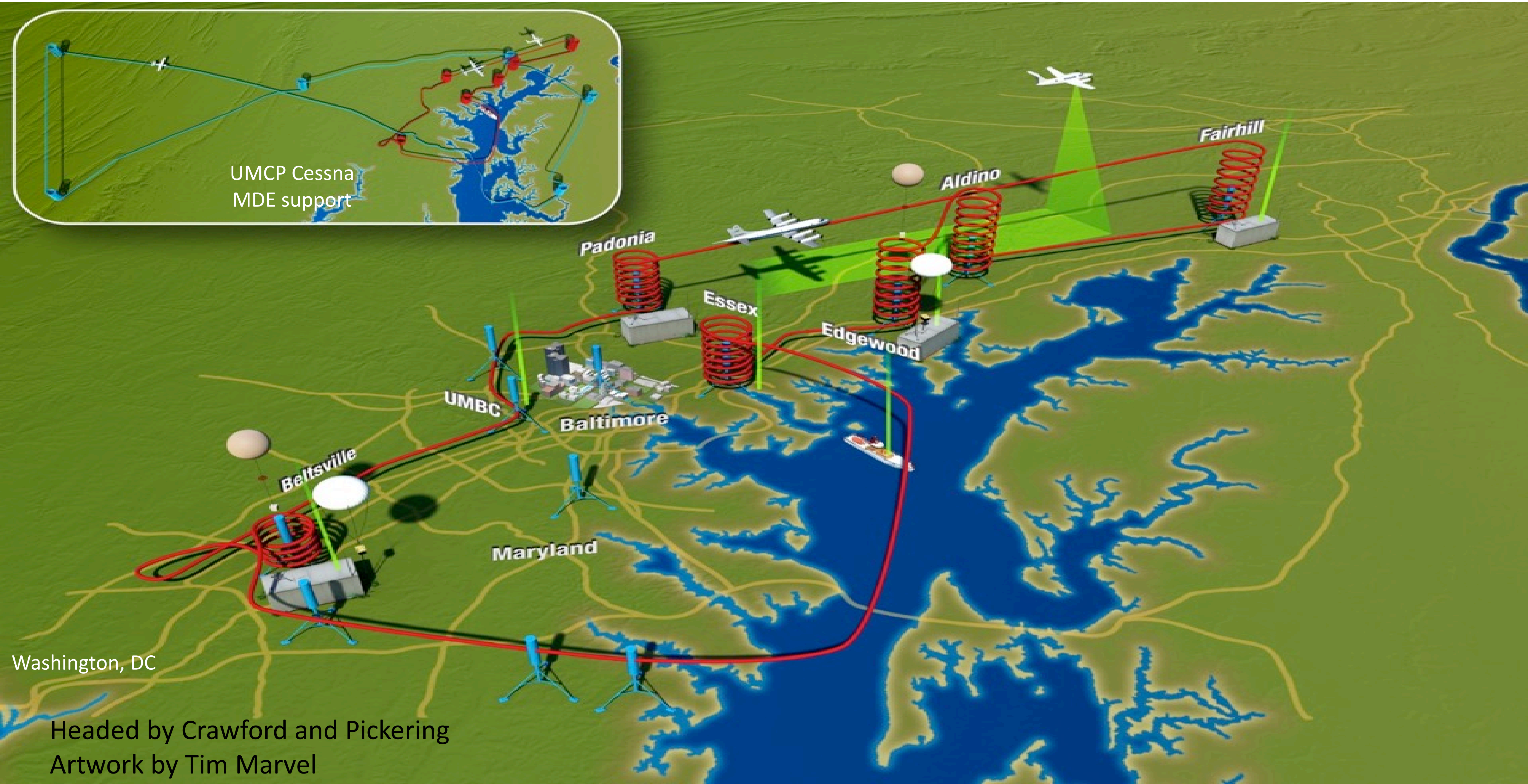
Aerosol Chemistry:

- Black Carbon: Aethalometer
- Major ions and SOA: filter samples

NASA P-3 during DISCOVER-AQ 2011 over Maryland's eastern shore.
AQAST and HAQAST

UMD/URF Cessna
Photo by J. Stehr

DISCOVER-AQ Maryland July 2011



Headed by Crawford and Pickering
Artwork by Tim Marvel

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.

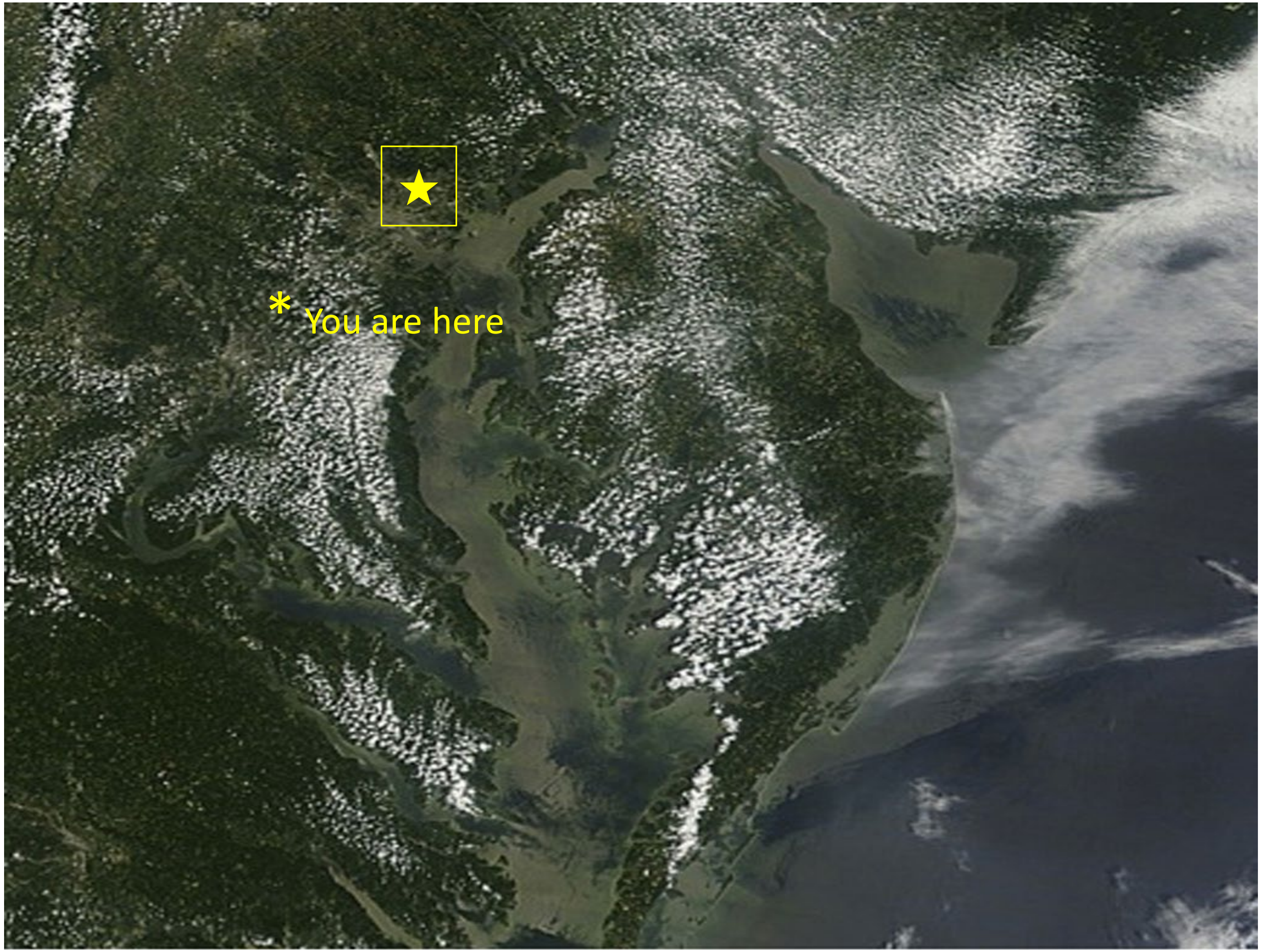


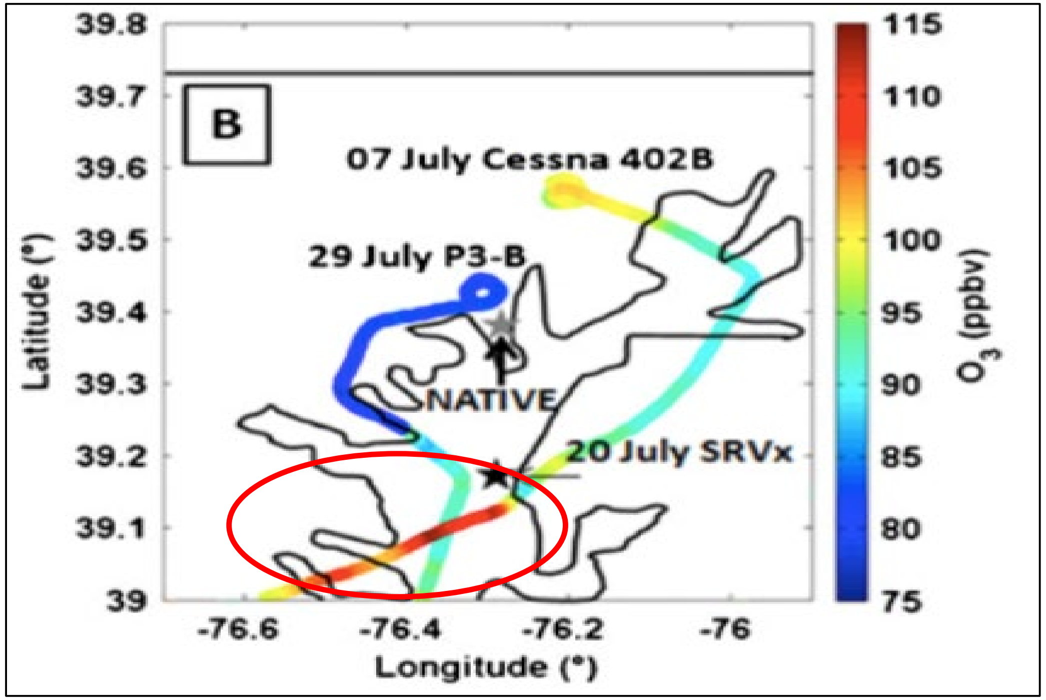
Fig. 13. Visible image from the MODIS satellite at 1610Z (2:10 PM local time) on July 20, 2011 showing the presence of low-level cumulus clouds only over the land.

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.

Mass Balance Method (NIST)

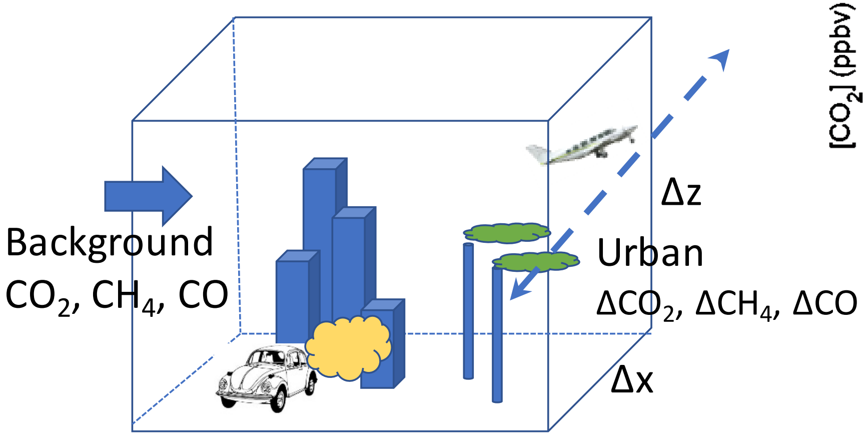
$$E.R._{CH_4} = \int_0^{z_i} \int_{-x}^{+x} ([C] - [C]_b) \times U_\perp \, dx dz$$

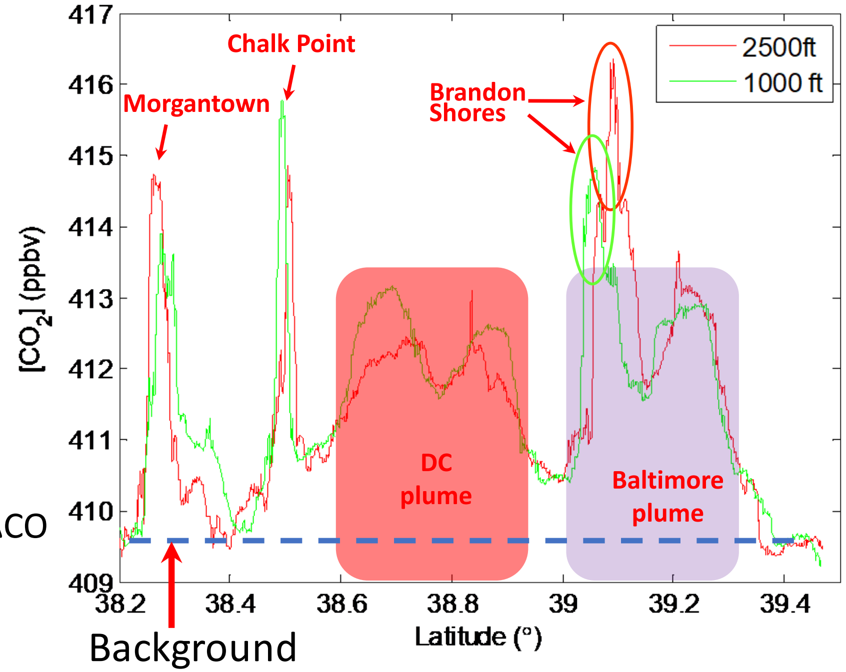
E. R. : emission rate (flux)

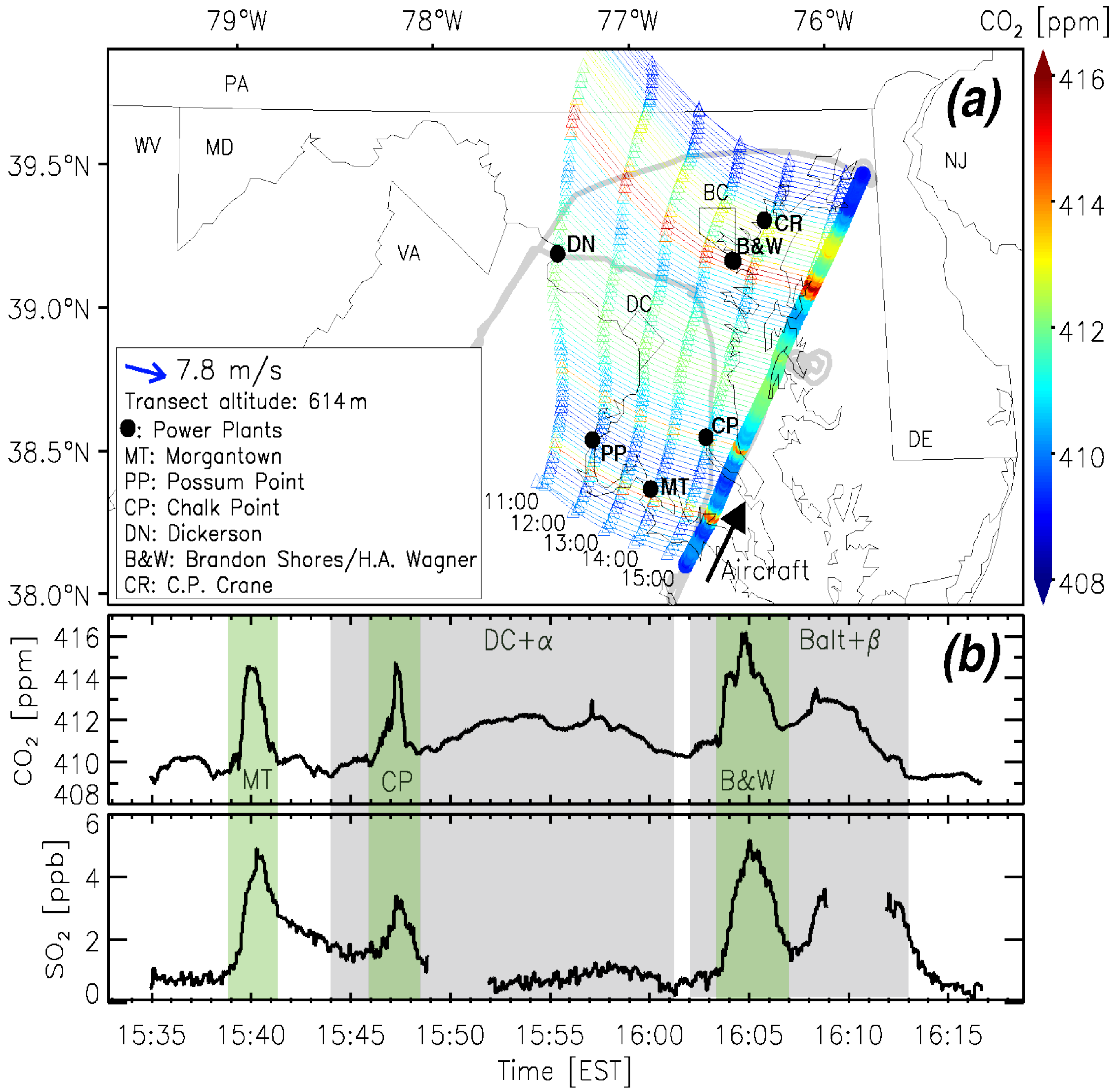
[C] : concentrations (downwind)

$[C]_b$: concentration in background

$U_\perp$: perpendicular wind speed







Constant altitude(s) downwind.
Spikes from point sources (HYSPLIT).
Broad plumes from urban areas.
Integrate flux through plane.
Using wings for background.
Ahn et al. submitted (2019).

Can also ratio short-lived pollutants such as NOx to CO_2 to test emissions inventories (Anderson et al. 2014; Salmon et al. 2018).

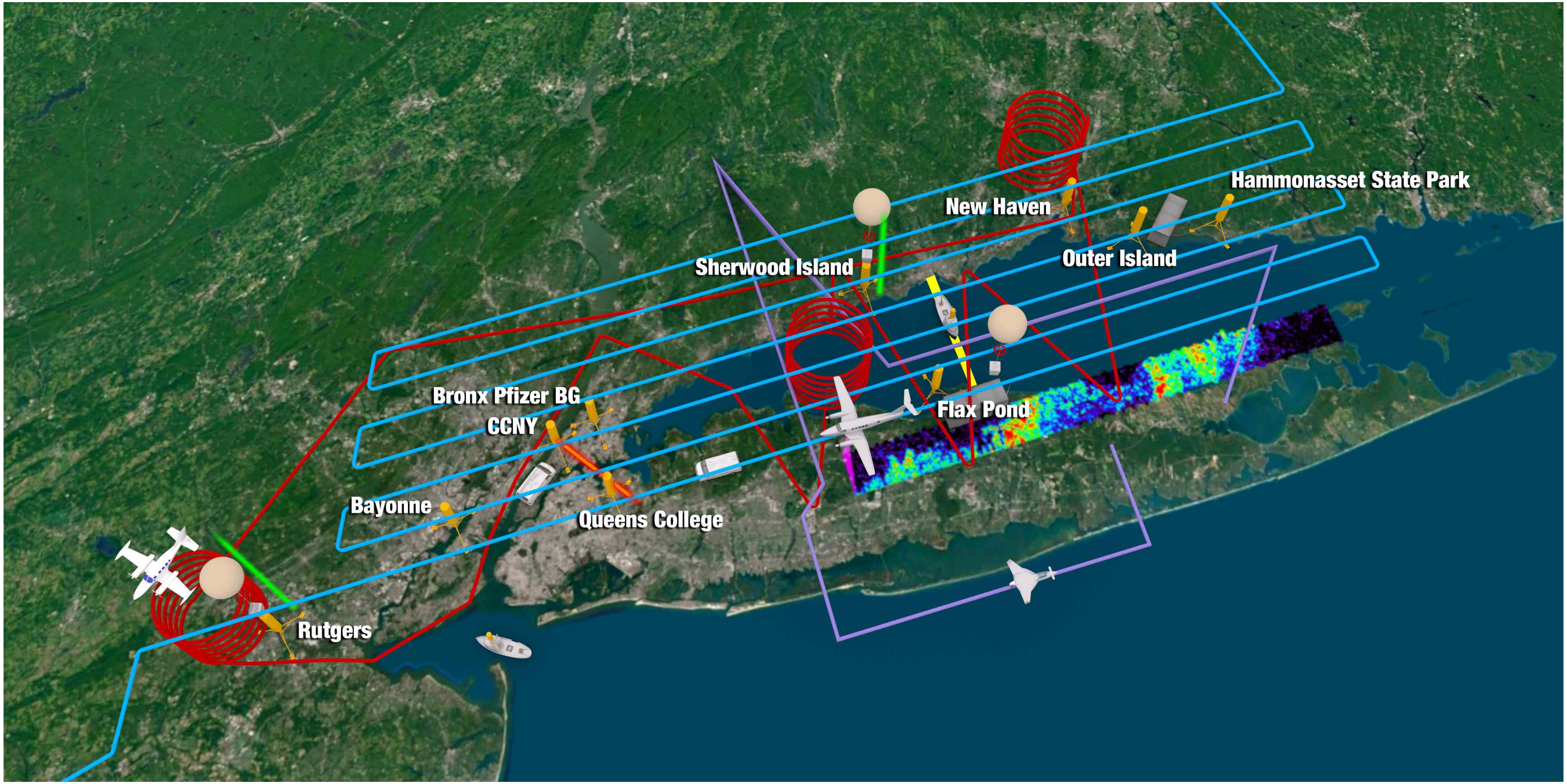
CH_4 emissions twice MDE (all) inventories.

Atmospheric Chemistry in New York

Amazing progress has been made on air quality in the US, but we have miles to go before we sleep.


Connecticut Coast
Xinrong Ren photo 2017

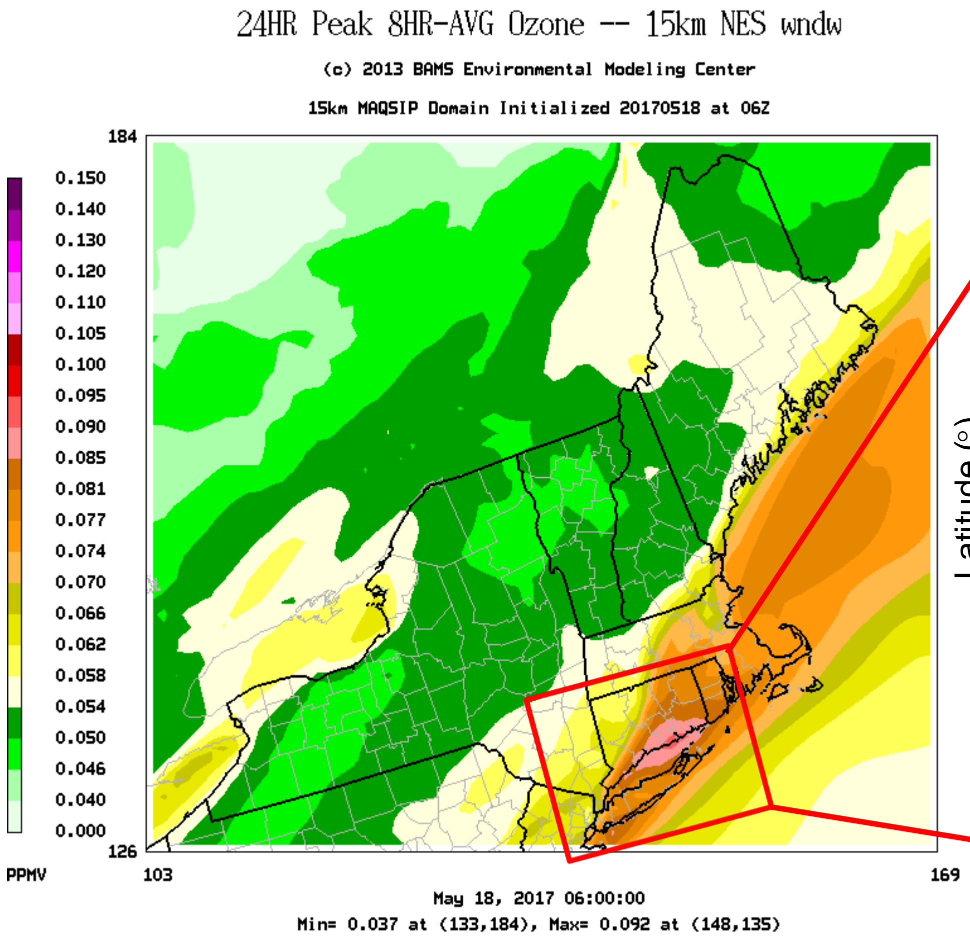
LISTOS in One Picture

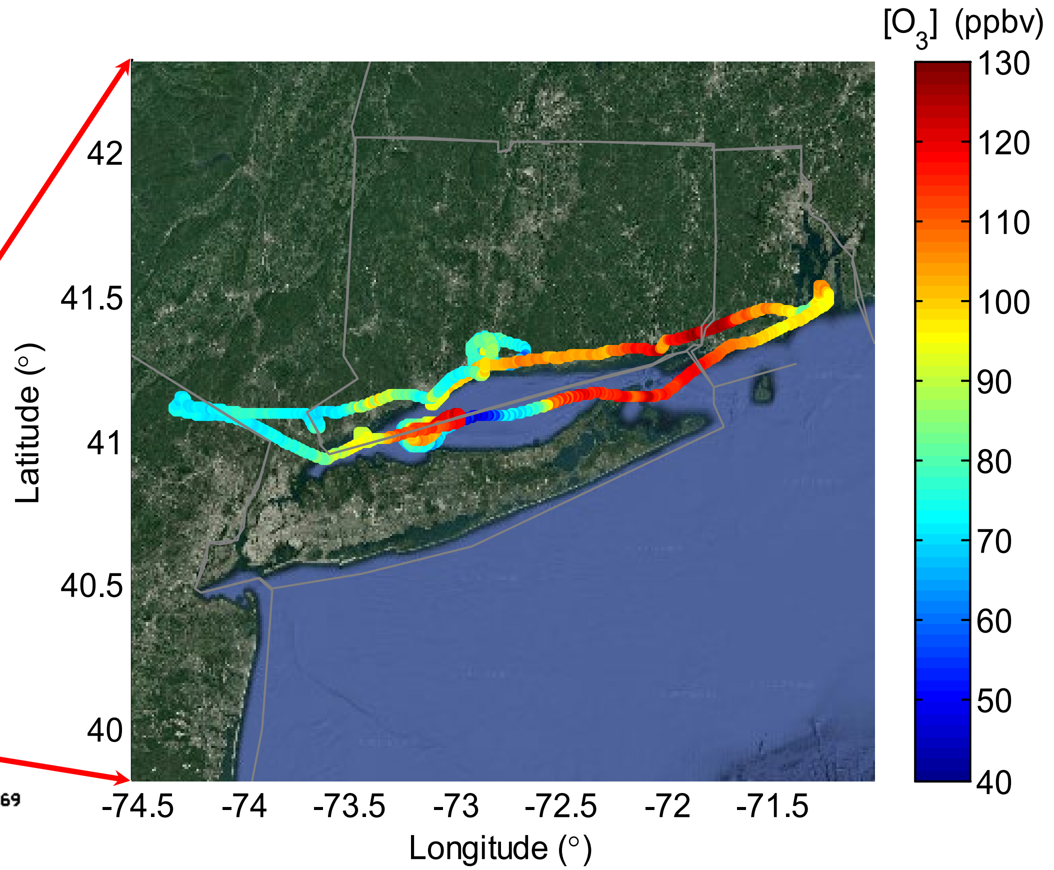


May 18, 2017 Afternoon Flight

Ozone forecast

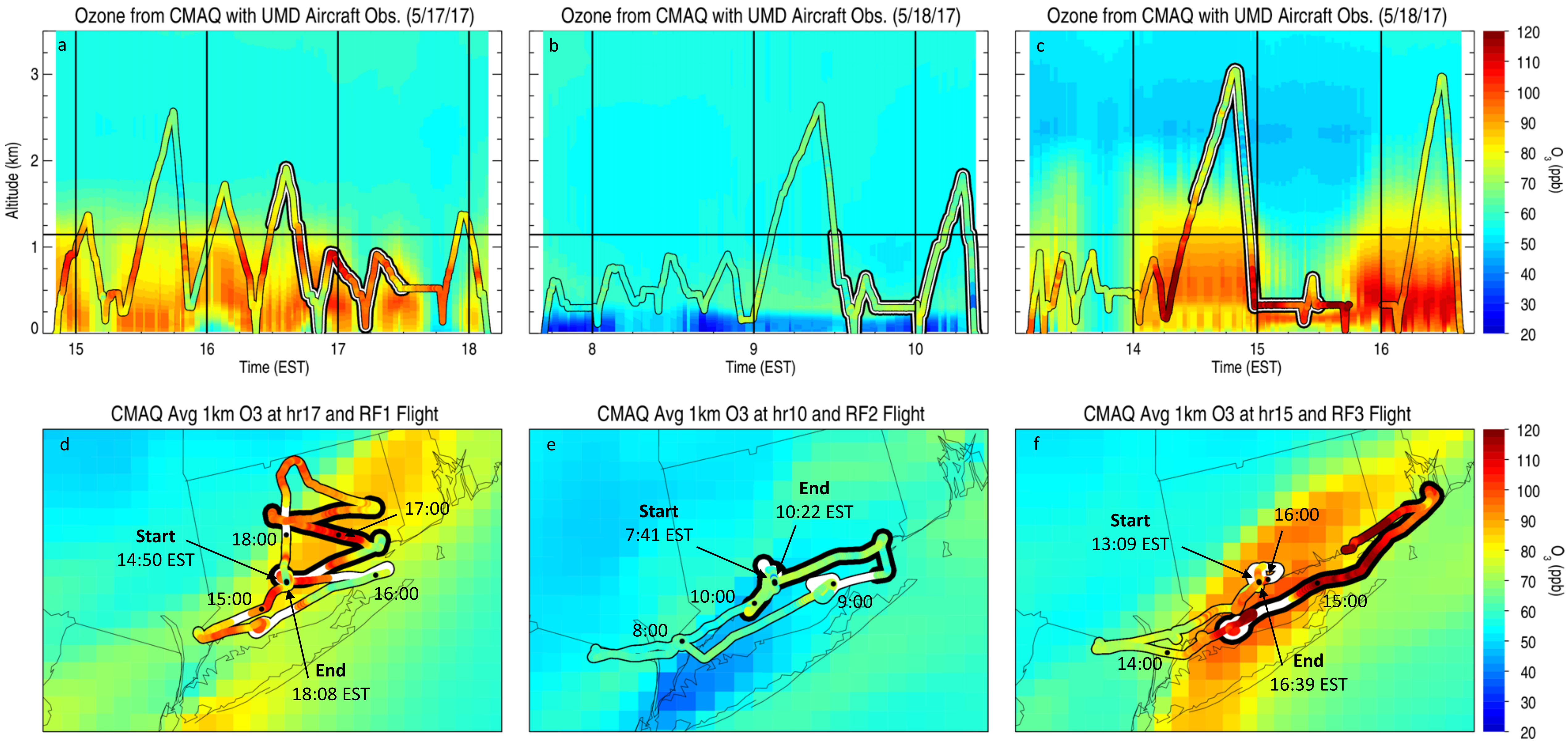
Observed O_3 on flight track





The ozone episode was well forecast by the ARL model!

Measurement vs. forecast model (ARL) **ozone** comparison for flights of 2017



Forecast episode verified!

Ring et al. (in prep)

July 2 from Above

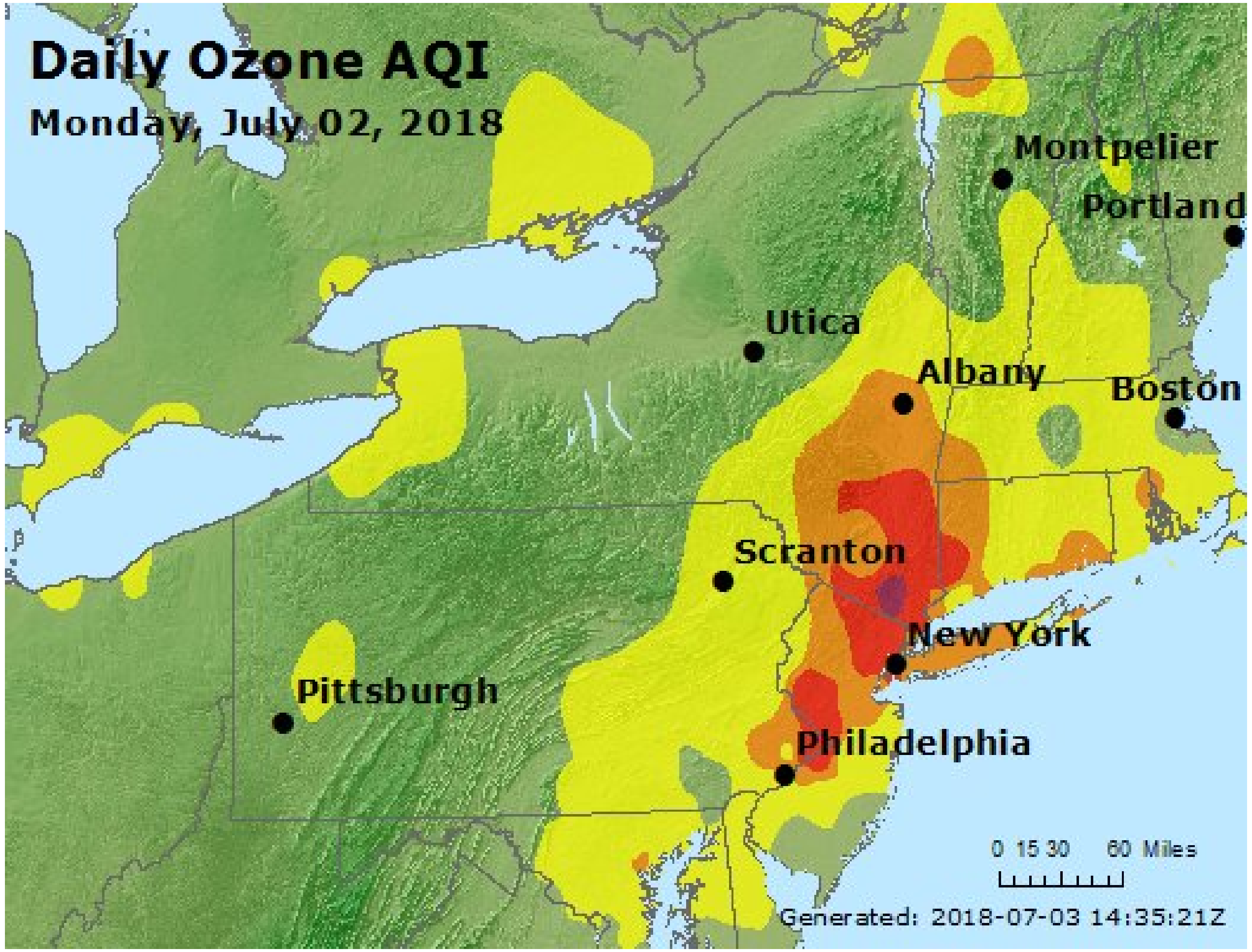
View from UMD airplane over Manhattan

July 2, 2018 Compared to Clean Day

NYC Bad Air Day: July 2, 2018

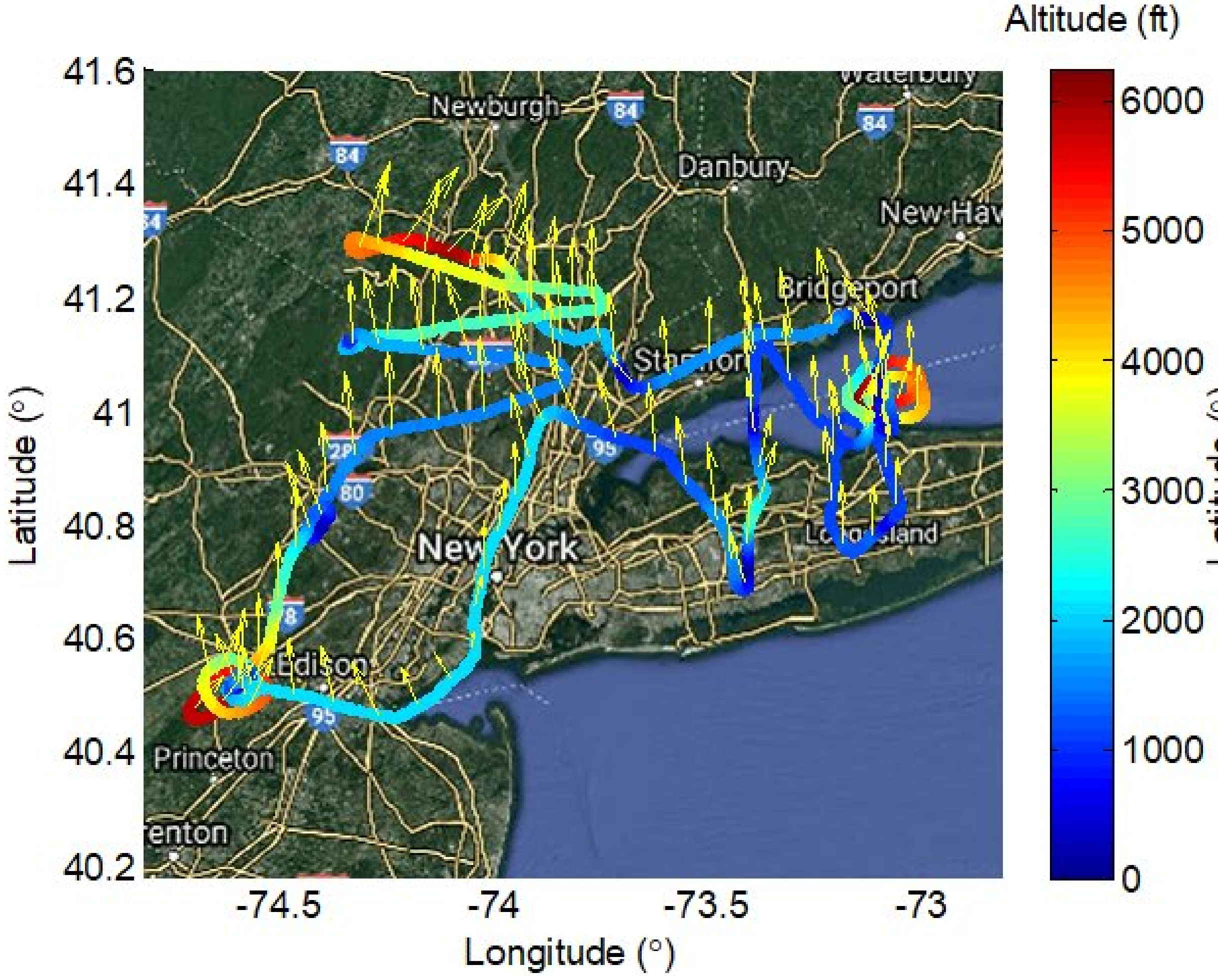
- Highest ozone
- since 2006:

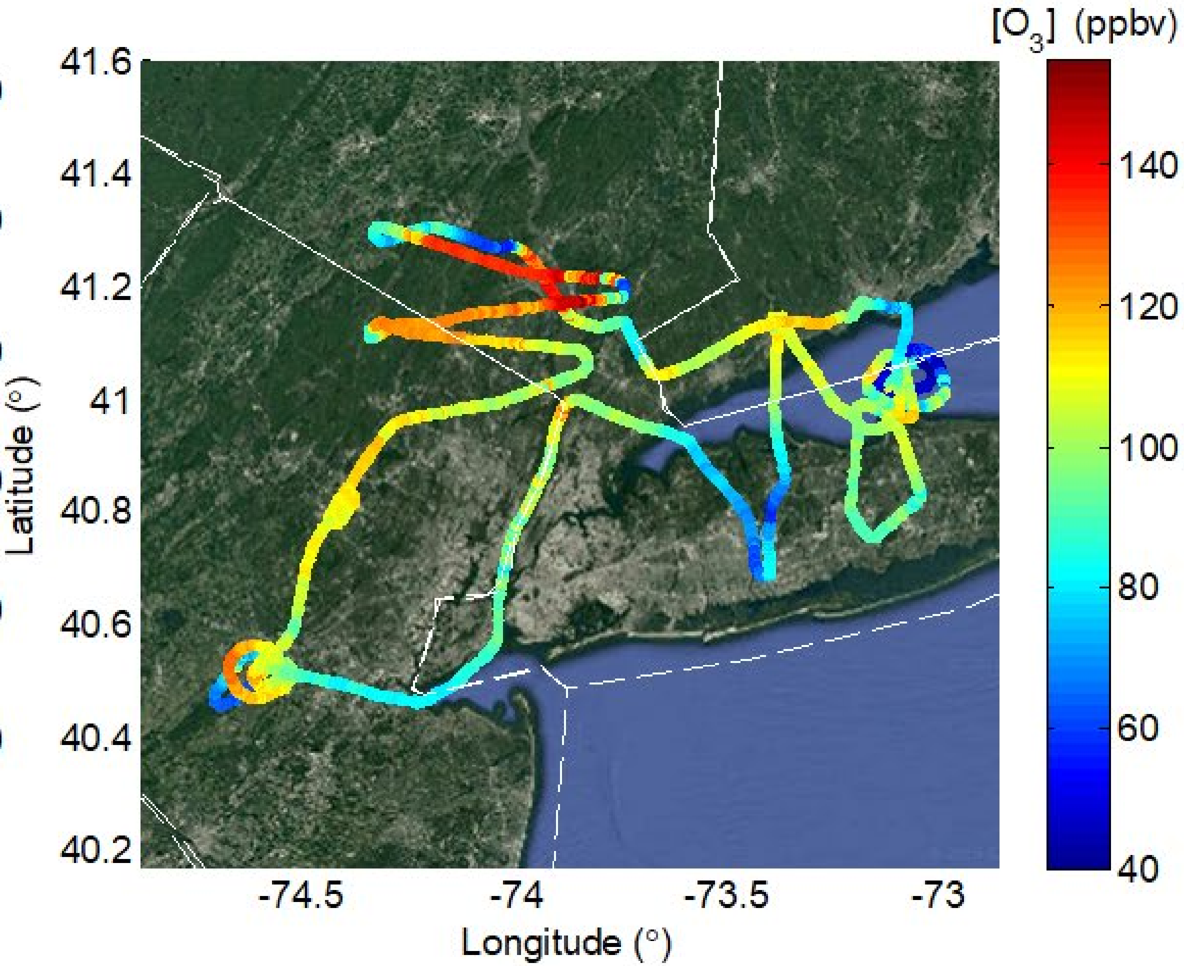
- 8 hr: 115 ppb
- 1 hr: 143 ppb



UMD Aircraft Flight Path July 2, 2018

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



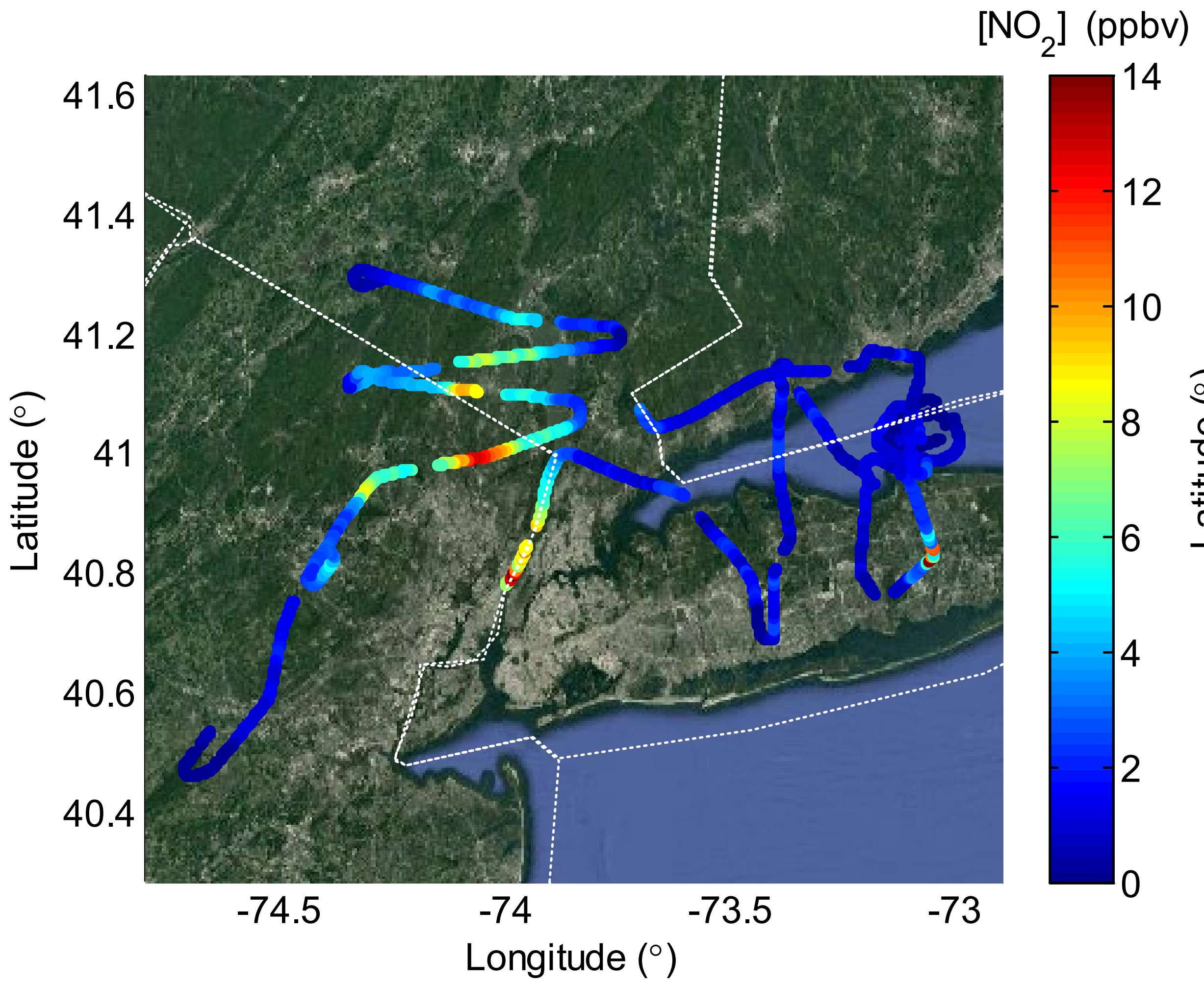


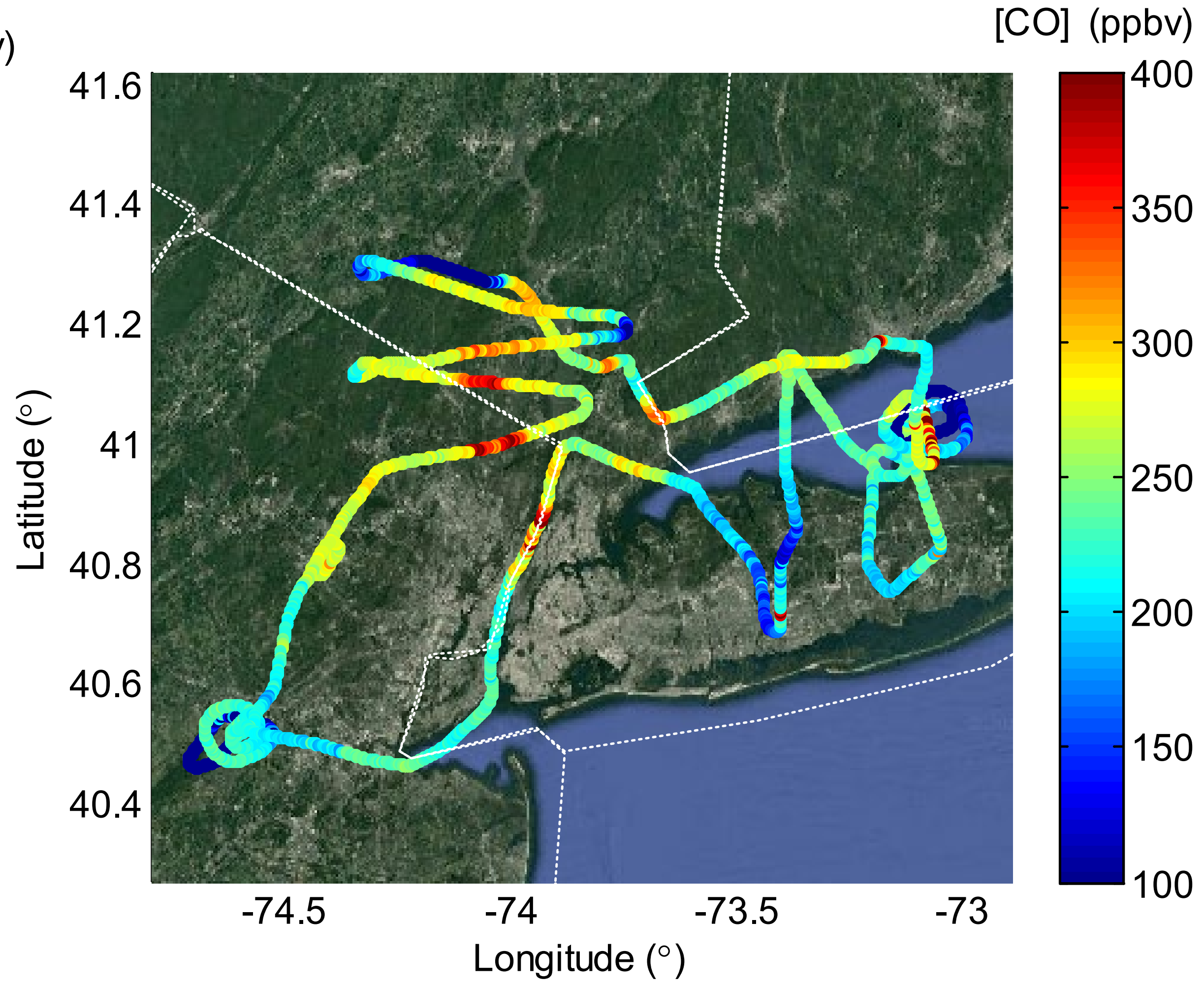
Yellow arrows show WD (southerly) and relative WS.
Spirals near Flax Pond and the Rutgers site.

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

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

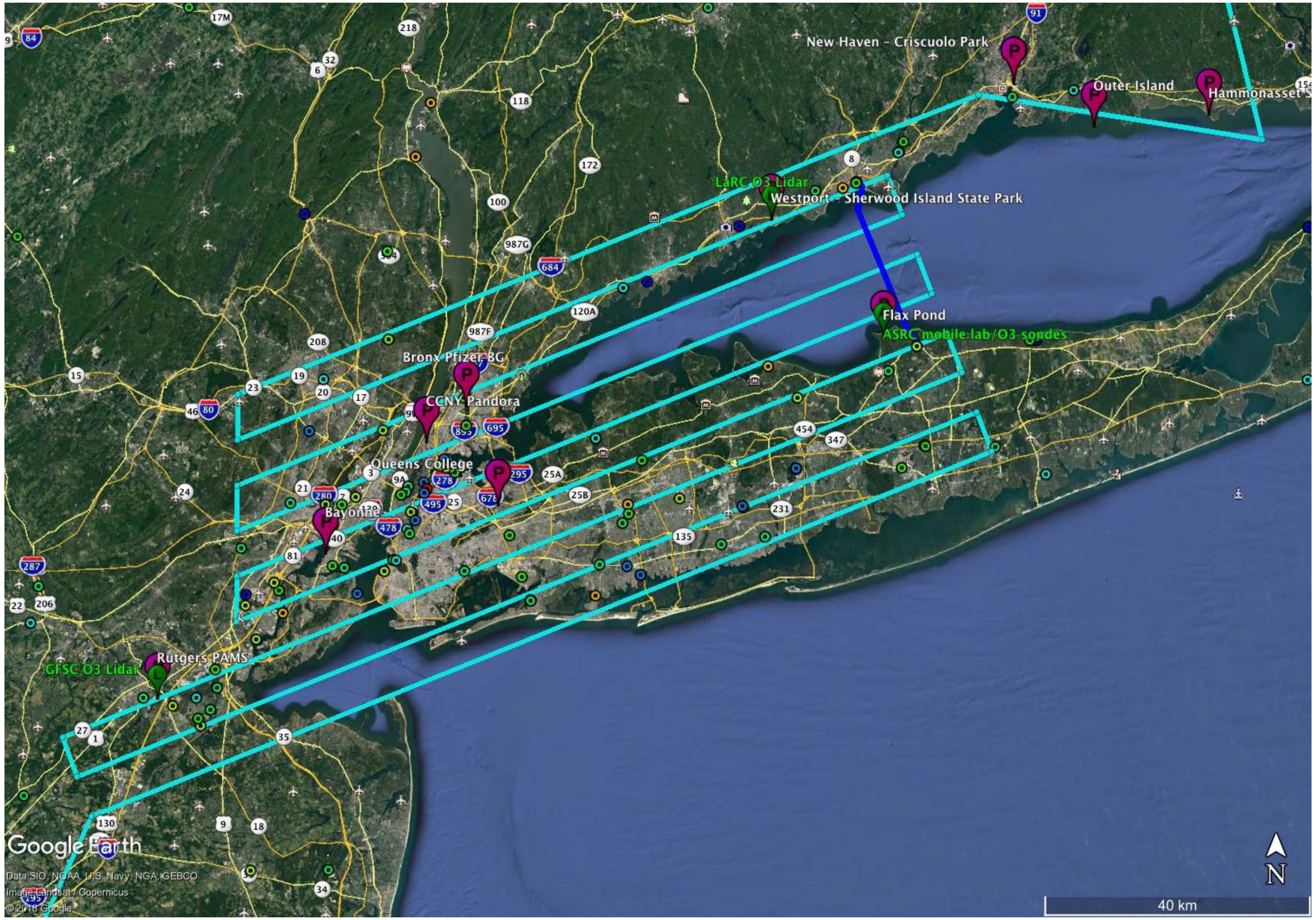
Afternoon Flight (~3:00-6:30 PM)





- Still high NO_2 and CO concentrations in the NYC outflow

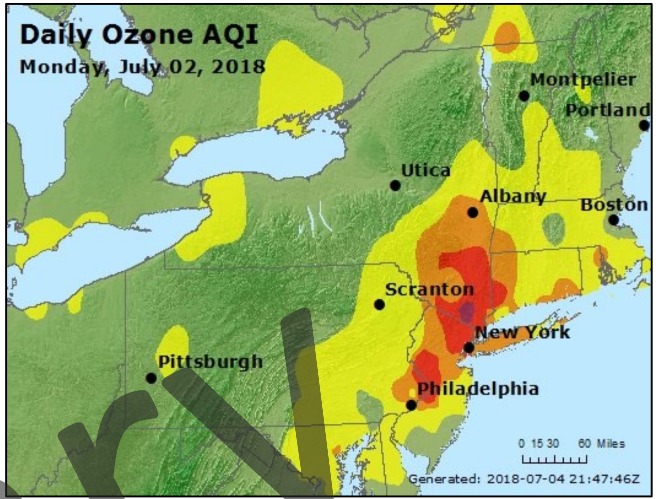
Ground truth for remote sensing
NASA Aircraft Flight Grid July 2

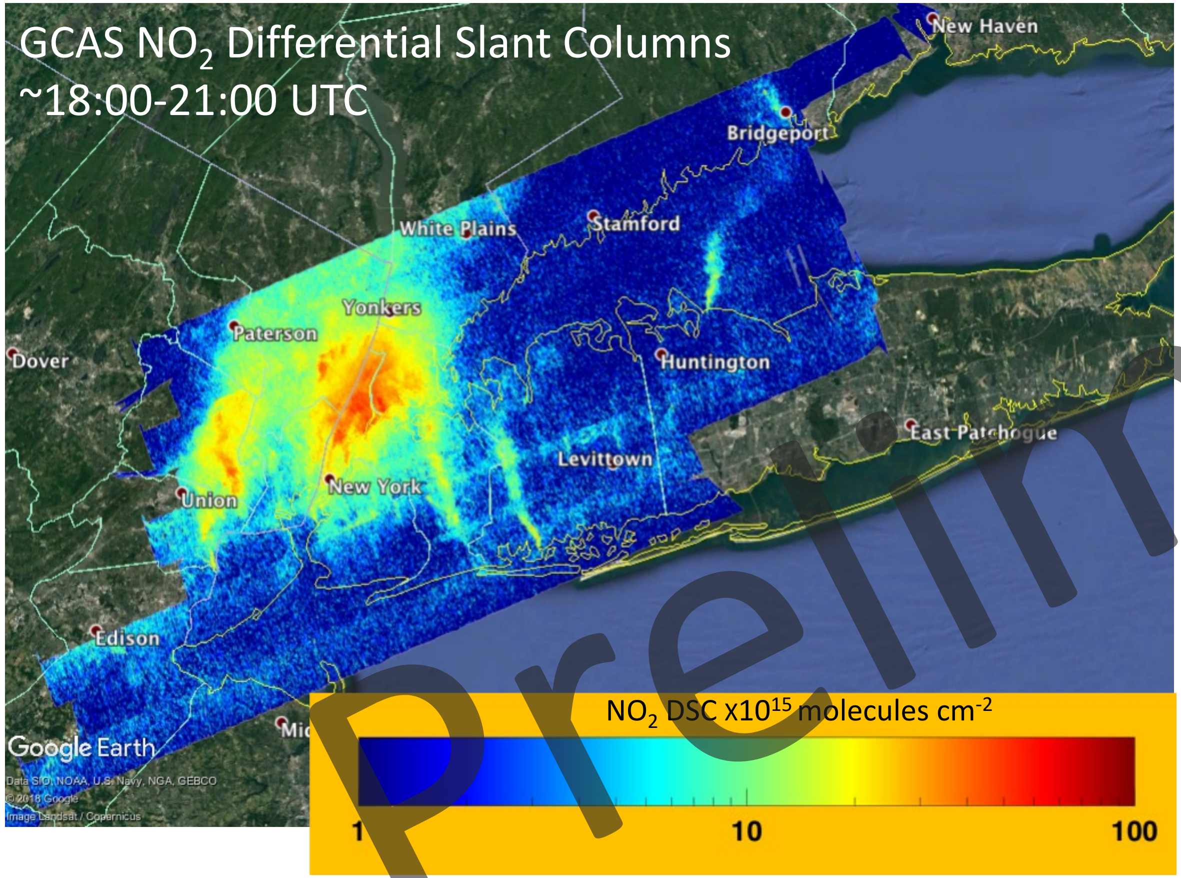


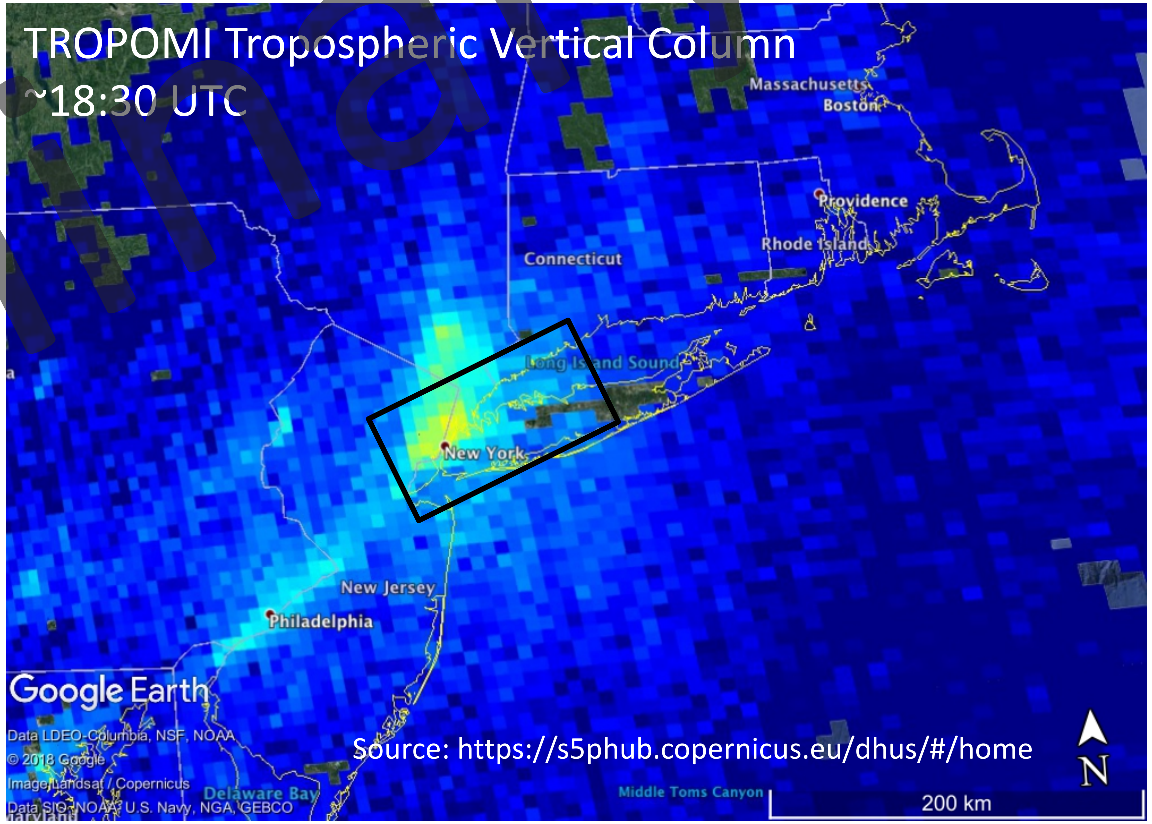
3. NASA GeoTASO (TEMPO Satellite Test-bed)

NYC July Heat Wave Day 3: July 2, 2018

Credit: NASA Langley, NOT FOR DISTRIBUTION

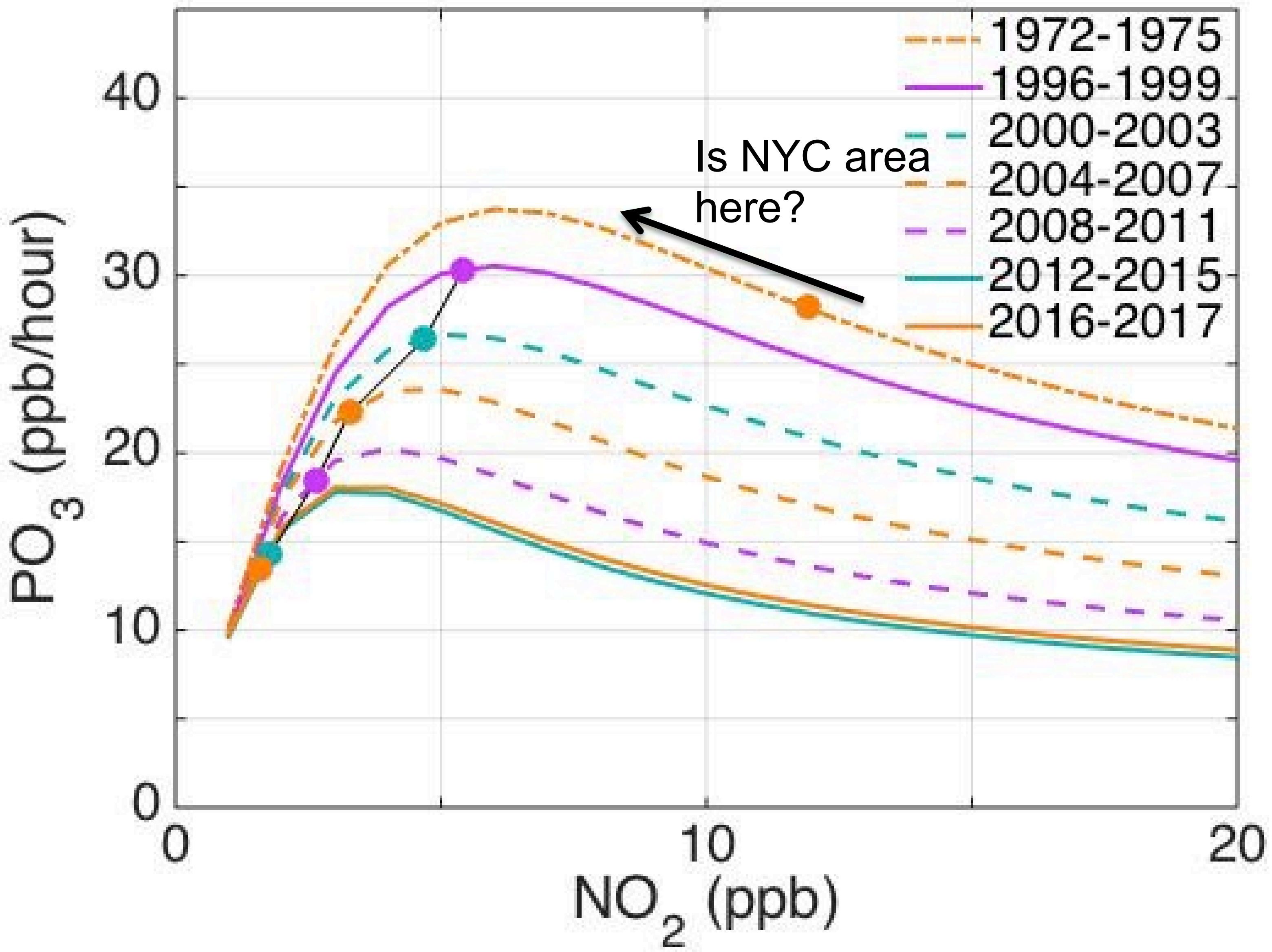






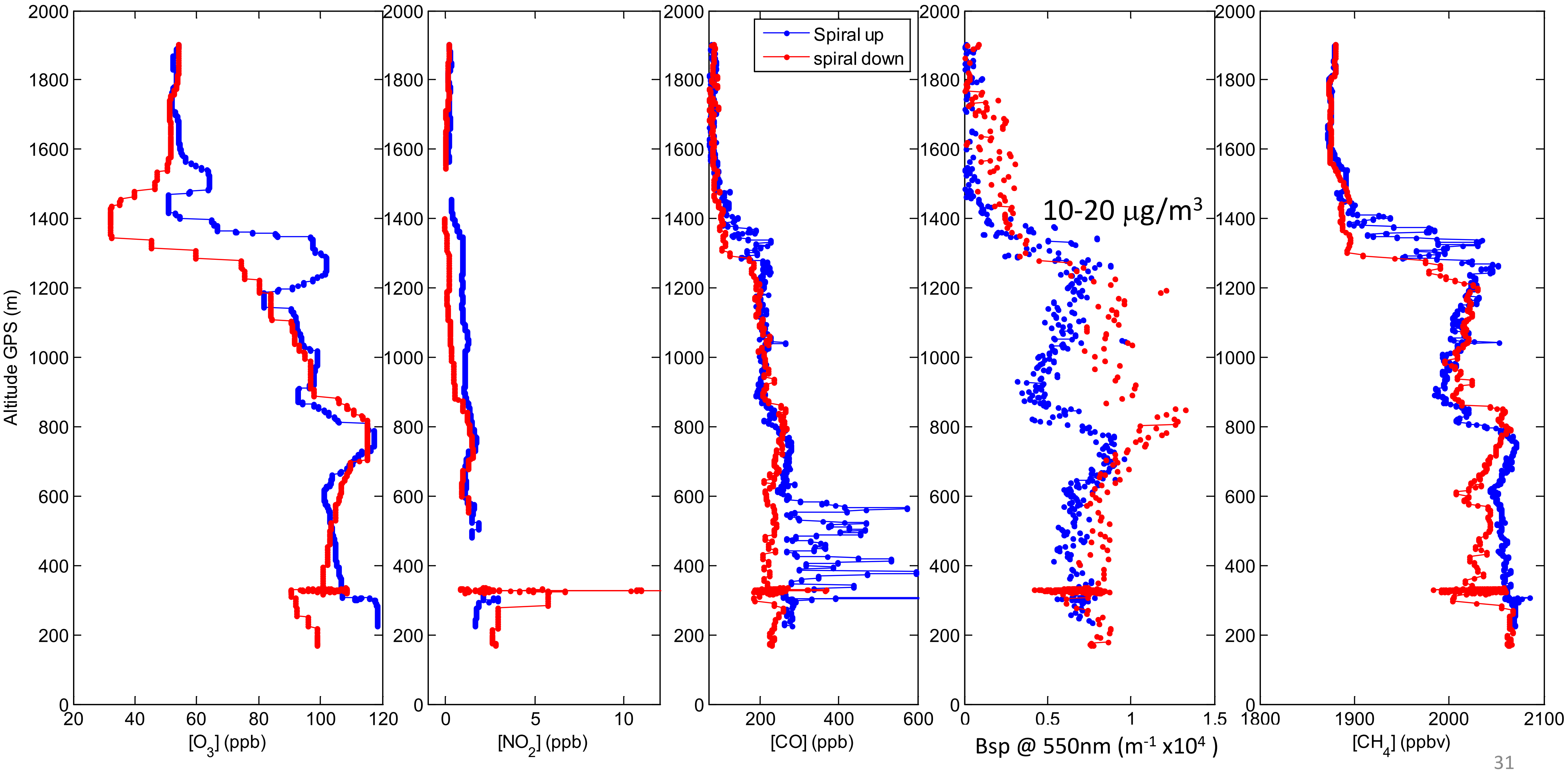
Source: https://s5phub.copernicus.eu/dhus/#/home

Preliminary


Is NYC area
here?
1972-1975
1996-1999
2000-2003
2004-2007
2008-2011
2012-2015
2016-2017
PO_3 (ppb/hour)
NO_2 (ppb)
0
10
20
30
40
0
10
20

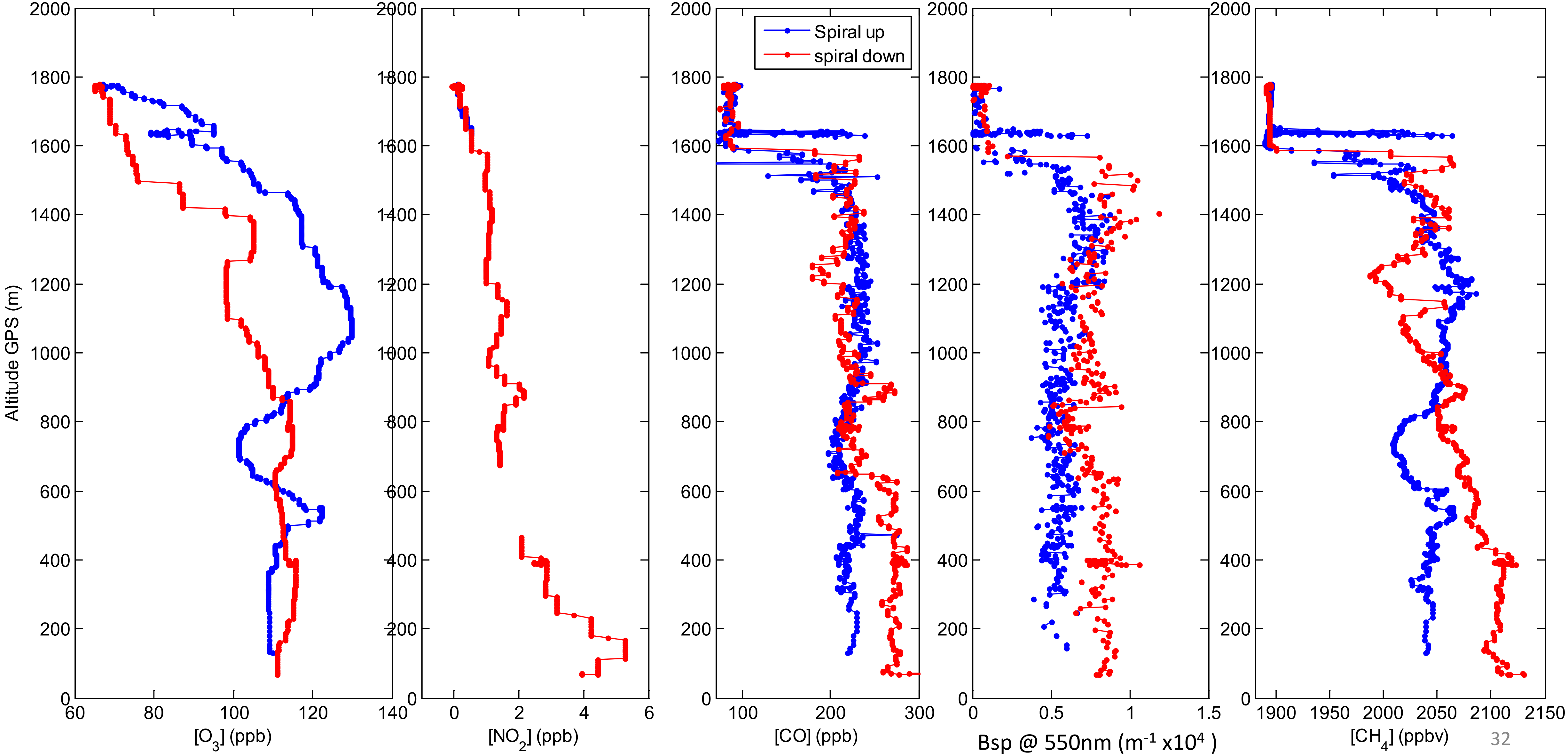
UMD Cessna LISTOS Flights on Monday, 7/2/2018

Spirals near Flax Pond during the afternoon flight

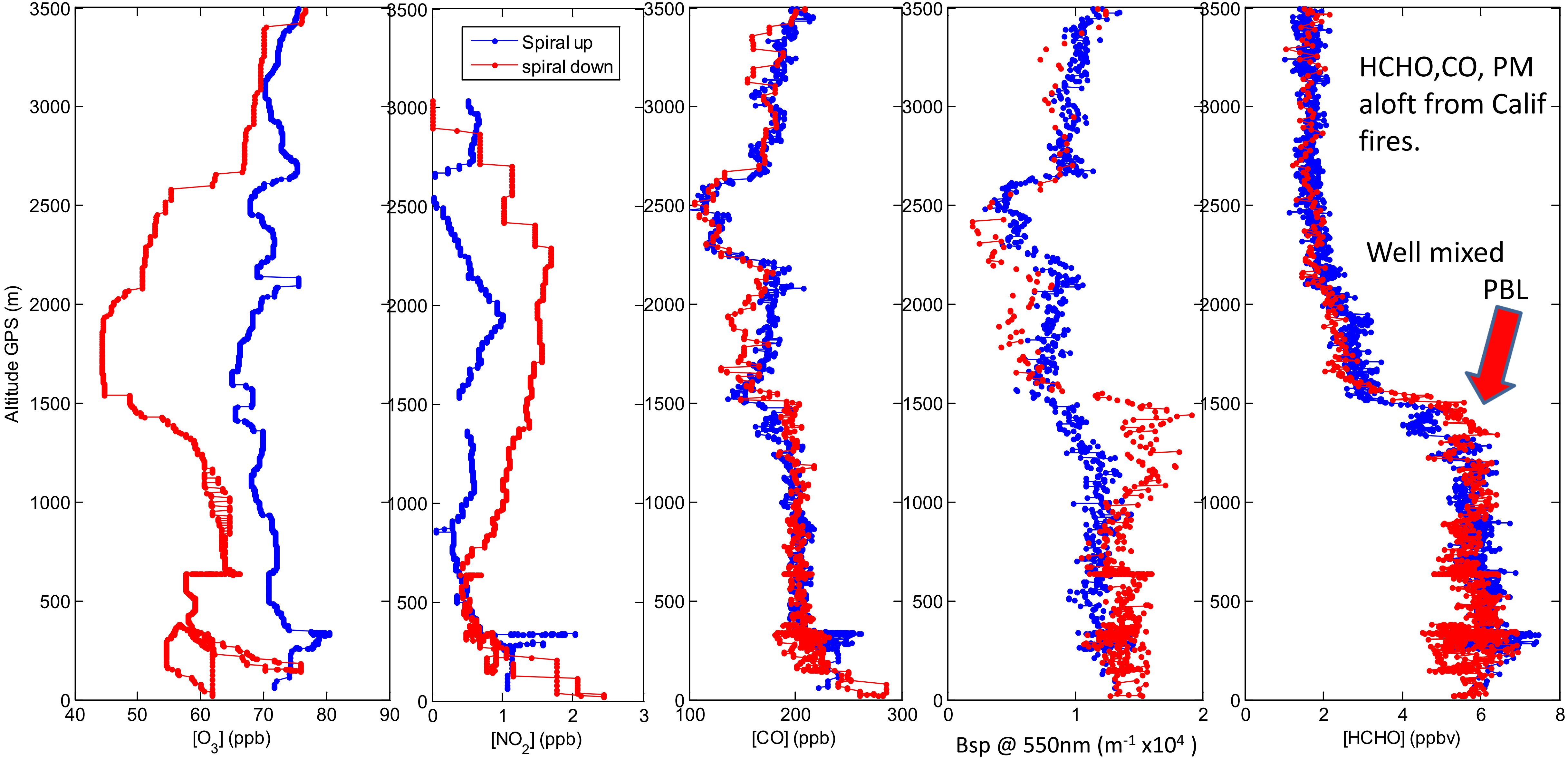


UMD Cessna LISTOS Flights on Monday, 7/2/2018

Spirals near Rutgers during the afternoon flight



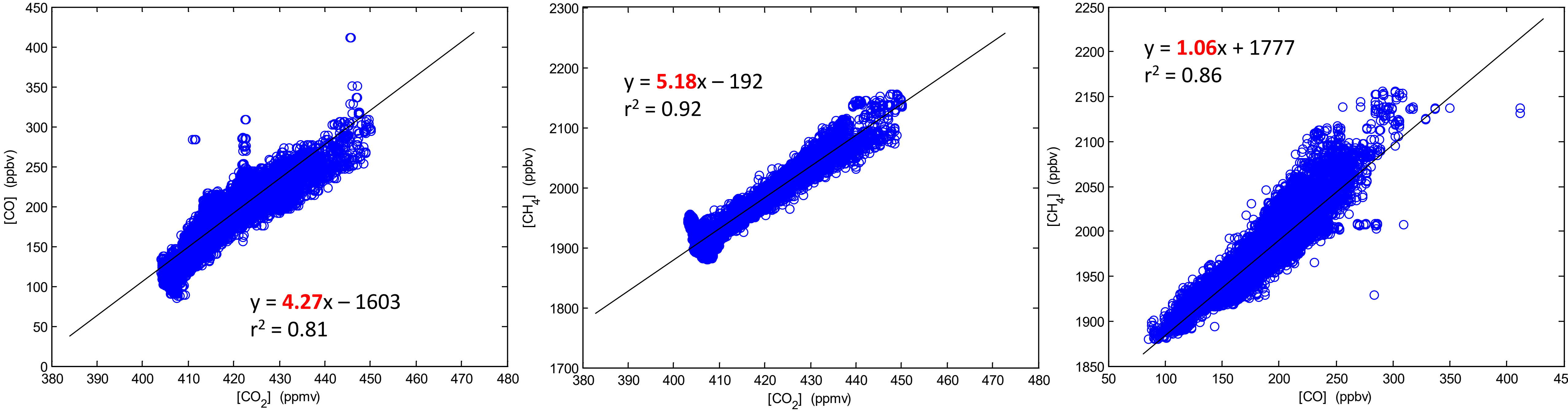
Over Flax Pond (Long Island) with HCHO Aug. 16, 2018



En route descent (red) was over the LIS between Flax Pond and Groton (New London) airport.

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.

Conclusions

- Collaboration between NOAA ARL and UMD AOSC has been fruitful!
    - Many publications
    - Graduate students Ahn, Benish, Goldberg, Mazzuca, Loughner, Ring et al.
- Field experiments indicate that sea breezes play a major role in air quality.
- High resolution models can capture this.
- Region-wide controls of NOx emissions worked to improve O_3.
- 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; Huang et al., 2019)
- Needed policy relevant science,
    - Ozone got worse before it got better.
    - Relative strength of NOx sources:

The End

Fear the Turtle!

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

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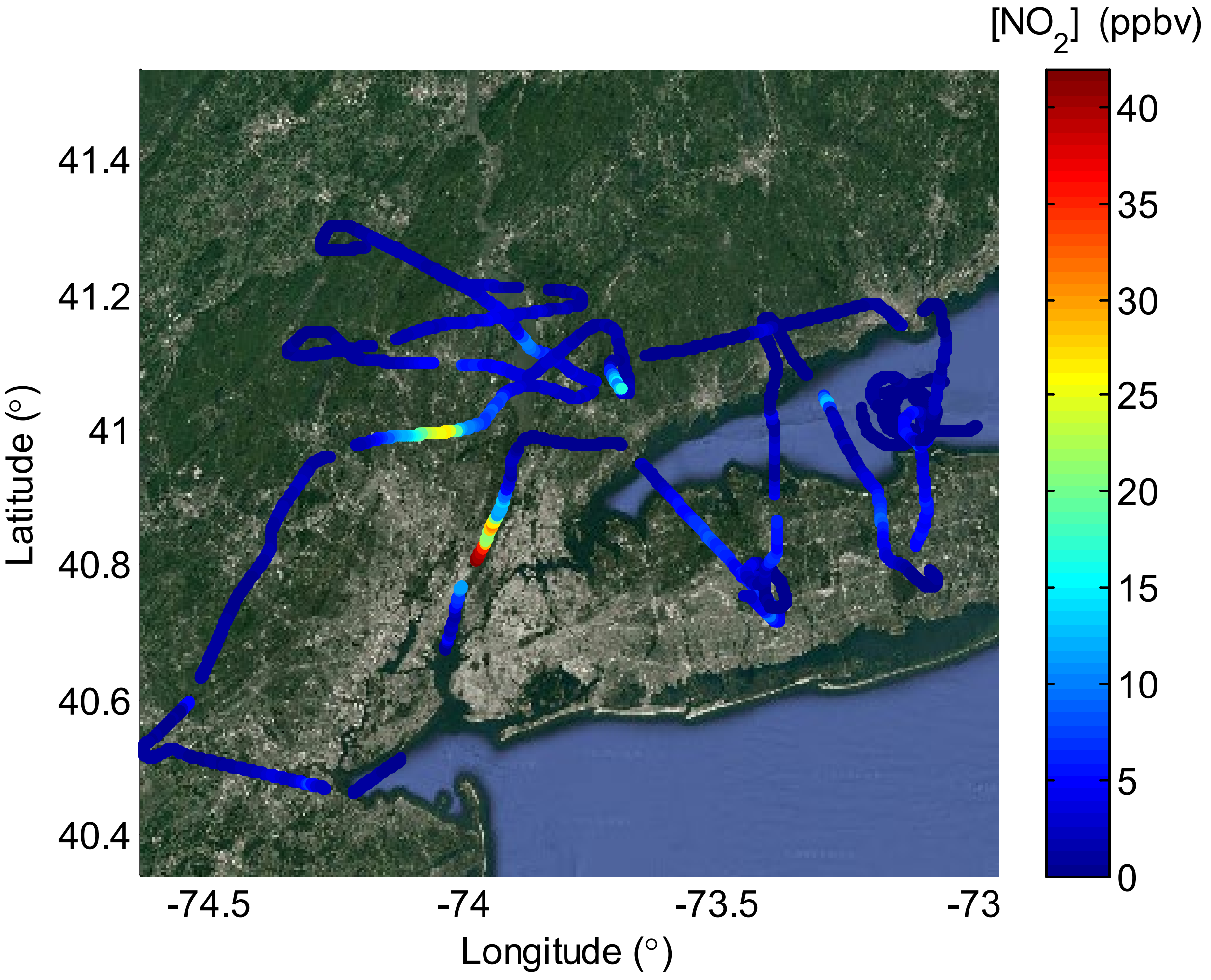
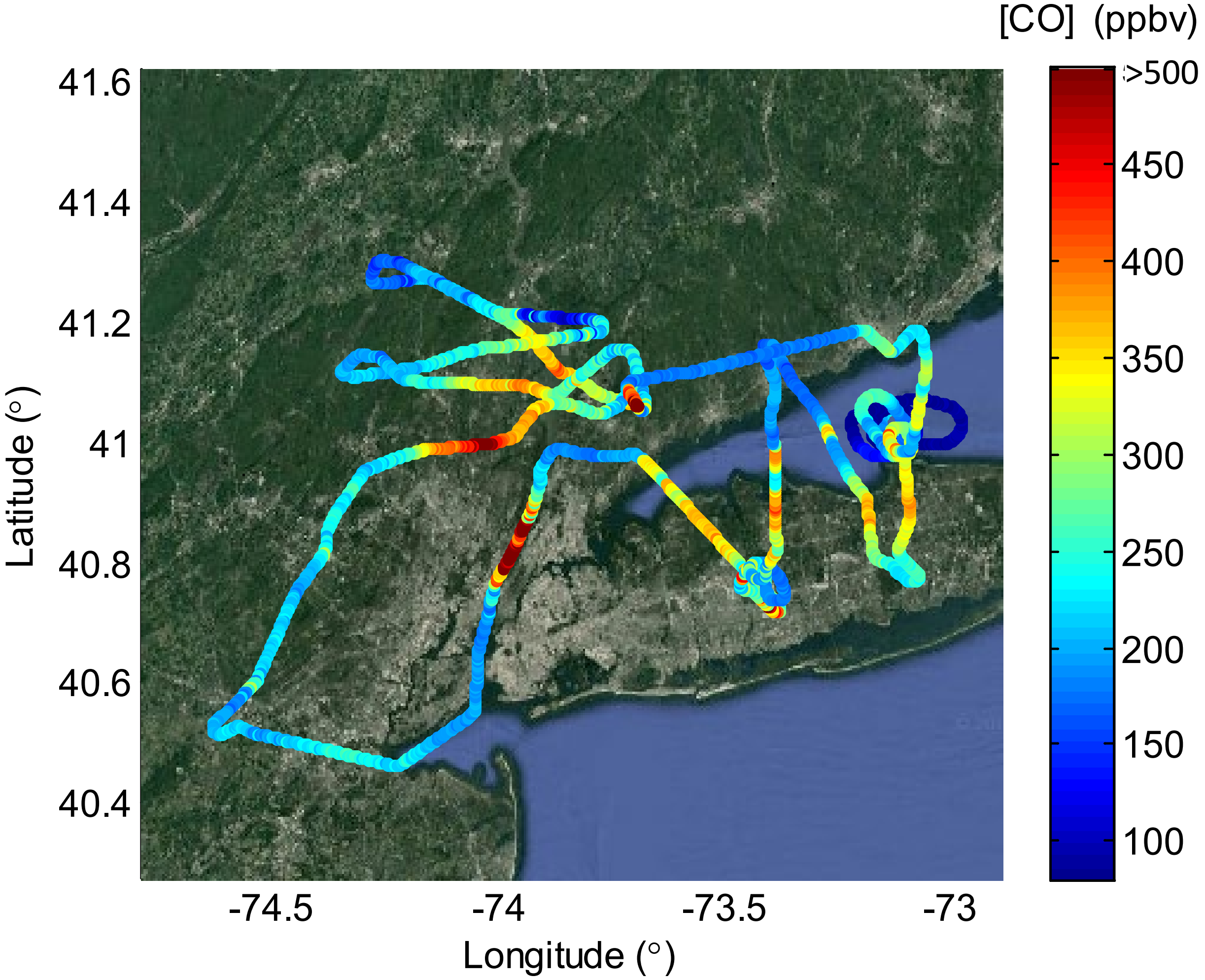
UMD Cessna LISTOS Flights on Monday, 7/2/2018 **heavy** primary **pollution**

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.

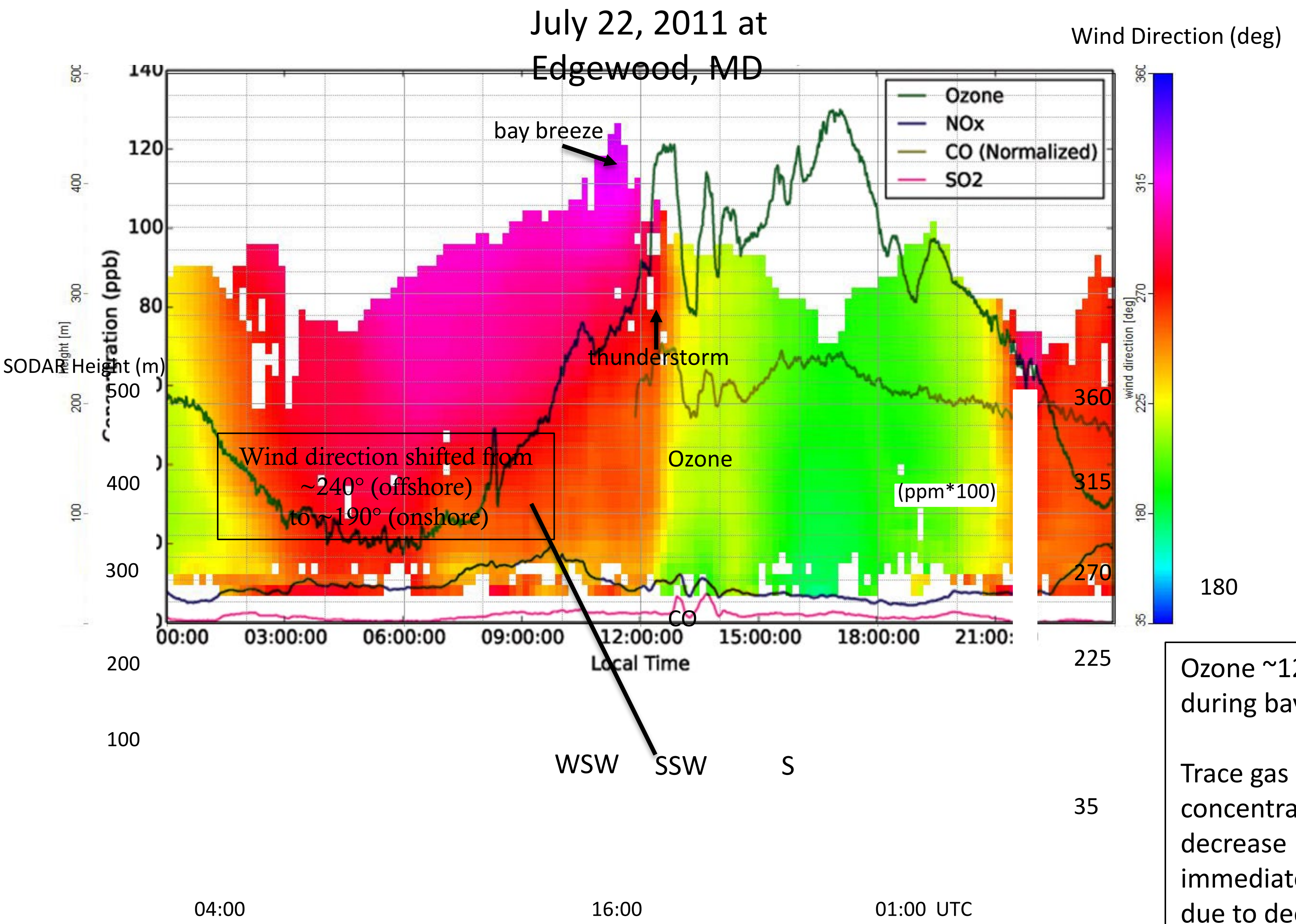
Extra slides

Mercury


The people who are
making the measurements
Winston Luke
Principal Investigator, NOAA
Air Resources Lab
Jake Walker
Site Operator,
Grand Bay NERR
Paul Kelley
Instrument engineer,
data acquisition and
management,
NOAA Air Resources Lab
Gulf of Mexico Alliance Mercury Forum, May 10-12, 2010, Mote Marine Lab, Sarasota, Florida

Motivation

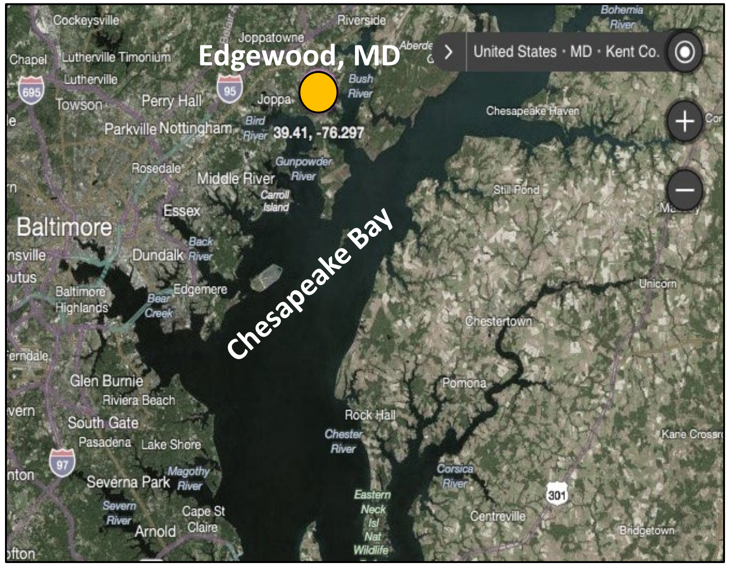
SODAR wind direction (background colors) and surface trace gas concentration (lines) Edgewood, MD 07-22-2011 (bottom)

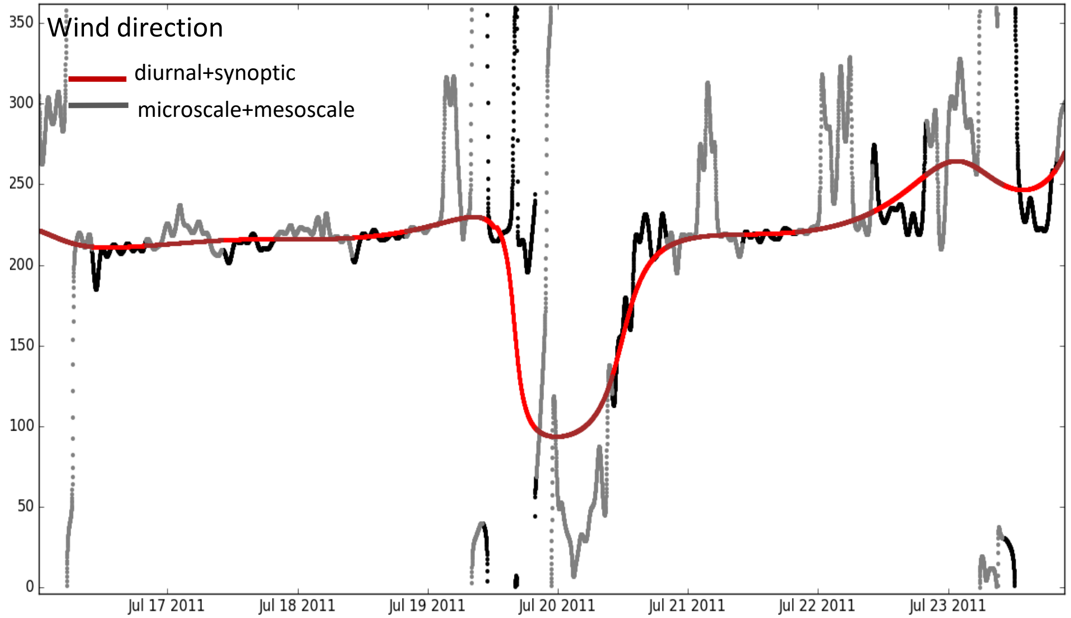


Ozone ~120 ppbv during bay breeze

Trace gas concentrations decrease immediately after due to deep convection

Methods
Bay Breeze Detection Algorithm





<u>Bay breeze detection technique using wind only</u>

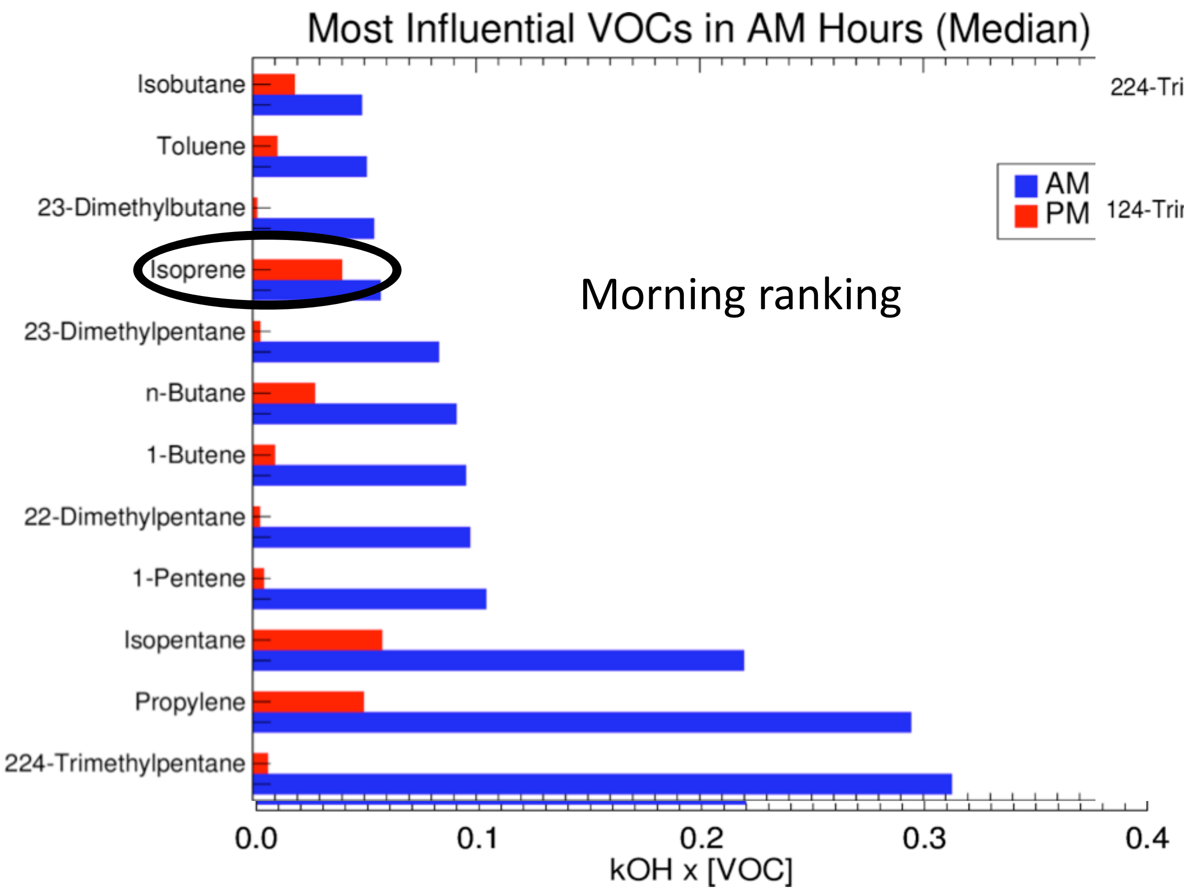
- Apply a low-pass filter to the 1-minute u & v components of the wind for June, July, and August 2011-2016 at Edgewood, MD
- Create a "microscale+mesoscale" signal and a "diurnal+synoptic" signal
- Bay breeze flag = yes when the following occur:
  - Wind direction is from the water
  - The microscale+mesoscale signal deviates from diurnal+synoptic signal
  - Winds are **not** out of the NNE/NNW

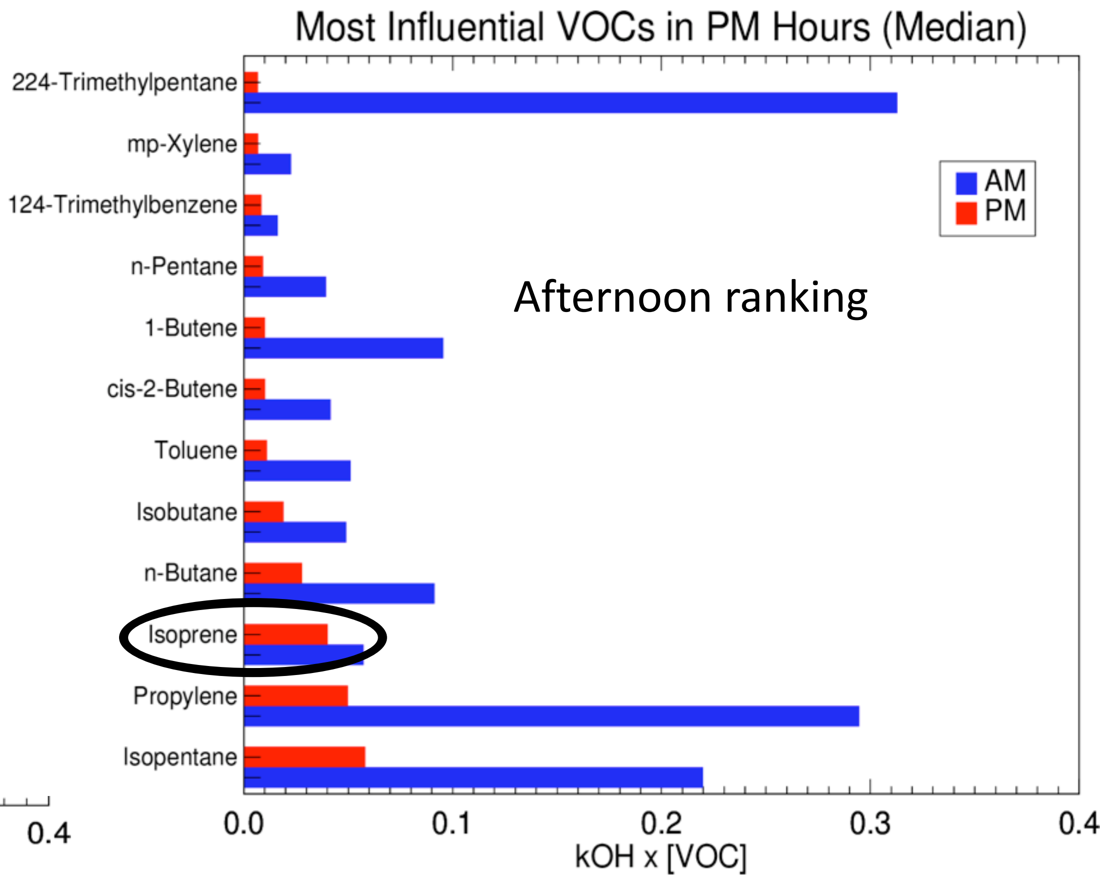
Chai, Tianfeng	401619	10	0:00	
No	He, Hao	601231	10	0:00
Yes	Kelley, Paul	512081	10	0:00
No	Kim, Hyun	512085	10	0:00
No	Ngan, Fong	662060	10	0:00
No	Ren, Xinrong	546536	10	0:00
No	Ring, Allison	677090	10	0:00
No	Tang, Youhua	458608	10	0:00
No	Tong, Daniel			

From New York City area mid PBL
PreLISTOS 2017 Analysis by A Ring et al.

Least important

Most important





Isoprene is not dominant

Does not yet include oxygenates or consumer VOCs.

Outline

- Problem: What are the gaps in our knowledge of the fundamental meteorology and chemistry that impede achieving the Air Quality Standards?
- Until recently, Edgewood Maryland on the Chesapeake Bay (downwind of Baltimore and Washington) had the worst ozone air pollution in the eastern US.
- Abatement policy was complicated by nonlinearities and **mesoscale meteorology involving the Bay,** but we are (finally) winning the battle.
- Even with reduced emissions, coastal Connecticut (downwind of New York City) has gotten worse.
- Recent results from field experiments.
- What recommendations might we have?
  - **Need a deeper understanding of the meteorology and chemistry to inform policy.**
  - **Leverage GHG measurements to understand better SO_2, NOx and VOC emissions.**