GHG-Air Quality Synergies

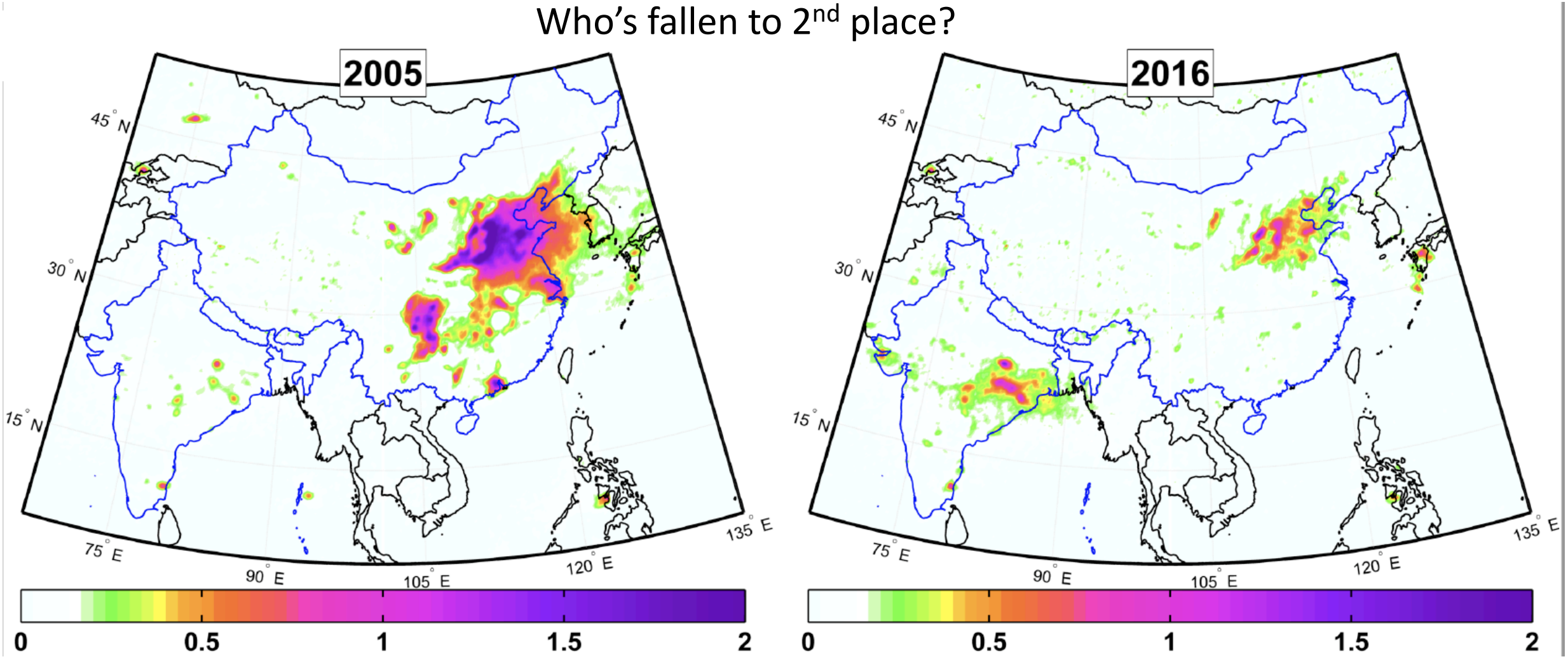
Presented at NIST
7 November 2017
Russell Dickerson, UMD

Funded by the NSF with Supported from NIST

OMI SO_2

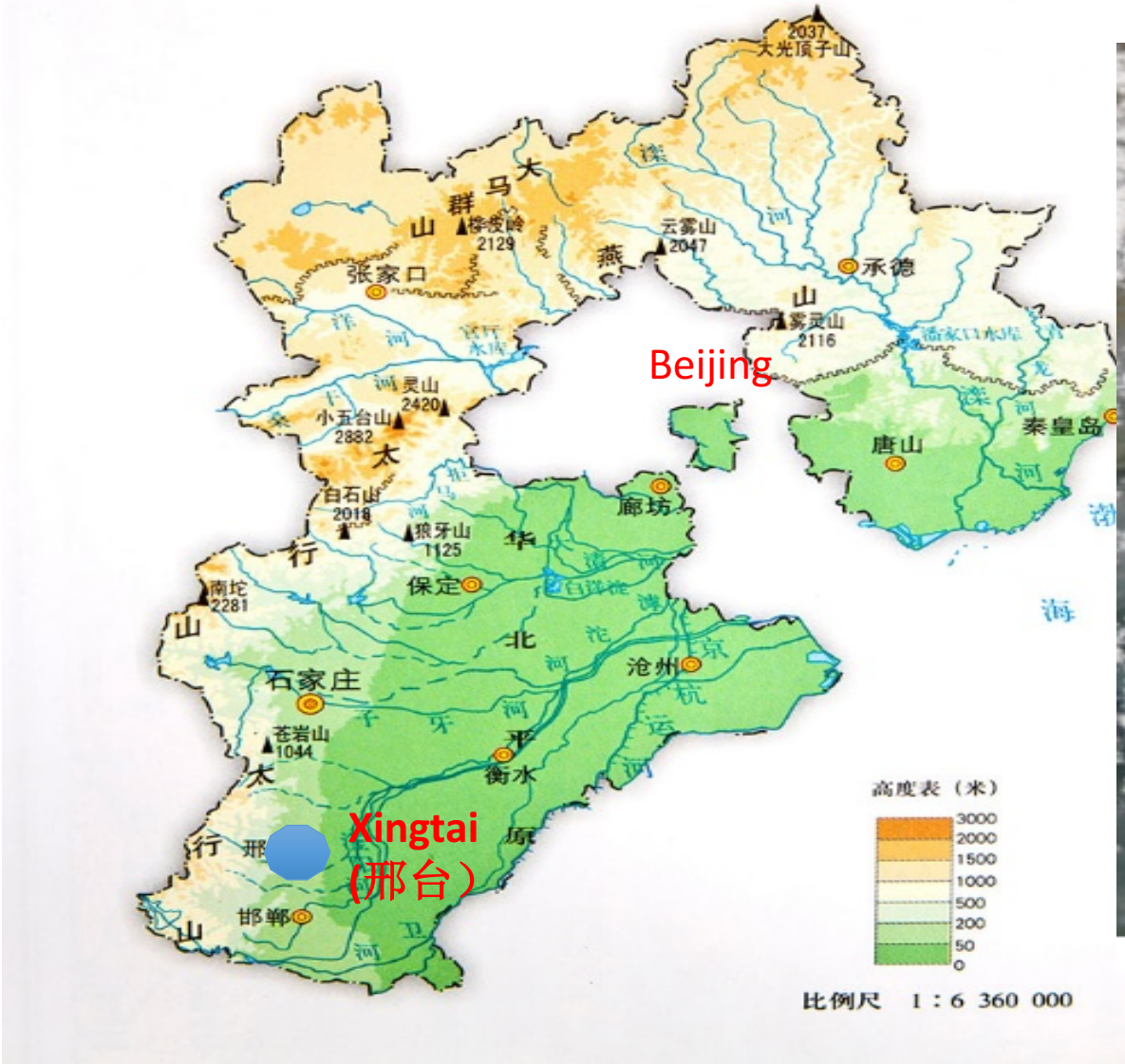
Li et al. *Scientific Reports* in press 2017.

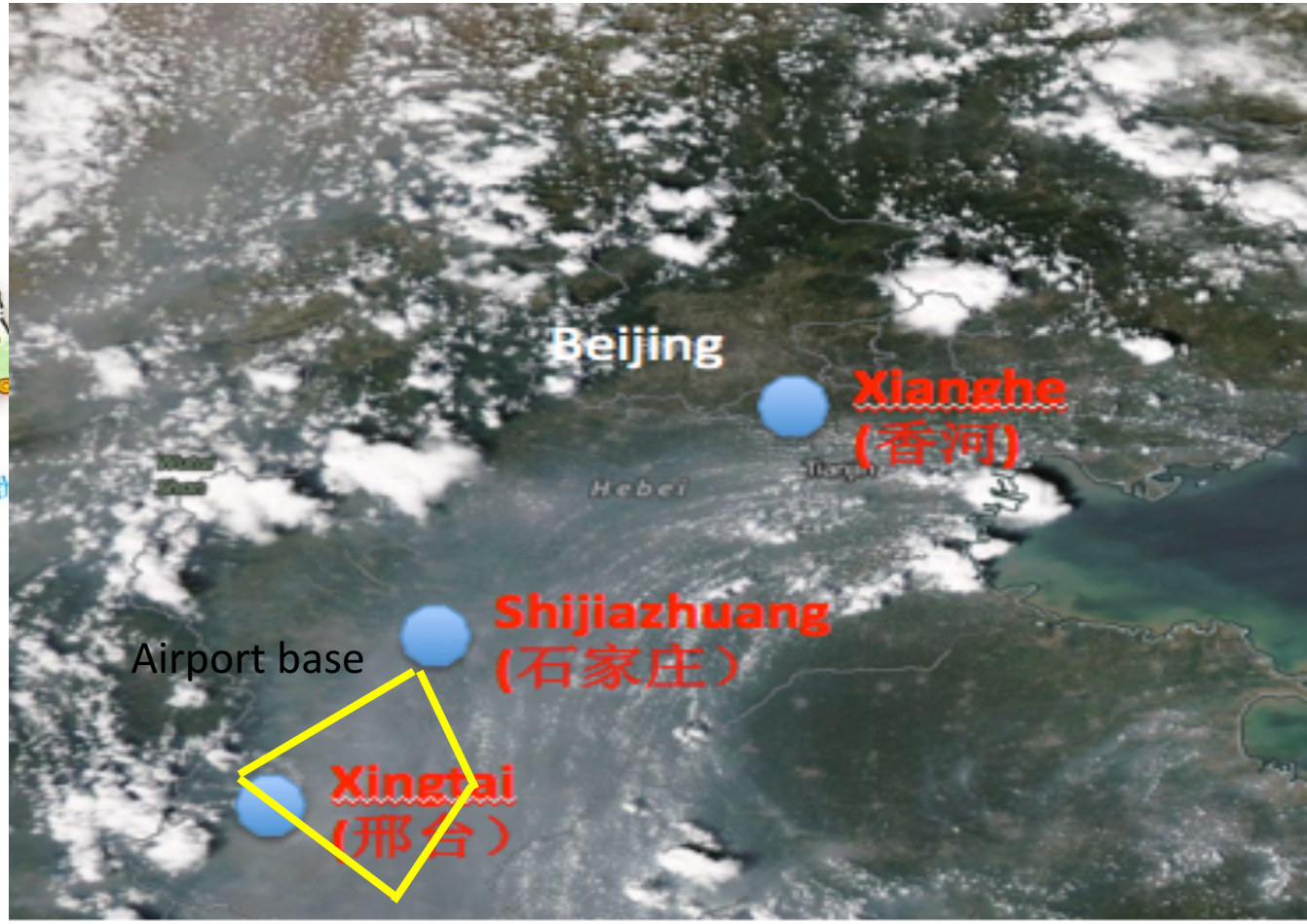
Who's fallen to 2nd place?



ARIAS Experimental Locations 2016

Aircraft Flies Across Hebei Province; Spirals Over Ground Stations





Y12 Instrumentation

GPS Position (Lat, Long, Altitude)

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

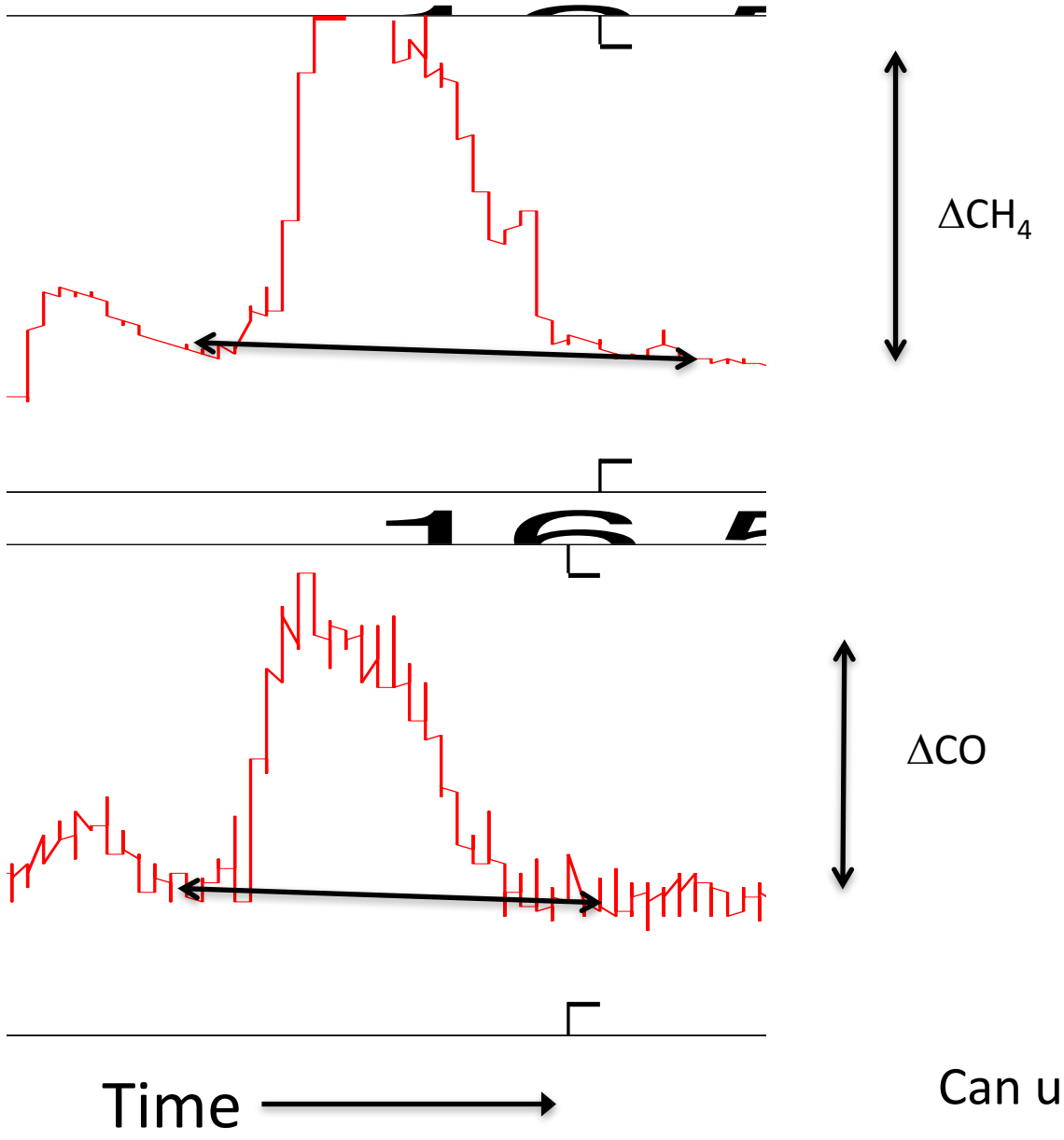
Trace gases:

- 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/NO_y: Chemiluminescence, TECO
- VOCs: grab canisters/GC-FID

Aerosols:

- Scattering: b_{scat} (@450, 550, 700 nm), Nephelometer
- Absorption: b_{ap} (565 nm), PSAP
- Black Carbon: Aethalometer, 7λ
- Cloud Condensation Nuclei (CCN)
- Single Particle Soot Photometer (SP^2) (MPI)

Evaluating emissions: Schematic of ratio method



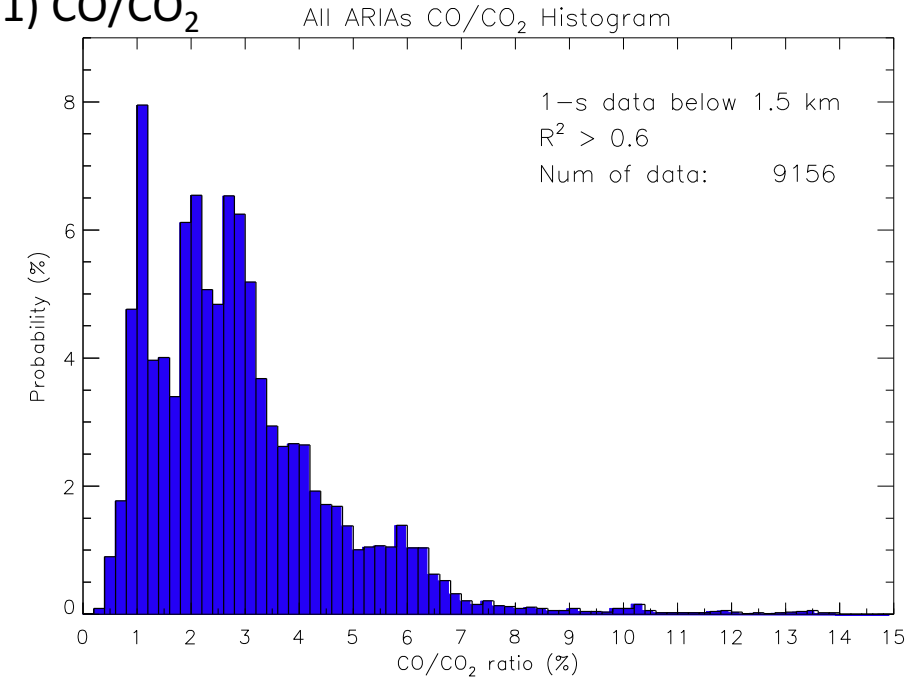
Can use CH_4/CO slope.

Plume Detection Algorithm

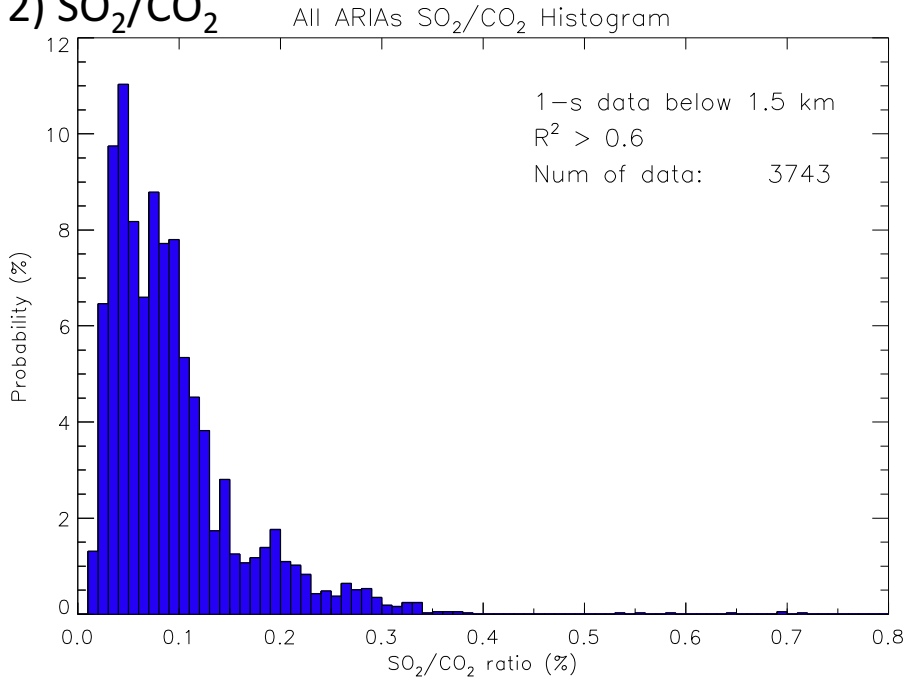
- Adapted from NASA-LaRC ICARTT plume detection mechanism
- Method:
  - 1) use moving window (1 min of 1-s data) to conduct a linear regression analysis of data collected within the PBL (< 1500 m), i.e., $\Delta XX/\Delta CO_2$ ratios.
  - 2) select statistically significant ($R^2 > 0.6$) $\Delta XX/\Delta CO_2$ ratios.
  - 3) calculate the ratio distribution and create the histogram plots.
- This algorithm can automatically detect emissions plumes.

Hao He, UMD

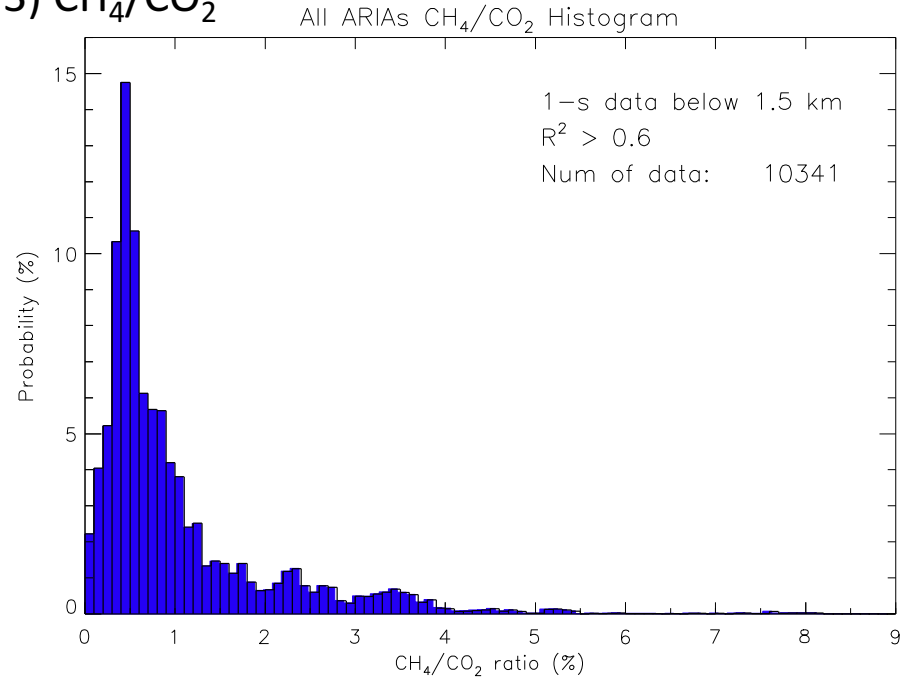
1) CO/CO_2



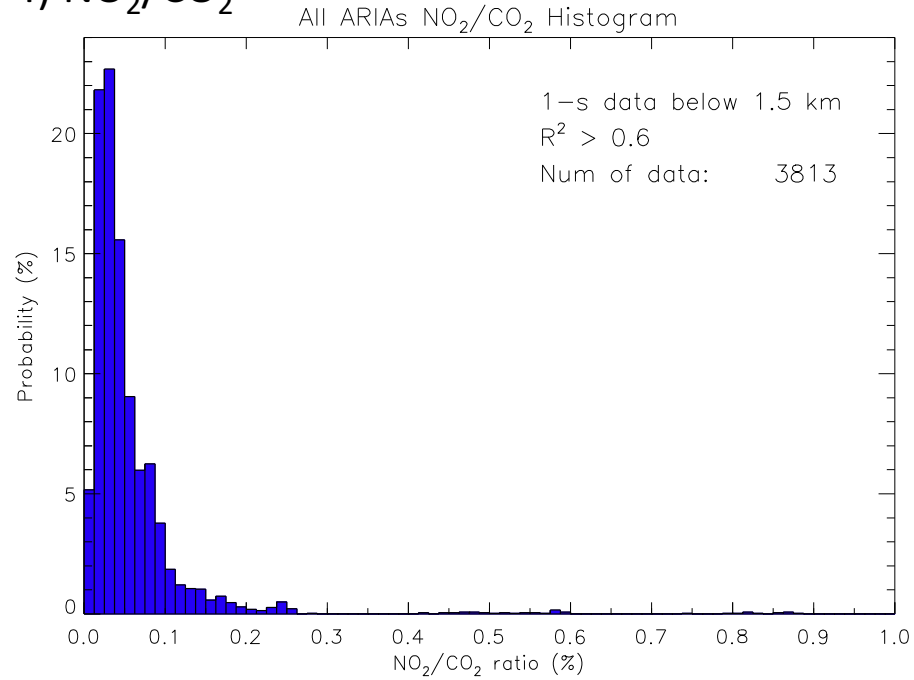
2) SO_2/CO_2



3) CH_4/CO_2



4) NO_2/CO_2



All ARIAs measurements

$\Delta XX/\Delta CO_2$ ratios histograms

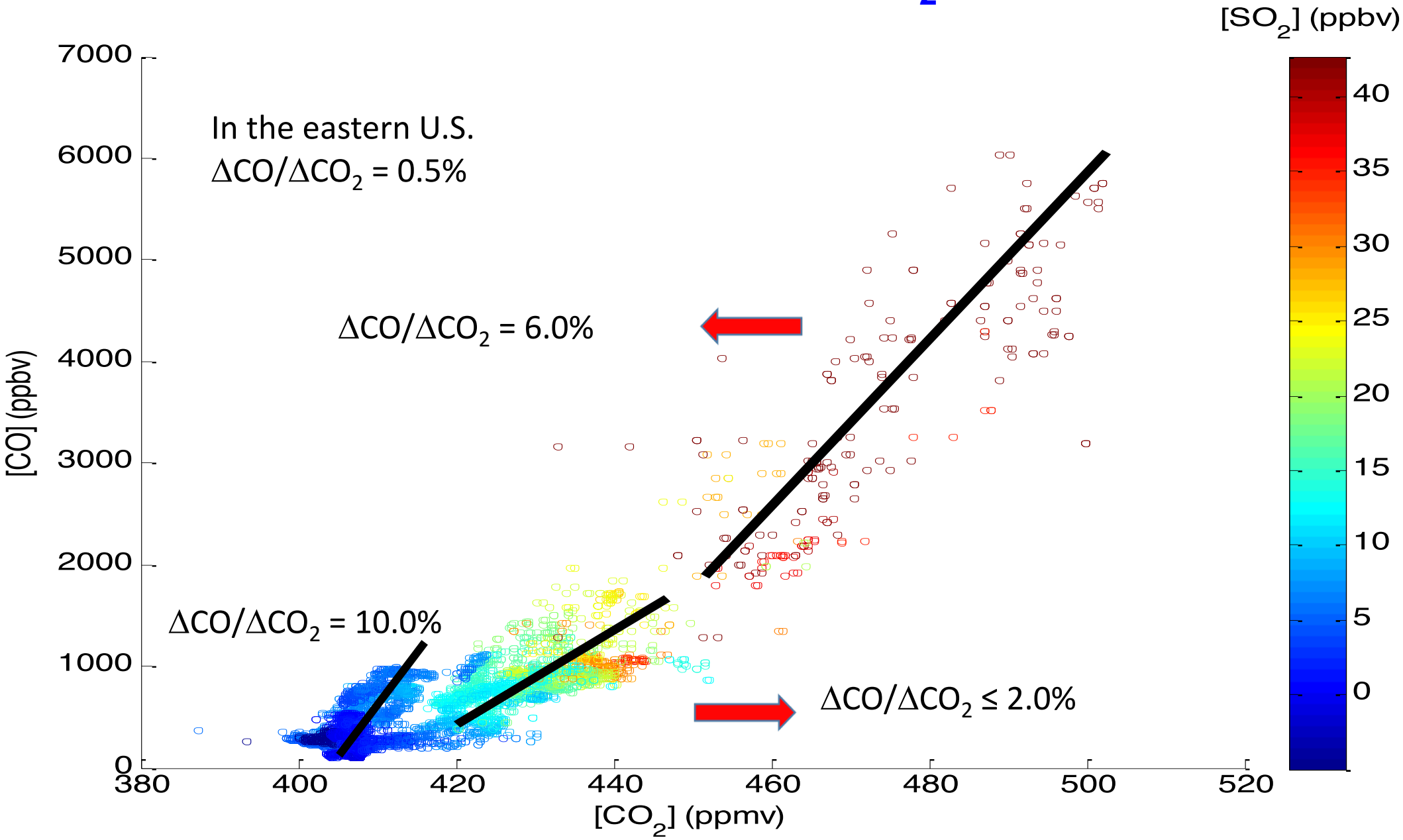
1) $\Delta CO/\Delta CO_2$: high means inefficient combustion

2) $\Delta SO_2/\Delta CO_2$: is low compared with our 2005 & 2008 flights. S/C in coal 1-3% says Scrubbing!

3) $\Delta CH_4/\Delta CO_2$: isolated plumes with high values observed.

4) $\Delta NO_2/\Delta CO_2$: episodes of large values (>0.1%) observed.

Emission Identification: CO to CO_2 ratios in Hebei



Characteristic Pollutant Emission Ratios

- **Efficient internal combustion** $\Delta CO:\Delta CO_2 < 1\%$
  $\Delta NOx:\Delta CO_2 < 0.1\%$
  $\Delta SO_2:\Delta CO_2 << 0.1\%$

- **High Tech coal combustion unscrubbed** $\Delta CO:\Delta CO_2 << 1\%$
  $\Delta NOx:\Delta CO_2 \sim 1\%$
  $\Delta SO_2:\Delta CO_2 = 0.5\text{-}2\%$

- **Biomass burning** $\Delta CO:\Delta CO_2$ 5-10%
  $\Delta NOx:\Delta CO_2 = 0.1$ to 1%
  $\Delta SO_2:\Delta CO_2 < 0.1\%$
  $\Delta CH_4:\Delta CO_2 = 0.2$ to 2%

Evaluating emissions inventories is essential.

- Borrow a classical technique for top down emissions estimates.
- First employed to study biomass burning in the Amazon (Crutzen et al., 1979) later for BC from India (Dickerson et al., 2002) and NOx in Baltimore (Anderson et al., 2014).

$$E_{CO} = \frac{\Delta CO}{\Delta CO_2} \times E_{CO2}$$

$$E_{NOx} = \frac{\Delta NOx}{\Delta CO} \times E_{CO} = \frac{\Delta NOx}{\Delta CO_2} \times E_{CO2}$$

Looking at ratios of short-lived pollutants to CO_2 can

show the use of control equipment,

indicate the efficiency of combustion,

help evaluate emissions inventories.

40% by 2030

Maryland Commission on Climate Change

DRAFT Annual Report

Prepared for:

Larry Hogan, Governor
State of Maryland

and the Maryland General Assembly

November 2017

Regional Atmospheric Measurement Modeling & Prediction Program

RAMMPP: Balanced Theory & Observations

WRF

Dynamical Model

1.3 to 4km Resolution

Forecasting

Input

Emissions Inventories

Emissions Models

(Chem Engineering)

Chem/Trans Models

CMAQ/CAMx

Modular
Open Code
Collaborative
w/EPA

or

WRF-CHEM
Regional
Linked met/chem

Goal: Prediction and Policy

Observations

Surface:

- Essex, MD
- Beltsville, MD
- I-95, MD
- Piney Run, MD
- Shenandoah National Park, VA

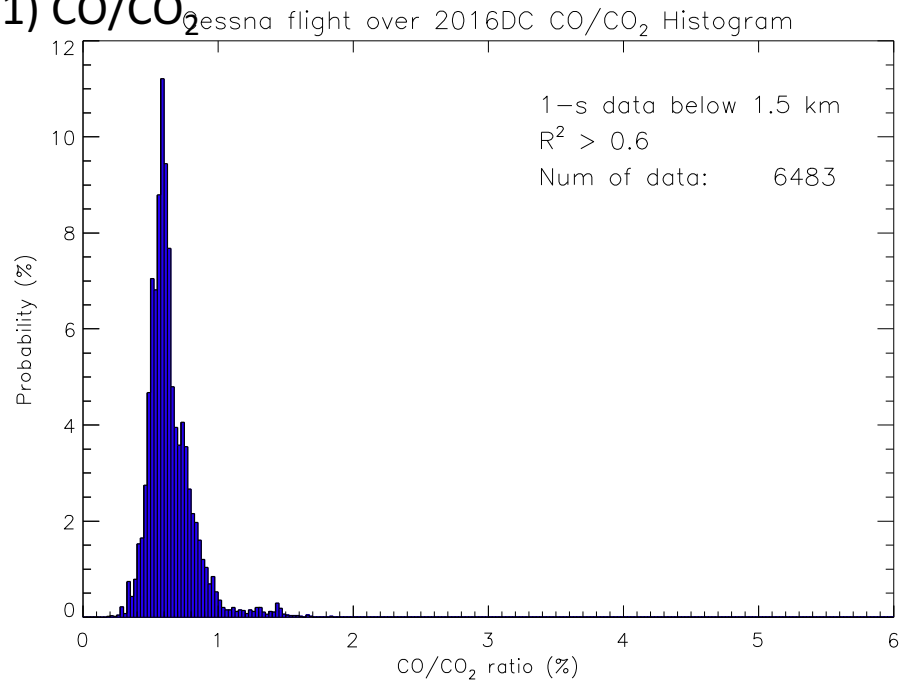
Aloft

- Cessna Aircraft
- Profiler
- Sondes/LIDAR

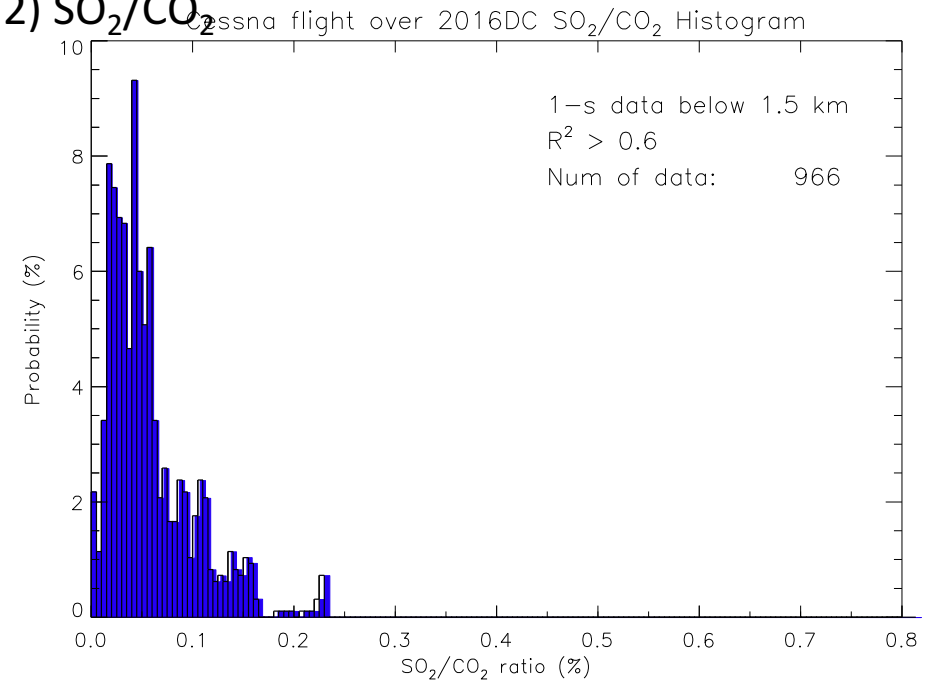
Remote (NASA)

- OMI
- MOPITT (CO)
- MODIS (particles)
- AIRS
- TEMPO

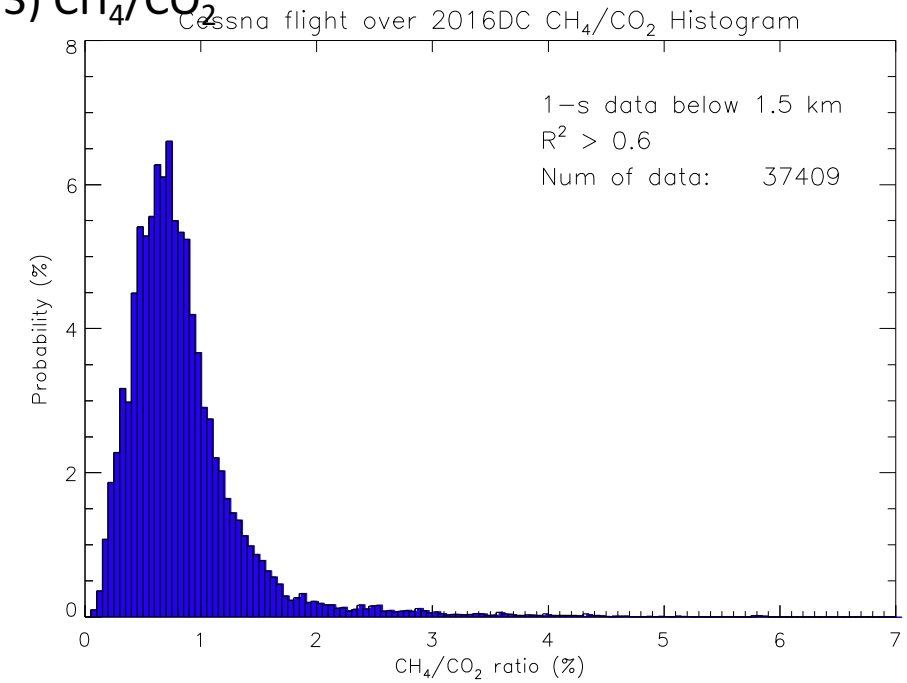
1) CO/CO_2



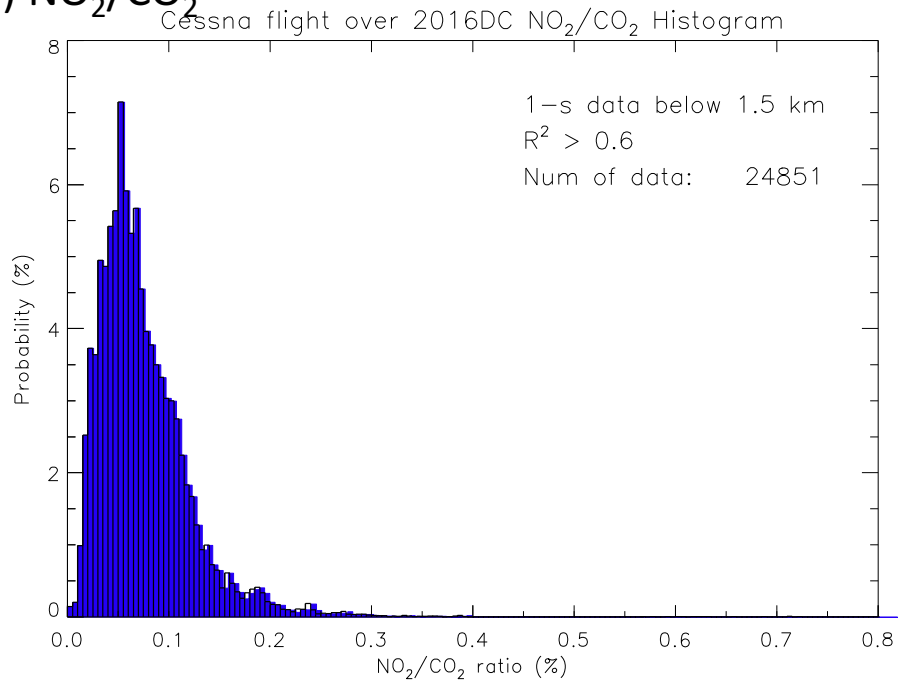
2) SO_2/CO_2



3) CH_4/CO_2



4) NO_2/CO_2



2016 FLAGG-MD flights in Balt/DC area.

$\Delta XX/\Delta CO_2$ ratios histogram

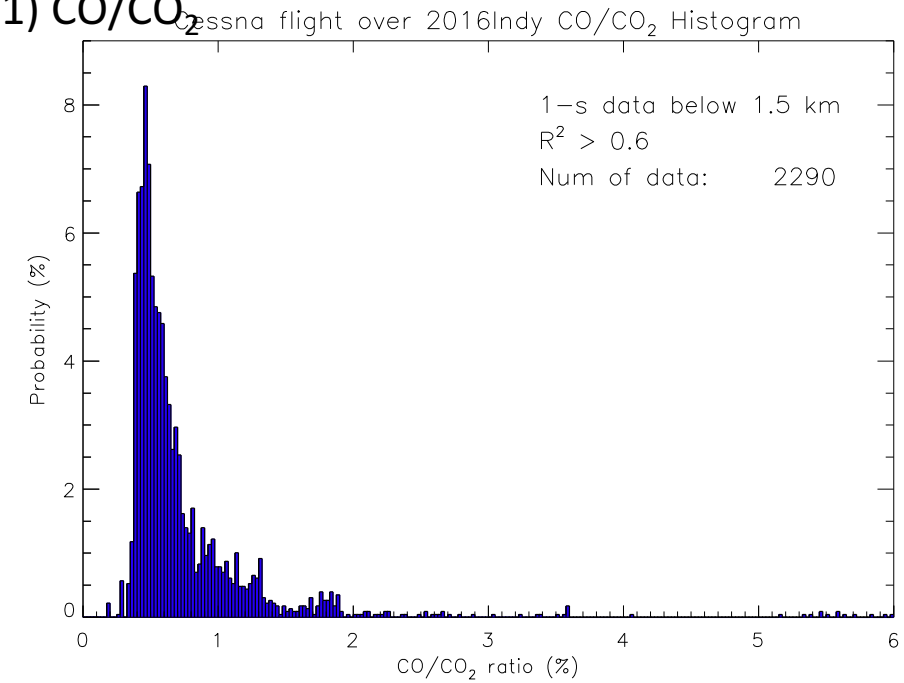
1) $\Delta CO/\Delta CO_2$: highly efficient combustion

2) $\Delta SO_2/\Delta CO_2$: Median similar to that measured in China but there are no spikes.

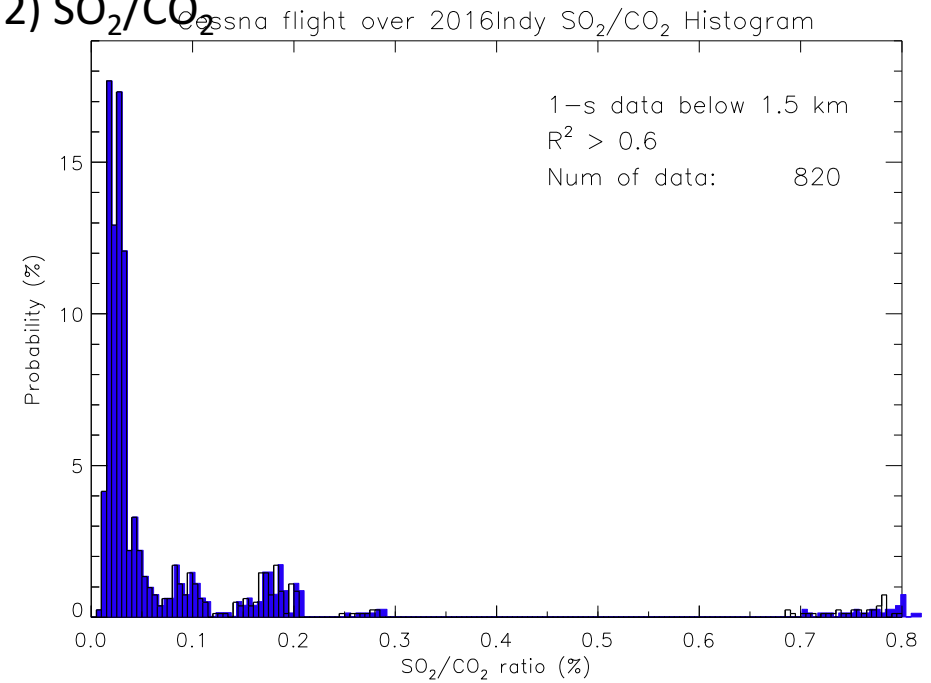
3) $\Delta CH_4/\Delta CO_2$: lower values than in China. (Co-located sources)

4) $\Delta NO_2/\Delta CO_2$: similar values observed in China.

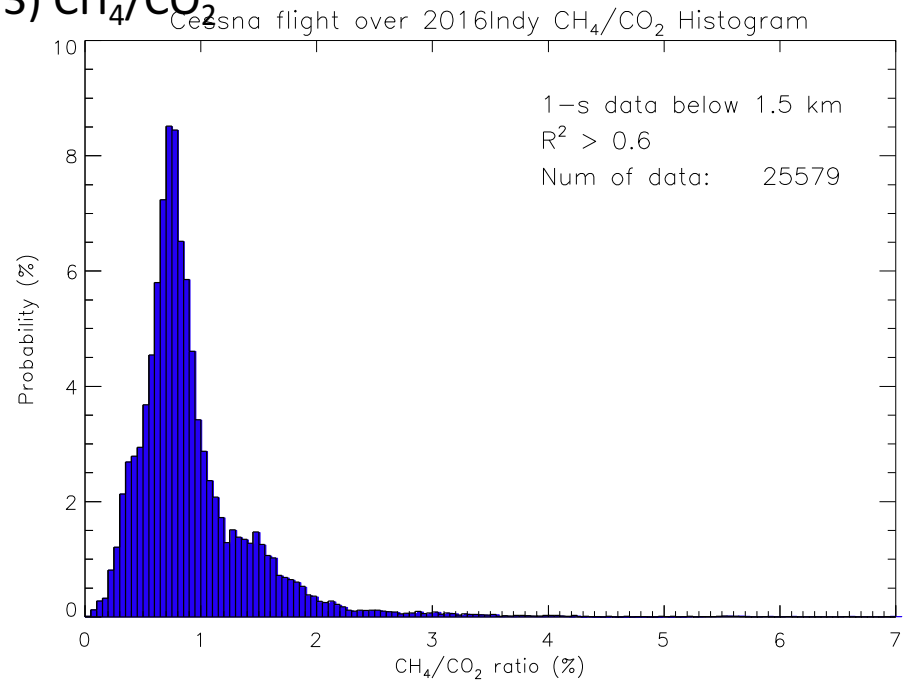
1) CO/CO_2



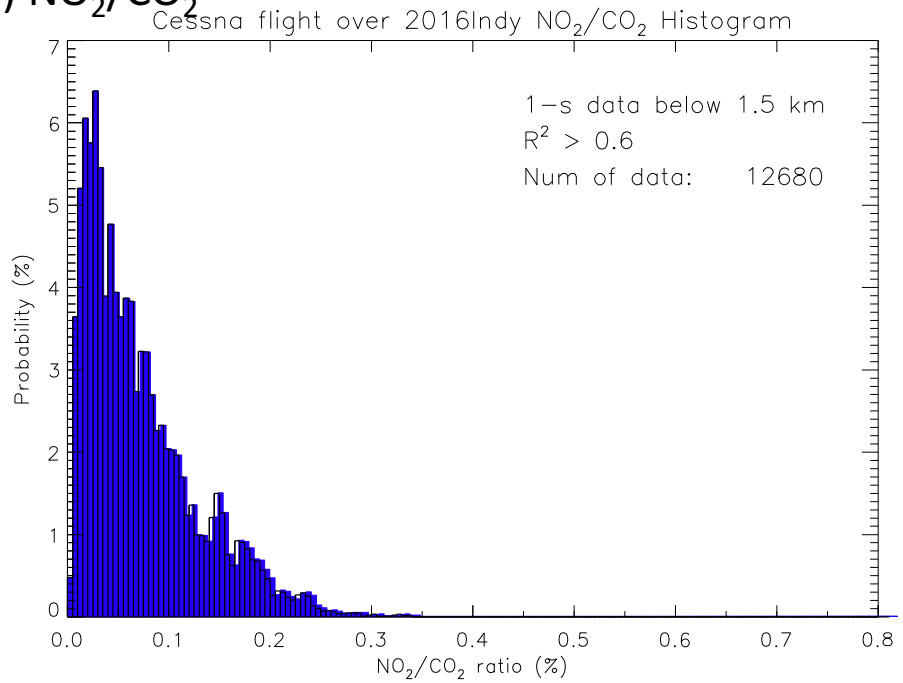
2) SO_2/CO_2



3) CH_4/CO_2



4) NO_2/CO_2



2016 FLAGG-MD flights in Indianapolis

$\Delta XX/\Delta CO_2$ ratios histograms

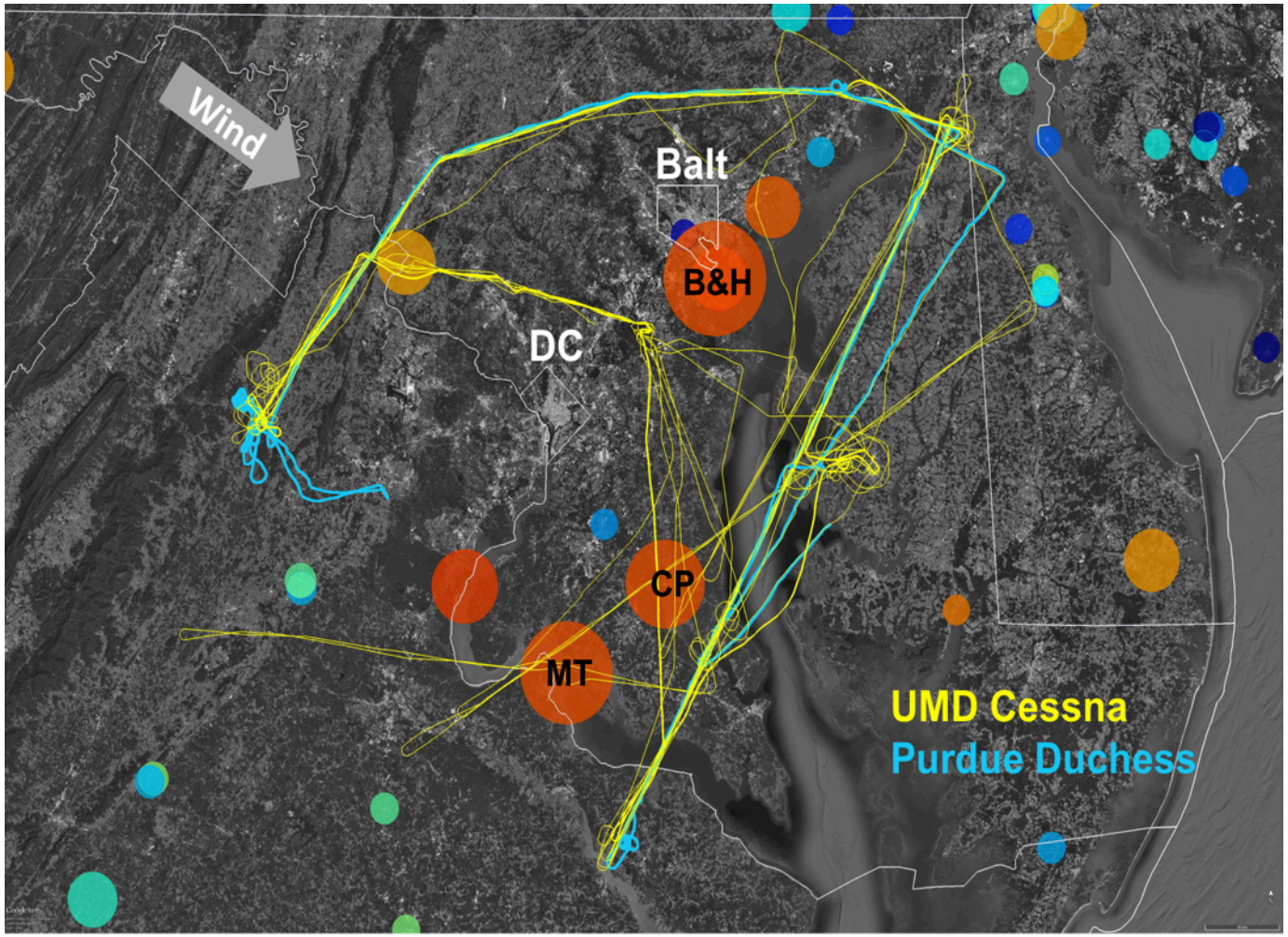
1) $\Delta CO/\Delta CO_2$: similar to Balt/DC, but more spikes.

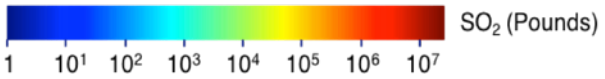
2) $\Delta SO_2/\Delta CO_2$: much lower mode than Balt/DC, but spikes

3) $\Delta CH_4/\Delta CO_2$: similar as to Balt/DC.

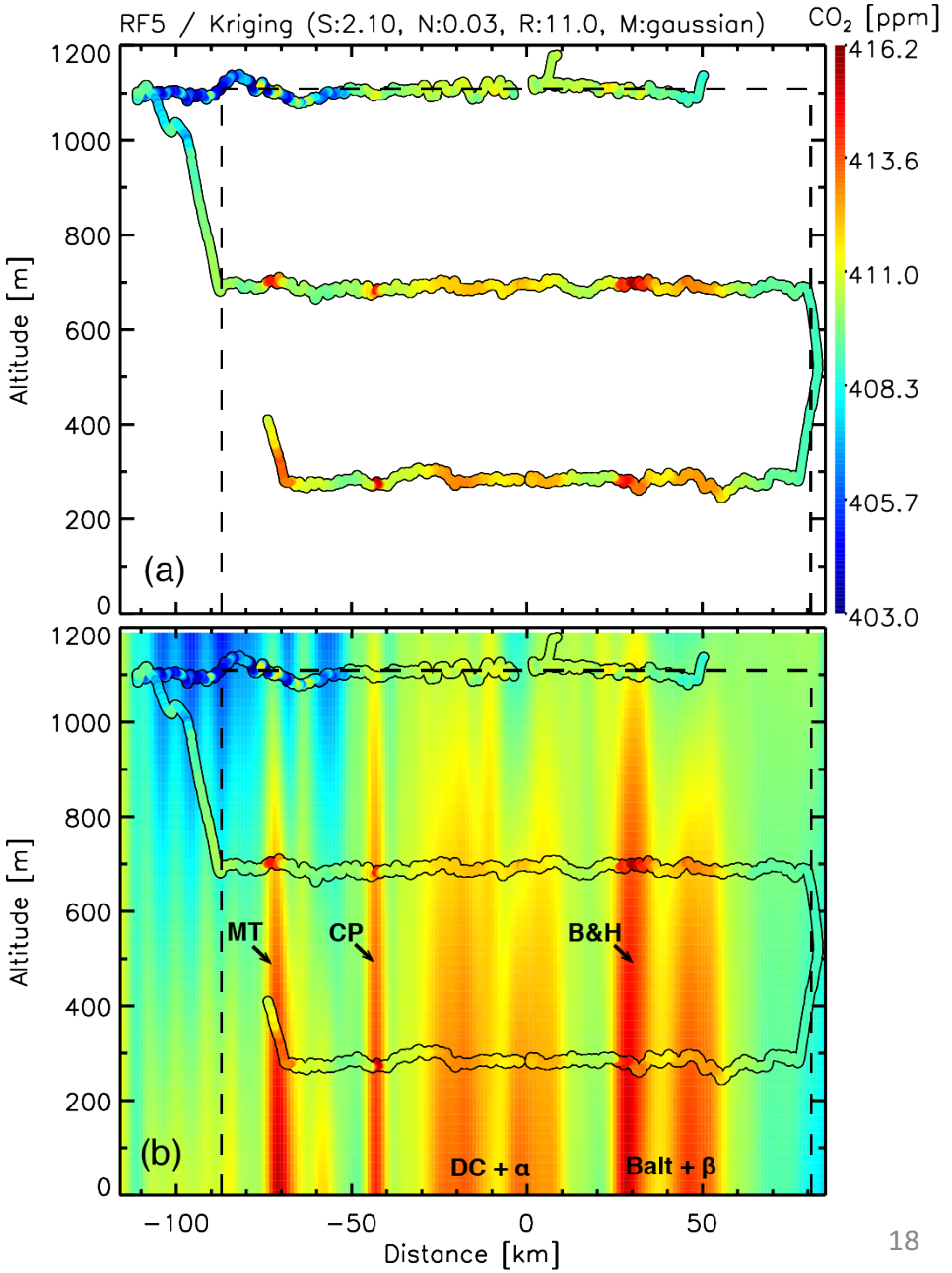
4) $\Delta NO_2/\Delta CO_2$: slightly lower values than Balt/DC.

Overview of FLAGG-MD aircraft camapign 2015

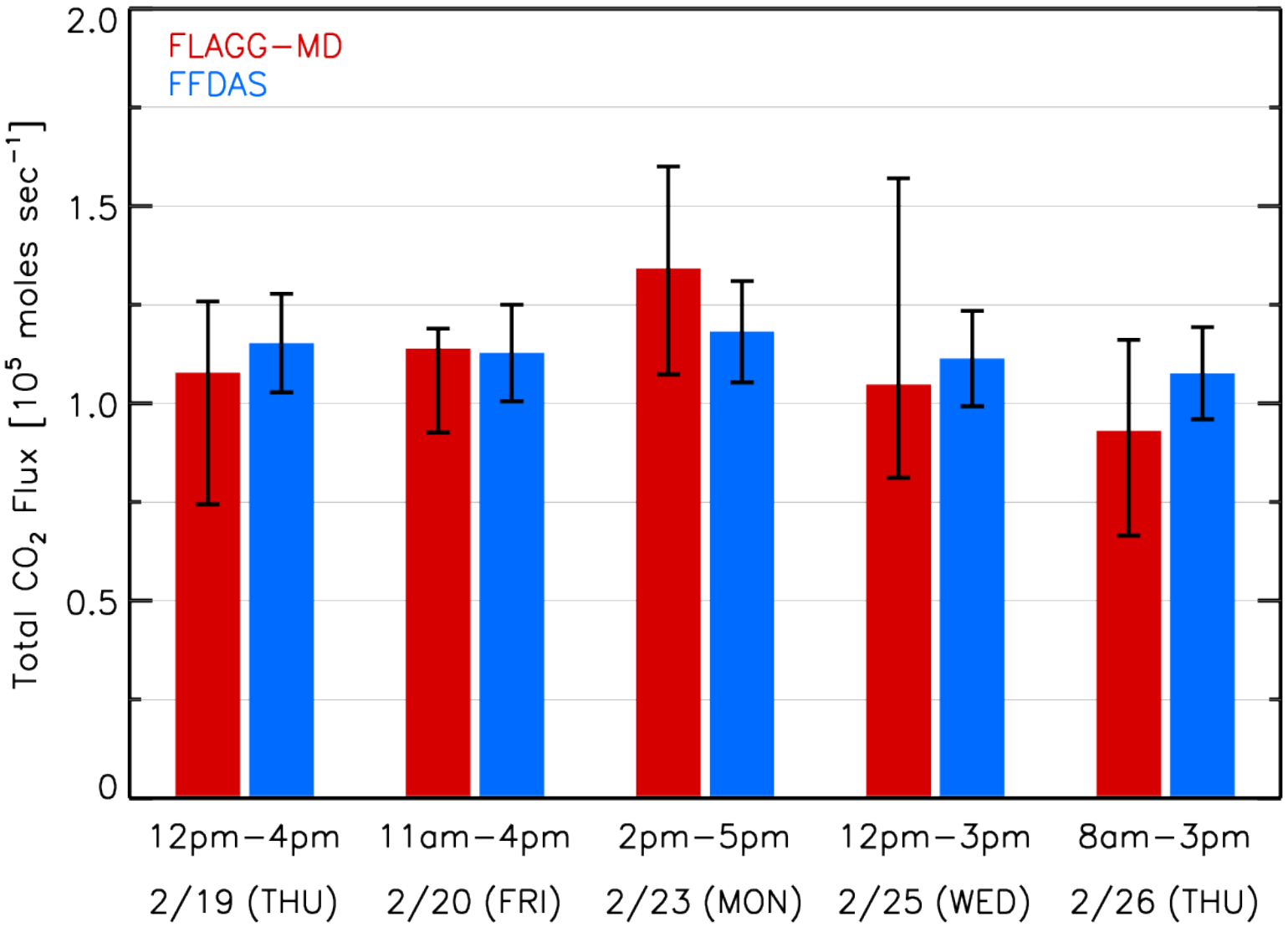




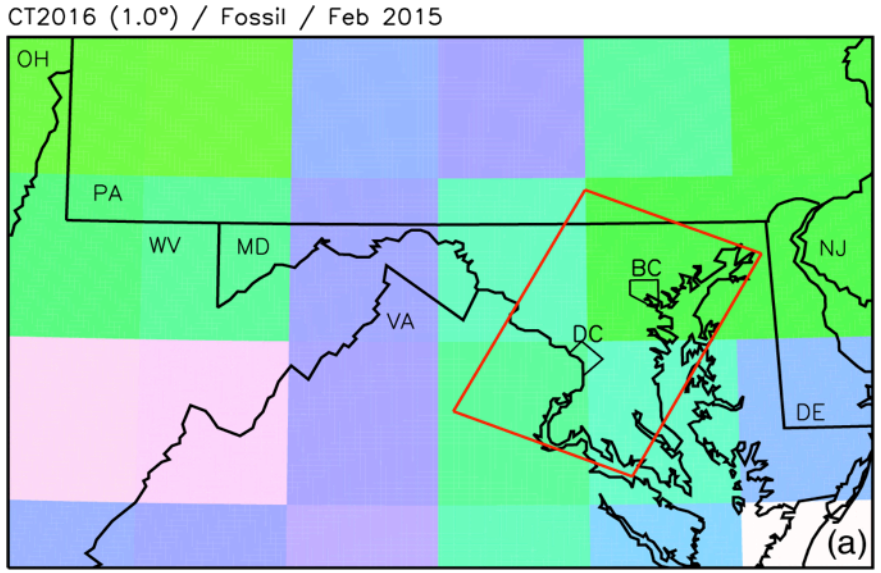
Example of CO_2 plumes captured by UMD Cessna

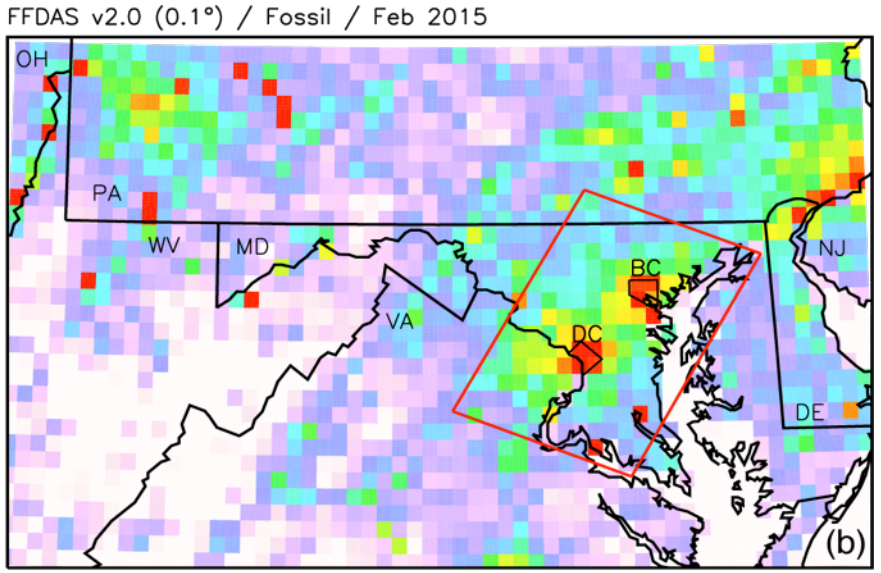


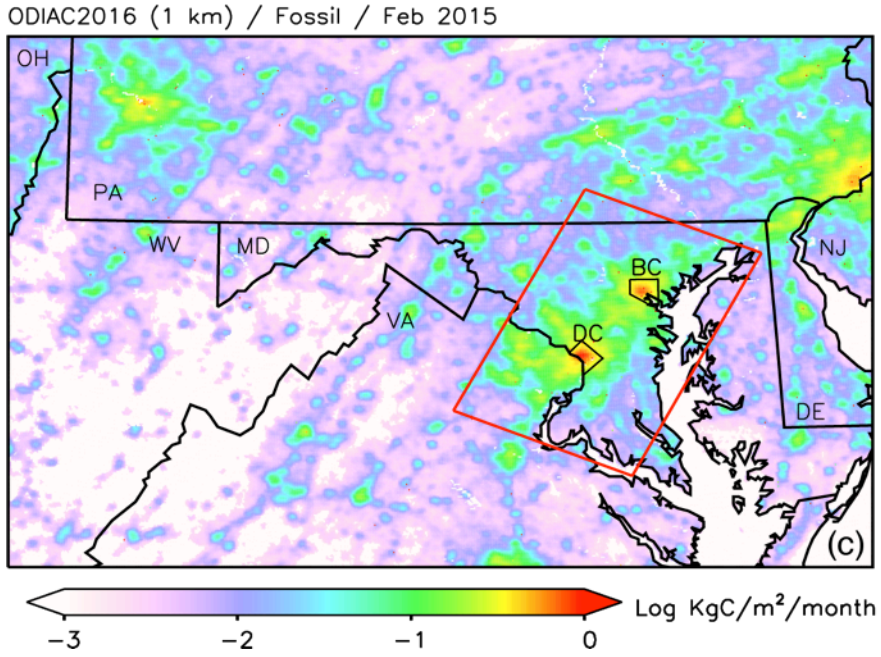
Hourly flux comparison: FLAGG-MD vs. FFDAS

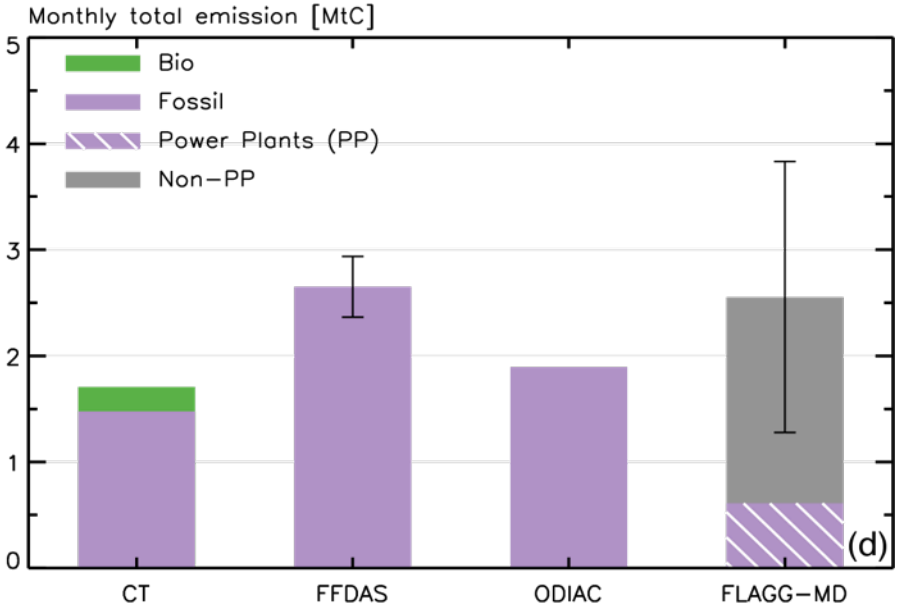


Monthly flux comparison: FLAGG-MD, CarbonTracker, FFDAS, ODIAC

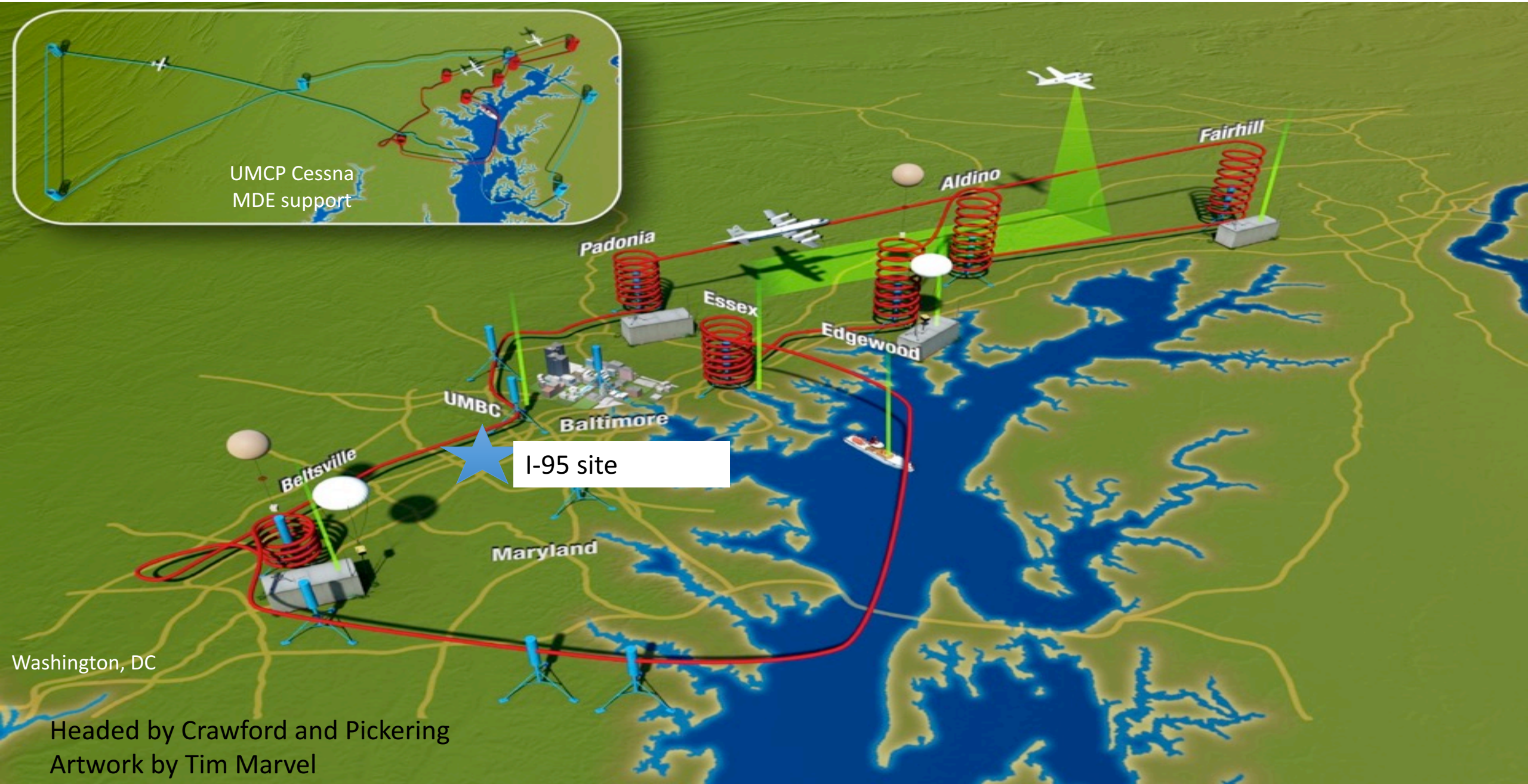






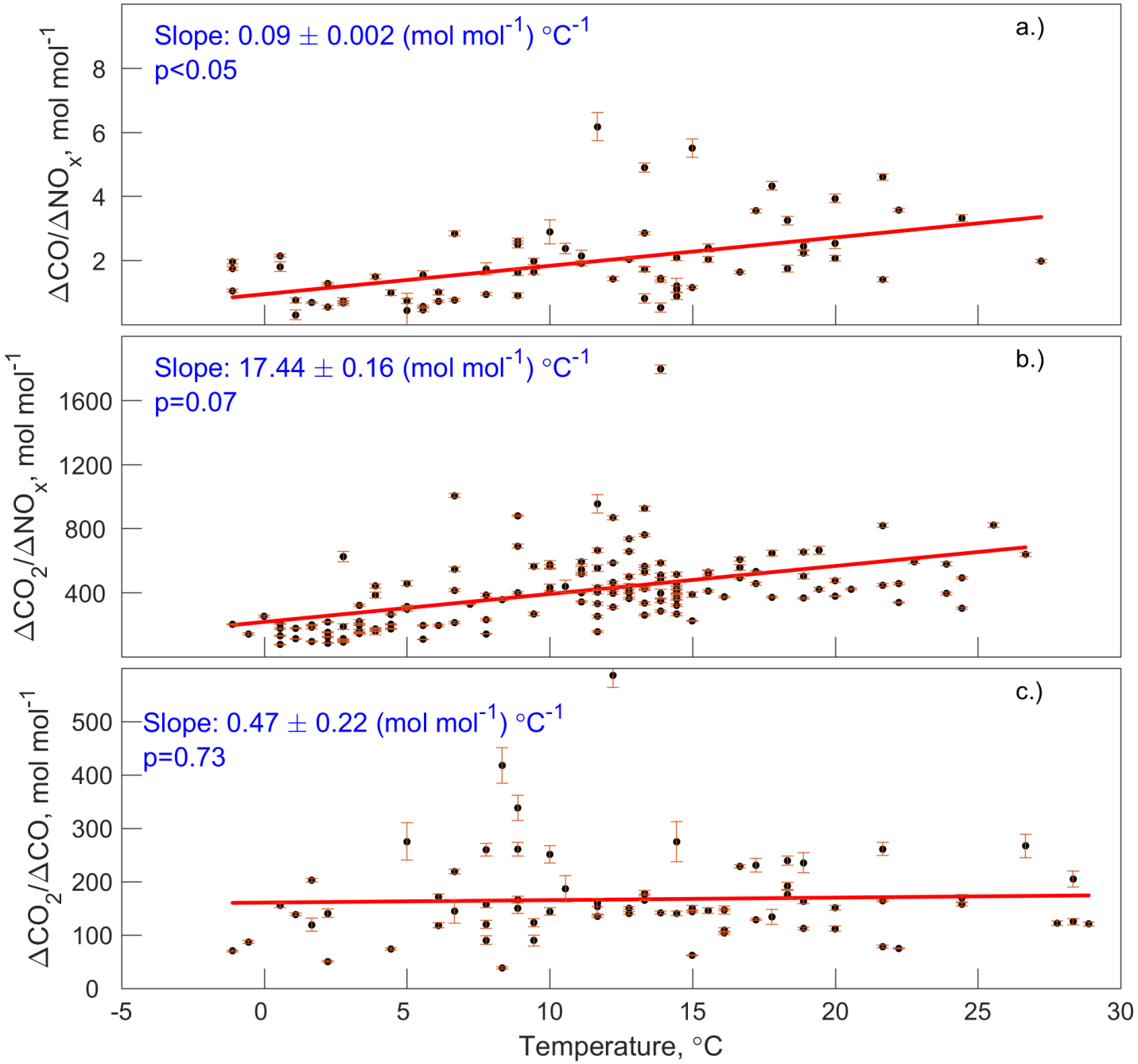


NASA's DISCOVER-AQ Maryland July 2011 & MDE's I-95 site

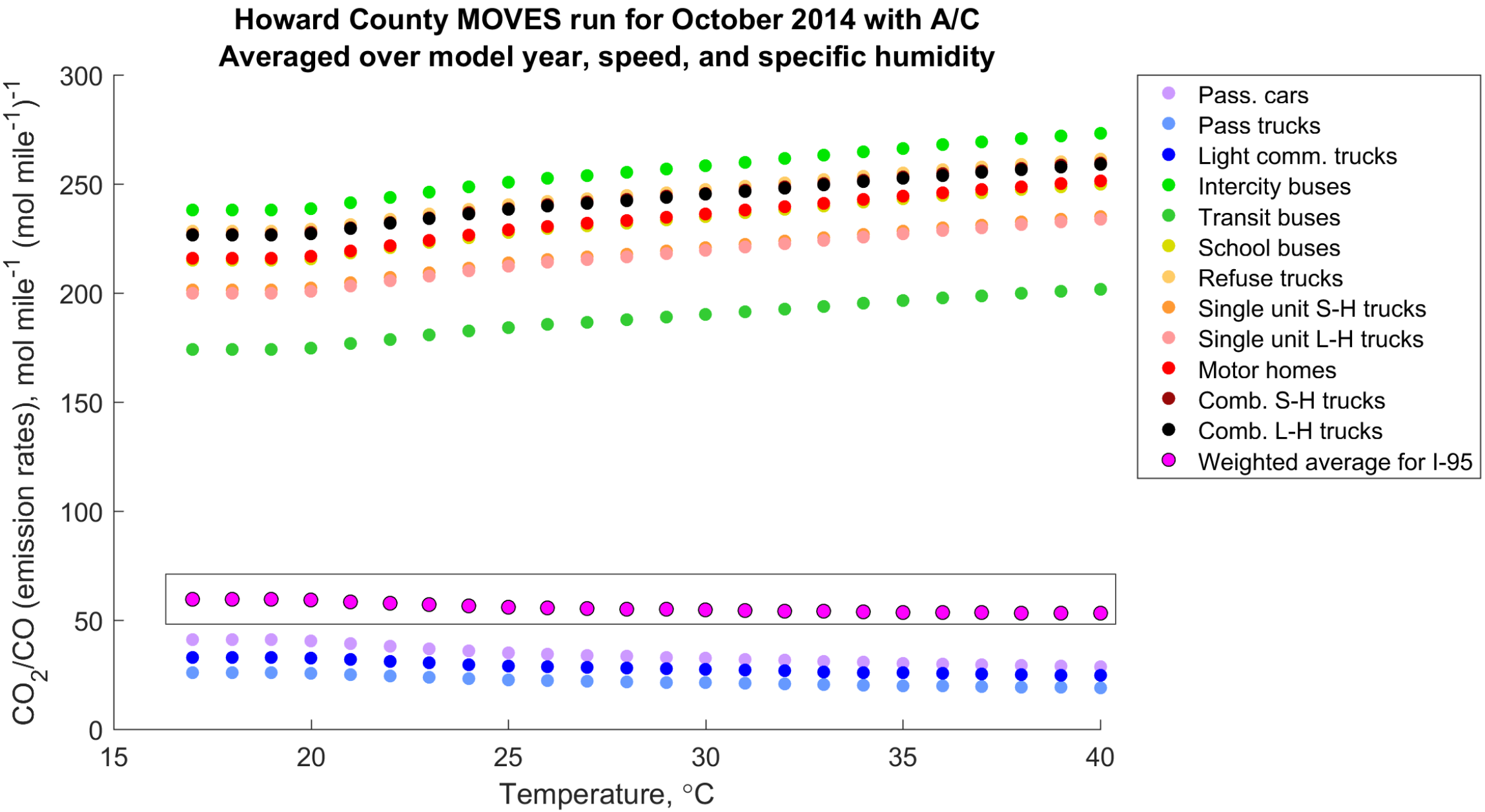


Headed by Crawford and Pickering
Artwork by Tim Marvel

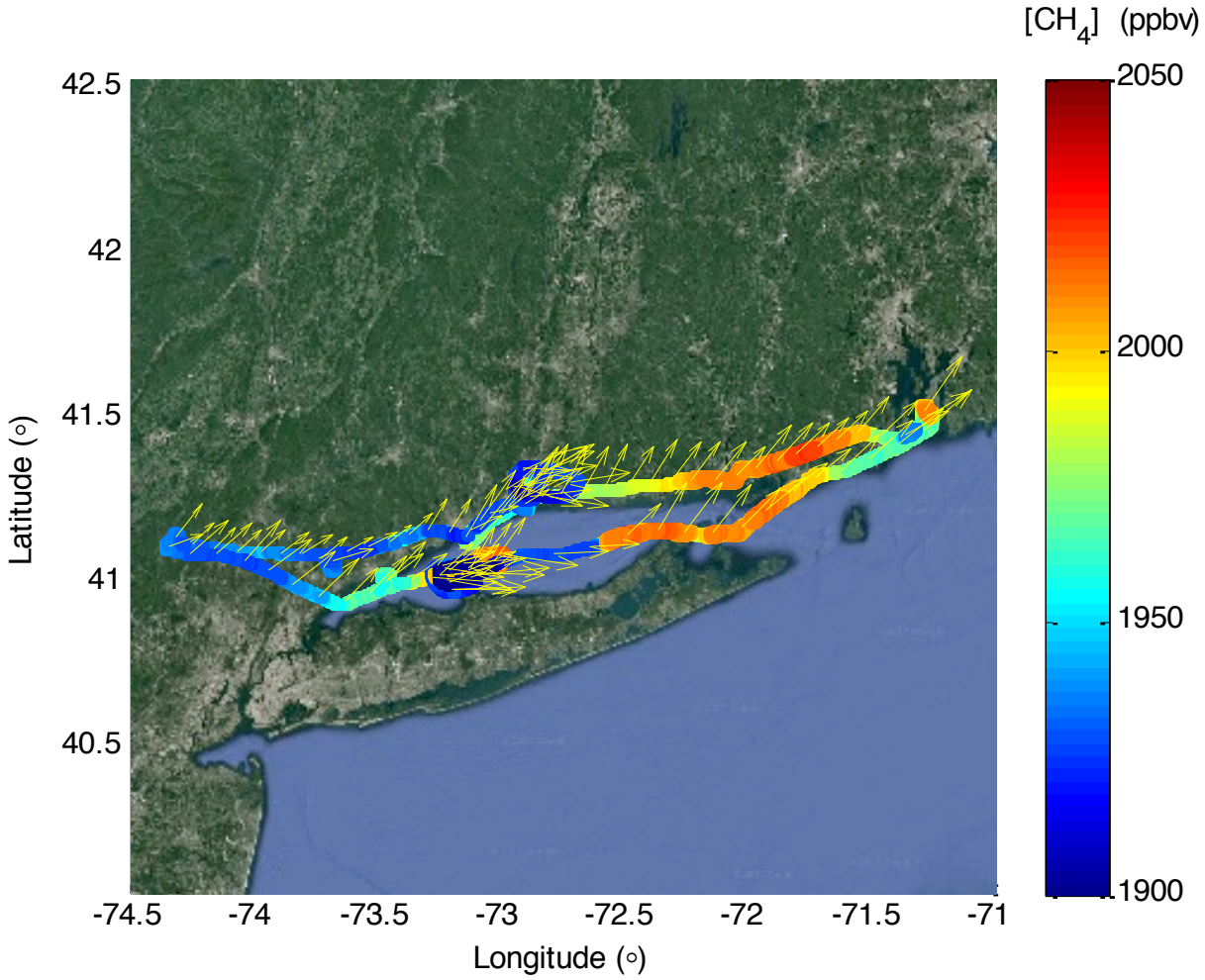

95
95
95
95
95

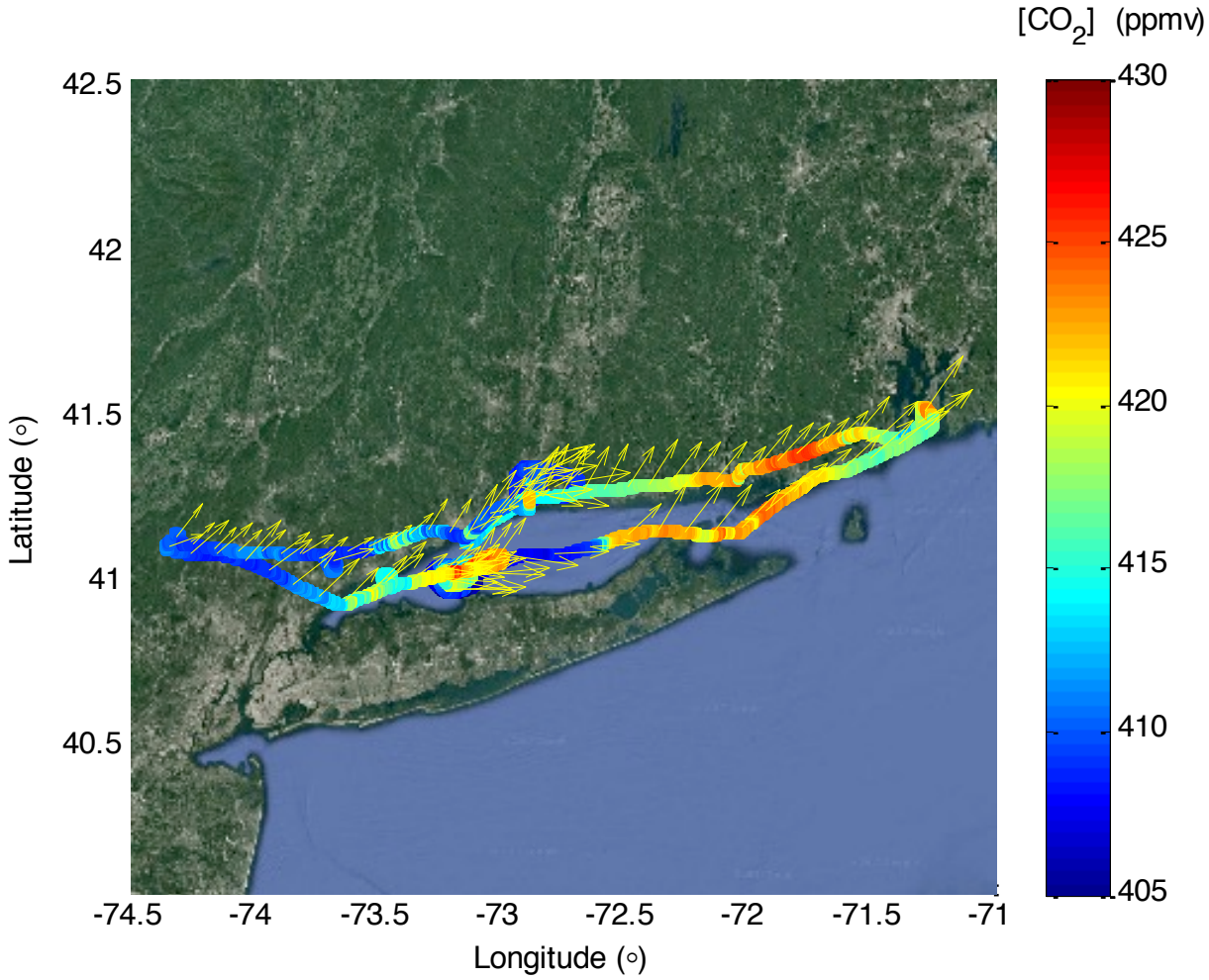


- Observations from I-95 NR site for October-November 2016
- Each dot represents an hourly emission ratio (not binned)
- Red line is the ordinary least-squares regression of the hourly ratios


Howard County MOVES run for October 2014 with A/C
Averaged over model year, speed, and specific humidity
CO2/CO (emission rates), mol mile-1 (mol mile-1)-1
300
250
200
150
100
50
0
15
20
25
30
35
40
Temperature, °C
Pass. cars
Pass trucks
Light comm. trucks
Intercity buses
Transit buses
School buses
Refuse trucks
Single unit S-H trucks
Single unit L-H trucks
Motor homes
Comb. S-H trucks
Comb. L-H trucks
Weighted average for I-95

New York Fight: May 18, 2017 Afternoon CH_4 and CO_2





Primary pollutants CH_4, CO_2 (& CO) as well as O_3 show higher conc's ENE of NYC/NJ.

Discussion points

CO was a good tracer when cars were dirty.
Now isoprene oxidation is comparable to direct emissions in summer in the daytime.
Calculating CO from isoprene oxidation is uncertain due to dependence on NOx and complexity of mechanism.

Cost benefit analysis for MD – saves lives thru reduced SO_2, NOx and VOC's = PM.
Success story – Brown Station Landfill CH_4.
States loved NASA's AQAST

Enhanced Ozone Monitoring Plan in the OTR
In open discussion EPA, States, MARAMA
judge.robert@epa.gov

Add CO_2 and CH_4
Mixing Height Measurements (PBL vs Residual layer, Lidar etc.)
Special Projects such as aircraft and ships.

Discussion Points Continued

What should be monitored?
What should be measured?
Who are out customers?
What do models most need?

Nonattainment: Ozone, but
Epidemiologists tell us that 12 μg/m^3 (35 μg/m^3 for 24 hr) is **not** protective of human health.

Sources SO_2, NH_3, NOx, mineral dust, VOC's

- SO_2 controlled to ~90%
- CO controlled to ~90%
- NOx controlled for ozone but still to high
- NH_3 going up
- VOC's critical

Uncertainty in US emissions opportunities for synergy

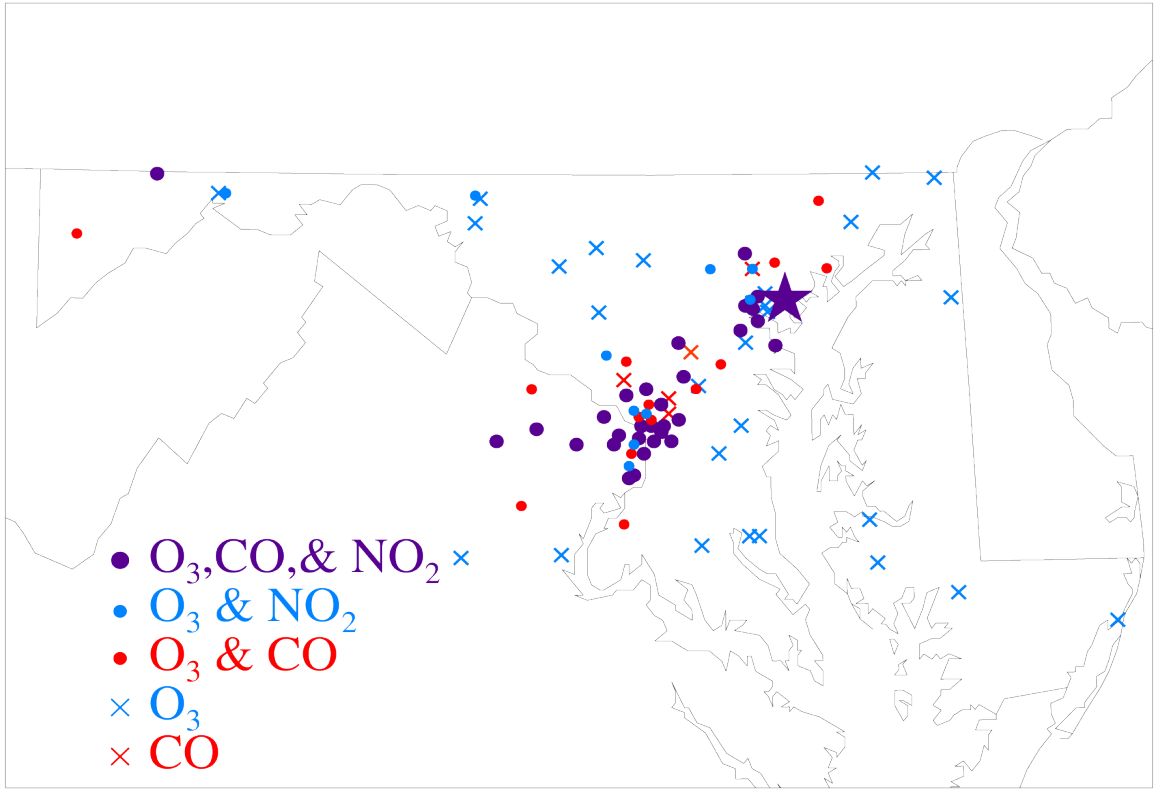
- CO_2 6-20%
- CO 15-150%
- SO_2 10-20%
- NOx Factor of 2
- NH_3 Factor of 2+
- VOC's 20% to factor of 10
- BC = ?

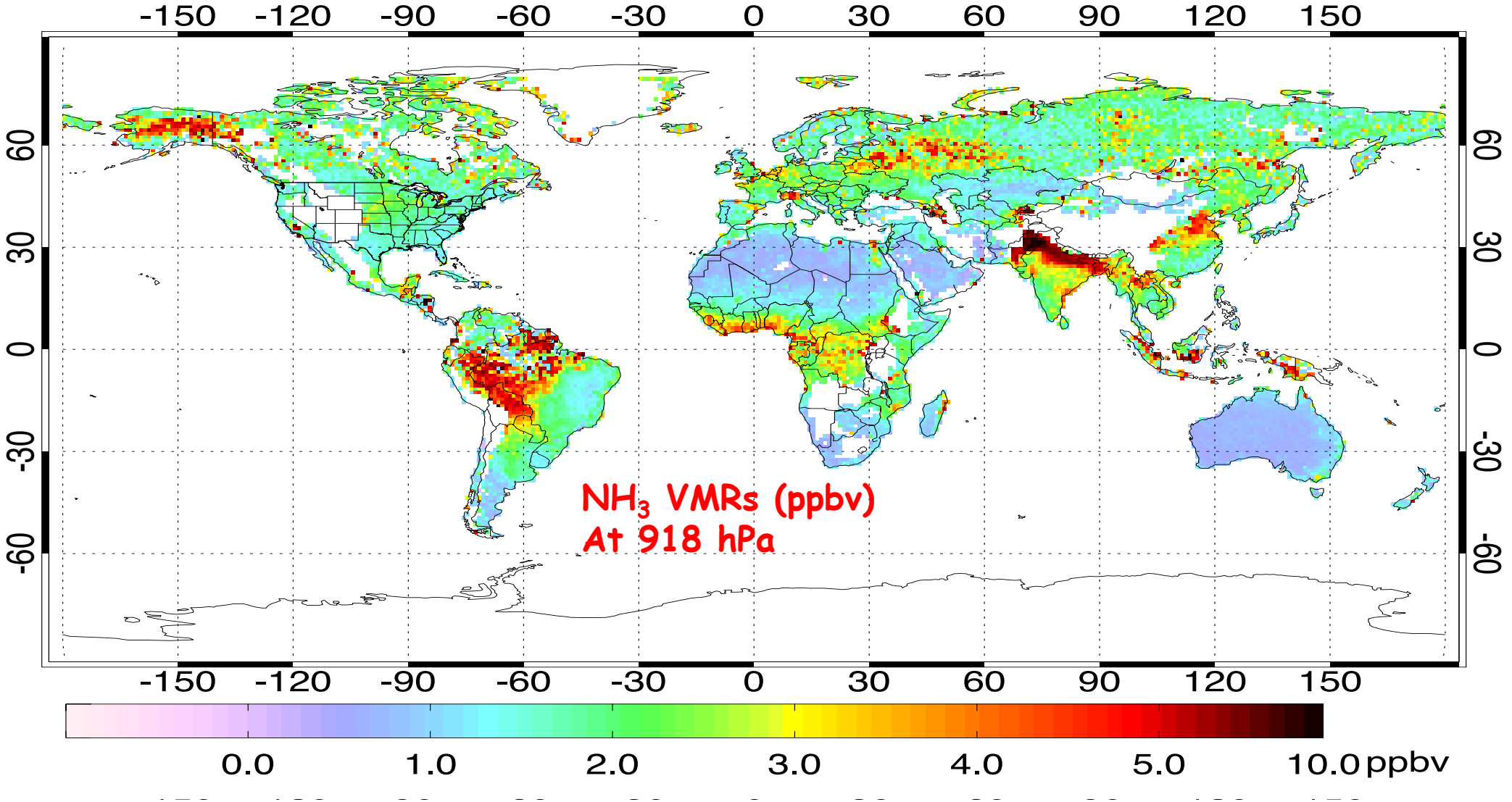
The End

Fear the Turtle!

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

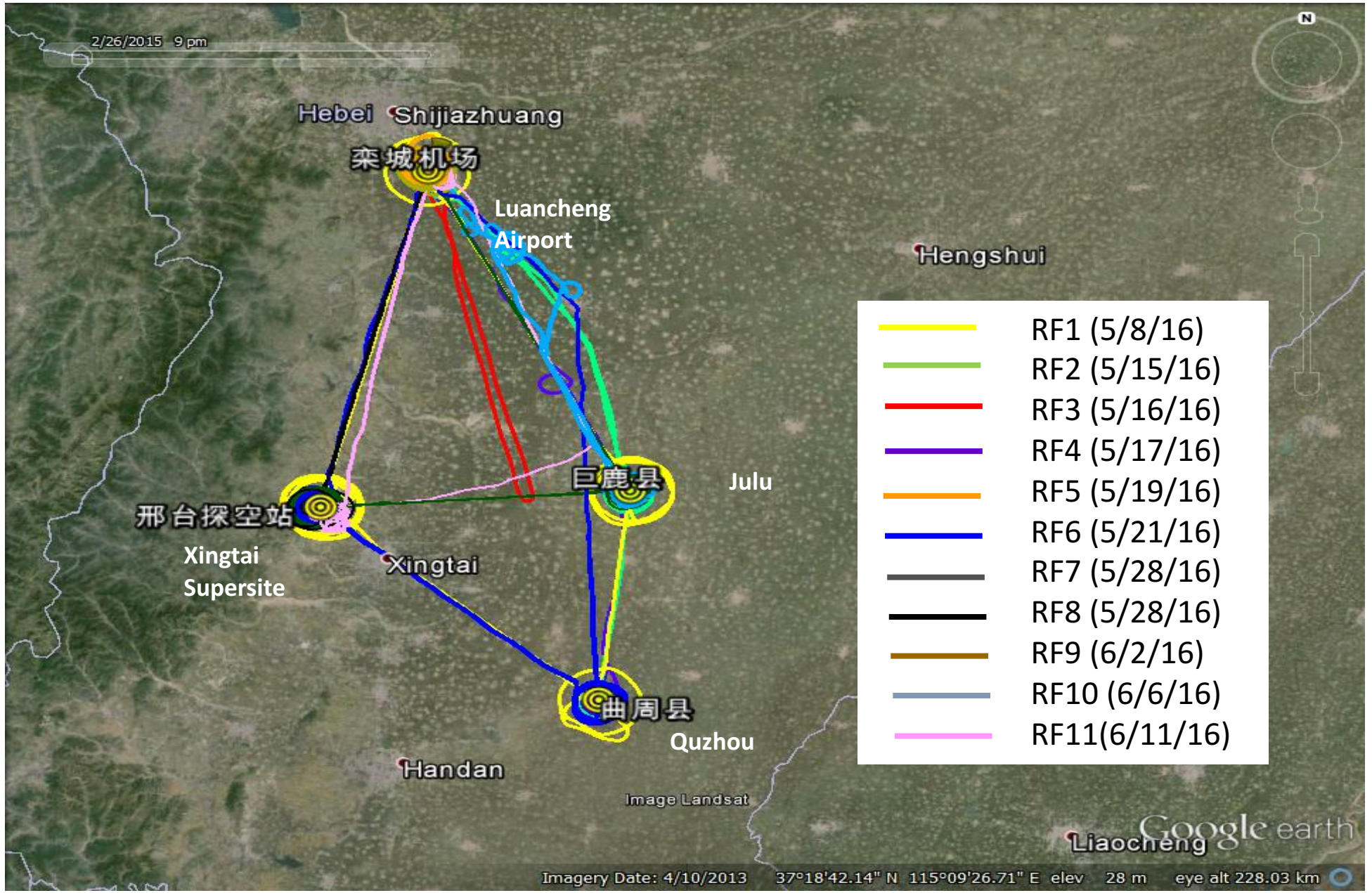
28


O_3,CO,& NO_2
O_3 & NO_2
O_3 & CO
O_3
CO

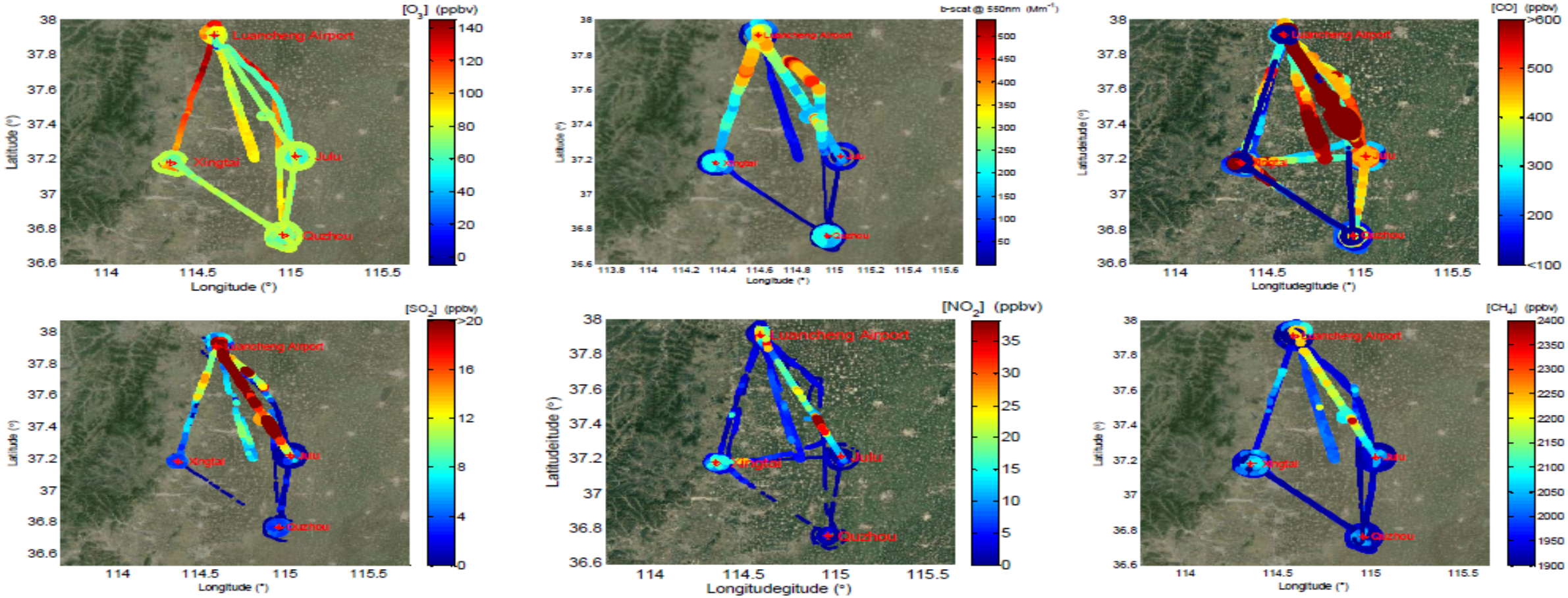


Warner et al., ACPD., 2016
Global NH_3 2002-2015

Y12 Flight Tracks

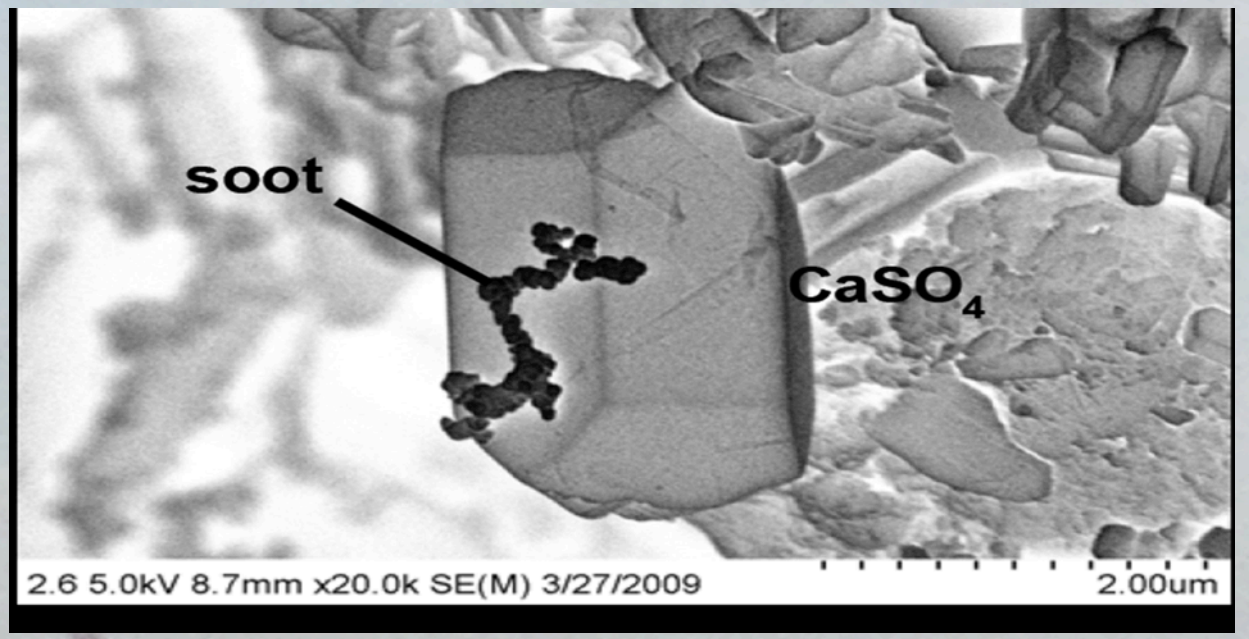


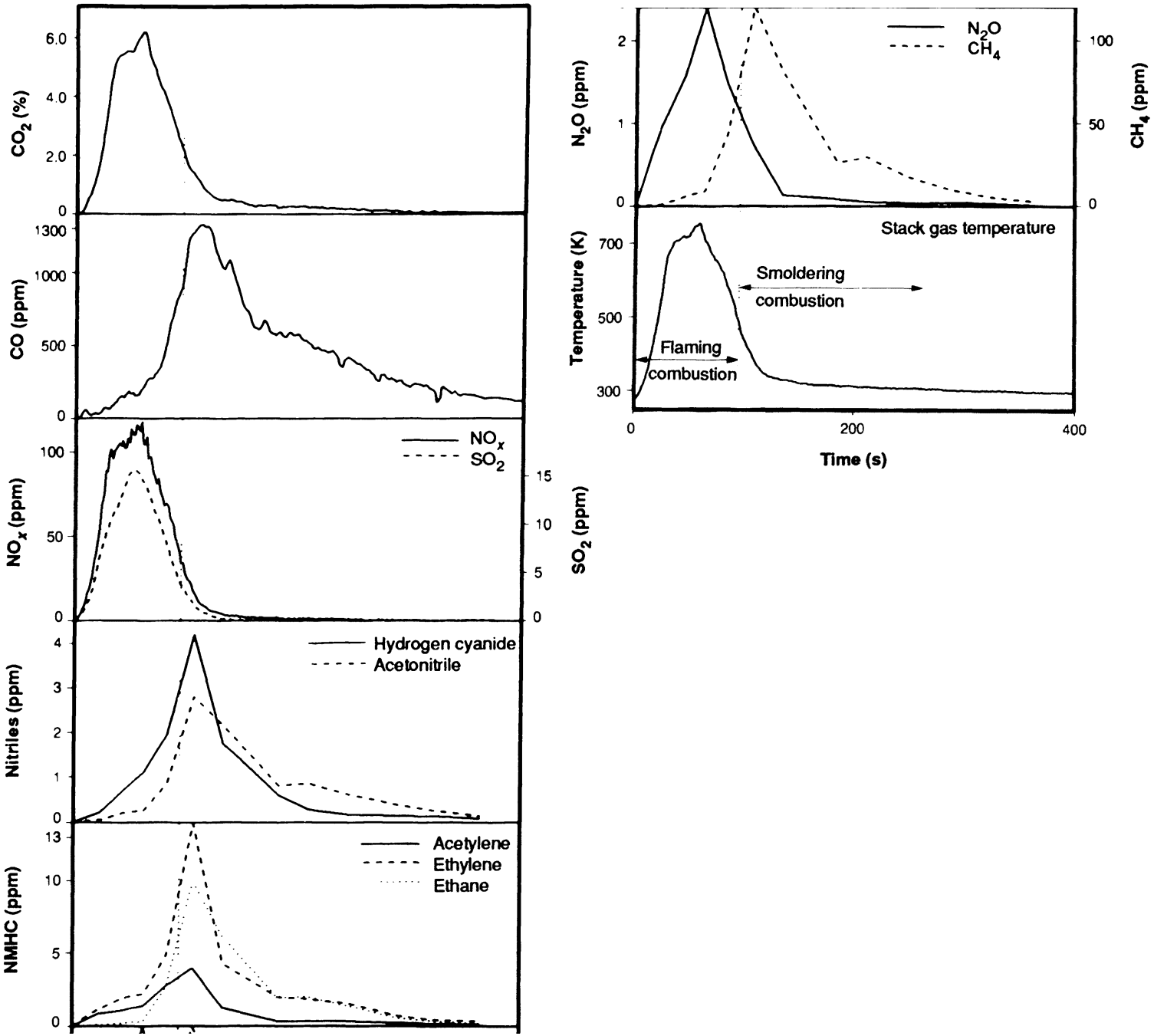
Aircraft measurements during ARIAs Campaign



In general higher [O_3] to the north and northwest area (Xingtai and Shijiazhuang) and lower [O_3] over Julu and Quzhou. Up to 6000 ppb of [CO], up to 80 ppbv of [SO_2], and up to 40 ppbv of [NO_2] were observed. A few CH_4 hot spots on the northeast leg.

Power Plant in Hebei, China





From Crutzen and Andreae (1990)