NO_x Emissions: Evaluation of CMAQ NO_2 through Satellite Retrievals and Aircraft Observations

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Y. Choi[2], P. Lee[2], F. Boersma[3], H. Eskes[3], N. Kroktov[4],
L. Lamsal[4] , R. Cohen[5], A. Weinheimer[6], K. Pickering[4], J. Crawford[7]

DISCOVER-AQ Data Workshop
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[5] University of California, Berkeley, Berkeley, CA
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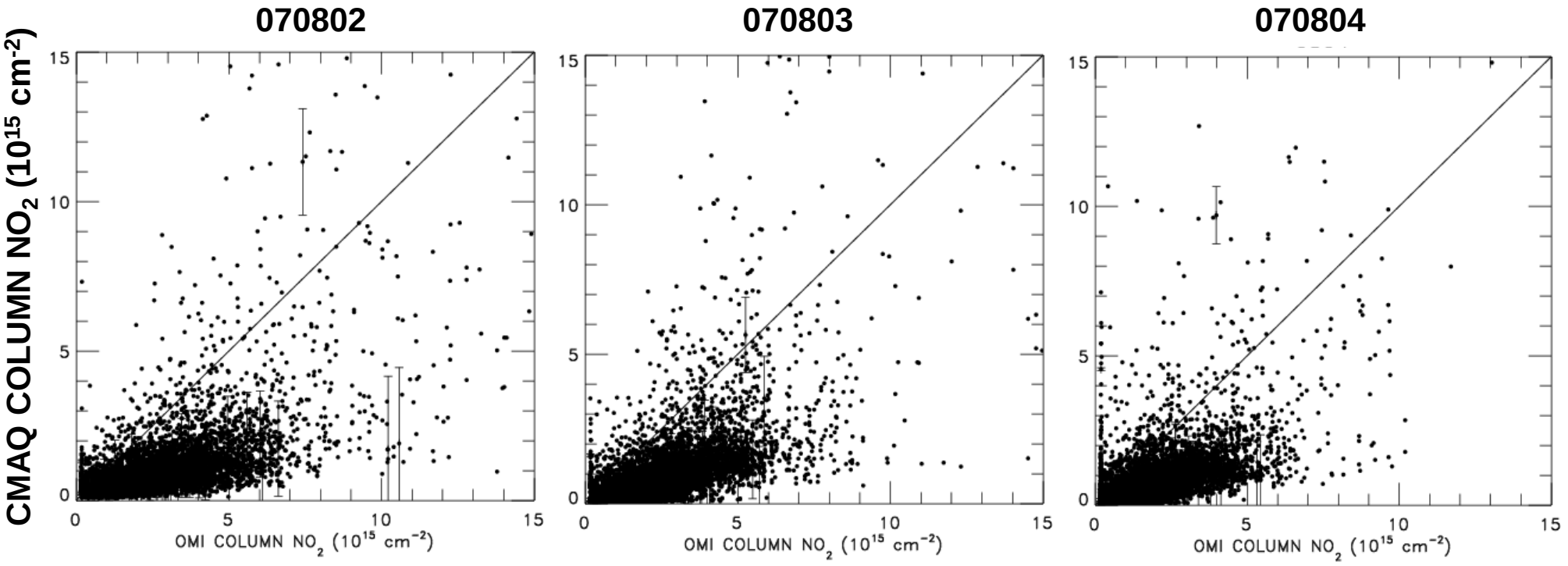
Recent AQ Modeling

August 2007: OMI observations (Goddard v1) of tropospheric column NO_2 disagree with CMAQ model (v4.7.1)

Model – *lower* than satellite in *rural* areas
***higher* than satellite in *urban* regions**

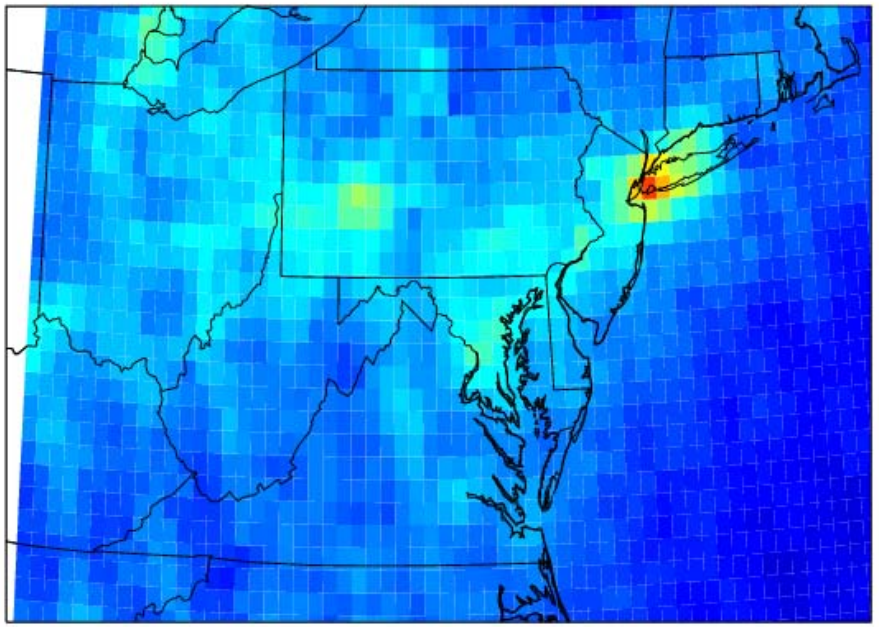


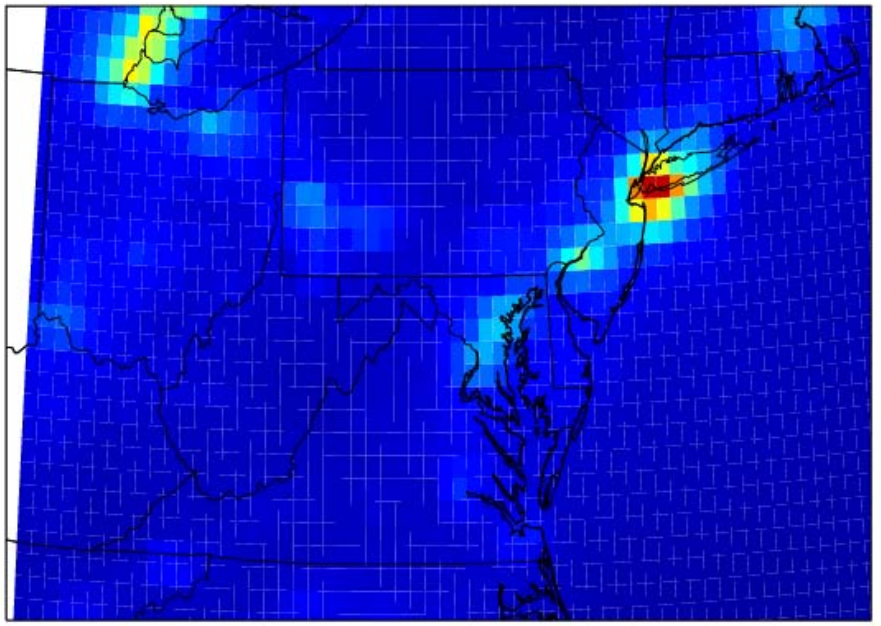
OMI COLUMN NO_2 (10^{15} cm^{-2})

DOMINO v1

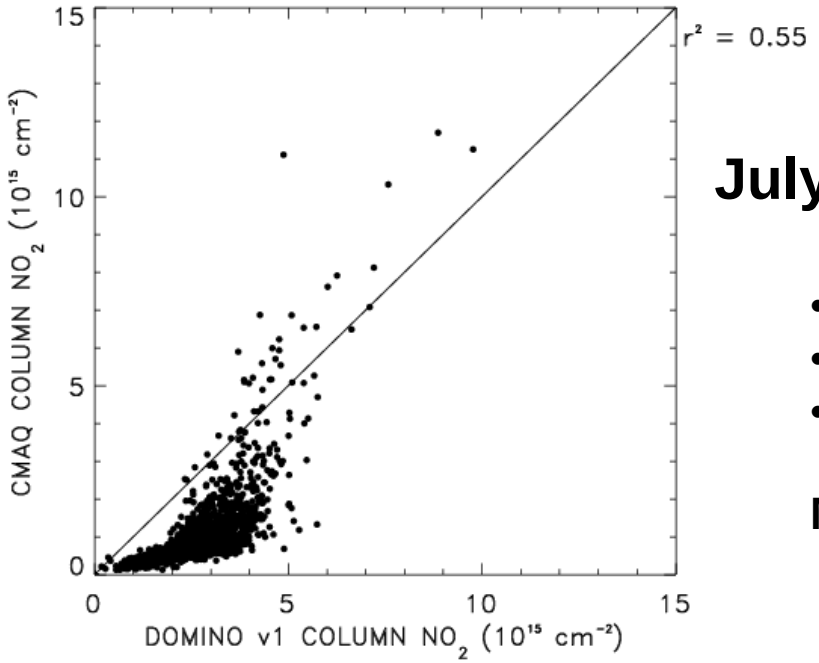
0.25^o x 0.25^o

CMAQ 4.6





Tropospheric Column



DISCOVER-AQ

July 2011

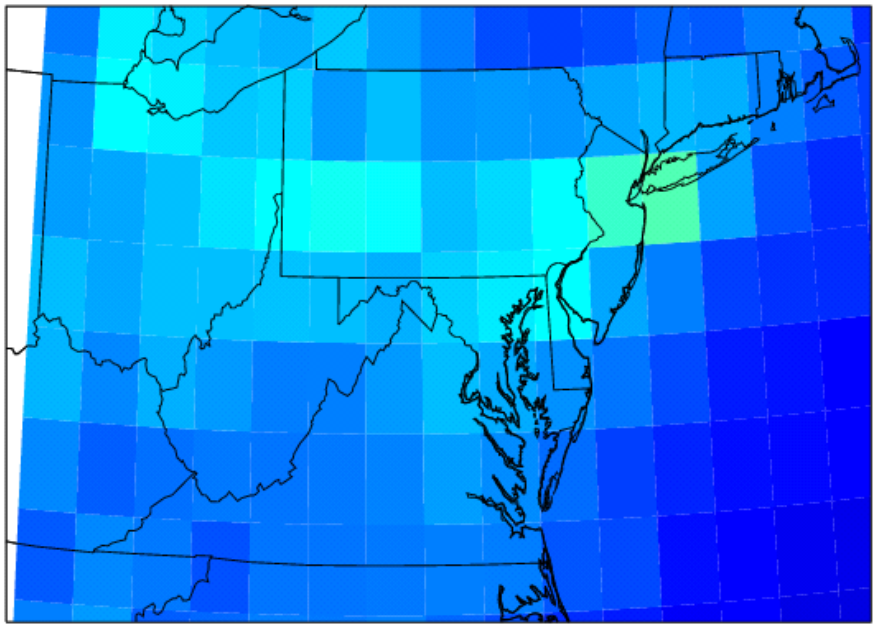
- Apply OMI averaging kernel to CMAQ
- Grid satellite swaths, account for viewing angle
- Grid CMAQ output in similar manner

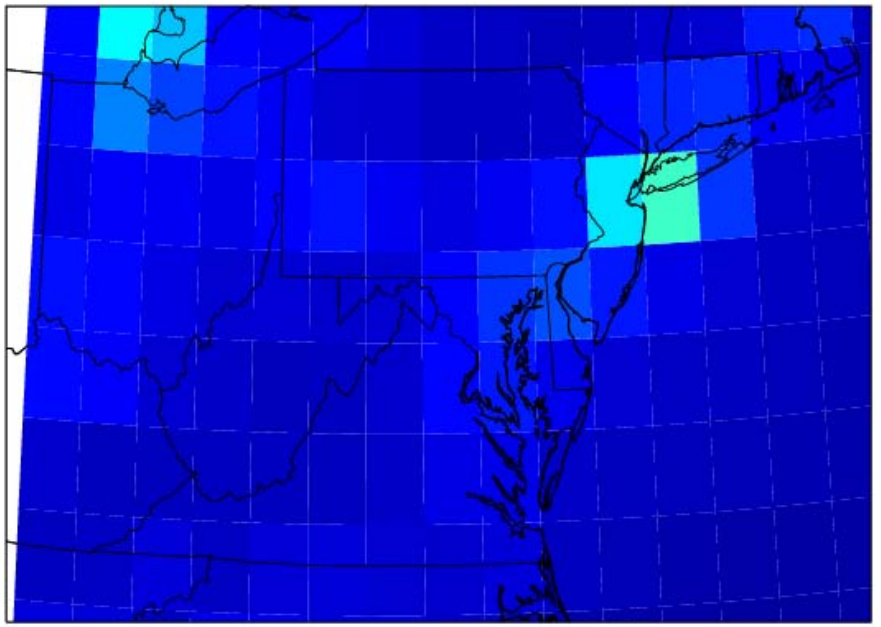
Model generally underpredicts trop. col. NO_2

DOMINO v1

1.0° x 1.0°

CMAQ 4.6





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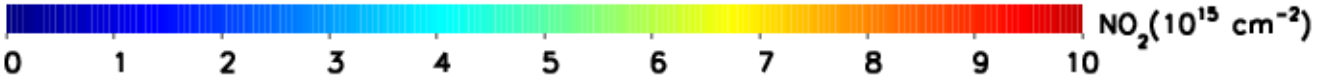
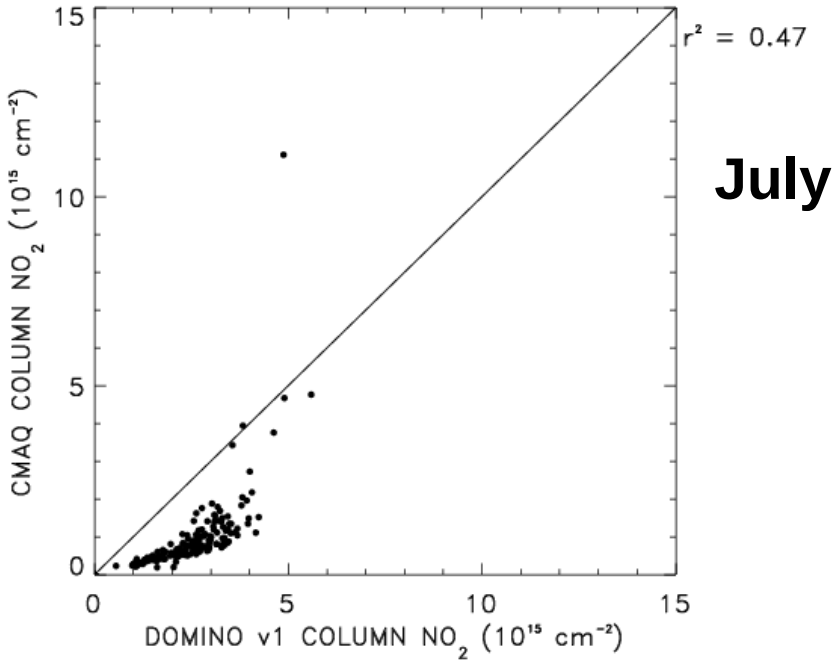




DISCOVER-AQ

July 2011

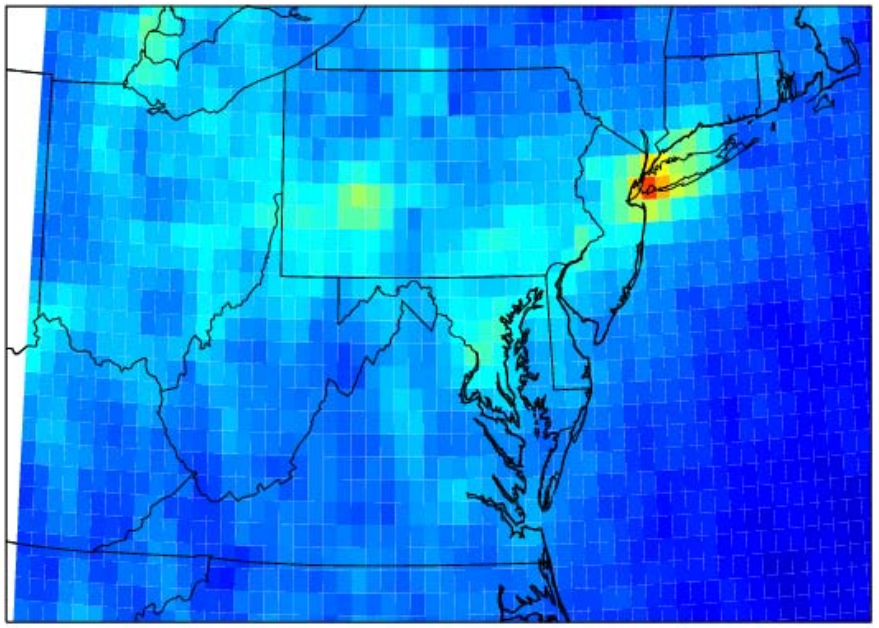
Grid size is important!!!

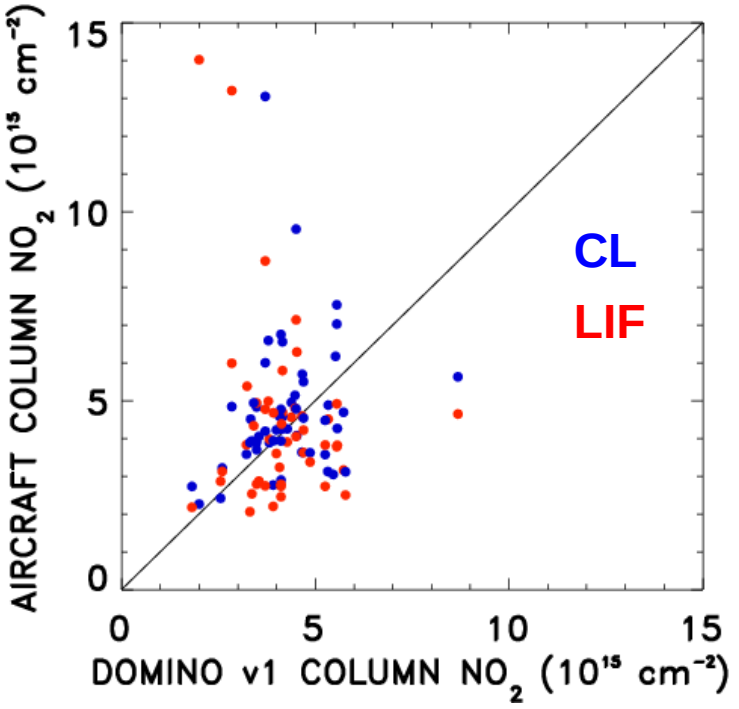
Coarse resolution grid effectively "washes out" large urban/rural gradient seen in column NO_2

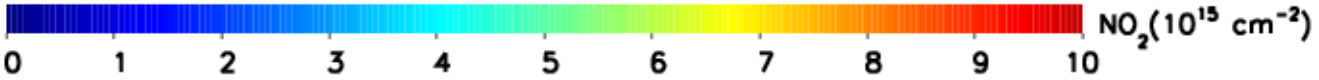
DISCOVER-AQ: Aircraft/OMI comparison

DOMINO v1

0.25° x 0.25°







Aircraft profiles chosen based on time of observation (13.5 +/–1hr, near OMI overpass)

Integrated aircraft profiles paired with nearest OMI grid

DISCOVER-AQ: Aircraft/OMI comparison

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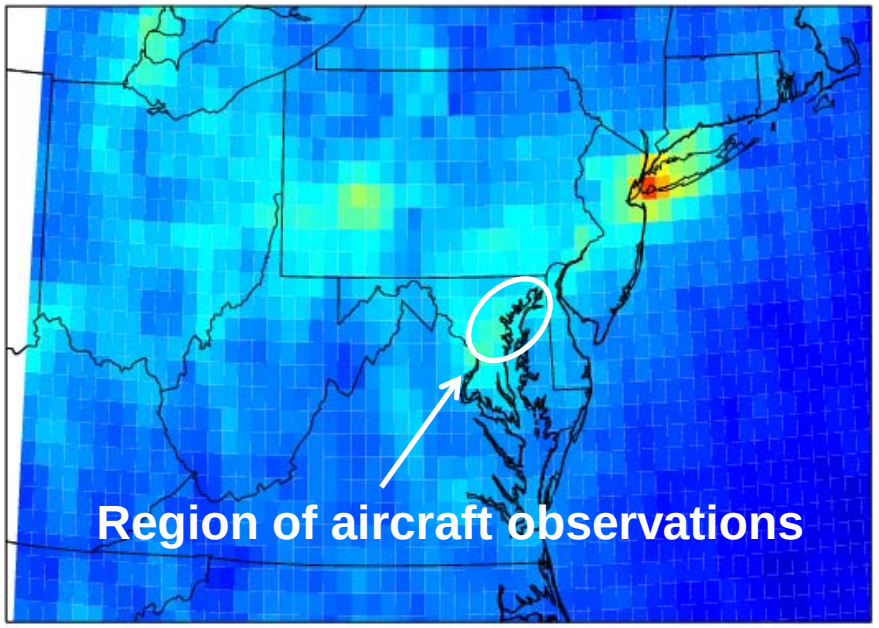
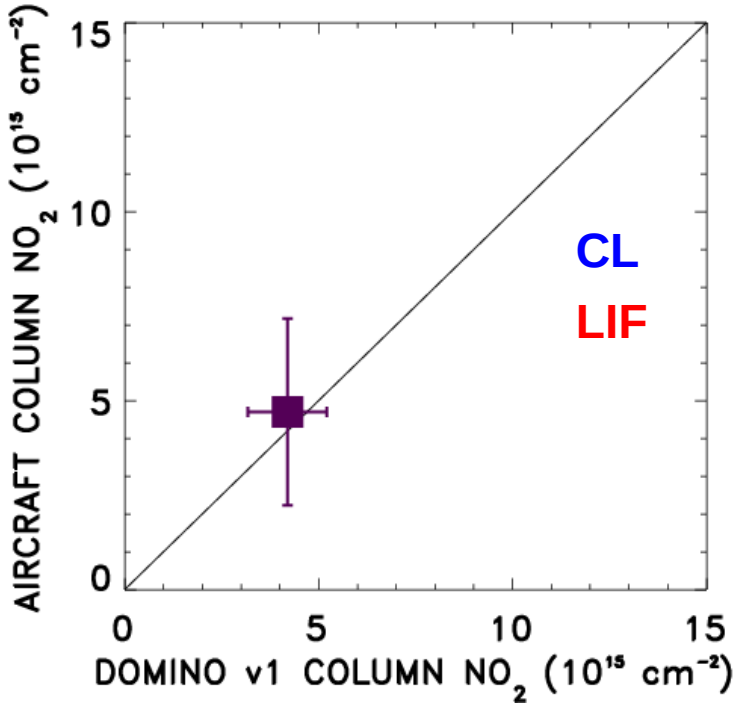
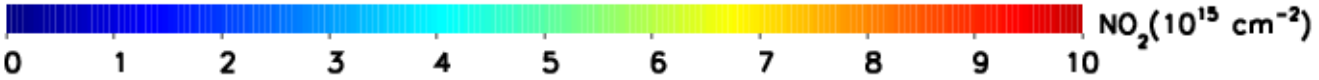
0.25° x 0.25°







Average aircraft based column NO_2 agrees with average OMI tropospheric column NO_2

Aircraft observations primarily urban region – model *higher* than satellite

DISCOVER-AQ: Aircraft/OMI comparison

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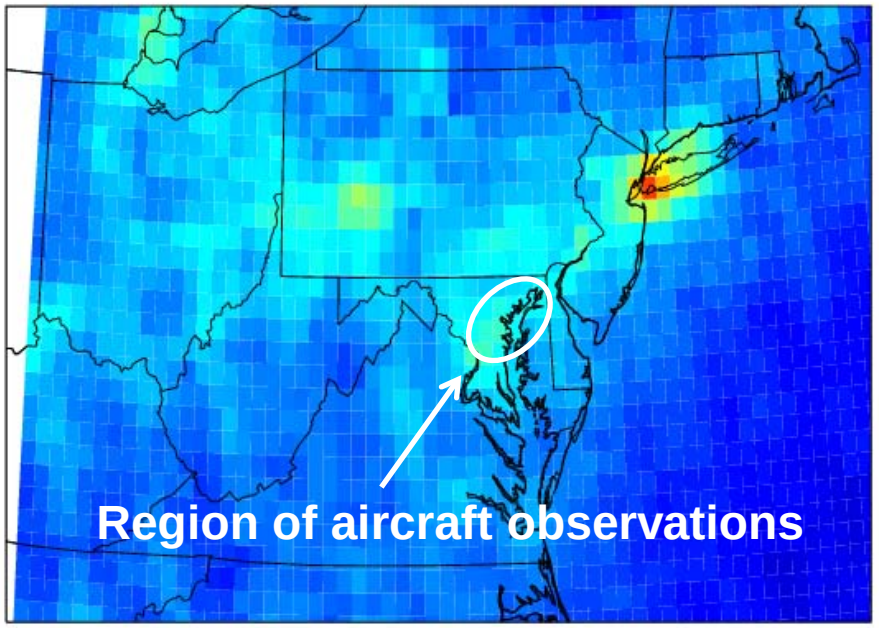
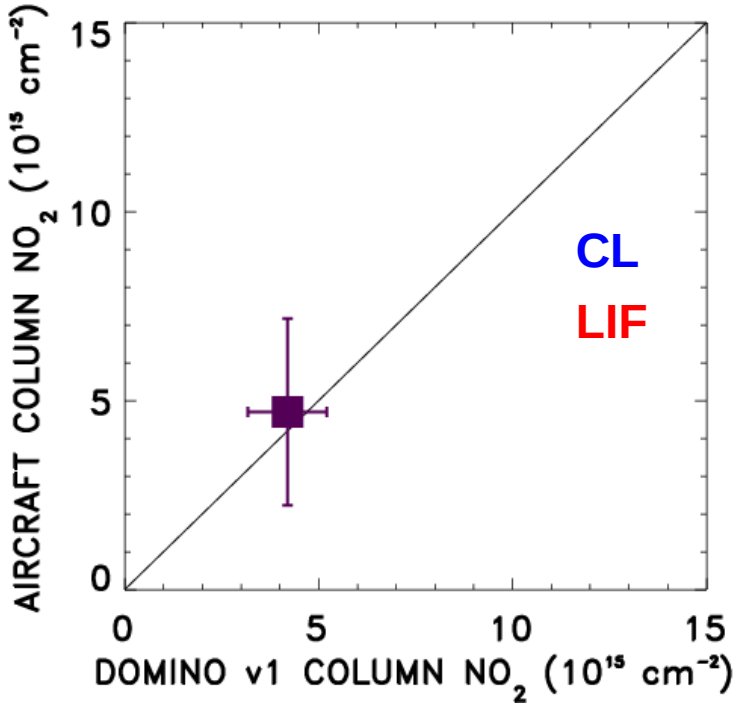
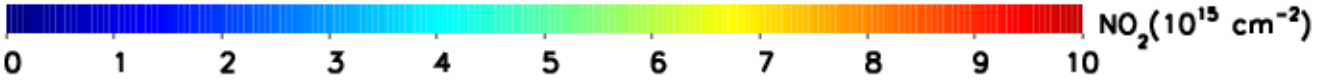
0.25° x 0.25°







Average aircraft based column NO_2 agrees with average OMI tropospheric column NO_2

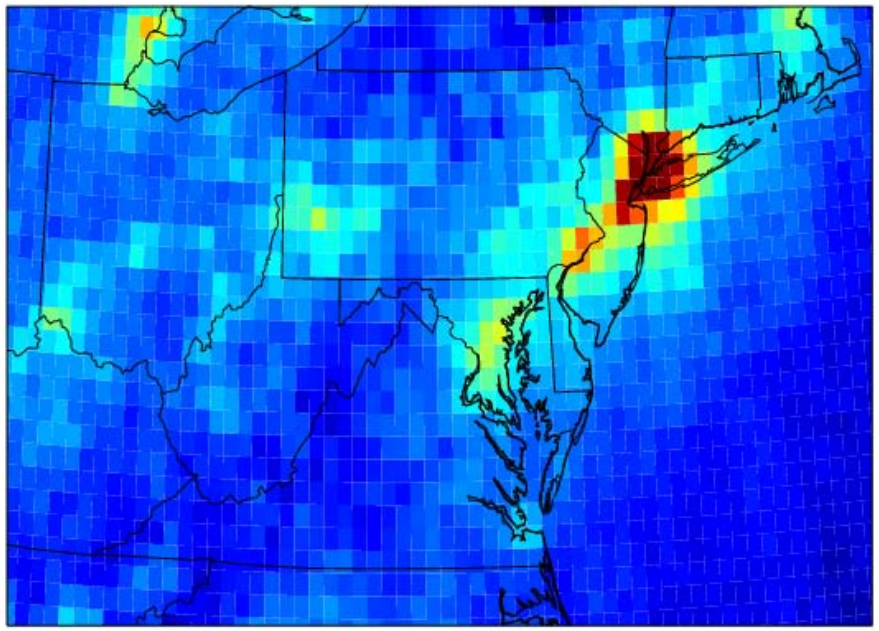
Aircraft observations primarily urban region – model *higher* than satellite

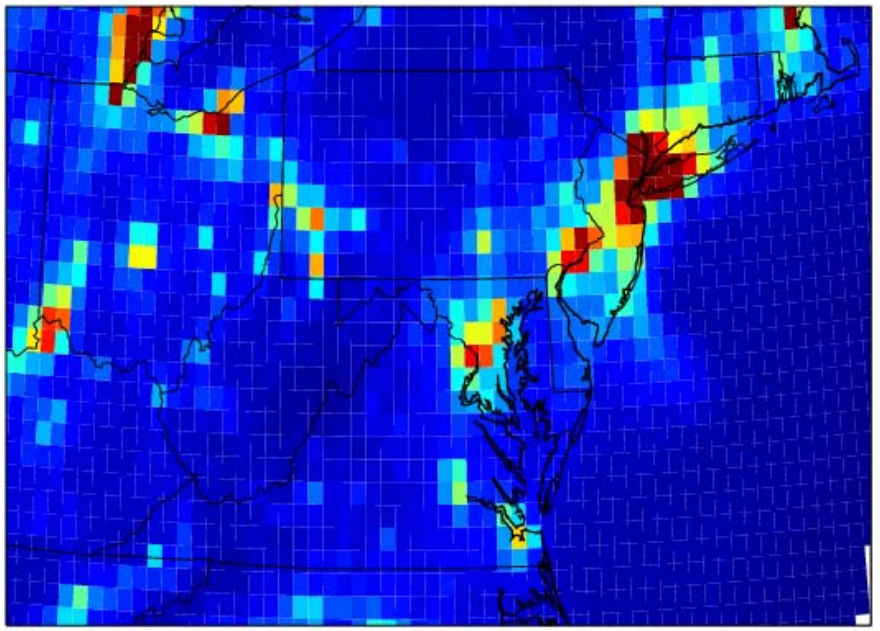
Re-visit 2007 model study with some confidence satellite is correct in urban region

DOMINO v1

0.25^o x 0.25^o

CMAQ 4.7.1





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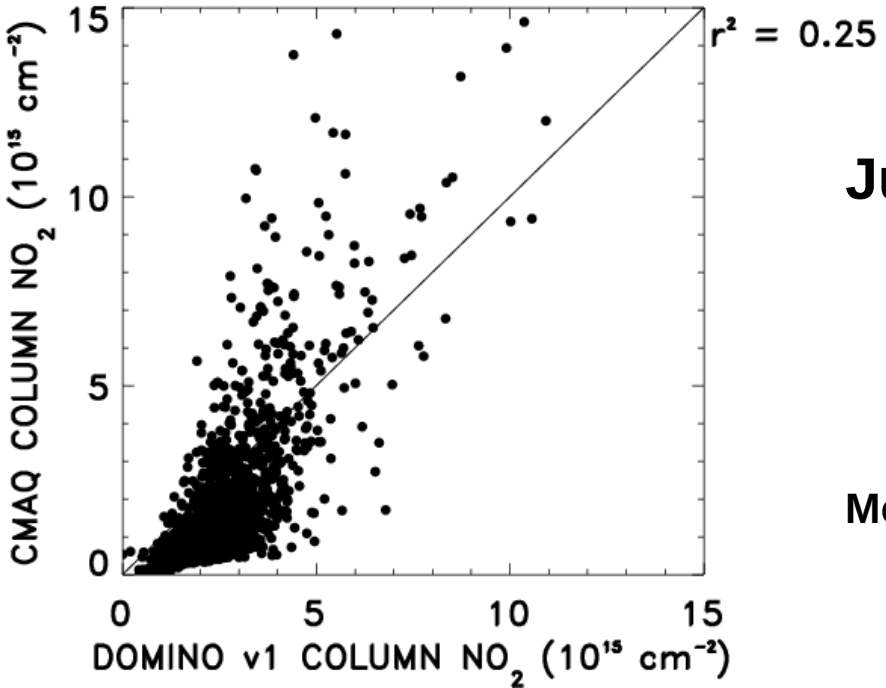


AQ SIP modeling

July 2007

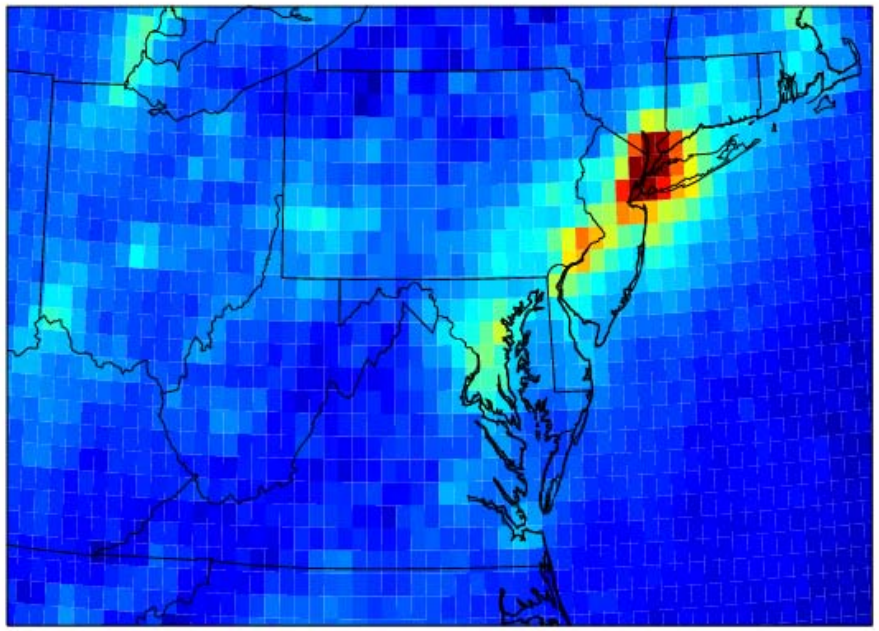
- Recent (n-1) version of CMAQ 4.7.1
- Considers 2007 emissions/met. Fields
- DOMINO v1 satellite retrieval

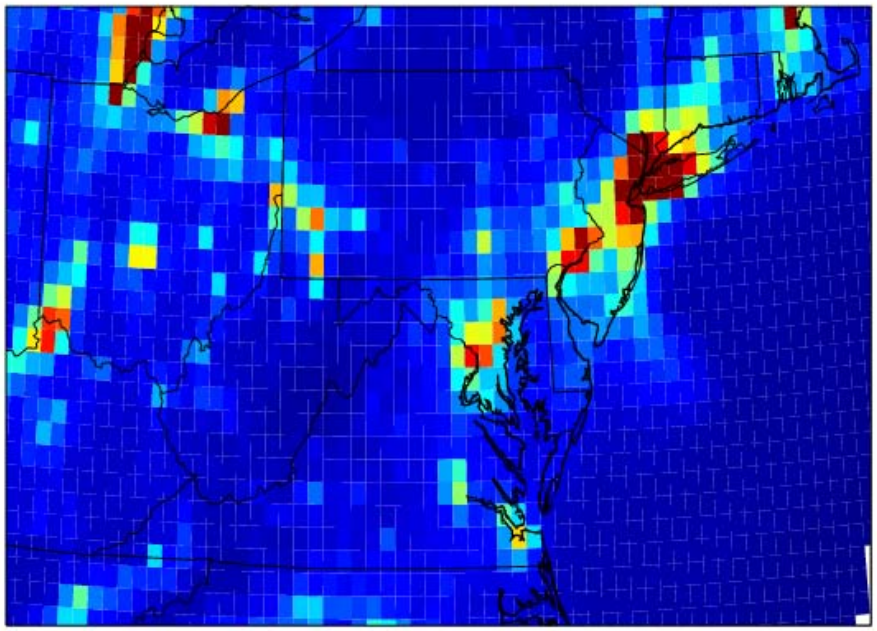
Model – ***lower*** than satellite in ***rural*** areas
higher than satellite in ***urban*** regions

DOMINO v2

0.25^o x 0.25^o

CMAQ 4.7.1





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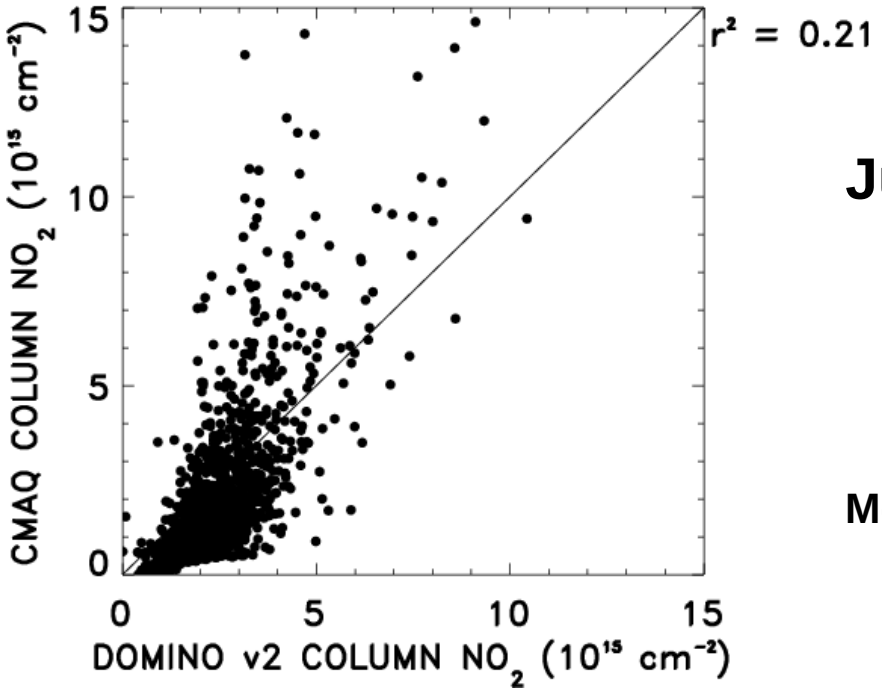

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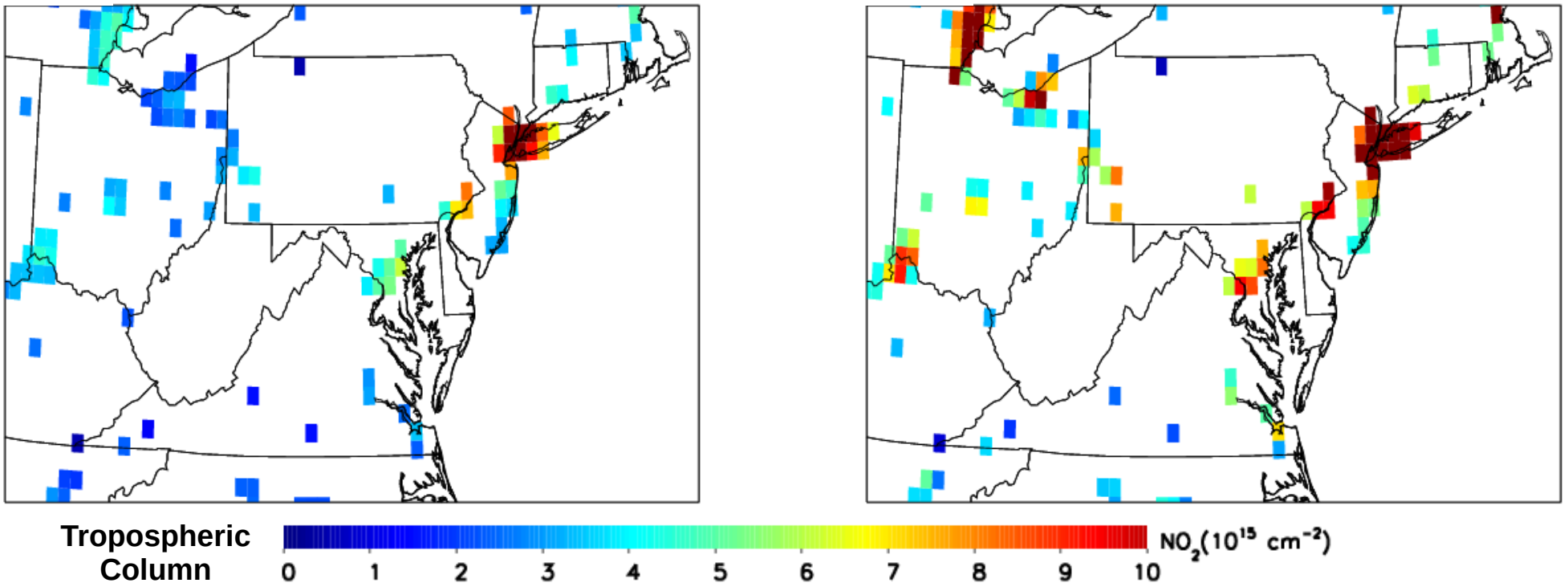
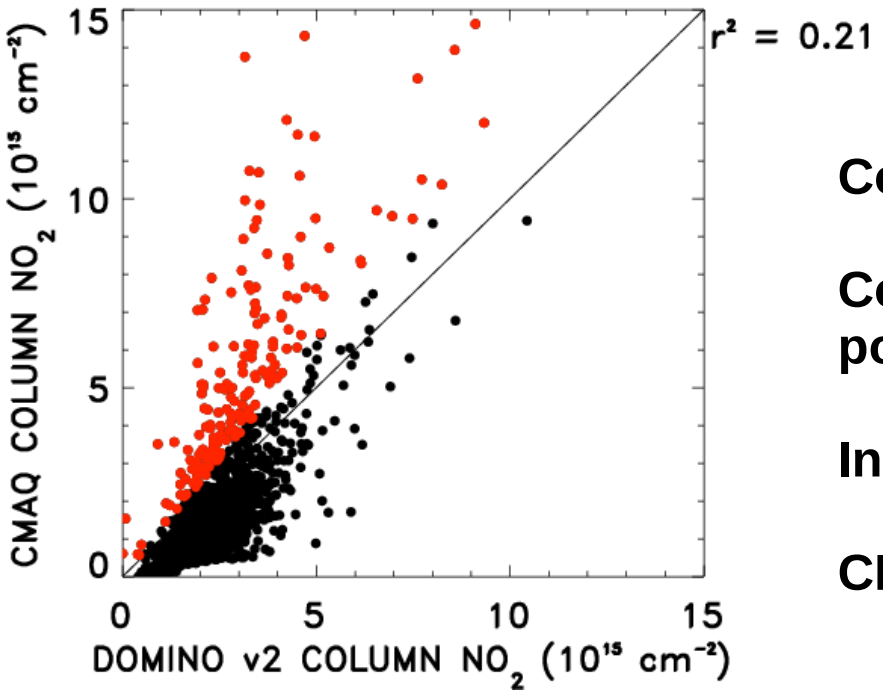
DOMINO v2

0.25° x 0.25°

CMAQ 4.7.1





AQ SIP modeling

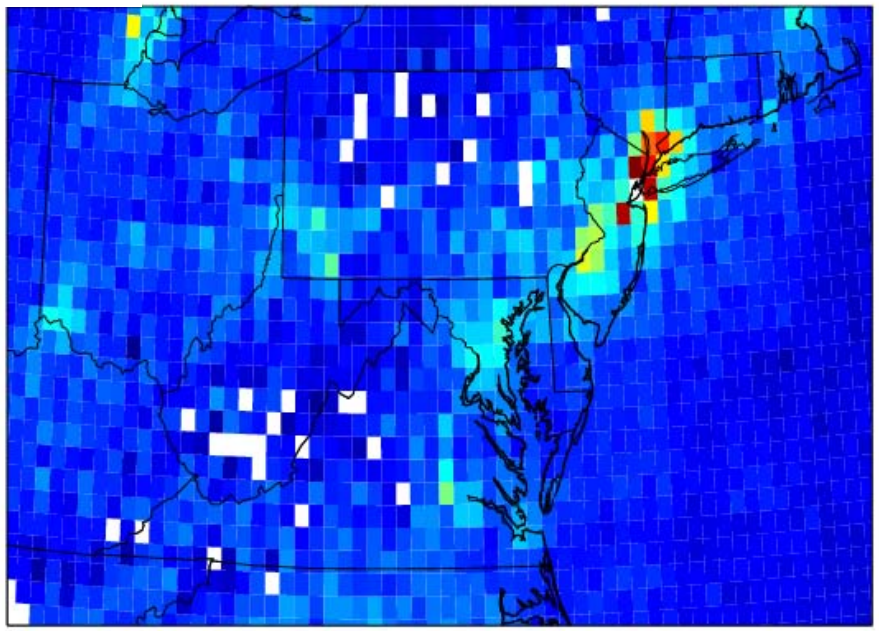
Consider areas where CMAQ ≥ 1.25xOMI

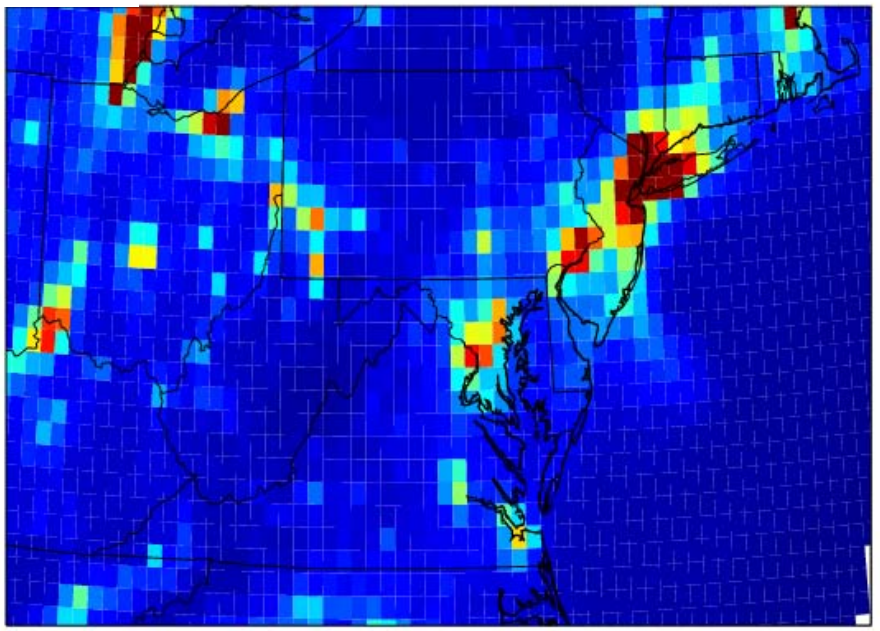
Colored boxes (above) correspond to red points (right)

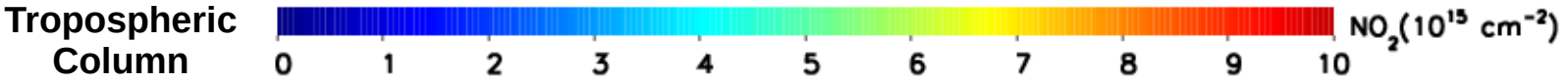
Indicates urban regions and power plants

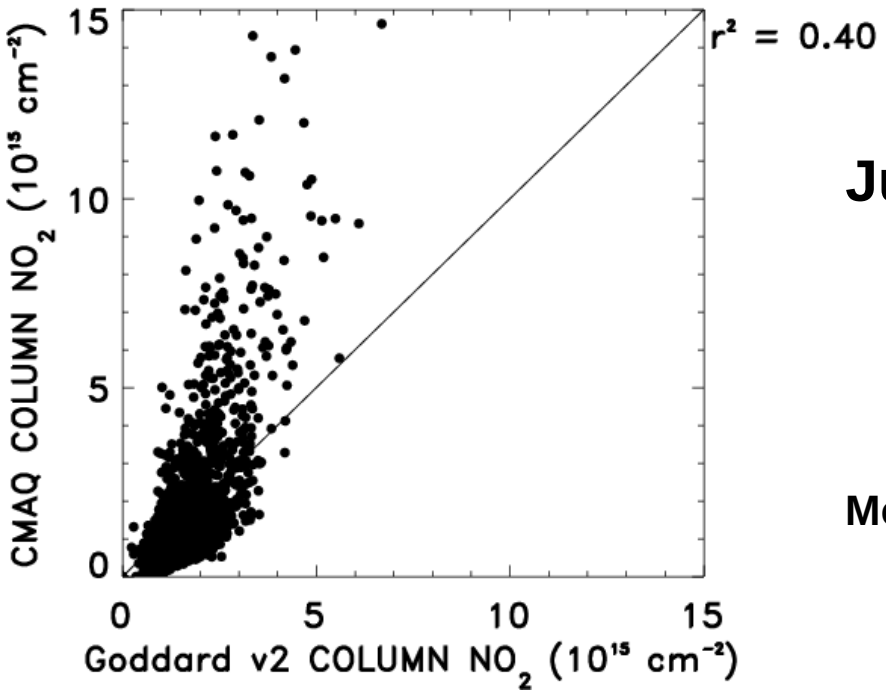
CMAQ: 2-3 times larger than OMI, mainly cities

Goddard v2 | 0.25° x 0.25° | CMAQ 4.7.1









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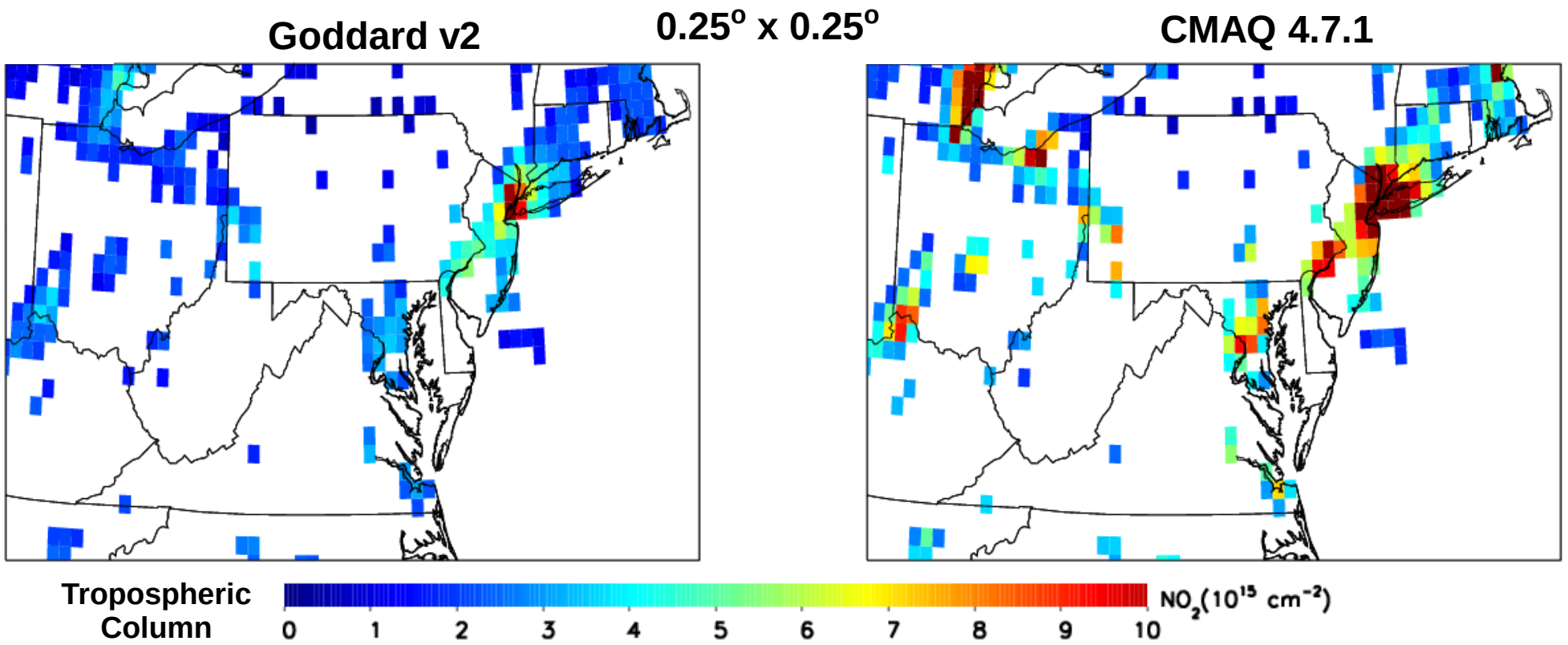

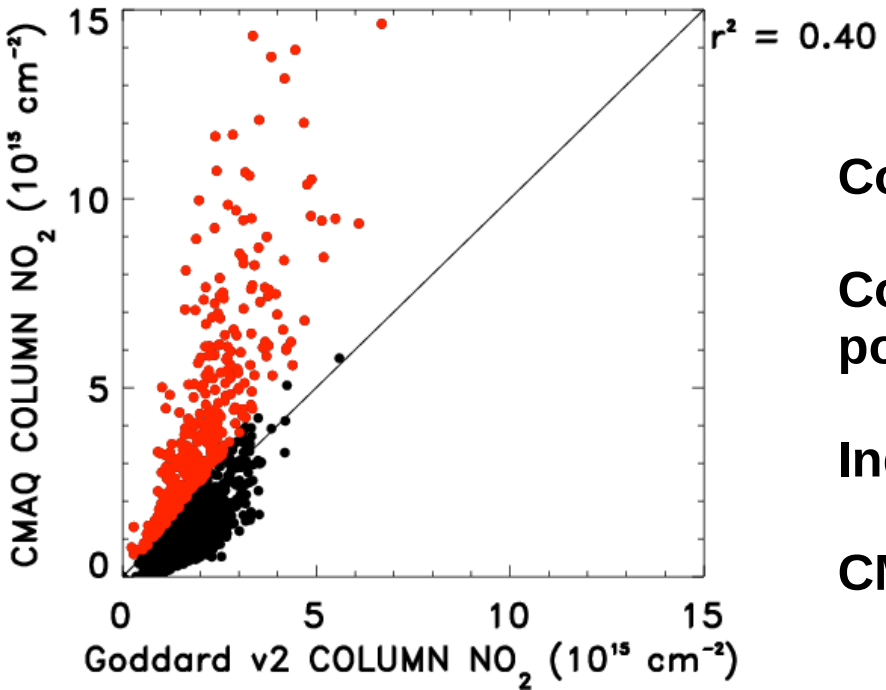

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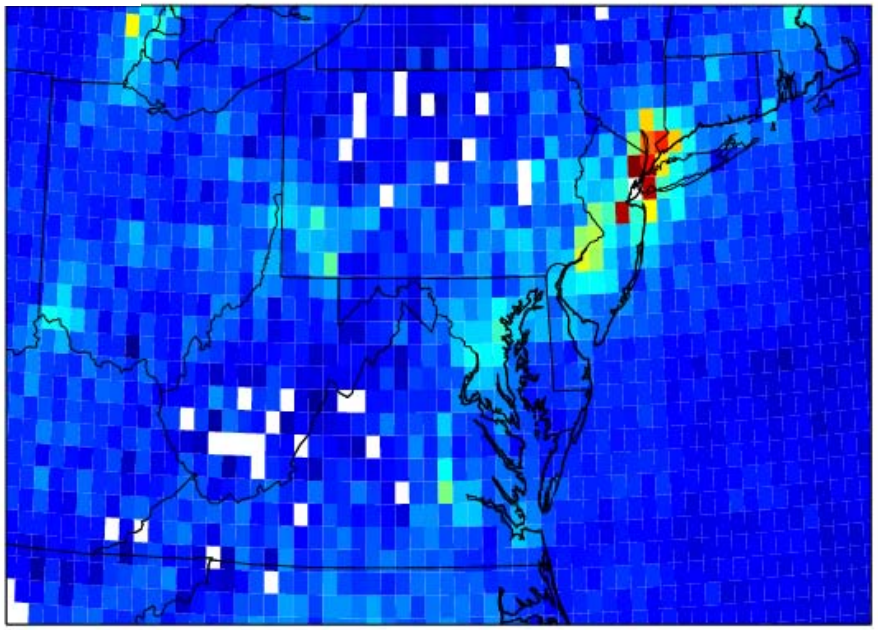
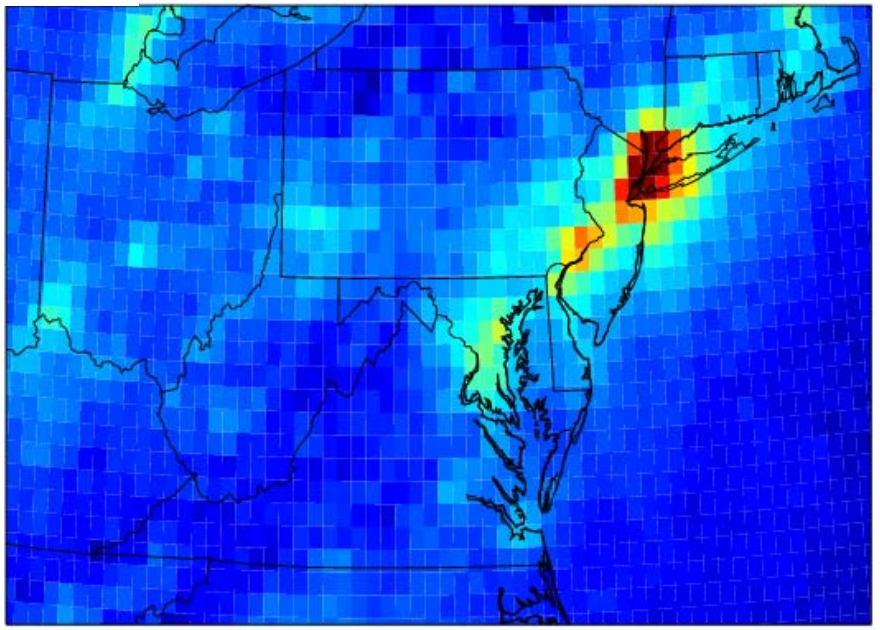
Goddard v2

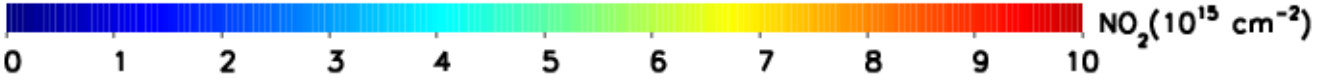
0.25° x 0.25°

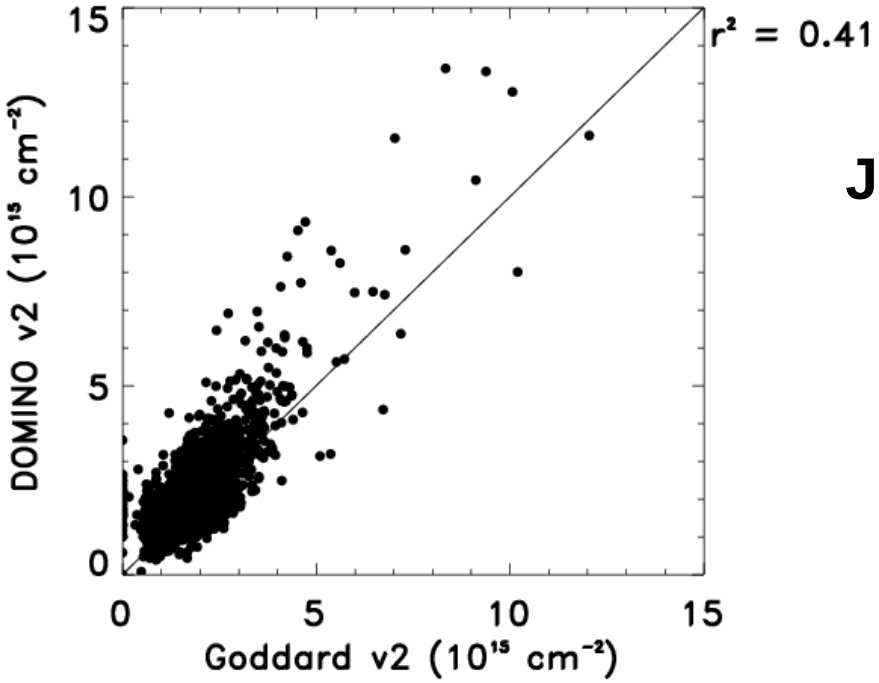
DOMINO v2





Tropospheric Column





AQ SIP modeling

July 2007

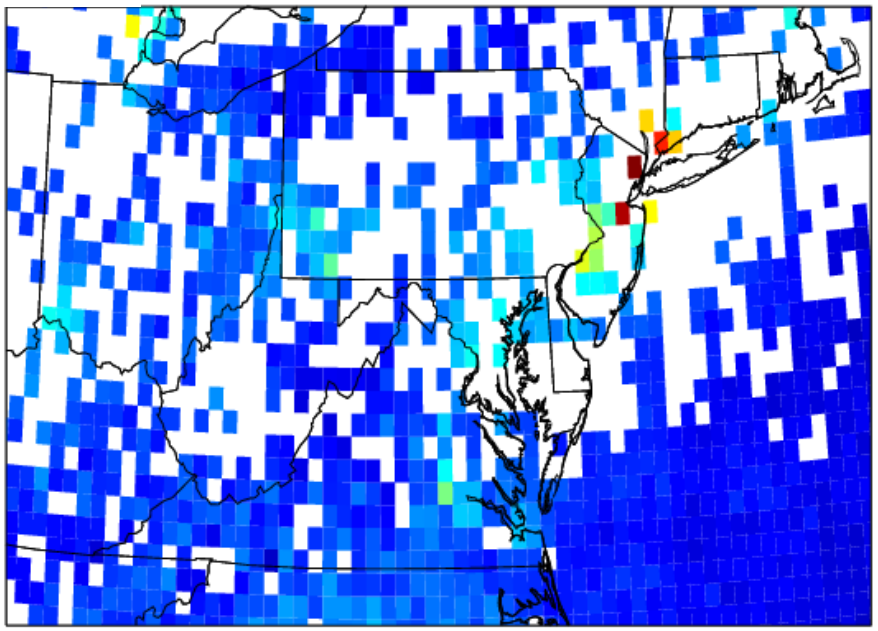
Satellite retrievals generally in good agreement

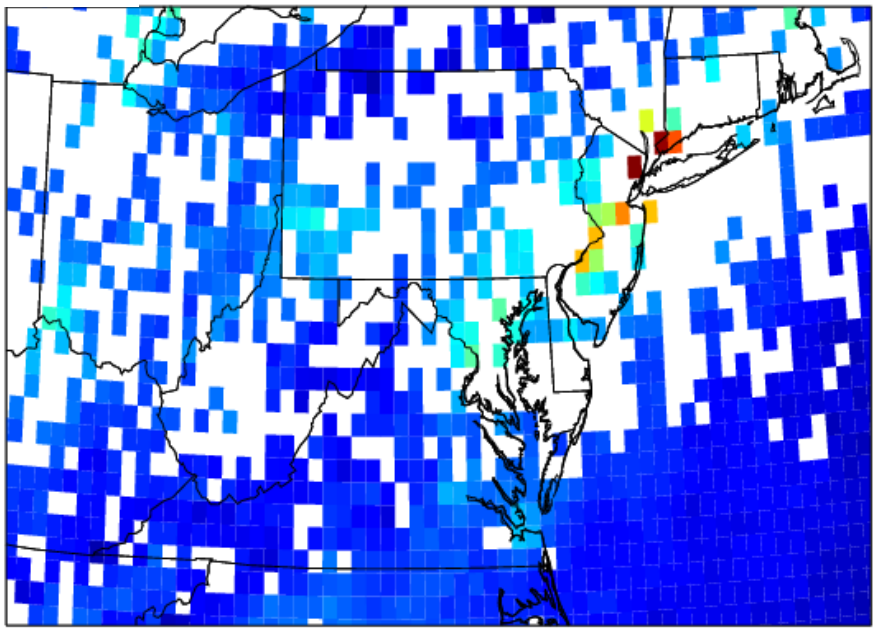
DOMINO possibly higher than Goddard

Goddard v2

0.25° x 0.25°

DOMINO v2





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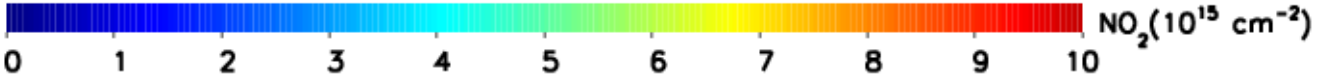
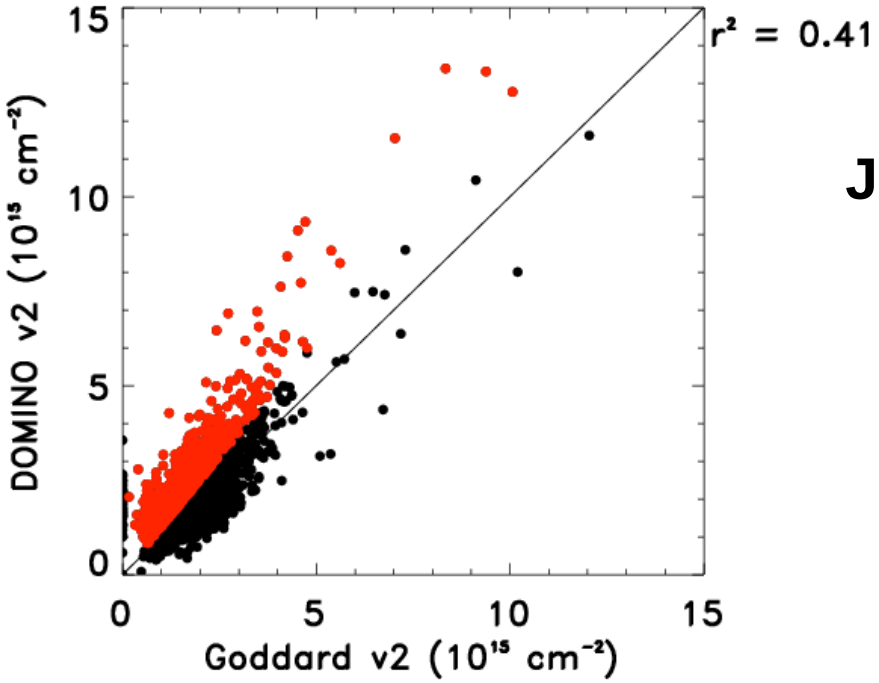




AQ SIP modeling

July 2007

Satellite retrievals generally in good agreement

DOMINO possibly higher than Goddard

Differences likely due to handling of stratospheric subtraction

Summary:

- **2 years of analysis (2007, 2011)**
- **2 configurations of CMAQ (v4.6, v4.7.1, etc…)**
- **2 satellite retrievals (KNMI, Goddard; 2 versions/retrieval)**

1. **CMAQ consistently over-predicts urban tropospheric NO_2**

2. **Under-prediction of rural NO_2 less noticeable with more recent satellite retrievals.**

3. **Addition of lightning NO_x may further decrease rural discrepancy**

Plan on looking at CMAQ handling of nitrogen reservoir species and boundary layer scheme

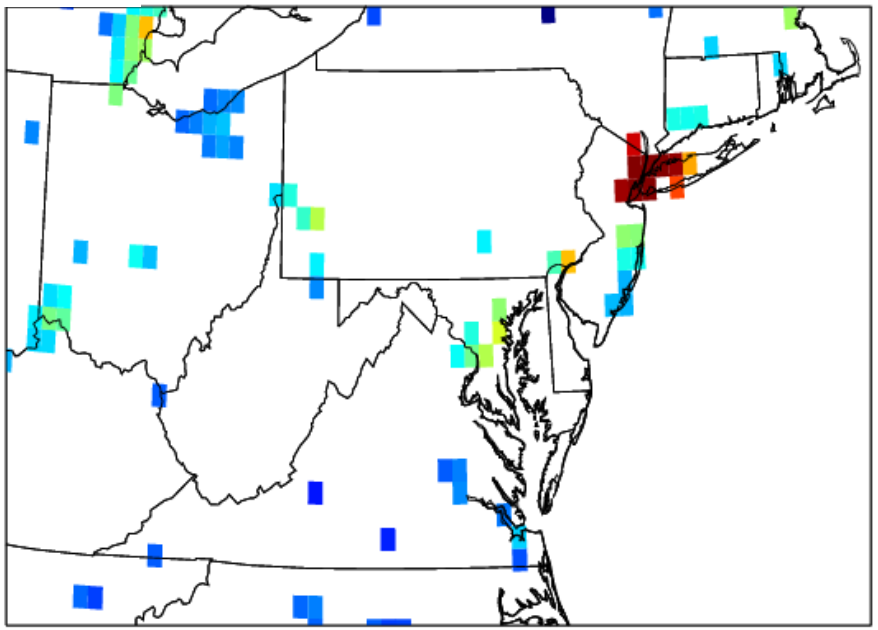
We thank Maryland Department of the Environment and the NASA DISCOVER-AQ science team for support, acquisition, and provision of the observations and model results used in this study

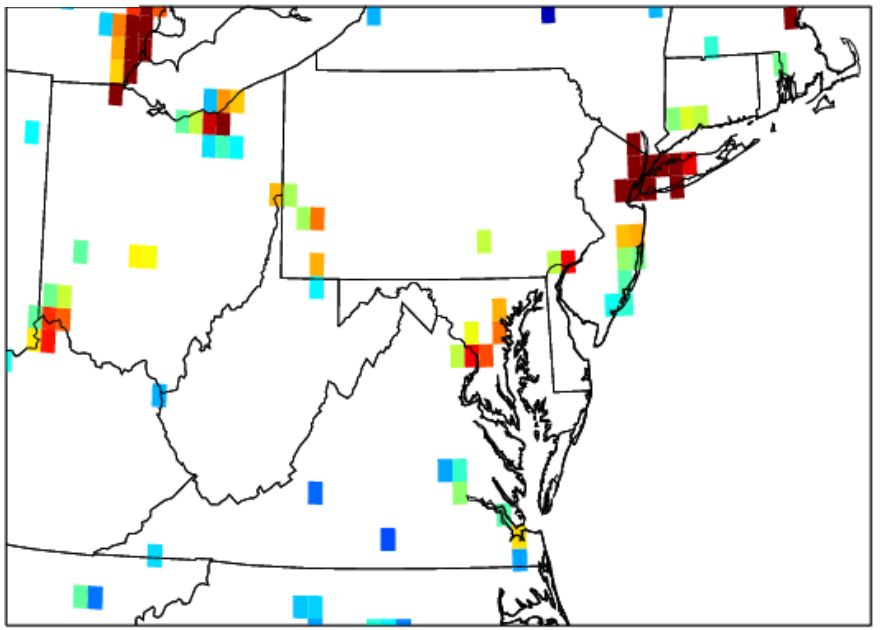
Thanks for letting us play with your stuff!!!

DOMINO v1

0.25° x 0.25°

CMAQ 4.7.1





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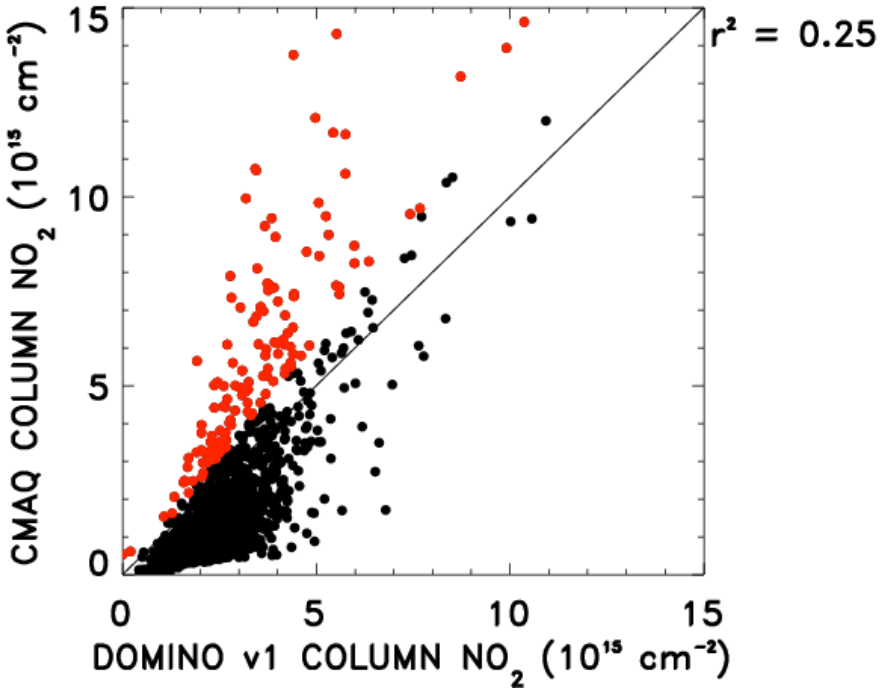
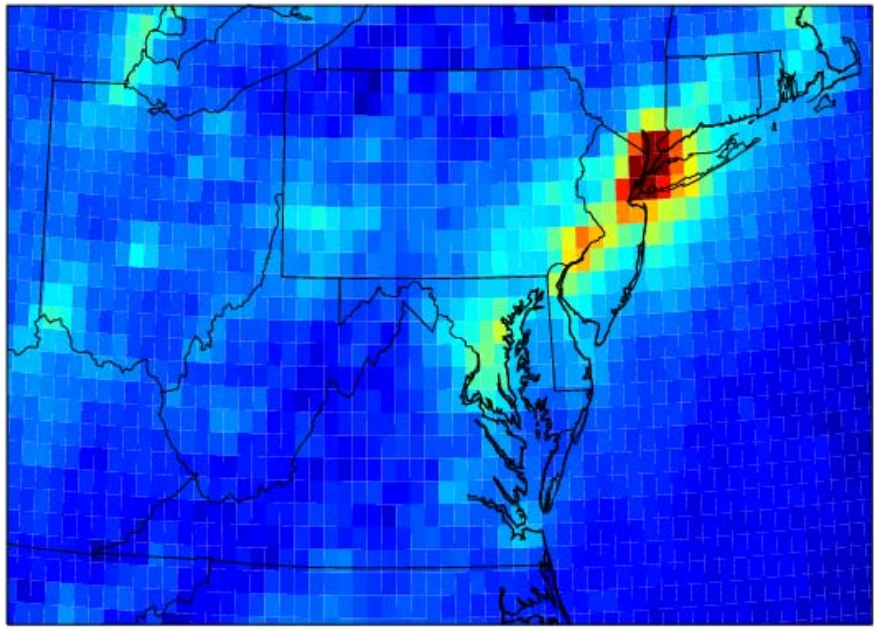
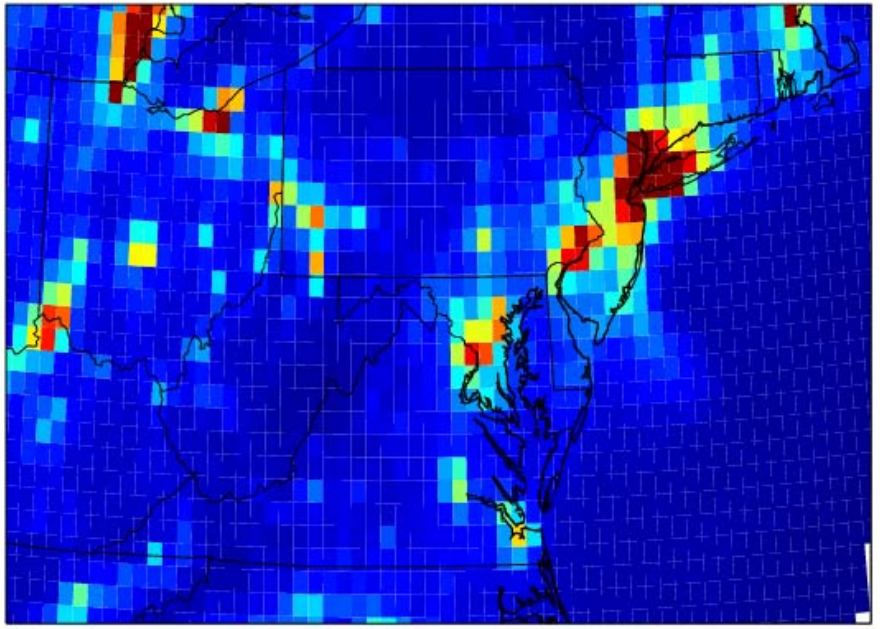


DOMINO v2

0.25° x 0.25°

CMAQ 4.7.1





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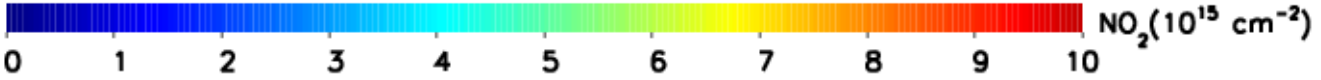
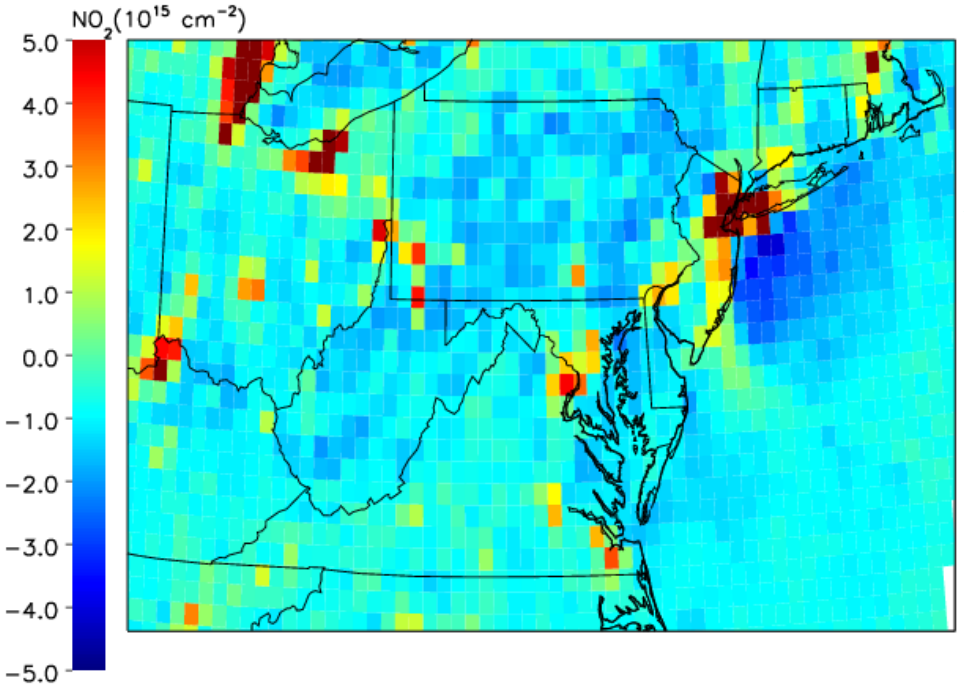




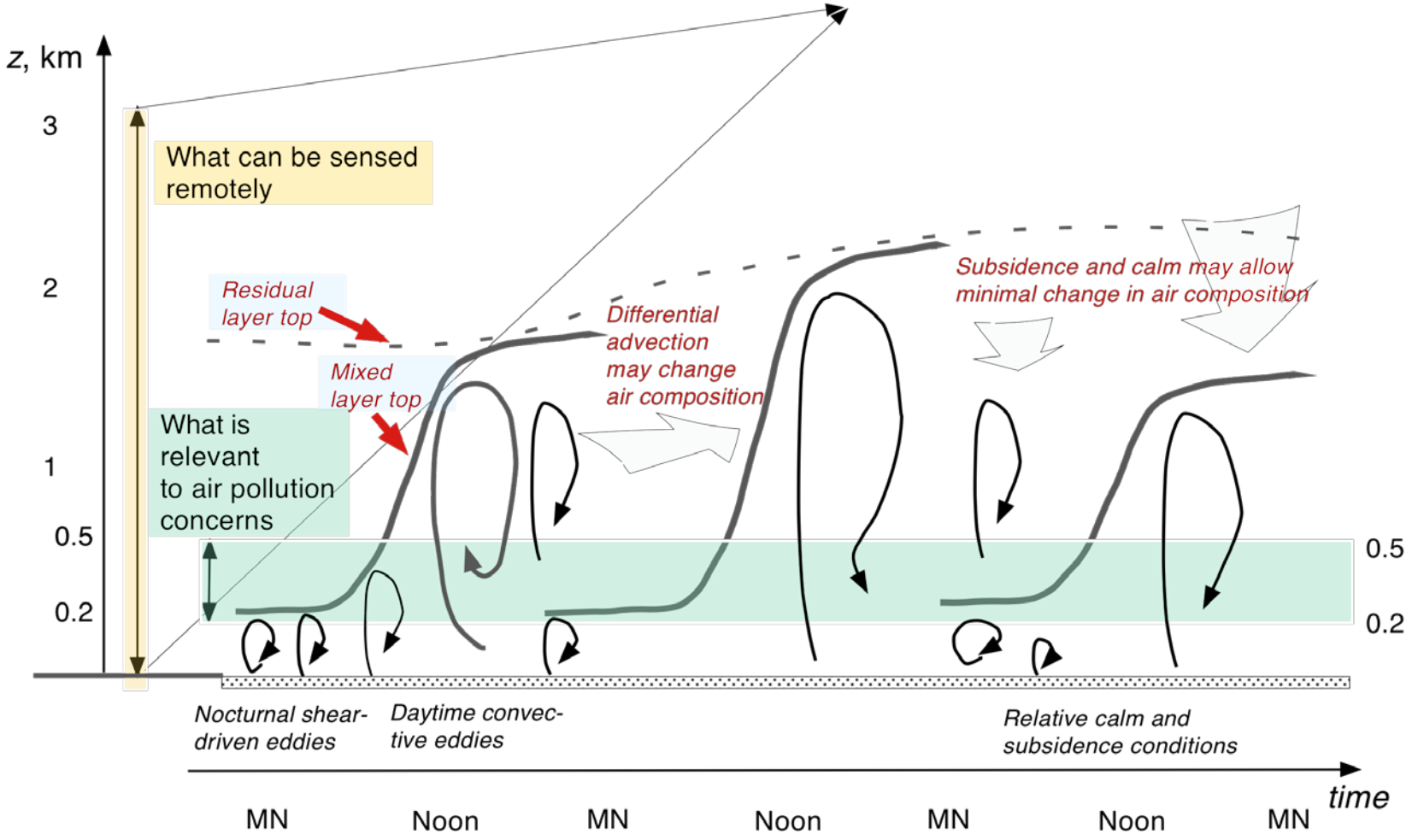
July 2007

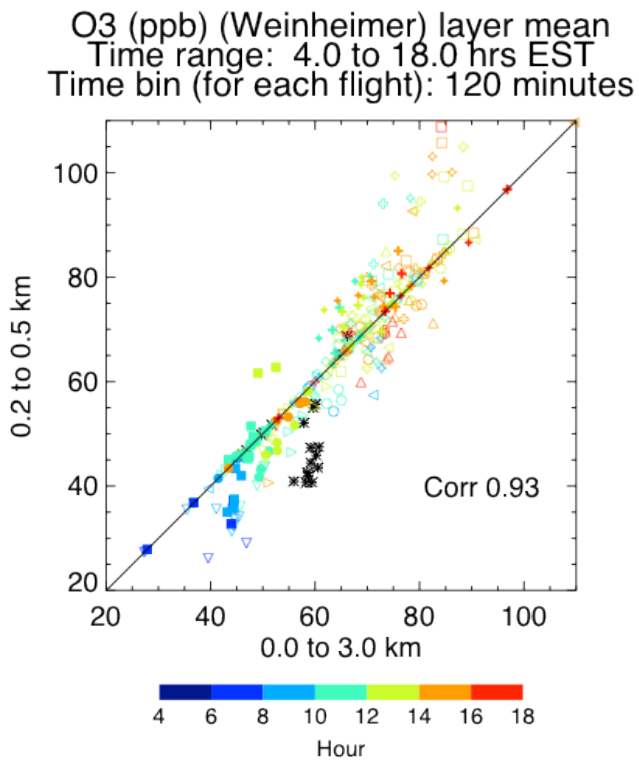
CMAQ minus DOMINO: Model minus data

Rural – model underpredicting NO_2
Urban – model overpredicting NO_2

Similar result for other years/model configuration

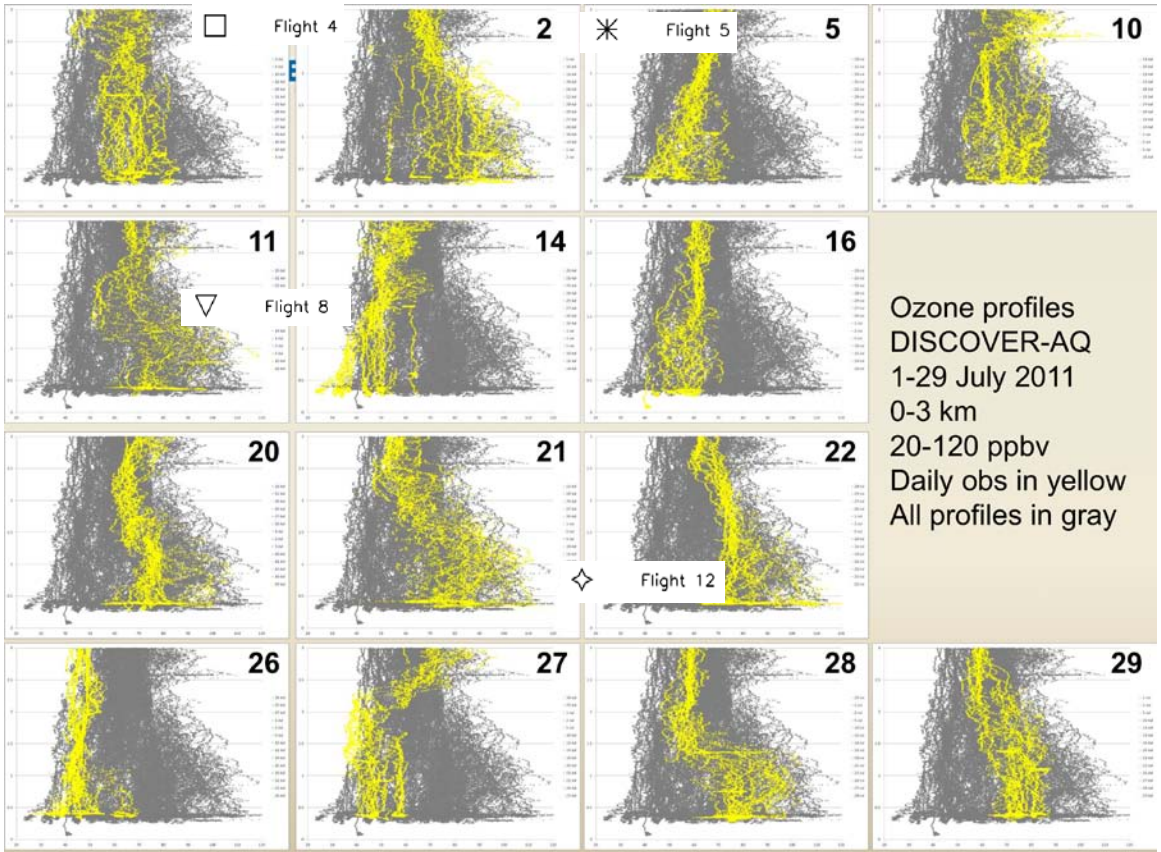
Quantifying Smog Ozone Pollution and Its Formation from Space: DISCOVER-AQ Airborne Measurements Connect the *Retrievable* to the *Relevant*



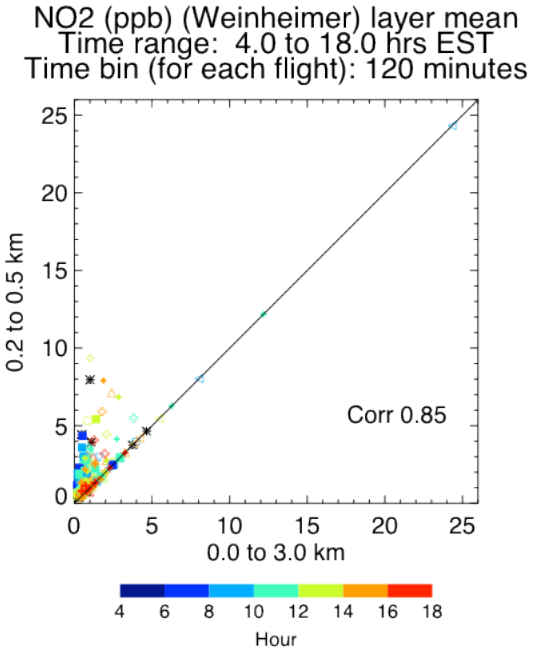


O_3

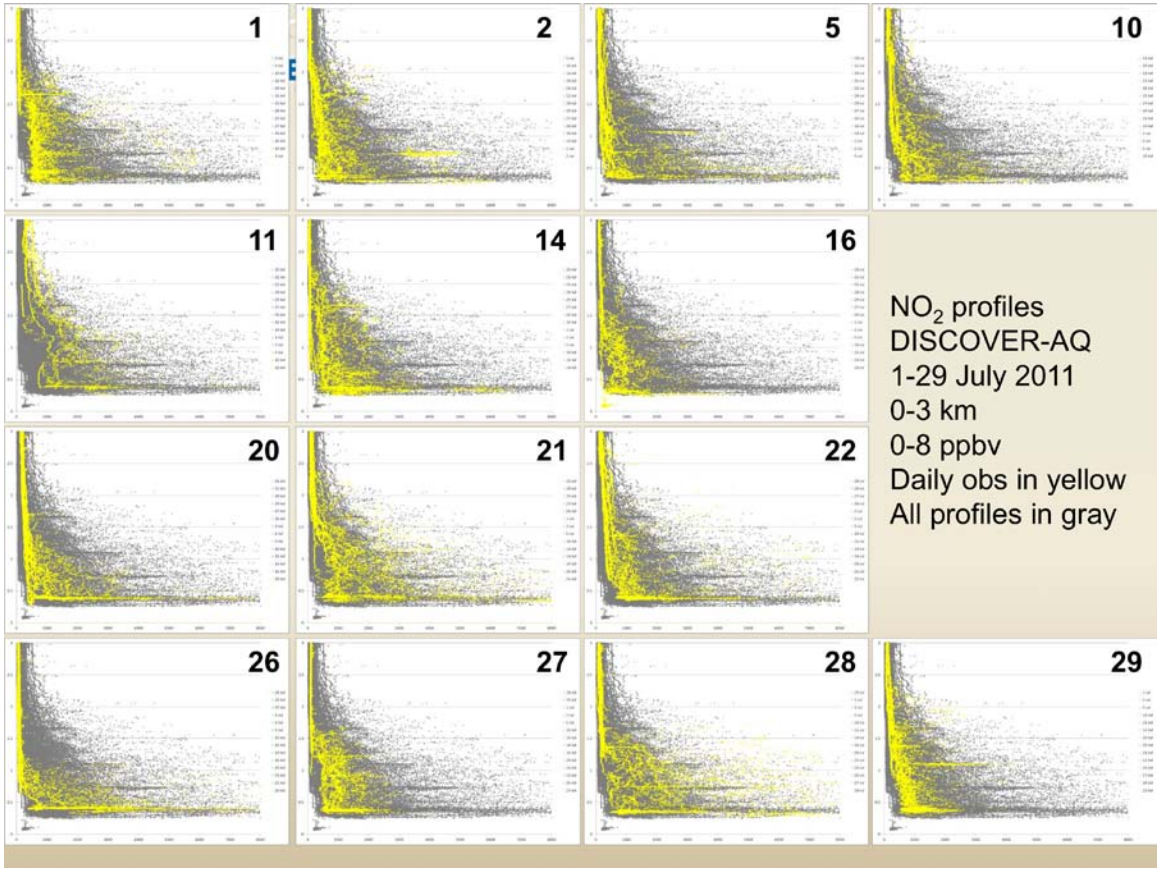
Flight 3
Flight 4
Flight 5
Flight 6
Flight 7
Flight 8
Flight 9
Flight 10
Flight 11
Flight 12
Flight 13
Flight 14
Flight 15
Flight 16



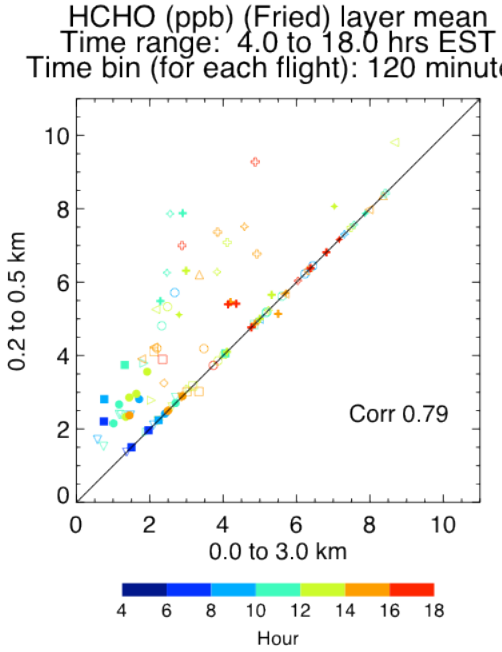
NO_2

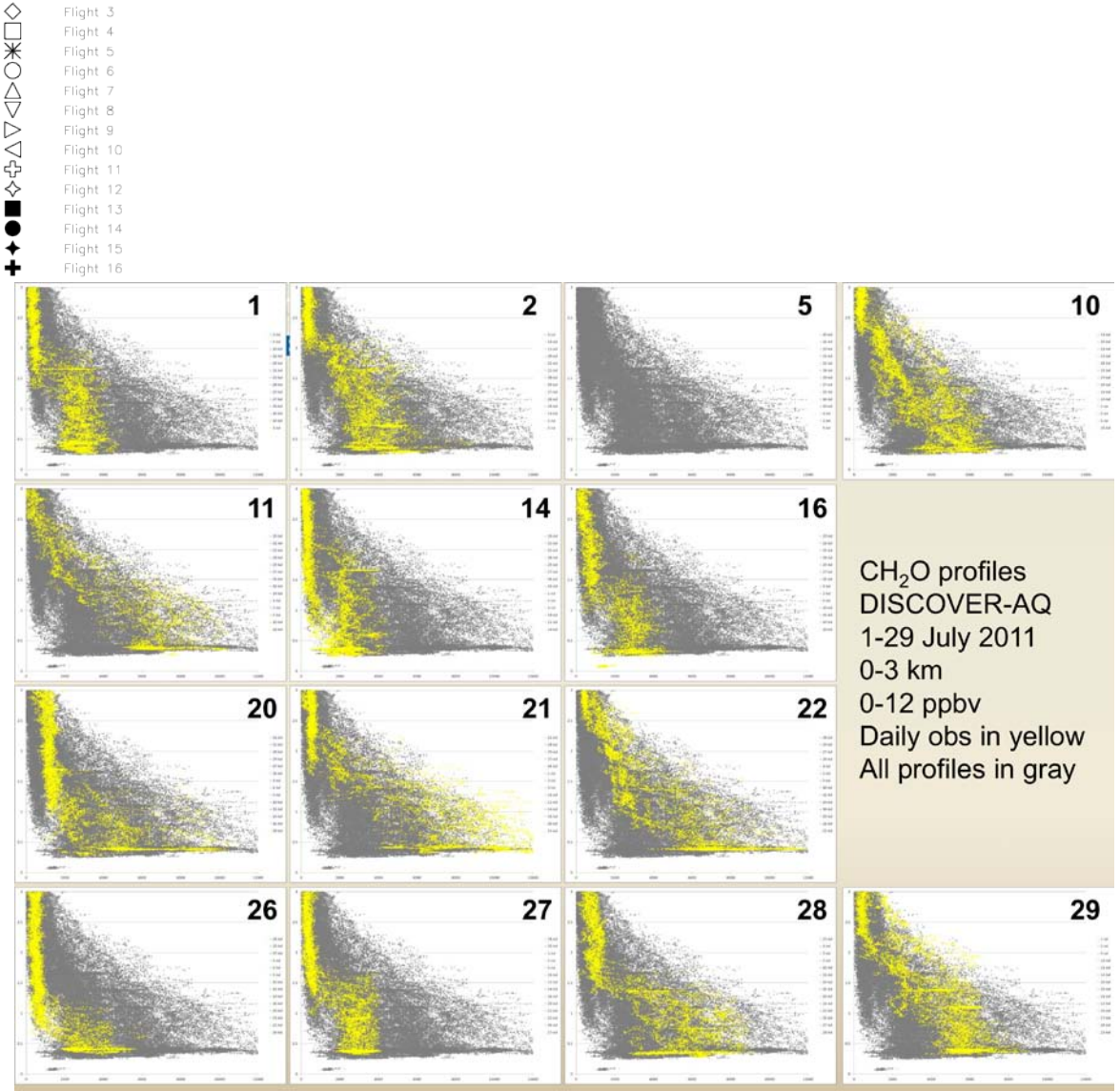

NO2 (ppb) (Weinheimer) layer mean
Time range: 4.0 to 18.0 hrs EST
Time bin (for each flight): 120 minutes
0.2 to 0.5 km
0.0 to 3.0 km
Corr 0.85
0
5
10
15
20
25
4
6
8
10
12
14
16
18
Hour

Flight 3
Flight 4
Flight 5
Flight 6
Flight 7
Flight 8
Flight 9
Flight 10
Flight 11
Flight 12
Flight 13
Flight 14
Flight 15
Flight 16

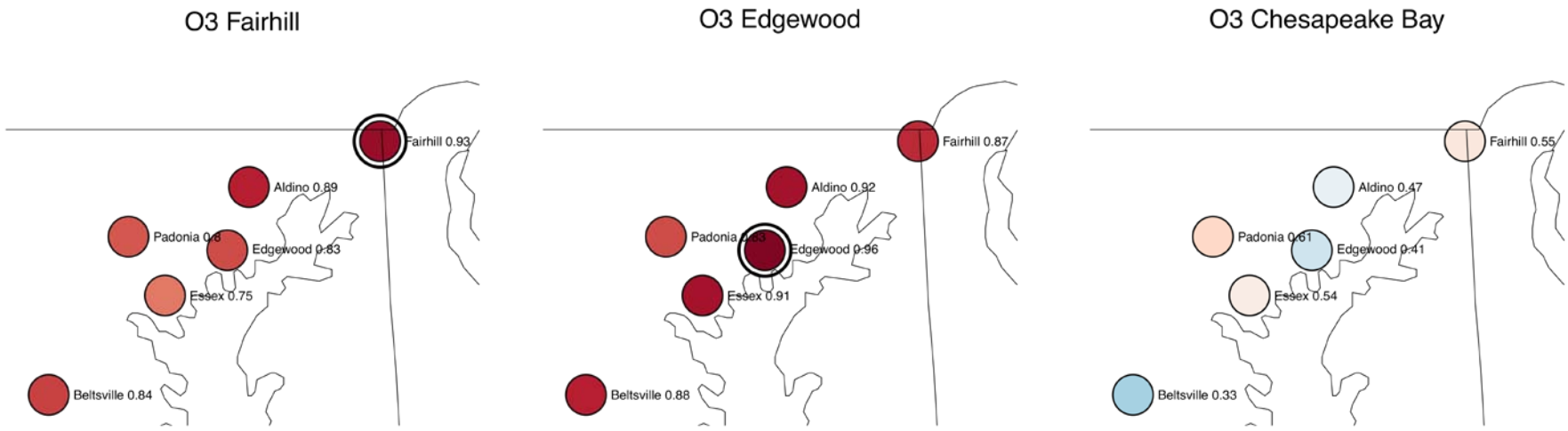

1
2
5
10
11
14
16
20
21
22
26
27
28
29
NO_2 profiles
DISCOVER-AQ
1-29 July 2011
0-3 km
0-8 ppbv
Daily obs in yellow
All profiles in gray

HCHO


HCHO (ppb) (Fried) layer mean
Time range: 4.0 to 18.0 hrs EST
Time bin (for each flight): 120 minutes
0.2 to 0.5 km
0.0 to 3.0 km
Corr 0.79
Hour
4 6 8 10 12 14 16 18


Flight 3
Flight 4
Flight 5
Flight 6
Flight 7
Flight 8
Flight 9
Flight 10
Flight 11
Flight 12
Flight 13
Flight 14
Flight 15
Flight 16
1
2
5
10
11
14
16
20
21
22
26
27
28
29
CH2O profiles
DISCOVER-AQ
1-29 July 2011
0-3 km
0-12 ppbv
Daily obs in yellow
All profiles in gray

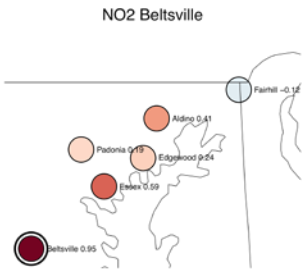
How far away from the retrieved site can this layer average be used?

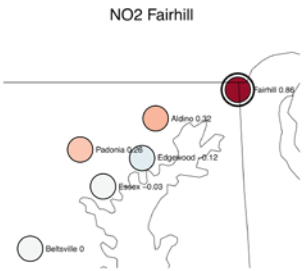


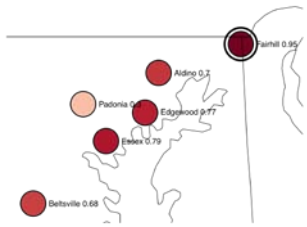
Blue-red scale runs from 0 to 1.

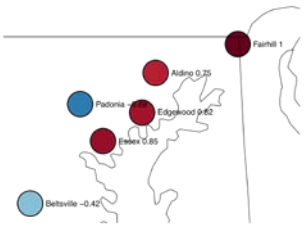
- Maps above show the correlation coefficient between 0–3 km "retrievable" average at the circled location and the 0.2–0.5 km average at other spiral locations. While correlations over land are high, diminishing with distance, correlations with the 0.2–0.5 km average for samples over the Chesapeake Bay are small.

How far away from the retrieved site can this layer average be used? (continued)

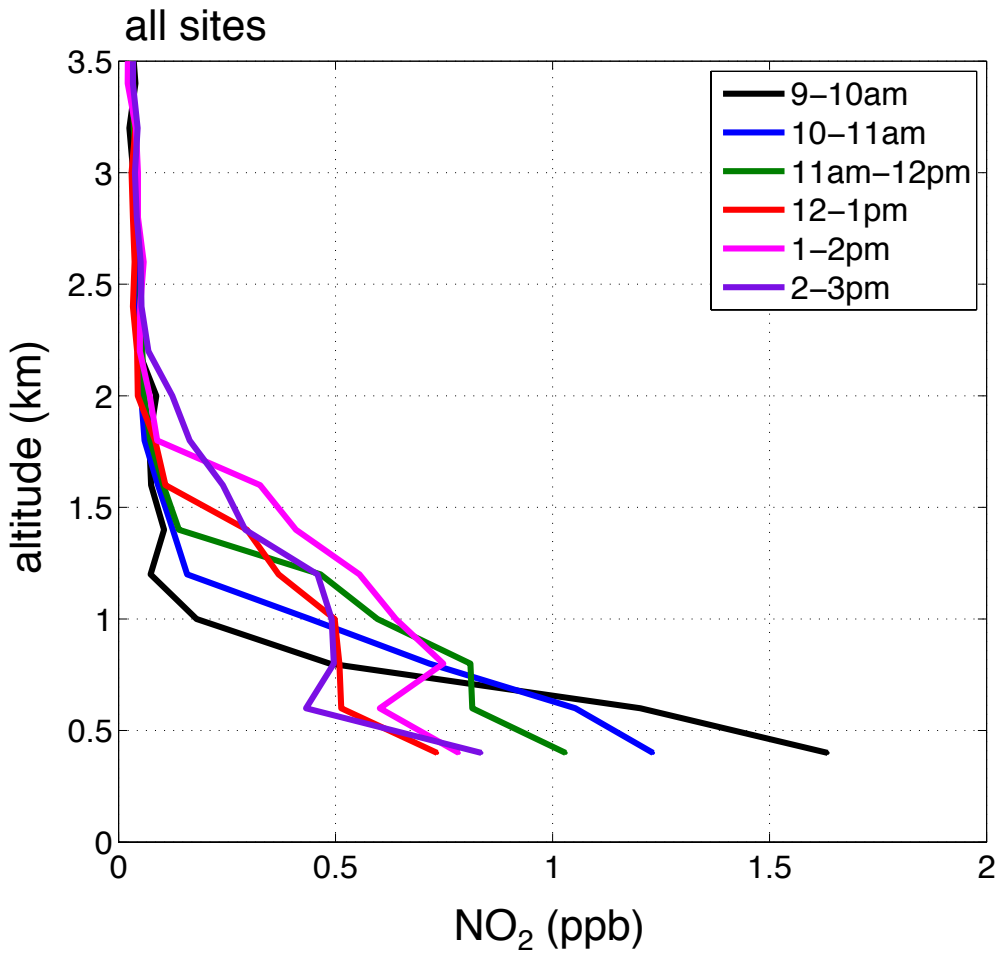








Blue-red scale runs from –1 to 1


all sites
9–10am
10–11am
11am–12pm
12–1pm
1–2pm
2–3pm
altitude (km)
NO2 (ppb)
0
0.5
1
1.5
2
2.5
3
3.5

Hourly Time Series Analysis of Column NO2 from Multiple Perspectives

Clare Flynn

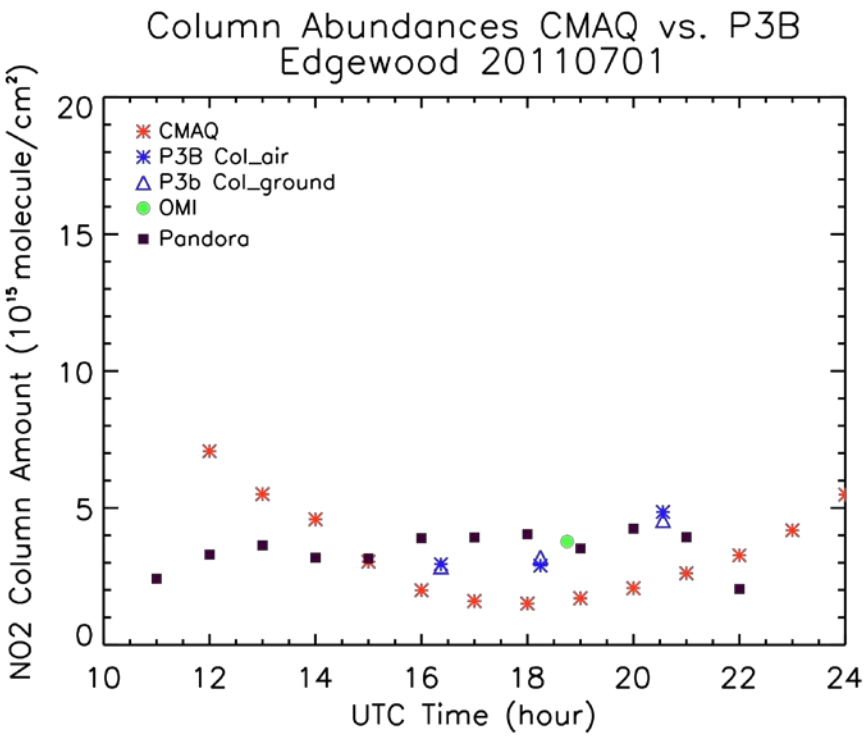
February 15, 2012

Acknowledgments:

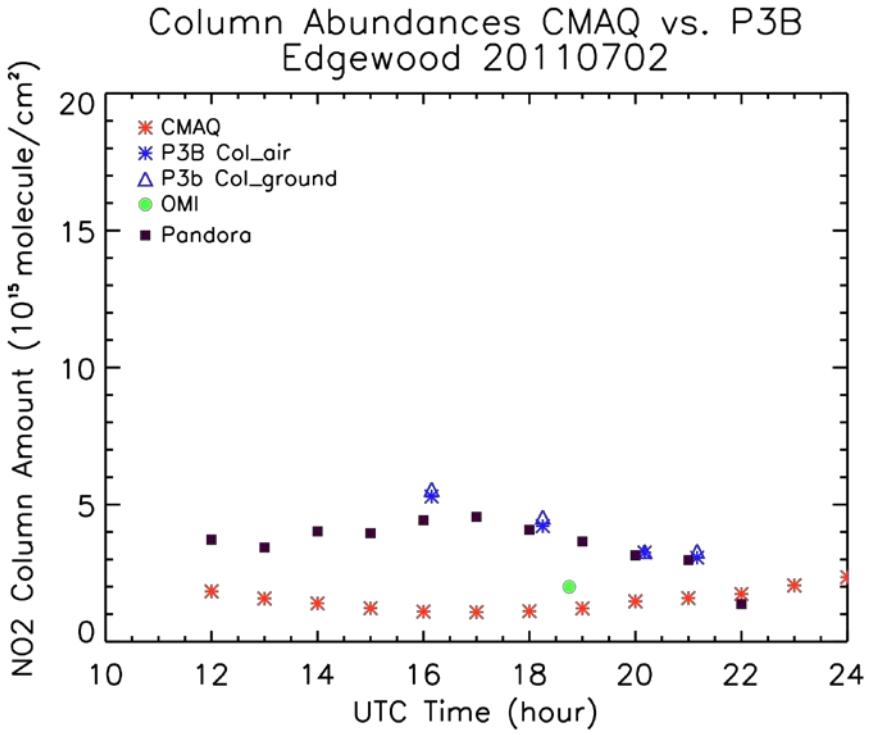
Gao Chen

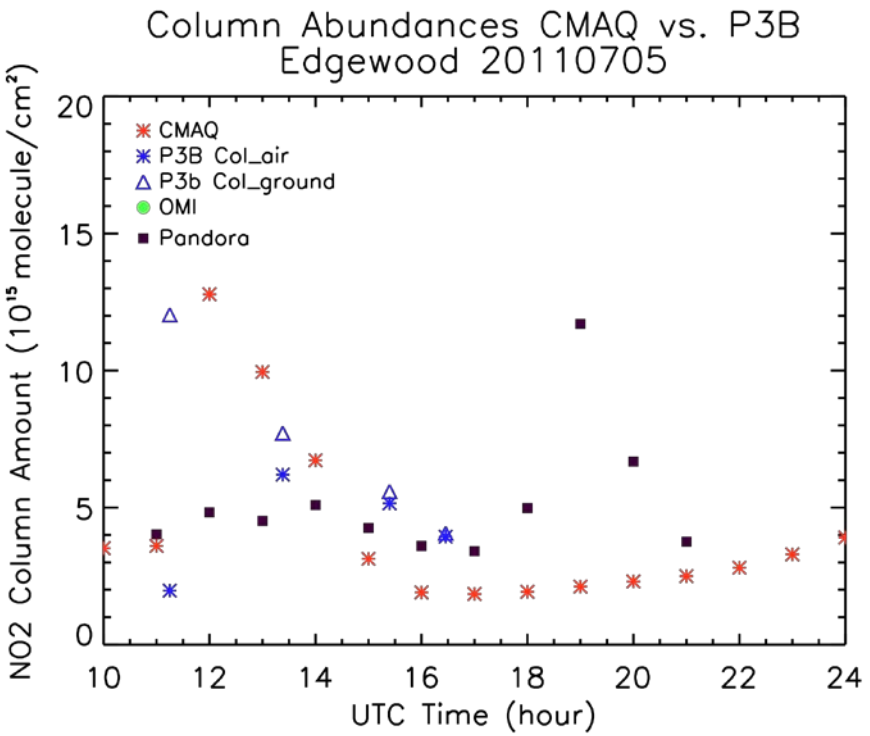
Jay Herman

Lok Lamsal

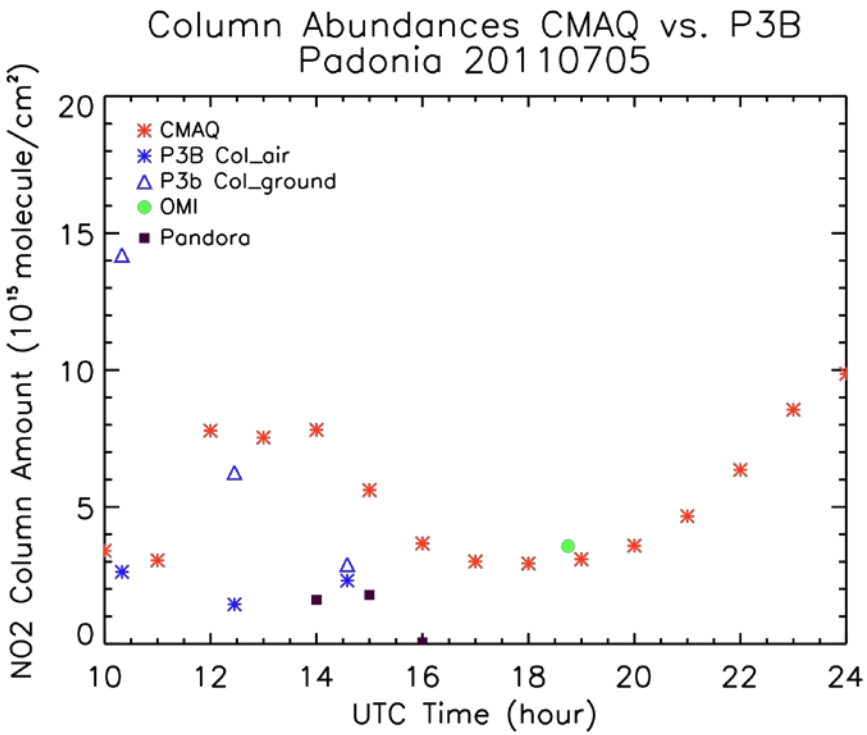


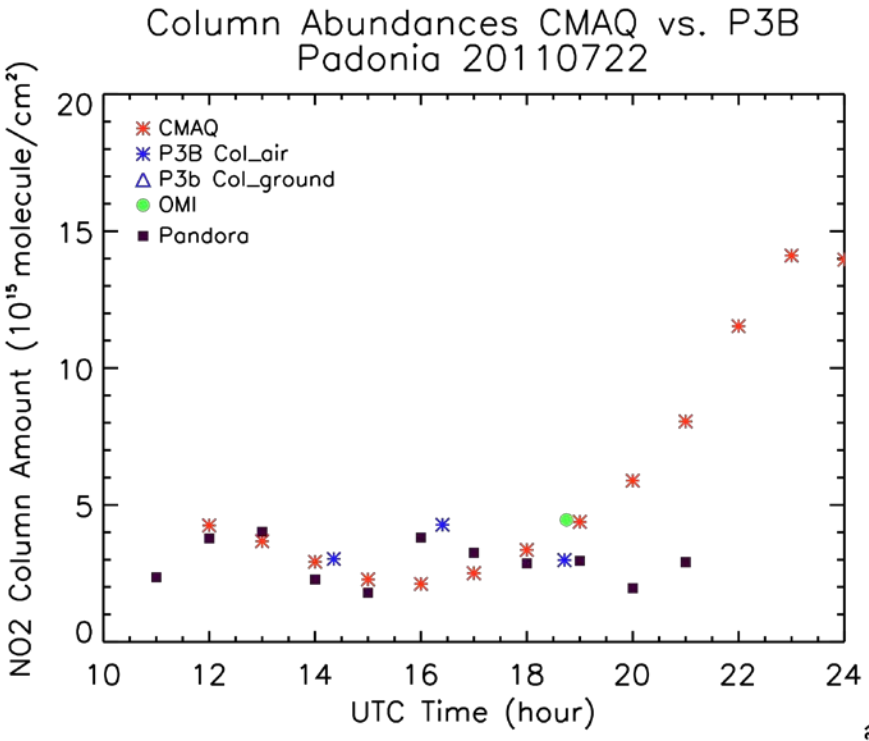
CMAQ demonstrates low bias compared to P-3B, Pandora, and OMI for NO2 during the July 4th weekend getaway days. CMAQ NOx emissions may be too low on these days.



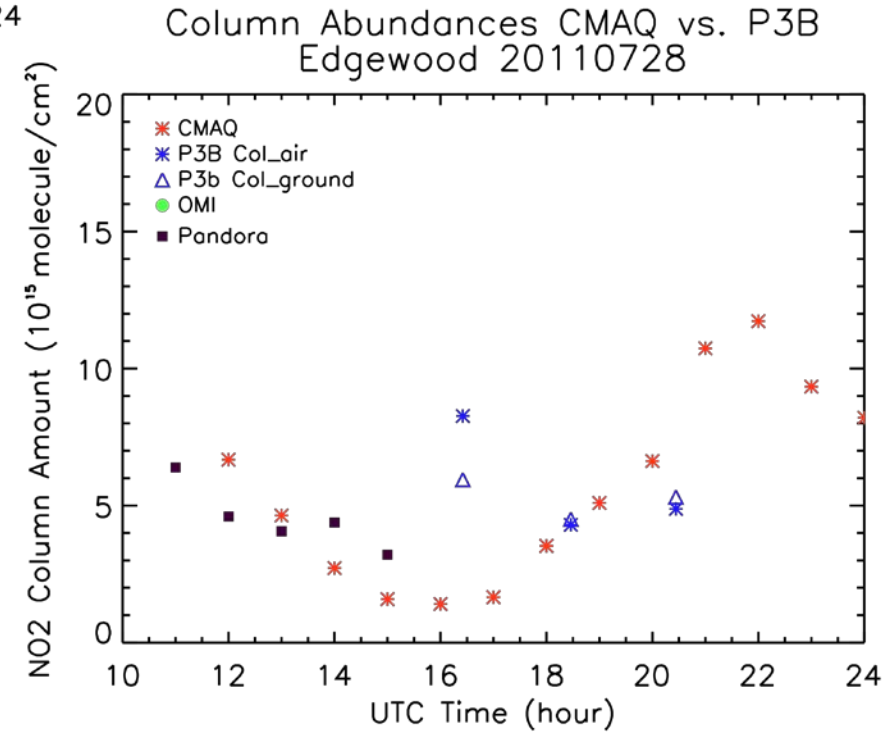


Morning high bias apparent in CMAQ compared to P-3B, indicating morning rush hour emissions may be too large. Good agreement with OMI in afternoon at Padonia, however. CMAQ underestimates the afternoon peak at Edgewood.





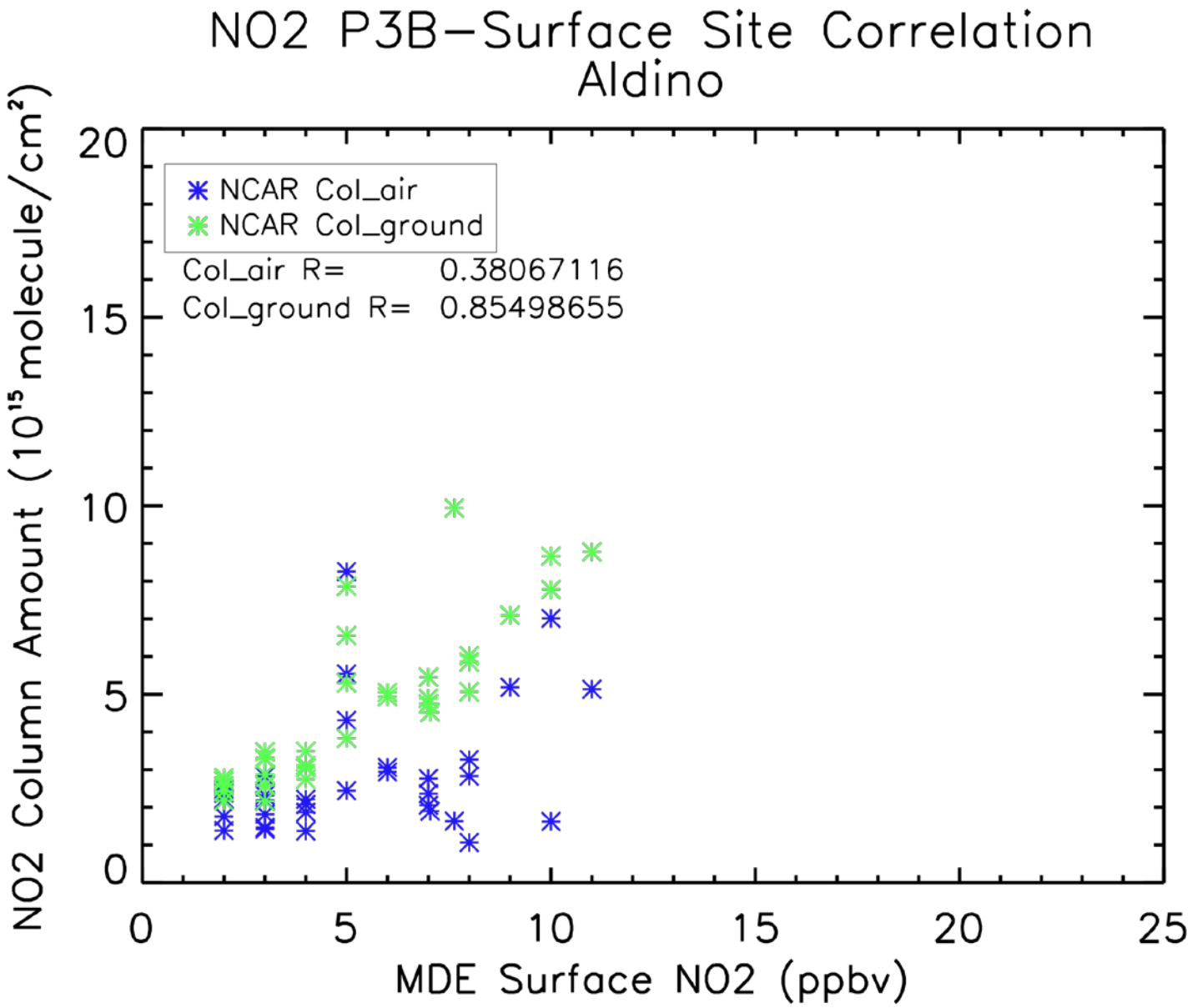
CMAQ demonstrates reasonable agreement with observations during late morning/afternoon, but transitions to high bias in the late afternoon/early evening. CMAQ still misses the observed peak at Edgewood on 7/28.

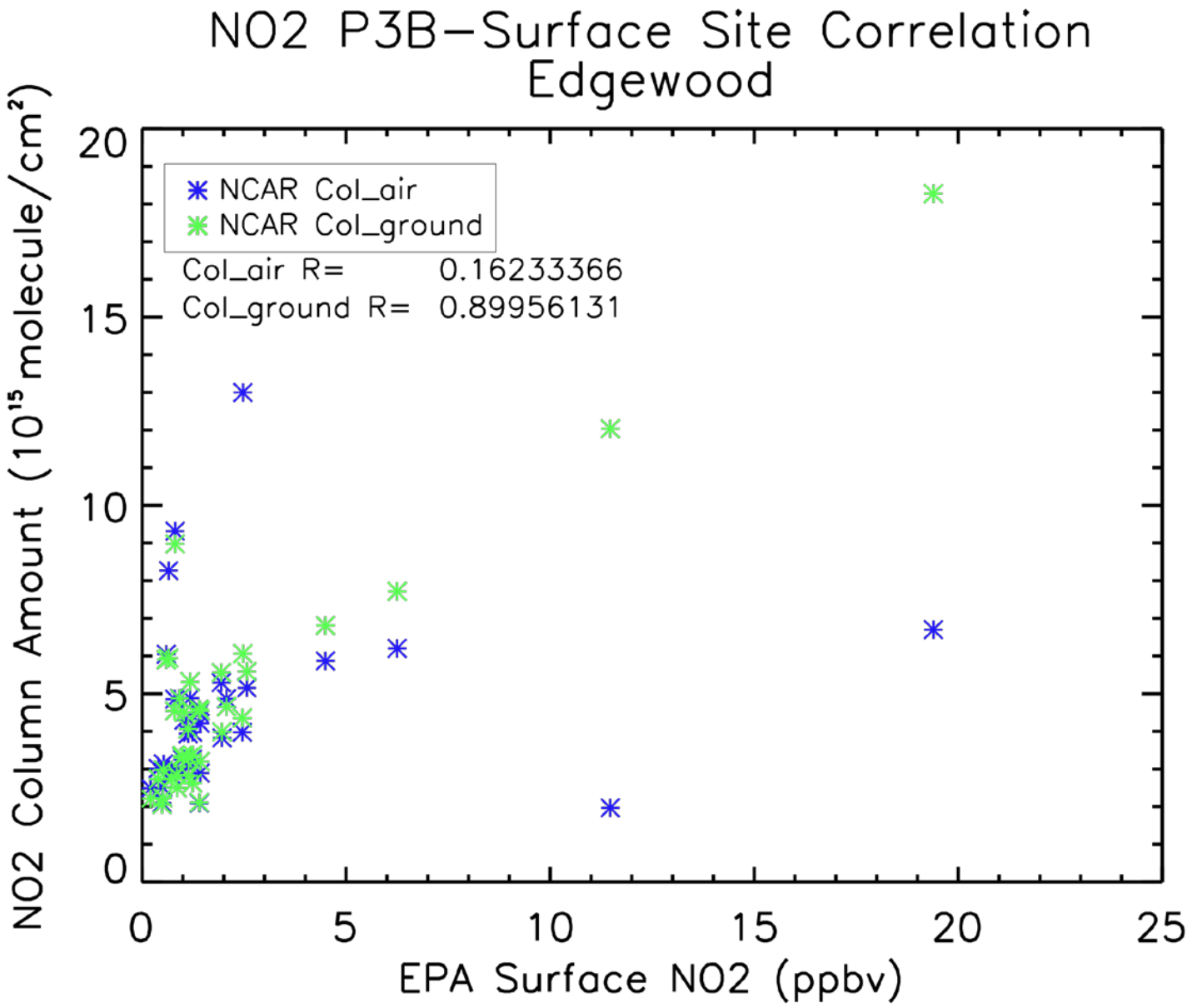


CMAQ/Observations Column NO2 Ratios Averaged over July 2011

	CMAQ/Column_air	CMAQ/Column_ground	CMAQ/Pandora	CMAQ/OMI
Aldino	1.474 (± 1.131)	0.809 (± 0.362)	1.598 (± 1.278)	1.362 (± 0.747)
Beltsville	1.069 (± 0.745)	0.748 (± 0.509)	0.999 (± 0.808)	1.067 (± 0.238)
Edgewood	0.806 (± 0.437)	0.710 (± 0.330)	1.076 (± 0.627)	0.871 (± 0.329)
Essex	0.592 (± 0.984)	0.386 (± 0.286)	1.167 (± 1.251)	0.631 (± 0.389)
Fair Hill	2.334 (± 4.519)	1.035 (± 0.501)	3.149 (± 3.779)	0.667 (± 0.361)
Padonia	1.353 (± 1.011)	0.891 (± 0.480)	2.922 (±3.151)	1.457 (± 0.719)

Surface vs. Column Correlation Analysis


NO2 P3B–Surface Site Correlation
Aldino
NCAR Col_air
NCAR Col_ground
Col_air R= 0.38067116
Col_ground R= 0.85498655
NO2 Column Amount (10^15 molecule/cm^2)
MDE Surface NO2 (ppbv)
0
5
10
15
20
25

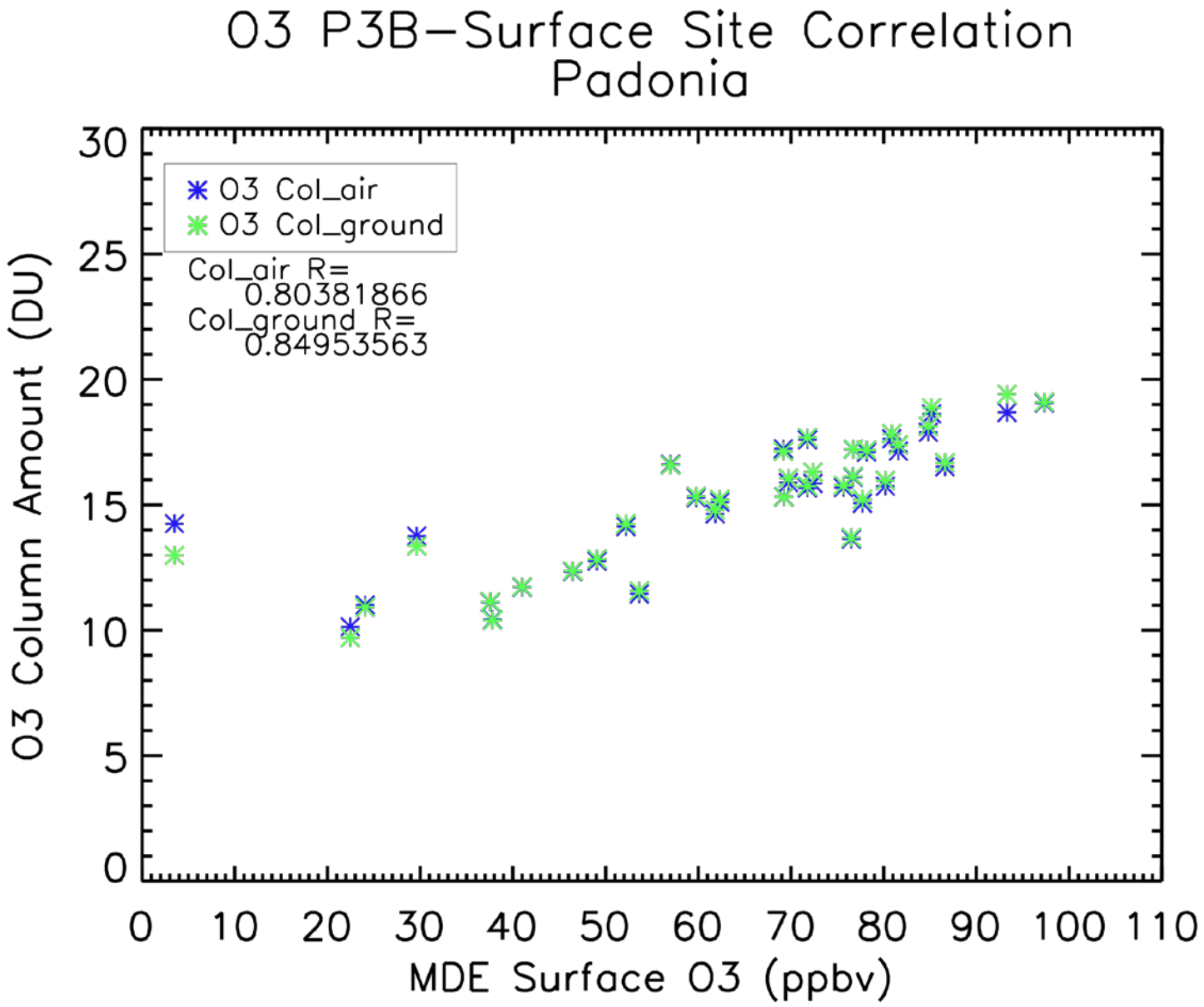

NO2 P3B–Surface Site Correlation
Edgewood
NCAR Col_air
NCAR Col_ground
Col_air R= 0.16233366
Col_ground R= 0.89956131
NO2 Column Amount (10^15 molecule/cm^2)
EPA Surface NO2 (ppbv)
0
5
10
15
20
25

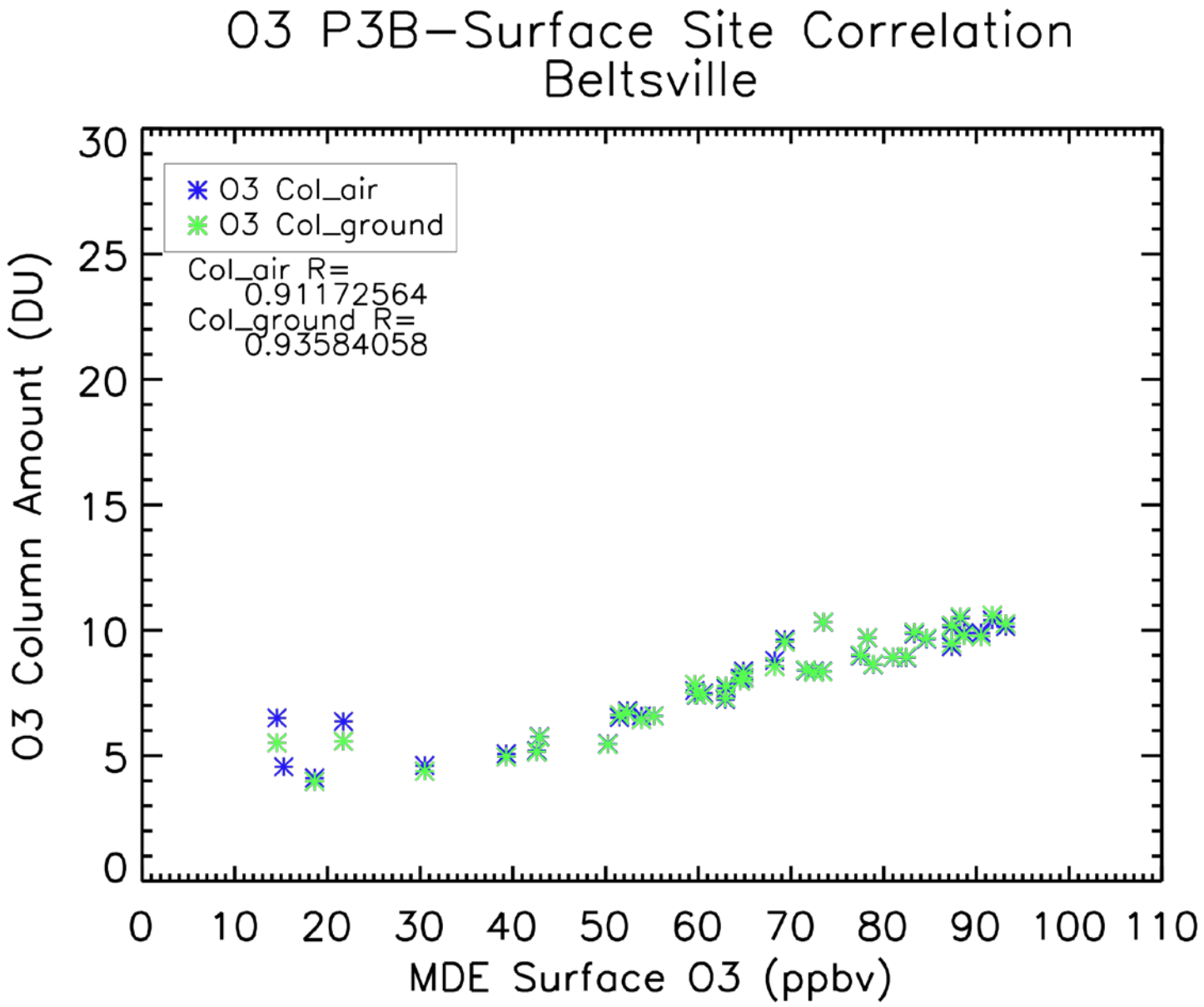
P-3B Correlation Summary: Hourly Surface NO2 Data

	Correlation Coeff. R (Col_ground)	Correlation Coeff. R (Col_air)	Coeff. R (after Col_air outlier rejected)
Edgewood	0.886	0.163	0.307
Essex	0.752	- 0.189	0.473
Padonia	0.811	0.085	0.295

P-3B Correlations: 1-min Resolution Surface NO2 Data

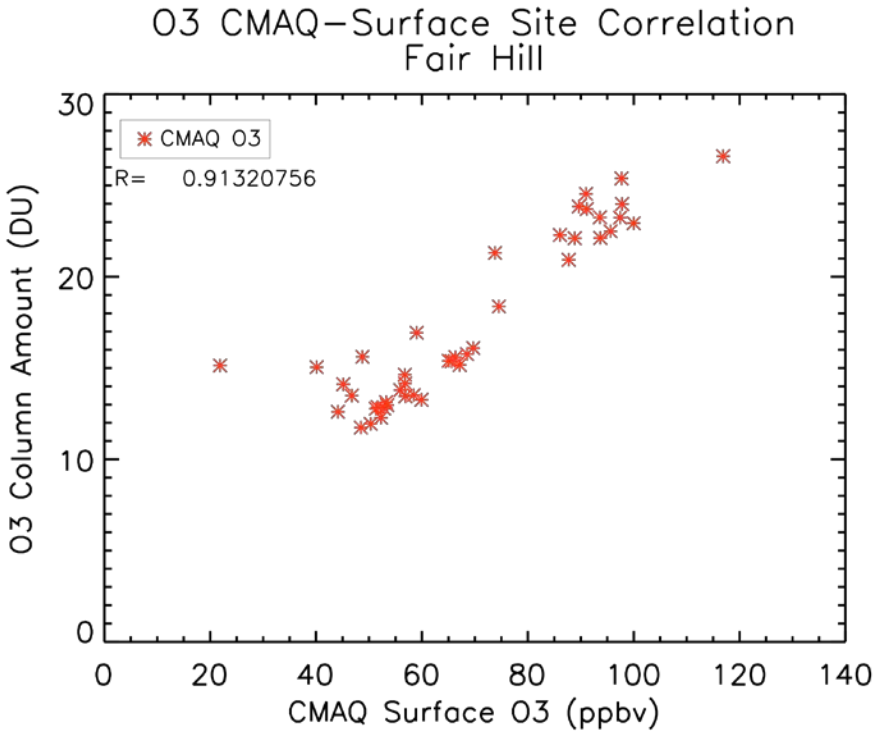
	Correlation Coeff. R (Col_ground)	Correlation Coeff. R (Col_air)	Coeff. R (after Col_air outlier rejected)
Aldino	0.855	0.381	---
Beltsville	0.639	0.303	0.425
Edgewood	0.899	0.162	0.332
Essex	0.801	- 0.163	0.399
Fair Hill	0.965	0.644	---
Padonia	0.856	- 0.046	0.042


O3 P3B–Surface Site Correlation
Padonia
O3 Col_air
O3 Col_ground
Col_air R=
0.80381866
Col_ground R=
0.84953563
O3 Column Amount (DU)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
110
MDE Surface O3 (ppbv)

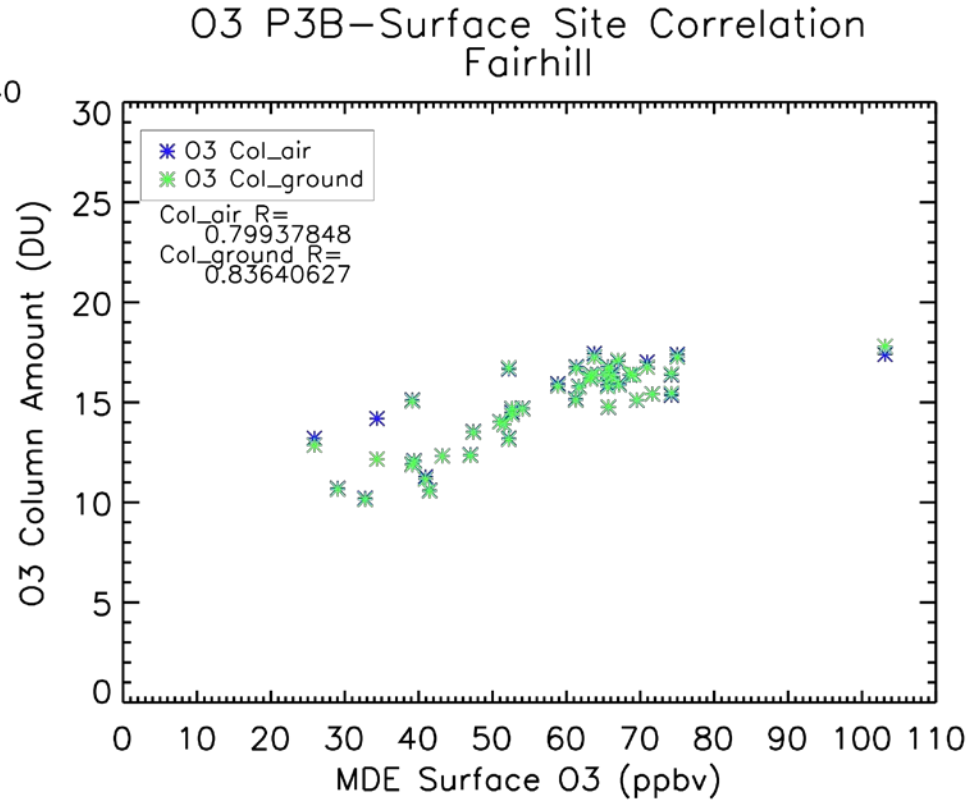

O3 P3B–Surface Site Correlation
Beltsville
O3 Col_air
O3 Col_ground
Col_air R=
0.91172564
Col_ground R=
0.93584058
O3 Column Amount (DU)
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100
110
MDE Surface O3 (ppbv)

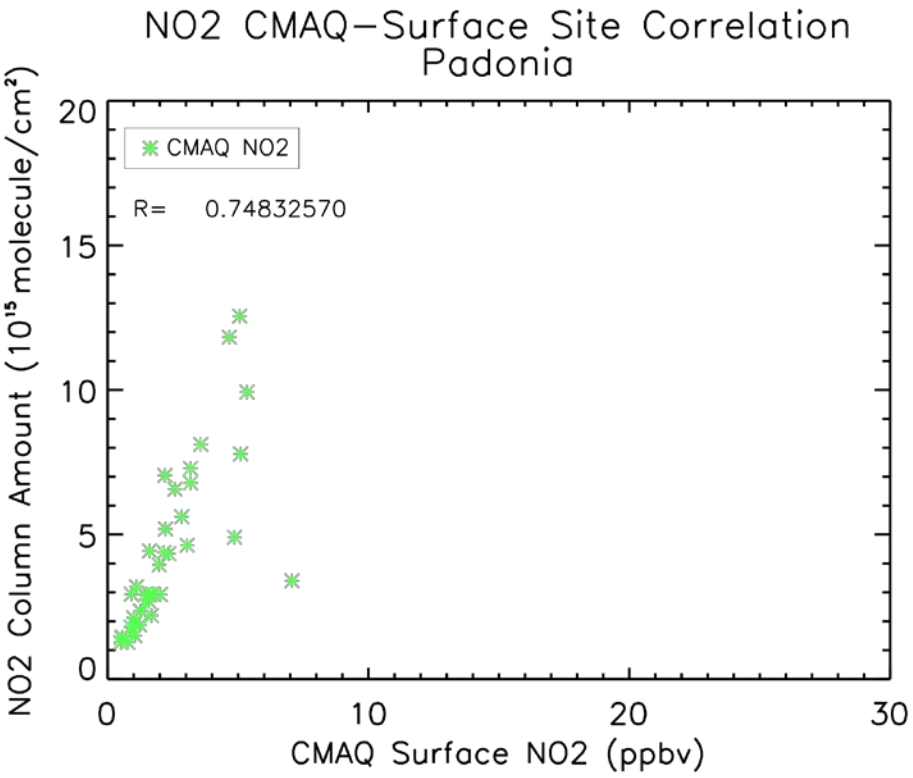
P-3B Correlations: 1-min Resolution Surface O3 Data

	Correlation Coeff. R (Col_ground)	Correlation Coeff. R (Col_air)
Aldino	0.889	0.870
Beltsville	0.936	0.912
Edgewood	0.808	0.778
Essex	0.795	0.762
Fair Hill	0.836	0.799
Padonia	0.849	0.803

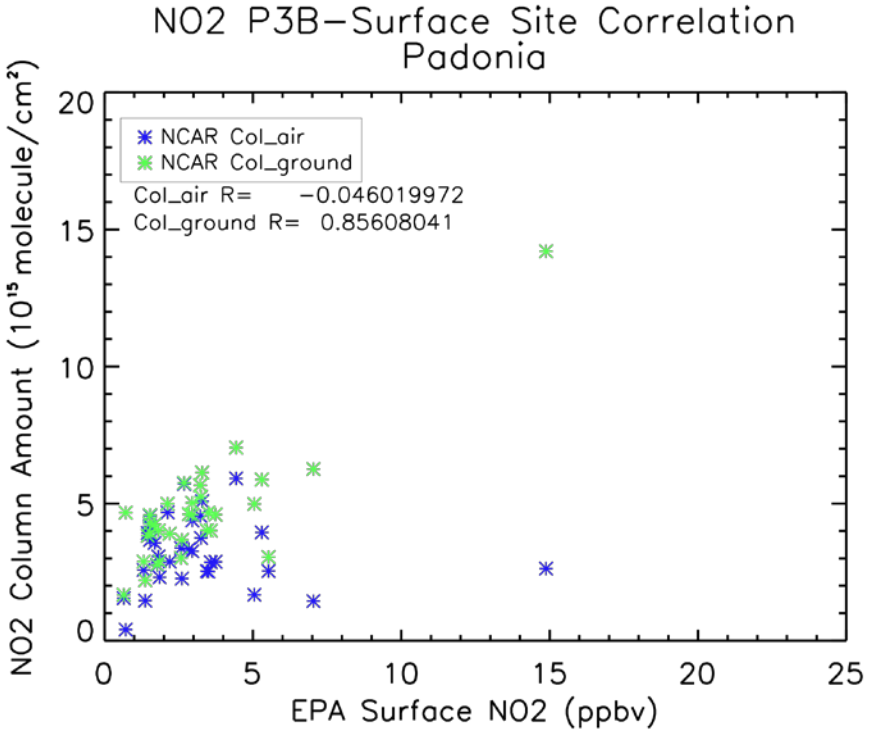


CMAQ surface appears more connected to the overlying column for O3 than in the P-3B observations—reason needs to be investigated





CMAQ surface also more connected to the overlying column for NO2 than in the P-3B observations



CMAQ Correlation Summary

	Correlation Coeff. R (O3)	Correlation Coeff. R (NO2)
Aldino	0.929	0.632
Beltsville	0.917	0.509
Edgewood	0.903	0.585
Essex	0.779	0.609
Fair Hill	0.913	0.930
Padonia	0.912	0.748

Preliminary Comparisons of CMAQ and in-situ O_3, NO_2, and HCHO observations during DISCOVER-AQ

MELANIE FOLLETTE-COOK

KEN PICKERING, PIUS LEE, RON COHEN, ALAN FRIED, ANDREW WEINHEIMER, JIM CRAWFORD, YUNHEE KIM, RICK SAYLOR

IWAQFR

NOVEMBER 30, 2011

Experimental NOAA CMAQ forecast

- **CMAQ v. 4.6**
- **Driven by WRF-NMM meteorology**
- **48 hour forecasts issued each day at 12Z during the campaign**
- **Therefore, for each flight there are two relevant forecasts**
  - **‘0 hr’ – the forecast that was issued the day of the flight**
  - **‘24 hr’ – the forecast that was issued the day before the flight**

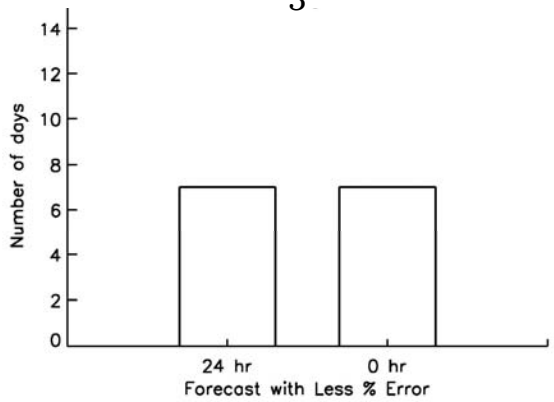
Chemical mechanism	CB05
Aerosol module	Aero4
Emissions	NEI-05
Domain	Rotated Lat-Lon E grid 12 km horizontal resolution
Vertical coordinate	NMM Hybrid (60L)
Radiation / Photolysis	Lacis-Hansen Bulk
PBL	Mellor-Yamada-Janjic (MYJ) local TKE
Clouds	Ferrier cloud water, graupel/ice
Convective cloud mixing	Betts-Miller-Janjic Mass Adjustment
Land surface	NOAH LSM

Forecast evaluation: 0 hr vs. 24 hr

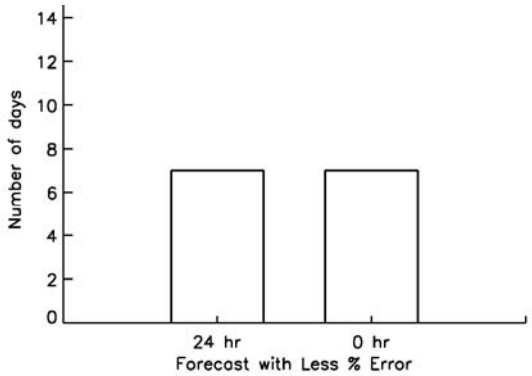
- *** All DISCOVER-AQ results are preliminary field data ***
- The flight data analyzed are 60 sec averages (rather than the native 1 sec resolution) for a more appropriate comparison to the 12 km CMAQ output
- The observations have been collocated in space and time with the CMAQ output
- Percent error =
  (model – observation)/ observation * 100
- For all flight days during the campaign it was noted which forecast had lower absolute values of percent error
- These results are summarized in the following histogram plots

Forecast evaluation: 0 hr vs. 24 hr Histograms

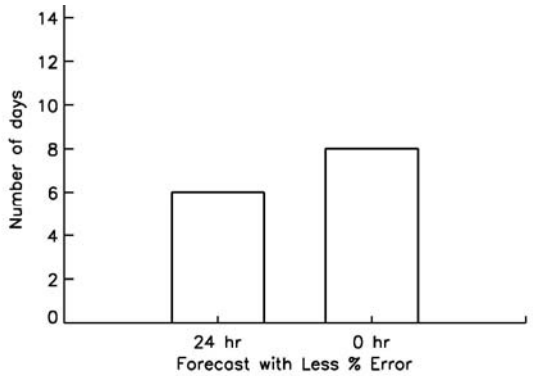
O_3



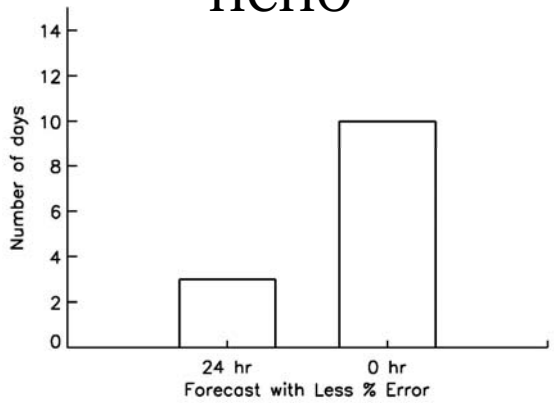
CO



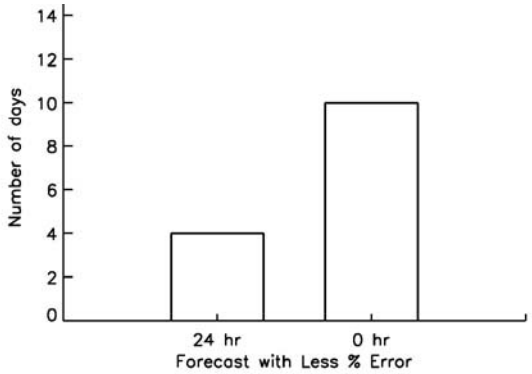
Isoprene



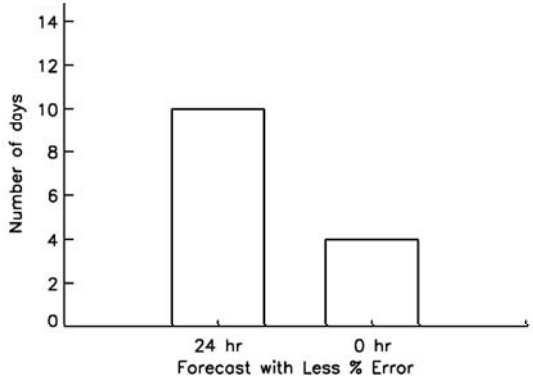
HCHO



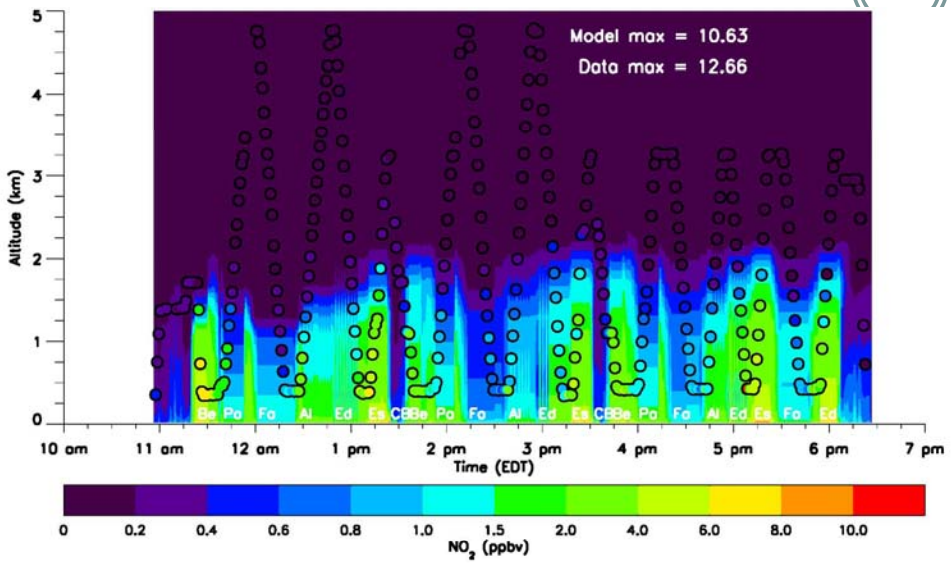
NO_2 (NCAR)



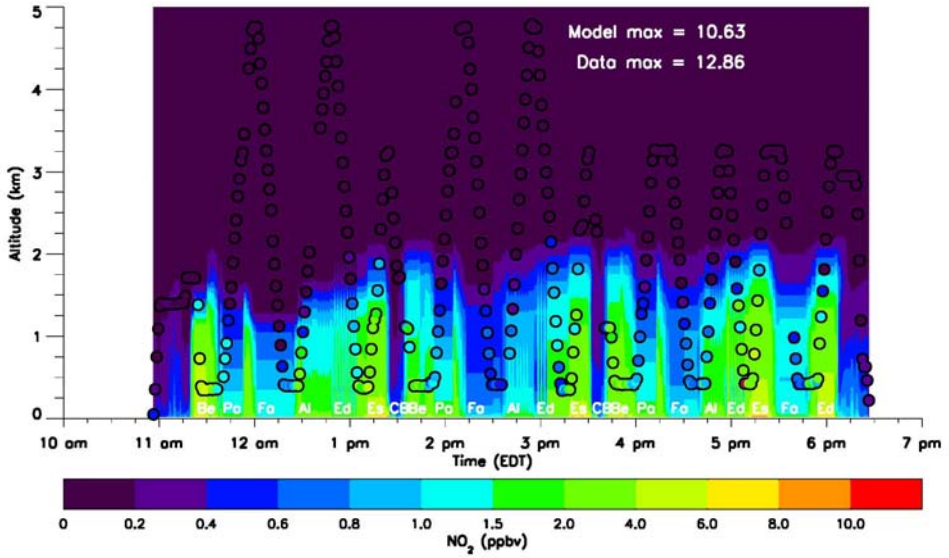
Peroxynitrates



Flight #9 Thursday 7-21-2011



CMAQ NO_2 Curtain with NCAR NO_2 R=0.85



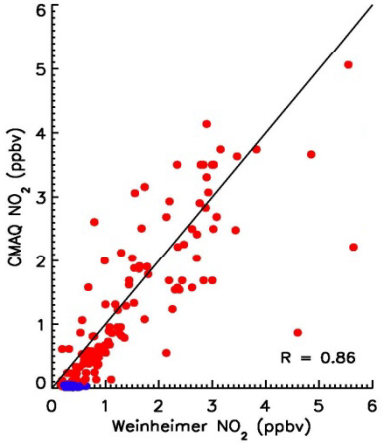
CMAQ NO_2 Curtain with Berkeley NO_2 R=0.83

CMAQ reproduces variability seen in the observations in both the PBL and FT

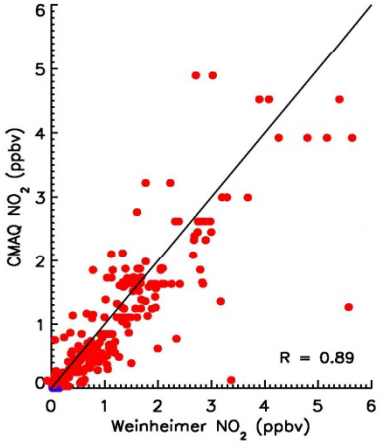
* Berkeley NO2 has less coverage than NCAR NO2 due to cycling through N species

CMAQ NO_2 vs. NCAR NO_2

07/10/2011



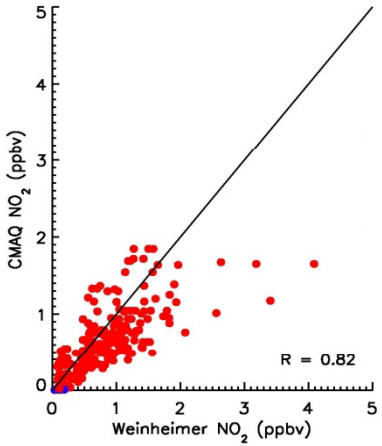
07/14/2011



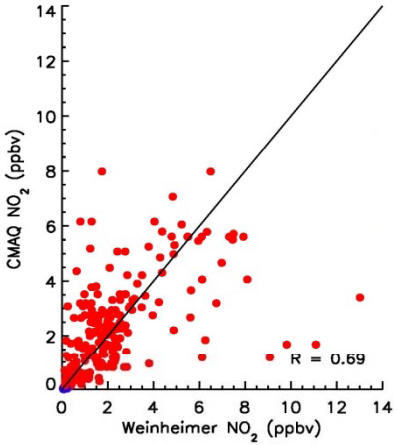
< 2.5 km

> 2.5 km

07/27/2011



07/28/2011

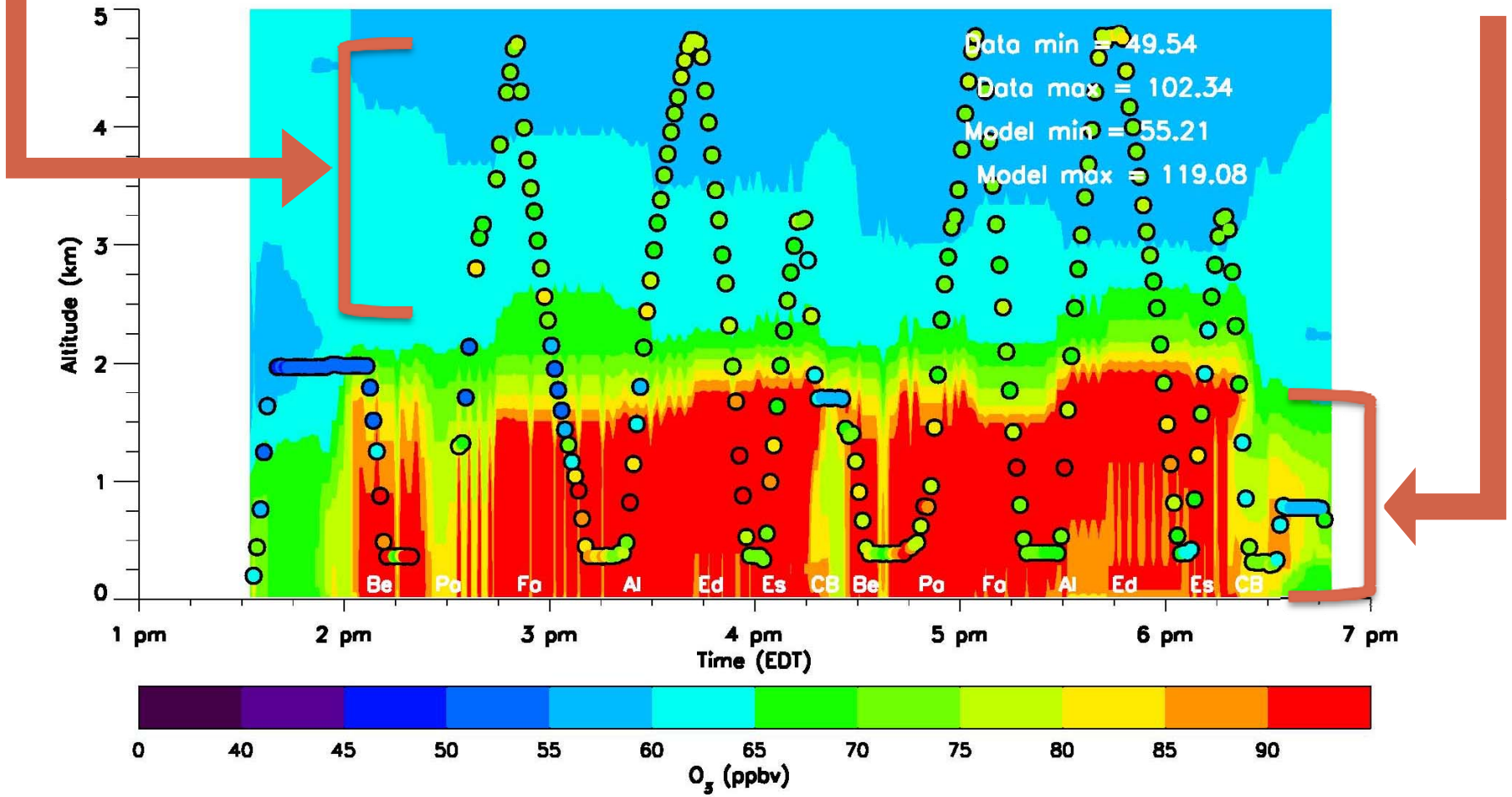


CMAQ agrees relatively well with both NO_2 datasets

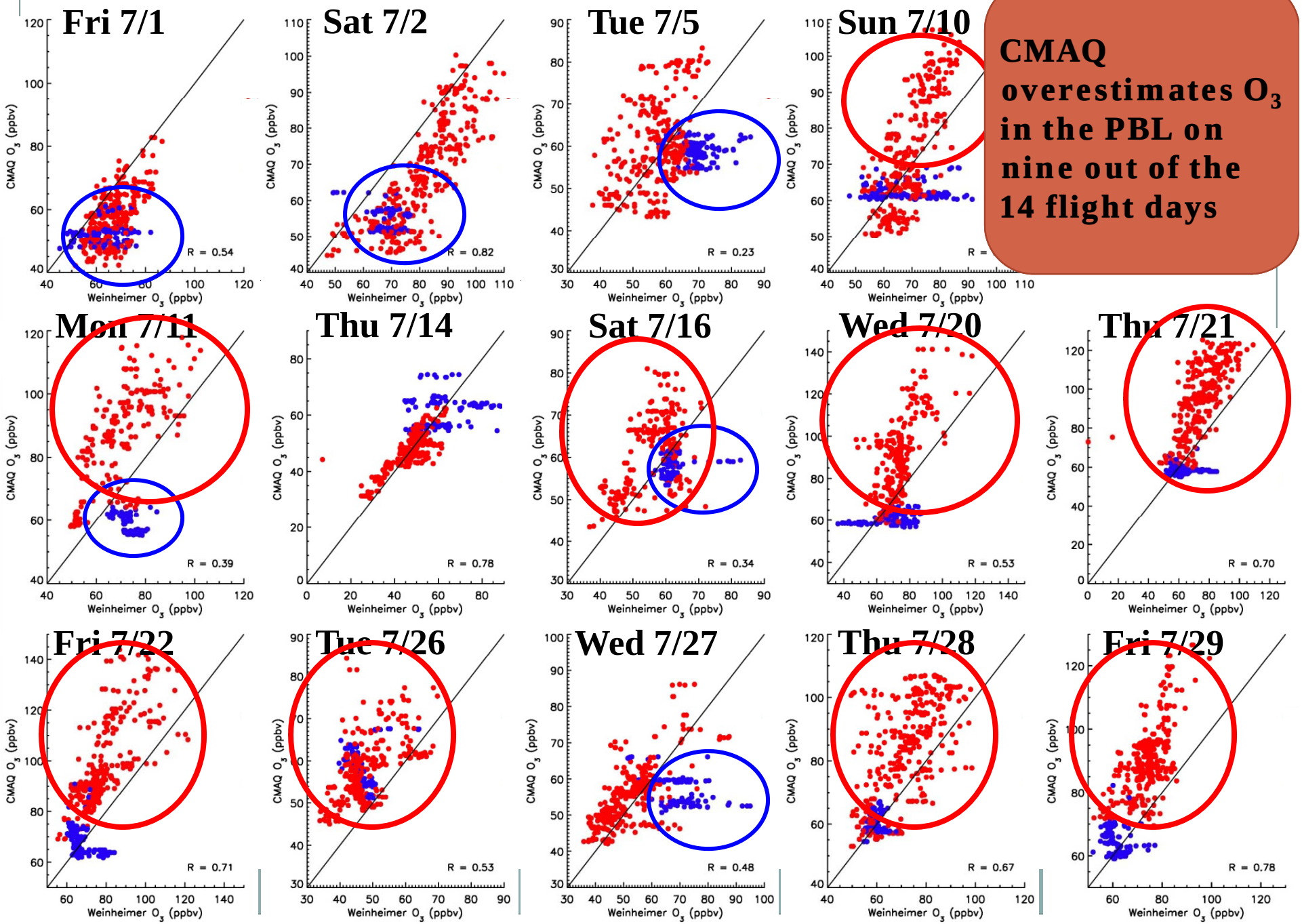
CMAQ O_3 Curtain with NCAR O_3 Flight #5 Monday 7-11-2011

CMAQ underestimates ozone above the boundary layer

CMAQ overestimates ozone in the boundary layer



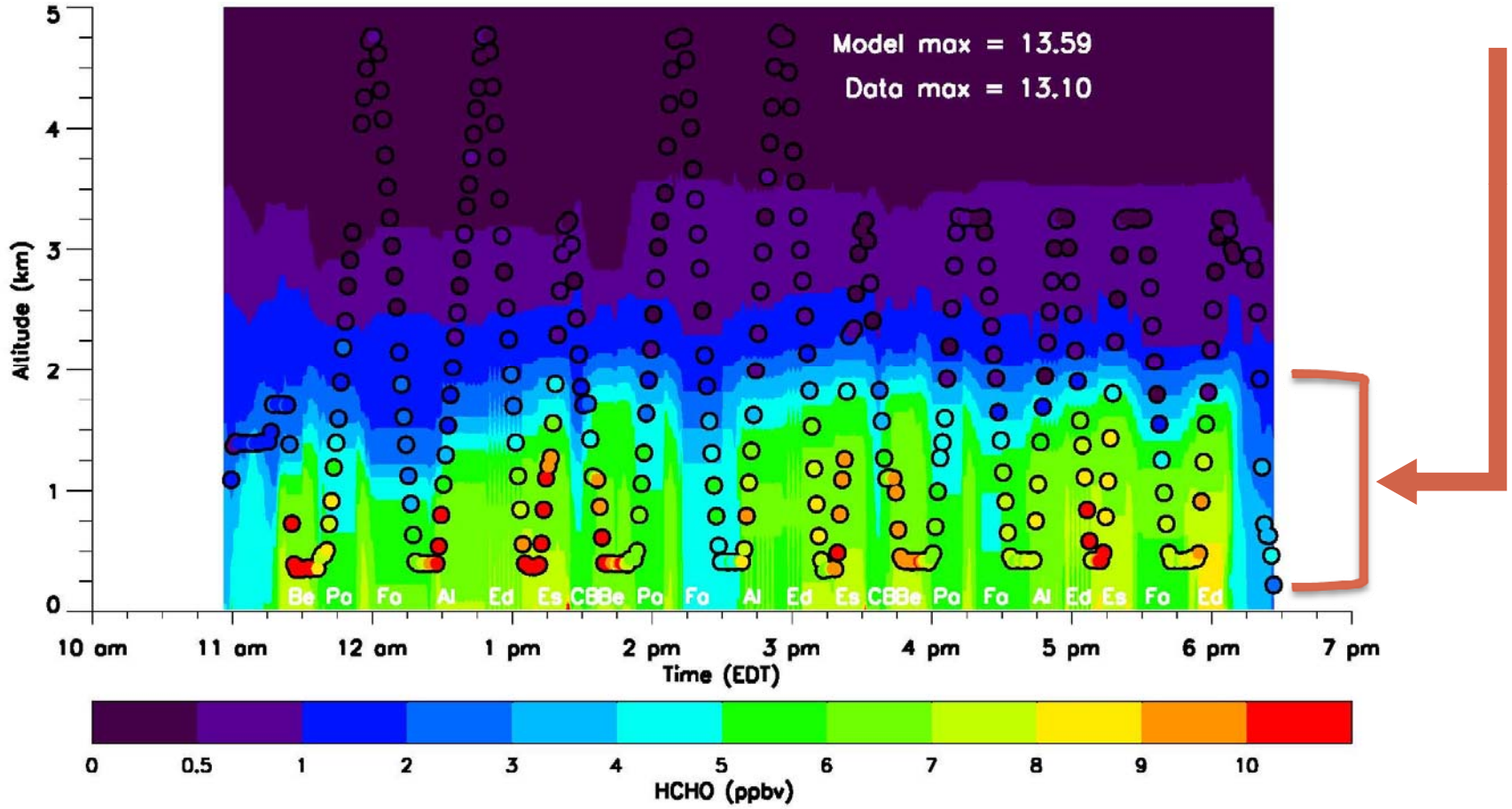
< 2.5 km > 2.5 km



CMAQ overestimates O_3 in the PBL on nine out of the 14 flight days

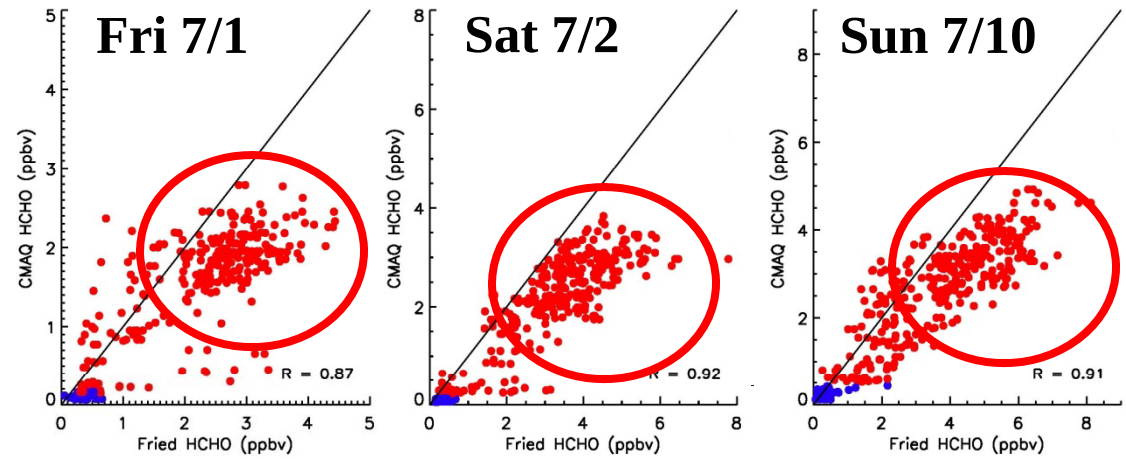
CMAQ HCHO Curtain with HCHO measurements Flight #9 Wednesday 7-21-2011

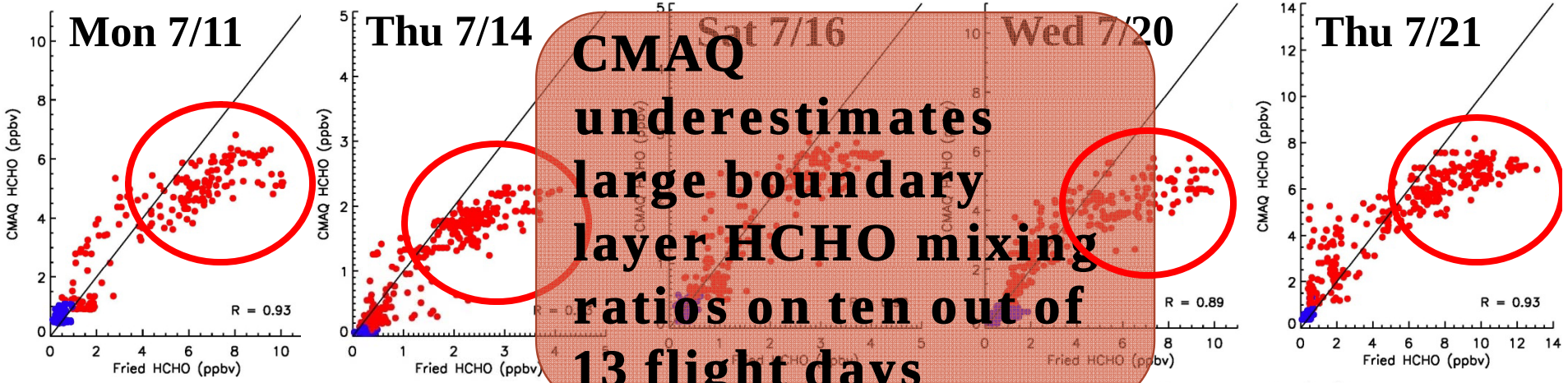
CMAQ underestimates HCHO in the boundary layer



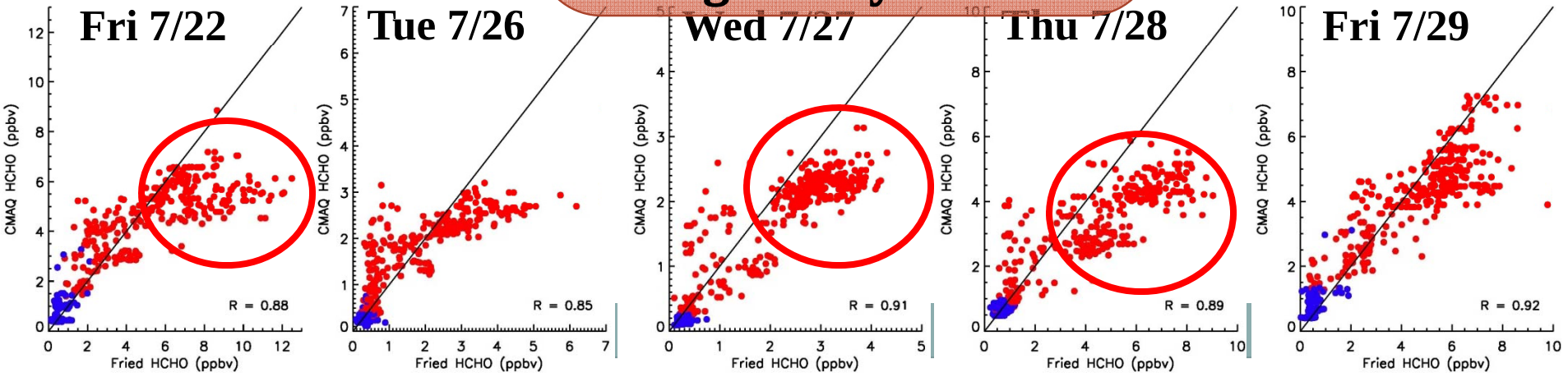
CMAQ HCHO vs. HCHO measurements

< 2.5 km **> 2.5 km**



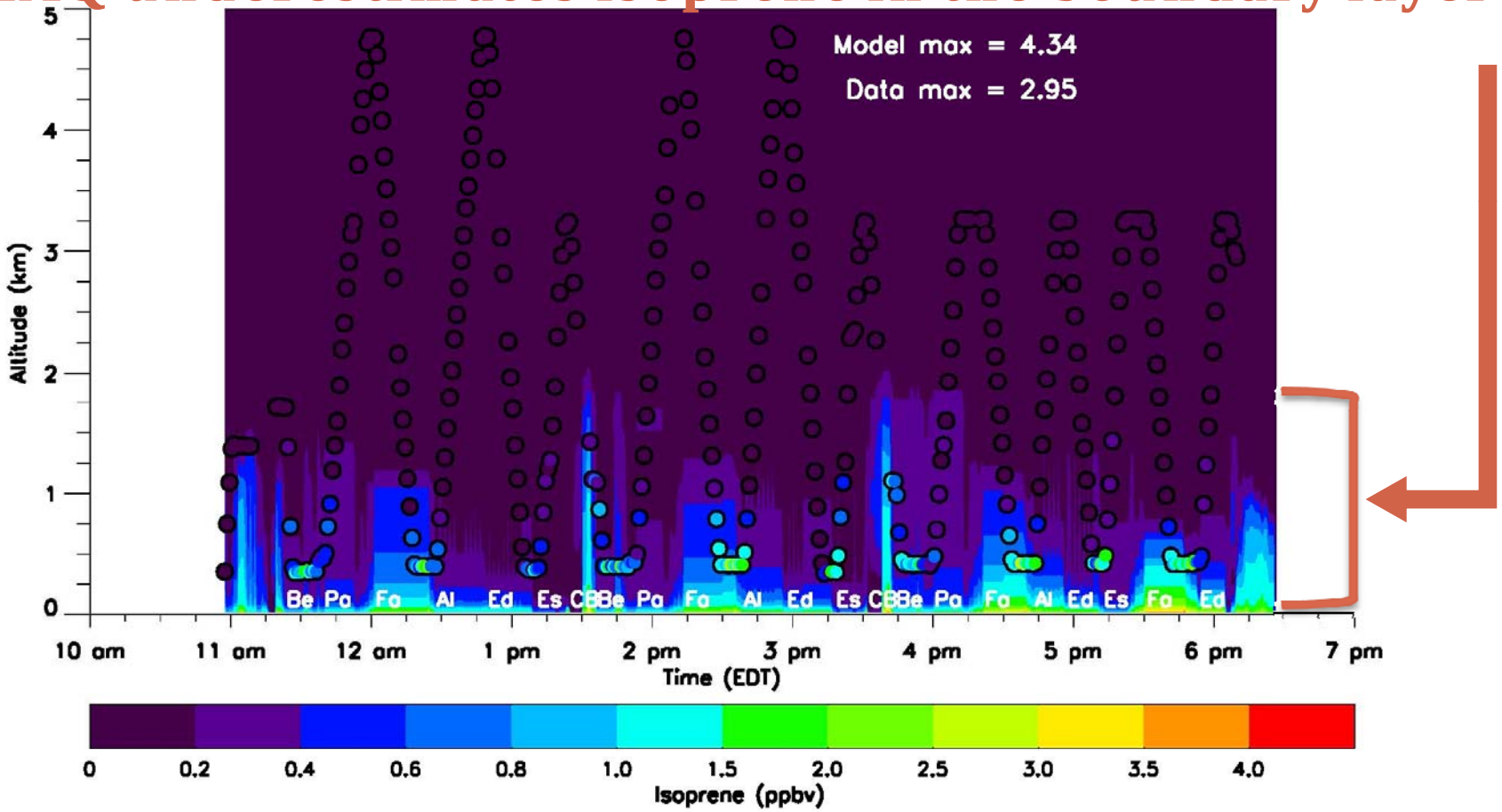


CMAQ underestimates large boundary layer HCHO mixing ratios on ten out of 13 flight days

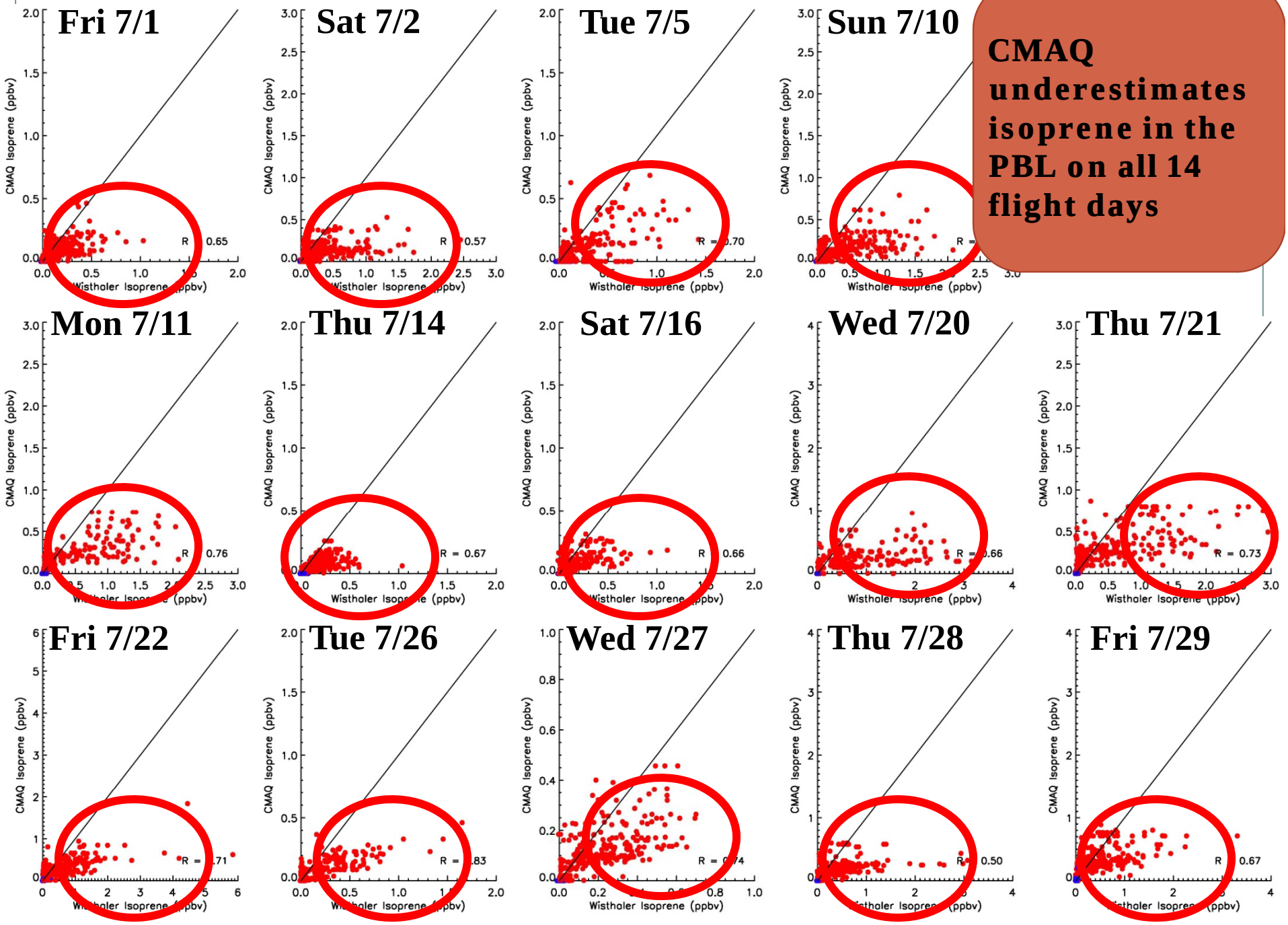


CMAQ Isoprene Curtain with isoprene measurements
Flight #9 Wednesday 7-21-2011

CMAQ underestimates isoprene in the boundary layer



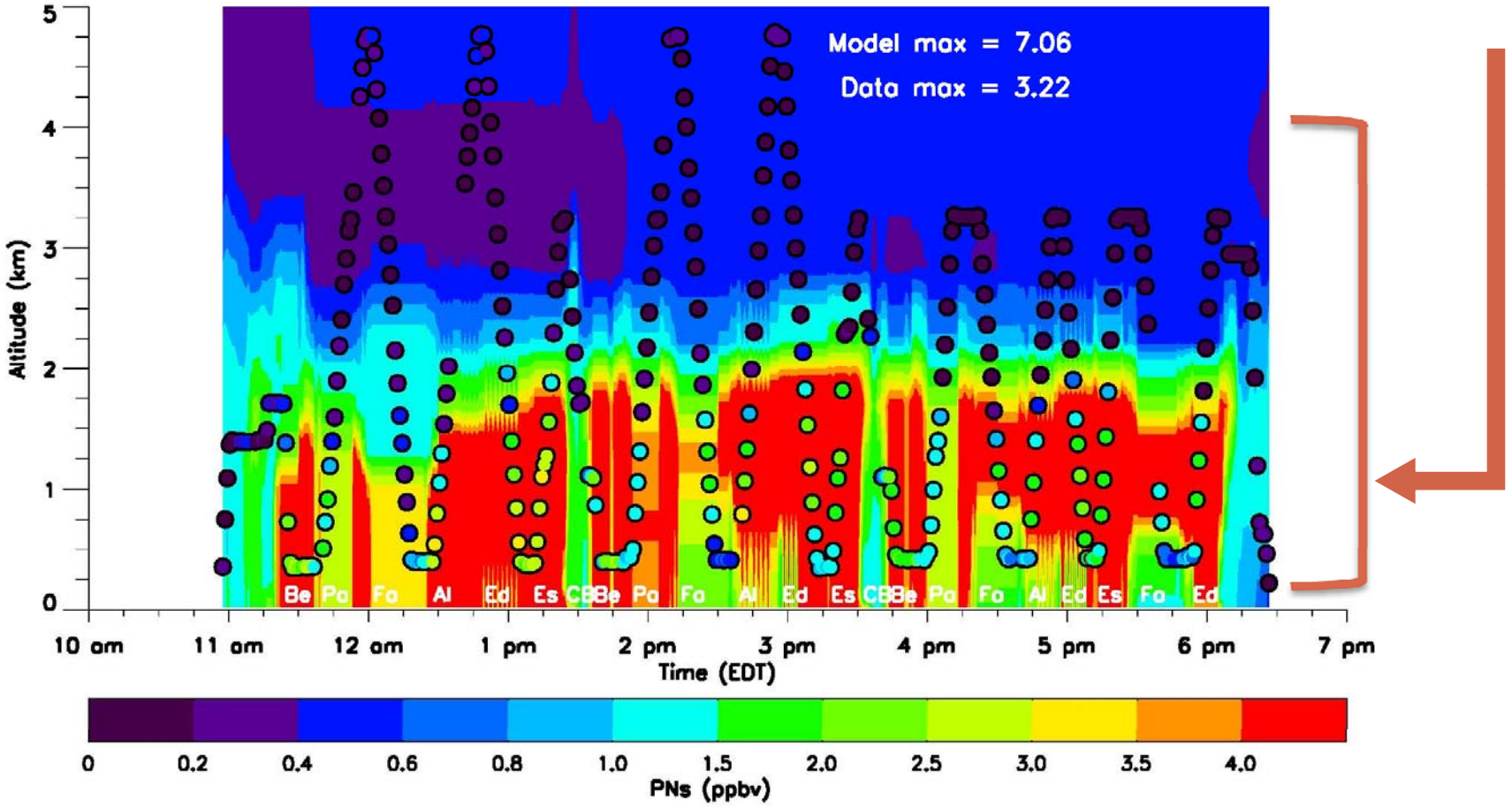
< 2.5 km > 2.5 km



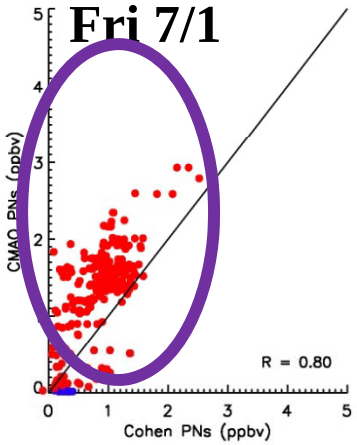
CMAQ underestimates isoprene in the PBL on all 14 flight days

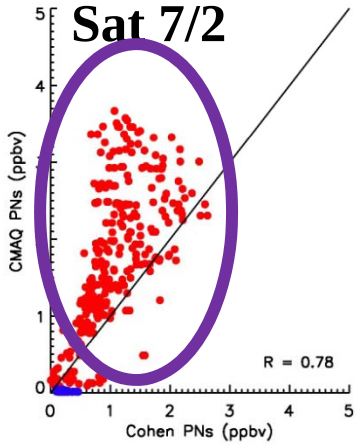
CMAQ PNs Curtain with PNs measurements
Flight #9 Wednesday 7-21-2011

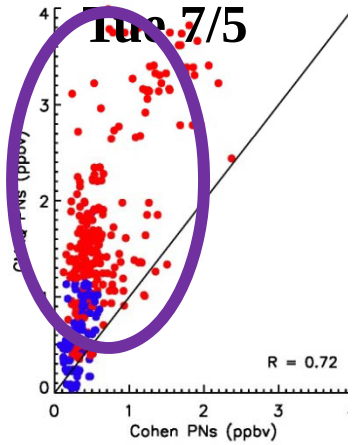
CMAQ overestimates peroxynitrates at all levels

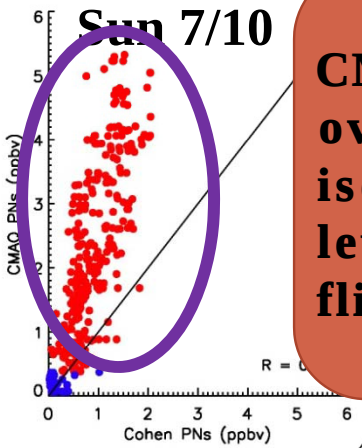


< 2.5 km > 2.5 km

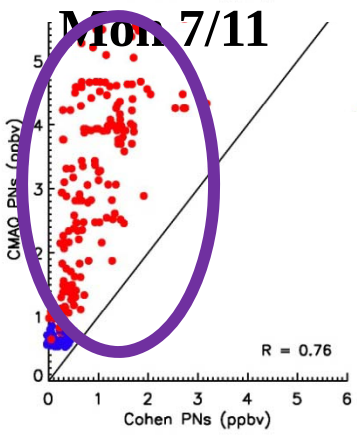


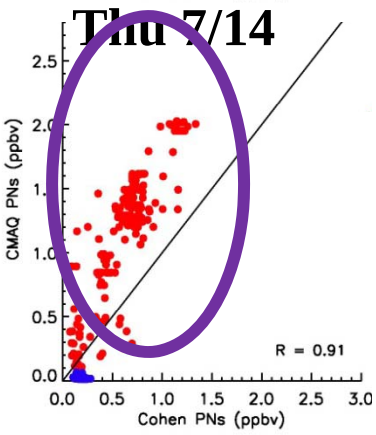


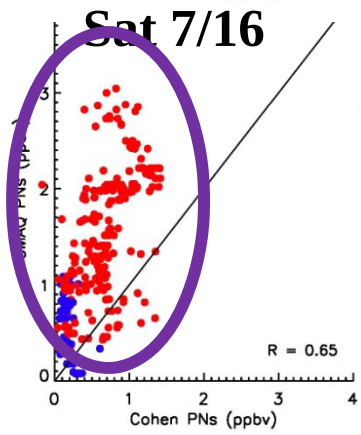


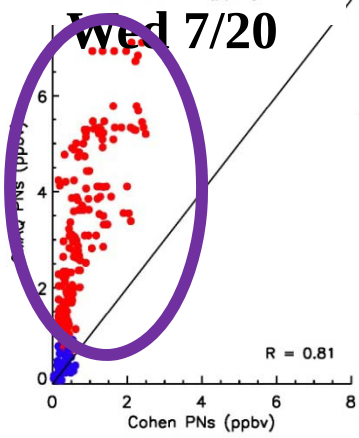


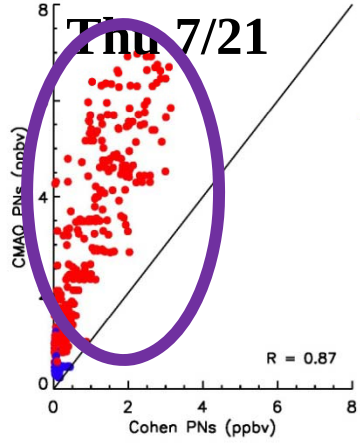
CMAQ overestimates isoprene at all levels on all 14 flight days

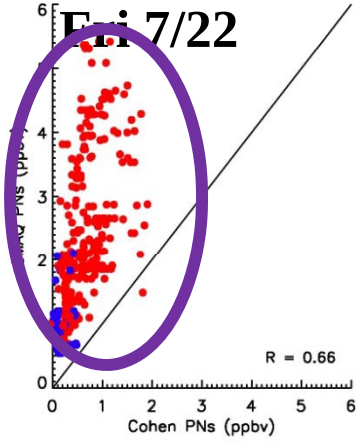


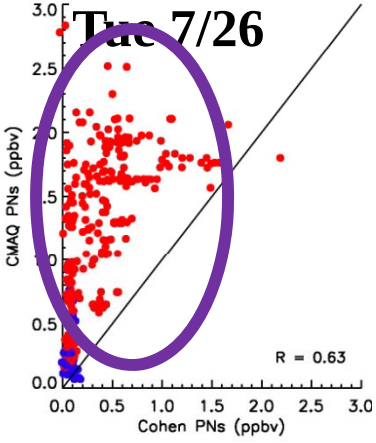


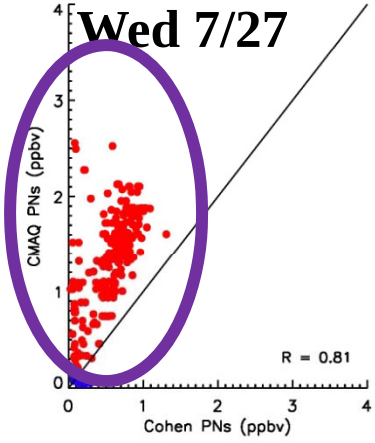


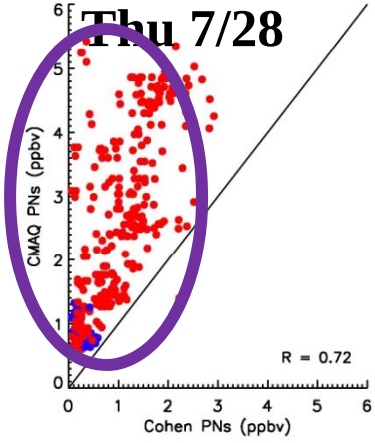


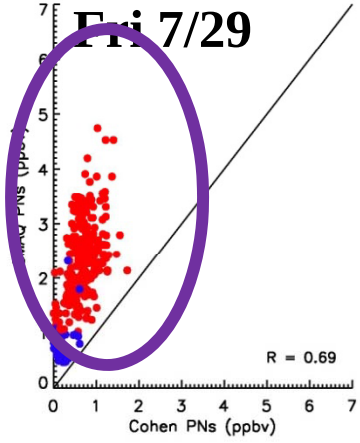




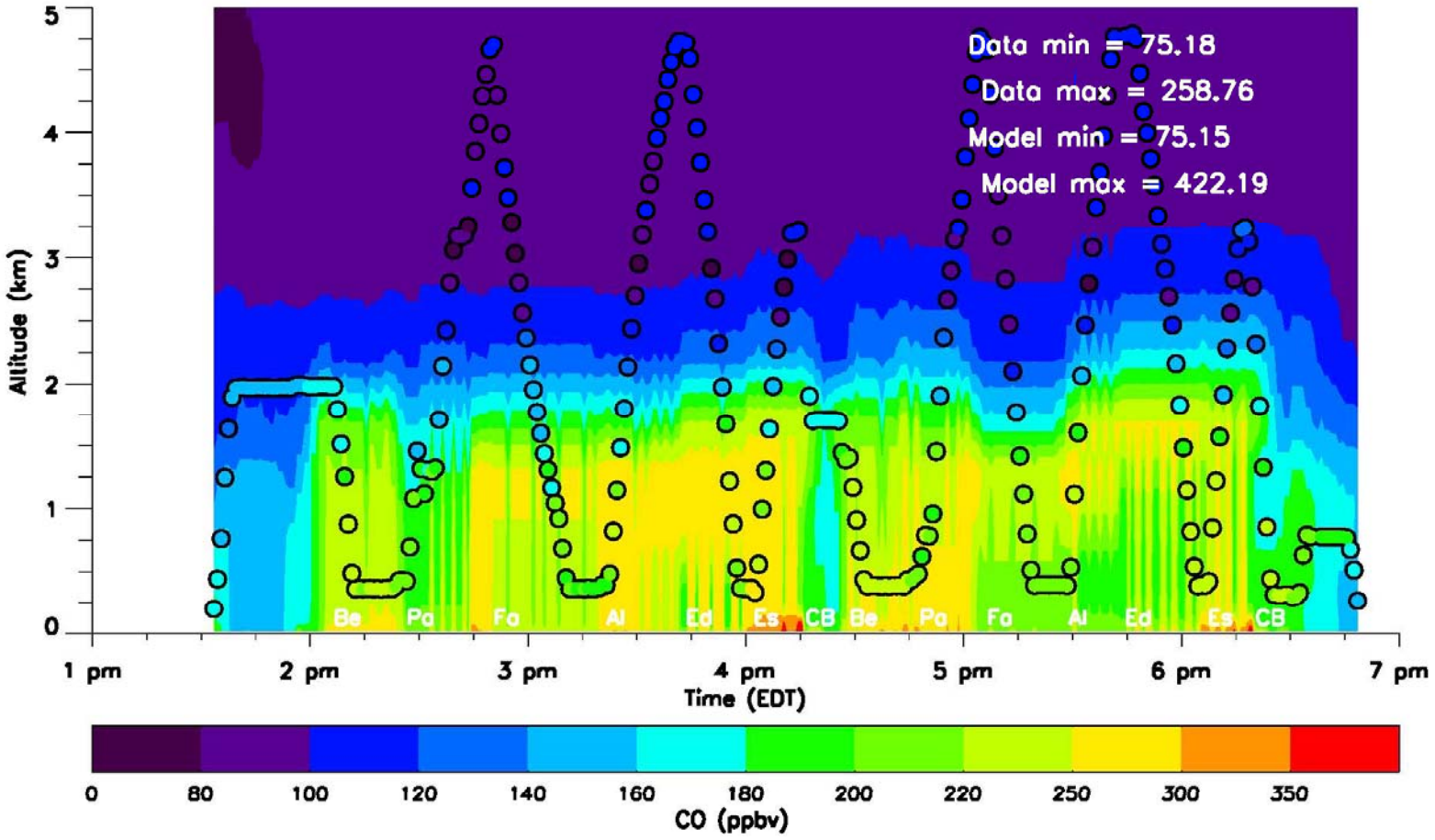




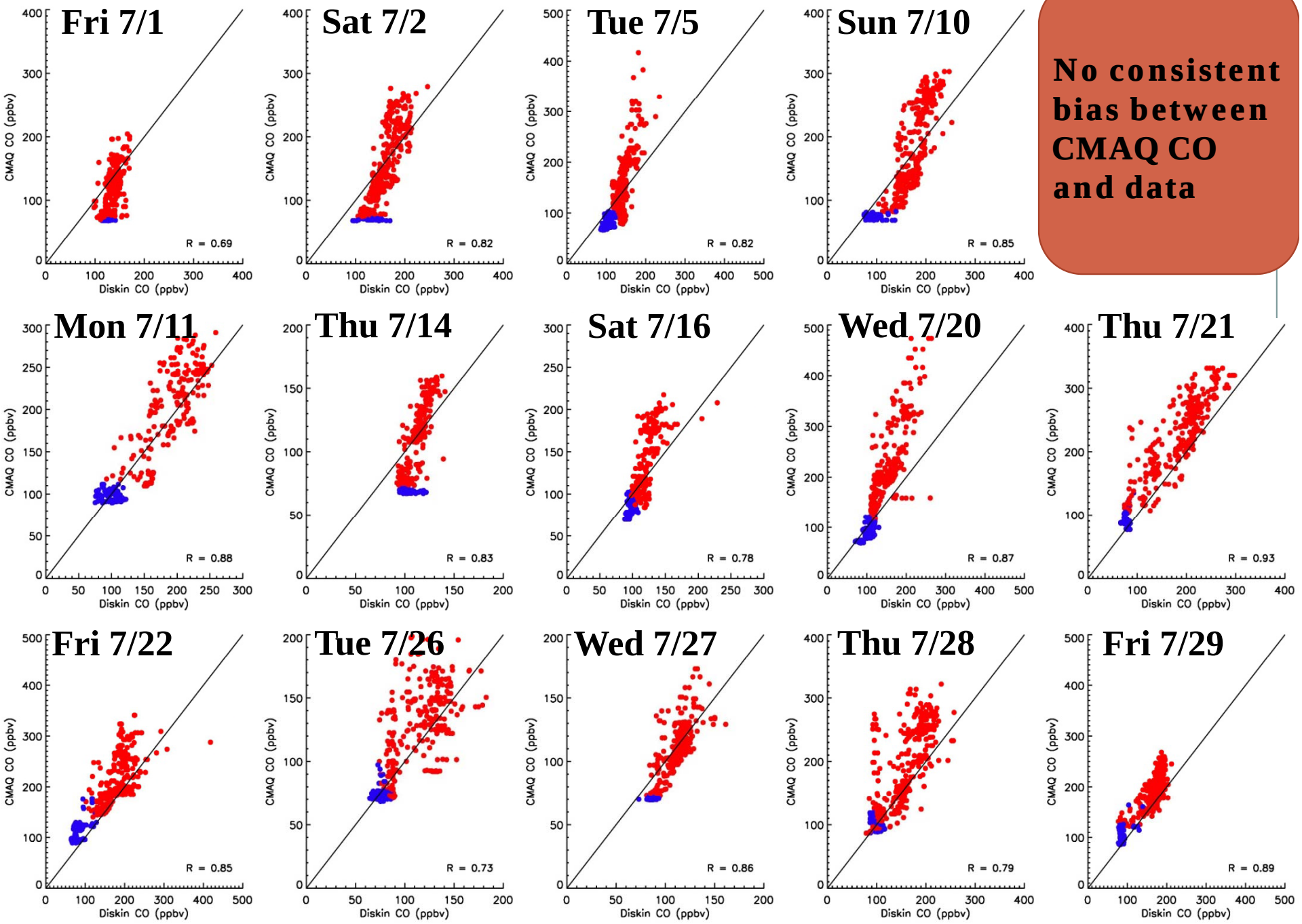




CMAQ CO Curtain with CO measurements Flight #5 Monday 7-11-2011



< 2.5 km > 2.5 km



No consistent bias between CMAQ CO and data

Summary

- Observations taken during DISCOVER-AQ were averaged to a temporal resolution of 60 sec to compare with two CMAQ forecasts
- When compared with HCHO and the NCAR NO_2 observations, the 0 hr forecast displayed lower absolute values of percent error
- The 0 hr and 24 hr forecasts performed equally with respect to the O_3 observations
- CMAQ reproduced the variability seen in the NO_2 observations, and no bias was observed
- CMAQ underestimated O_3 above 2.5 km on six out of the 14 flight days, and overestimated O_3 below 2.5 km on nine out of 14 flight days
- CMAQ underestimated HCHO below 2.5 km on ten out of 13 flight days
- CMAQ underestimated isoprene below 2.5 km and peroxynitrates at all levels on all flight days
- No clear bias was observed between the CO measurements and CMAQ

AQ Model Performance

Gregory Garner

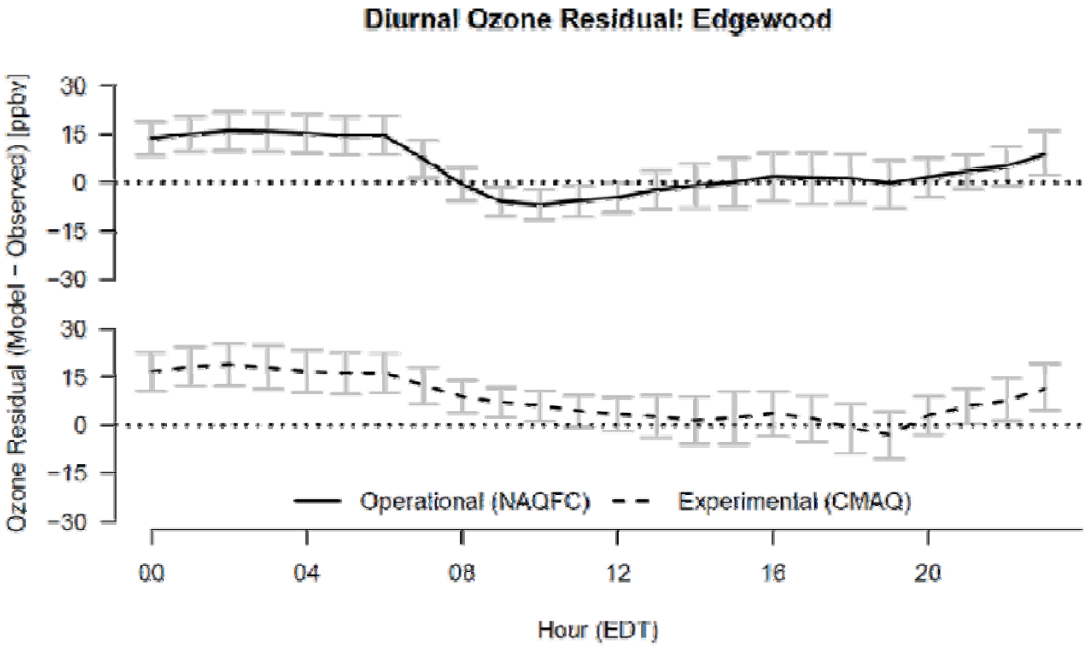
Pennsylvania State University

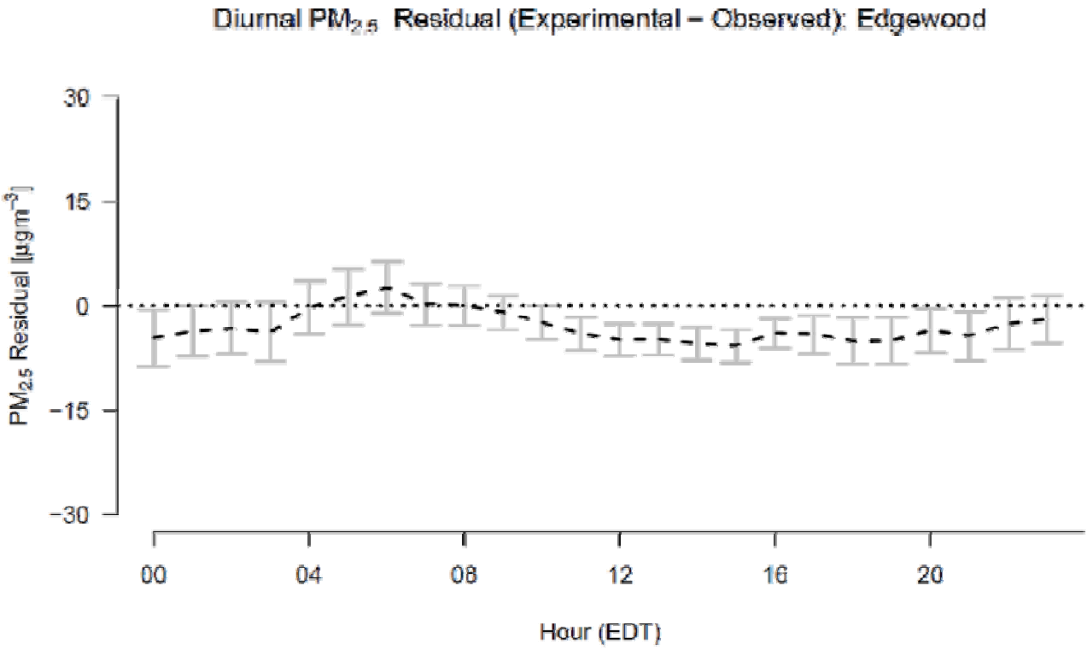
Poster Figures (Beltsville and Edgewood Focus):

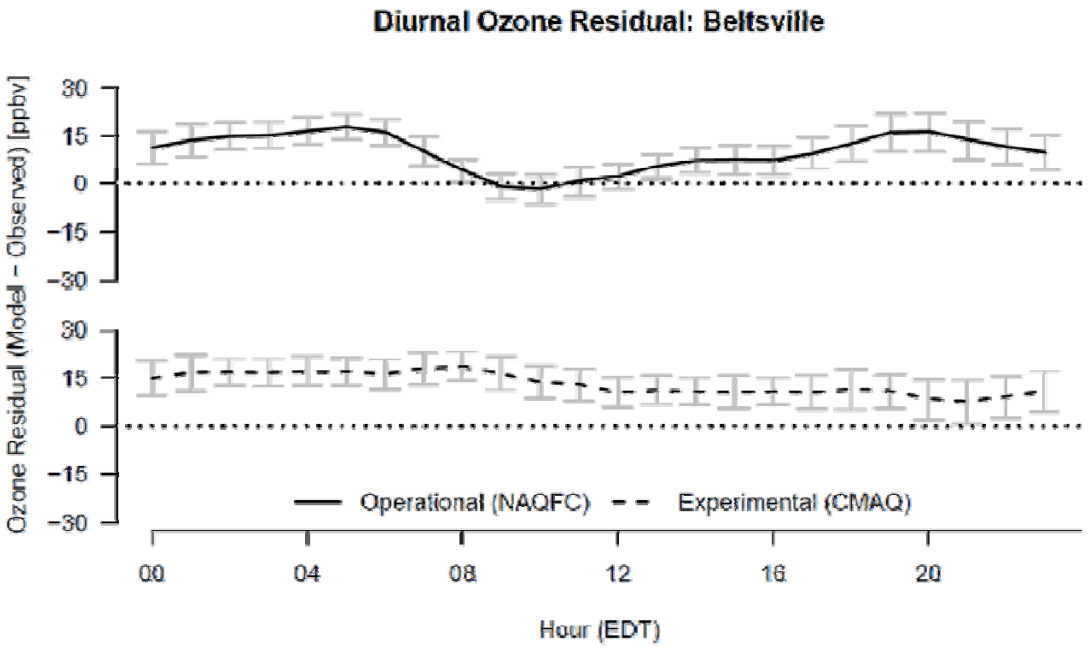
- Diurnal variability in O_3 and $PM_{2.5}$ residuals
- Exp-CMAQ profile residuals
- NAQFC-MOS evaluation
- Value of Information (all locations)

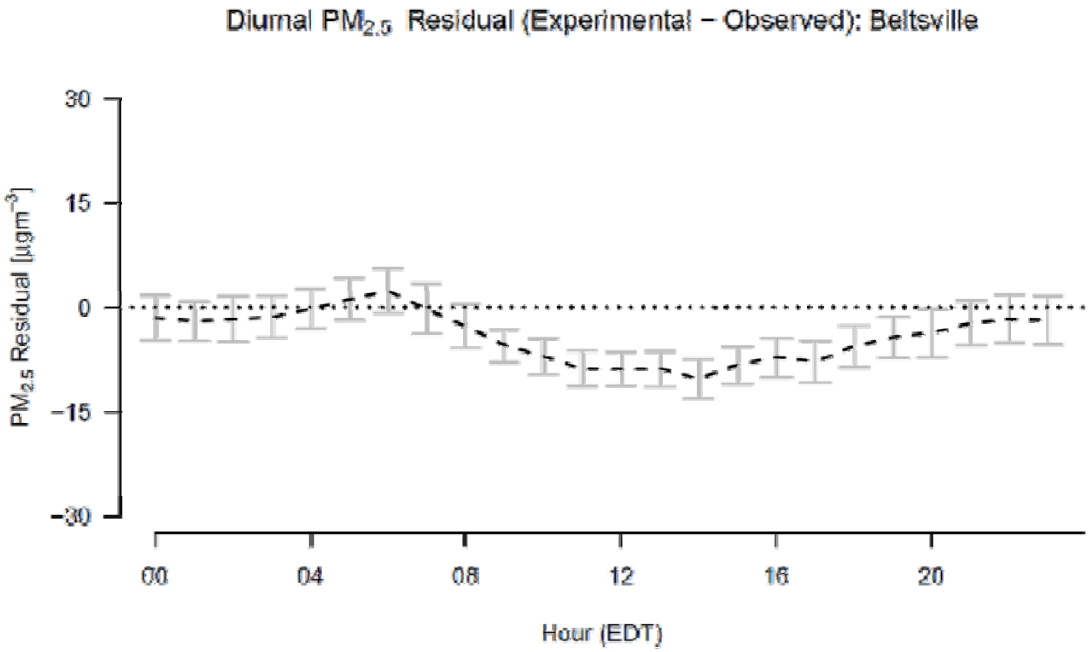
Extra Figures:

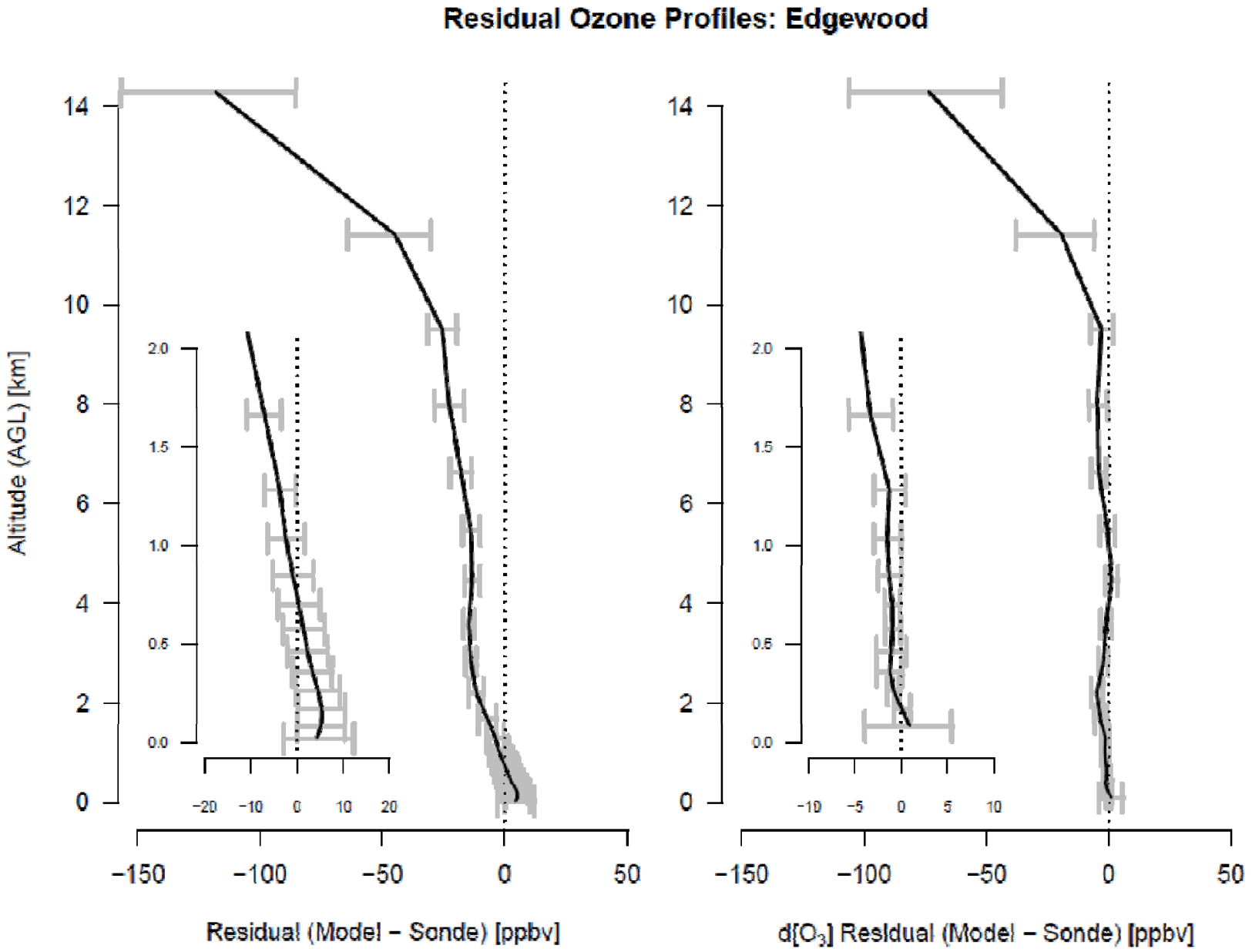
- Diurnal variability in O_3 residuals at remaining sites

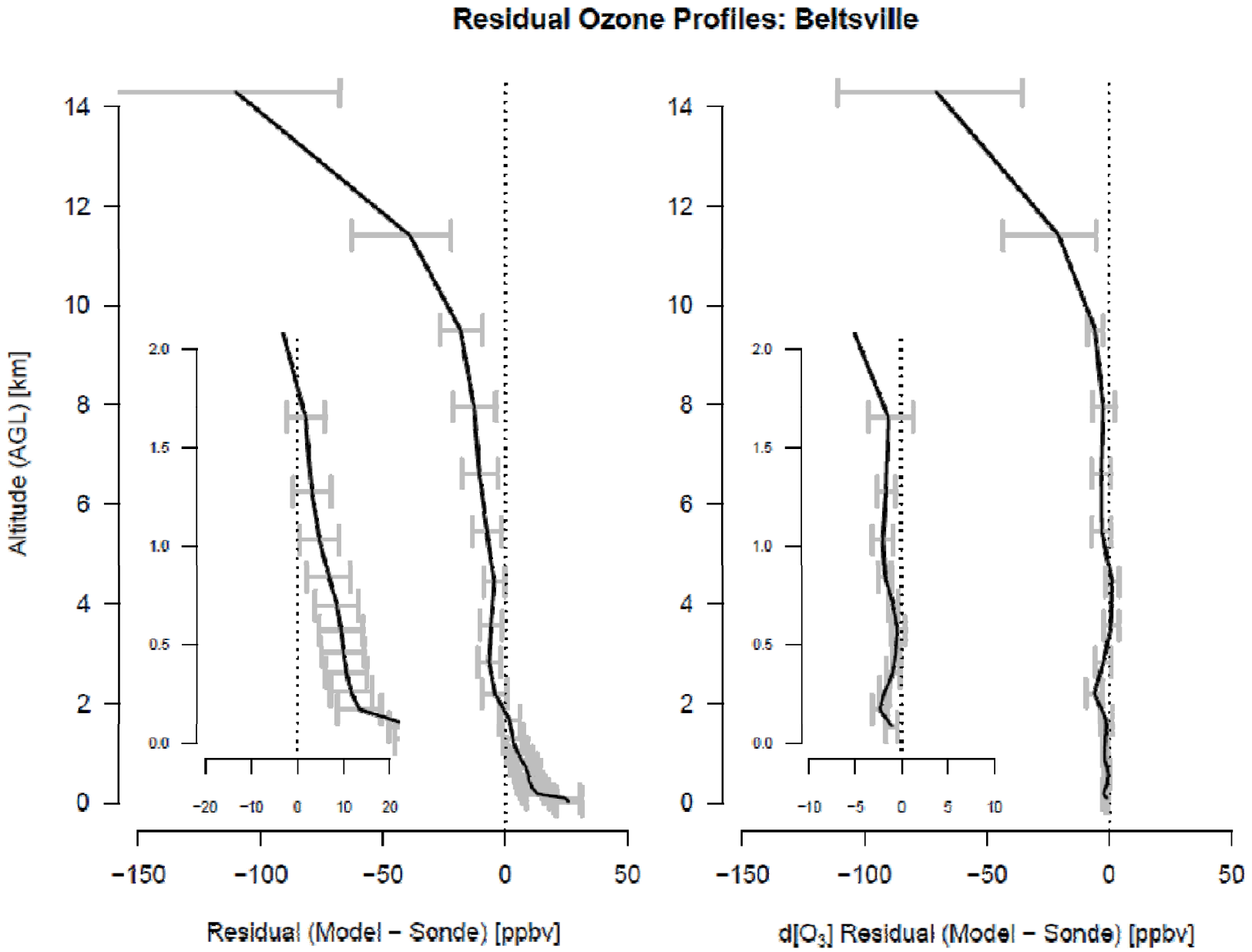

Diurnal Ozone Residual: Edgewood
Ozone Residual (Model – Observed) [ppbv]
30
15
0
−15
−30
Operational (NAQFC)
Experimental (CMAQ)
00
04
08
12
16
20
Hour (EDT)

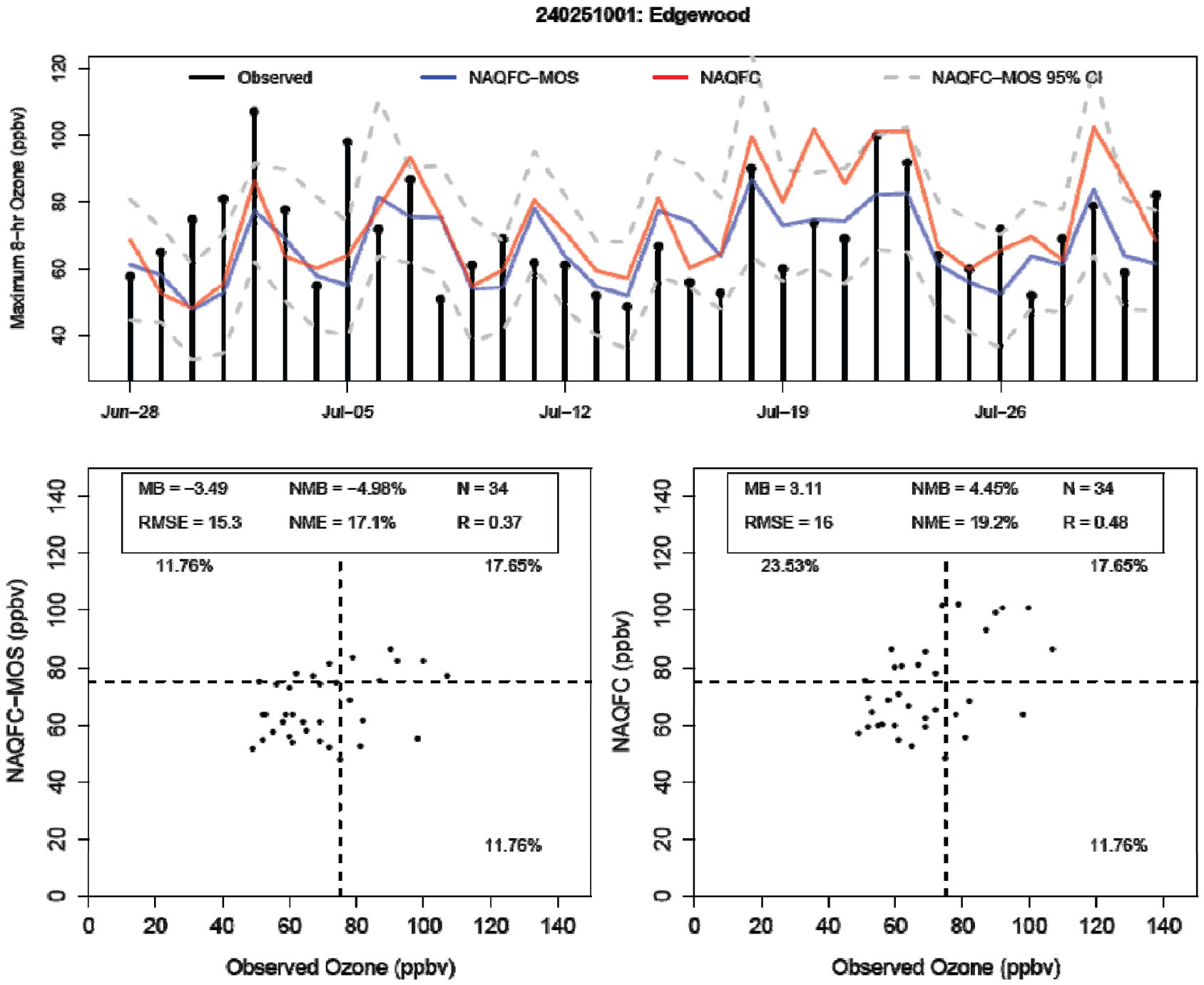

Diurnal PM2.5 Residual (Experimental – Observed): Edgewood
PM2.5 Residual [µgm−3]
30
15
0
−15
−30
00
04
08
12
16
20
Hour (EDT)

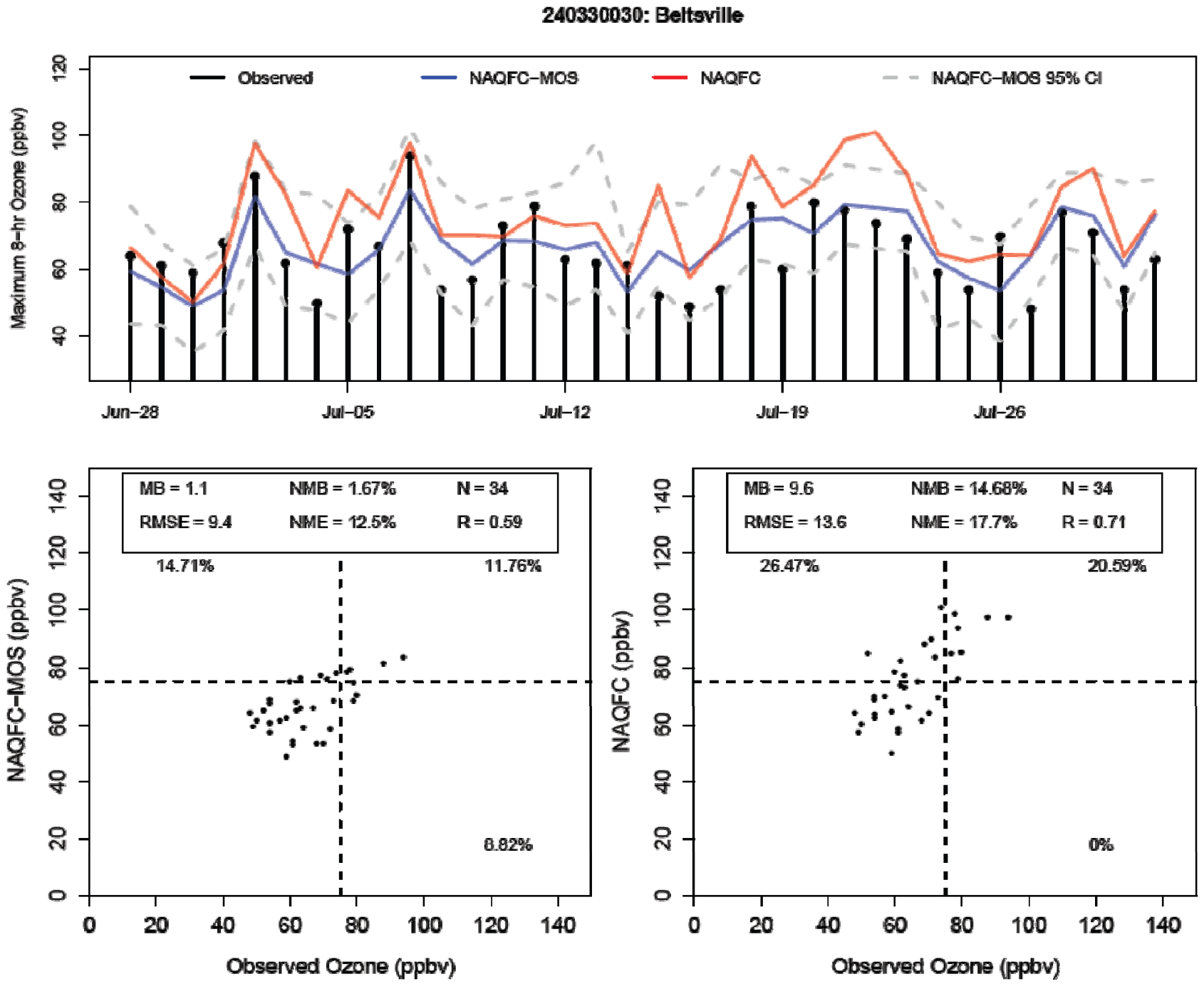

Diurnal Ozone Residual: Beltsville
Ozone Residual (Model − Observed) [ppbv]
30
15
0
−15
−30
Operational (NAQFC)
Experimental (CMAQ)
00
04
08
12
16
20
Hour (EDT)

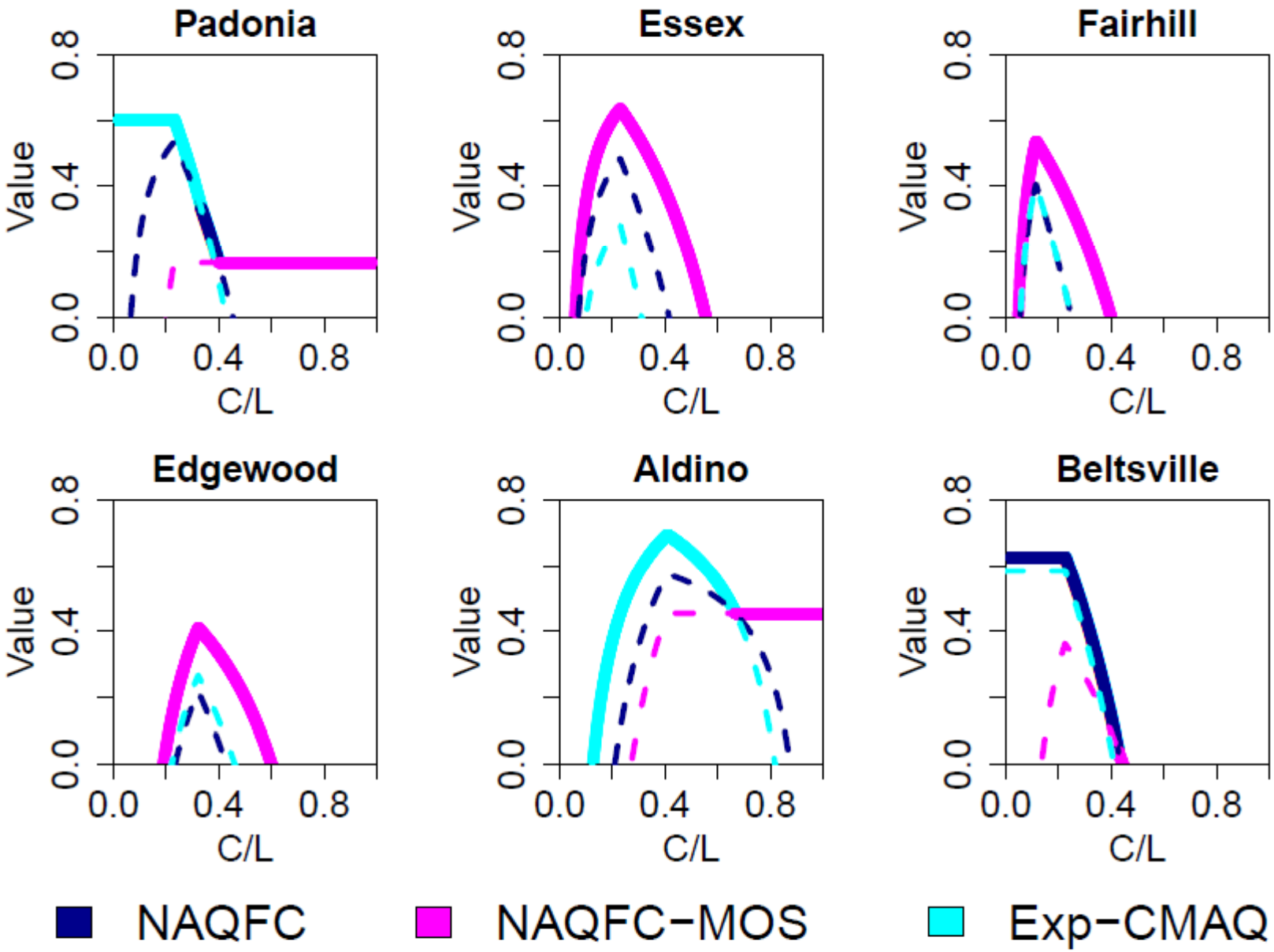

Diurnal PM2.5 Residual (Experimental − Observed): Beltsville
PM2.5 Residual [µgm−3]
30
15
0
−15
−30
00
04
08
12
16
20
Hour (EDT)


Residual Ozone Profiles: Edgewood
Altitude (AGL) [km]
Residual (Model – Sonde) [ppbv]
d[O3] Residual (Model – Sonde) [ppbv]

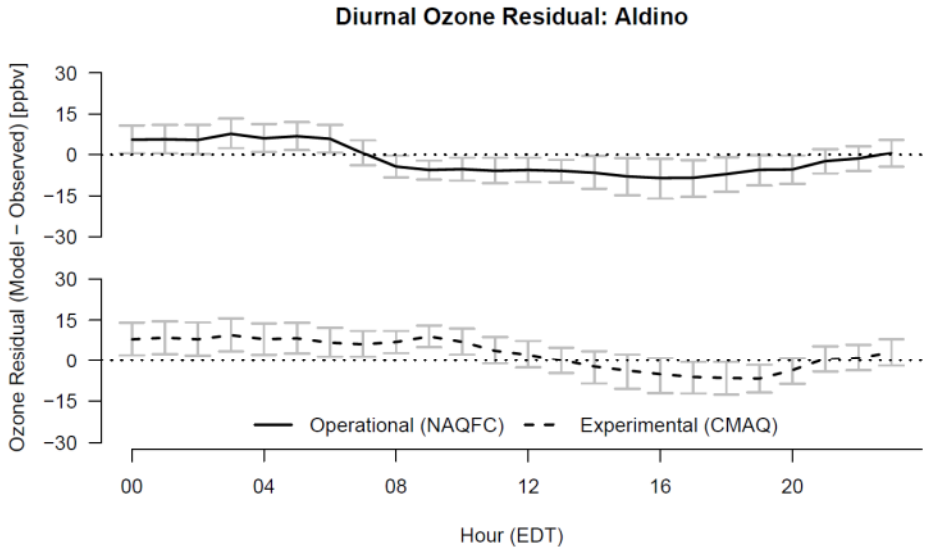

Residual Ozone Profiles: Beltsville
Altitude (AGL) [km]
Residual (Model − Sonde) [ppbv]
d[O3] Residual (Model − Sonde) [ppbv]

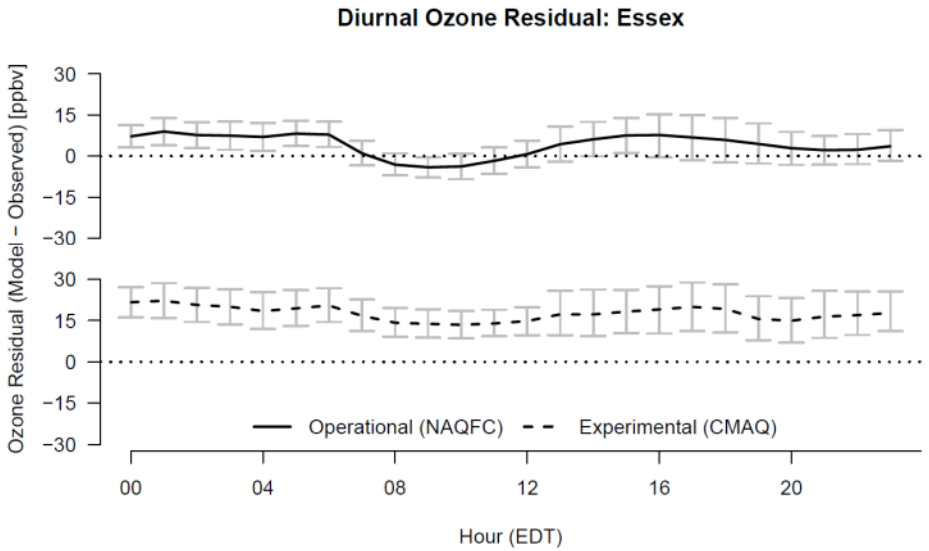

240251001: Edgewood
Observed
NAQFC–MOS
NAQFC
NAQFC–MOS 95% CI
Maximum 8–hr Ozone (ppbv)
Jun–28
Jul–05
Jul–12
Jul–19
Jul–26
MB = –3.49
NMB = –4.98%
N = 34
RMSE = 15.3
NME = 17.1%
R = 0.37
11.76%
17.65%
11.76%
NAQFC–MOS (ppbv)
Observed Ozone (ppbv)
MB = 3.11
NMB = 4.45%
N = 34
RMSE = 16
NME = 19.2%
R = 0.48
23.53%
17.65%
11.76%
NAQFC (ppbv)
Observed Ozone (ppbv)

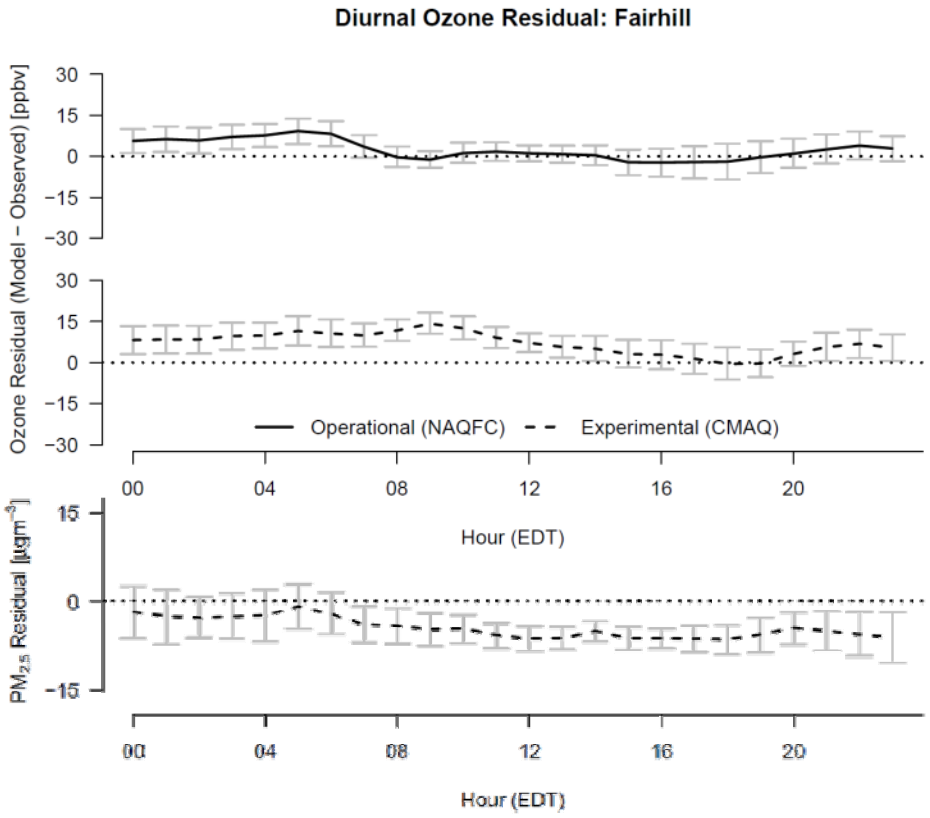

240330030: Beltsville
Observed
NAQFC-MOS
NAQFC
NAQFC-MOS 95% CI
Maximum 8-hr Ozone (ppbv)
Jun-28
Jul-05
Jul-12
Jul-19
Jul-26
MB = 1.1
NMB = 1.67%
N = 34
RMSE = 9.4
NME = 12.5%
R = 0.59
14.71%
11.76%
6.82%
NAQFC-MOS (ppbv)
Observed Ozone (ppbv)
MB = 9.6
NMB = 14.68%
N = 34
RMSE = 13.6
NME = 17.7%
R = 0.71
26.47%
20.59%
0%
NAQFC (ppbv)
Observed Ozone (ppbv)

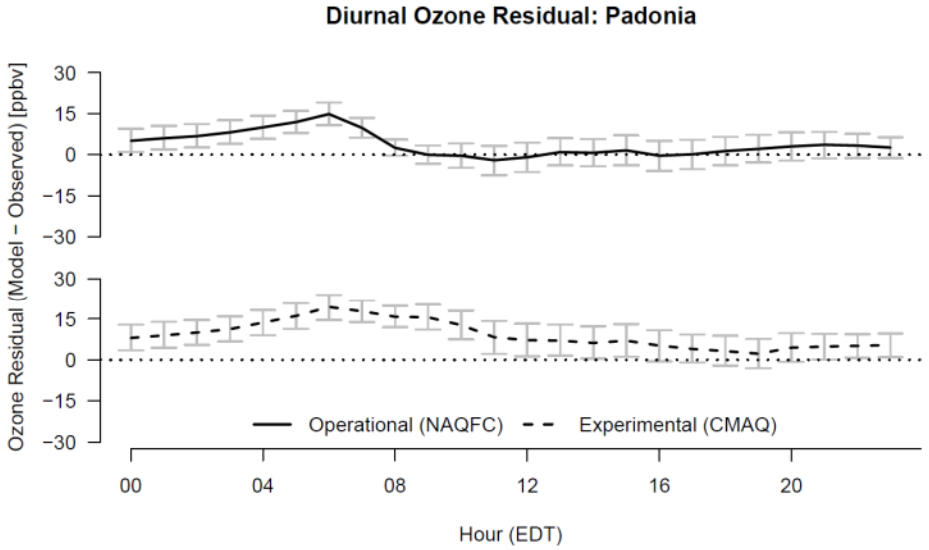

Padonia
Essex
Fairhill
Edgewood
Aldino
Beltsville
Value
C/L
0.0
0.4
0.8
NAQFC
NAQFC−MOS
Exp−CMAQ

Extra Figures


Diurnal Ozone Residual: Aldino
Ozone Residual (Model – Observed) [ppbv]
30
15
0
−15
−30
Operational (NAQFC)
Experimental (CMAQ)
00
04
08
12
16
20
Hour (EDT)


Diurnal Ozone Residual: Essex
Ozone Residual (Model – Observed) [ppbv]
30
15
0
−15
−30
Operational (NAQFC)
Experimental (CMAQ)
00
04
08
12
16
20
Hour (EDT)


Diurnal Ozone Residual: Fairhill
Ozone Residual (Model – Observed) [ppbv]
30
15
0
−15
−30
Operational (NAQFC)
Experimental (CMAQ)
00
04
08
12
16
20
Hour (EDT)
PM2.5 Residual [μgm−3]
15
0
−15
Hour (EDT)


Diurnal Ozone Residual: Padonia
Ozone Residual (Model – Observed) [ppbv]
30
15
0
−15
−30
Operational (NAQFC)
Experimental (CMAQ)
00
04
08
12
16
20
Hour (EDT)

Horizontal and vertical distribution of air pollution over Maryland and the Chesapeake Bay

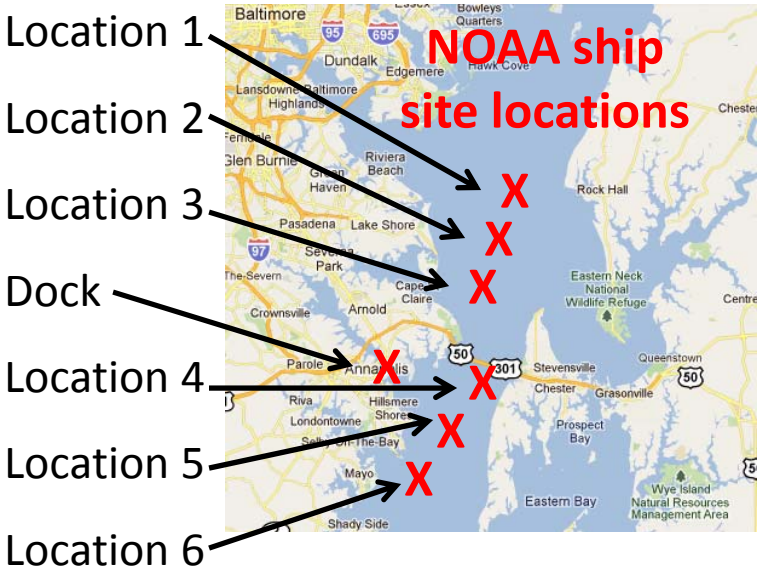
DISCOVER-AQ Science Team Meeting

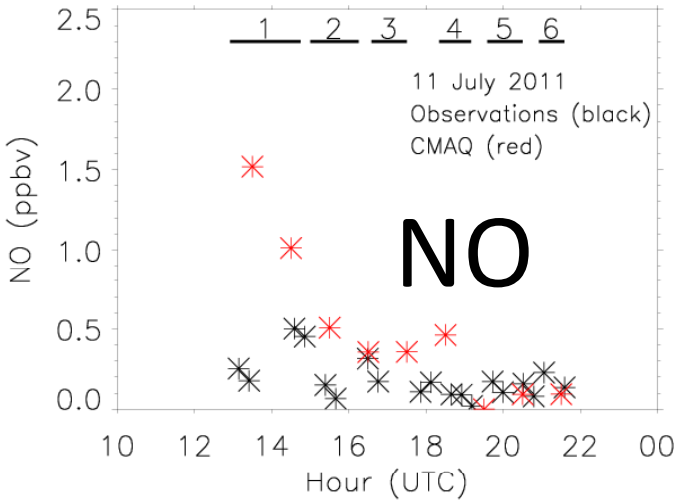
14-16 February 2012

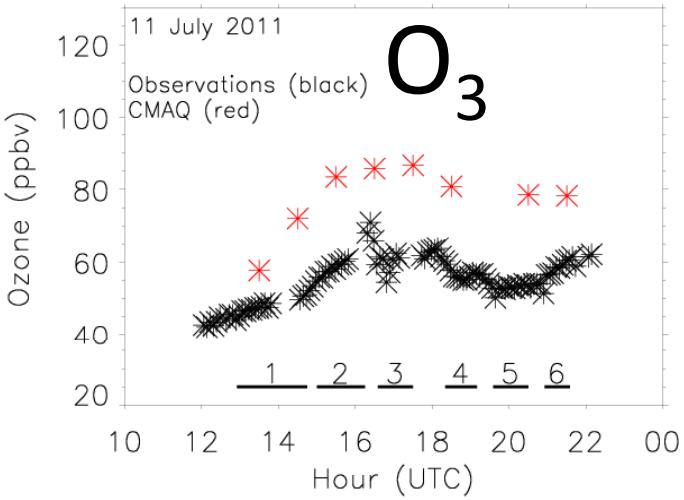
Chris Loughner

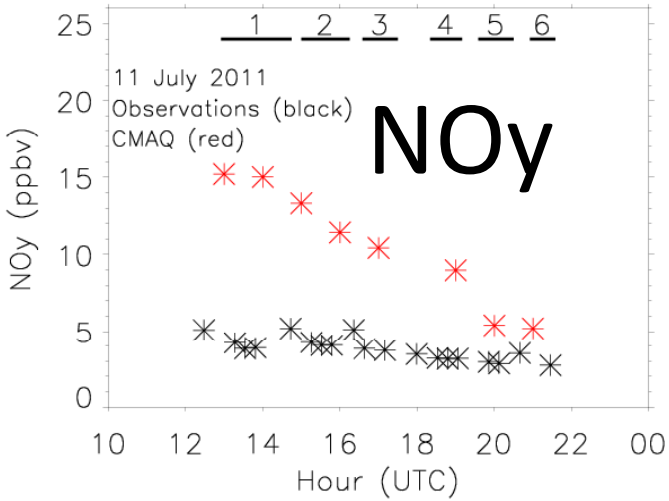
Daniel Goldberg, Maria Tzortziou, Alexander Cede, Nader Abuhassan, Christian Retscher, Andrew J. Weinheimer, Richard A. Ferrare, Chris A. Hostetler, Pius Lee, Kenneth E. Pickering, James H. Crawford, Antonio Mannino, Jay R. Herman, David J. Knapp, Deedee Montzka, Tamba L. Marufu, Russell R. Dickerson, Johnathan W. Hair, Raymond Rogers, and Michael D. Obland

July 11 Chesapeake Bay surface concentrations



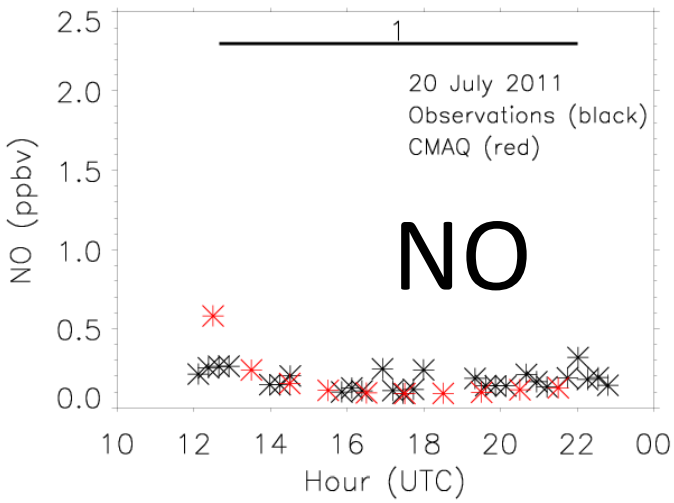


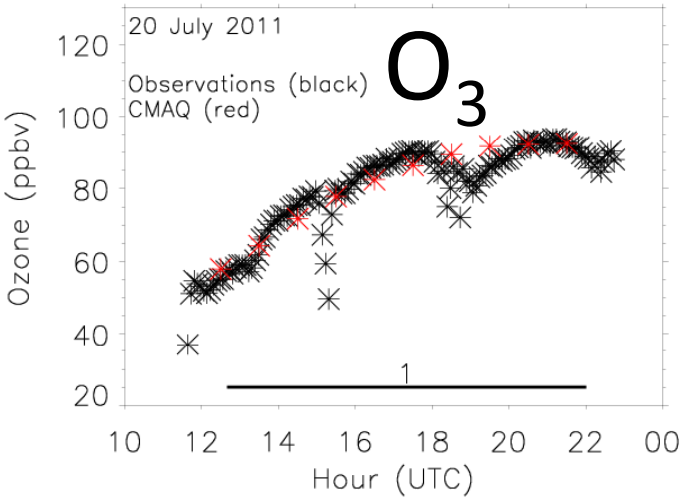


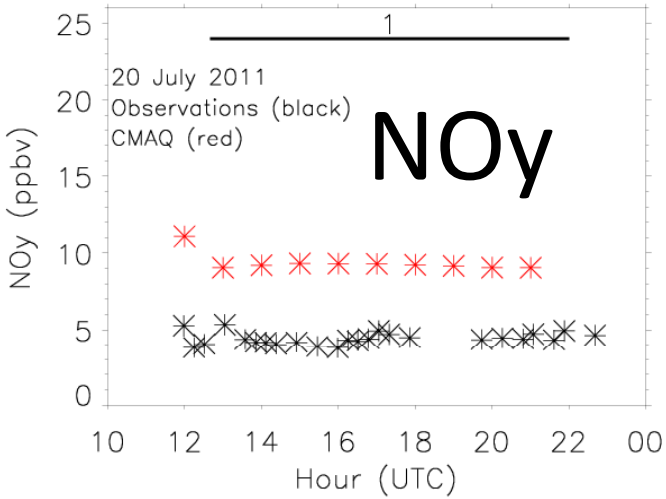


CMAQ has high O_3, NO, and NOy biases compared with observations.

July 20 Chesapeake Bay surface concentrations

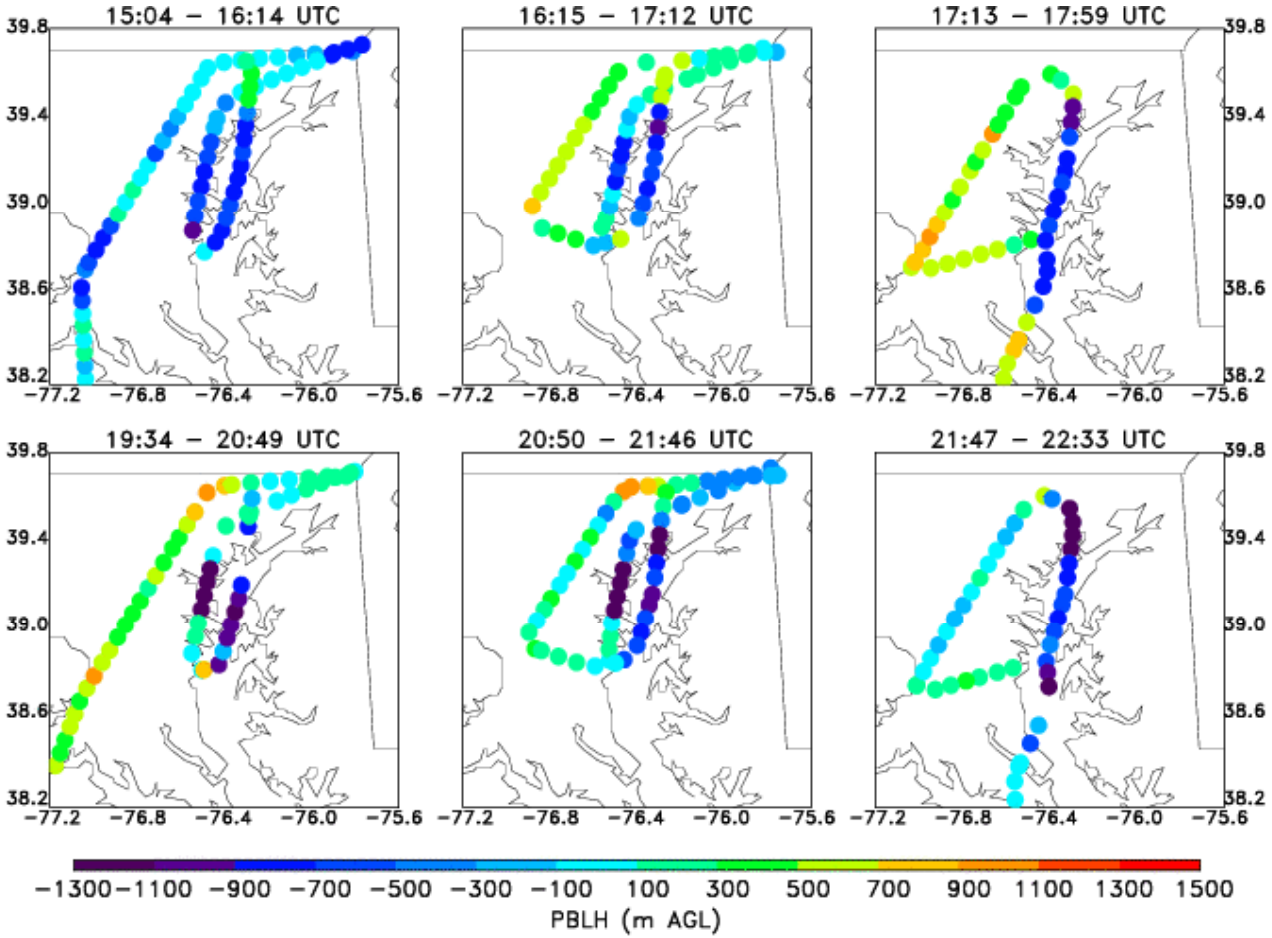






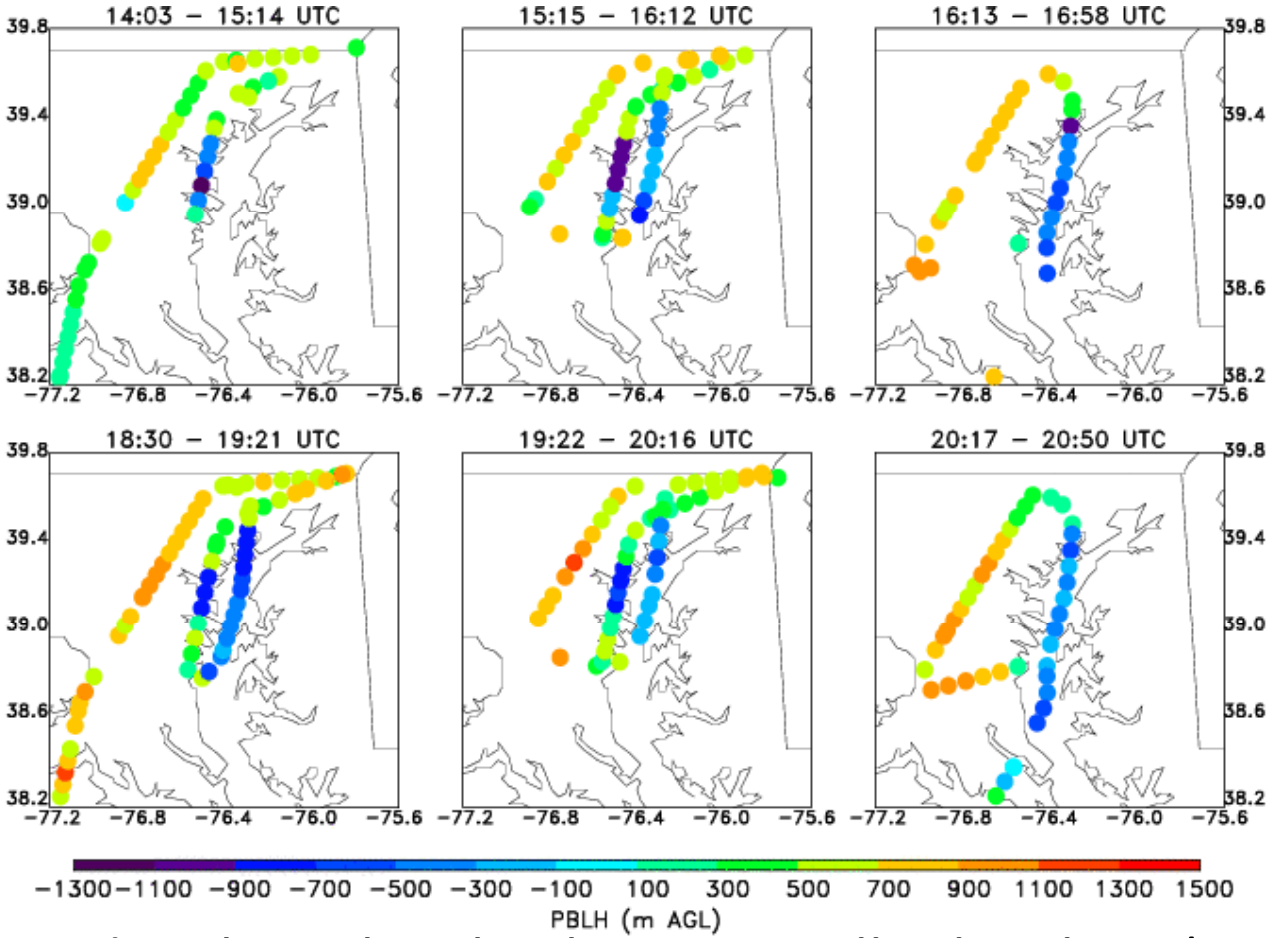
Better agreement between observed and simulated O_3 and NO than on July 11. However, CMAQ's high NOy bias persists throughout the field campaign.

July 11 boundary layer heights: WRF-NMM minus HSRL observed



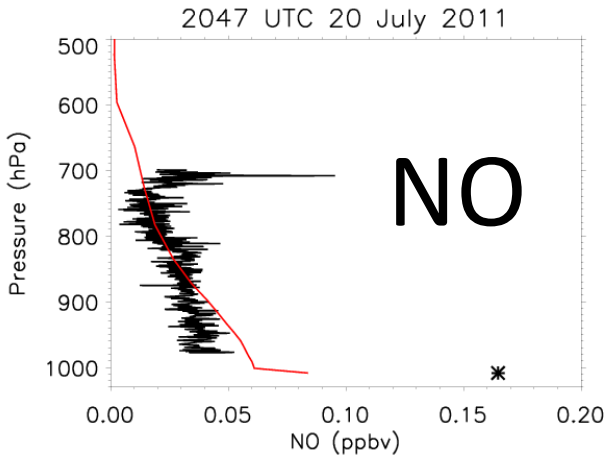
Model boundary layer heights have a large low bias (500-1,300m) over the Chesapeake Bay, which contributes to CMAQ's high surface O_3, NO, and NOy biases.

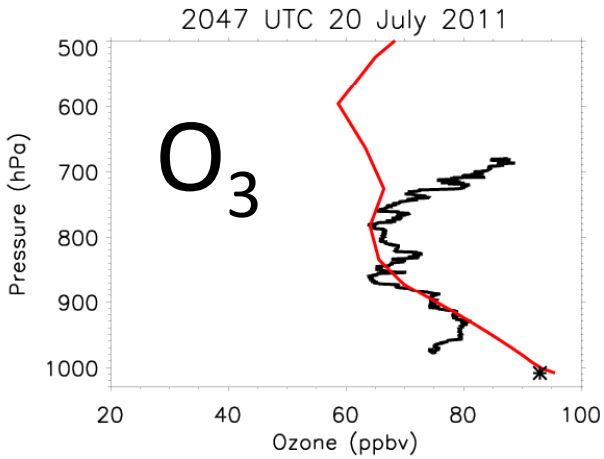
July 20 boundary layer heights: WRF-NMM minus HSRL observed

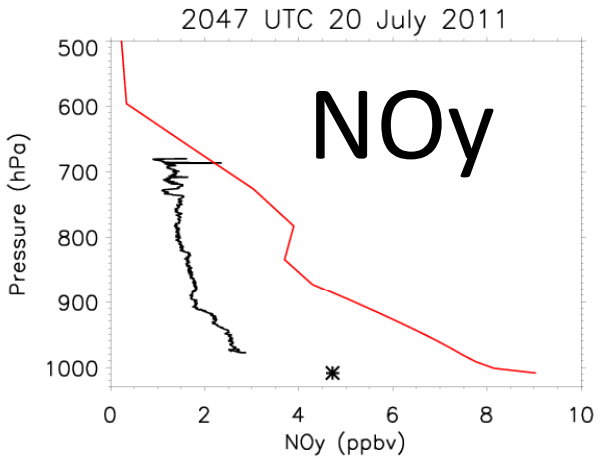


Model boundary layer heights have a smaller low bias (100-500m) than on July 11 over the Chesapeake Bay, which coincides with better agreement between observed and simulated surface O_3 and NO concentrations.

O_3, NO, and NOy observed (P3B profiles and NOAA ship surface concentrations; black) and CMAQ simulated (red) profiles over the Chesapeake Bay at 2047 UTC (4:47 PM EDT) 20 July 2011

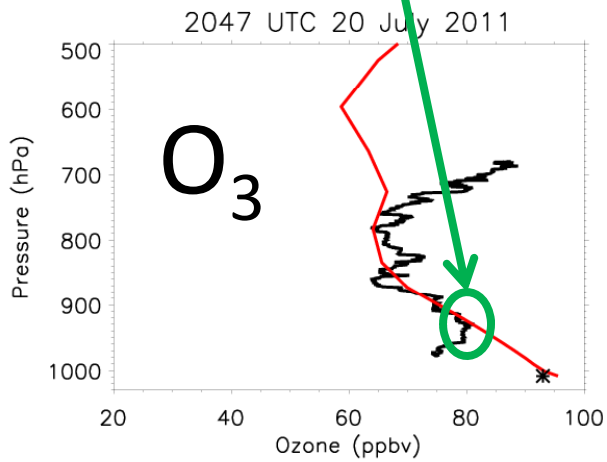


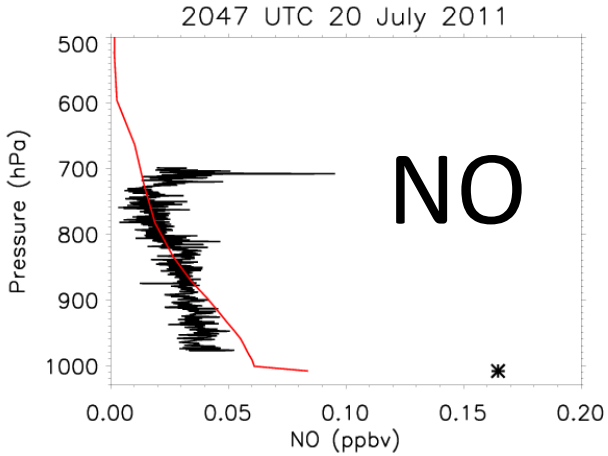


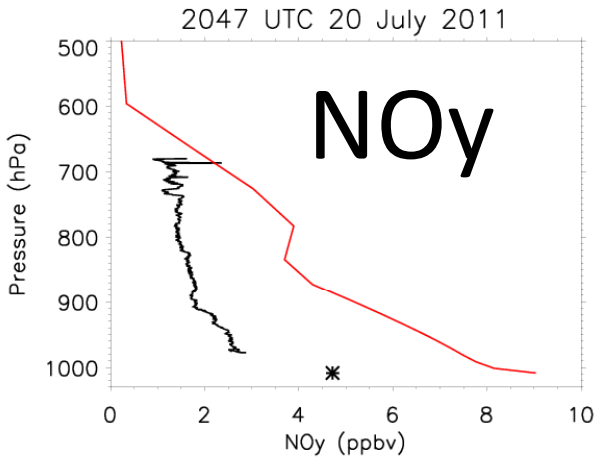


O_3, NO, and NOy observed (P3B profiles and NOAA ship surface concentrations; black) and CMAQ simulated (red) profiles over the Chesapeake Bay at 2047 UTC (4:47 PM EDT) 20 July 2011

Elevated ozone aloft suggests a lifting mechanism is transporting pollution aloft - possibly due to a weak bay breeze



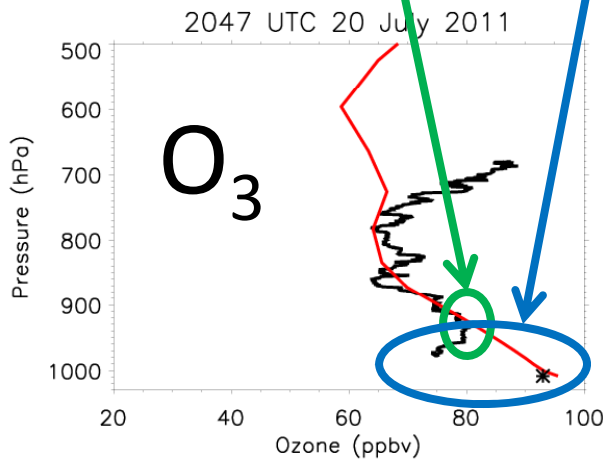


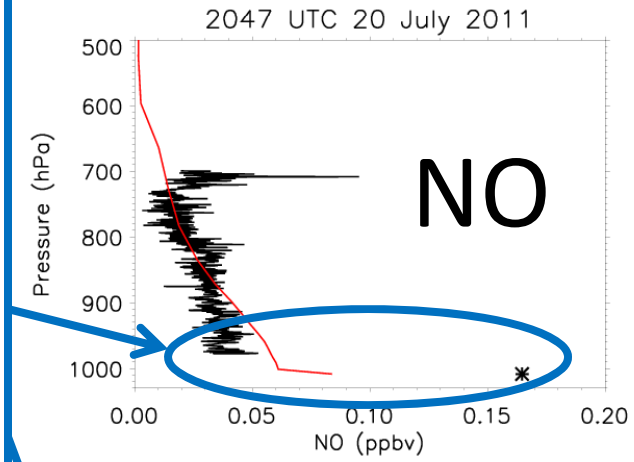


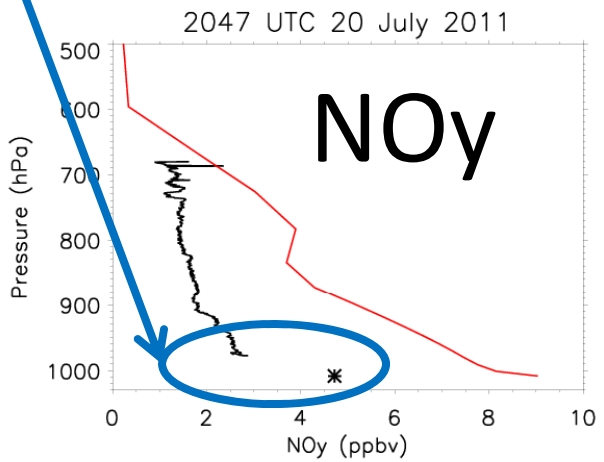
O_3, NO, and NOy observed (P3B profiles and NOAA ship surface concentrations; black) and CMAQ simulated (red) profiles over the Chesapeake Bay at 2047 UTC (4:47 PM EDT) 20 July 2011

Elevated ozone aloft suggests a lifting mechanism is transporting pollution aloft - possibly due to a weak bay breeze

Large vertical gradient observed near surface not captured by CMAQ suggesting model vertical mixing is too fast in stable marine boundary layer





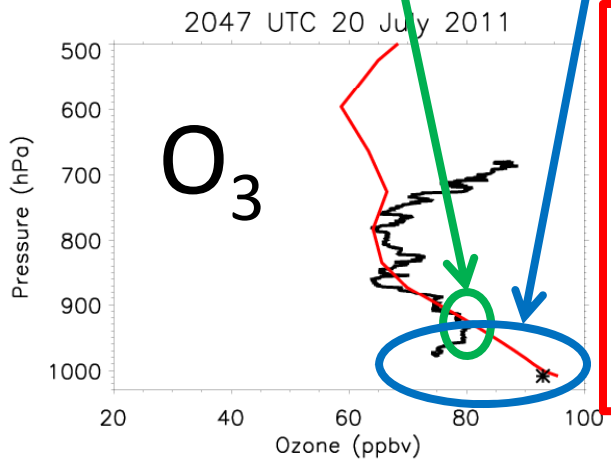


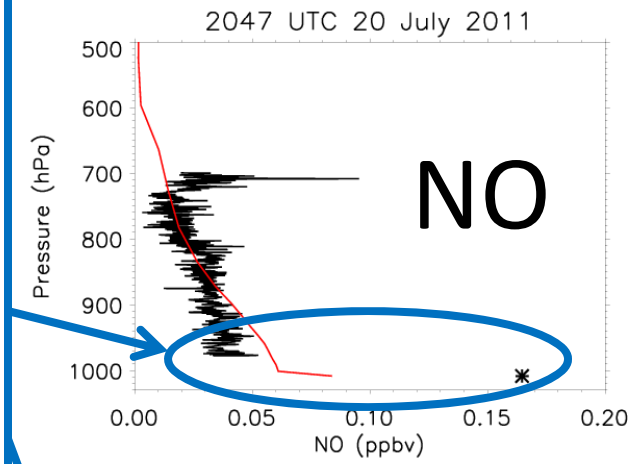
O_3, NO, and NOy observed (P3B profiles and NOAA ship surface concentrations; black) and CMAQ simulated (red) profiles over the Chesapeake Bay at 2047 UTC (4:47 PM EDT) 20 July 2011

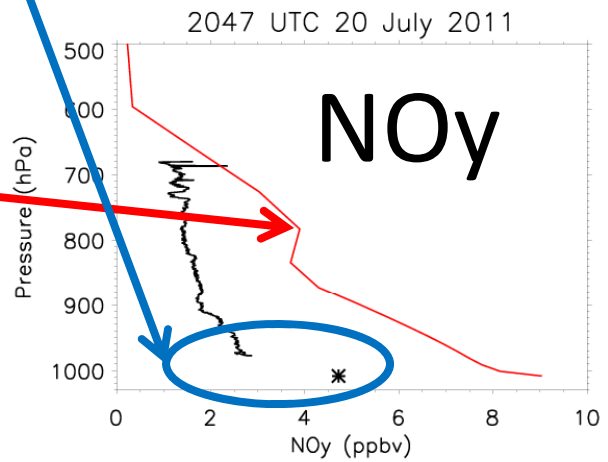
Elevated ozone aloft suggests a lifting mechanism is transporting pollution aloft - possibly due to a weak bay breeze

Large vertical gradient observed near surface not captured by CMAQ suggesting model vertical mixing is too fast in stable marine boundary layer

High NOy bias throughout the observed column from the surface to 700 hPa







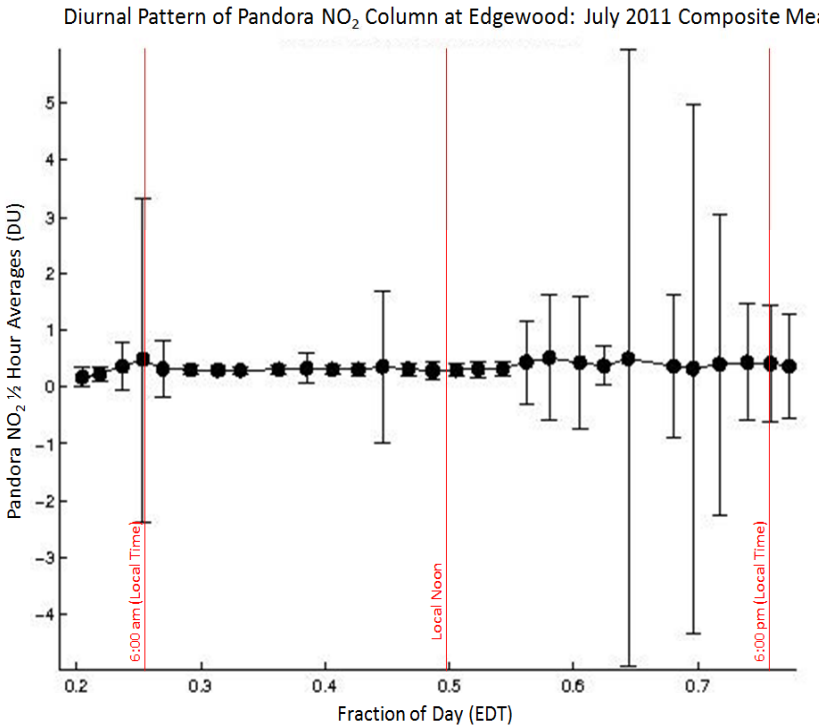
Summary

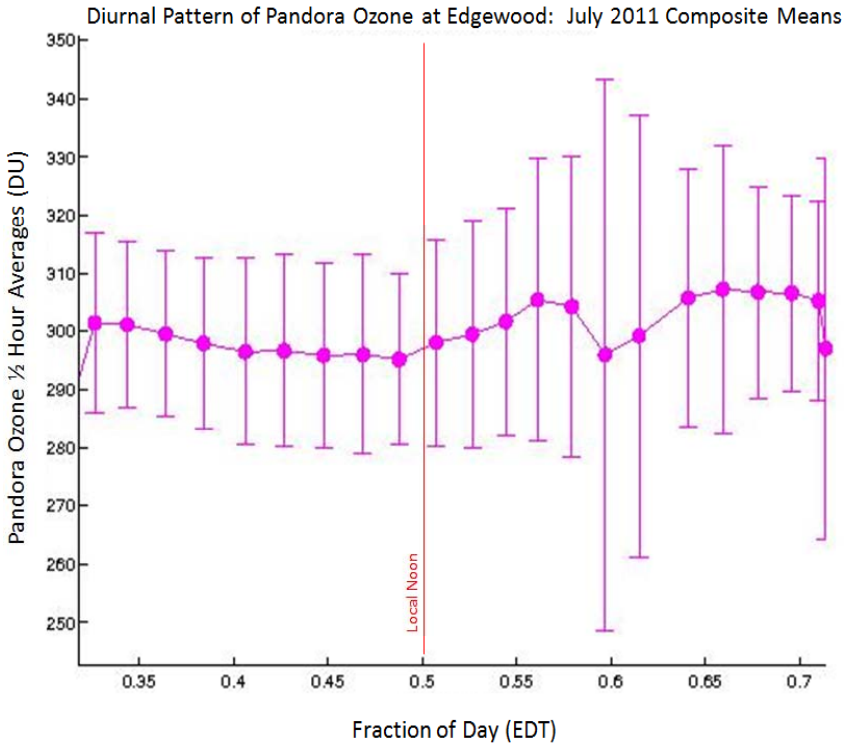
- CMAQ-simulated surface O_3, NO, and NOy have high biases when model boundary layer heights have large low biases.
- When model boundary layer heights improve, simulated surface O_3 and NO come into agreement with observations.
- Profiles over the Chesapeake Bay show that the model does not capture the shape of observed profiles of O_3, NO, and NOy.
  - The profiles show elevated O_3 aloft, which may be due to a weak bay breeze transporting pollution aloft.
  - The observed profiles also show a larger vertical gradient near the surface than CMAQ, which suggests there is too much vertical mixing in the stable marine boundary layer.
- CMAQ-simulated NOy has a large high bias compared with observations throughout the observed profile.

Comparison of Satellite and Ground-based Measurements of Total Column Ozone and Nitrogen Dioxide from Edgewood, MD in July 2011

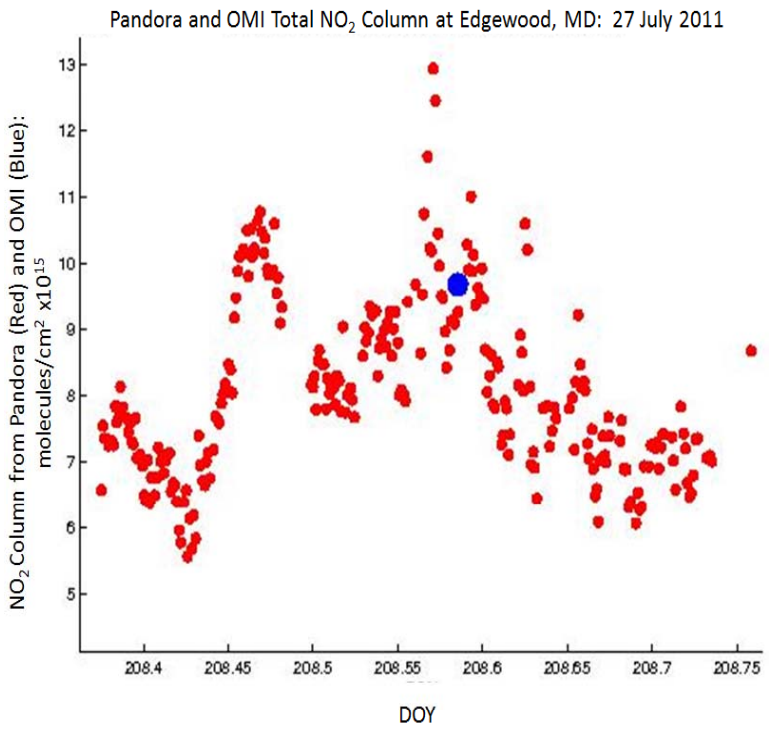
Andra J. Reed[1], A.M. Thompson[1],
D.K. Martins[1], J. R. Herman[2]

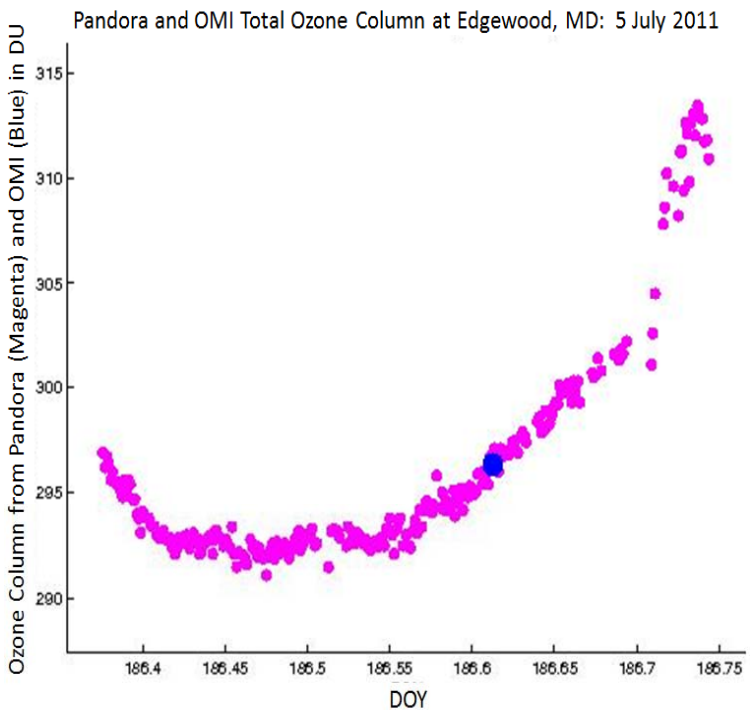
[1]Department of Meteorology, Penn State University, State College PA (axr5145@psu.edu)
[2]JCET, University of Maryland Baltimore County, Greenbelt, MD



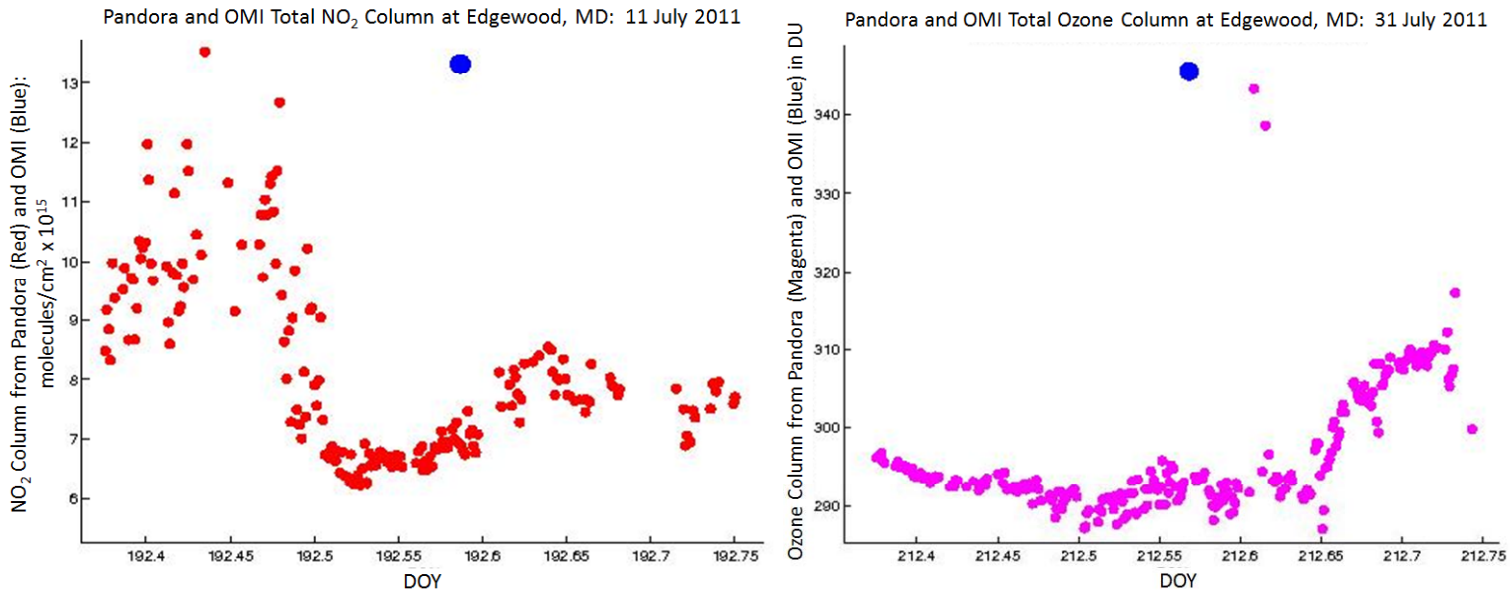


Diurnal Patterns of Pandora total column NO_2 and Pandora total column Ozone measured at Edgewood, MD during July 2011. As expected due to rush-hour traffic patterns, we see a bimodal pattern in NO_2 levels, with peaks in the morning and afternoon. Also, we see the expected increase of Ozone levels throughout the afternoon as photochemistry becomes more effective.

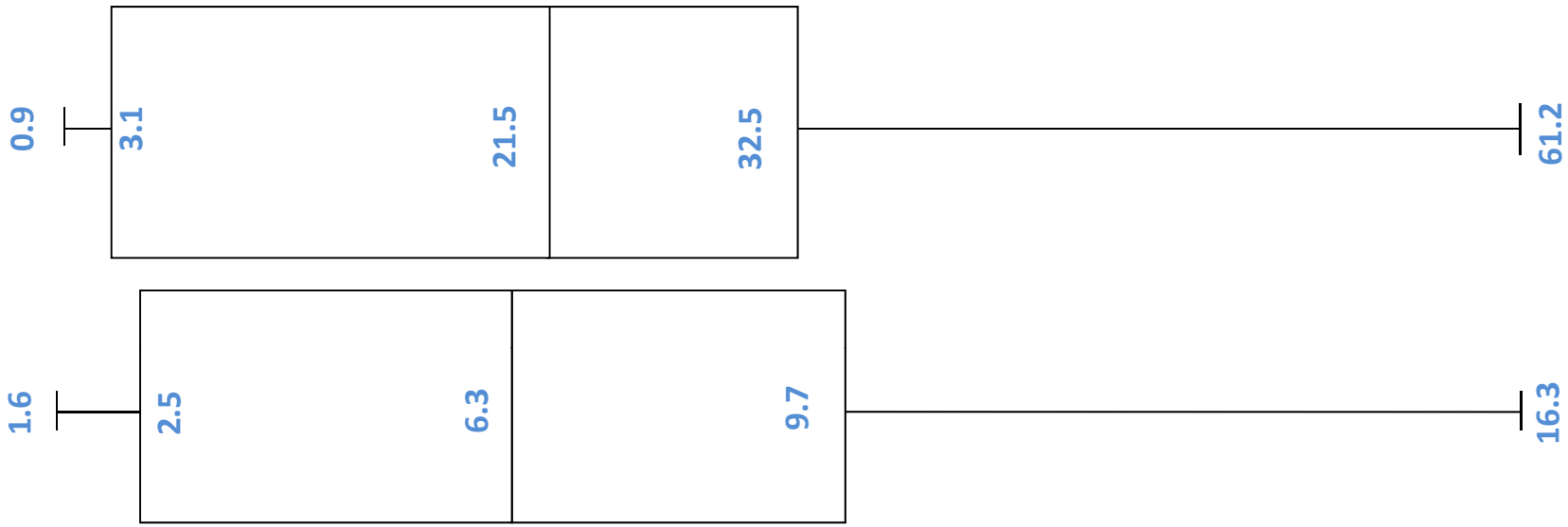




Plots of Pandora and OMI total column NO_2 from 27 July 2011, and Pandora and OMI total column ozone from 5 July 2011. These two days show the best agreement between Pandora and OMI total column amounts. The percent difference between Pandora and OMI total column NO_2 on 27 July was 0.8939%; the percent difference between Pandora and OMI total column ozone on 5 July was 1.6424%



Plots of Pandora and OMI total column NO_2 from 11 July 2011, and Pandora and OMI total column ozone from 31 July 2011. These two days show the worst agreement between Pandora and OMI total column amounts. The percent difference between Pandora and OMI total column NO_2 on 11 July was 61.2345%; the percent difference between Pandora and OMI total column ozone on 31 July was 16.2804%



Box and whiskers plots of the percent difference between Pandora and OMI a) NO_2 column measurements and b) ozone column measurements.

Future Work

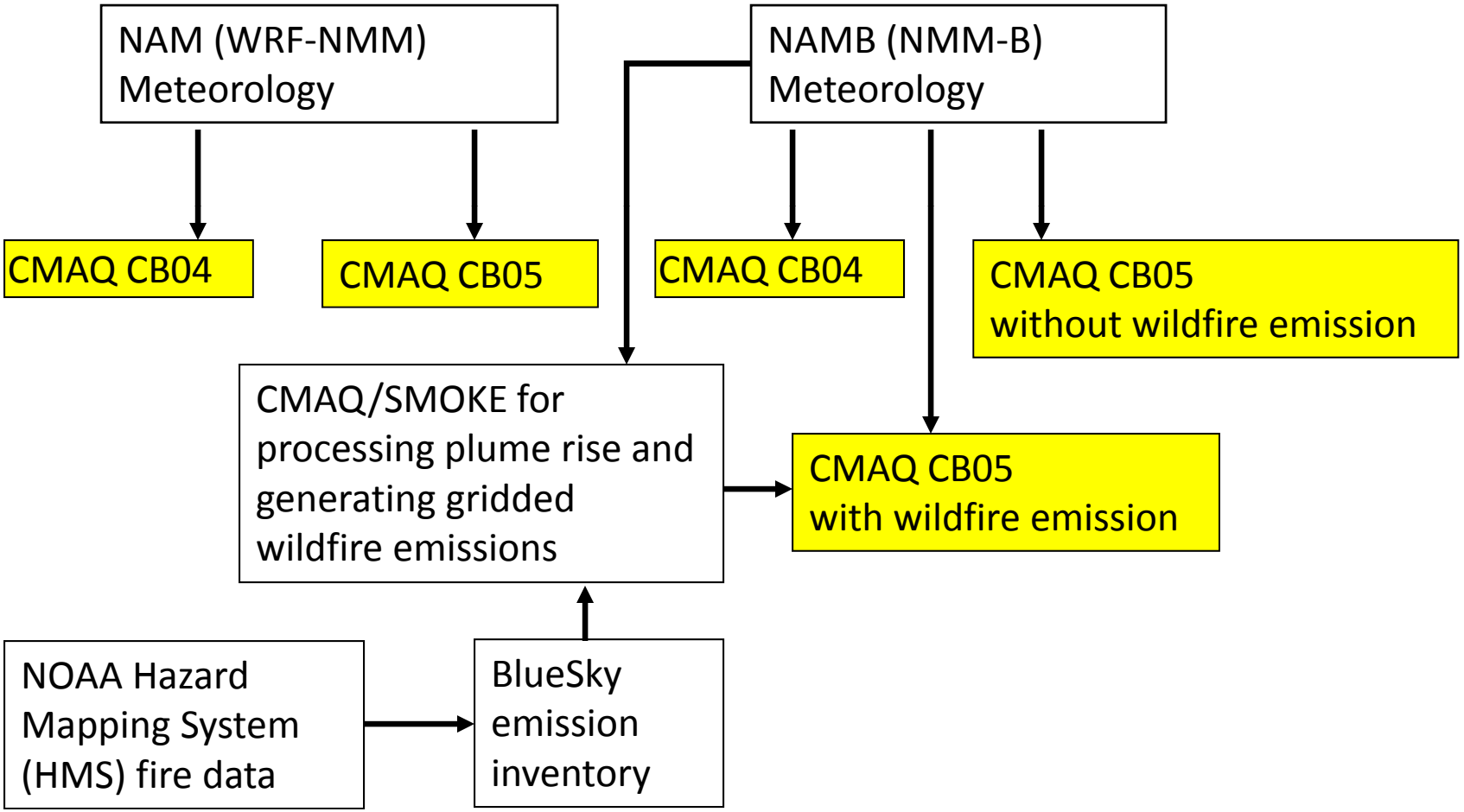
Further analysis of data collected at Edgewood, MD during July 2011 is required to determine why some days during this time period show poor agreement between Pandora and OMI total column NO_2 and ozone amounts. This work will include a study of differences in time and space as comparisons are made, as well as an in-depth analysis of variables such as relative humidity and aerosol amounts that may impact the amount of light received by the Pandora spectrometer.

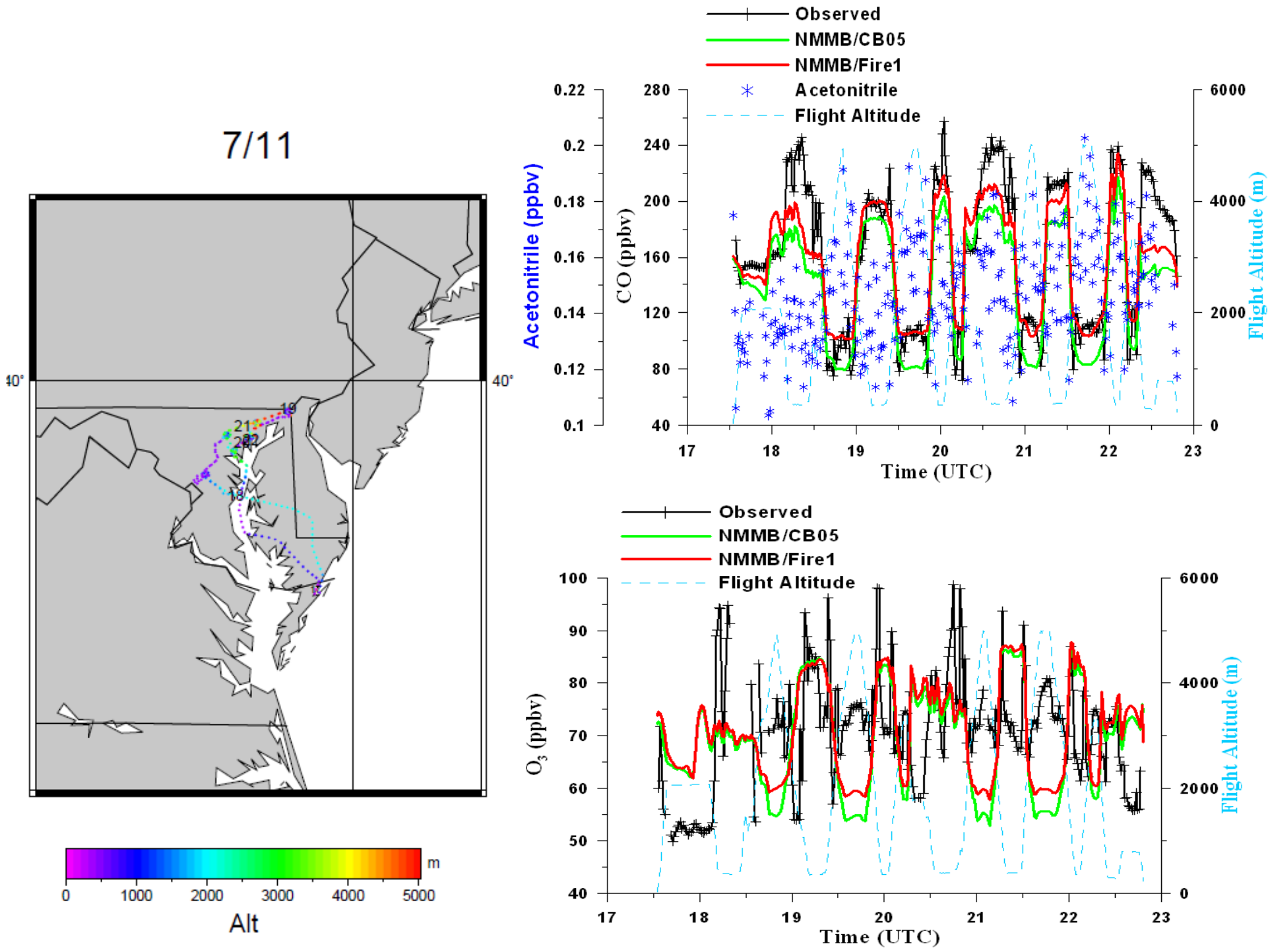
Wildfire Events Identified by the P-3B Measurements and Models During Discover-AQ period

At least 4:

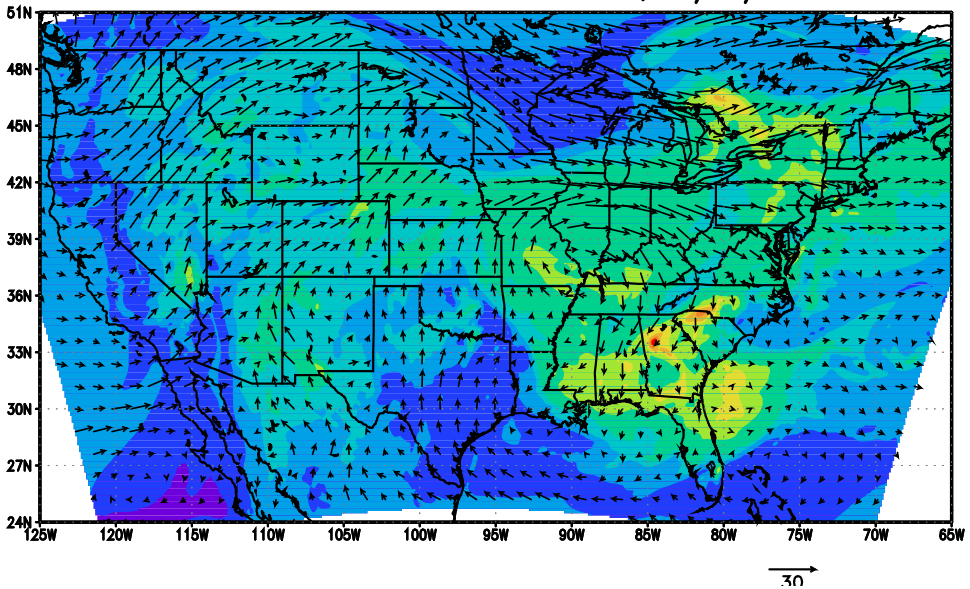
07/01, 07/11, 07/14 and 07/27

Operational and Developmental 12km NAQFC Systems (July 2011)

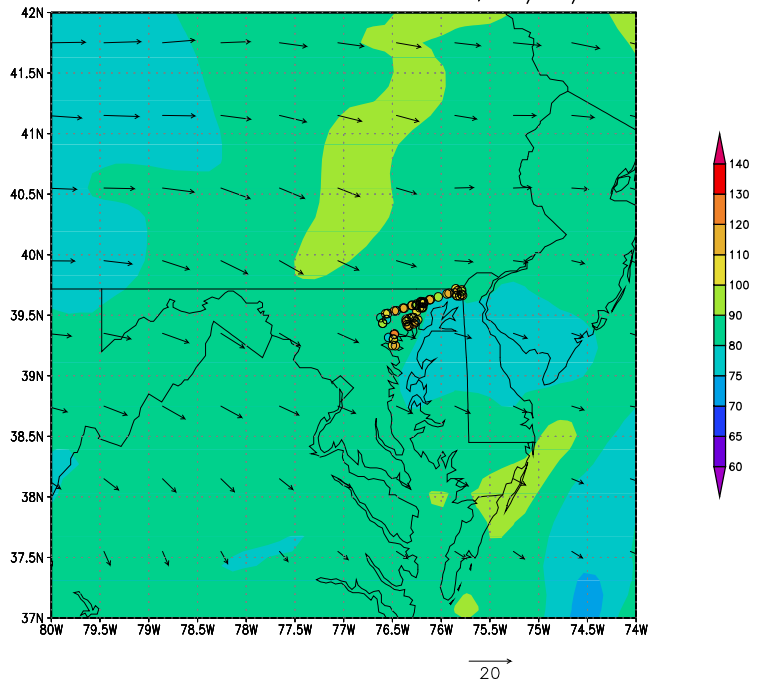



7/11
40°
40°
19
21
22
18
0
1000
2000
3000
4000
5000
m
Alt
Observed
NMMB/CB05
NMMB/Fire1
Acetonitrile
Flight Altitude
Acetonitrile (ppbv)
CO (ppbv)
Flight Altitude (m)
Time (UTC)
Observed
NMMB/CB05
NMMB/Fire1
Flight Altitude
O3 (ppbv)
Flight Altitude (m)
Time (UTC)

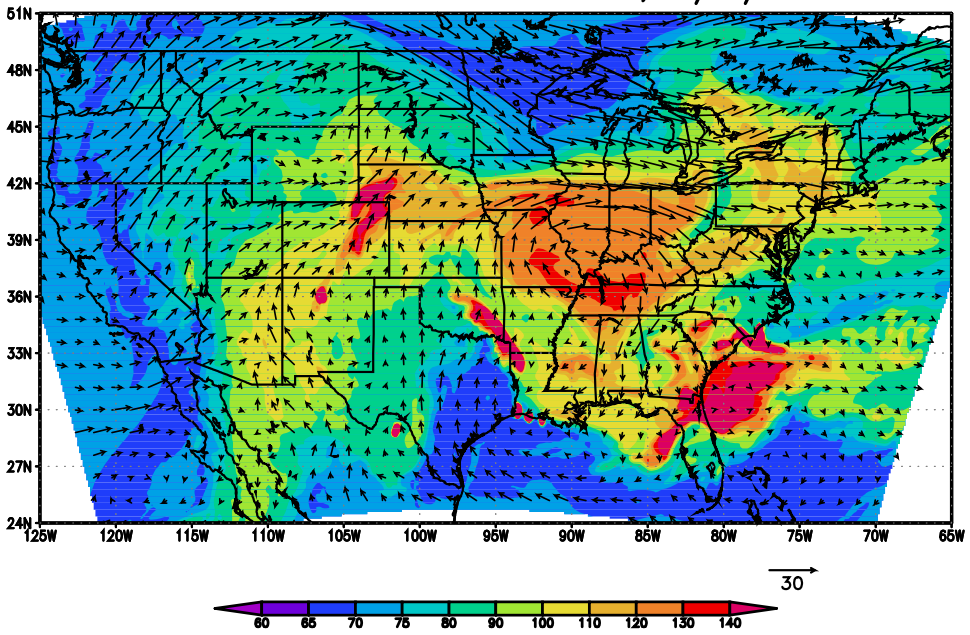
NMMB/CB05 Predicted CO (ppbv) Compared to the flight measurements
for the Altitudes 3–5 km at 20 UTC, 07/11/2011



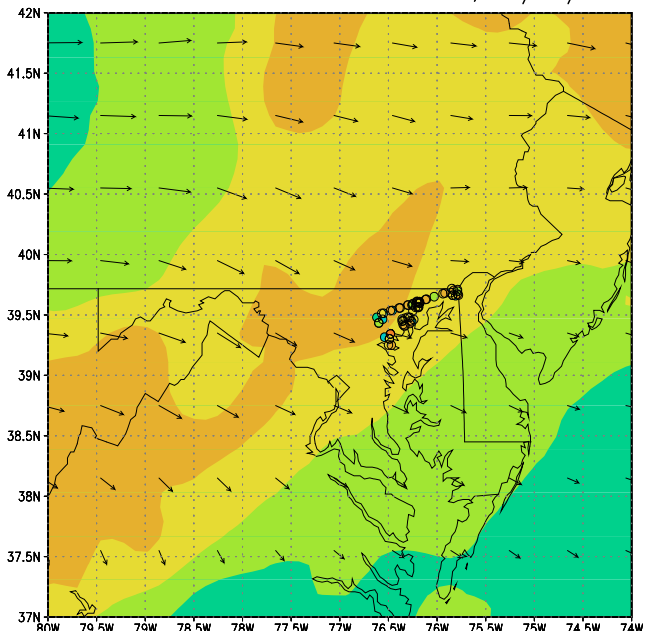
NMMB/CB05 Predicted CO (ppbv) Compared to the flight measurements
for the Altitudes 3–5 km at 20 UTC, 07/11/2011



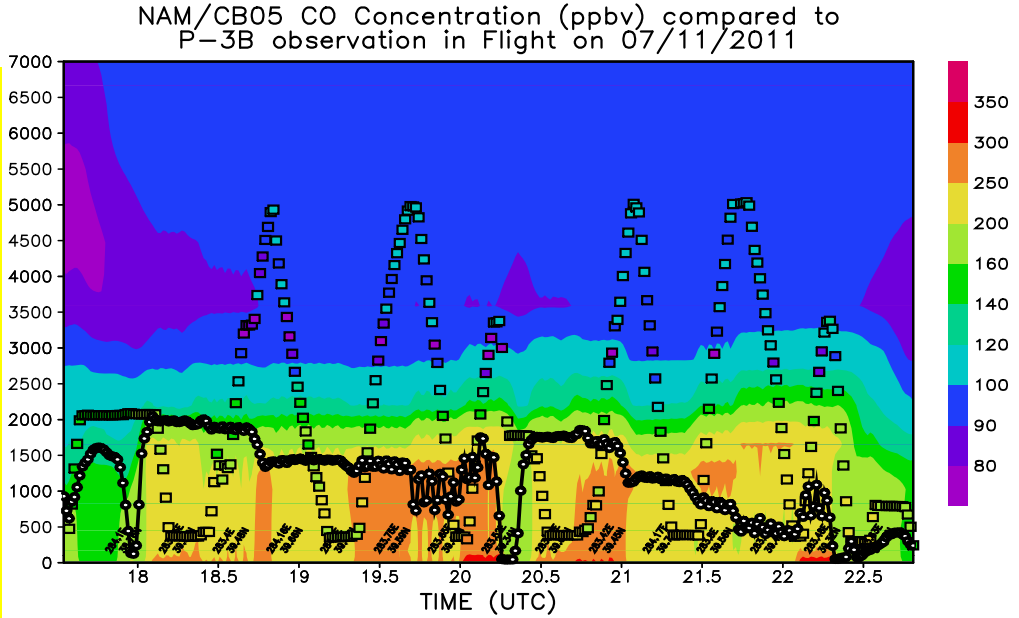
NMMB/Fire1 Predicted CO (ppbv) Compared to the Flight Measurements
for the Altitudes 3–5 km at 20 UTC, 07/11/2011

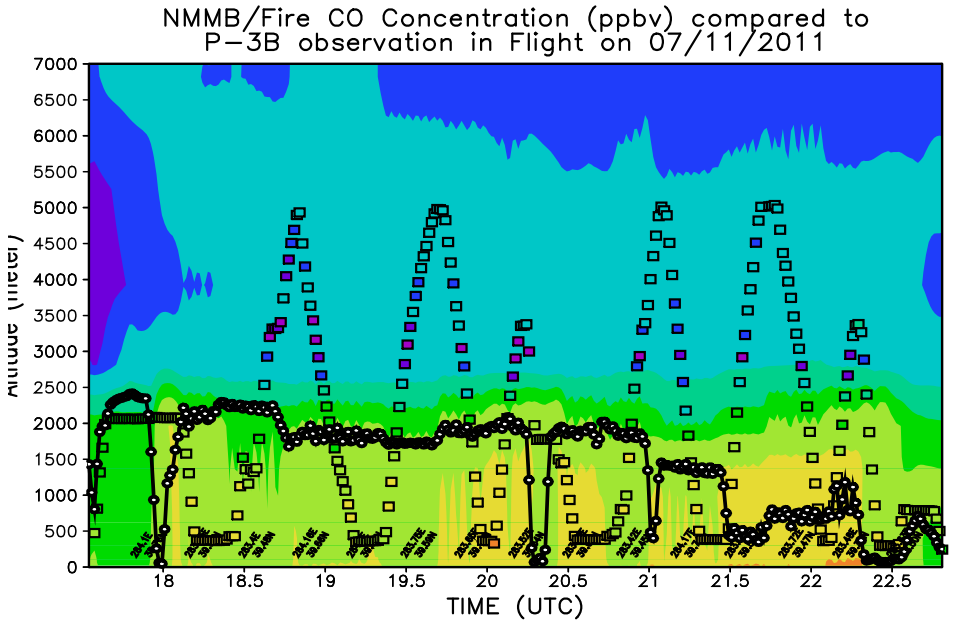


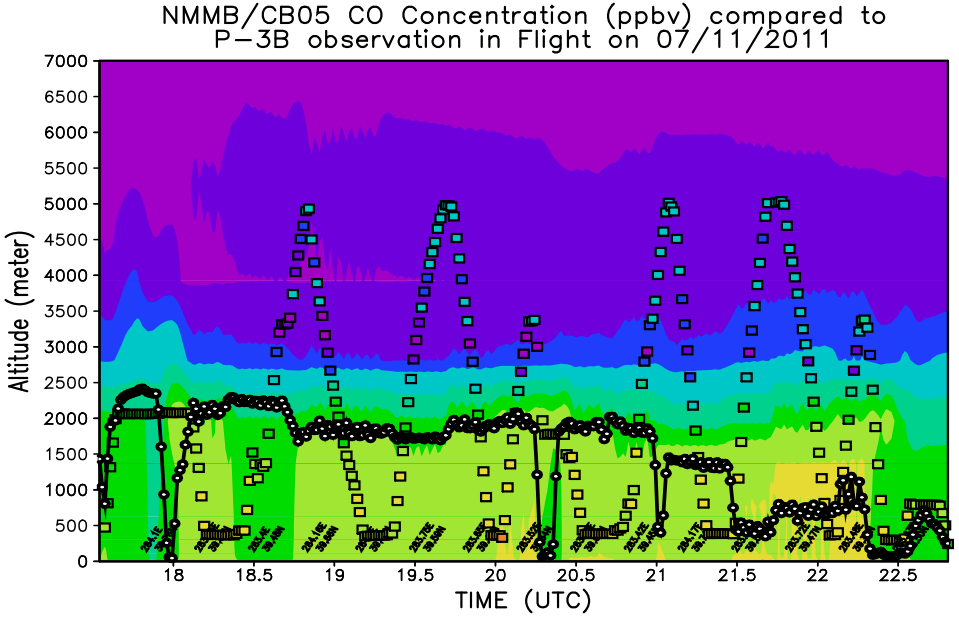
NMMB/Fire1 Predicted CO (ppbv) Compared to the Flight Measurements
for the Altitudes 3–5 km at 20 UTC, 07/11/2011

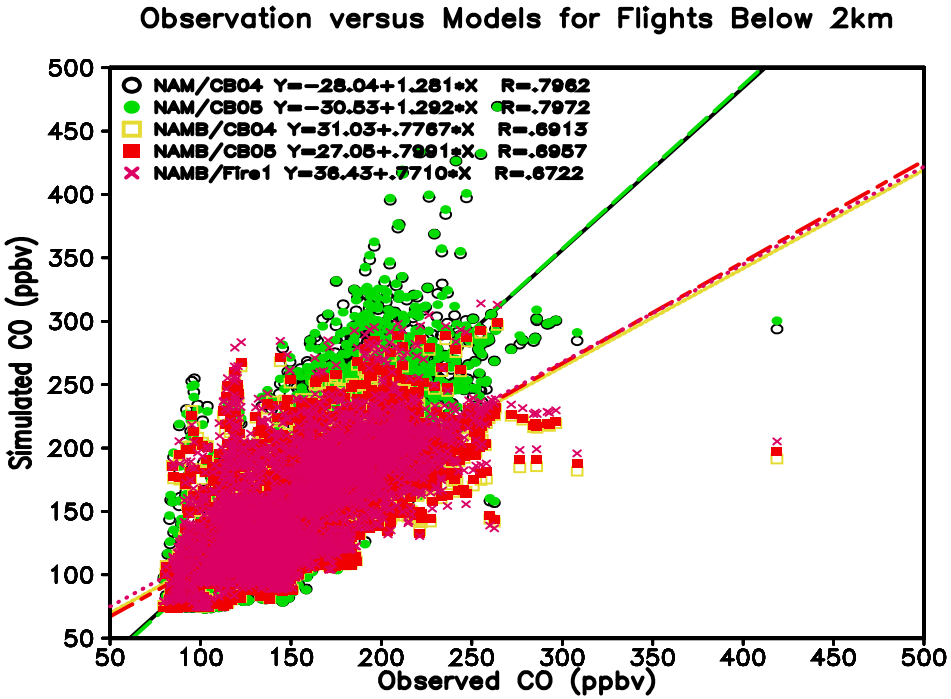


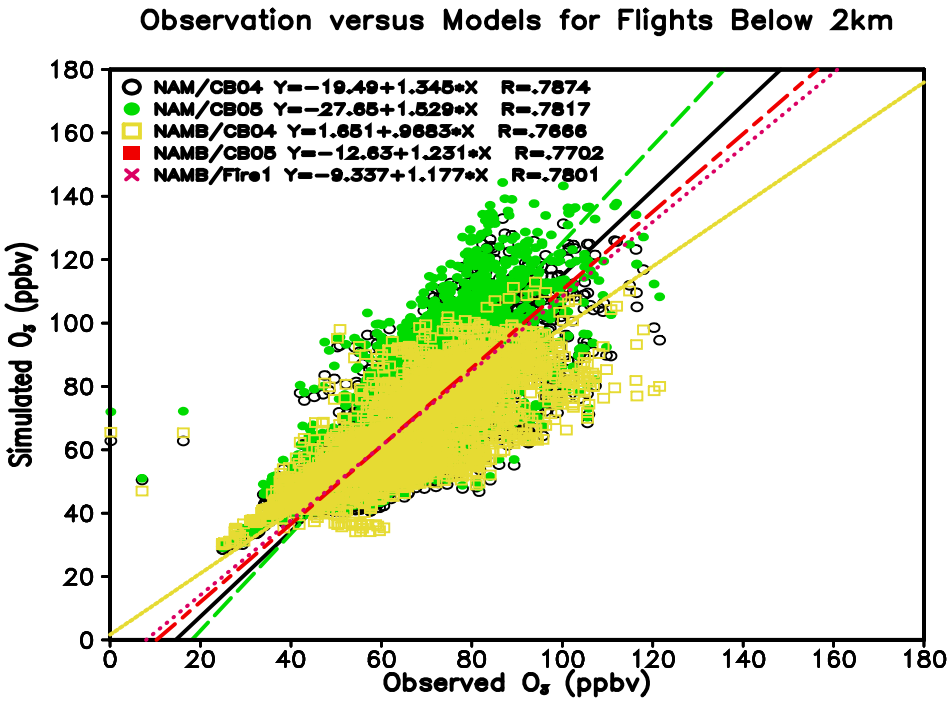
WRF-NMM and NMM-B yield very different background CO concentrations over the east coast, though their local PBL heights are similar (black-and-white lines show the PBL heights). The wildfire run yields remarkable fire-emitted CO, but tends to be too diffusive.



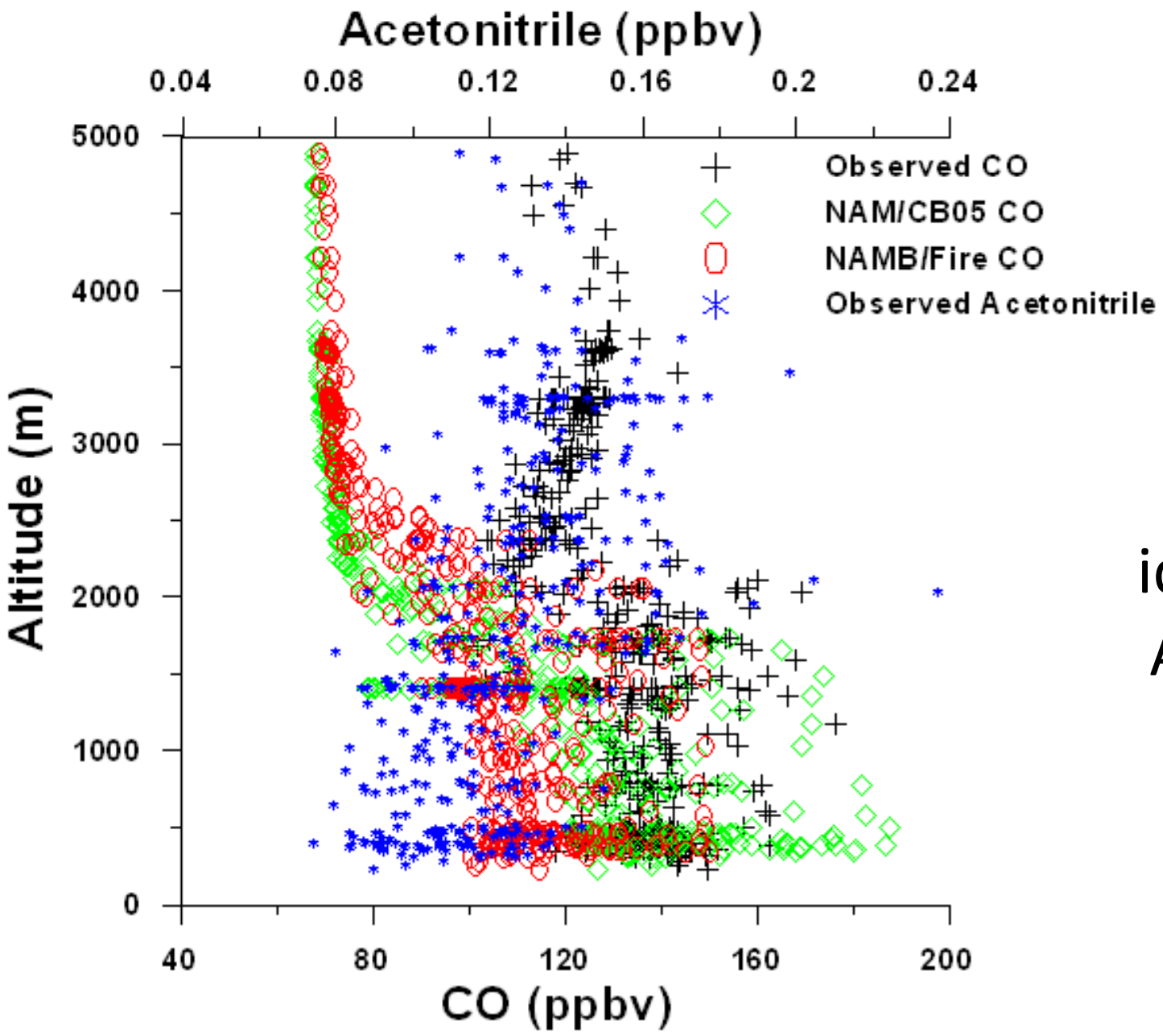






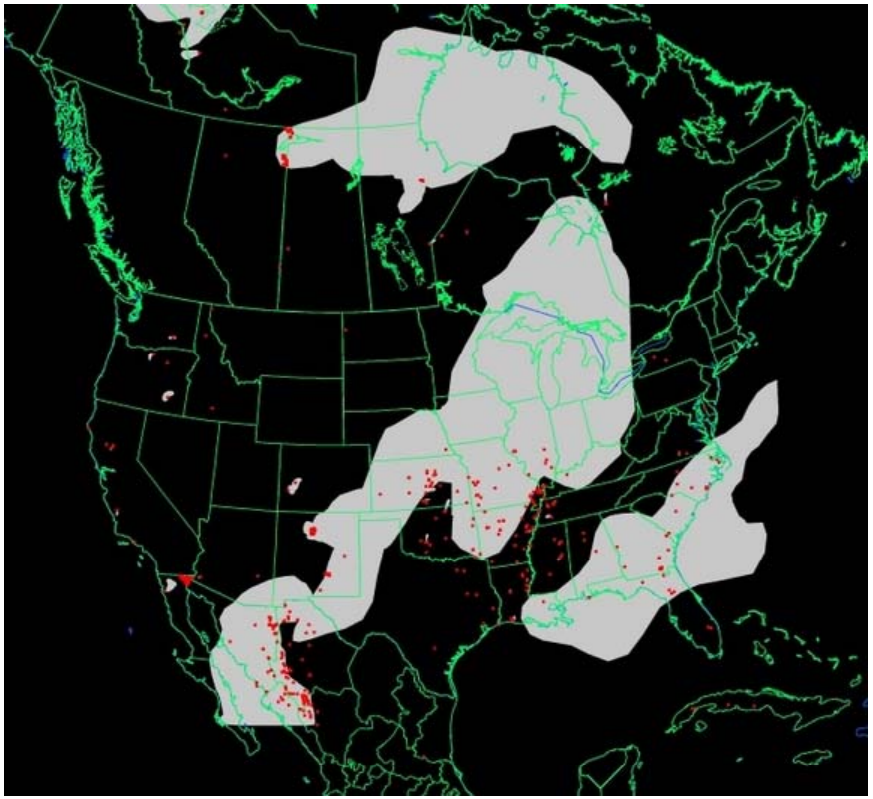


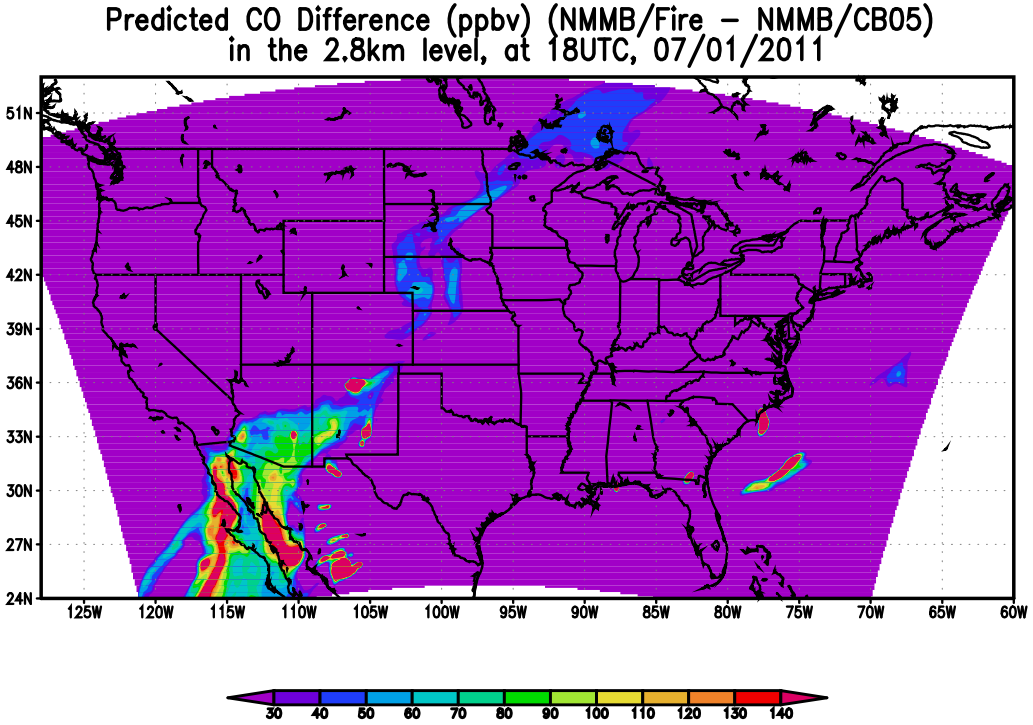
Meteorology change has significant impact on transported species. NMM-B/CMAQ yield lower concentrations than the WRF-NMM/CMAQ for almost all species for both CB4 and CB05 mechanism.

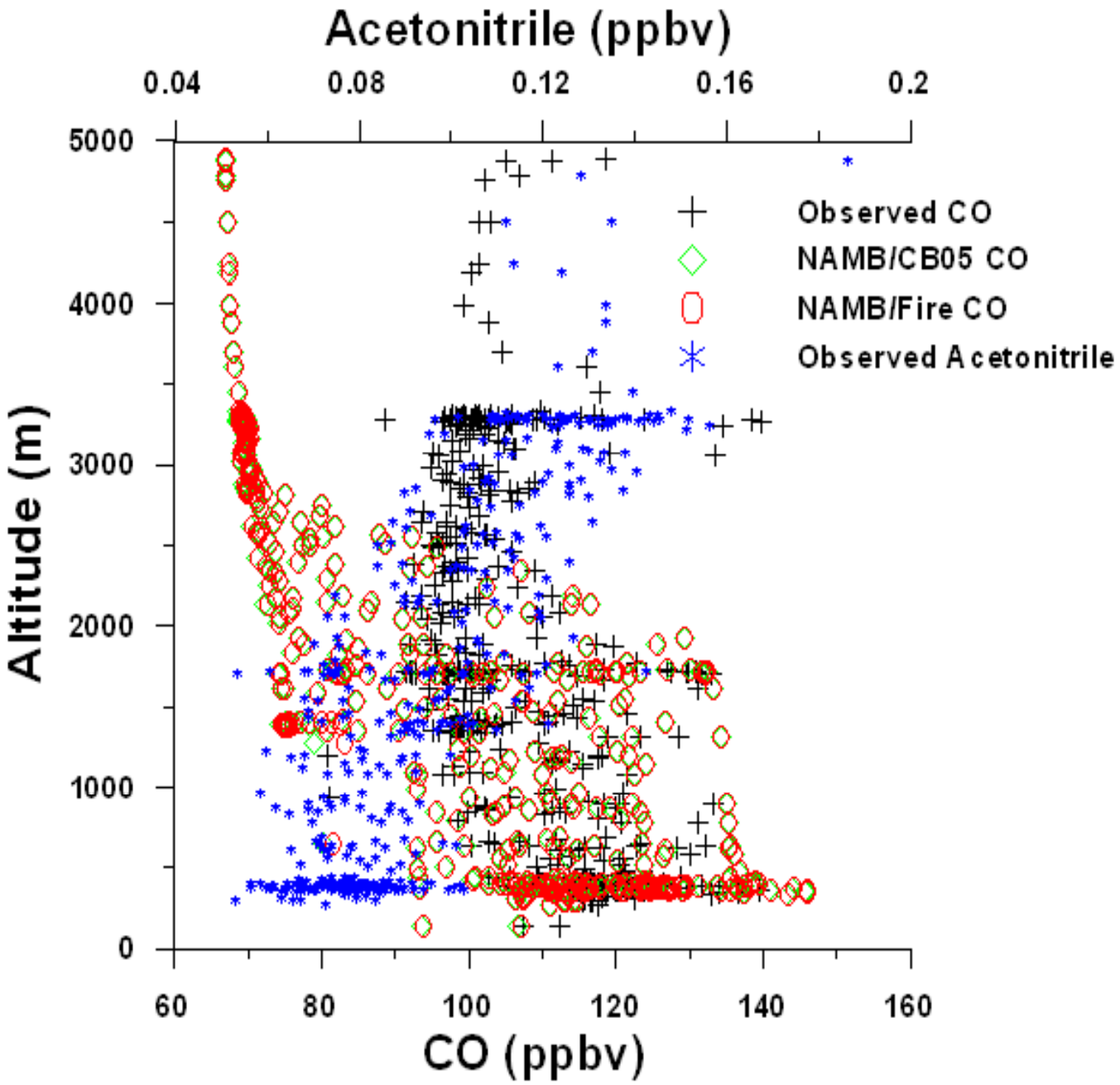


Missed wildfire plumes On 07/01 identified by Acetonitrile

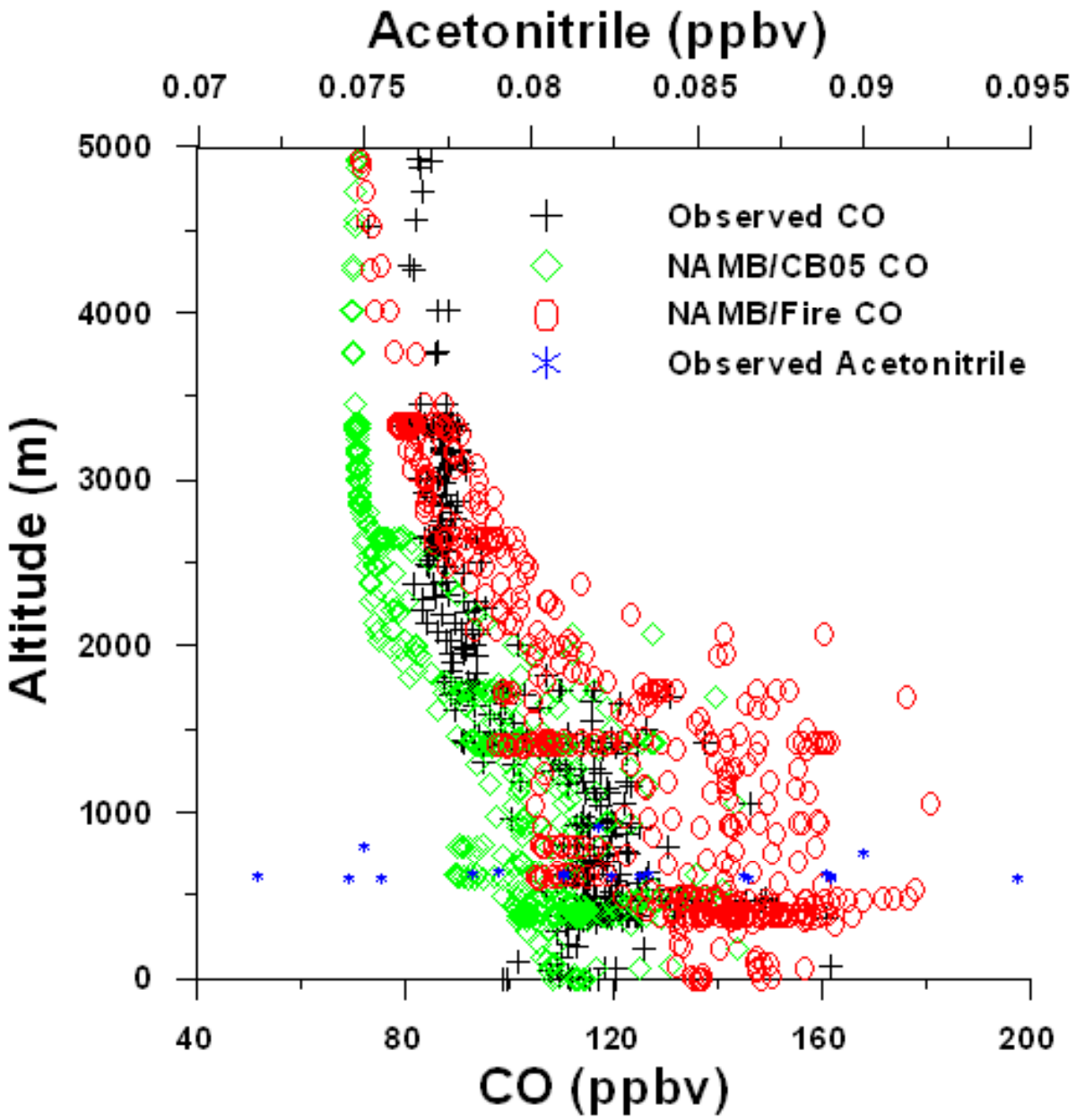
Model predicted wildfire CO compared to HMS plumes





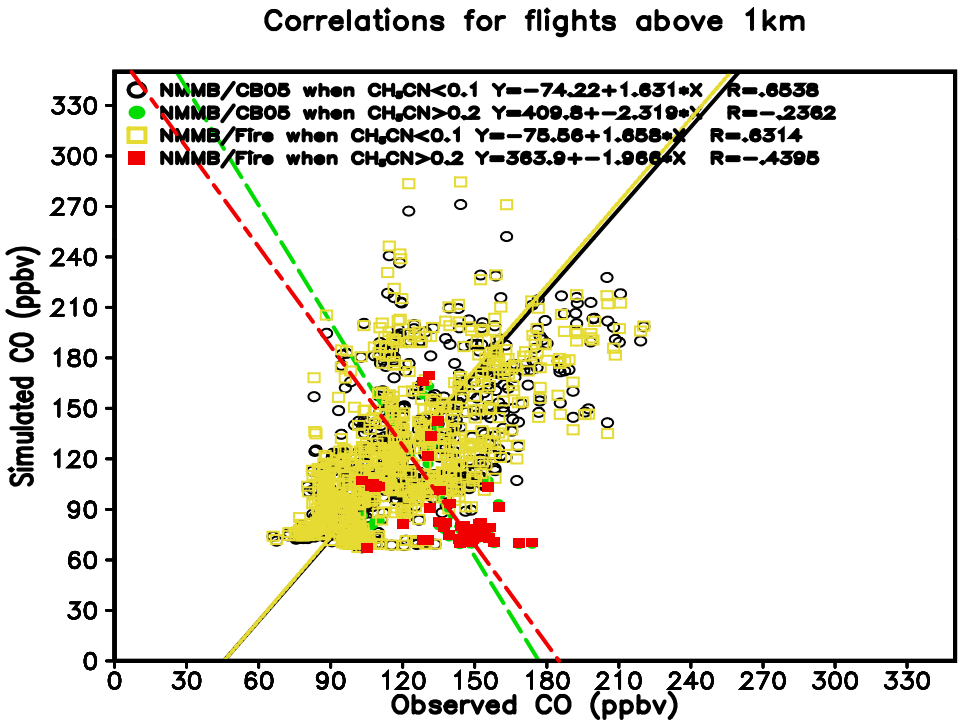


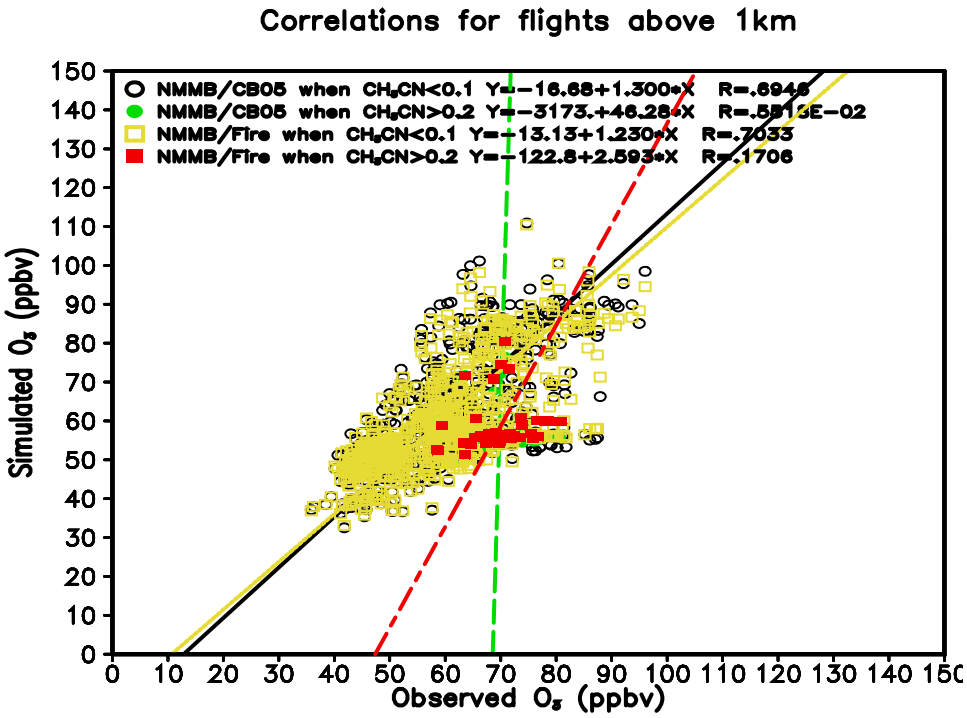
The flight on 07/14. The model missed wildfire plumes



The flight on 07/27. The model overpredicted wildfire plumes below 3km

The models have relatively poor performance during wildfire events, especially for fire-emitted species, like CO.





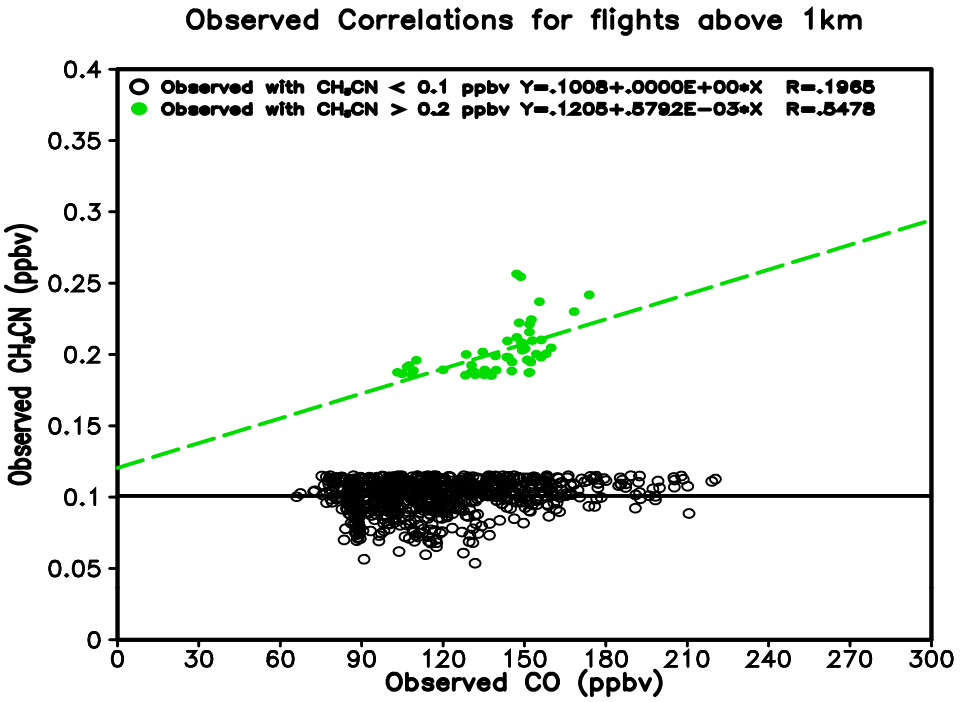
Summary

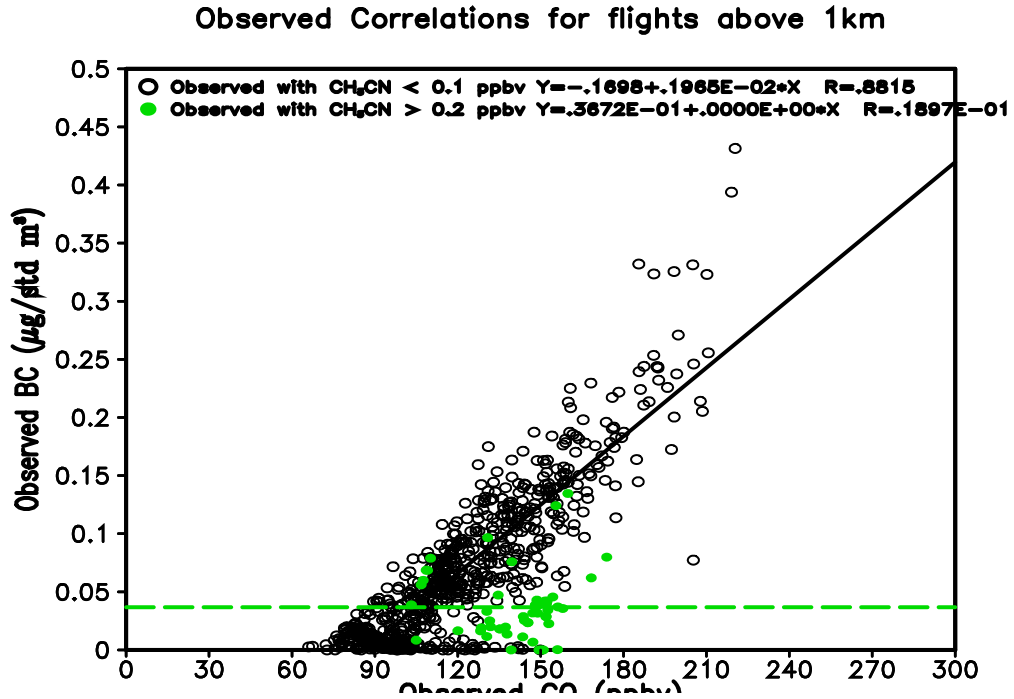
- Meteorology has a large impact on CMAQ predictions.
  - NMM-B/CMAQ yields lower concentrations than the WRF-NMM/CMAQ for almost all species,
  - Most pronounced for long-lived and long-range transported species, like CO and NO_y.

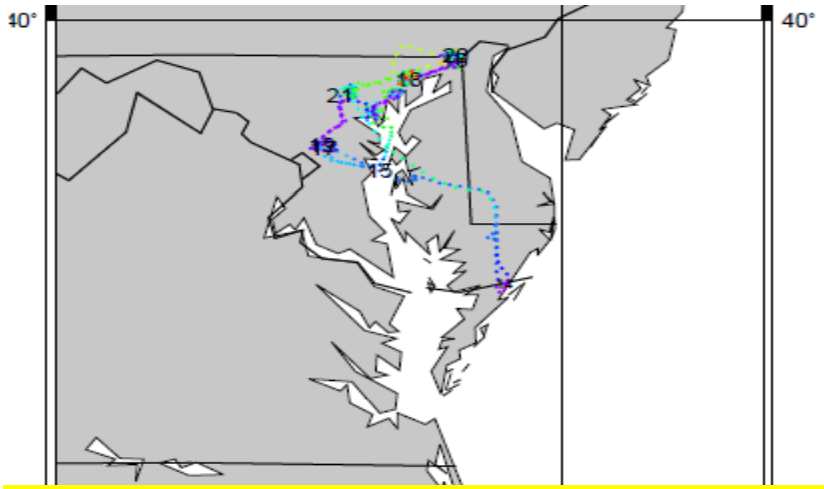
- In July 2011, there were many wildfire events that through long-range transport affected forecasts along P3-B flight tracks:
  - Underprediction (07/01 and 07/14)
  - Good prediction (07/11),
  - Overpredicted for a nearby fire event (07/27).
  - In general, poorer predictions for wildfire events than for no-fire events.

For All flights above 1km

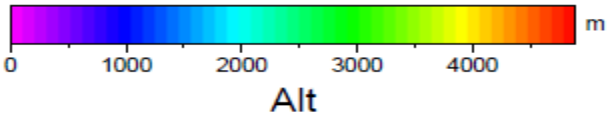
Acetonitrile is highly correlated with CO enhancement in wildfire plumes. Black carbon or aerosol absorption seems not a good tracer for long-range transported fire plumes as it could be wet removed.

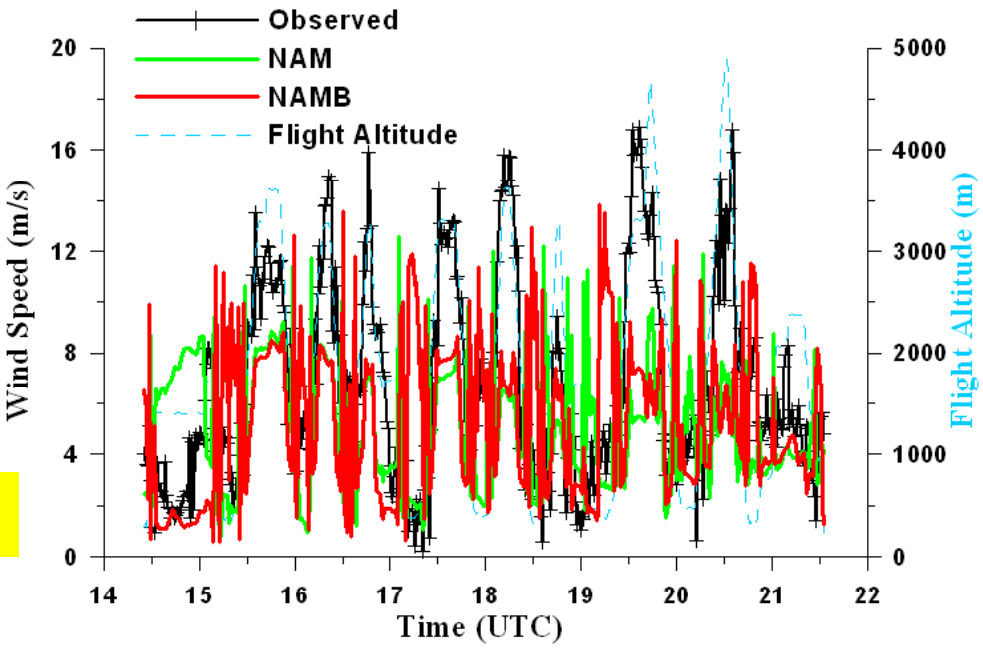


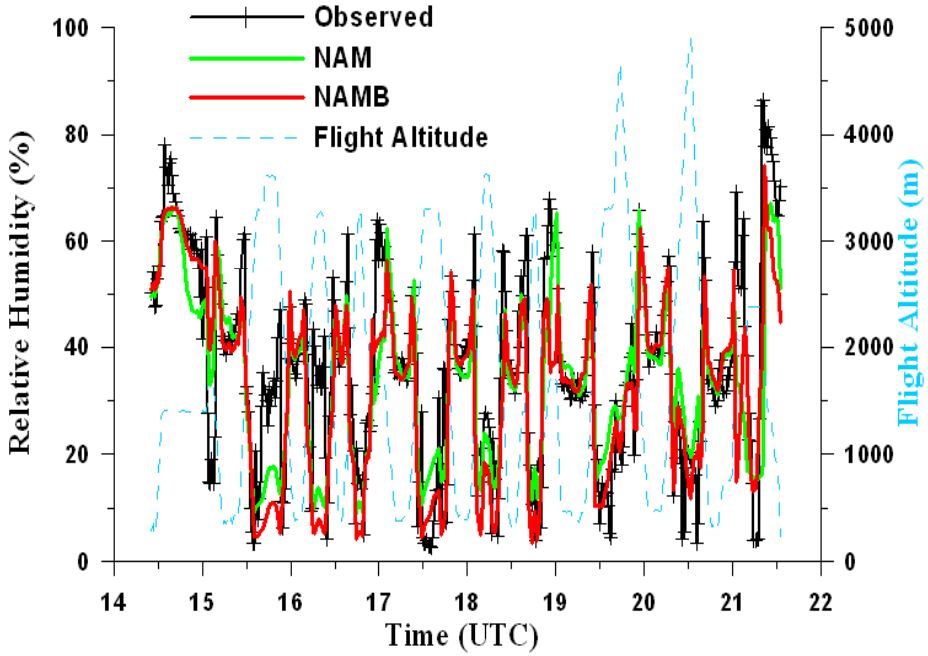


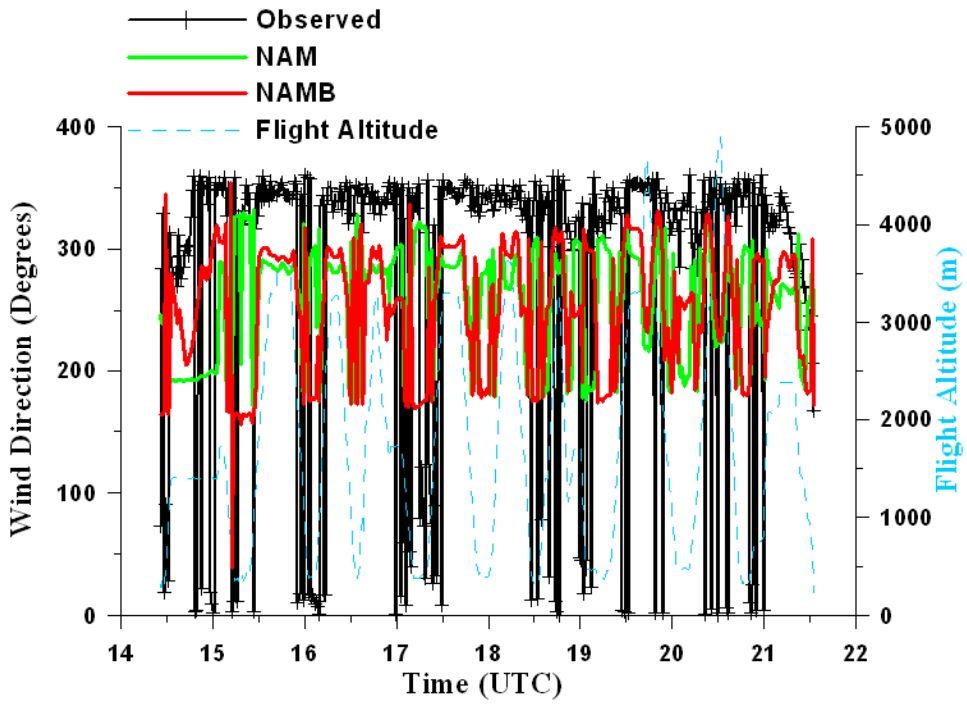


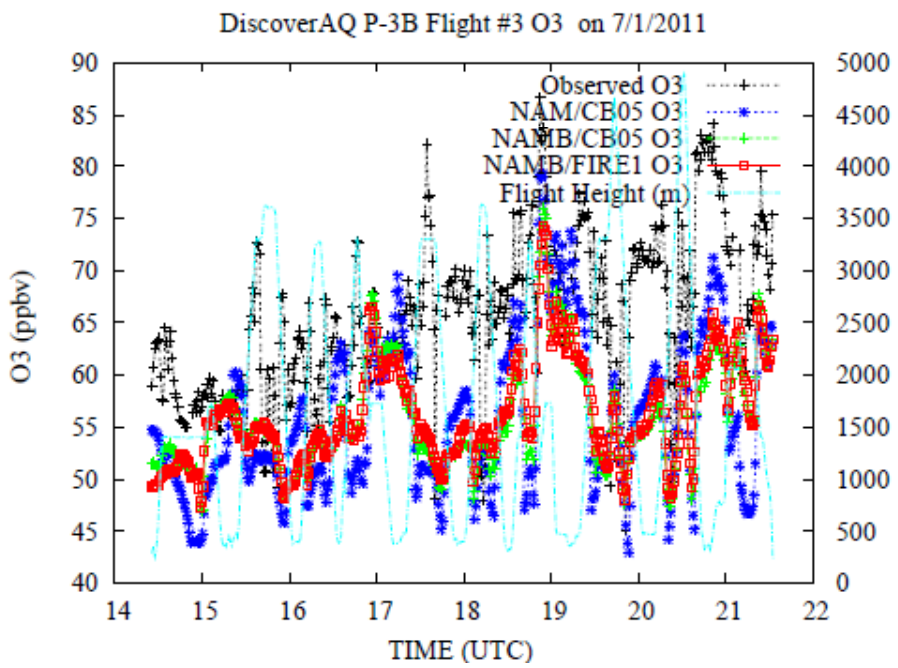
Discover-AQ P-3B Flight on 07/01

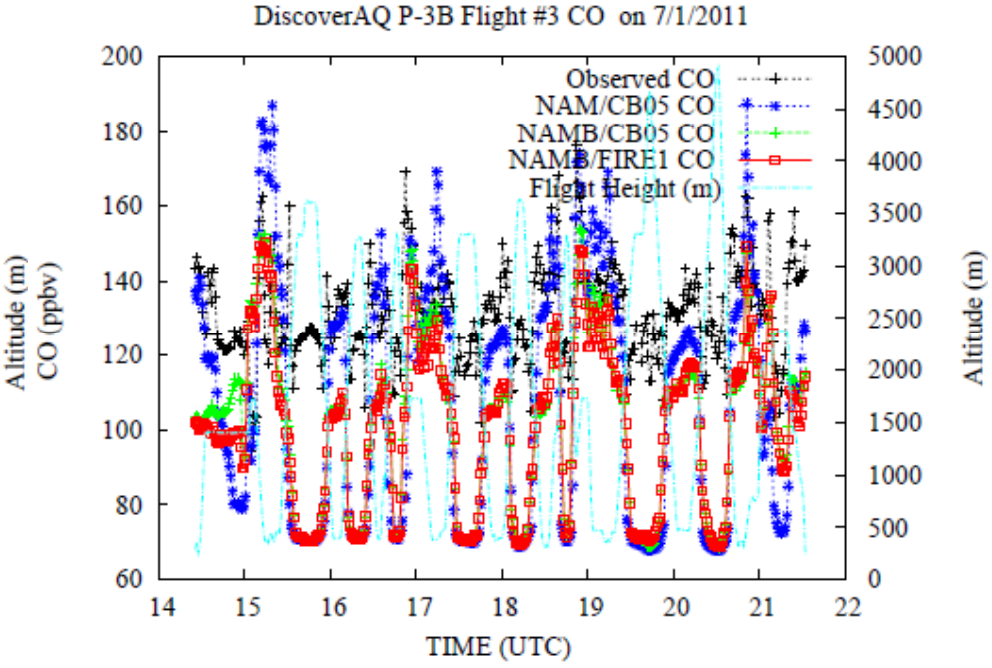


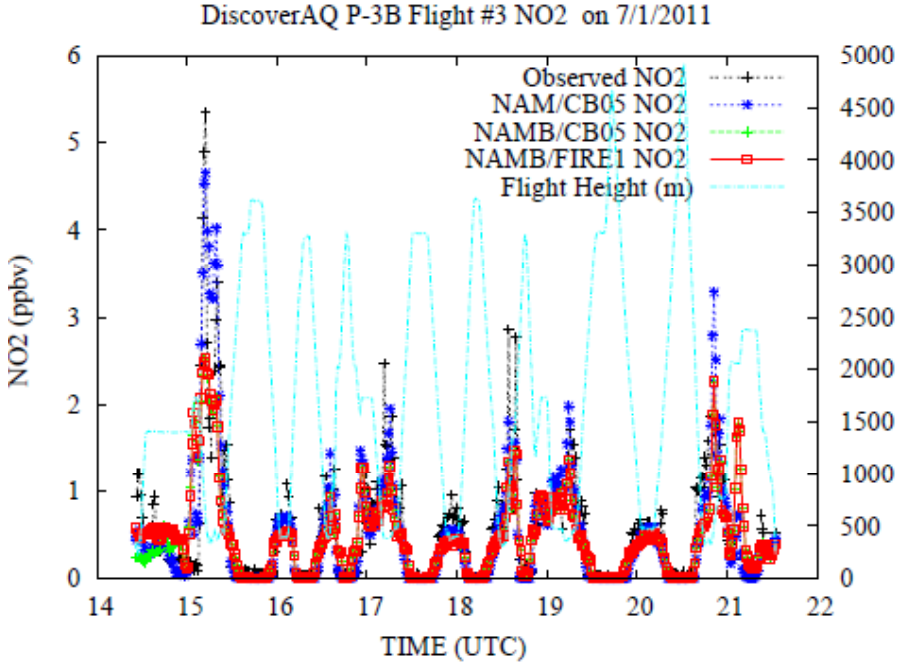


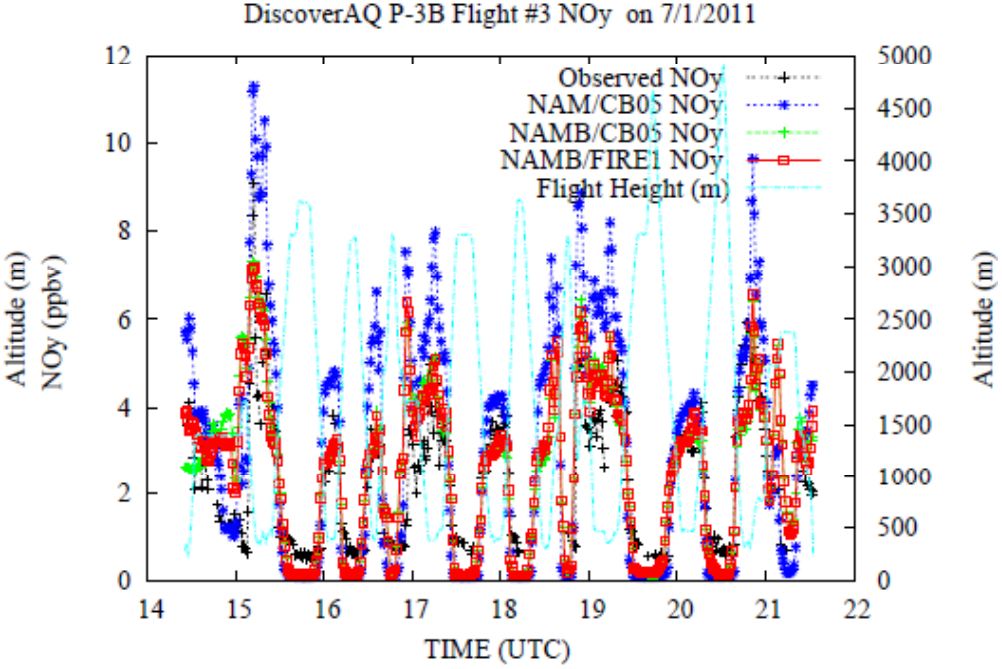


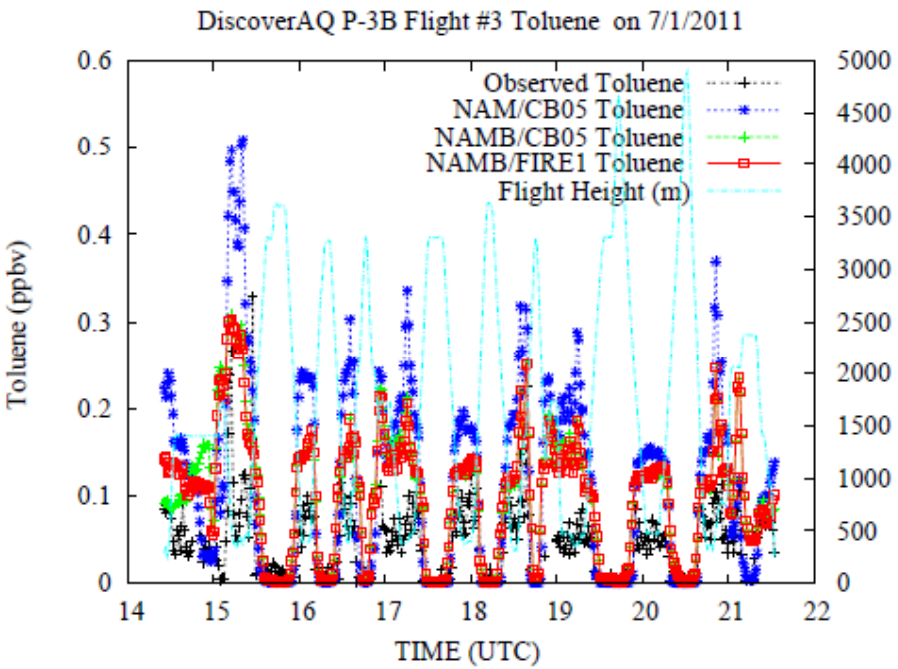


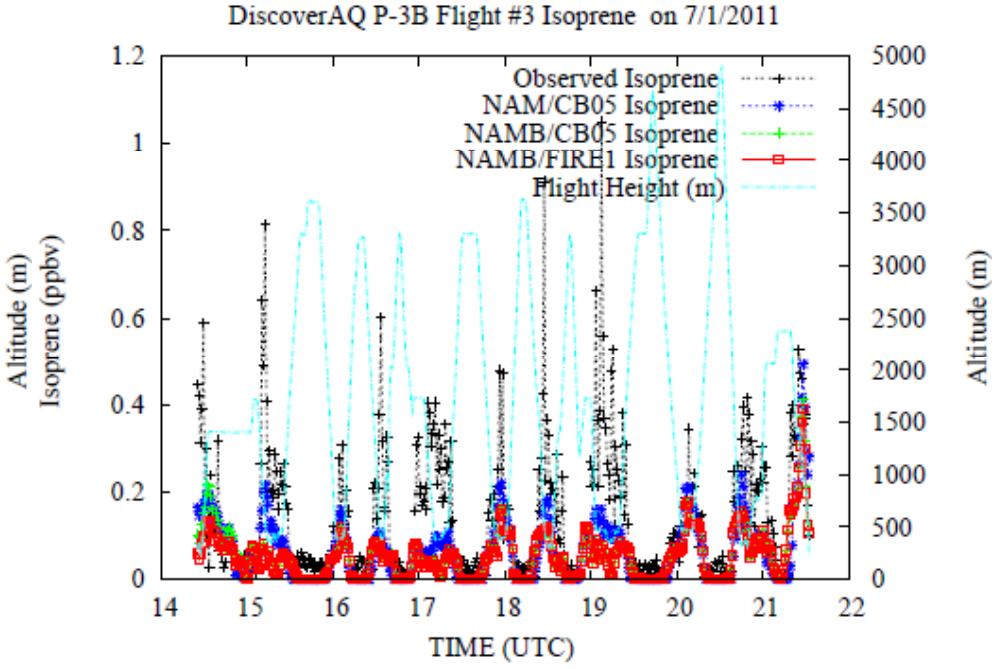

DiscoverAQ P-3B Flight #3 O3 on 7/1/2011
Observed O3
NAM/CB05 O3
NAMB/CB05 O3
NAMB/FIRE1 O3
Flight Height (m)
O3 (ppbv)
Altitude (m)
TIME (UTC)

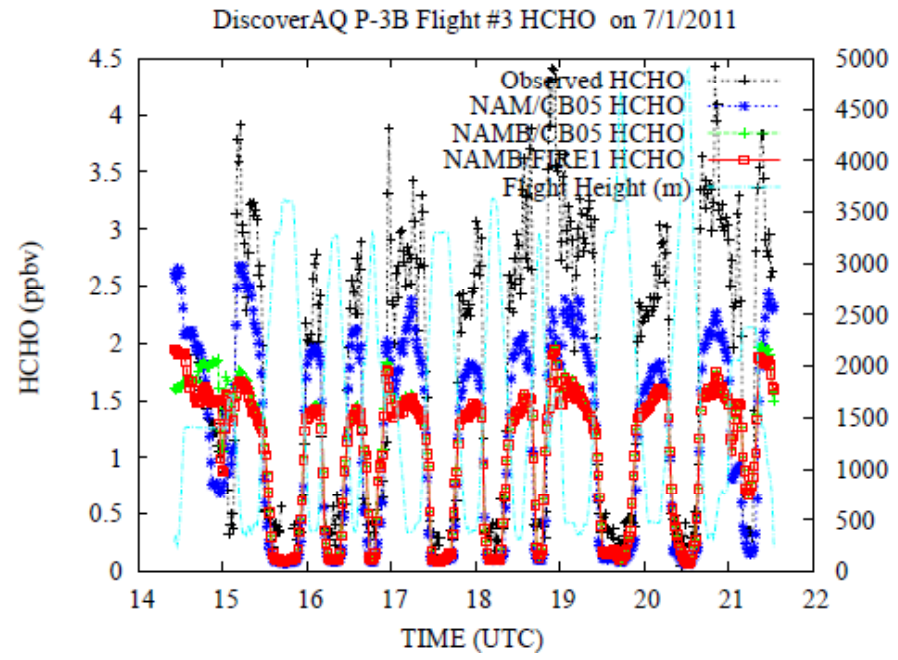

DiscoverAQ P-3B Flight #3 CO on 7/1/2011
Observed CO
NAM/CB05 CO
NAMB/CB05 CO
NAMB/FIRE1 CO
Flight Height (m)
CO (ppbv)
Altitude (m)
TIME (UTC)

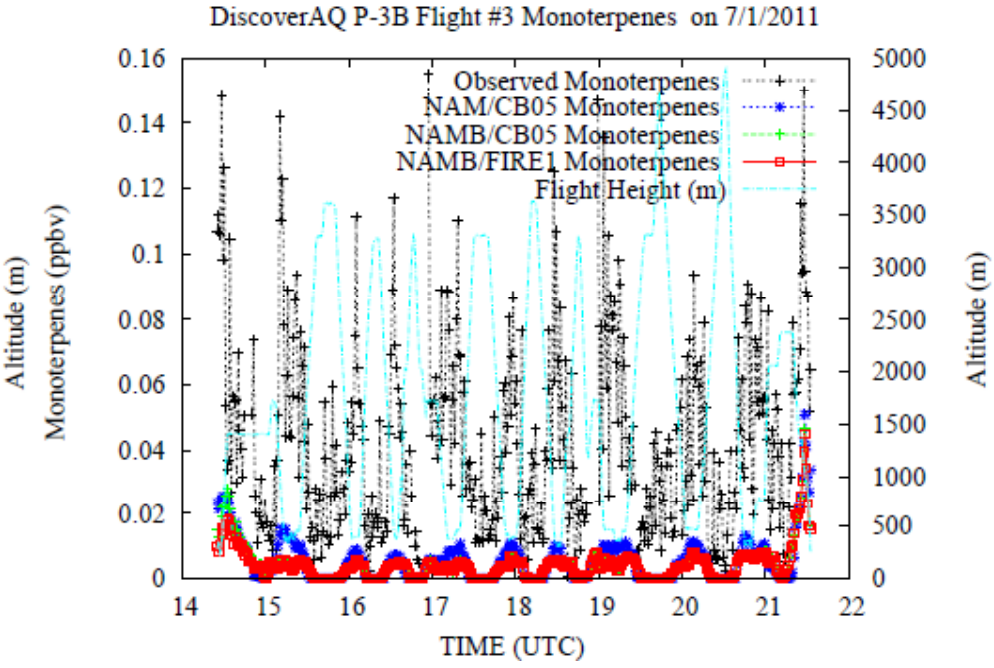

DiscoverAQ P-3B Flight #3 NO2 on 7/1/2011
Observed NO2
NAM/CB05 NO2
NAMB/CB05 NO2
NAMB/FIRE1 NO2
Flight Height (m)
NO2 (ppbv)
Altitude (m)
TIME (UTC)


DiscoverAQ P-3B Flight #3 NOy on 7/1/2011
Observed NOy
NAM/CB05 NOy
NAMB/CB05 NOy
NAMB/FIRE1 NOy
Flight Height (m)
NOy (ppbv)
Altitude (m)
TIME (UTC)


DiscoverAQ P-3B Flight #3 Toluene on 7/1/2011
Observed Toluene
NAM/CB05 Toluene
NAMB/CB05 Toluene
NAMB/FIRE1 Toluene
Flight Height (m)
Toluene (ppbv)
Altitude (m)
TIME (UTC)

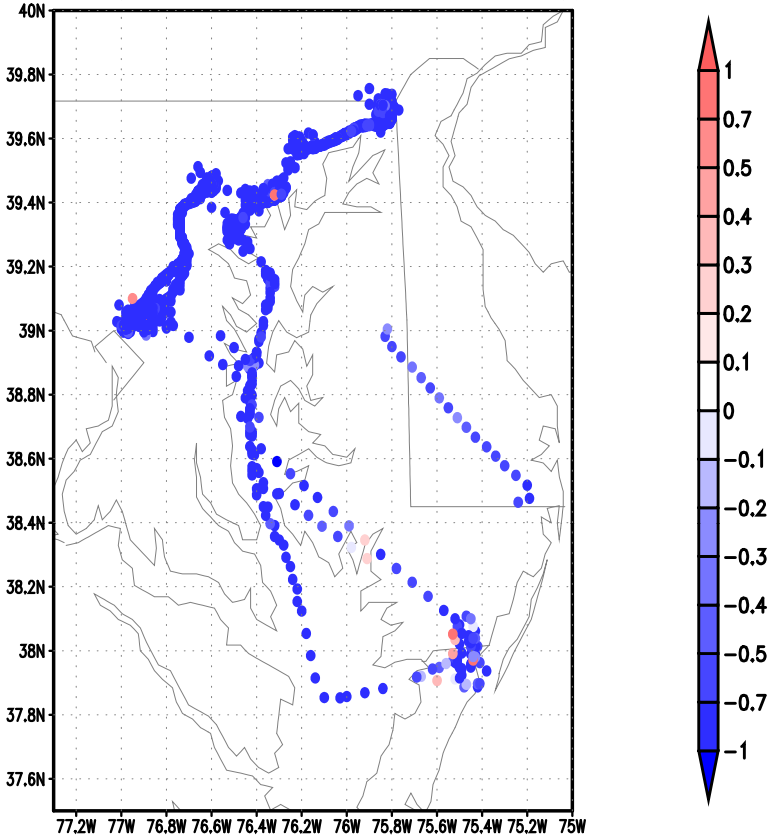

DiscoverAQ P-3B Flight #3 Isoprene on 7/1/2011
Observed Isoprene
NAM/CB05 Isoprene
NAMB/CB05 Isoprene
NAMB/FIRE1 Isoprene
Flight Height (m)
Isoprene (ppbv)
Altitude (m)
TIME (UTC)


DiscoverAQ P-3B Flight #3 HCHO on 7/1/2011
Observed HCHO
NAM/CB05 HCHO
NAMB/CB05 HCHO
NAMB/FIRE1 HCHO
Flight Height (m)
HCHO (ppbv)
Altitude (m)
TIME (UTC)

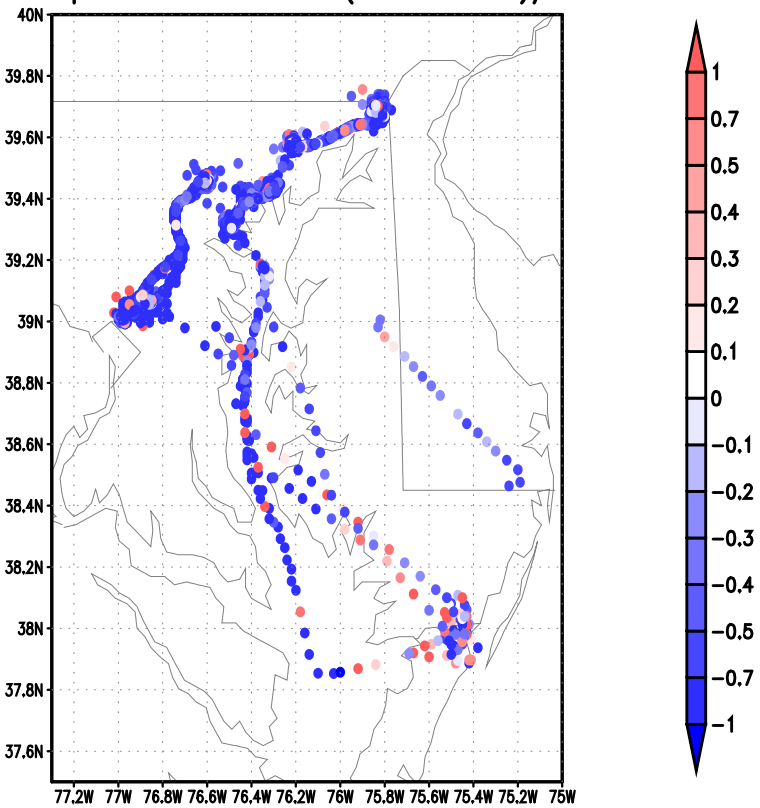

DiscoverAQ P-3B Flight #3 Monoterpenes on 7/1/2011
Observed Monoterpenes
NAM/CB05 Monoterpenes
NAMB/CB05 Monoterpenes
NAMB/FIRE1 Monoterpenes
Flight Height (m)
Monoterpenes (ppbv)
Altitude (m)
TIME (UTC)

For all flights (July 1-29) below 1km

NMMB/CB05 Monoterpene Bias Ratio (Model−Obs)/Obs below 1km



NMMB/CB05 Isoprene Bias Ratio (Model−Obs)/Obs below 1km



The models generally undepredicted biogenic emitted species, especially for terpenes. The bias is related to certain areas.