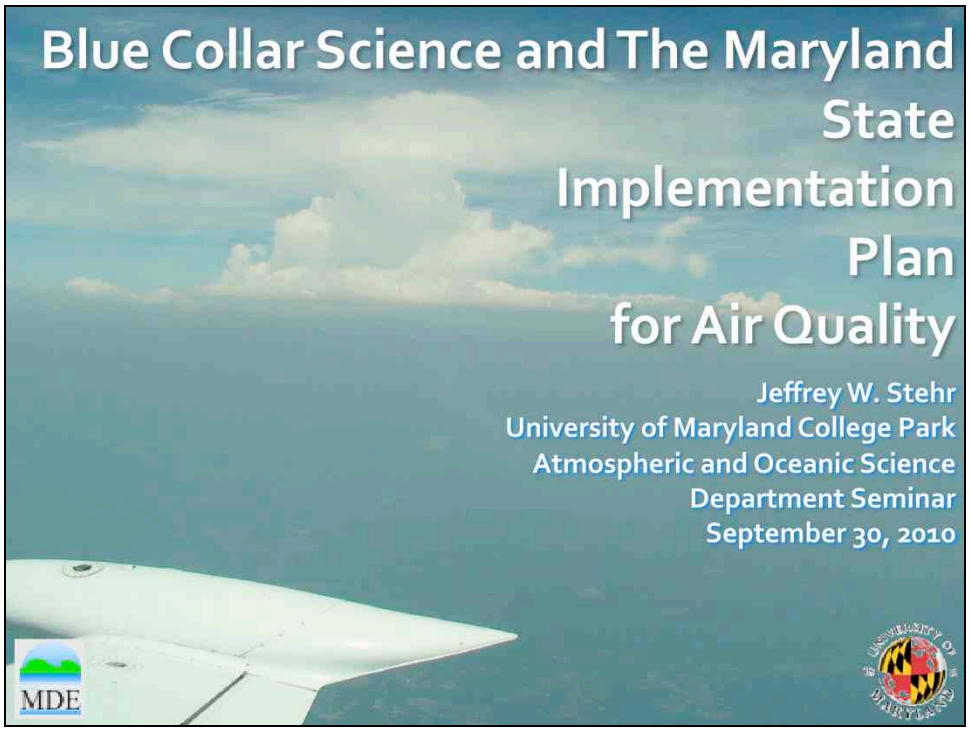
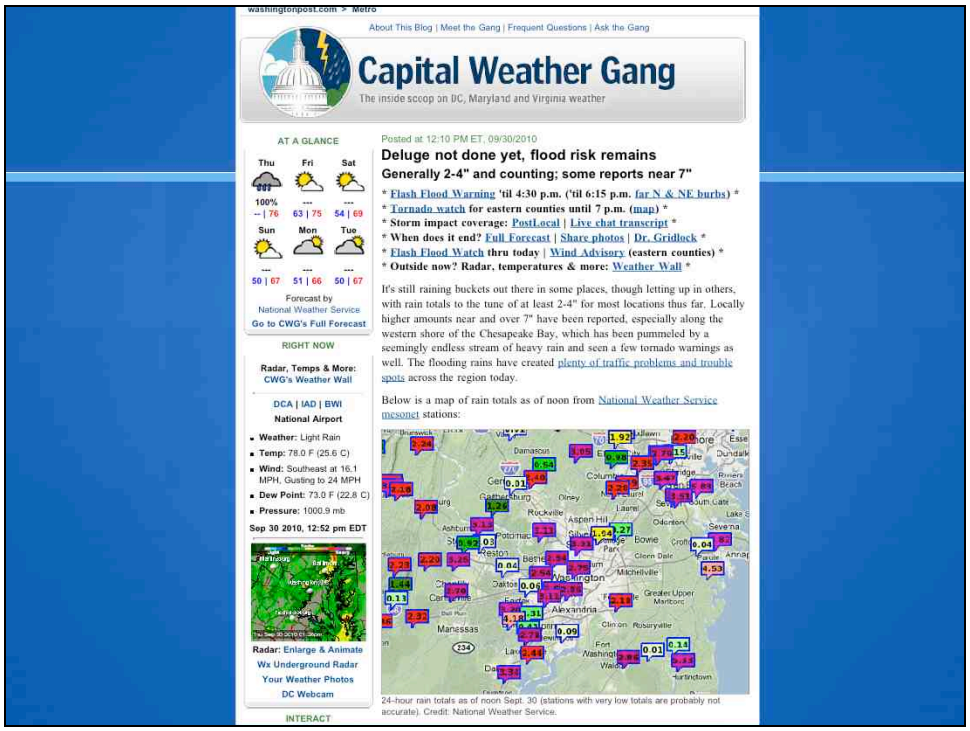

Blue Collar Science and The Maryland State Implementation Plan for Air Quality
Jeffrey W. Stehr
University of Maryland College Park
Atmospheric and Oceanic Science
Department Seminar
September 30, 2010
MDE


USA SCIENCE & ENGINEERING FESTIVAL
A FREE EVENT FOR CURIOUS PEOPLE LIKE YOU
CELEBRATE SCIENCE
USASCIENCEFESTIVAL.ORG
BE THERE WHEN SCIENCE TAKES OVER THE NATION'S CAPITAL
EXPO ON THE NATIONAL MALL & SURROUNDING AREAS
OCTOBER 23 & 24, 2010, 10AM-5:30PM
Cathy Sabol
Javier Amezcua
Steven Greybush
Anthony Santorelli
Thank You!



washingtonpost.com > Metro

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Capital Weather Gang

The inside scoop on DC, Maryland and Virginia weather

AT A GLANCE

Thu	Fri	Sat
100%	---	---
-- | 76	63 | 75	54 | 69
Sun	**Mon**	**Tue**
---	---	---
50 | 67	51 | 66	50 | 67

Forecast by National Weather Service

Go to CWG's Full Forecast

RIGHT NOW

Radar, Temps & More: CWG's Weather Wall

DCA | IAD | BWI

National Airport

- **Weather:** Light Rain
- **Temp:** 78.0 F (25.6 C)
- **Wind:** Southeast at 16.1 MPH, Gusting to 24 MPH
- **Dew Point:** 73.0 F (22.8 C)
- **Pressure:** 1000.9 mb

Sep 30 2010, 12:52 pm EDT

Radar: Enlarge & Animate

Wx Underground Radar

Your Weather Photos

DC Webcam

INTERACT

Posted at 12:10 PM ET, 09/30/2010

Deluge not done yet, flood risk remains

Generally 2-4" and counting; some reports near 7"

* Flash Flood Warning 'til 4:30 p.m. ('til 6:15 p.m. far N & NE burbs) *
* Tornado watch for eastern counties until 7 p.m. (map) *
* Storm impact coverage: PostLocal | Live chat transcript *
* When does it end? Full Forecast | Share photos | Dr. Gridlock *
* Flash Flood Watch thru today | Wind Advisory (eastern counties) *
* Outside now? Radar, temperatures & more: Weather Wall *

It's still raining buckets out there in some places, though letting up in others, with rain totals to the tune of at least 2-4" for most locations thus far. Locally higher amounts near and over 7" have been reported, especially along the western shore of the Chesapeake Bay, which has been pummeled by a seemingly endless stream of heavy rain and seen a few tornado warnings as well. The flooding rains have created plenty of traffic problems and trouble spots across the region today.

Below is a map of rain totals as of noon from National Weather Service mesonet stations:

24-hour rain totals as of noon Sept. 30 (stations with very low totals are probably not accurate). Credit: National Weather Service.


Last time I was invited to give a talk…


UNION FEDERAL
Last time I was invited to give a talk…


(cute video of me in the snow)

Air Chemistry 101.01

- Ozone in the troposphere:
- NOx and hydrocarbons react in sunlight to produce ozone
- NOx comes from high temperature processes
  - power plants, diesels and gasoline engines
- Natural process
  - Lightning, soils,
- Hydrocarbons from vegetation, autos, paint, evaporation…

Implementing the Clean Air Act

- In 1997, EPA set a standard, 85 ppbv for 8 hour average ozone (now: 75→60-70?)
- Monitoring, states & EPA determine (non)compliance & classify severity
- Severity sets a timeline for compliance with the standard: worse problems get more time
- Figure of merit: 3 year average of each year's 4th highest daily maximum 8-hour average ozone at each monitor = Design Value

Modeling Clean Air Act compliance

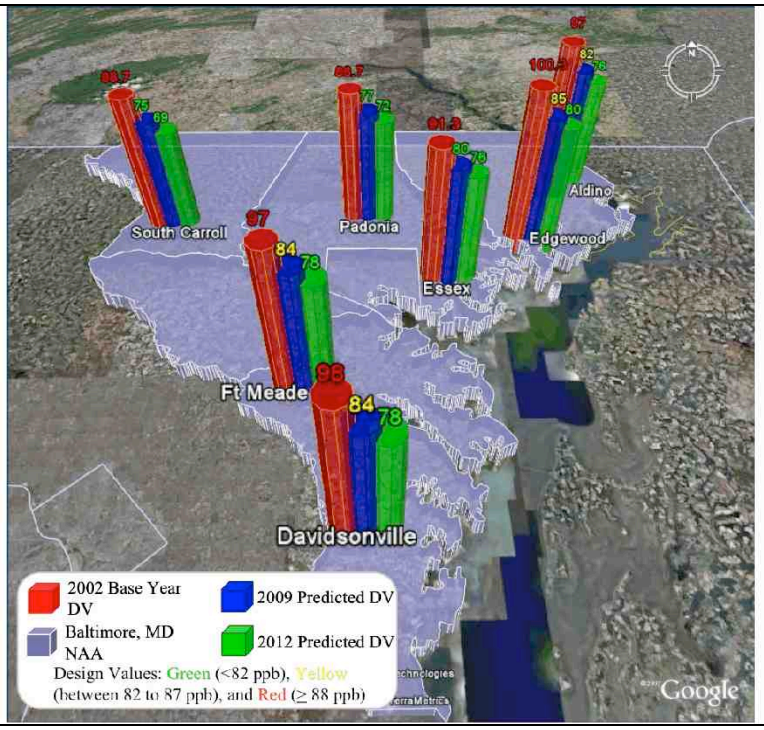
- GUIDANCE is set out by EPA
- Do a model run for base (2002) and future (2009) years
- Calculate ratios between future and base year modeled ozone: *a relative response factor*
- Observations form the baseline→"design value" calculated as a weighted average of 5 years around a base year (2002). This sets your starting point
- Multiply design value by RRF to get future year prediction

Model Predictions

Modeling Attainment Test Using EPA Preferred Methodology

Site Name	County	State	DVB	RRF	DVF
Davidsonville	Anne Arundel	MD	98.0	0.858	84
Ft. Meade	Anne Arundel	MD	97.0	0.869	84
Padonia	Baltimore	MD	88.7	0.872	77
Essex	Baltimore	MD	91.3	0.879	80
South Carroll	Carroll	MD	88.7	0.847	75
Edgewood	Harford	MD	100.3	0.852	85
Aldino	Harford	MD	97.0	0.846	82

MDE, Baltimore SIP, 2007



Model Evaluation

- Run the model according to EPA guidance
- Compare the model to ground-level monitoring according to EPA guidance
- Calculate mean error and bias as suggested by EPA guidance
- If they fall within certain limits (set by EPA guidance), then
- **THE MODEL IS VALID FOR ANY USE!!**

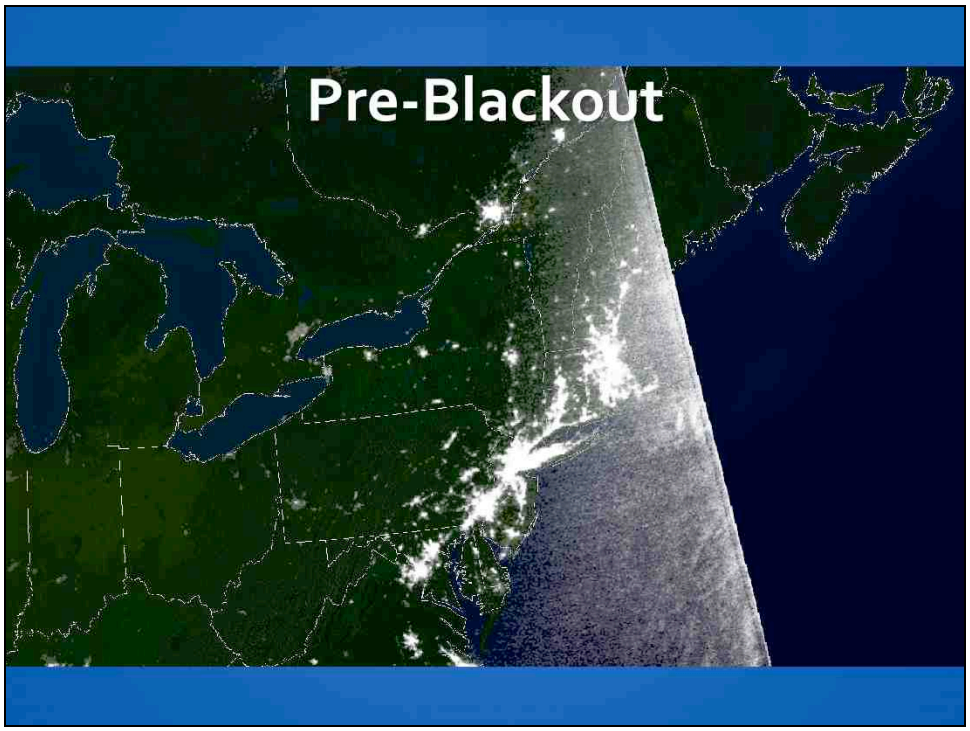
(no!)

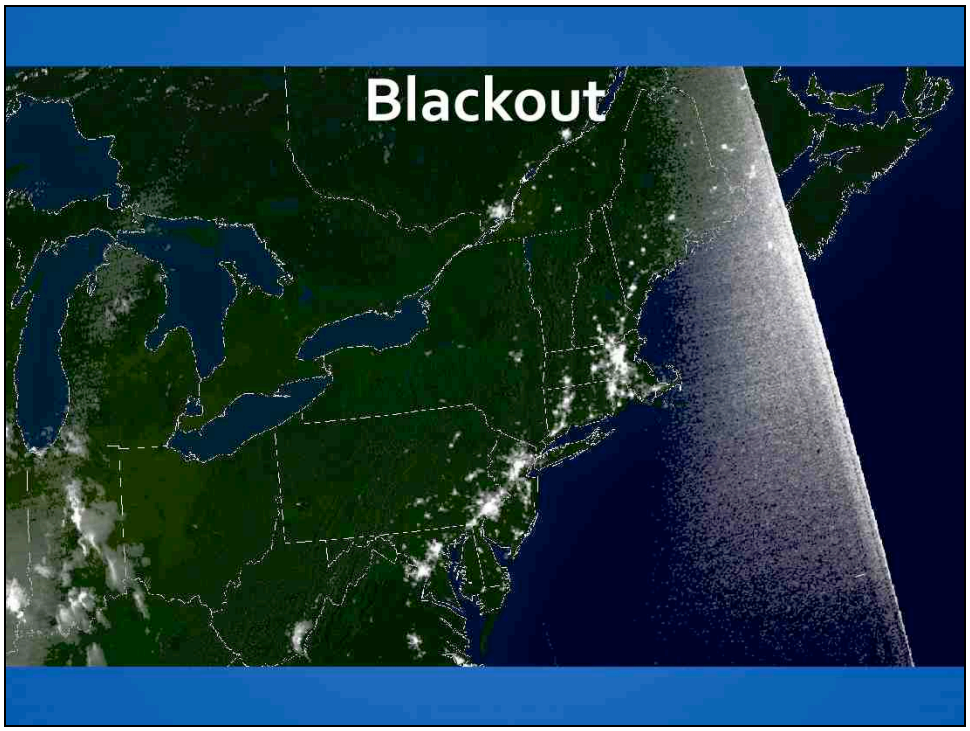
The Disconnect

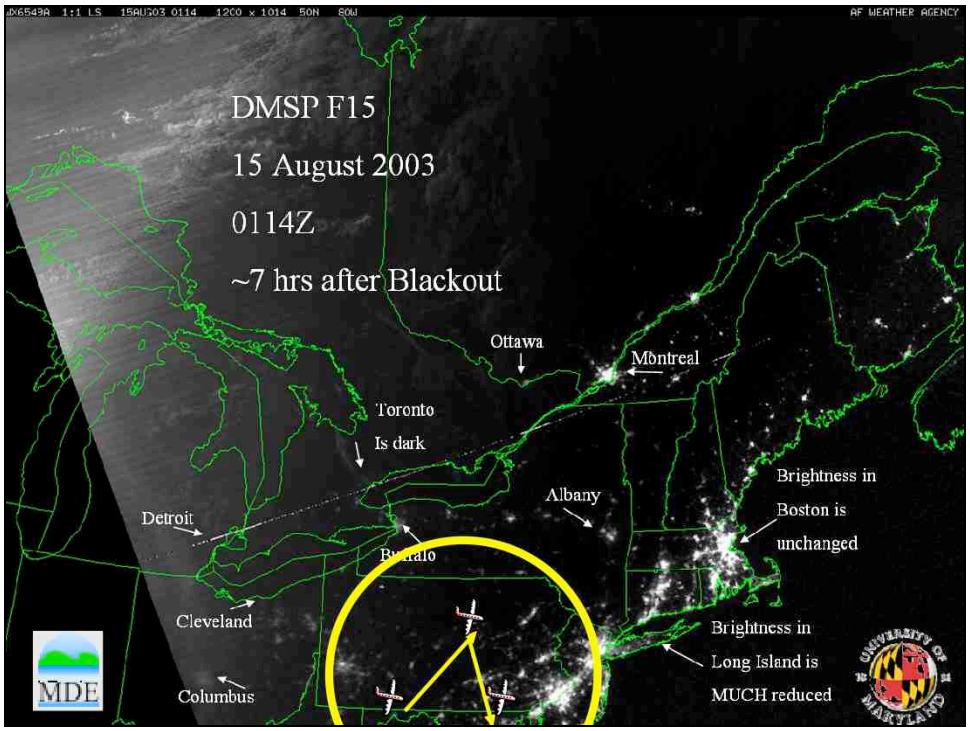
- Base year compared to concentrations at the surface and for that year only to vet performance—a *static* evaluation
- We evaluate the model based on its static performance, not its ability to predict change
- Then use it dynamically to predict changes

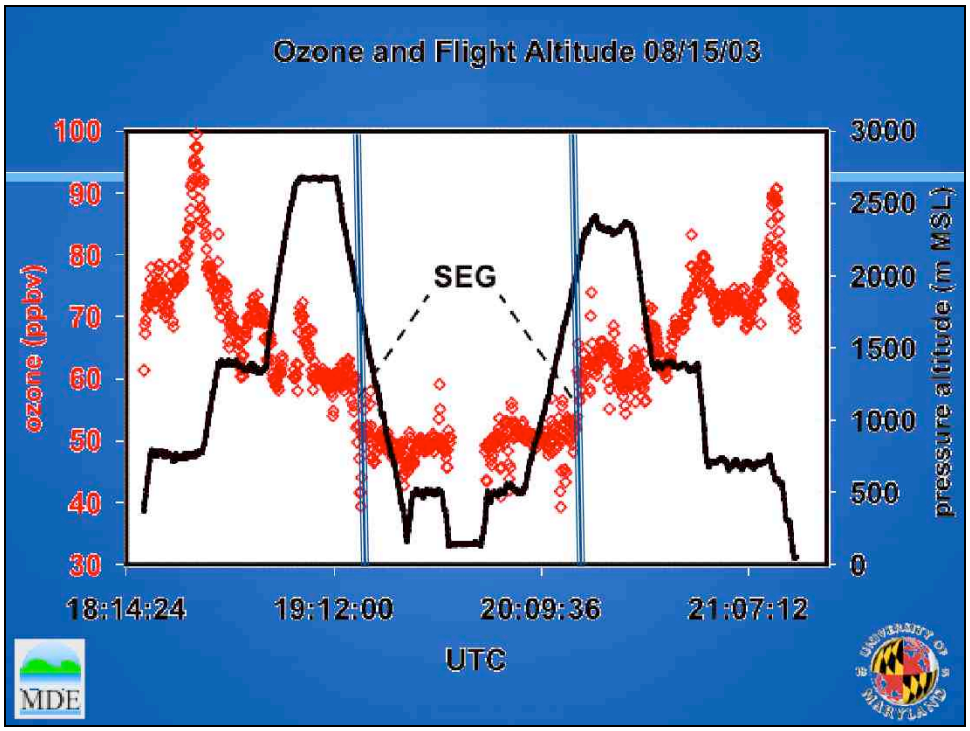
How about a *dynamic* model evaluation?

- Sudden changes in emissions are rare, but can be found:
  - 2003 Northeast Electrical Blackout
  - NOx controls installed around 2002 (the NOx SIP Call)
- Using the observations differently helps
  - Emphasize diagnostics and changes, not absolute concentrations
  - Diel cycles in ozone
  - Compare model to aircraft vertical profiles of pollutants
    - Transport and mixing of pollution

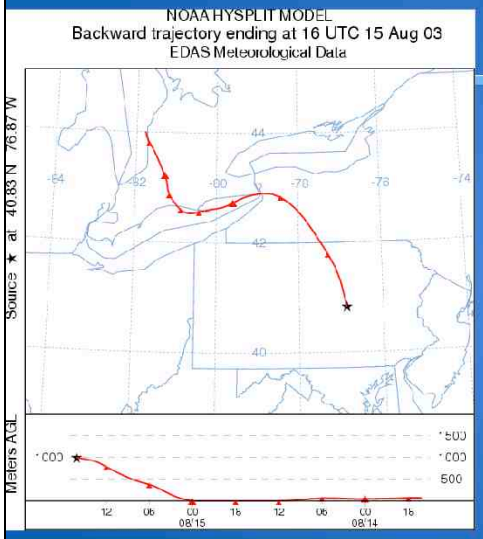

Pre-Blackout


Blackout

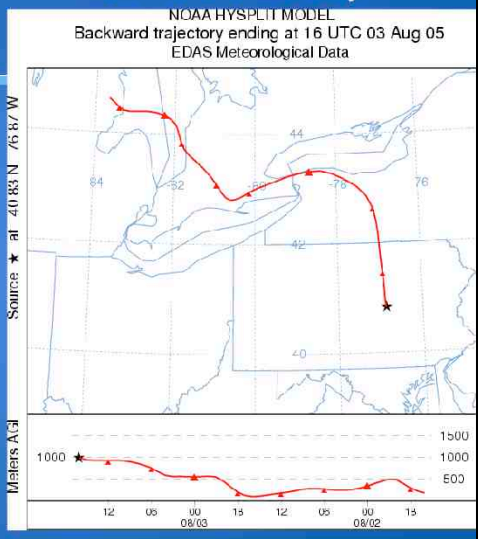

DMSP F15
15 August 2003
0114Z
~7 hrs after Blackout
Ottawa
Montreal
Toronto
Is dark
Albany
Brightness in
Boston is
unchanged
Detroit
Buffalo
Cleveland
Columbus
Brightness in
Long Island is
MUCH reduced
MDE


Ozone and Flight Altitude 08/15/03
100
90
80
70
60
50
40
30
ozone (ppbv)
3000
2500
2000
1500
1000
500
0
pressure altitude (m MSL)
SEG
18:14:24
19:12:00
20:09:36
21:07:12
UTC
MDE

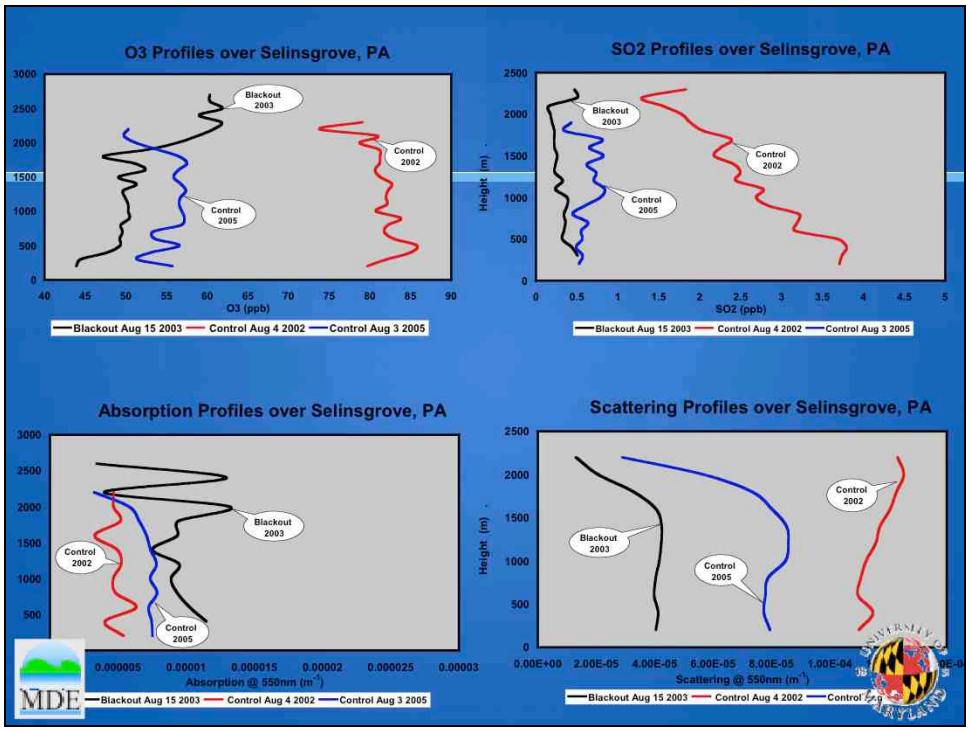
Blackout Day

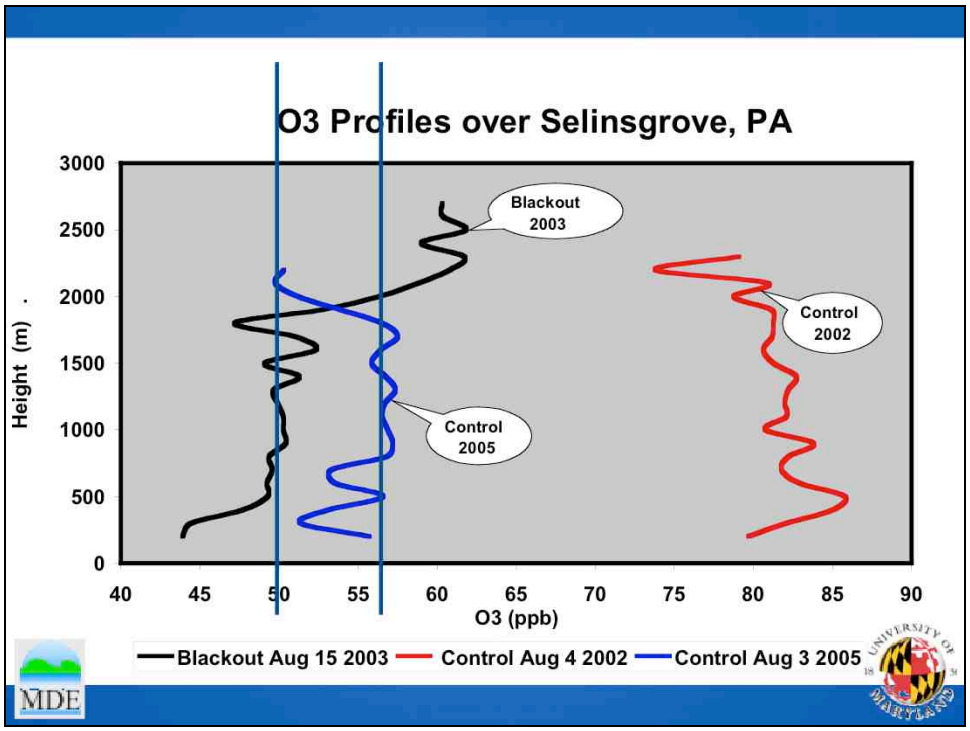


Original Reference Day
New Reference Day



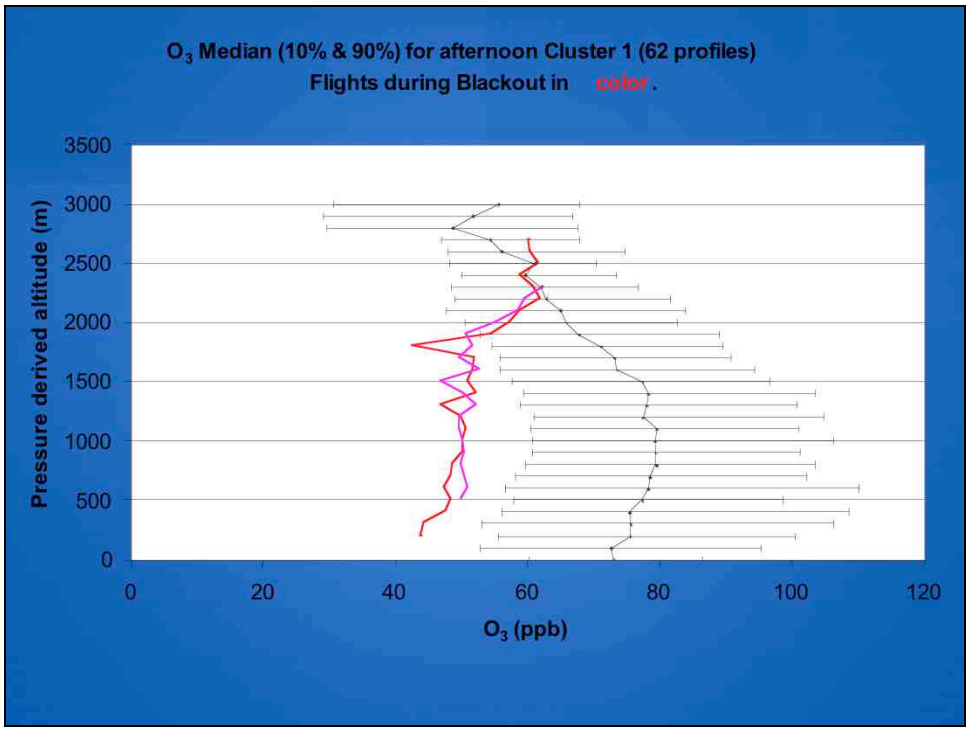
BUT the new day is after the NOx SIP Call's implementation!


O3 Profiles over Selinsgrove, PA
Blackout 2003
Control 2002
Control 2005
O3 (ppb)
Blackout Aug 15 2003
Control Aug 4 2002
Control Aug 3 2005
SO2 Profiles over Selinsgrove, PA
Blackout 2003
Control 2002
Control 2005
Height (m)
SO2 (ppb)
Blackout Aug 15 2003
Control Aug 4 2002
Control Aug 3 2005
Absorption Profiles over Selinsgrove, PA
Blackout 2003
Control 2002
Control 2005
Absorption @ 550nm (m-1)
Blackout Aug 15 2003
Control Aug 4 2002
Control Aug 3 2005
Scattering Profiles over Selinsgrove, PA
Blackout 2003
Control 2002
Control 2005
Height (m)
Scattering @ 550nm (m-1)
Blackout Aug 15 2003
Control Aug 4 2002
MDE


O3 Profiles over Selinsgrove, PA
Height (m)
3000
2500
2000
1500
1000
500
0
40
45
50
55
60
65
70
75
80
85
90
O3 (ppb)
Blackout 2003
Control 2002
Control 2005
Blackout Aug 15 2003
Control Aug 4 2002
Control Aug 3 2005
MDE
UNIVERSITY OF MARYLAND

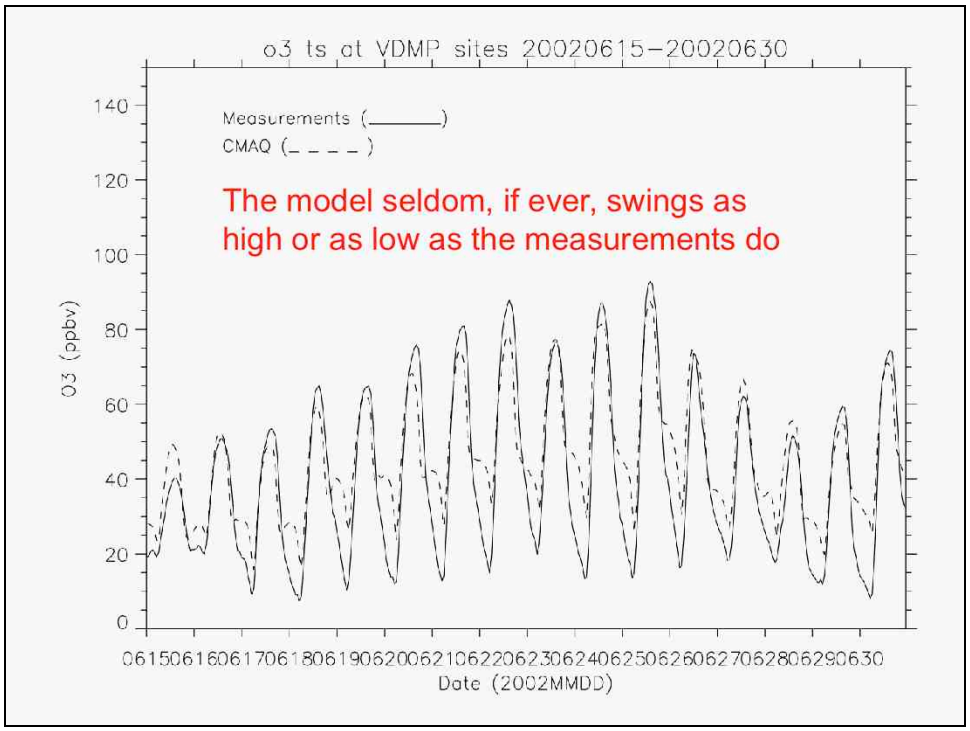
Climatology

- Compare with historical ozone flights under similar meteorological conditions
- Cluster back-trajectories to determine transport patterns on the days we flew
- Compare blackout ozone profile to statistical summary of all flights within the cluster that contains the blackout flight

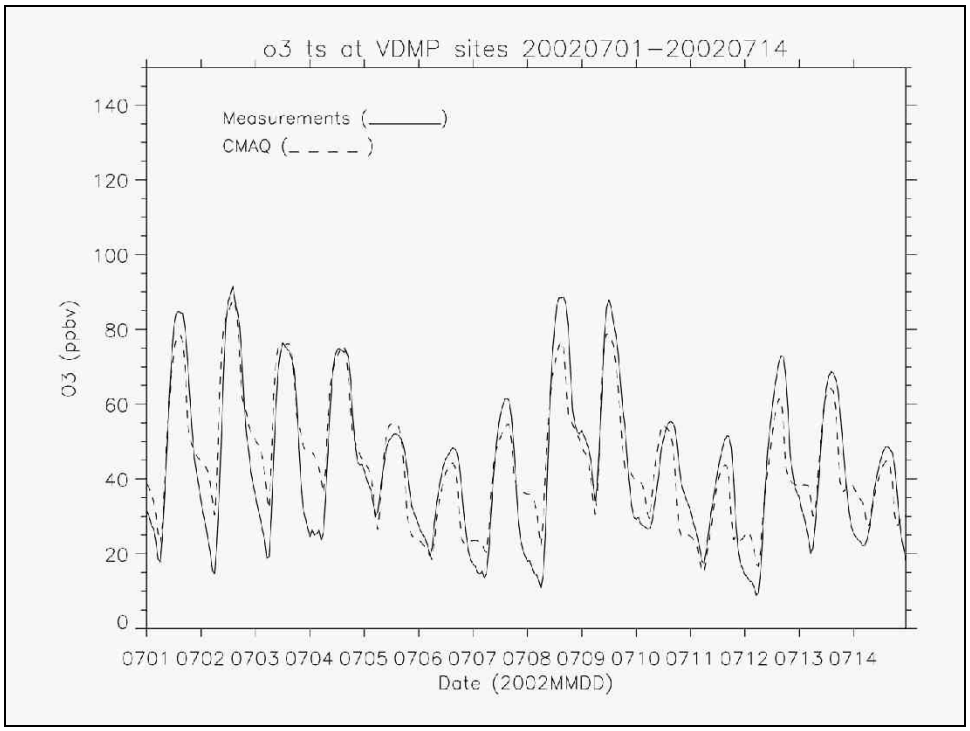

O_3 Median (10% & 90%) for afternoon Cluster 1 (62 profiles)
Flights during Blackout in color.
Pressure derived altitude (m)
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
120
O_3 (ppb)

Dynamic evaluation of the model

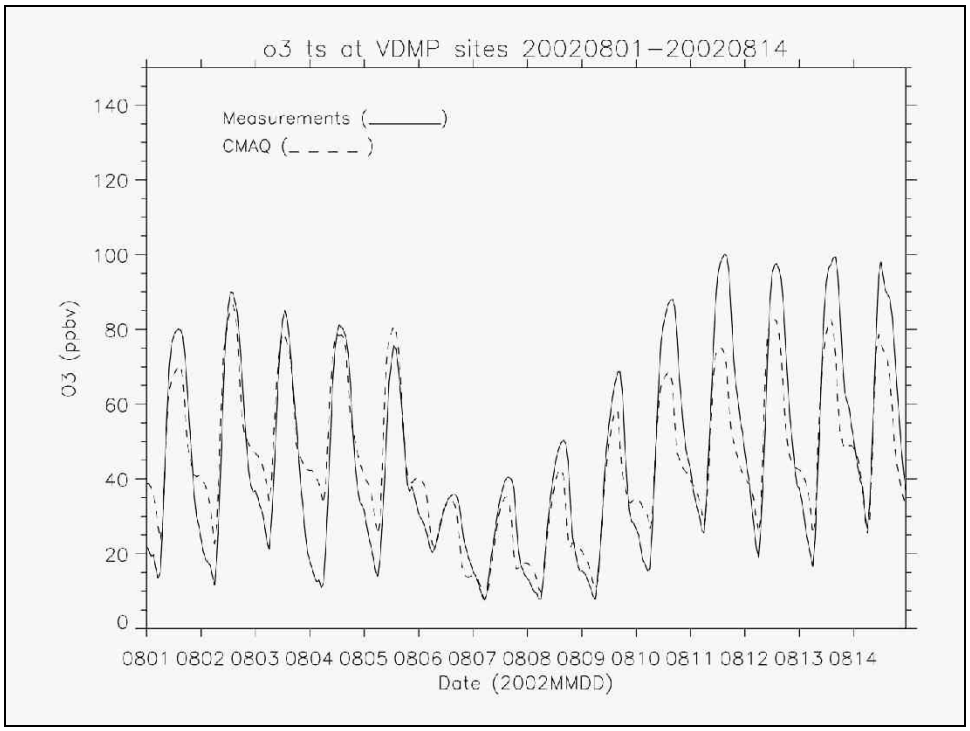
- CMAQ does not reproduce diurnal cycles well
  - Nighttime ozone performance poor, but perhaps expected?
  - Daytime peaks poor as well
- Statistics like mean error and bias necessarily make you look at average performance
  - Model development geared towards these measures!
  - Time to look at some new measures



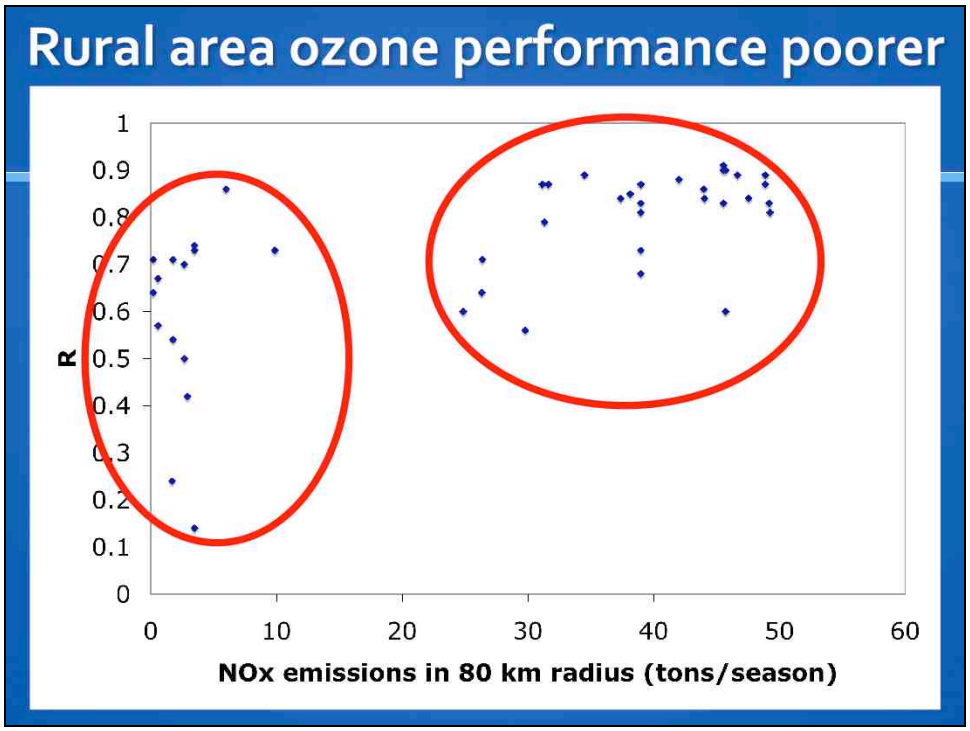
Averages taken at all monitoring stations in Virginia, Maryland, Delaware and Pennsylvania (VDMP); model sampled at those grid cells and averaged. June 15-30, 2002



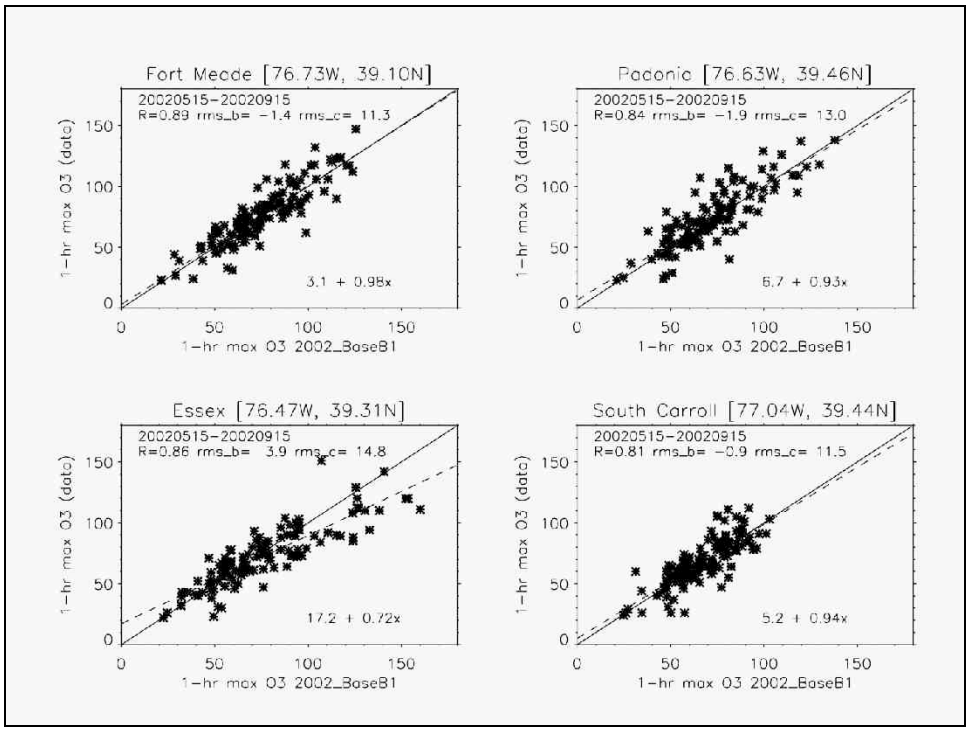
July 1-14, 2002

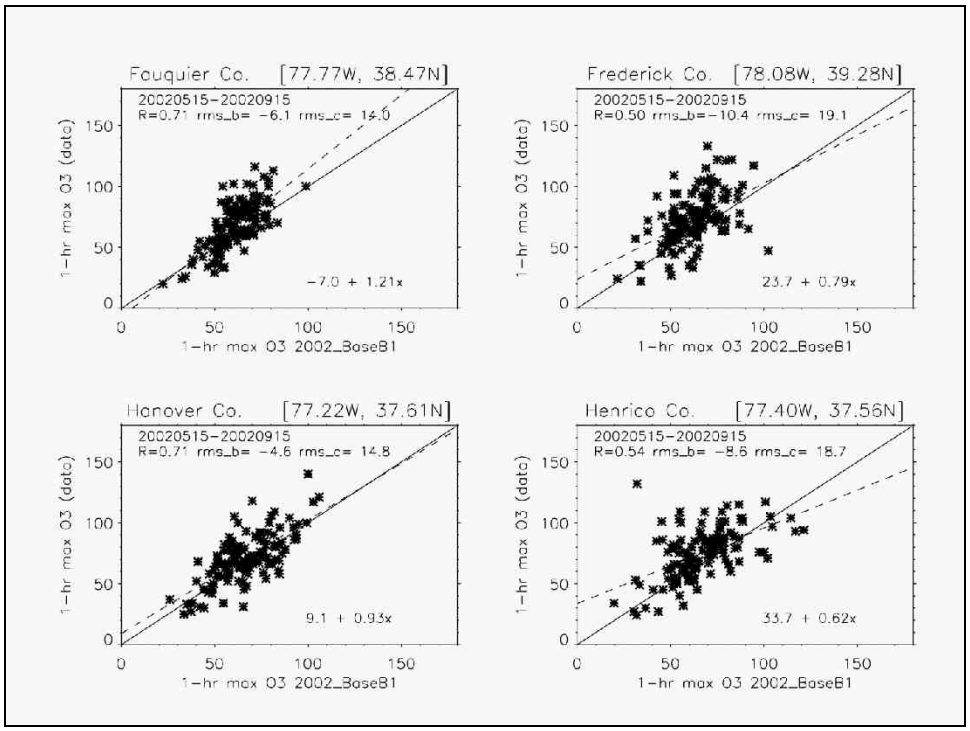


August 1-14, 2002.



Urban areas tend to have lots of cars, rural areas tend to have power plants. If we mess up the rural areas, we mess up the ozone that's coming into the city from outside and emphasize the wrong controls.

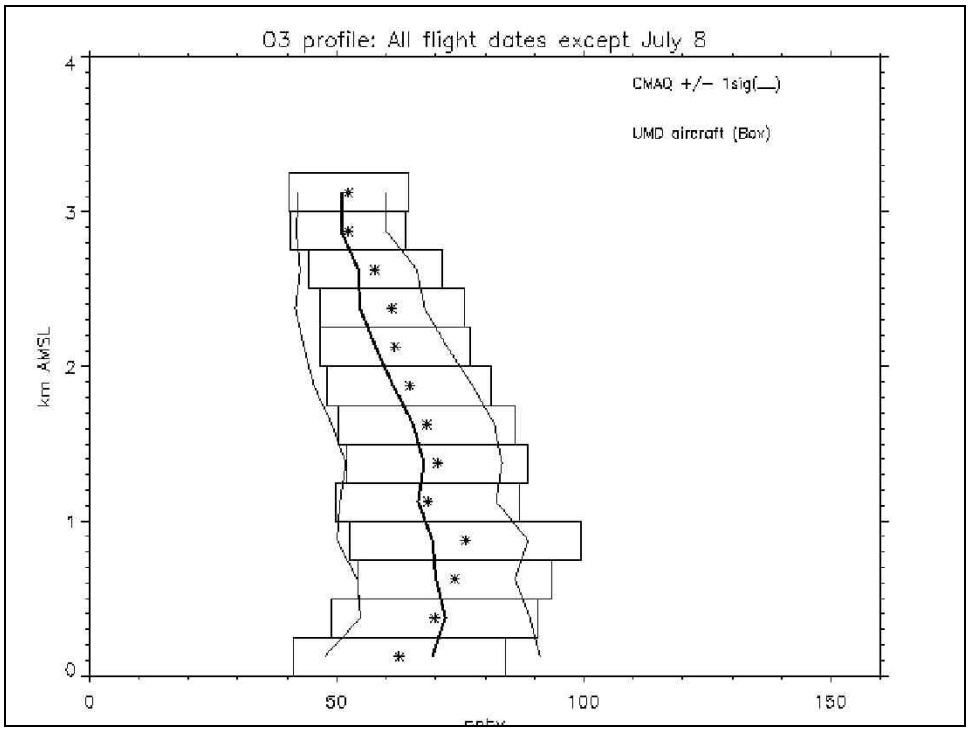

Fort Meade [76.73W, 39.10N]
20020515-20020915
R=0.89 rms_b= -1.4 rms_c= 11.3
3.1 + 0.98x
Paconic [76.63W, 39.46N]
20020515-20020915
R=0.84 rms_b= -1.9 rms_c= 13.0
6.7 + 0.93x
Essex [76.47W, 39.31N]
20020515-20020915
R=0.88 rms_b= 3.9 rms_c= 14.8
17.2 + 0.72x
South Carroll [77.04W, 39.44N]
20020515-20020915
R=0.81 rms_b= -0.9 rms_c= 11.5
5.2 + 0.94x
1-hr max O3 (data)
1-hr max O3 2002_BaseB1
0
50
100
150



Correlations much poorer at more rural sites.

Aloft performance

- CMAQ generally overpredicts ozone at the surface and underpredicts aloft
- Transport likely underrepresented
- Better than in the past, still not right.



CMAQ underpredicts ozone aloft and overpredicts it at the surface. Graph based on all flights in 2002 except July 8, which was heavily influenced by smoke from forest fires in central Quebec.

Dynamic Response Missing

- Generally falls short of peaks
  - Peaking units? Dyanmics? Chemistry?
- Generally overpredicts nighttime minima
  - NOx titration, sure, but:
    - Everywhere?
    - What about the odd shape?
- Model lacks dynamic range.
- Lack of response due to…?

Long-term response to emissions changes

- In New Jersey, 2009 design values arrived in 2006!
- There were still more emissions reductions to come

2009 Came Early to New Jersey

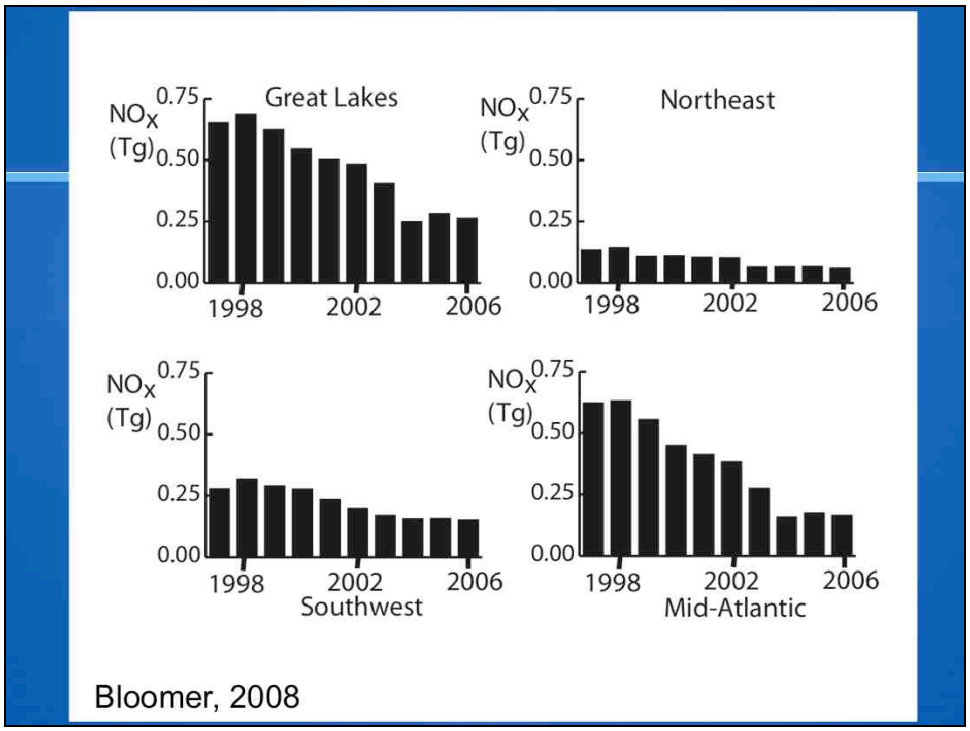
		2006	Model 2009	
COUNTY	OZONE MONITOR LOCATION	2004-2006 DESIGN VALUE	Modeled Predicted O3 Concentration (BOTW-v.3)	
Atlantic	Nacote Creek	78	75	+
Passaic	Ramapo	79	79	o
Monmouth	West Long Beach (Monmouth Univ)	81	83	-
Morris	Chester	82	85	-
Camden	Camden Lab	83	89	-
Bergen	Teaneck	85	87	-
Cumberland	Millville	85	82	+
Gloucester	Clarksboro	85	88	-
Hudson	Bayonne	85	80	+
Mercer	Rider U	87	87	o
Middlesex	Rutgers U	88	86	+
Hunterdon	Flemington	88	84	+
Camden	Ancora	88	90	-
Ocean	Colliers Mills	92	93	-
	Average (ppb)	85	85	

Papalski, NJDEP, 2006

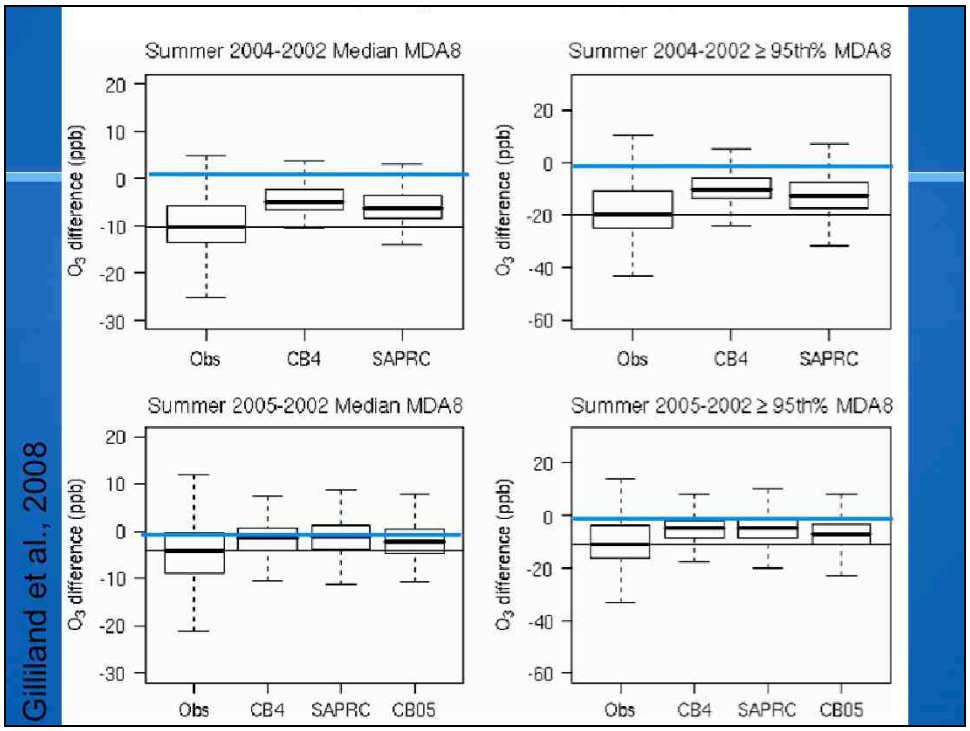
The +/-/o signs along the right side indicate where 2006 numbers were with respect to 2009

Response to the NOx SIP Call

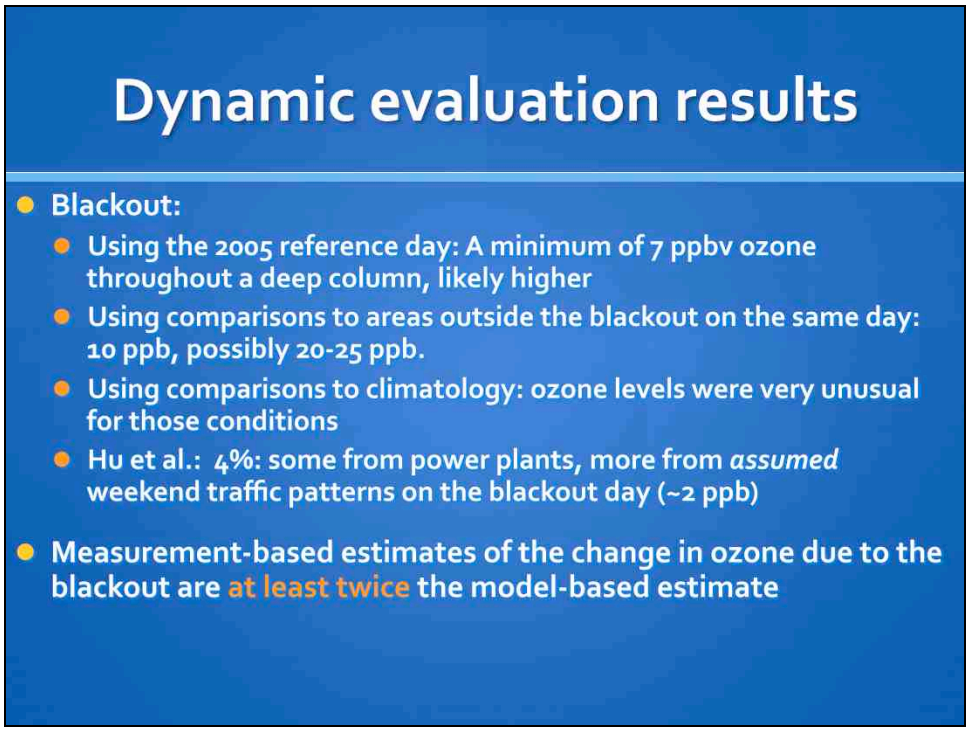
- Around 2002-2004, HUGE emissions controls went in on power plants, many upwind of Maryland—the NOx SIP Call
- EPA and collaborators modeled 2002, 2004 and 2005 meteorology, emissions, and chemistry
- Look at CMAQ's response to the NOx SIP Call



Bloomer, 2008



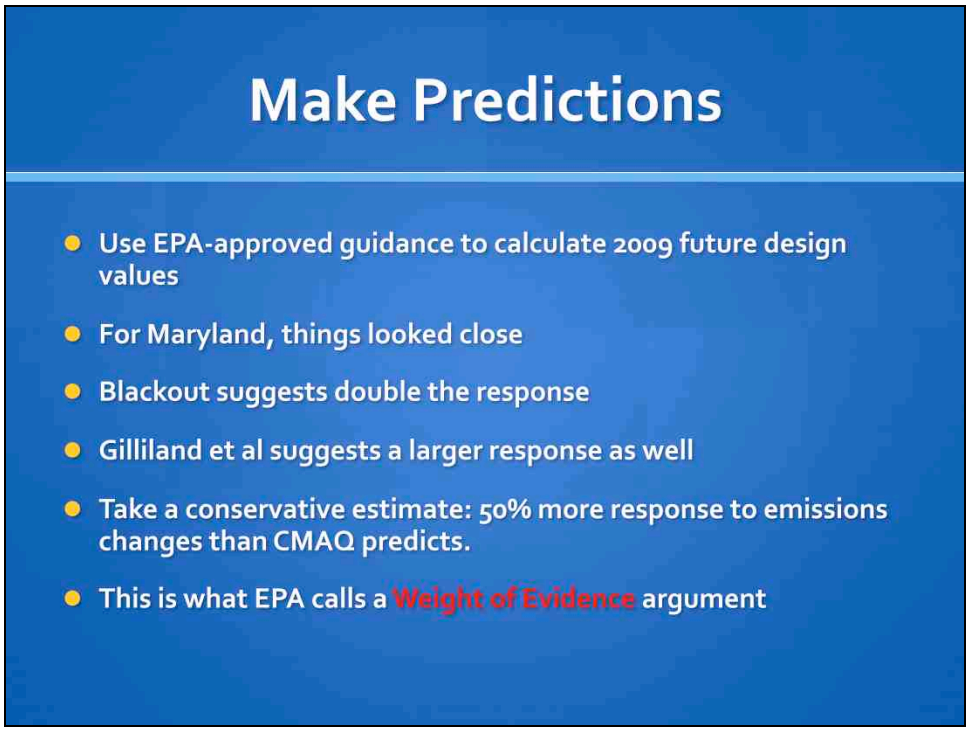
The model never shows the same level of change that the measurements indicate between 2002 and 2004/2005. Generally, the response is about half that measured in reality.



Hu et al. is a paper from Georgia Tech that simulated the effects of the blackout by examining the measured emissions from the blacked out plants and assuming weekend travel patterns on that day (toll booth records and measurements of species other than ozone suggest otherwise) throughout the affected area. They got a 4% reduction in ozone from the blackout.

Dynamic Evaluation Results

- Dynamic model evaluation
  - CMAQ underpredicts the peaks, overpredicts nighttime lows: poor response to emissions changes
  - Performance poorer in upwind rural areas
- New Jersey effect
  - 2009 modeled design values at the highest monitors (New Jersey) were already there by 2006

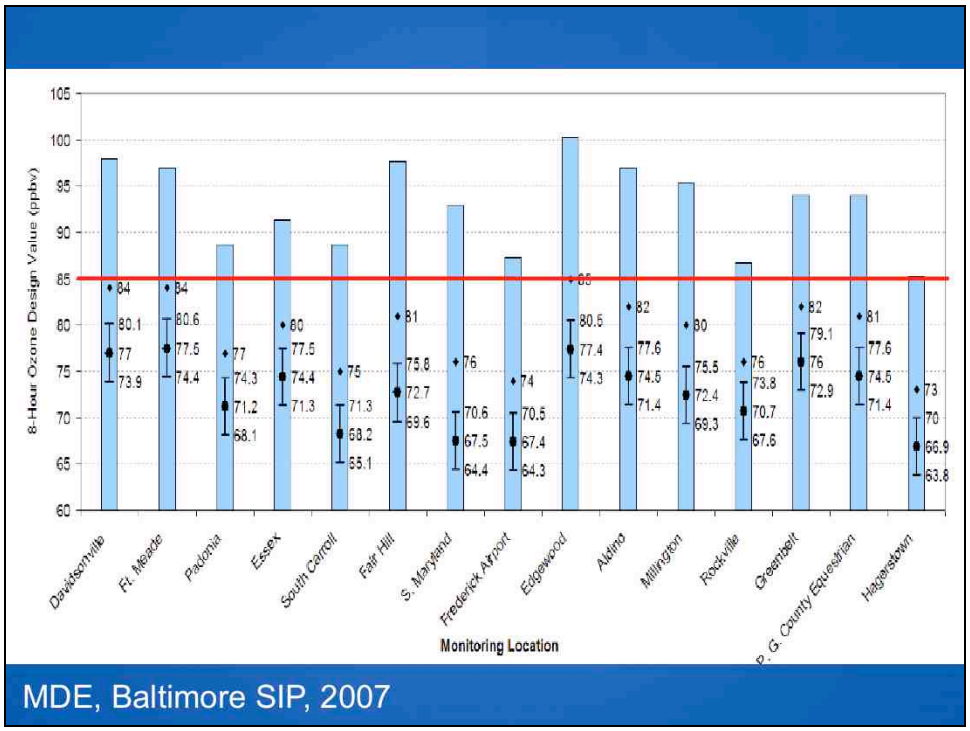


Weight of evidence is essentially arguing. If your prediction is that you will be close to the standard (below or above) in the future, you have to argue why your area should be able to attain the standard using more than just model results. In my view, this amounts to "prove the model is right".

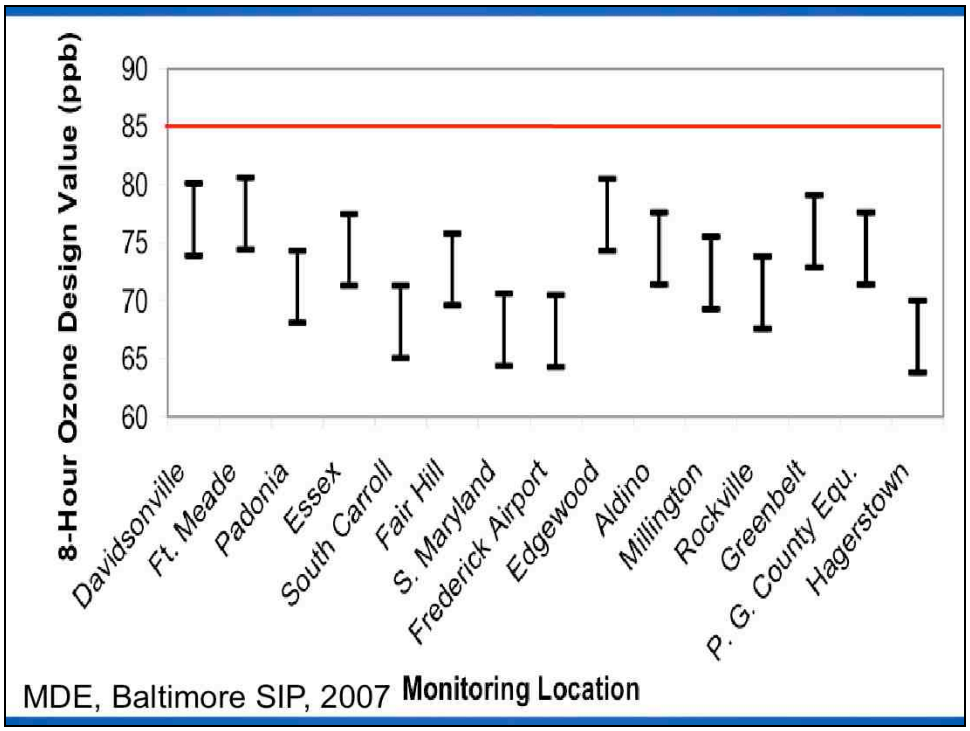
Maryland Model Predictions

- Also include a RANGE of possible future outcomes
- Spread in model runs using estimates of future year emissions
- Spread in 4th highest ozone from years around the base year*

*The only idea EPA liked



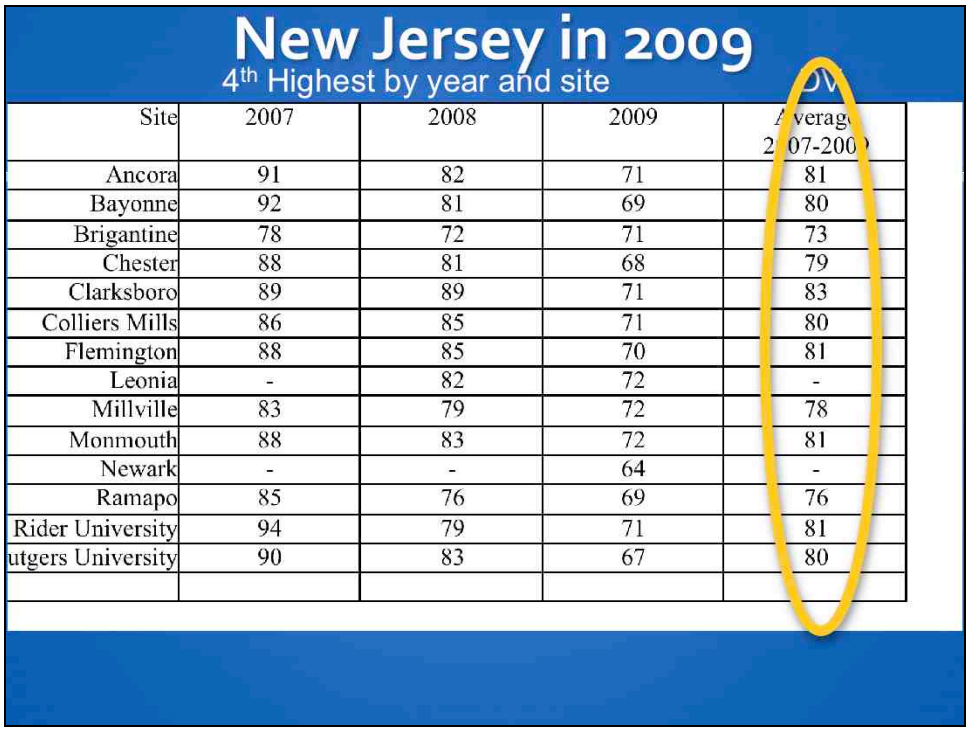
The red line was the ozone standard for this SIP = State Implementation Plan



MDE = Maryland Department of the Environment

Table 3. Current and Projected Design Values and Their Uncertainties for Maryland Monitors

Monitor Name	AIRS-ID	Observed	Modeled		Probable		
		2002 Design Value	2009 Design Value	2012 Design Value	2009 Design Value	2009 Lower Bound	2009 Upper Bound
Davidsonville	240030014	98.0	84	78	77.0	73.9	80.1
Ft. Meade	240030019	97.0	84	78	77.5	74.4	80.6
Padonia	240051007	88.7	77	72	71.2	68.1	74.3
Essex	240053001	91.3	80	76	74.4	71.3	77.5
South Carroll	240130001	88.7	75	69	68.2	65.1	71.3
Fair Hill	240150003	97.7	81	75	72.7	69.6	75.8
S. Maryland	240170010	93.0	76	70	67.5	64.4	70.6
Frederick Airport	240210037	87.3	74	68	67.4	64.3	70.5
Edgewood	240251001	100.3	85	80	77.4	74.3	80.5
Aldino	240259001	97.0	82	76	74.5	71.4	77.6
Millington	240290002	95.3	80	74	72.4	69.3	75.5
Rockville	240313001	86.7	76	71	70.7	67.6	73.8
Greenbelt	240330002	94.0	82	76	76.0	72.9	79.1
P. G. County Equestrian	240338003	94.0	81	76	74.5	71.4	77.6
Hagerstown	240430009	85.3	73	67	66.9	63.8	70.0



Site	2007	2008	2009	Average 2007-2009
Ancora	91	82	71	81
Bayonne	92	81	69	80
Brigantine	78	72	71	73
Chester	88	81	68	79
Clarksboro	89	89	71	83
Colliers Mills	86	85	71	80
Flemington	88	85	70	81
Leonia	-	82	72	-
Millville	83	79	72	78
Monmouth	88	83	72	81
Newark	-	-	64	-
Ramapo	85	76	69	76
Rider University	94	79	71	81
utgers University	90	83	67	80

All sites in attainment!!

New Jersey in 2009

COUNTY	OZONE MONITOR LOCATION	2004-2006 DESIGN VALUE	Modeled Predicted O3 Concentration (BOTW-v.3)
Atlantic	Nacote Creel	78	75
Passaic	Ramapo	79	79
Monmouth	West Long B	81	83
Morris	Chester	82	85
Camden	Camden Lab	83	89
Bergen	Teaneck	85	87
Cumberland	Millville	85	82
Gloucester	Clarksboro	85	88
Hudson	Bayonne	85	80
Mercer	Rider U	87	87
Middlesex	Rutgers U	88	85
Hunterdon	Flemington	88	84
Camden	Ancora	88	90
Ocean	Colliers Mills	92	93
	Average (ppb	85	85

Site	Average 2007-2009
Nacote Creek	-
Ramapo	76
Monmouth	81
Chester	79
Camden Lab	-
Teaneck	-
Millville	78
Clarksboro	83
Bayonne	80
Rider U	81
Rutgers U	80
Flemington	81
Ancora	81
Colliers Mills	80

Note how many sites were projected to be far out of attainment

Site Name	Design Value (ppb)		4th Maximum Concentration (ppb)				Modeled		Probable		
	2008	2009	2006	2007	2008	2009	2009 DV	2012 DV	2009 DV	2009 Lower Bound	2009 Upper Bound
Southern Maryland	82	75	85	83	78	66	76	70	67.5	64.4	70.6
Frederick Airport	82	76	85	86	75	69	74	68	67.4	64.3	70.5
Rockville	84	78	88	88	76	70	76	71	70.7	67.6	73.8
PG Equestrian Center	87	78	95	88	79	67	81	76	74.5	71.4	77.6
Mount Vernon	87	80	88	88	85	69					
Franconia	85	80	87	85	85	70					
McMillian Reservoir	87	80	90	87	84	71					
Davidsonville	87	80	92	89	81	70	84	78	77	73.9	80.1
Padonia	80	75	81	72	87	68	77	72	71.2	68.1	74.3
Essex	85	78	91	83	81	71	80	76	74.4	71.3	77.5
South Carroll	83	78	82	89	78	68	75	69	68.2	65.1	71.3
Edgewood	91	87	95	90	88	83	85	80	77.4	74.3	80.5
Aldino	89	82	90	92	85	69	82	76	74.5	71.4	77.6
Millington	83	78	82	83	85	66	80	74	72.4	69.3	75.5
Hagerstown	78	73	79	81	75	65	73	67	66.9	63.8	70
Fairhill	90	84	92	92	88	72	81	75	72.7	69.6	75.8
Colliers Mills	87	80	91	86	85	71					
Bucks Co PA	91	87	87	102	85	74					

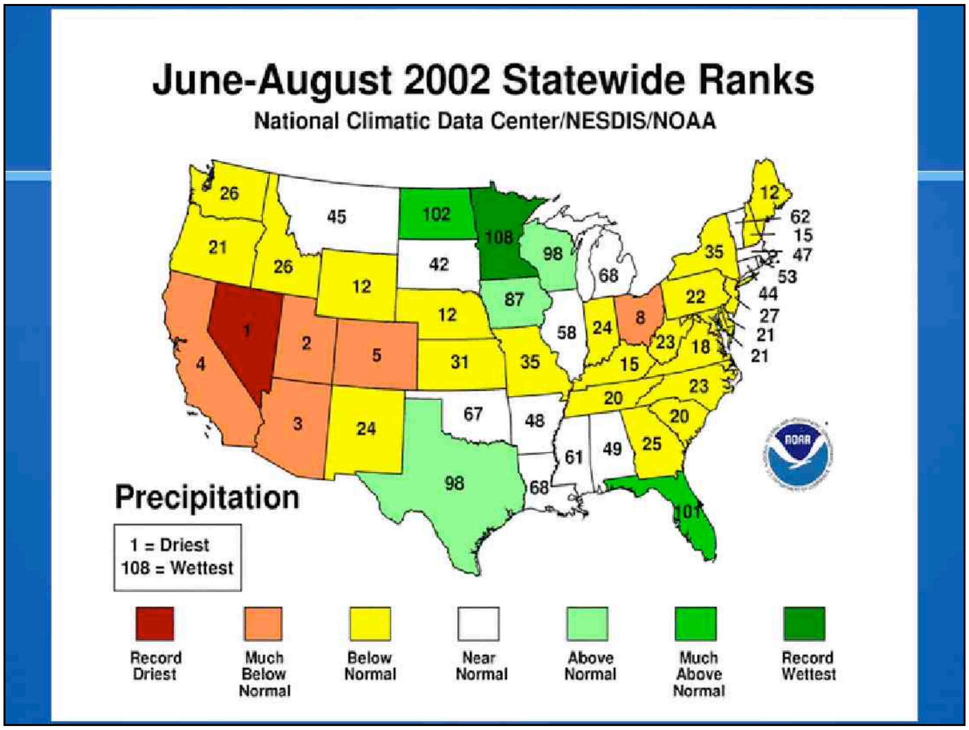
Note the boxes in pink and blue in the 2009 DV column. Four of our predictions were too high for 2009 and only one was too low. Clearly something is unusual about Edgewood.

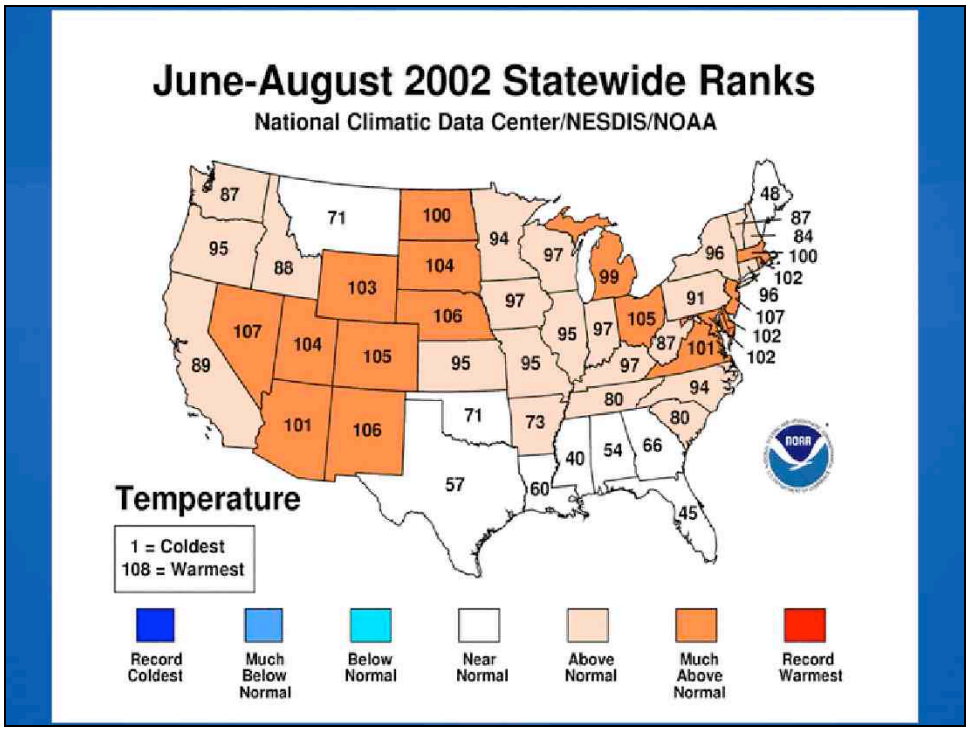
Site Name	Design Value (ppb)	4th Maximum Concentration (ppb)	Modeled	Most Probable
	2009	2009	2009 DV	2009 DV
Southern Maryland	75	66	**76**	67.5
Frederick Airport	76	69	**74**	67.4
Rockville	78	70	**76**	70.7
PG Equestrian Center	78	67	**81**	74.5
Mount Vernon	80	69		
Franconia	80	70		
McMillian Reservoir	80	71		
Davidsonville	80	70	**84**	77
Padonia	75	68	**77**	71.2
Essex	78	71	**80**	74.4
South Carroll	78	68	**75**	68.2
Edgewood	87	83	**85**	77.4
Aldino	82	69	**82**	74.5
Millington	78	66	**80**	72.4
Hagerstown	73	65	**73**	66.9
Fairhill	84	72	**81**	72.7
Colliers Mills	80	71		
Bucks Co PA	87	74		

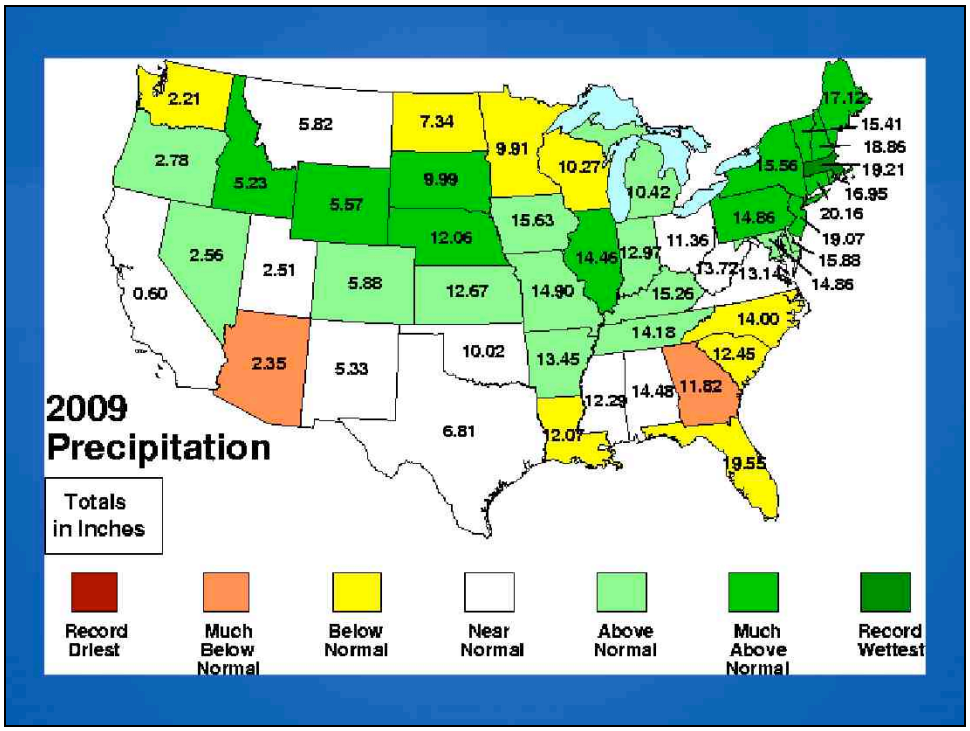
Even the 3 year average “design values” were close. (Colliers Mills (NJ) and Bucks County (PA) are particularly difficult sites in the Philadelphia nonattainment area)

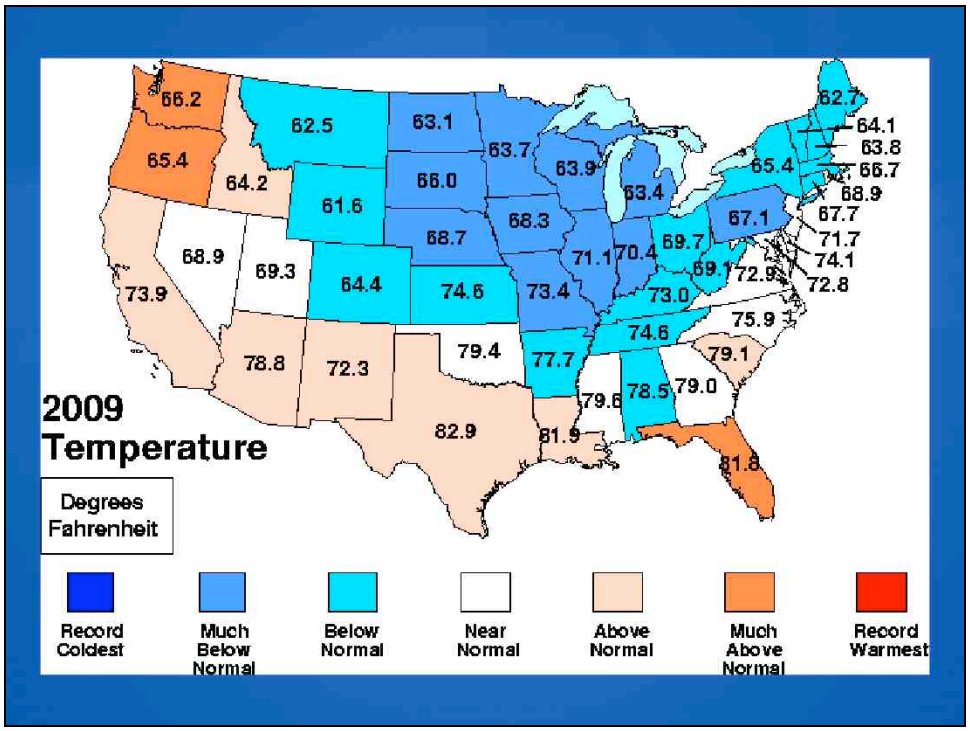
Lucky or good?

- 2009 was not 2002
- 2009 unusually wet, cool…
- 2002 unusually hot, dry


June-August 2002 Statewide Ranks
National Climatic Data Center/NESDIS/NOAA
Precipitation
1 = Driest
108 = Wettest
Record Driest
Much Below Normal
Below Normal
Near Normal
Above Normal
Much Above Normal
Record Wettest


June-August 2002 Statewide Ranks
National Climatic Data Center/NESDIS/NOAA
87
71
100
94
97
99
48
87
84
100
102
96
107
102
102
95
88
104
103
97
96
91
107
104
105
106
95
97
105
87
101
89
95
97
80
94
101
106
71
73
80
40
54
66
57
60
45
Temperature
1 = Coldest
108 = Warmest
Record Coldest
Much Below Normal
Below Normal
Near Normal
Above Normal
Much Above Normal
Record Warmest


2009
Precipitation
Totals
in Inches
2.21
5.82
7.34
9.91
10.27
10.42
17.12
15.41
18.86
19.21
16.95
20.16
19.07
15.88
14.86
15.56
14.86
2.78
5.23
5.57
9.99
12.06
15.63
14.46
12.97
11.36
13.72
13.14
15.26
14.18
14.00
12.45
11.82
19.55
14.48
12.29
12.07
2.56
2.51
5.88
12.67
14.90
0.60
2.35
5.33
10.02
13.45
6.81
Record
Driest
Much
Below
Normal
Below
Normal
Near
Normal
Above
Normal
Much
Above
Normal
Record
Wettest


66.2
65.4
64.2
62.5
61.6
63.1
66.0
68.7
63.7
68.3
63.9
63.4
62.7
64.1
63.8
66.7
68.9
65.4
67.1
67.7
71.7
74.1
72.8
72.9
69.7
71.1
70.4
69.1
73.0
75.9
74.6
68.9
69.3
64.4
74.6
73.4
73.9
78.8
72.3
79.4
77.7
79.6
78.5
79.0
79.1
82.9
81.9
81.8
2009
Temperature
Degrees
Fahrenheit
Record
Coldest
Much
Below
Normal
Below
Normal
Near
Normal
Above
Normal
Much
Above
Normal
Record
Warmest

Lucky or Good? Both!

- Substantial power plant emission reductions were installed in Maryland for the summer of 2009
- Summer of 2009 was cool and wet, then just cool, then warm and convectively active
- Summer of 2002 was very hot and dry
- Predictions for 2012 suggest greatly improved air quality due to ongoing automobile fleet turnover & better exhaust systems

Site Name	Design Value (ppb)	4th Maximum Concentration (ppb)	Modeled	Most Probable	
	2009	2009	2012 DV	2009 DV	2009 Upper Bound
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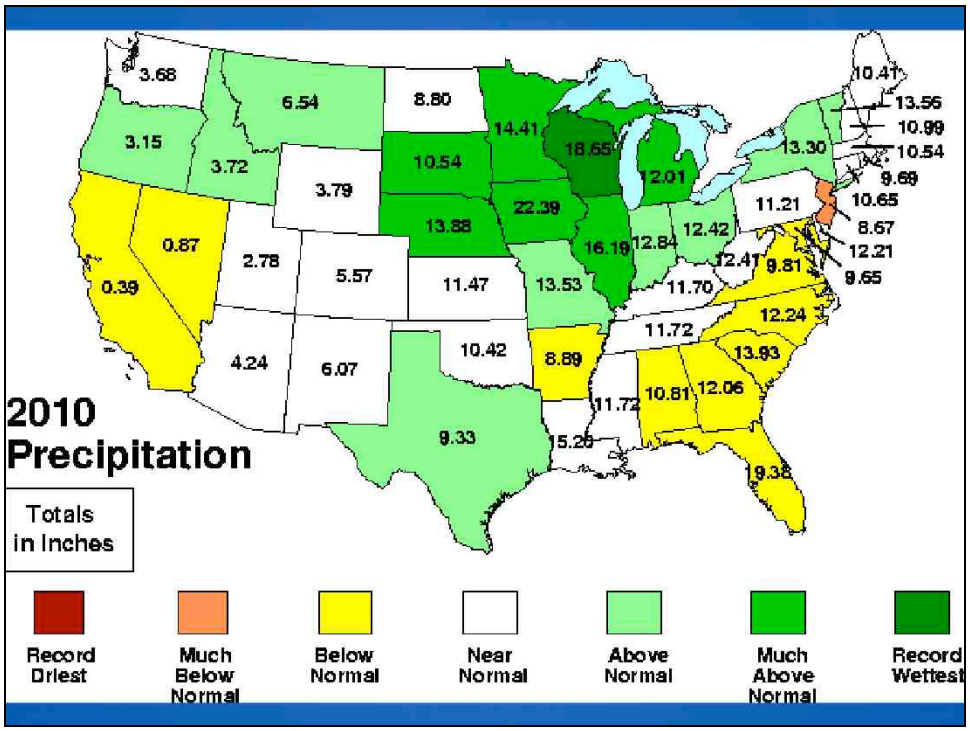
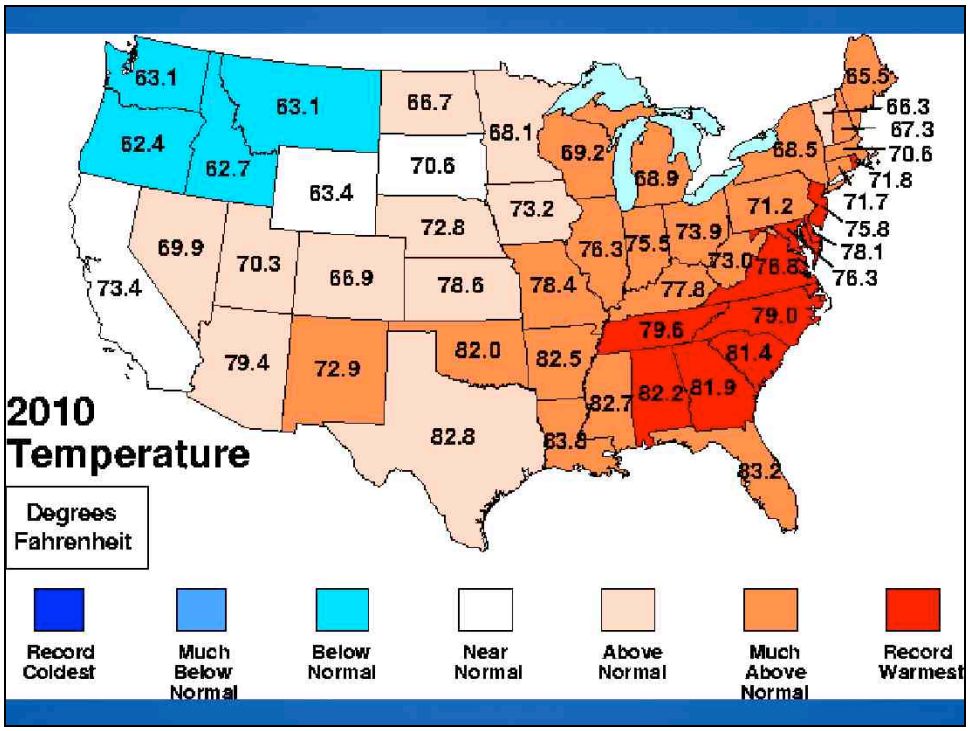
PG Equestrian Center	78	67	76	74.5	77.6
Mount Vernon	80	69			
Franconia	80	70			
McMillian Reservoir	80	71			
Davidsonville	80	70	78	77	80.1
Padonia	75	68	72	71.2	74.3
Essex	78	71	76	74.4	77.5
South Carroll	78	68	69	68.2	71.3
Edgewood	87	83	80	77.4	80.5
Aldino	82	69	76	74.5	77.6
Millington	78	66	74	72.4	75.5
Hagerstown	73	65	67	66.9	70
Fairhill	84	72	75	72.7	75.8
Colliers Mills	80	71			
Bucks Co PA	87	74			

We're going to start thinking of Edgewood as its own private nonattainment area.


2010
Precipitation
Totals
in Inches
3.68
6.54
8.80
14.41
18.65
12.01
10.41
13.56
10.99
10.54
9.69
10.65
8.67
12.21
9.65
3.15
3.72
3.79
10.54
22.39
13.88
16.19
12.84
12.42
12.41
9.81
11.21
13.30
0.67
0.39
2.78
5.57
11.47
13.53
11.70
11.72
12.24
13.93
4.24
6.07
10.42
8.89
11.72
10.81
12.06
9.33
15.20
9.38
Record
Driest
Much
Below
Normal
Below
Normal
Near
Normal
Above
Normal
Much
Above
Normal
Record
Wettest


2010
Temperature
Degrees
Fahrenheit
63.1
63.1
66.7
68.1
65.5
66.3
67.3
70.6
71.8
71.7
75.8
78.1
76.3
62.4
62.7
63.4
70.6
69.2
68.9
68.5
71.2
73.9
73.0
72.8
73.2
69.9
70.3
66.9
78.6
76.3
75.5
78.4
77.8
73.4
79.4
72.9
82.0
82.5
79.6
79.0
81.4
82.7
82.2
81.9
82.8
83.8
83.2
Record
Coldest
Much
Below
Normal
Below
Normal
Near
Normal
Above
Normal
Much
Above
Normal
Record
Warmest

Lucky or Good? Both!

- Taking model predictions at face value, we needed a little help in 2009 and we got it.
- We didn't get that much help!
- We got no help in 2010, and with the exception of one site, we were fine
- Two very interesting/irritating sites: Edgewood, MD and Bucks Co, PA.
- The standard will probably fall to 60-70 ppbv in the near future, which will be difficult to achieve

Conclusions

- Dynamic model evaluation produced more reasonable results for most sites
- Edgewood is clearly quite different
  - Think of it as its own area with its own problems?
- Fine particles did NOT work this way (attainment was easy)
- Models only develop the way we push them to
- If we're going to use a model to predict change, we must evaluate its ability to do so and develop the model accordingly.

Acknowlegements

- Lackson Marufu, Jennifer Hains, Russ Dickerson, Charles Piety, Dale Allen, Brett Taubman, Bruce Doddridge, Bob Hudson, Shunli Zhang, Da-Lin Zhang, Lacey Brent, Hao He, Heather Arkinson
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- Christian Hogrefe, everyone else at NYDEC
- Ray Papalski, Andy Mikula NJDEP


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