Performance of the NAQFC in Philadelphia during Summer 2016

Amy K. Huff
William F. Ryan
Matthew Brown

Department of Meteorology
Pennsylvania State University

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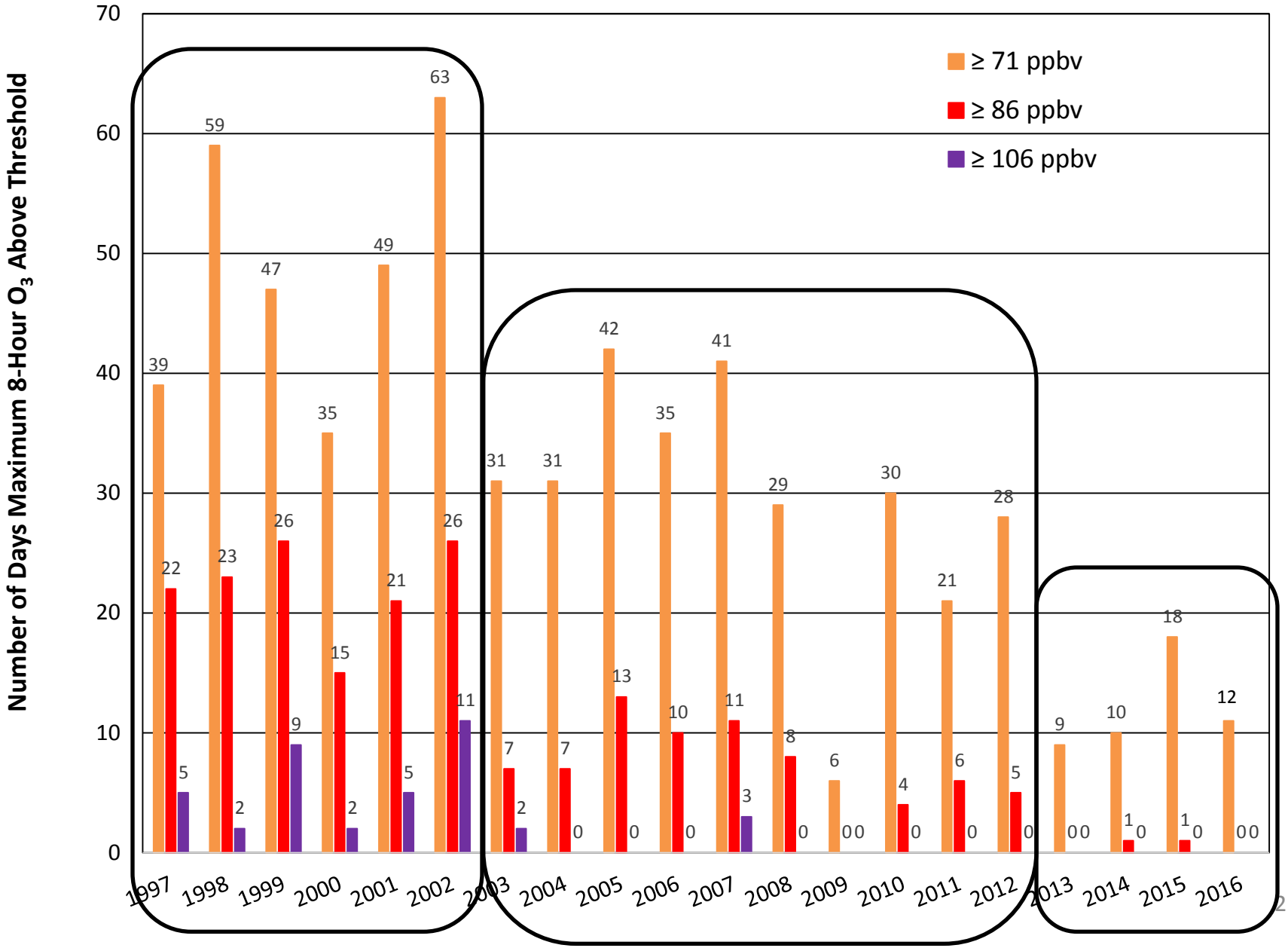
4th Consecutive Historically Low O_3 Season in PHL

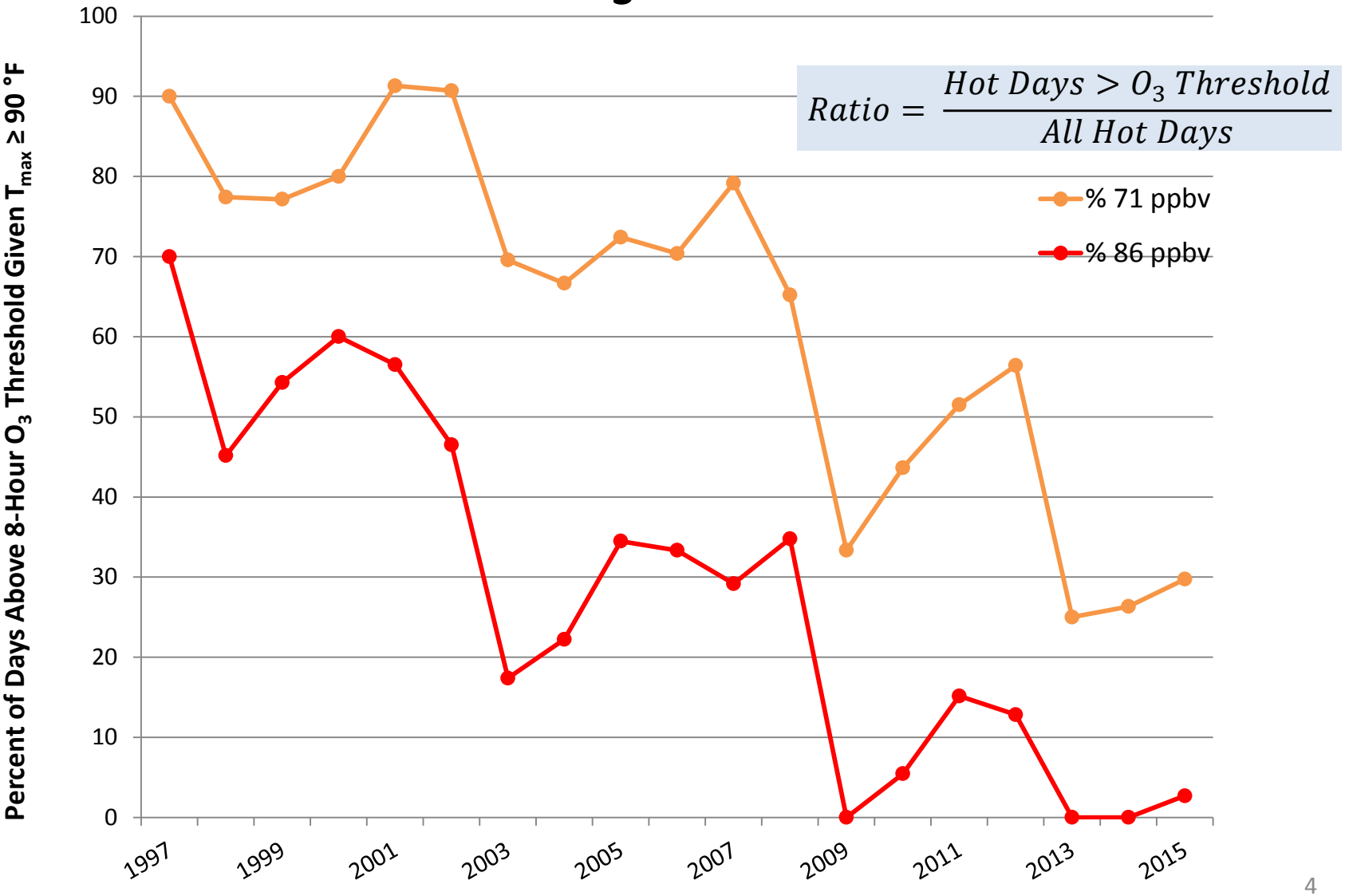


12 Ozone Exceedance Days So Far in PHL in 2016

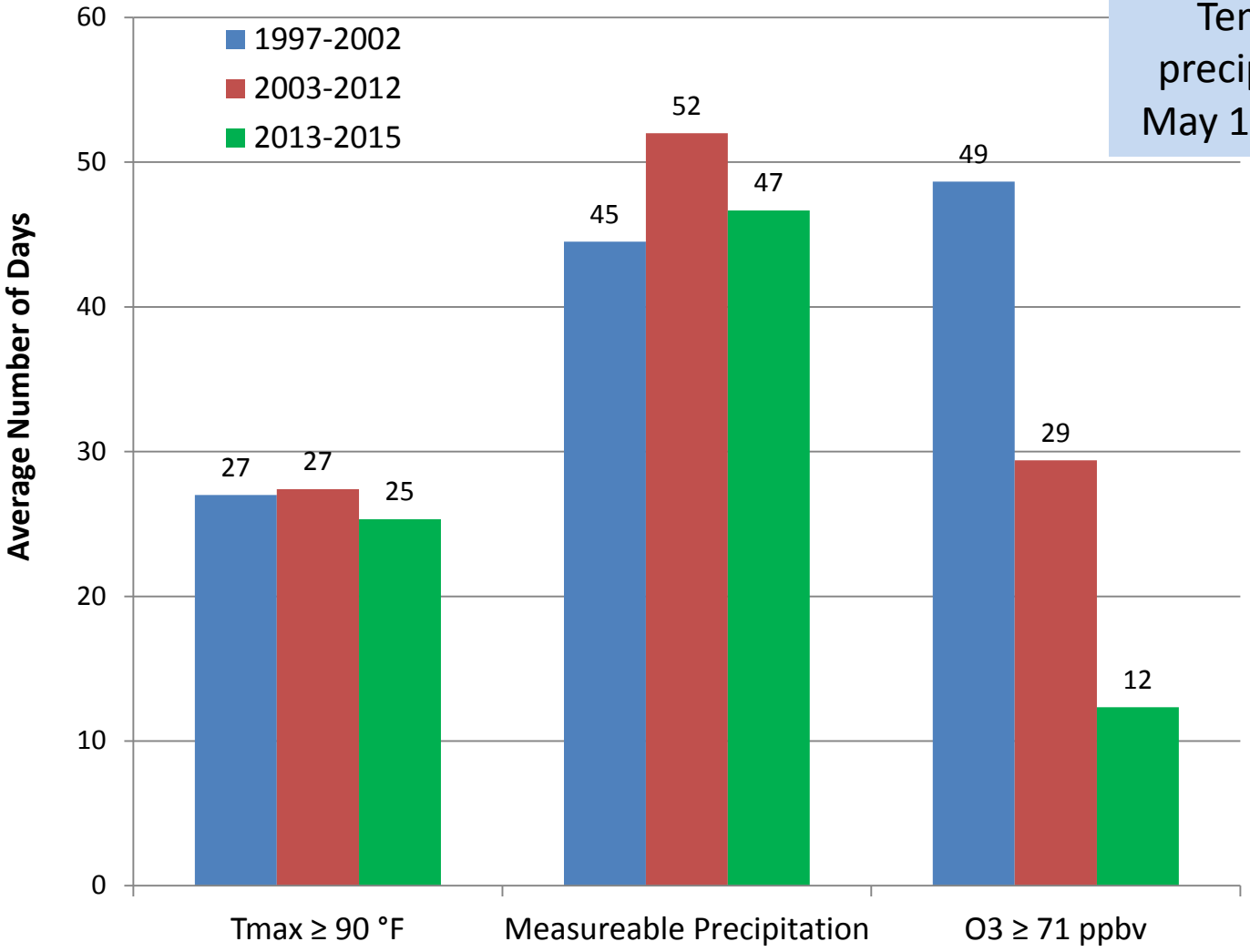
Date	Day of Week	Philadelphia		Delaware		Notes on Event
		Number of Monitors	Max ppbv	Number of Monitors	Max ppbv	
5/25	Wed	6	84	6	87	Transported smoke
5/26	Thu	6	81	5	75	Transported smoke
6/1	Wed	1	71	----	----	Weak frontal boundary
6/11	Sat	3	75	4	74	Hot; upwind transport; previous day Good
6/15	Wed	1	75	----	----	Recirculation aloft; previous day Good
6/20	Mon	6	75	2	73	Classic hot w/ westerly transport aloft
6/25	Sat	1	72	----	----	Light easterly surface winds
6/26	Sun	1	76	----	----	Stagnation; mid-level high overhead
7/21	Thu	3	81	----	----	Transported smoke; stagnation
7/22	Fri	7	84	4	84	Transported smoke; classic hot
8/27	Sat	----	----	2	73	Recirculating surface winds; MLR
8/30	Wed	4	80	----	----	b/w CF and TD8; hot; light SW winds
9/14	Wed	1	71	2	73	Pre-frontal; hot; light SW winds; previous day Good

Indicates forecast hit

Hot Days (T_{max} > 90°F) are No Longer Strongly Associated with O_3 Exceedances in PHL



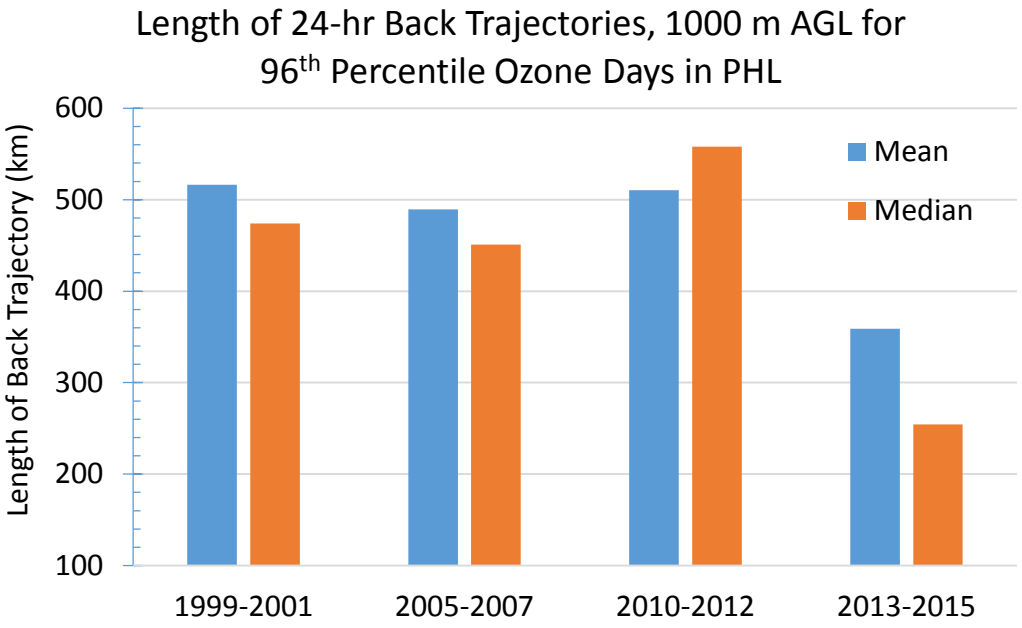
Recent Reductions in Observed O_3 Not Primarily Due to Meteorology



Temperature and precipitation at KPHL, May 1 to September 30

Implications for Forecasting O_3

- Historical forecast variables no longer reliably predict high O_3 days
  - $T_{max} \geq 90\,^{\circ}F$ rarely necessary and sufficient; T_{max} threshold lower ($83\,^{\circ}F$?)
  - Persistence less reliable: fewer multi-day, regional events, more single day isolated "spikes" at only 1-2 monitor locations; periodic Good to USG O_3
  - Stagnation cases more prevalent, less emphasis on westerly transport from precursor source region in Ohio River Valley
- Mesoscale features increasingly important for forecast skill



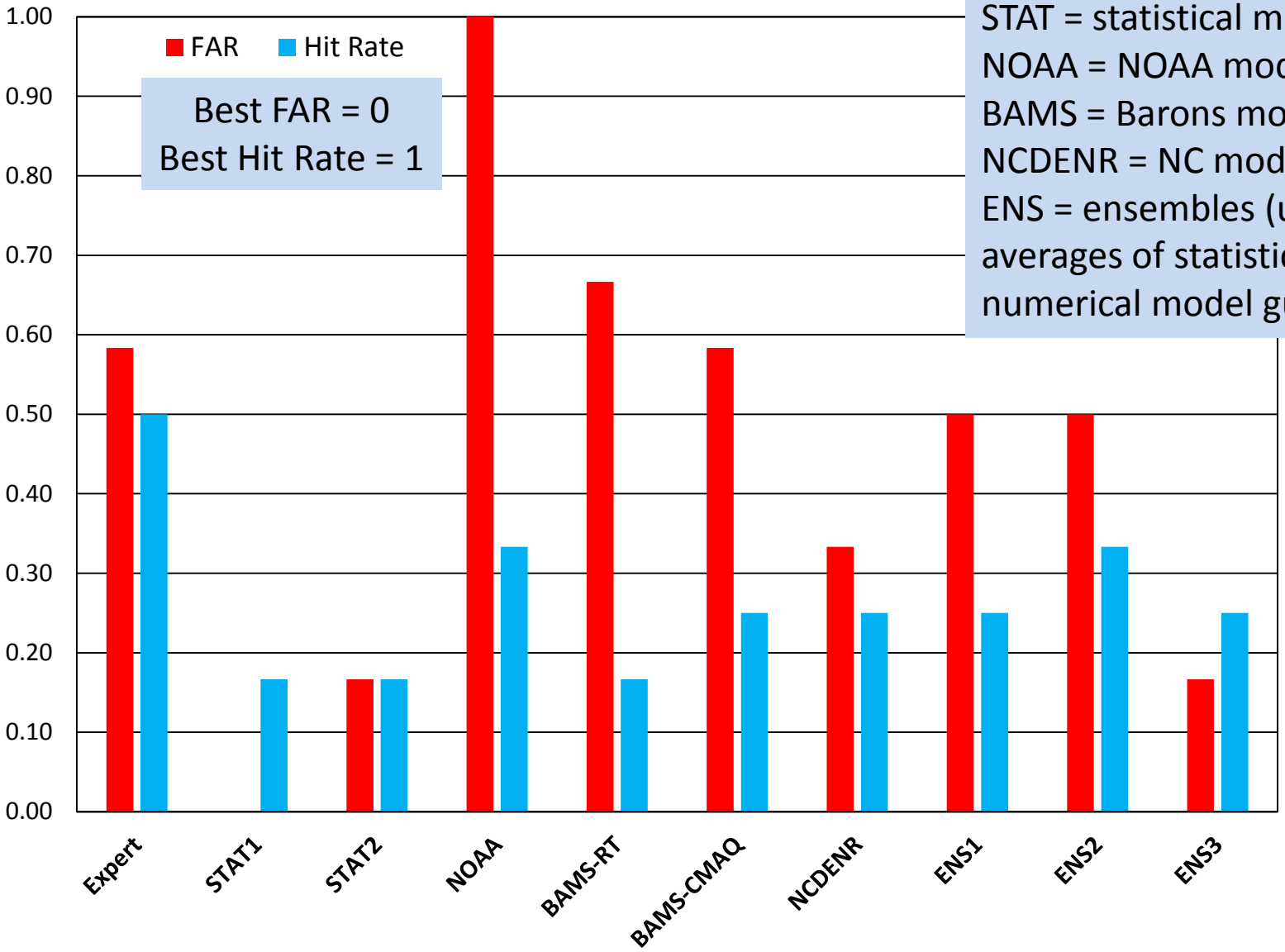
Update on Statistical O_3 Models

- Historically, very useful due to strong relationship b/w high O_3 and T_{max} (hot weather)
  - Used predictor variables such as temperature, humidity, wind speed, O_3 persistence, SZA or Julian day
- Discontinued use of statistical models ~ 2008 in PHL
  - Models trained on data from prior to 2003 no longer skillful due to O_3 reductions associated with NOx SIP Rule
- REU student updated statistical models in 2014, but used training data from 2004-2013 and 2007-2013
  - We weren't sure yet that recent decrease in observed O_3 beginning in 2013 was "real"
- Updated models were shown to have poor skill in 2015
  - No help in identifying O_3 exceedance days

New Statistical Models for 2016

- After 3 years of historically low O_3 observations, we realized that another "step-down" in O_3 precursor emissions had likely occurred
- Developed new set of statistical models trained on data from 2013-2015
  - Only 3 years of data: not ideal, but worth a try
- 2 models for PHL, 1 for DE
  - T_{max}
  - RH (15-21 UTC)
  - Surface wind speed (03-12 UTC)
  - SNP O_3 persistence, local O_3 persistence
  - 12 UTC NAQFC guidance, "lag" NAQFC guidance

Skill for 2016 O_3 Exceedance Days in PHL
(Season to Date)

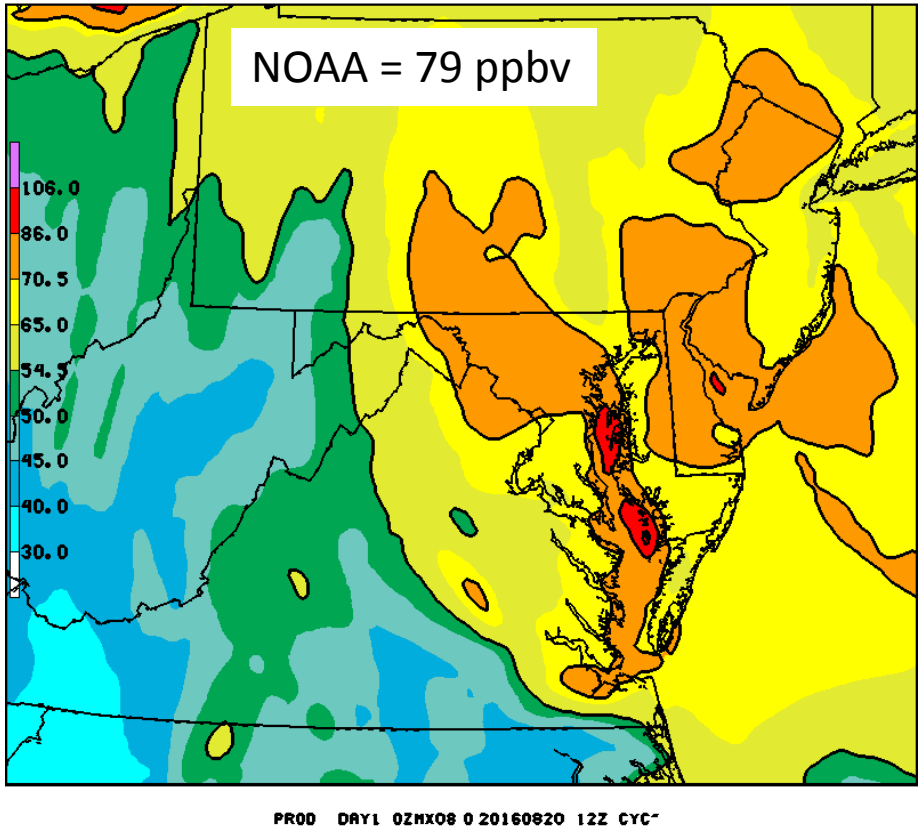


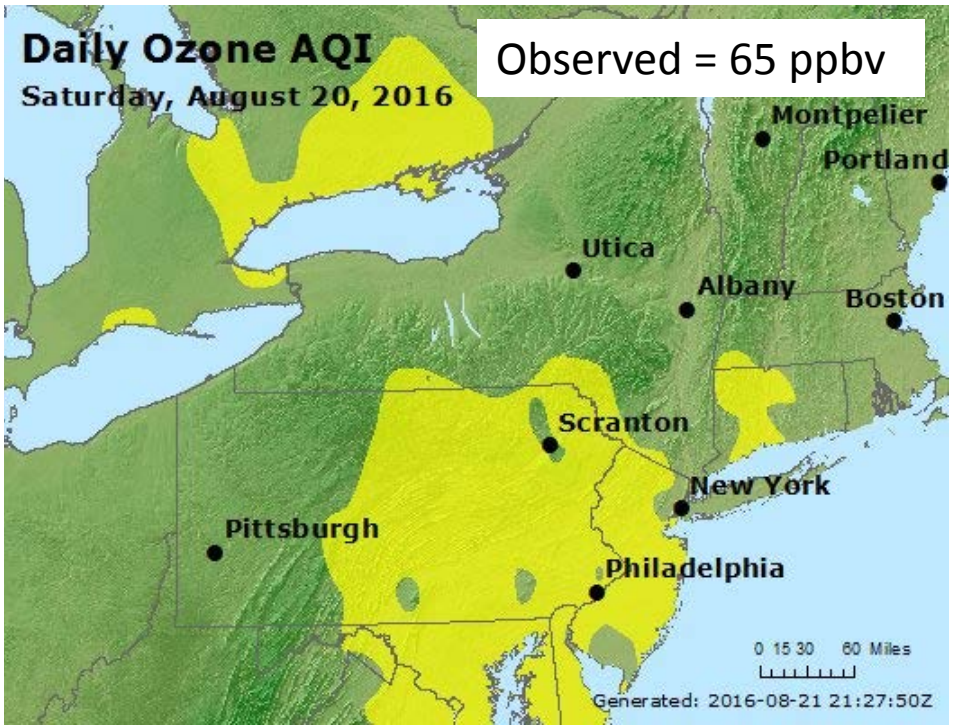
Issues with 2016 NOAA Model Guidance for PHL

- Very high false alarm rate
  - 13 false alarms!!! Especially poor in July and August
- Low hit rate
  - Correctly identified only 4 exceedance days (out of 12 total)
  - Missed first 5 exceedance days

NOAA Model	Late May to mid June	Late June to Sept	TOTAL
Hits	1	3	4
False Alarms	1	12	13
Missed	5	3	8

Example: August 20, 2016



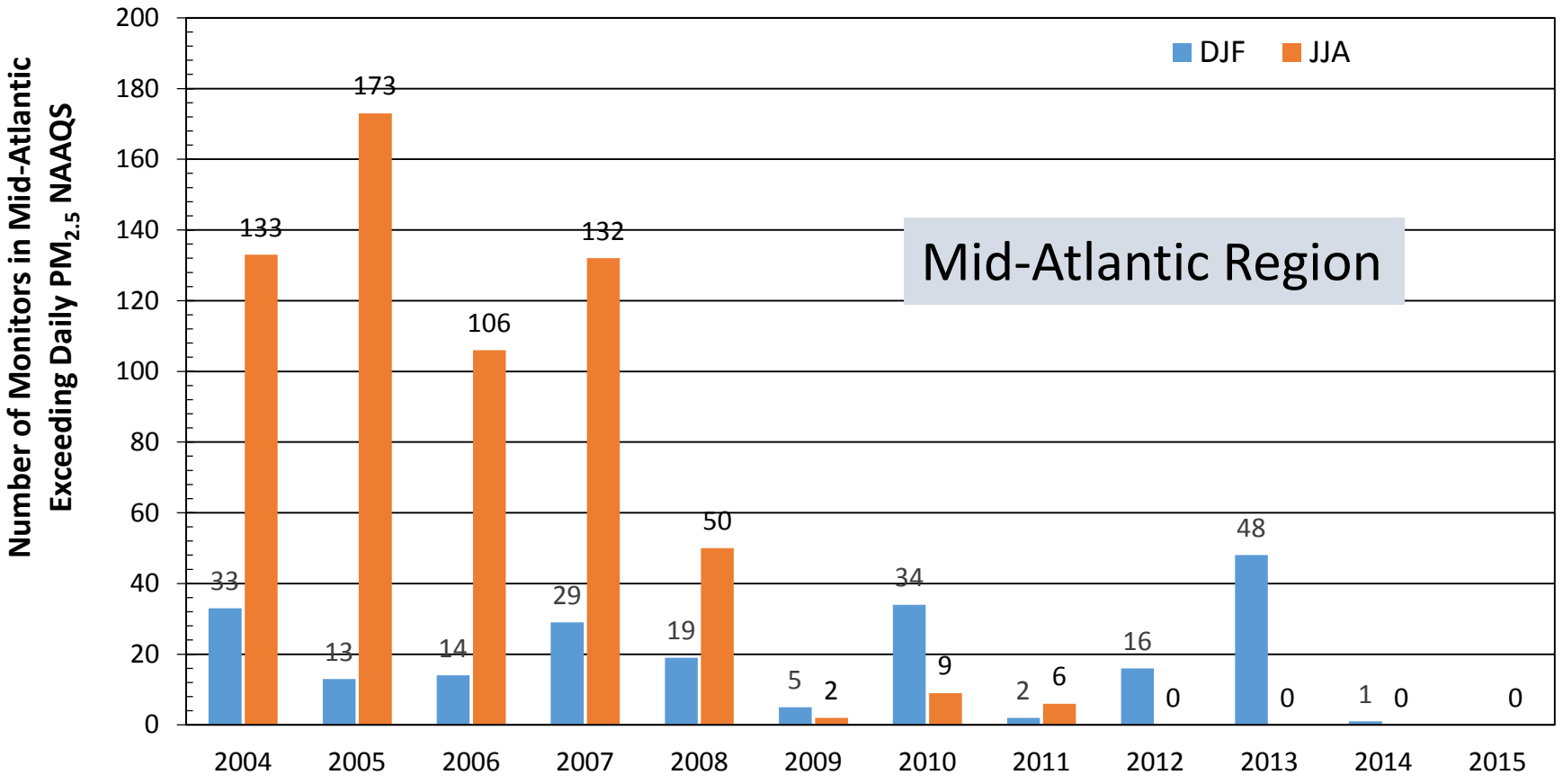


- Sunny, hot (T_{max} = 93 °F), humid (T_d = 69 ° F)
- Calm winds overnight/AM, light SE in PM
- Relatively clean air mass in place (persistence = 55 ppbv)

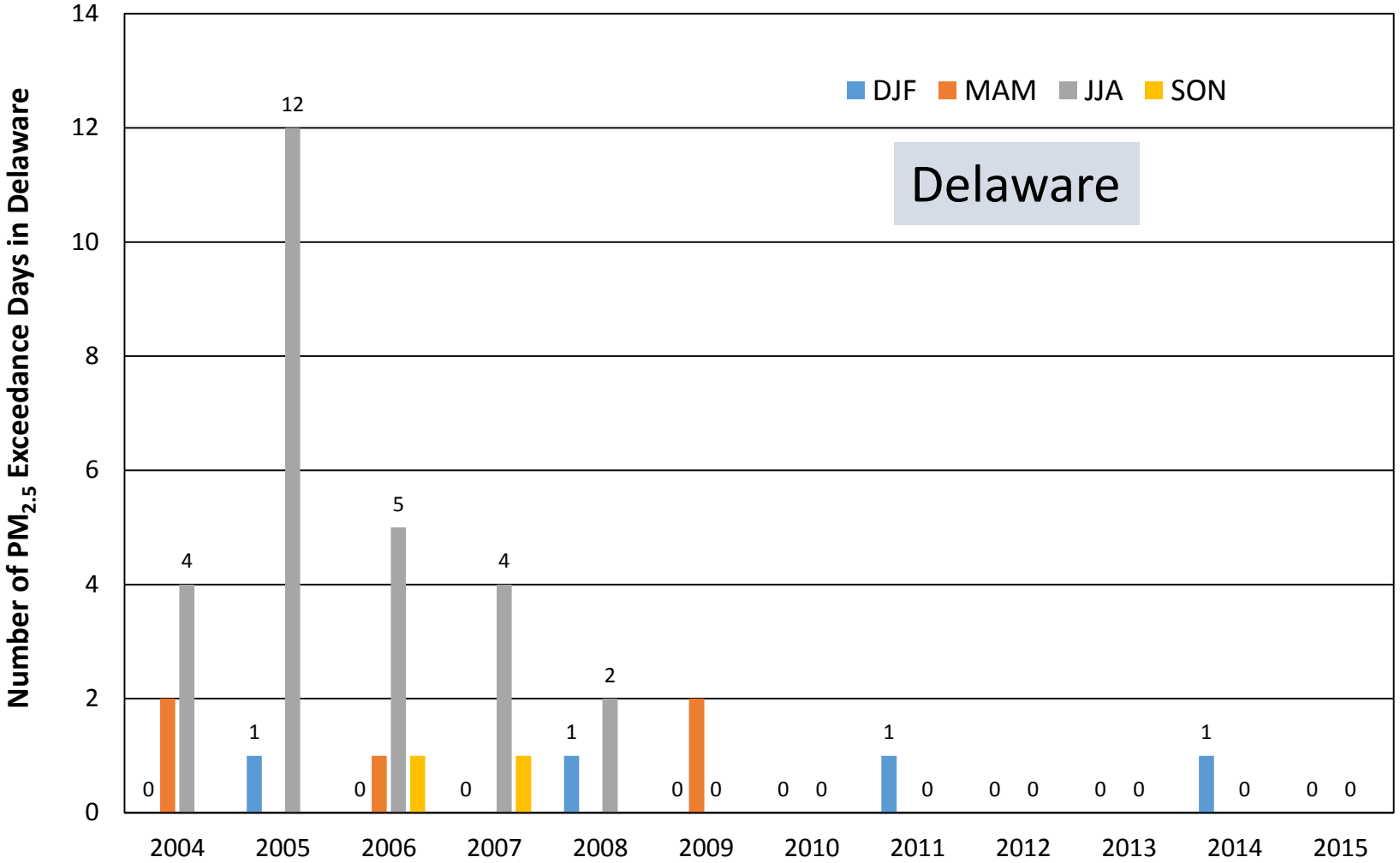
Summary: O_3

- 2016 was 4th consecutive historically low O_3 year for PHL
  - New "step-down" period for O_3
  - Driven primarily by regional decreases in O_3 precursor emissions (NOx)
- 2 mainstays of O_3 forecasting in Mid-Atlantic no longer reliable
  - Only ~25-30% of hot days are O_3 exceedance days
  - Fewer regional, multi-day events, many more localized "spikes"
  - Periodically have exceedance day directly following Good O_3 day (3 of 12 exceedance days in 2016!)
- Smoke continued to be big influence in 2016 (4 of 12 exceedance days in 2016, highest observed O_3 of season)
- Mesoscale features much more important (harder to forecast)
  - Makes accurate forecasts very challenging, for us and models (numerical and statistical)
- NOAA model did not perform well in 2016 in PHL (or Delaware)
  - Very high number of false alarms, especially in July and August
  - Missed first 5 exceedance days (and last day on Sept 14)

$PM_{2.5}$ Concentrations Also Decreasing in Mid-Atlantic, Especially During Summer (JJA)



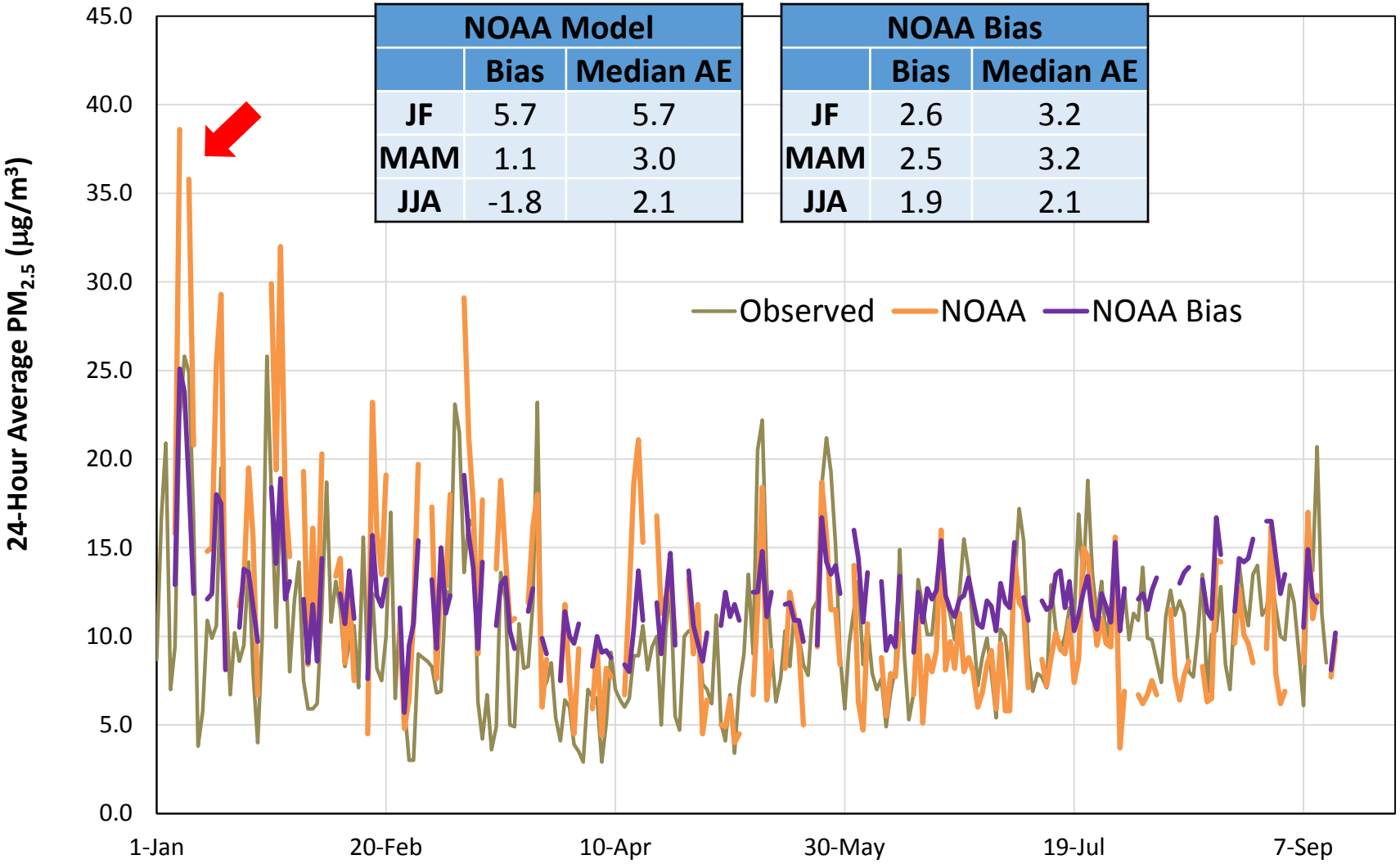
$PM_{2.5}$ Exceedances Are Now Rare



2016 PHL Observed $PM_{2.5}$ Compared to NOAA Model and NOAA Bias Guidance

NOAA Model	Bias	Median AE
JF	5.7	5.7
MAM	1.1	3.0
JJA	-1.8	2.1

NOAA Bias	Bias	Median AE
JF	2.6	3.2
MAM	2.5	3.2
JJA	1.9	2.1



Summary: $PM_{2.5}$

- Summer season peak in $PM_{2.5}$ has disappeared in Mid-Atlantic
  - Downward trend began in 2009
  - Due to continued reductions in regional SO_2 emissions
  - No $PM_{2.5}$ summer exceedance days in 2014 or 2015 (probably 2016 too)
  - Highest summer $PM_{2.5}$ associated with transported smoke (~low to mid 20s $\mu g/m^3$ for PHL/ILG)
- Winter peak due to local nitrate continues
  - But big drop in number of exceedances in 2014-2015
- NOAA model and NOAA Bias help identifying trends in $PM_{2.5}$
  - Less useful during smoke events since smoke is not part of model boundary conditions
- NOAA model had large over-prediction in winter (+5.7 $\mu g/m^3$)
- NOAA Bias much less winter over-prediction (+2.6 $\mu g/m^3$)
- Both models had lowest bias (1.8-1.9 $\mu g/m^3$), highest accuracy (error of 2.1 $\mu g/m^3$) in summer

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