2014 Air Quality Season

MARAMA Monitoring Meeting

December, 2014

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Summer Weather Conditions

- The persistent weather pattern during the summer of 2014 featured a Bermuda High circulation located further south than normal with no period of strong westward extension.
- This limited the frequency of extended periods of hot weather, particularly in our source regions to the west.
- Temperature was slightly below average for the summer and precipitation slightly above average.
- As a result, the 2014 summer season was historically very low with respect to O_3.

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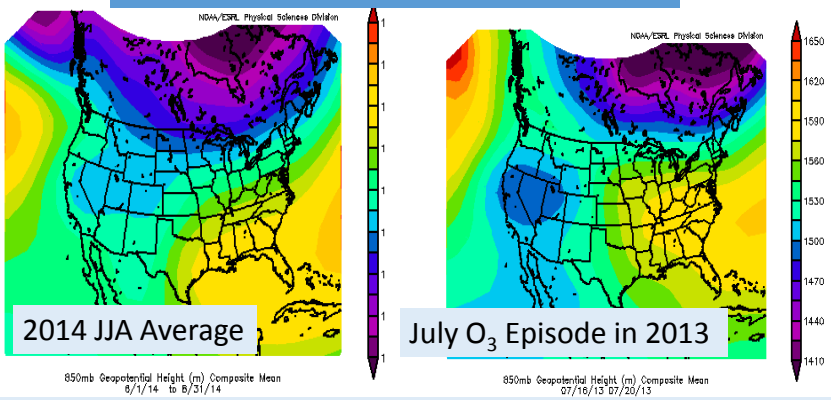
The Preferred Large Scale Pattern for High O_3 (right) Compared to Average Summer Conditions in 2014

Geopotential Height at 850 mb (≈ transport layer)

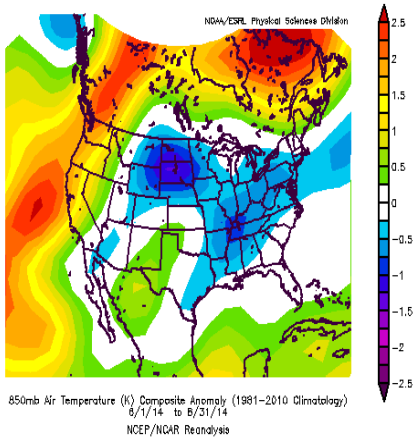


The Bermuda high in the summer of 2014 set up south of the preferred position for high O_3. As a result, 2014 was a benign summer with respect to O_3 and $PM_{2.5}$.

3

The Suppressed Bermuda High Led to a Cooler than Normal Summer – Especially in the Midwest

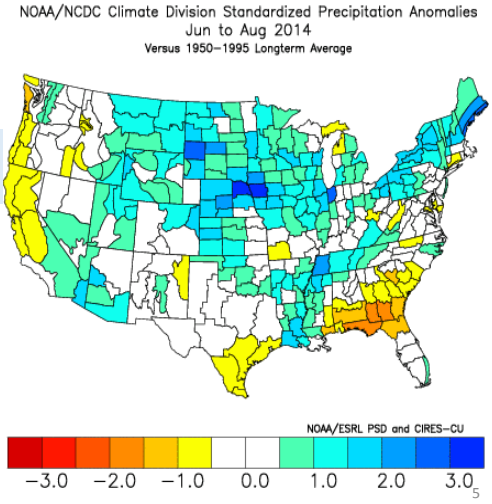
Temperatures were cooler than normal – see 850 mb temperature field (right). With the Bermuda High circulation suppressed southward, more frequent pulses of cool air reached the Mid-Atlantic. In addition, upwind locations in the Ohio River Valley (source region) were well below normal.



4

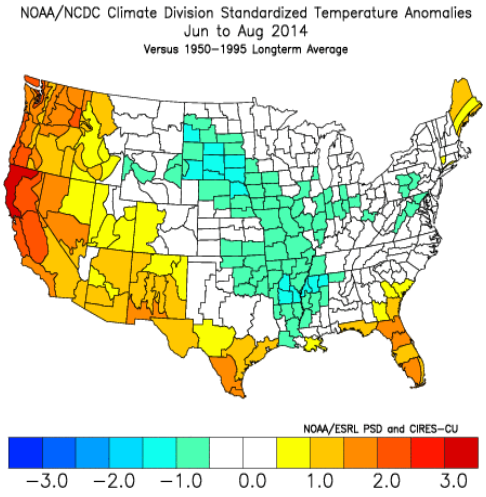
2014 was a Slightly Wetter Than Average Summer

NCDC Precipitation Anomalies
Cooler Colors = Wetter Conditions



5

Surface Temperatures Were Slightly Below Normal



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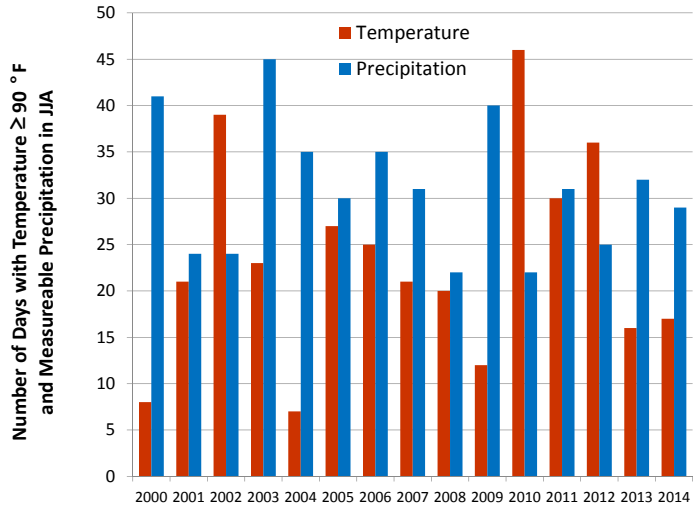
Summer (JJA) Temperature and Precipitation Were Similar to Last Summer in PHL



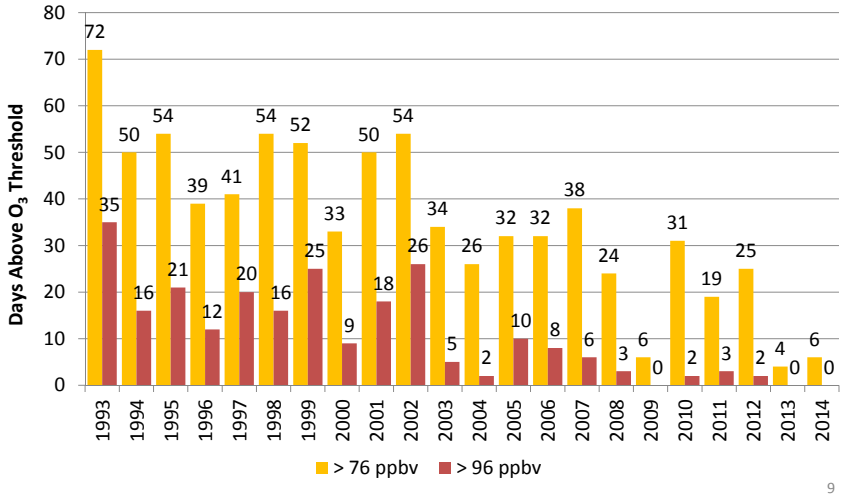
7

Ozone (O_3) in 2014 – Focus on Philadelphia Metro Area

- The number of Code Orange and Code Red O_3 Days continue to decline. 2014 was the second consecutive historically low O_3 season.
- O_3 in the Mid-Atlantic region, and to our west, followed the same pattern.
- The association of high O_3 with hot weather was much weaker.
- There were no multi-day O_3 events in the Philadelphia metro area. The pattern over the past several years is that Code Orange days are less likely to occur in multi-day events.

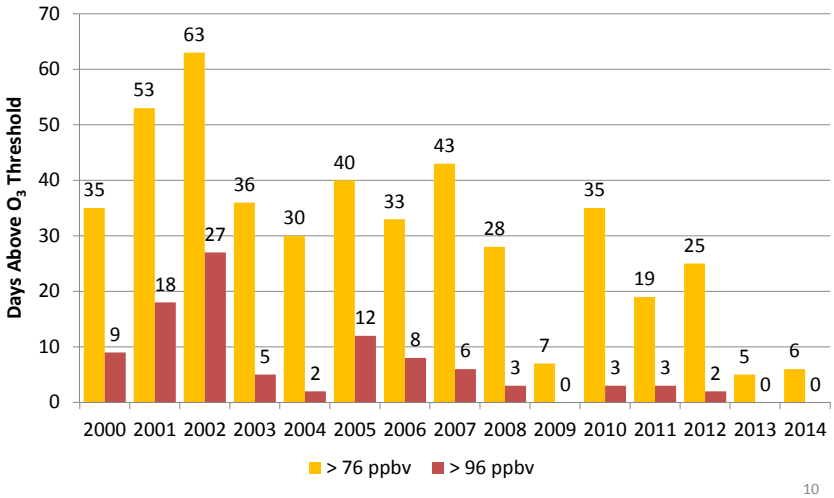
8

2014 Had the Second Lowest Frequency of Code Orange O_3 Days in JJA (Tied With 2009 Recession Year)



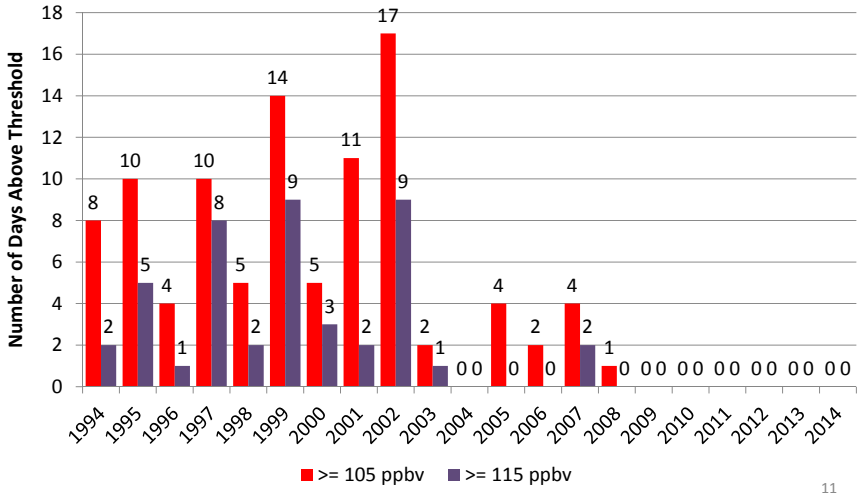
9

Results are Similar for the Entire O_3 Season (AMJJAS)



10

Extremely Bad O_3 Days Appear to Be A Thing of the Past



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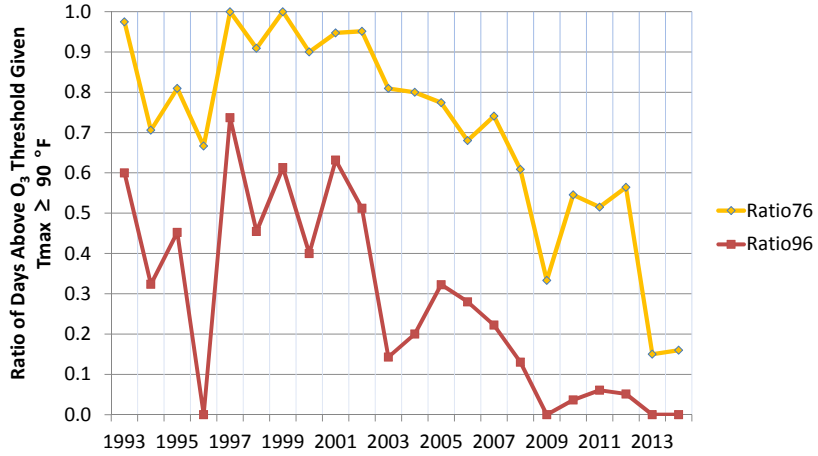
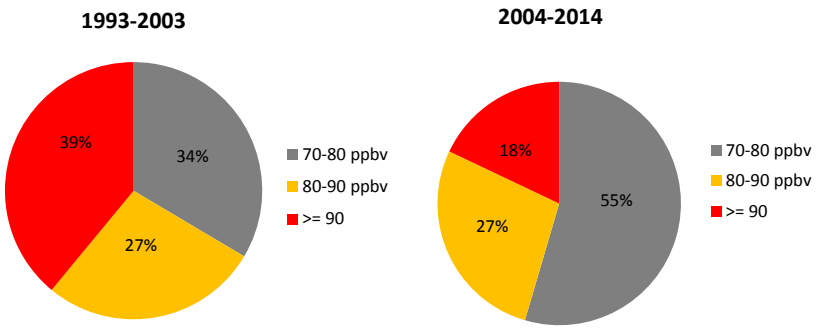
Hot Days Are Less Likely To Be High O_3 Days. What Are the Implications for Forecasting?



Given a "hot" day ($T_{max} \geq 90\,^{\circ}F$), how likely is a Code Orange or Code Red O_3 day?

Maximum Peak O_3 Now Predominately in the 70-80 ppbv Range



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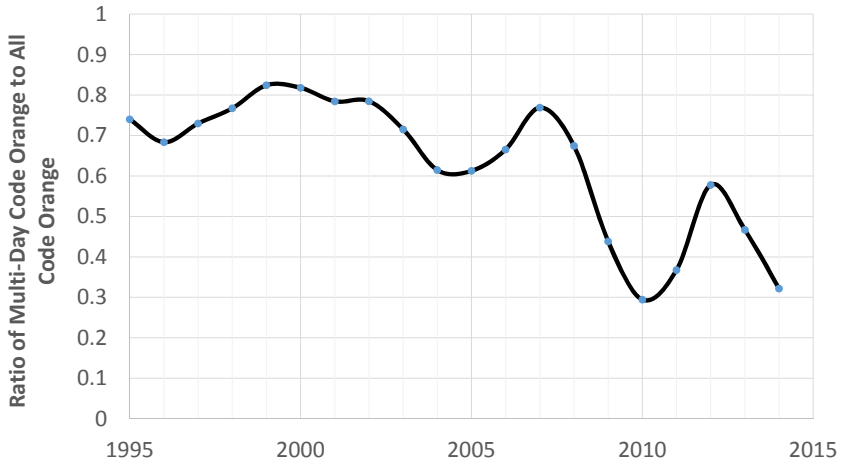
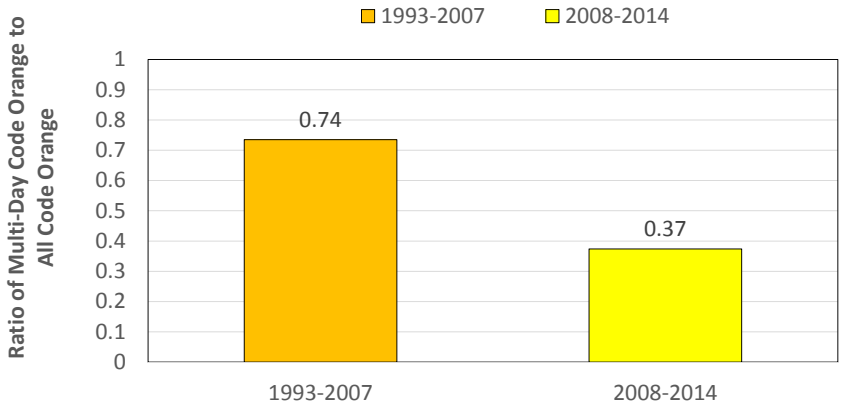
Multi-Day Code Orange O_3 Events Have Accounted for Less Than Half of All Code Orange O_3 Days in 5 of Last 6 Years



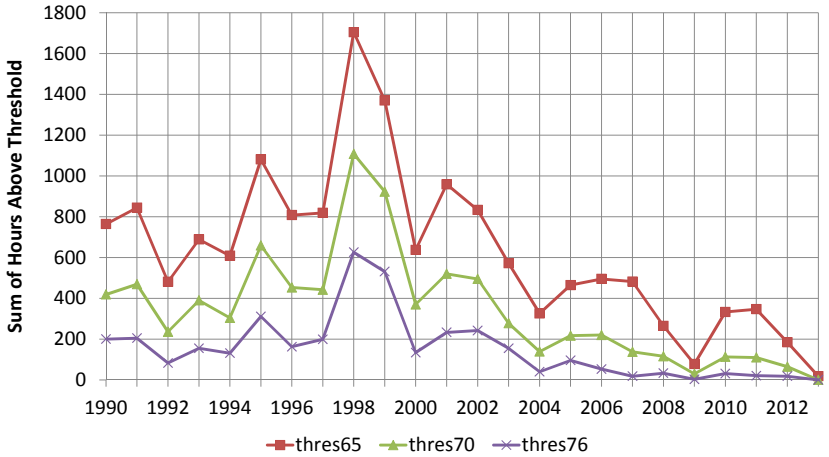
14

Since 2008, Two of Three Code Orange O_3 Days in PHL are Single Day "Spikes"



15

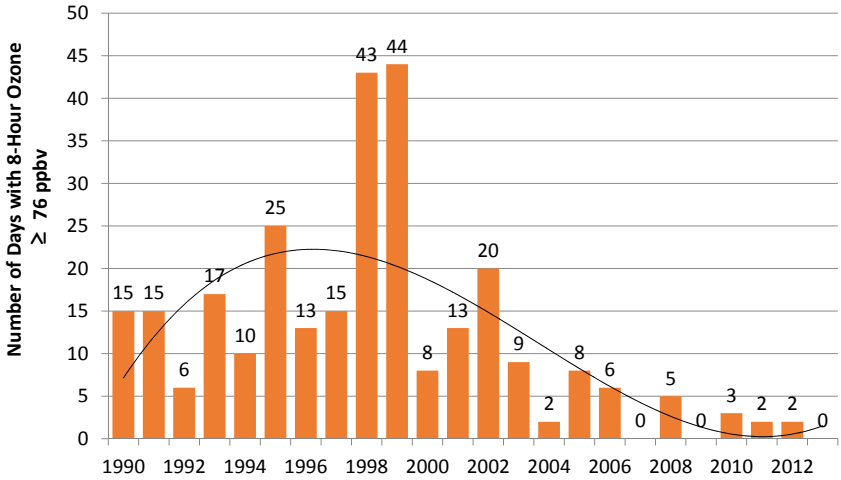
Regional Scale O_3 Significantly Reduced



Shenandoah NP: Number of Monitor Hours Above Given Thresholds of 65, 70, 76 ppbv

16

Code Orange O_3 Days at SNP Now Rare



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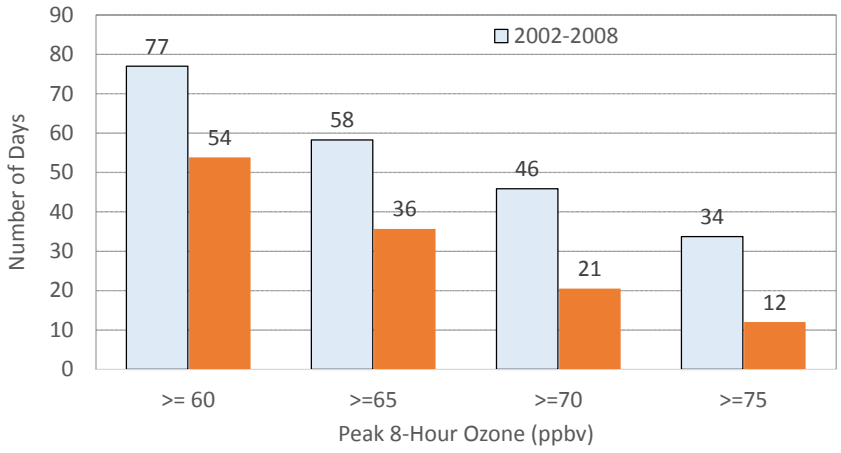
Expected Frequency of Days Above Given O_3 Threshold in PHL



What are expected impacts of change in 8-Hr O_3 NAAQS to 70 ppbv?

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Fine Particles ($PM_{2.5}$) in 2014 – Focus on Philadelphia Metro Area

- Historically, $PM_{2.5}$ peaked in PHL during summer (regional sulfate) and winter (local nitrate)
- In 2014, maximum daily average $PM_{2.5}$ continued its downward trend during the summer months (JJA)
  - During summer 2014, there were no Code Orange or high Code Yellow ($PM_{2.5} \geq$ 30 µg/m^3) events
  - On days when Moderate $PM_{2.5}$ was observed, the total area impacted by Moderate concentrations continued to decrease
- Maximum daily average $PM_{2.5}$ during the winter months (DJF) has remained relatively constant since 2003
  - Winter peak due to conversion of NO_x from combustion sources to nitrate has remain essentially unchanged

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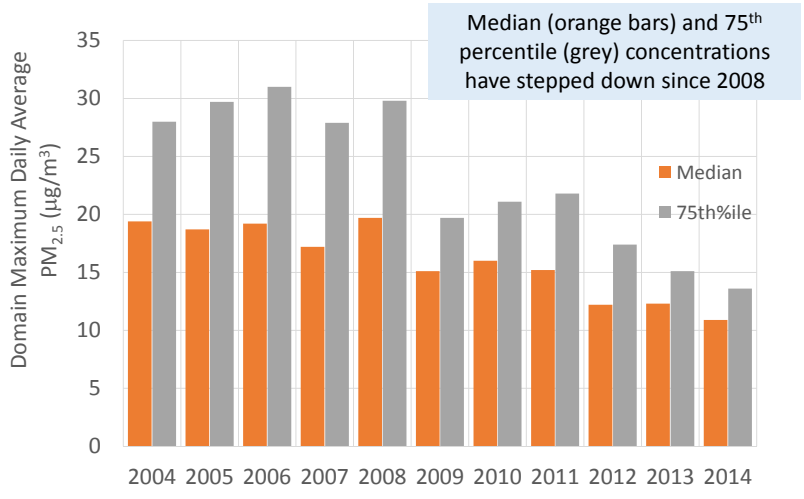
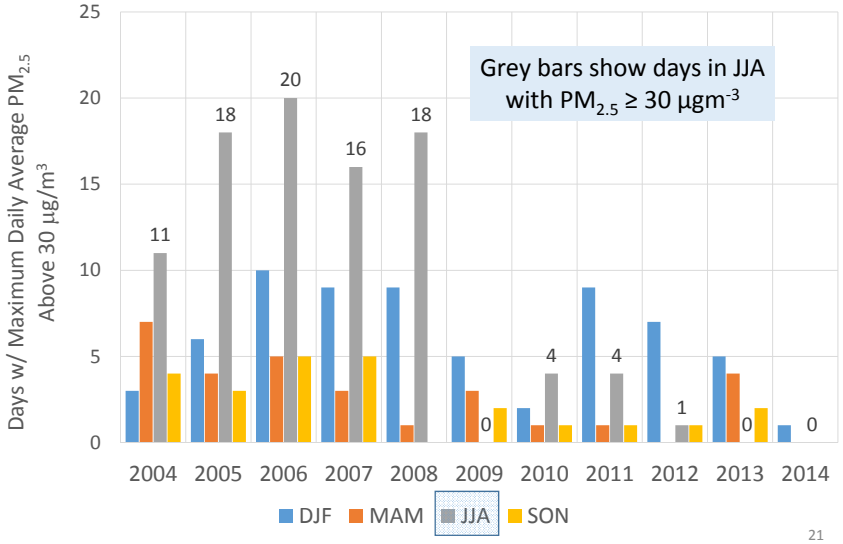
In PHL, Summer Season $PM_{2.5}$ Maximum Daily Average Concentrations Continue to Fall



20

Summer Season $PM_{2.5}$ "Bad Air Days" Are Now Rare in PHL



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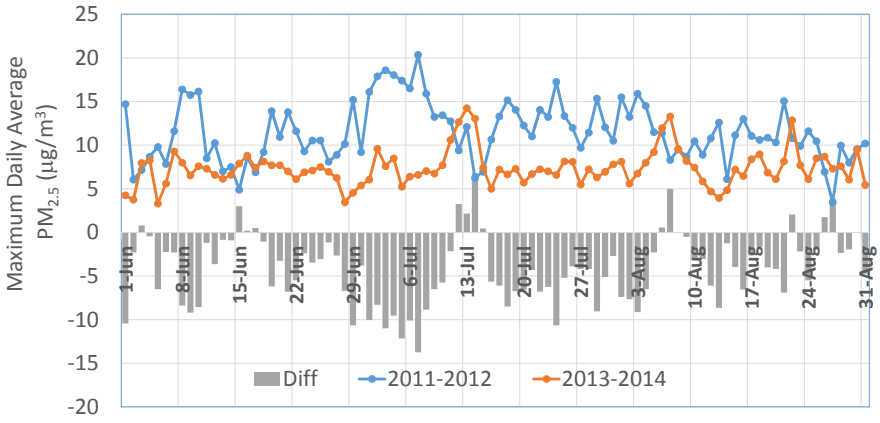
The Past Two Summers Have Shown a Decrease in Maximum Daily Average $PM_{2.5}$ Concentrations in PHL



Average of all PHL Monitors: 2011-2012 in blue, 2013-2014 in red, difference in grey bars

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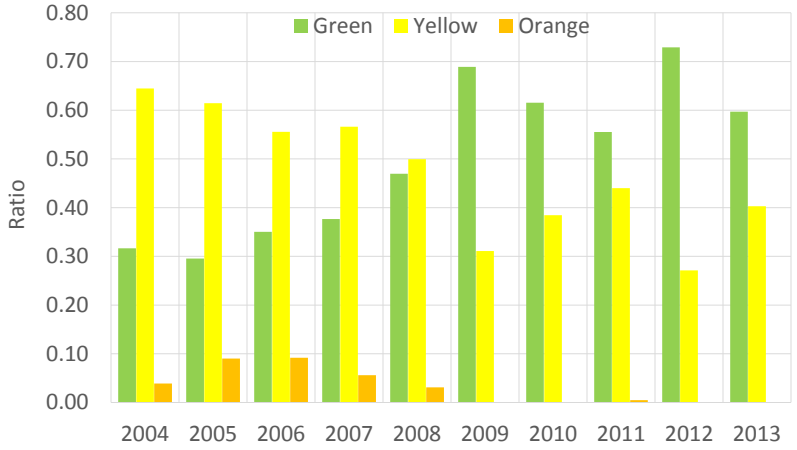
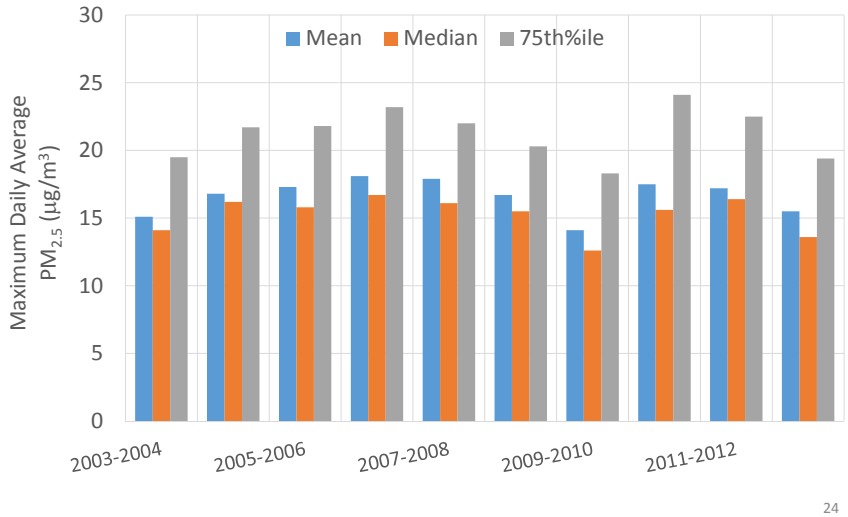
Total Area Affected by High $PM_{2.5}$ Concentrations in the Summer Season in PHL Has Been Reduced



On days with Code Yellow air quality ($PM_{2.5} \geq 12.1\ \mu gm^{-3}$), what fraction of all PHL continuous monitors were in the Green, Yellow, or Orange Range?

Winter (DJF) is a Different Story – Little to No Change in Maximum Daily Average $PM_{2.5}$ Concentrations in PHL



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What Does a Winter $PM_{2.5}$ Episode "Look Like"?

- Light near surface winds
  - Stagnation and accumulation of primary and secondary particles
- High humidity
  - Primary constituent of $PM_{2.5}$ in winter is particulate nitrate
  - Nitrate concentrations increase with high humidity and cool temperatures
  - Melting snow increases low level humidity
- Limited vertical mixing
  - Traps emissions within a small volume
  - Cloud cover decreases sunlight and limits buoyant mixing
  - Snow cover has high albedo and reflects what sunlight is available so that surface remains cool and buoyancy reduced (humidity stays high)

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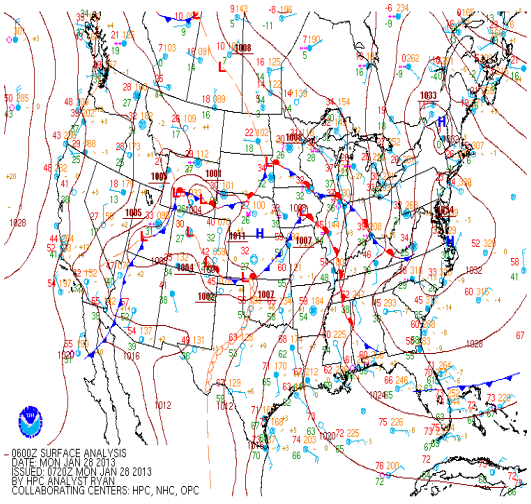
"Standard" Winter Season Poor Air Quality Synoptic Pattern in the Mid-Atlantic (January 2013)



Left: NCEP surface analysis for 0600 UTC on January 28th. High pressure overhead with stagnant near-surface winds.

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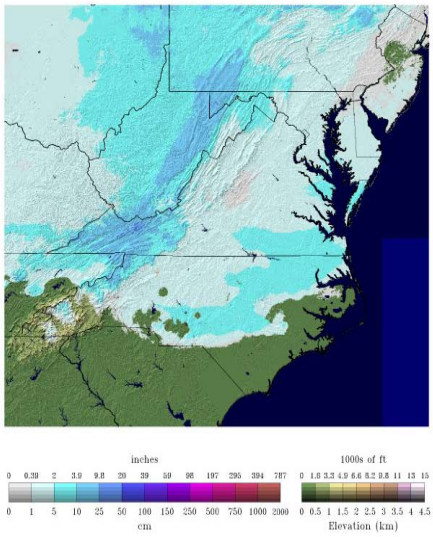
Snow Cover, January 27, 2013



27

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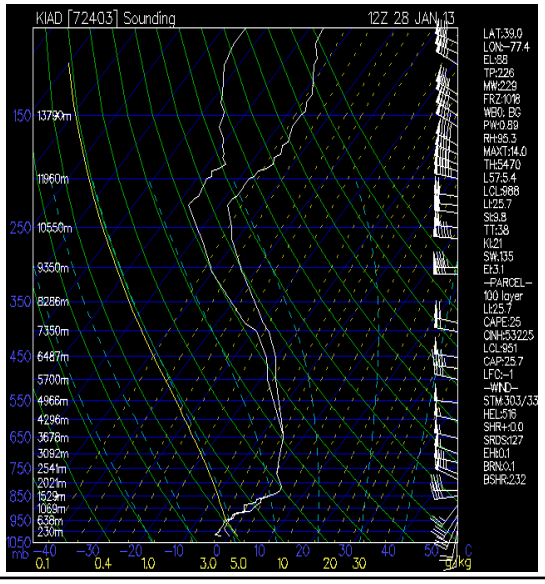

Left: Sounding from Dulles (IAD) at mid-episode (January 28) shows a very stable and almost completely saturated lower troposphere.

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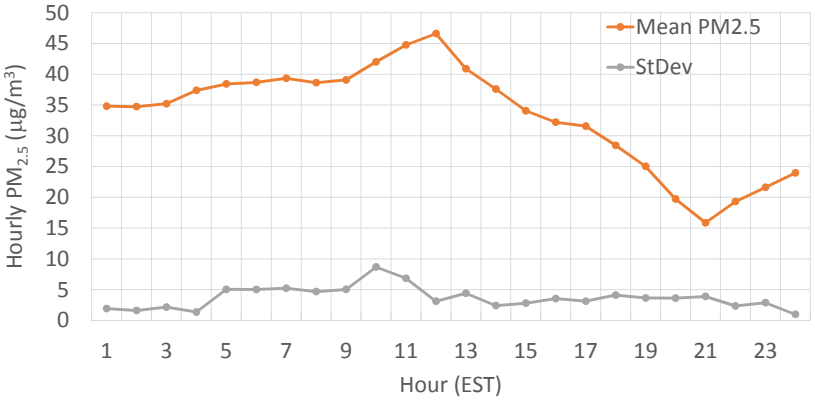
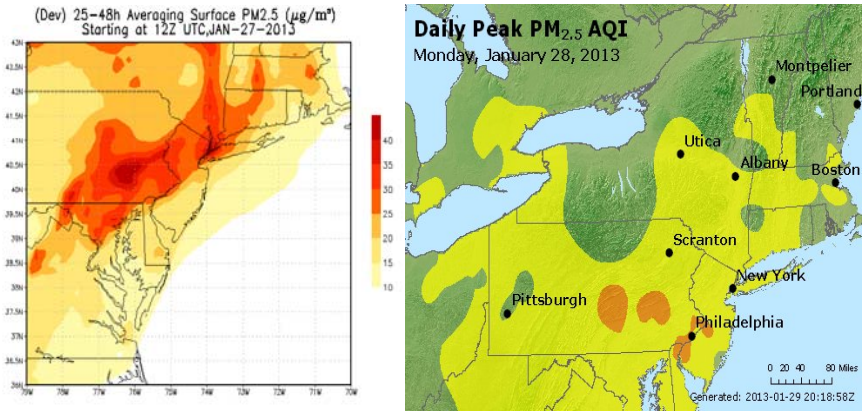
Hourly $PM_{2.5}$ Concentrations for a "Standard" Winter Season Poor Air Quality Day



Hourly $PM_{2.5}$ observations for January 28th for the PHL metropolitan area. A strong inversion reflected in persistent high concentrations well past the morning rush hour.

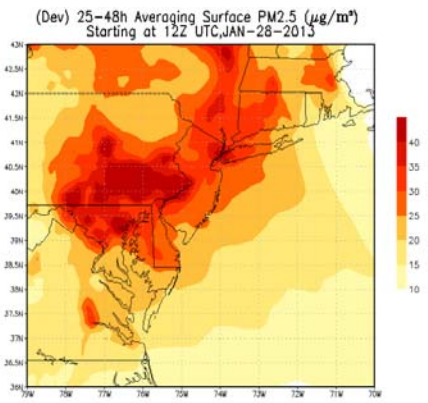
January 28, 2013: NOAA $PM_{2.5}$ Model Forecast (left) and Observations (right)

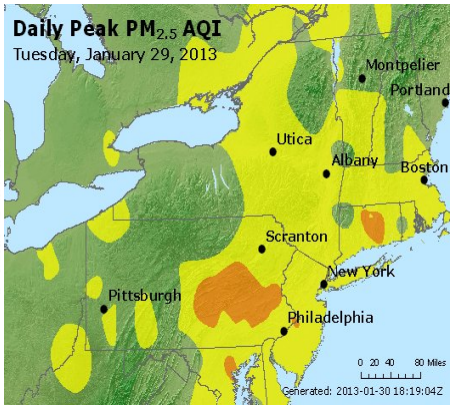


NAQC

Observations via AirNow

January 29, 2013: NOAA $PM_{2.5}$ Model Forecast (left) and Observations (right)





NAQC

Observations via AirNow

Summary

- Association between high O_3 (≥76 ppbv) and high temperature (T_{max}≥90°F) and persistence (previous day O_3 ≥76 ppbv) continues to weaken for the Mid-Atlantic region
  - Preferred regional pattern for high O_3 occurred less frequently in recent years
  - Changes in regional emissions (e.g., power plant fuel switching)
  - Makes accurate forecasts very challenging! Fewer multi-day events
- Summer season peak in daily average $PM_{2.5}$ essentially gone
  - Code Orange and high Code Yellow days ($PM_{2.5}$ ≥30 μg/m³) during summer are now rare
  - Likely due to change in regional SO_2 emissions from fuel switching
  - Winter peak associated with local nitrate remains unchanged

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