Ozone and Meteorology over the Chesapeake Bay

Conditions for High Ozone over the Northern Chesapeake Bay Pilot Project [2016, 2017][1]

&

The OWLETS-2 Campaign [2018][2]

Joel Dreessen[1,2] & Jay Symborski[1],

(1) Maryland Department of the Environment;

(2) John Sullivan, Ruben Delgado, Xinrong Ren, Tim Berkoff, Guillaume Gronoff, Lance Niño, Ricardo Sakai, Adrian Flores, and the OWLETS-2 Science Team

December 2018

OWLETS-2 Ozone Water-Land Environmental Transition Study

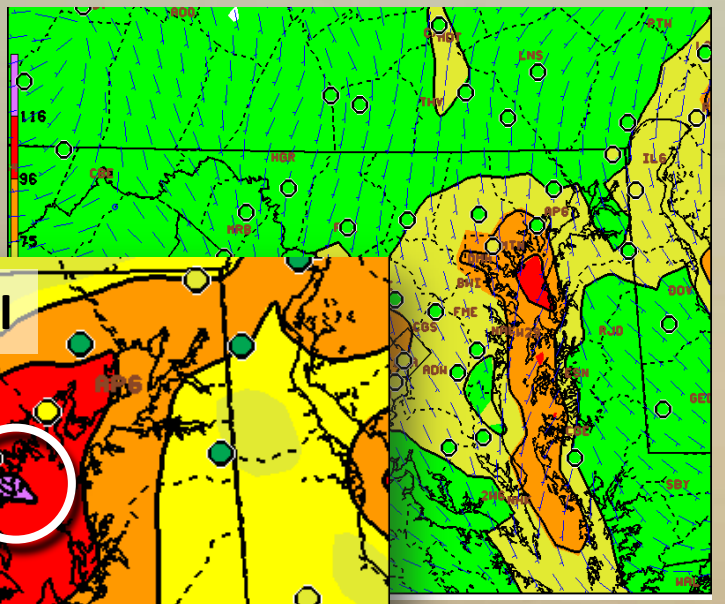
AGU 100 ADVANCING EARTH AND SPACE SCIENCE FALL MEETING Washington, D.C. | 10-14 Dec 2018

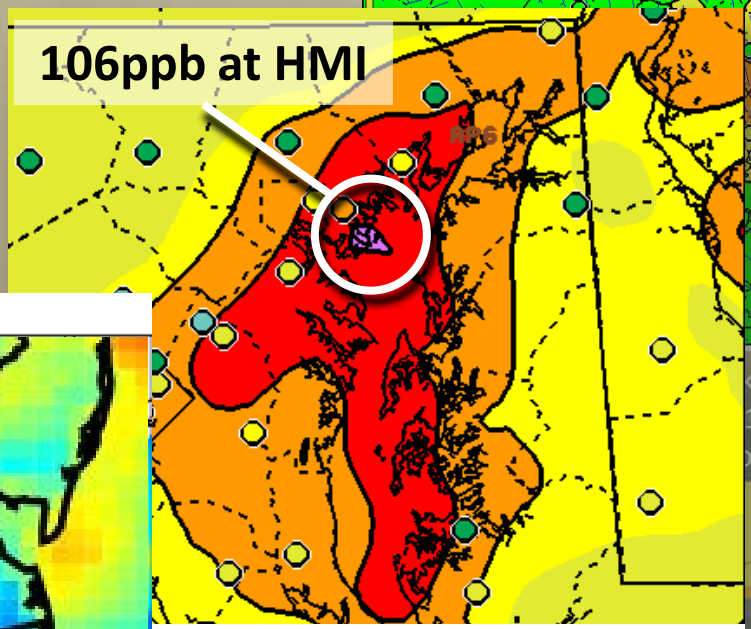
Maryland Department of the Environment

Chesapeake Bay Ozone Background

Maryland "Water Issues"

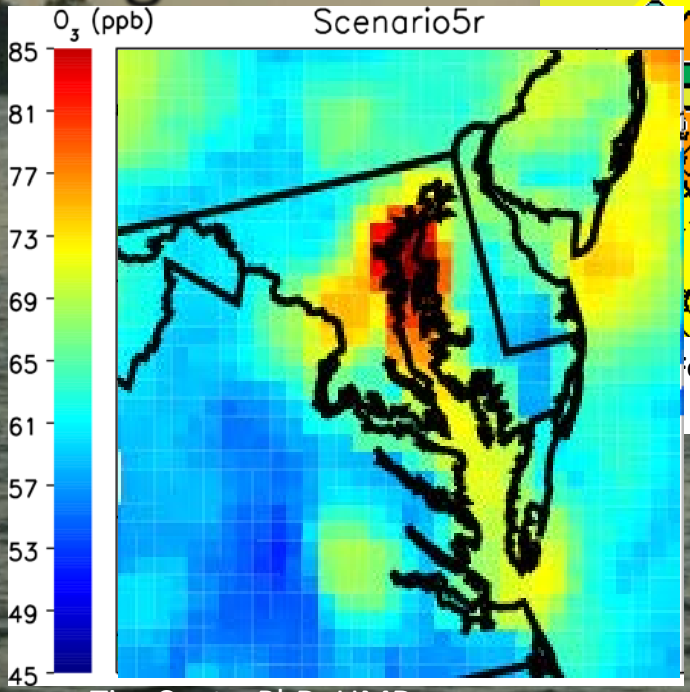
- Edgewood's "Bay Breeze"
- Ozone Forecasts
- Compliance modeling



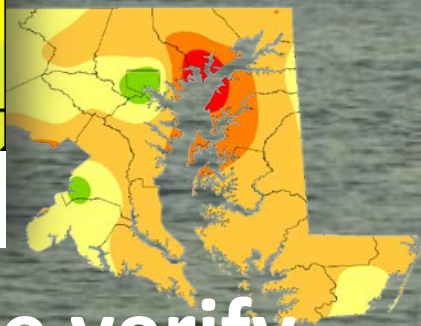


ground fill by Air Quality Index
11, 2015 overlaid with verified
ns across the region (circles).

orecast 8-hour maximum ozone averages
July 6, 2016 [06z run]



Tim Canty, PhD, UMD



How do we verify any of this?

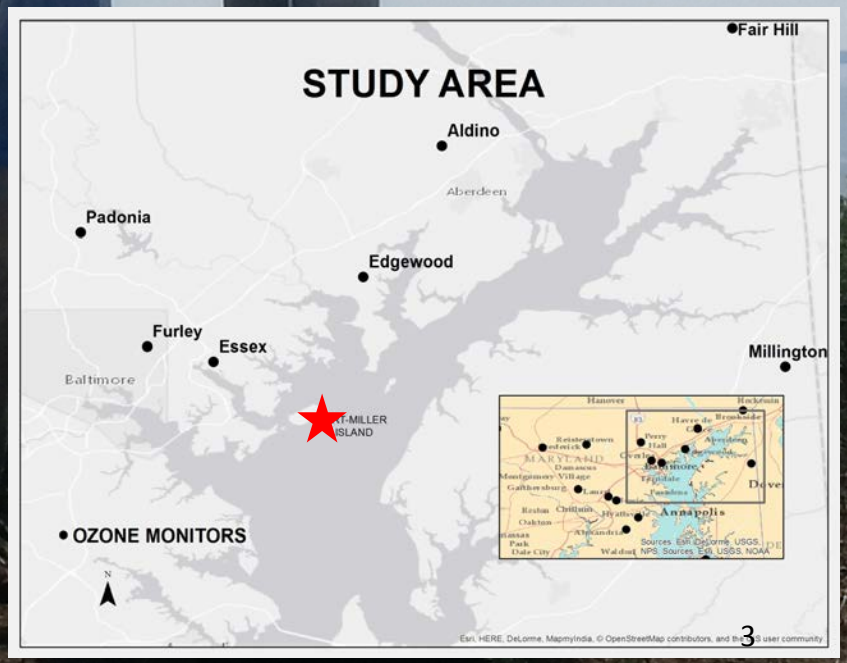
Picture: Chesapeake Bay, July 20, 2017

OWLETS-2 Background & Purpose

- Portable Ozone Monitor [“POM”] - mobile autonomous ozone observing platform
- Solar panel charges 2 deep cell batteries
- Communication via cell signal
- Includes weather data

POM

- East of the Baltimore Inner Harbor by 15 miles
- Northeastern most point on the Island putting it as close to the middle of the Bay as possible
- Access via boat only



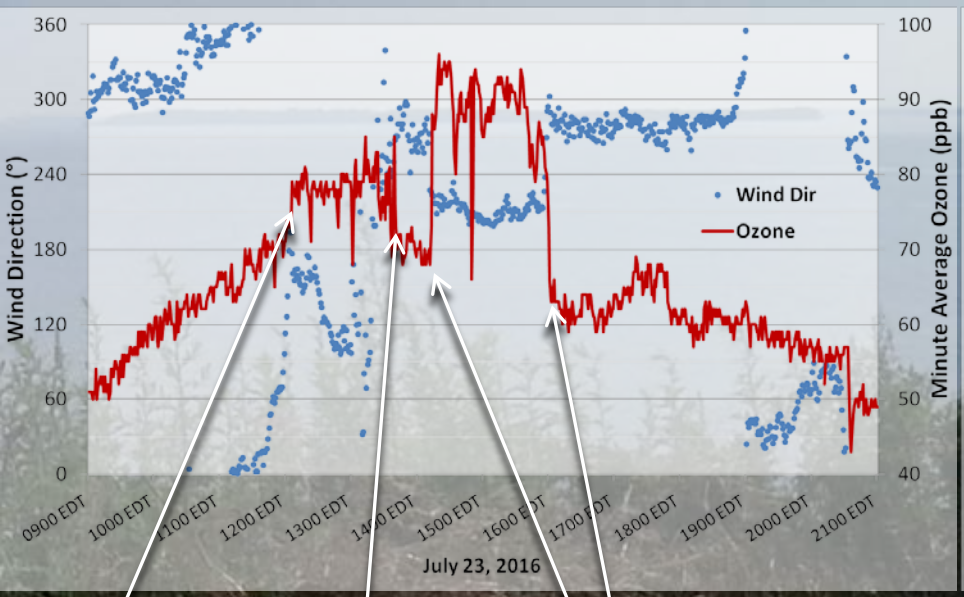
Hart-Miller Island Pilot Project Results

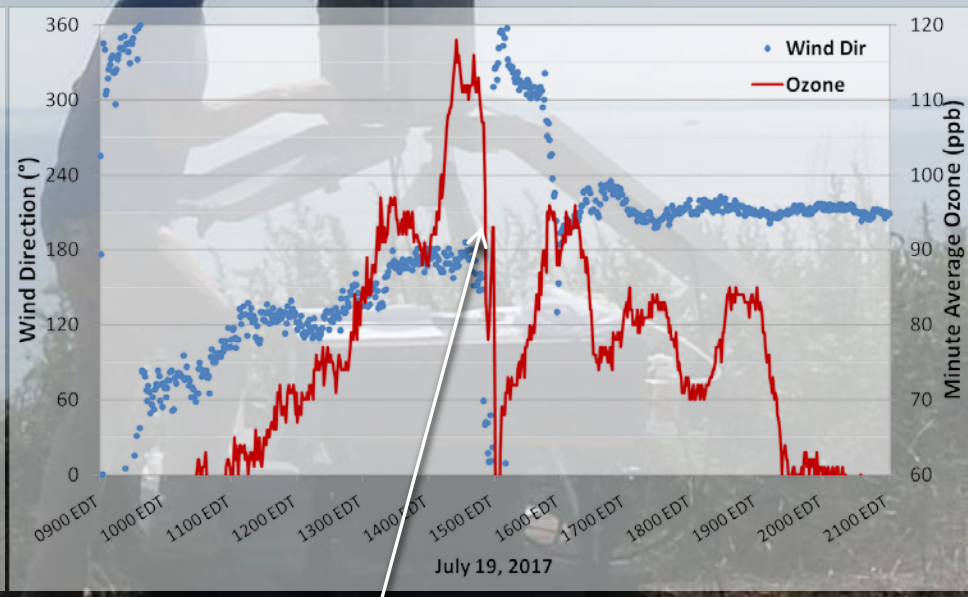
240 observation days; 2016 and 2017; Exceedances of 70ppb: 24; 75ppb: 12; 84ppb: 7; Small number of days that ultimately exceed the standard; When ozone IS present, higher than land

Exceedance Days Highest Ozone Hour:

Hourly HMI	Ozone (ppb)	Wind Direction (°)	Land-Water Temperature Afternoon Difference (°)	850mb 12Z Wind Direction (°)
Mean(Med)	92 (89.5)	192 (191)	11.1 (9.9)	300 (300)

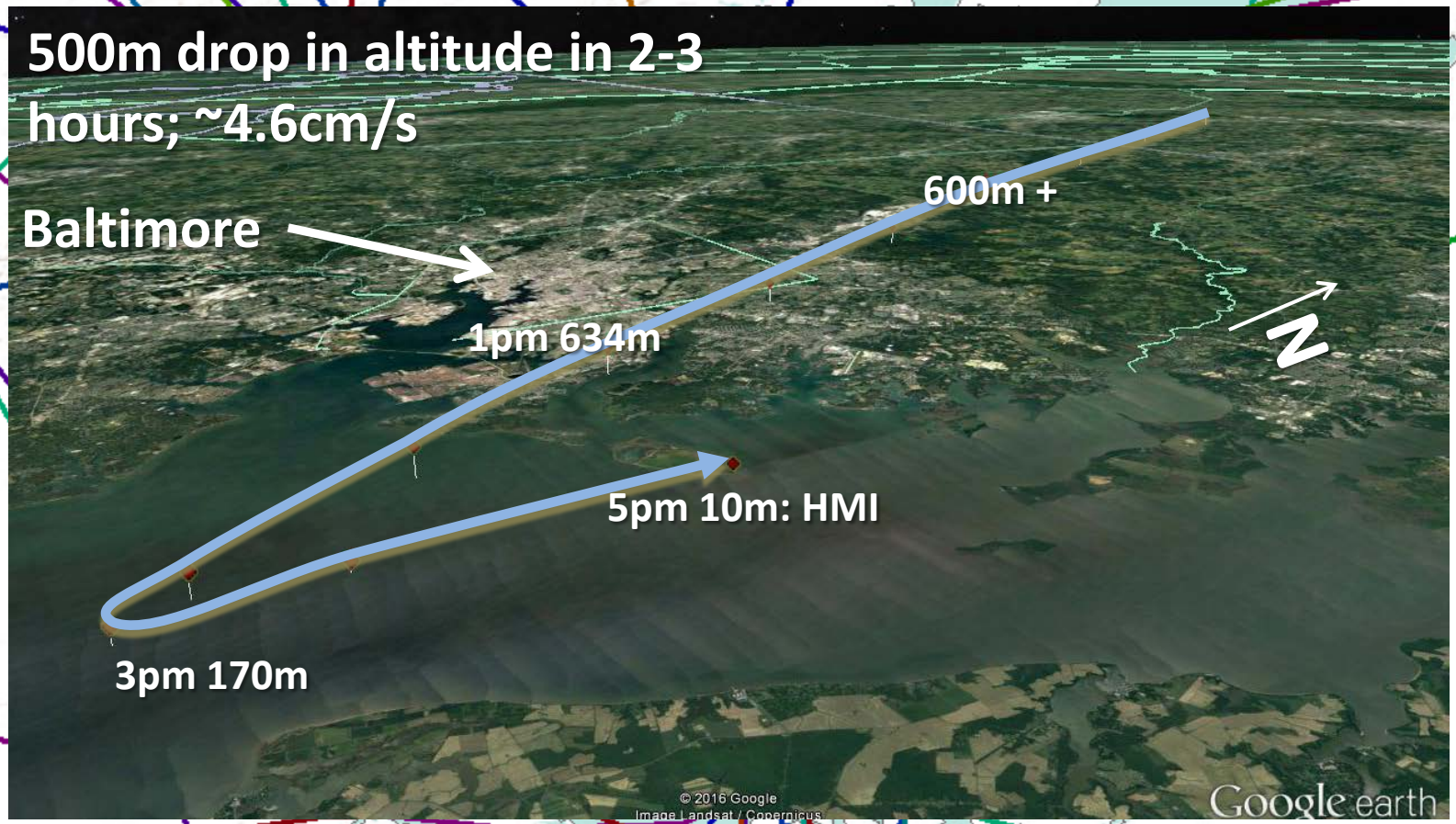
Changes in wind direction led to BIG ozone changes at HMI





10m HRRR Trajectories on Days with Bay ozone >70ppb

The HRRR is a 3km resolution dataset

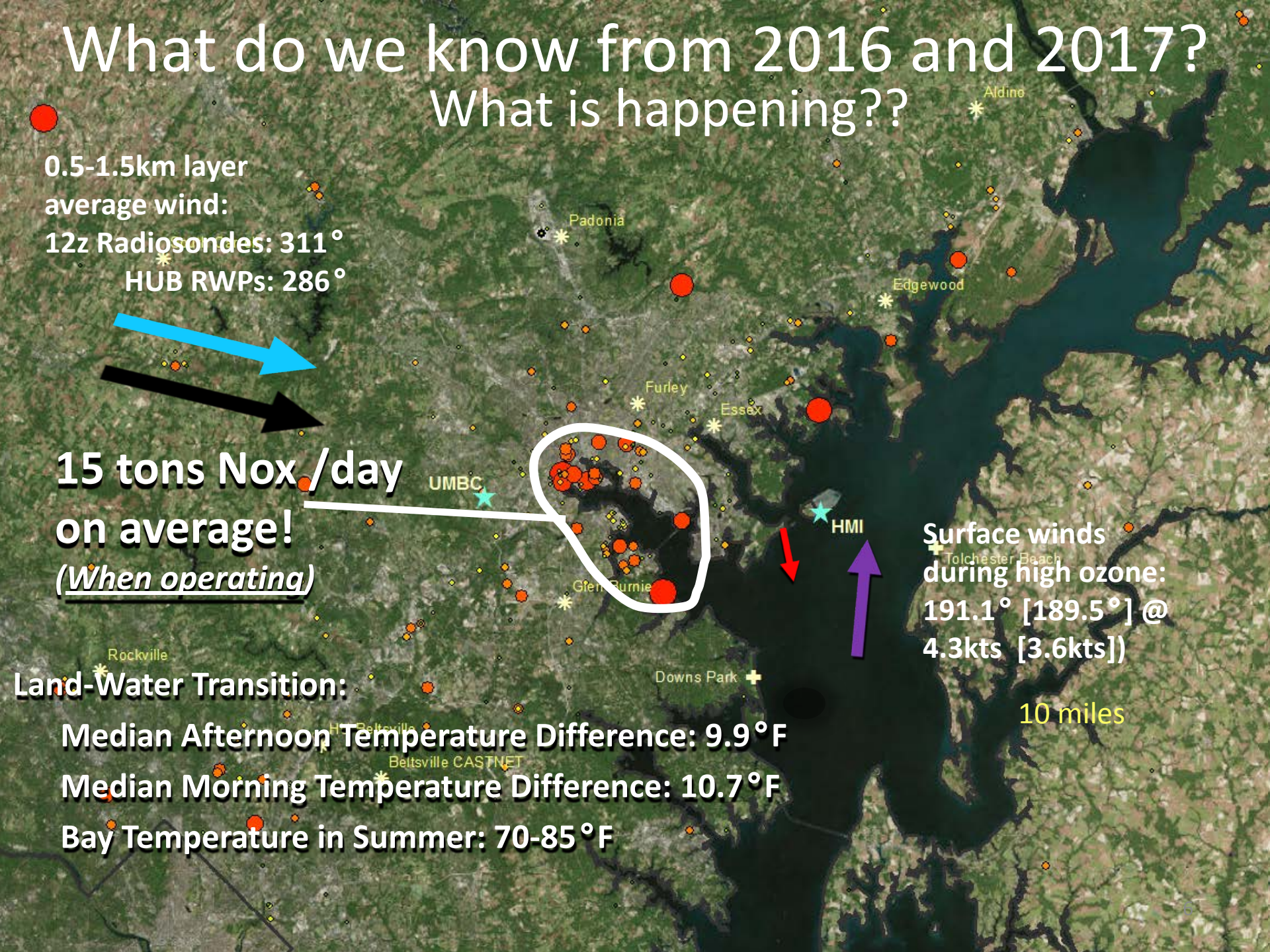


Data Source: Air Resources Laboratory: HYSPLIT

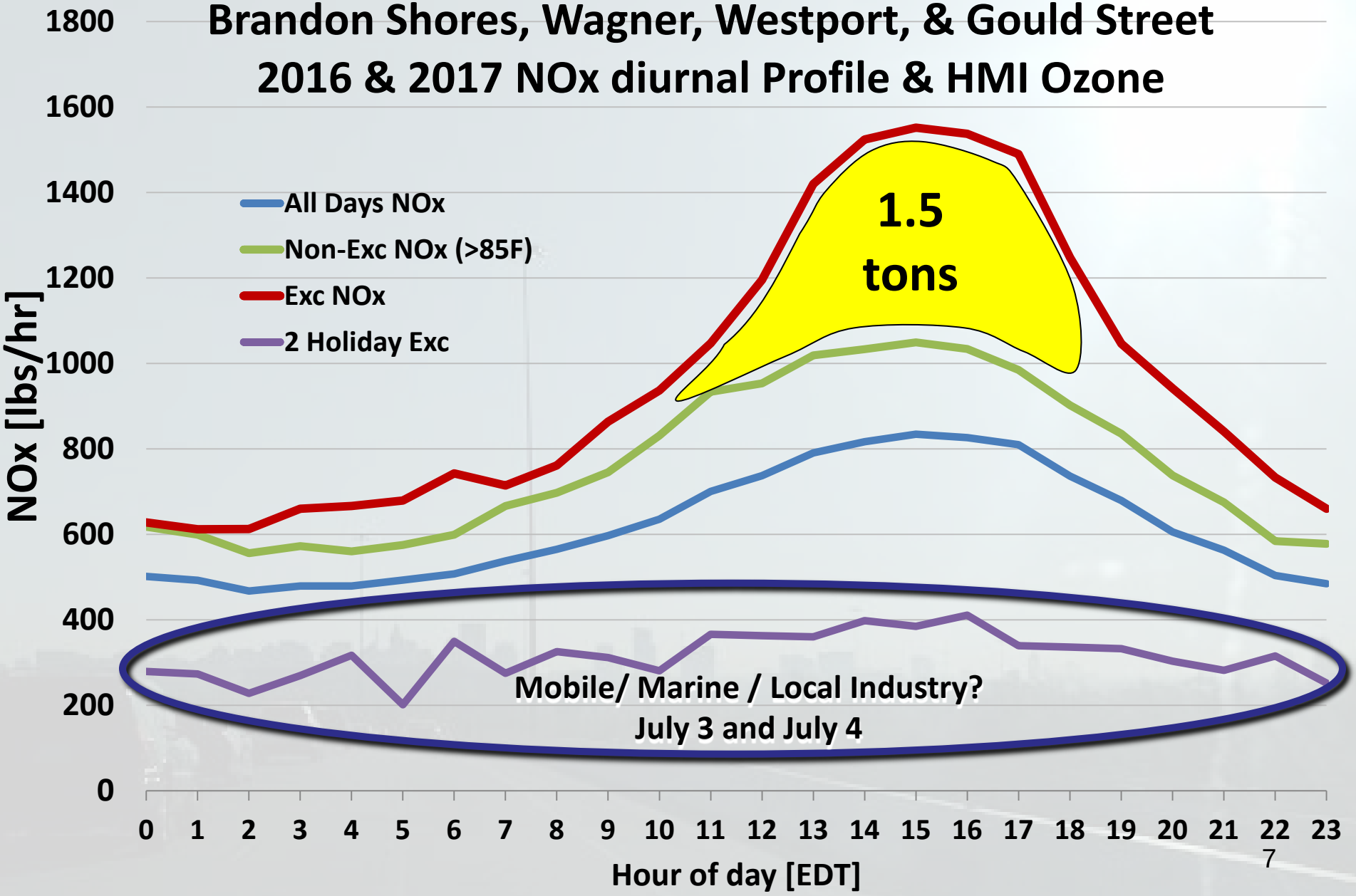
*Rolph, G., Stein, A., and Stunder, B., (2017). Real-time Environmental Applications and Display sYstem: READY. Environmental Modelling & Software, **95**, 210-228, https://doi.org/10.1016/j.envsoft.2017.06.025*

What do we know from 2016 and 2017?

What is happening??



Exceedances at HMI: Baltimore EGUs



OWLETS-2

Date	HMI Max 8-hr Avg (ppb)	
June 1	73	Not Intensive Campaign
June 17	**74**	
June 18	**63**	
June 29	**79**	Bay Only Exceedance
June 30	**84**	Saturday
July 1	**80**	Bay Only Exceedance/Sunday
July 2	**64**	
July 3	**79**	
July 9	71	Not Intensive Campaign
July 10	99	Not Intensive Campaign

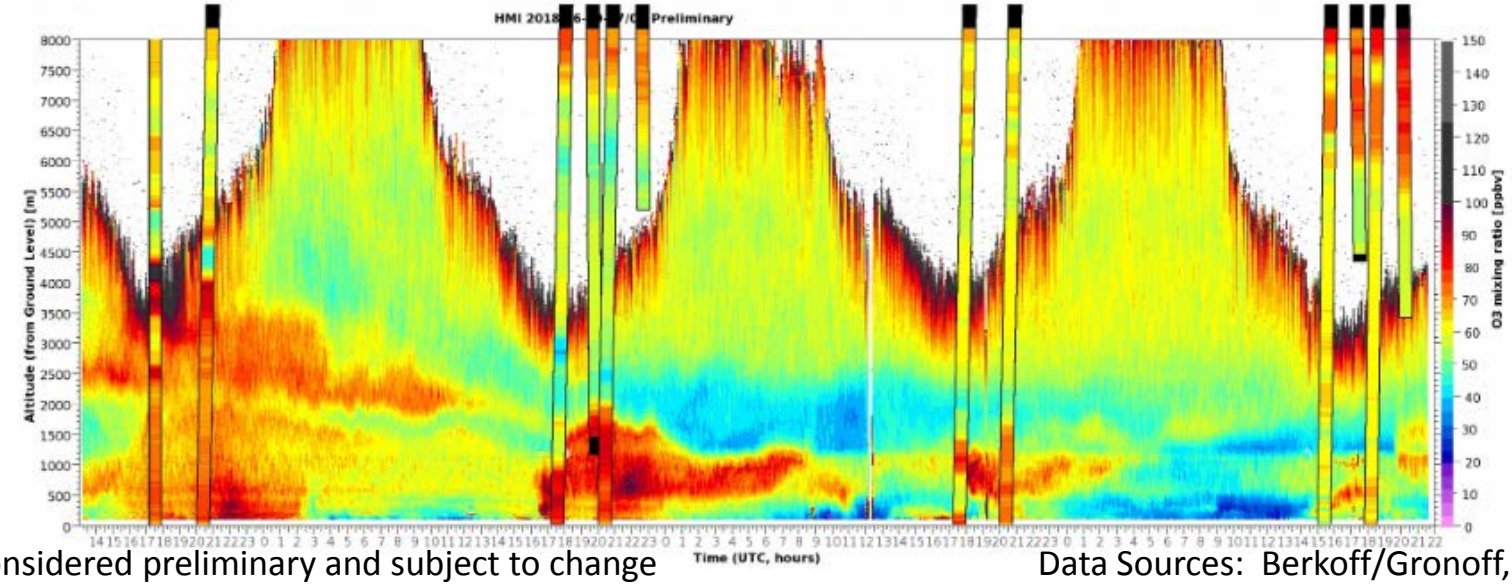
Intensive Campaign

HMI's fourth high for 2018 was 79 ppb (with a pretty short record compared to other years). If the island had a design value, it would be 82ppb (fourth highs: 2017 - 81ppb 2016 - 88ppb); Highest DV in Maryland at the moment is Edgewood at 75ppb

All data is considered preliminary and subject to change

Types of Exceedances at Hart-Miller Island

- Type-α: 'α' or "air above"
  - Air is transported downward from above the Bay's Surface
- Type-β: 'β' or "bottom-boats-below"
  - Pollution confined to air directly over the water's surface or the "bottom" of the atmosphere. Primary source appears to be boats
- Type-c : 'c' or "carry-over"
  - Carry-over from a previous day's pollution helps to further exacerbate either Type-α or β



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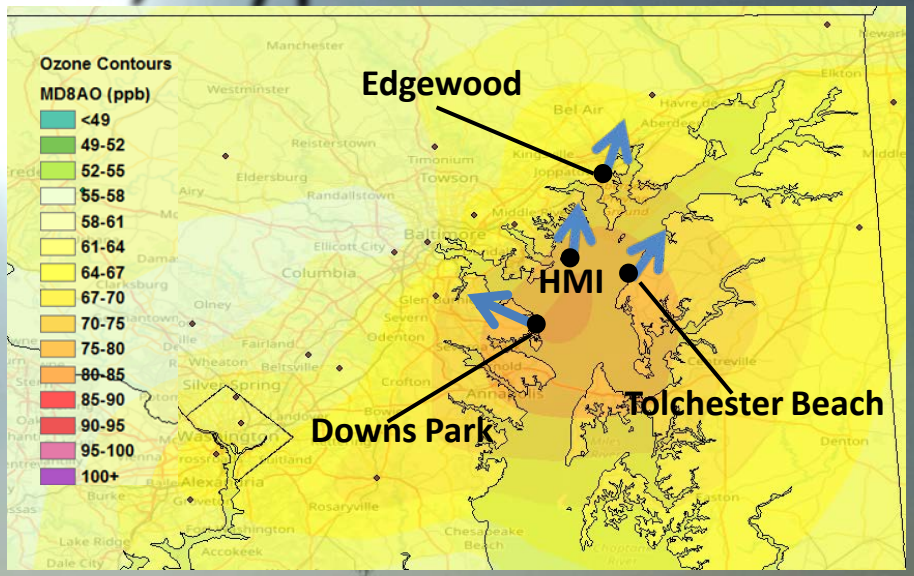
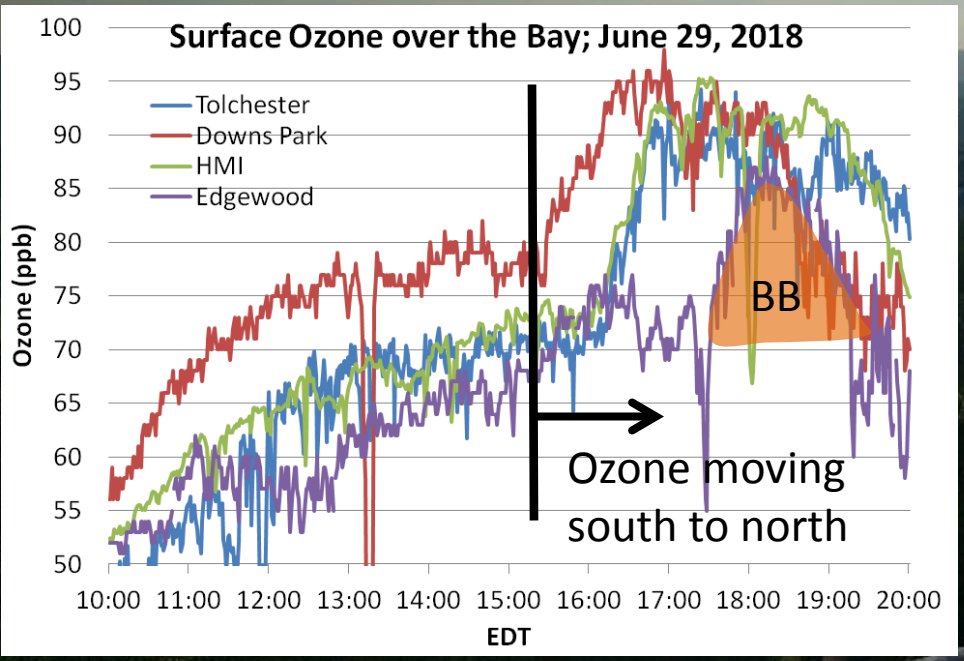
Data Sources: Berkoff/Gronoff, NASA; MDE

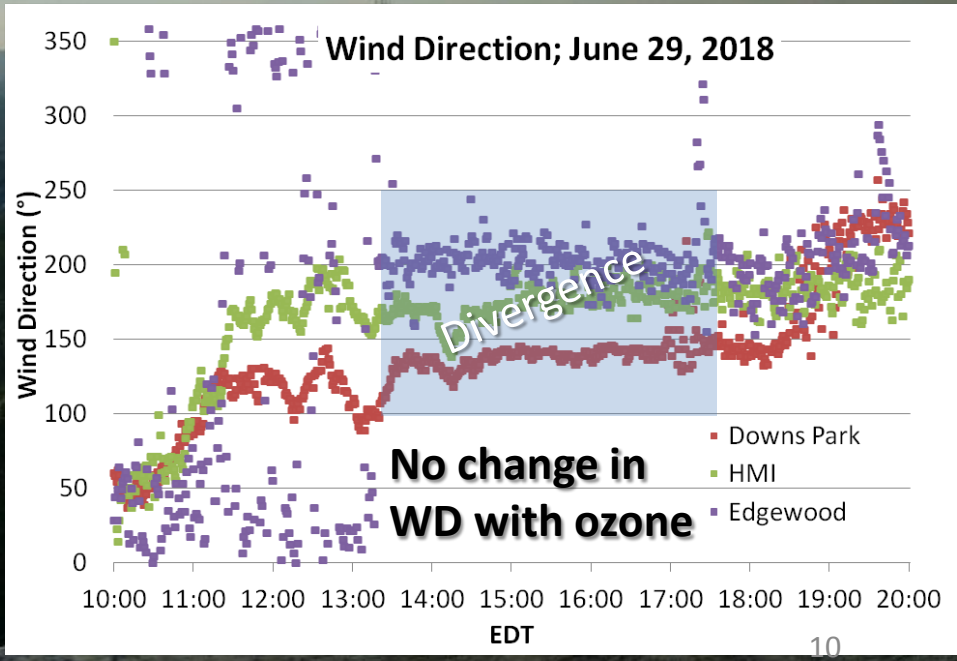
June 29, 2018; Type-α

- Exceedance at HMI, Downs Park and Tolchester Beach
- 93°F @ BWI; North winds
- 20ppb increases in 1 hour
- "Classic" Edgewood late-day BB

Edgewood [70ppb Max 8-hr Avg]







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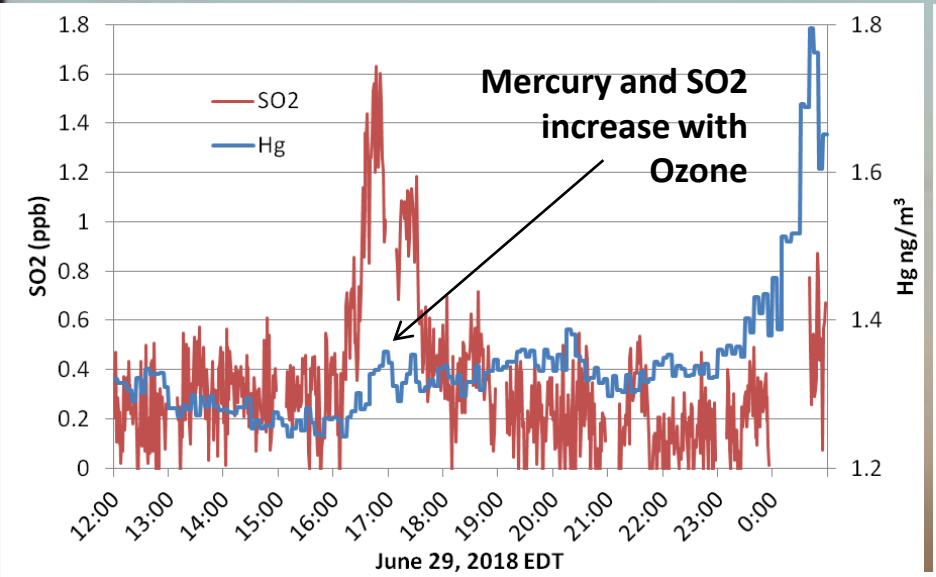
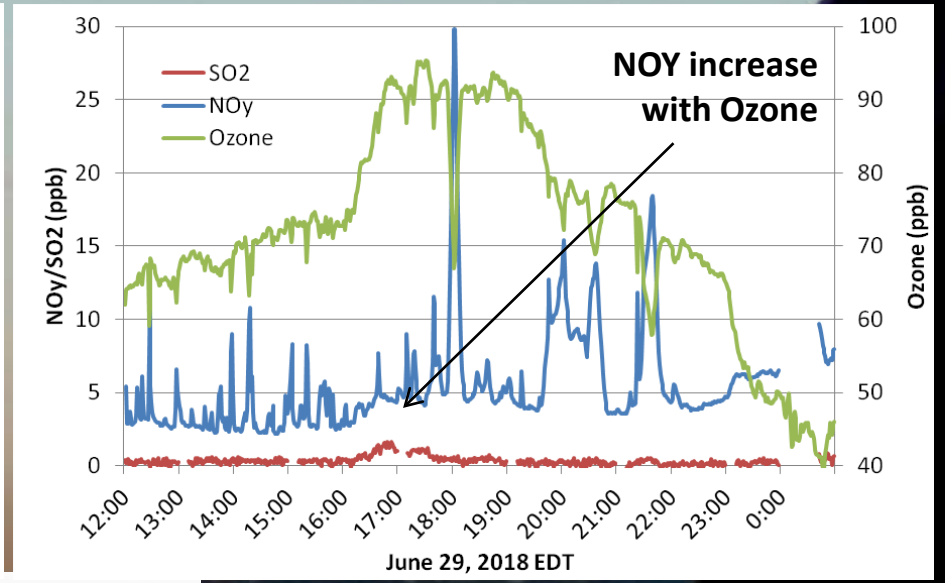
HMI Surface Observations: June 29, 2018





HMI surface observations provided by Xinrong Ren, UMD/NOAA

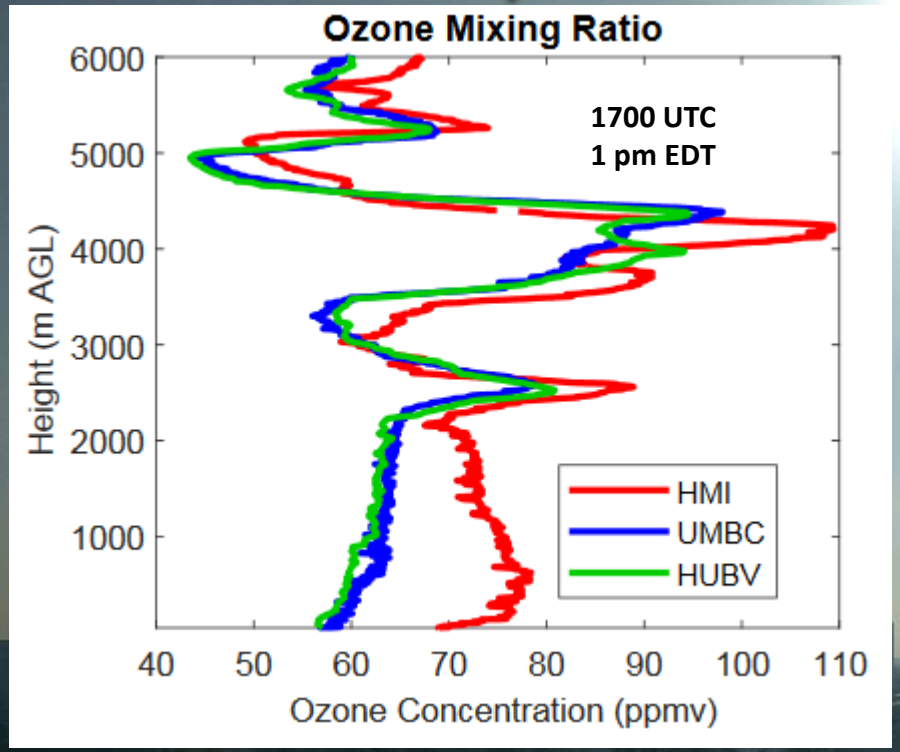
- Increase in SO2 and Mercury (Hg) at the same time ozone increased around 4:30pm (EDT) on June 29, 2018
- Increase in NOy for the duration of the heightened ozone period
- This ozone led to the dirty Edgewood BB!
- VOCs during high ozone (3-6pm) are consistent with coal, but also with gasoline….
…But all found in Curtis Bay area (white circle)

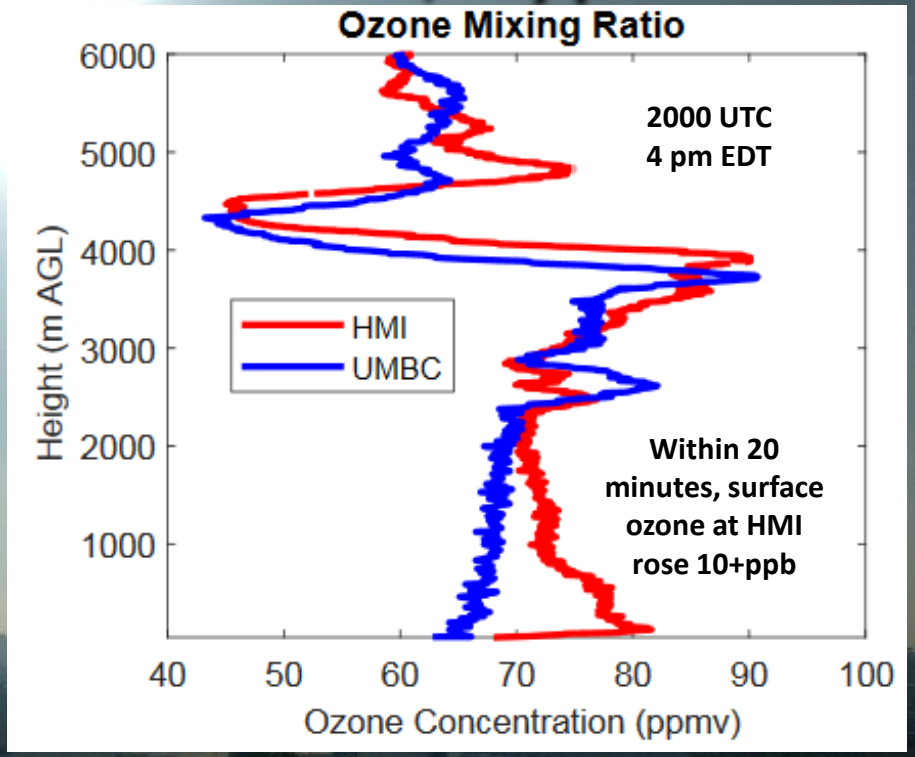
VOC Canisters at HMI showed greatest increases (%) from 12-3pm to 3-6pm (EDT) in:

o-, m&p -XYLENE
TOLUENE
ETHYLBENZENE
HEPTANE
2-METHYLHEXANE
Trichloroethene

All data is considered preliminary and subject to change

June 29, 2018 Observations; Type-α





- Extreme vertical ozone gradient at HMI ~20 ppb in 120 m
- Greater ozone downwind of Baltimore than upstream, but not at surface of water initially (~10 m)
- Still ~70ppb of ozone at Bay surface corresponding to southerly winds seen in earlier years

Ozonesondes provided by OWLETS-2 Science team

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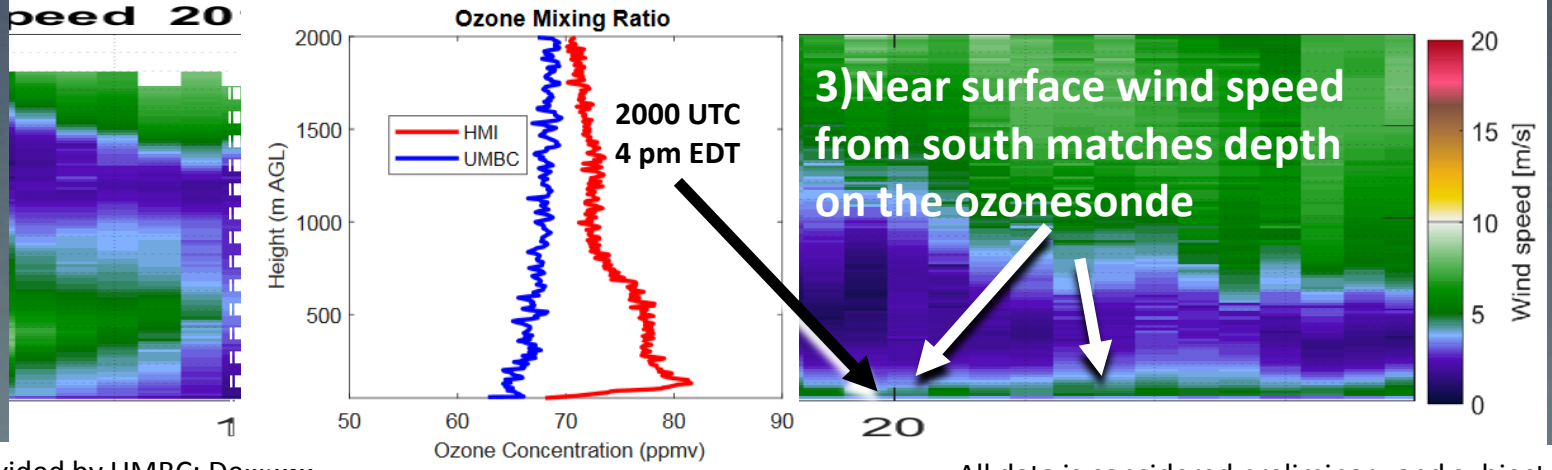
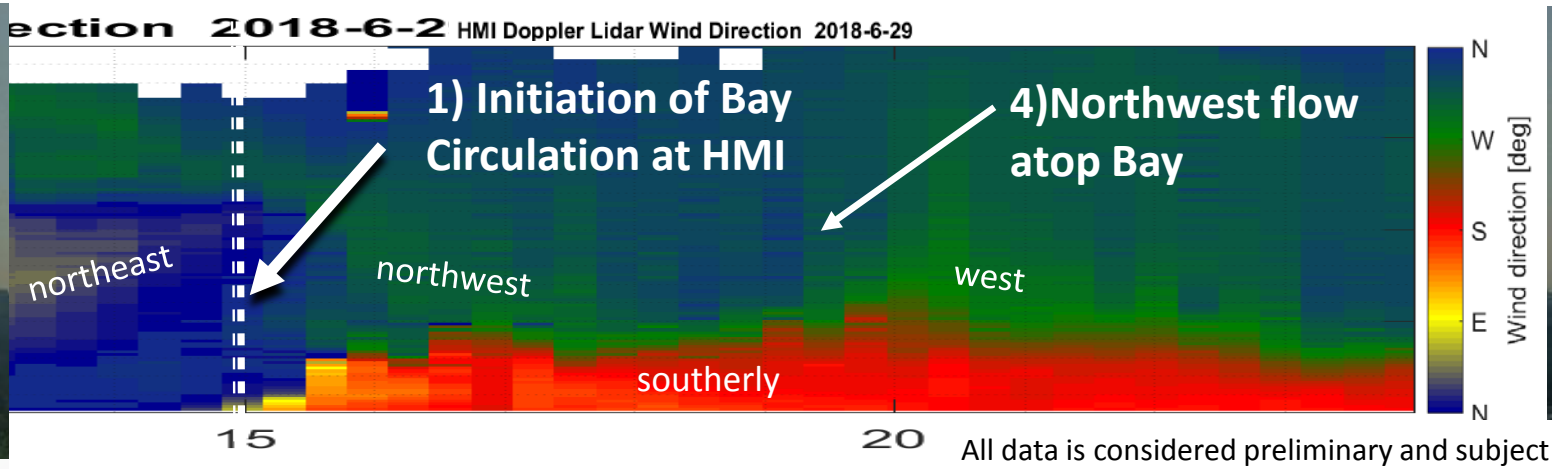


Wind Lidar provided by UMBC: Delgado

All data is considered preliminary and subject to change



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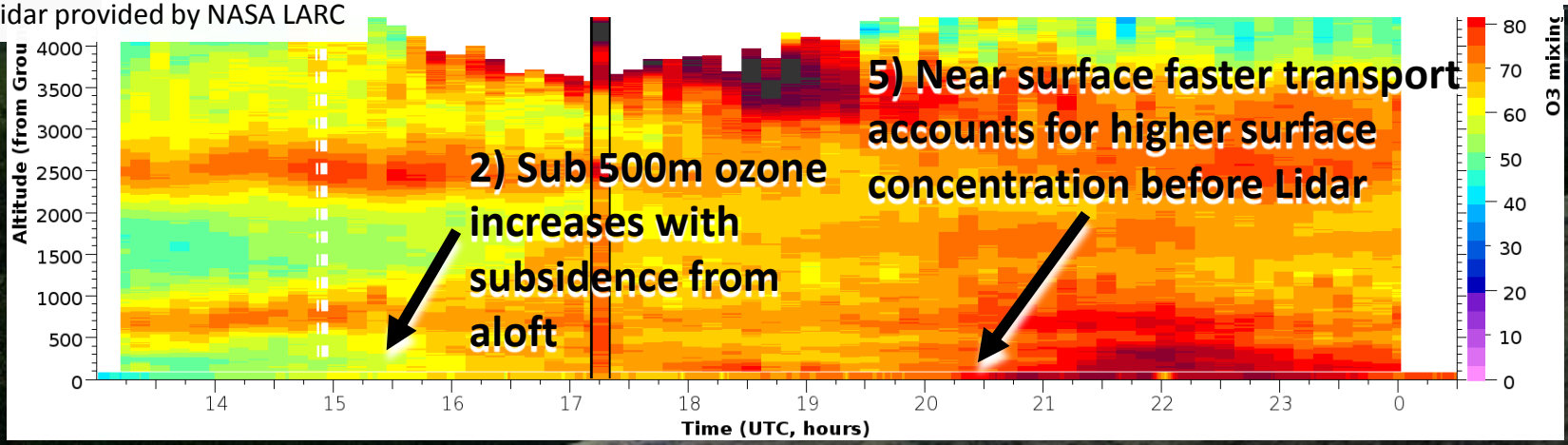
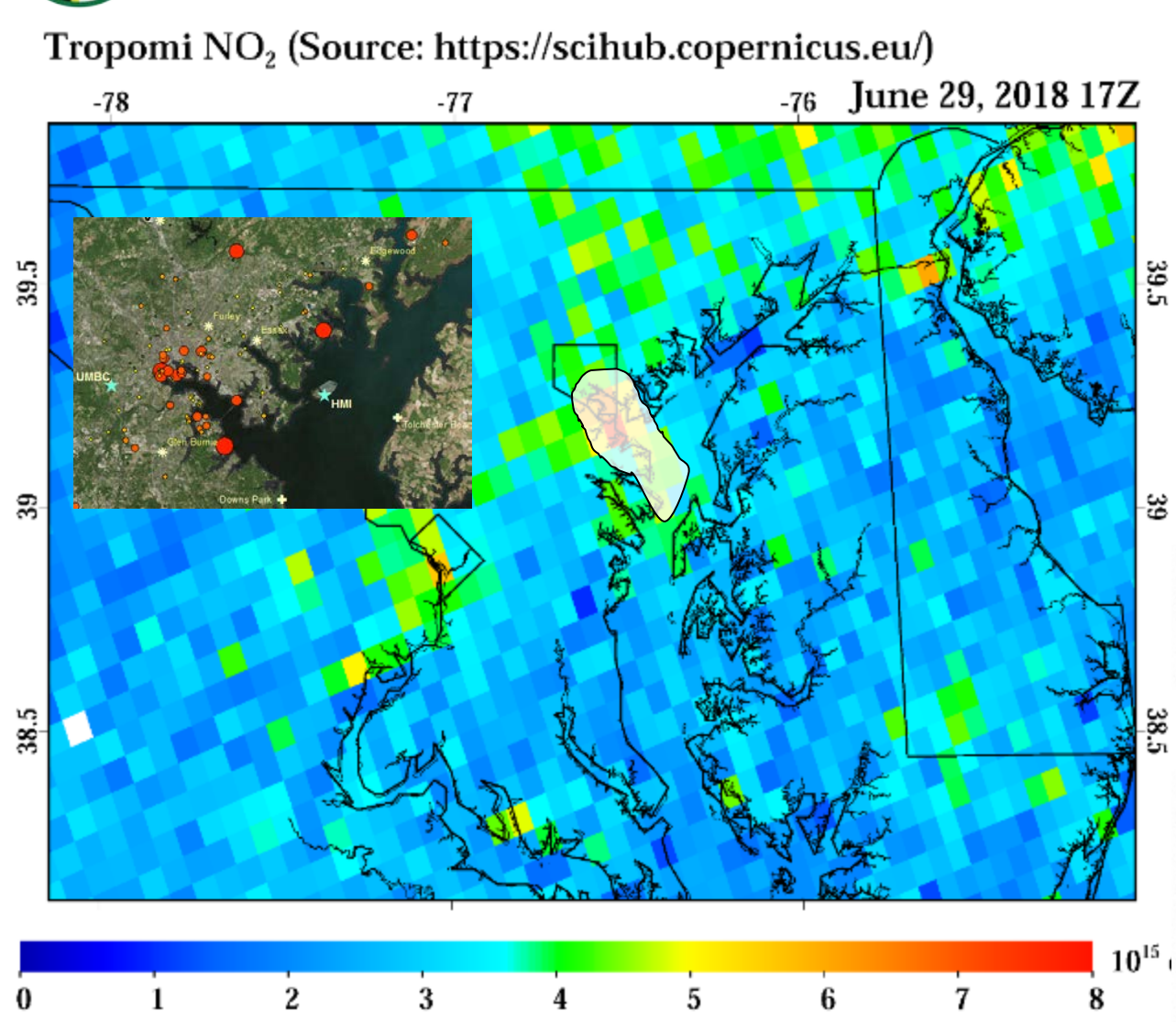
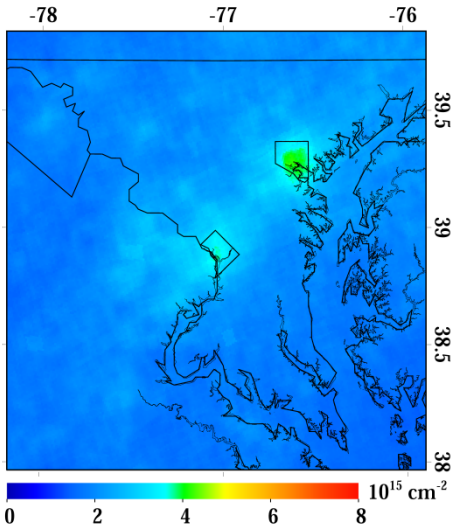
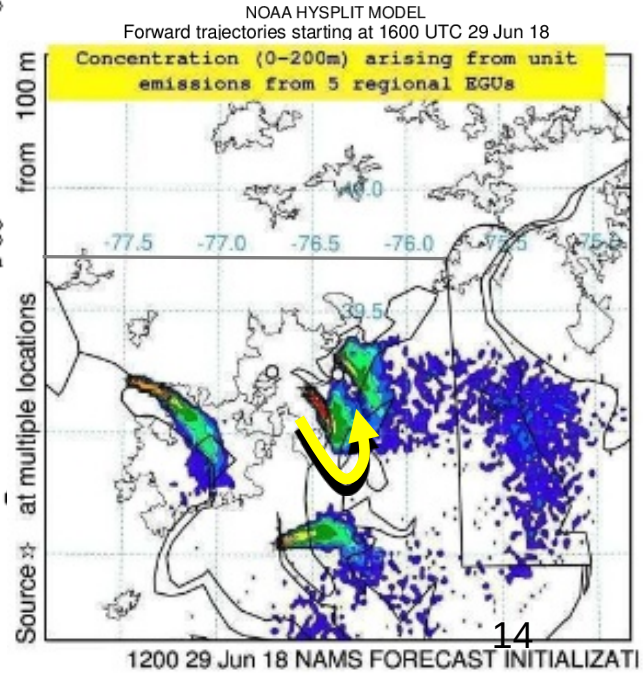
Ozone Lidar provided by NASA LARC



Satellite Captured "City" Plume

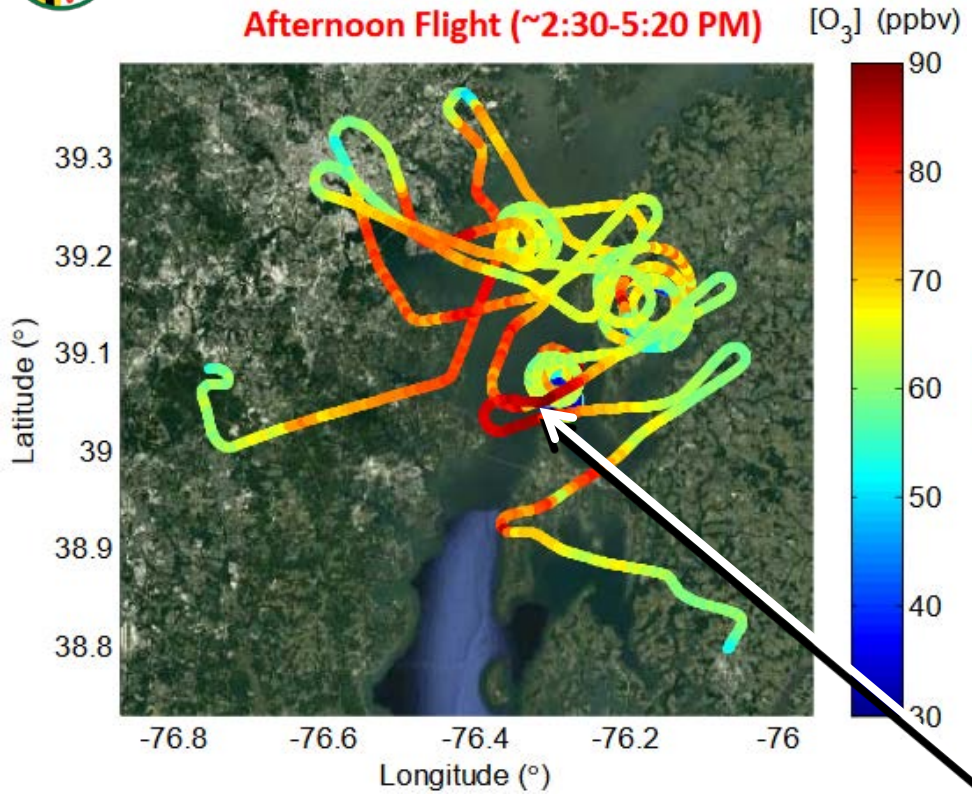


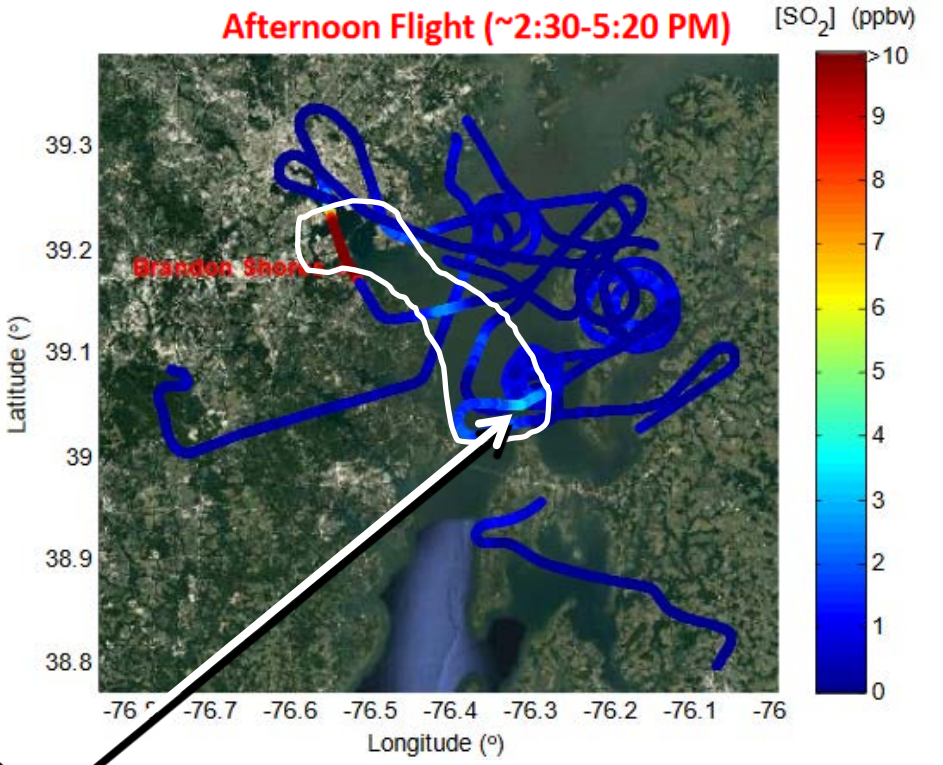




TropOMI: Dan Goldberg; Argonne National Laboratory
Hysplit Dispersion: Mark Cohen; Air Resources Lab; NOAA

Plane – Sampled EGU plume





- Co-located maximum in SO2 (~2-3ppb) with ozone (~90ppb) at ~1000m (winds are west and northwesterly @1000m)
- Note SO2 >>10ppb north of Brandon Shores and Wagner EGUs (south winds below 500m [stack height of Brandon Shores and Wagner:122m & 106m]
- Emissions go north first, turn, then move south out to the Bay

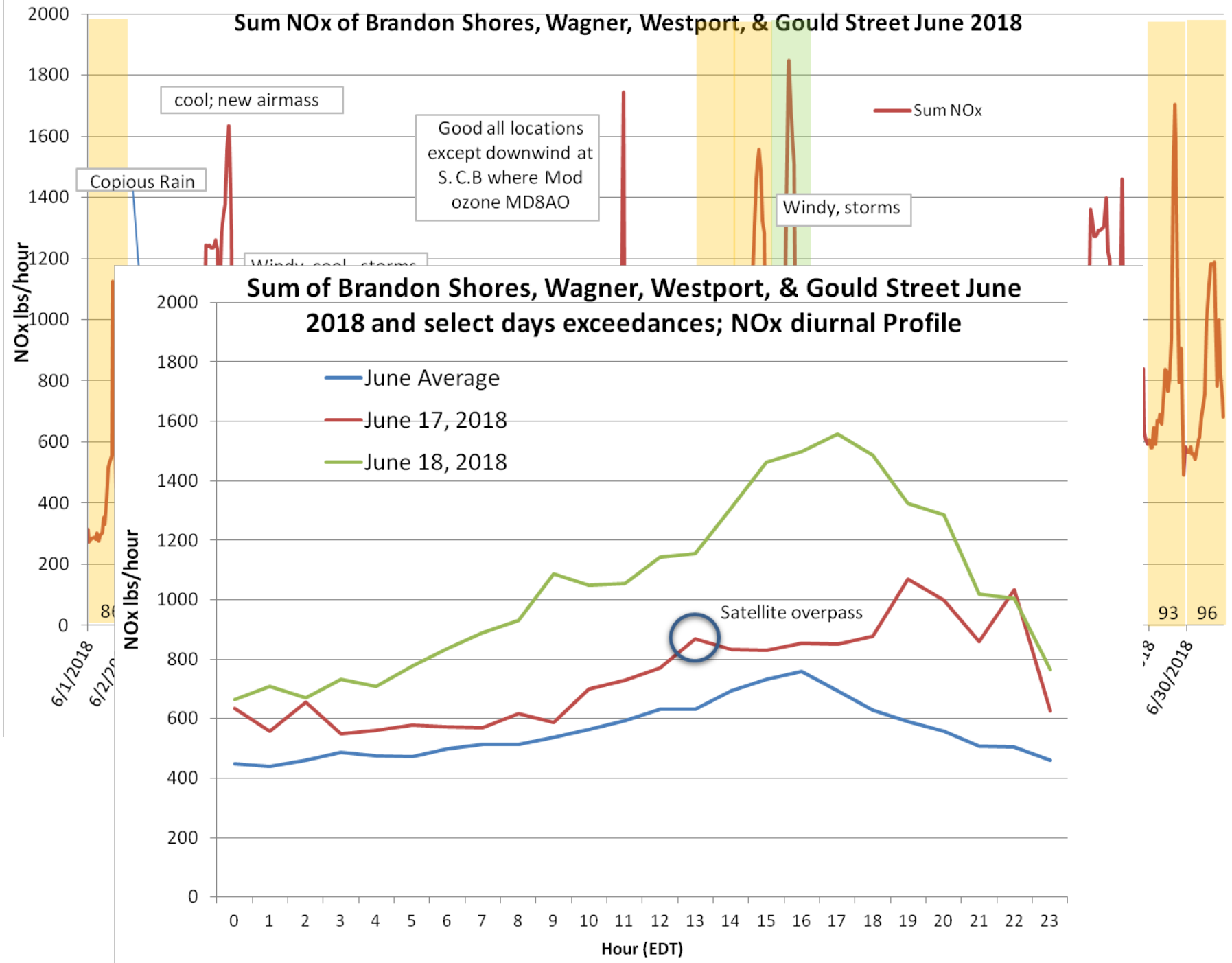
Aircraft Data: Xinrong Ren; UMD/NOAA

All data is considered preliminary and subject to change

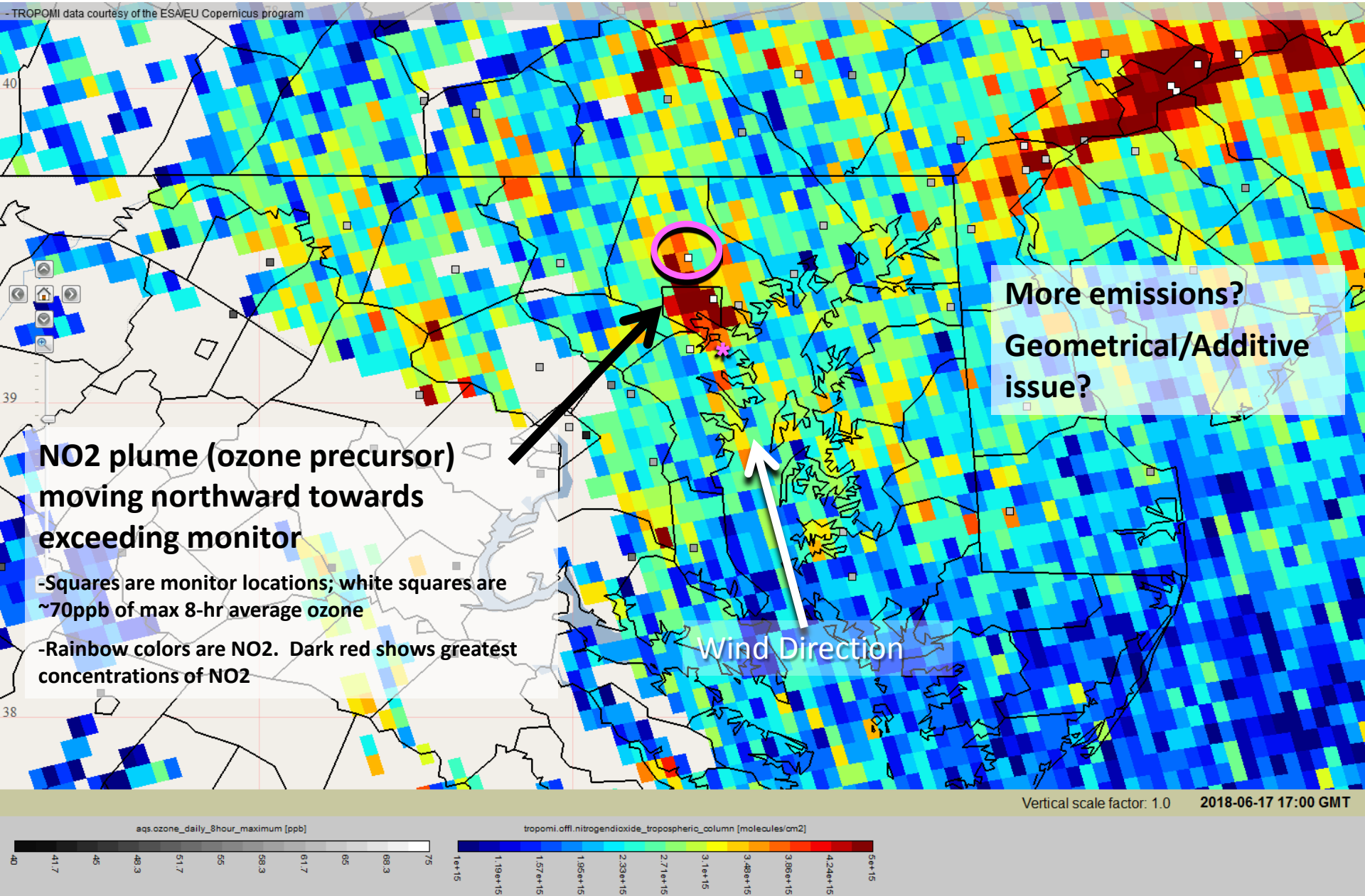
June 29, 2018; Type-α

- Northwest flow transported pollution a-top the marine boundary layer south of Baltimore over the Chesapeake Bay
- Subsidence took pollutants towards the surface
- Eventual breakdown of near-surface inversion caused further ozone enhancements as added pollution from Baltimore arrived
- Ozone increase associated with more NOy, along with SO2 and Hg, indicating coal combustion

All data is considered preliminary and subject to change


Sum NOx of Brandon Shores, Wagner, Westport, & Gould Street June 2018
cool; new airmass
Copious Rain
Good all locations except downwind at S. C.B where Mod ozone MD8AO
Windy, storms
Sum NOx
NOx lbs/hour
2000
1800
1600
1400
1200
1000
800
600
400
200
0
6/1/2018
6/30/2018
93
96
Sum of Brandon Shores, Wagner, Westport, & Gould Street June 2018 and select days exceedances; NOx diurnal Profile
June Average
June 17, 2018
June 18, 2018
Satellite overpass
NOx lbs/hour
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour (EDT)

NO2 from TropOmi Sunday, June 17, 2018.
Ozone exceedance at Padonia monitor and HMI. Near exceedance at UMBC, Furley.



Type-β: Boats/Below

Sunday June 17 *First weekend in June with good weather!*

Southerly winds = no transport from Baltimore to the Bay. Where does the ozone come from? Similar to previous days with low EGUs output in 2016/17

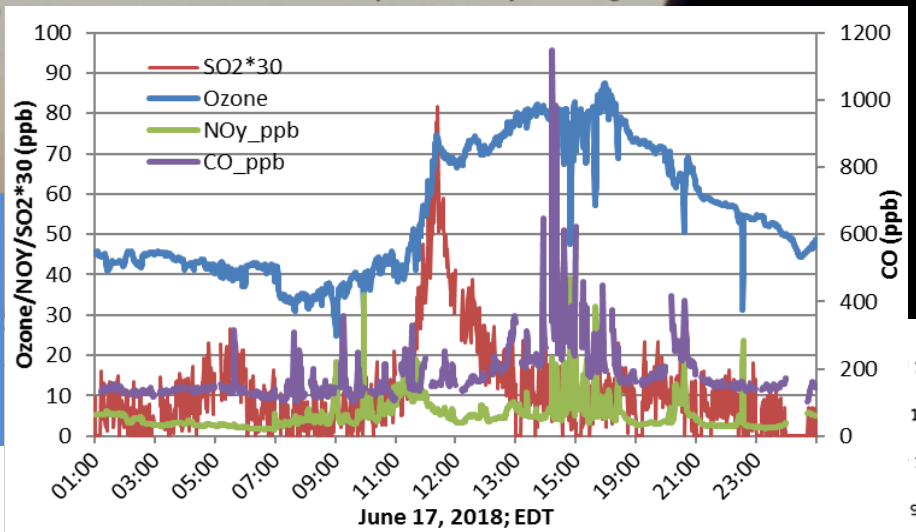
Morning surge: high SO2, low CO (EGUs)

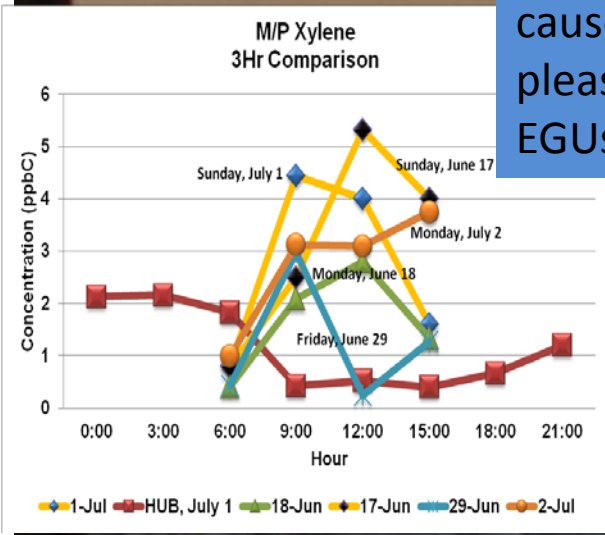
Afternoon: High CO/NOx; low SO2;

VOCs: gasoline & oil (Butene rose 900% - oil by-product)

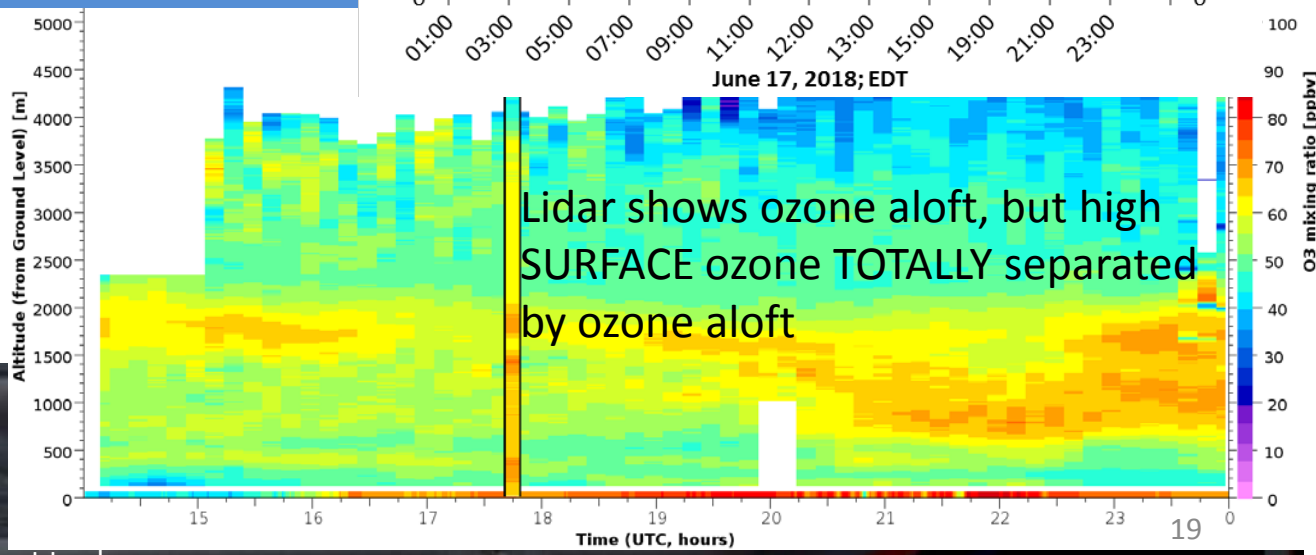
EGUs/Baltimore caused Padonia Exc; pleasure craft and EGUs at HMI

HMI surface observations provided by Xinrong Ren, UMD/NOAA





Large amounts of Xylene in the afternoon



Lidar shows ozone aloft, but high SURFACE ozone TOTALLY separated by ozone aloft

All data is considered preliminary and subject to change

Maryland Department of the Environment

Conclusions

OWLETS-2 Ozone Water-Land Environmental Transition Study

- Local Transport from Baltimore contributes to heighted ozone at Edgewood, MD
- "Dirty" Bay Breezes occur only in "special" circumstances of Northwest synoptic flow and heightened NOx profiles
- Enhanced ozone develops in a low-momentum airmass over the water (but above the surface layer)
- Vertical transport of pollutants into the Bay is key to the evolution of the surface ozone plume that develops
- EGUs(incinerator?) were a prime contributor to Bay ozone, but evidence shows boats may contribute to high ozone over the water
- Industry and cars also contribute

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OWLETS-2 Participants

https://www-air.larc.nasa.gov/missions/owlets/reports.2018/index.html

- Maryland Department of the Environment (MDE)
- Maryland Environmental Services (MES)
- Maryland Port Administration (MPA)
- Maryland Department of Natural Resources (DNR)
- National Aeronautics and Space Administration (NASA)
- National Oceanic and Atmospheric Administration (NOAA)
- University of Maryland Baltimore County (UMBC)
- University of Maryland College Park (UMCP)
- Howard University (HU)
- Hampton University (HU)
- Virginia Commonwealth University (VCU)
- Anne Arundel County (AAC)
- Peninsula Drone Services,LLC
  - PENINSULA DRONE SERVICES, WILLIAMSBURG, VA, 23185, UNITED STATES
  - INFO@PENINSULADRONES.COM
- Bill's Boats
- Tolchester Marina
- Interns
- Many More…

OWLETS-2 Participants (non-exhaustive)

Joel Dreessen[1], John T Sullivan[2], Ruben Delgado[3], Timothy Berkoff[4], Guillaume Gronoff[5,6], Lance Nino[7], Brian Carroll[8], Vanessa Caicedo[9], Laura Margaret Judd[10], Jassim A Al-Saadi[2], Maria Tzortziou[11], Vernon R Morris[12], Christopher J Hennigan[13], Stephan De Wekker[14], Misti Zamora[15], Ricardo Sakai[12], Adrian Flores[12], Xinrong Ren[16], Russell R. Dickerson[17], Philip Stratton[18], Winston T Luke[19], Paul Kelley[20], Sean Flynn[21], William Shuart[22], Reem A Hannun[2,23], Grant K. Sumnicht[2], Larry Twigg[2], Natasha Dacic[2], Belay Demoz[24], Robert Swap[25], Thomas J McGee[2] and OWLETS-2 Science Team,
(1) Maryland Department of the Environment, Air Monitoring Program, Baltimore, MD, United States, (2) NASA Goddard Space Flight Center, Greenbelt, MD, United States, (3) Joint Center for Earth Systems Technology, University of Maryland, Baltimore County, Baltimore, MD, United States, (4) NASA Langley Research Center, Hampton, VA, United States, (5)NASA LaRC, Hampton, VA, United States, (6)SSAI, Hampton, VA, United States, (7)Cornell University/NASA Goddard, Beltsville, United States, (8)University of Maryland, Baltimore County, MD, United States, (9)UMBC/GSFC, JCET, Savage, MD, United States, (10)Universities Space Research Association Columbia, Columbia, MD, United States, (11)CUNY City College of New York, New York, United States, (12)Howard University, Washington, DC, United States, (13)University of Maryland, Baltimore County, Baltimore, MD, United States, (14)University of Virginia, Environmental Sciences, Charlottesville, VA, United States, (15)Johns Hopkins Univ, Environmental Health & Engineering, Baltimore, United States, (16)University of Maryland, Dept. of Atmos. & Oceanic Sci., NOAA Air Resources Laboratory, College Park, MD, United States, (17)University of Maryland College Park, College Park, United States, (18)University of Maryland, College Park, United States, (19)NOAA-Air Resources Lab, Silver Spring, MD, United States, (20)NOAA College Park, College Park, MD, United States, (21)Peninsula Drone Services, LLC, Williamsburg, VA, United States, (22)Virginia Commonwealth University, Richmond, VA, United States, (23)Joint Center for Earth Systems Technology, Baltimore, MD, United States, (24)University of Maryland Baltimore County, Joint Center for Earth Systems Technology (JCET), Baltimore, MD, United States, (25)NASA Goddard Space Flight Center, Greenbelt, United States

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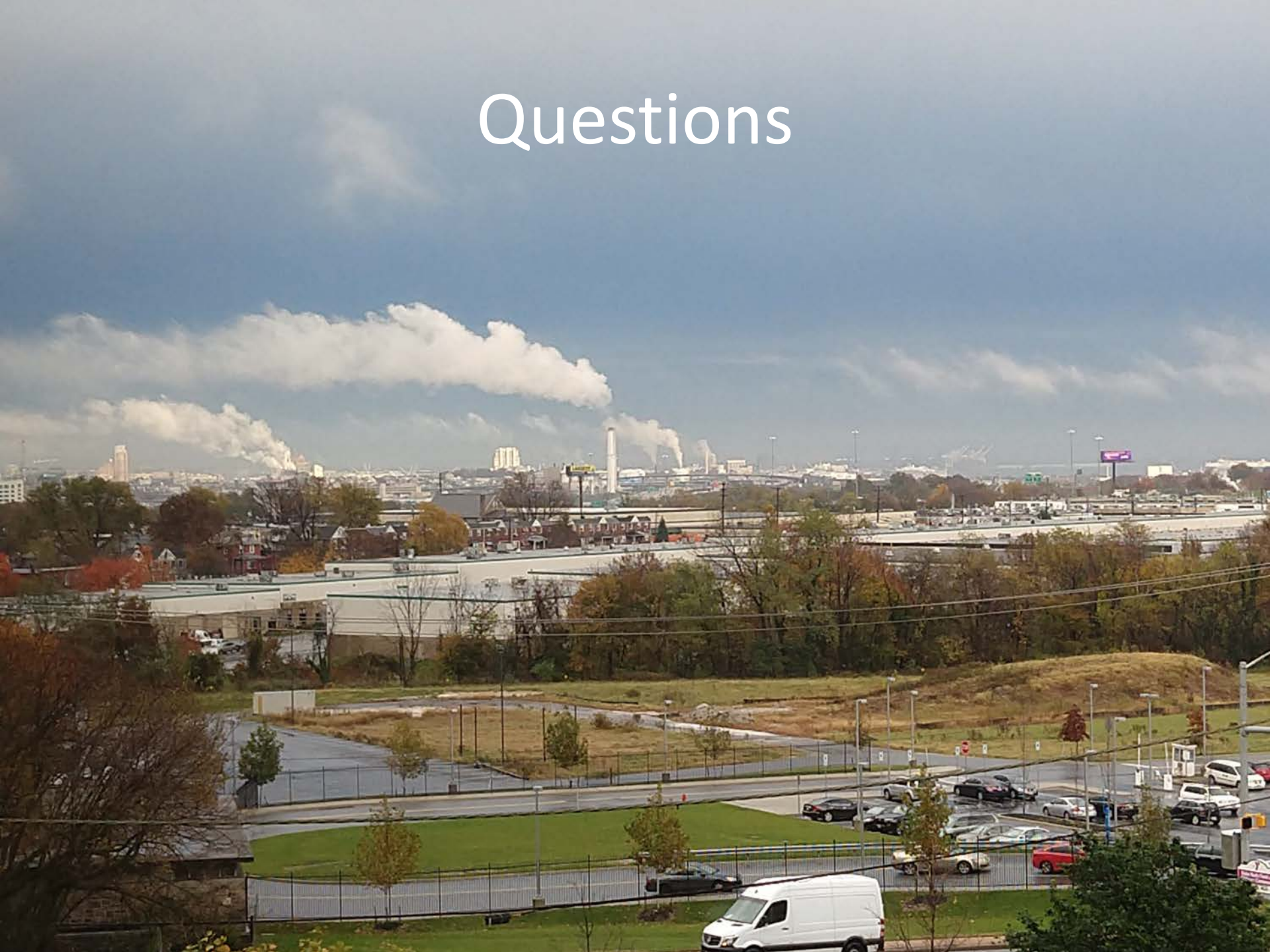
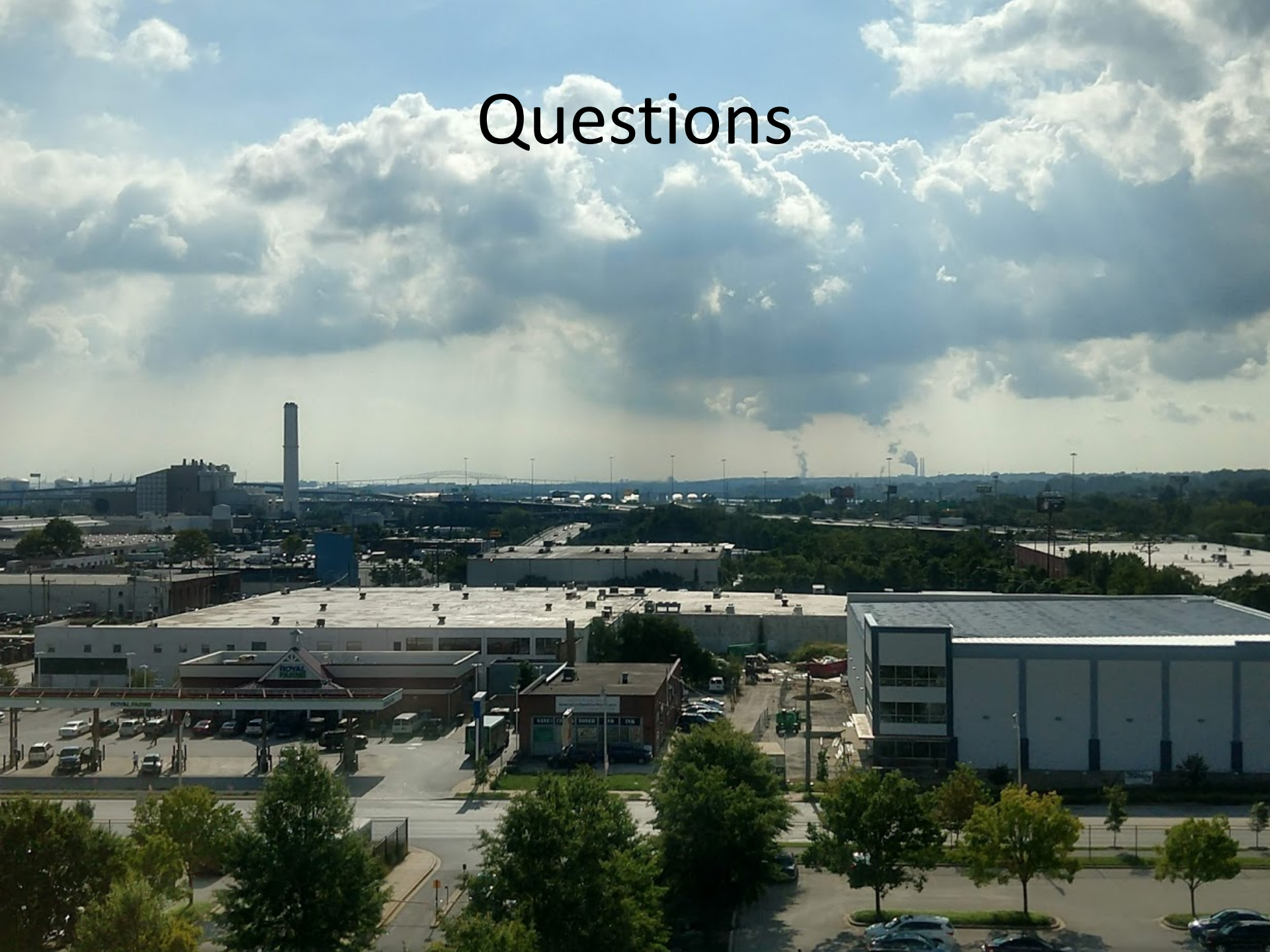
Washington, D.C. | 10–14 Dec 2018

Questions

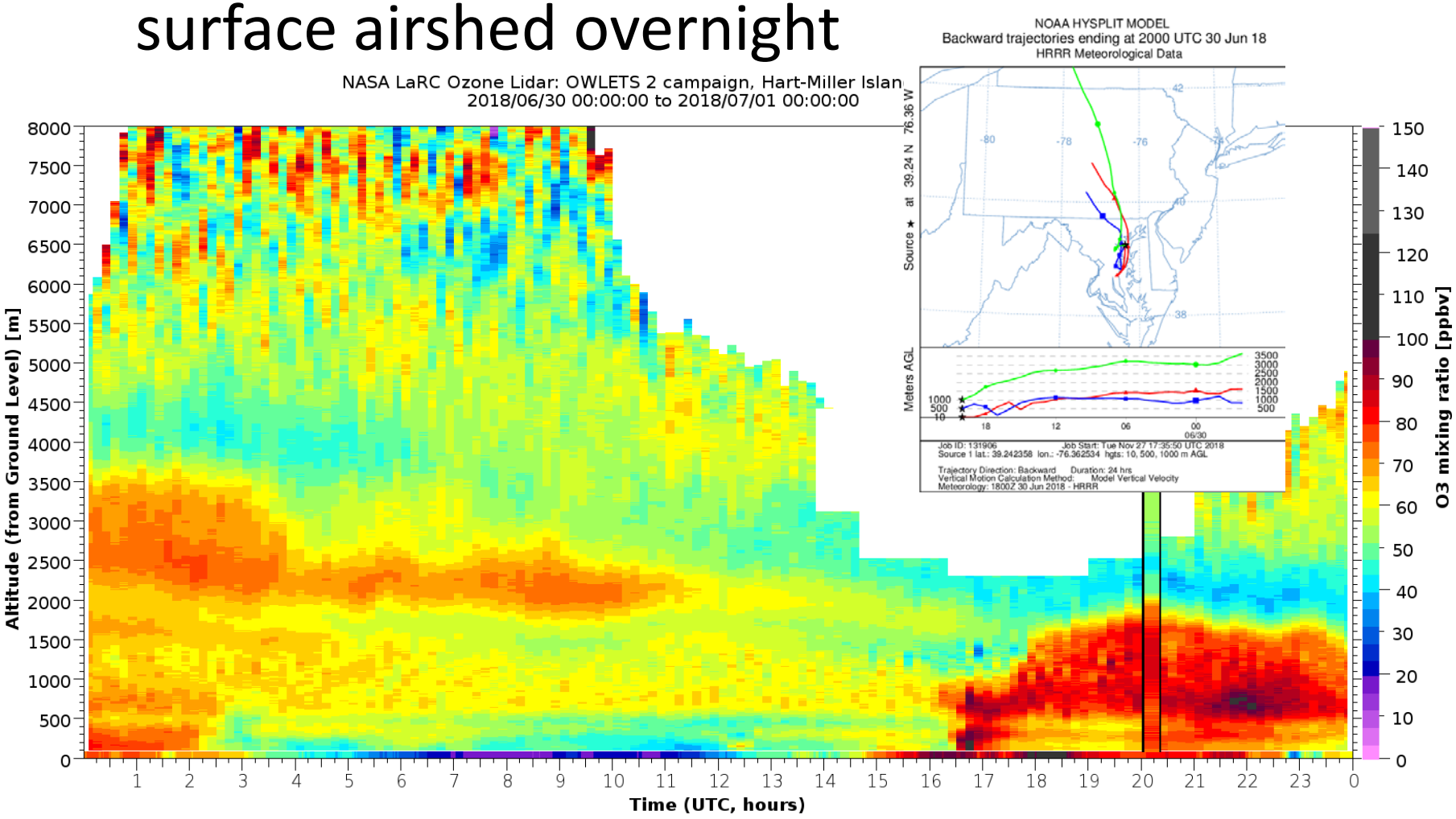


Questions



Type-c: Carry-Over

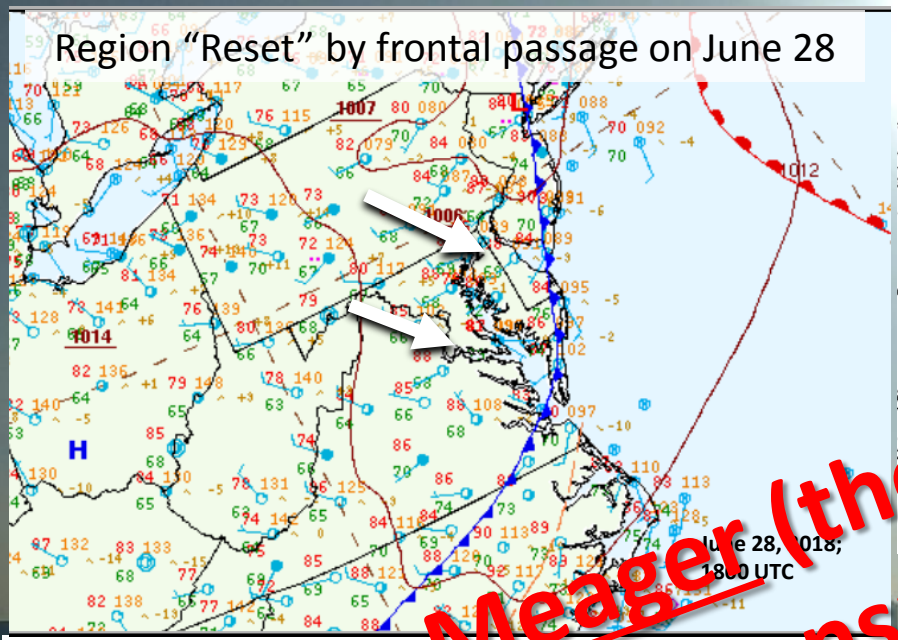
- Residual Pollution (NOy) remains in the near surface airshed overnight

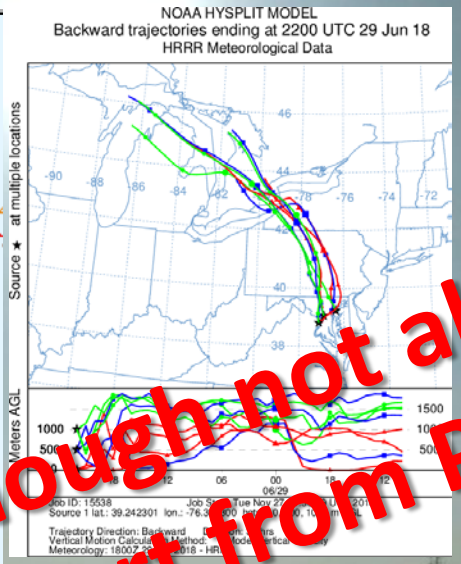


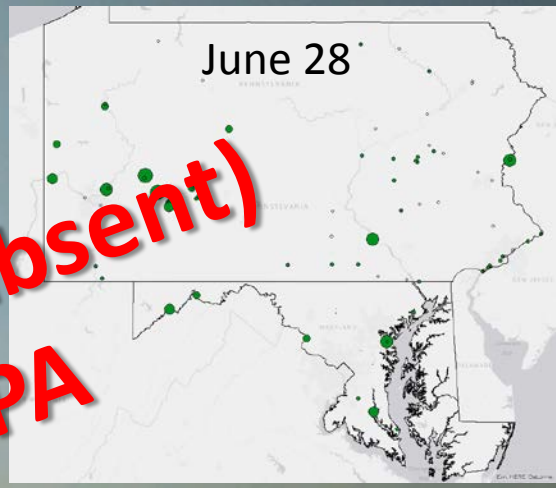
OWLETS-2 Objectives

1. What is the spatial and vertical extent of the ozone (and ozone precursors) in and around the Chesapeake Bay?
2. What are the mechanisms (low boundary layer, chemistry, weather) that produce high ozone over the Chesapeake Bay and lead to high ozone at locations on land near the Chesapeake Bay?
3. How much of the ozone (ozone precursors) is a result of local sources (EGUs, mobile, ship, boat, etc) and/or pollutant transport (westerly, nocturnal low level jet) into Maryland?
4. Why do the photochemical models appear to over-predict ozone concentrations in and around the Chesapeake Bay?
5. What source groups and in what locations do policy makers need to focus on to reduce ozone over the Chesapeake Bay?

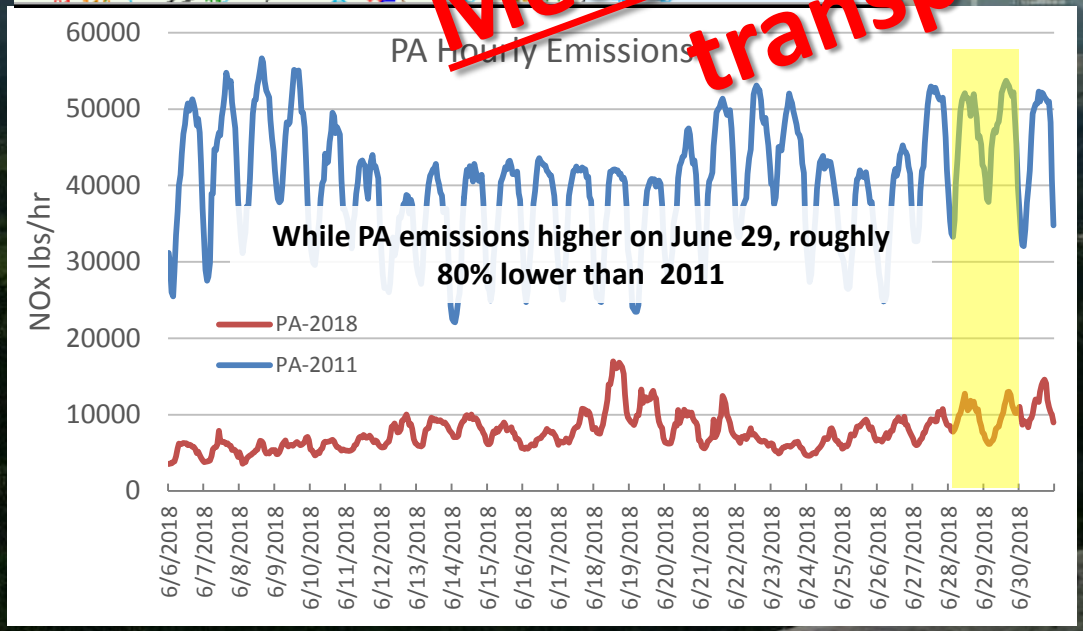
June 29, 2018; Type-α; Not Long Distance

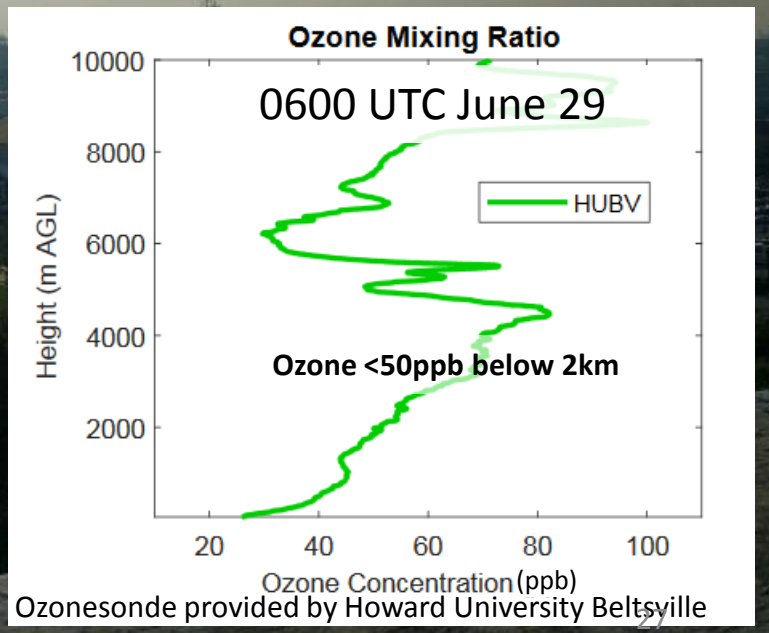






Meager (though not absent) transport from PA





Ozonesonde provided by Howard University Beltsville

All data is considered preliminary and subject to change

OWLETS-2

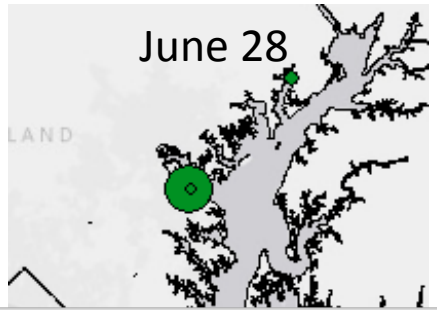
- Intensive study period from June 6 – July 6
  - Island instrumentation in place May 25 – July 26
  - 9 MD/8 HMI ozone exceedances in that time
  - 5 MD/HMI exceedance during intensive campaign
  - 2 days with exceedances at HMI only (no where else in the network exceeded) during intensive period [6/29; 7/1]
  - Weekend vs Weekday Exceedance

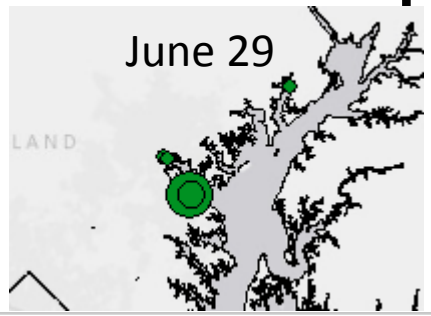
HMI's fourth high for 2018 was 79 ppb (with a pretty short record compared to other years). If the island had a design value, it would be 82ppb (fourth highs: 2017 - 81ppb 2016 - 88ppb); Highest DV in Maryland at the moment is Edgewood at 75ppb

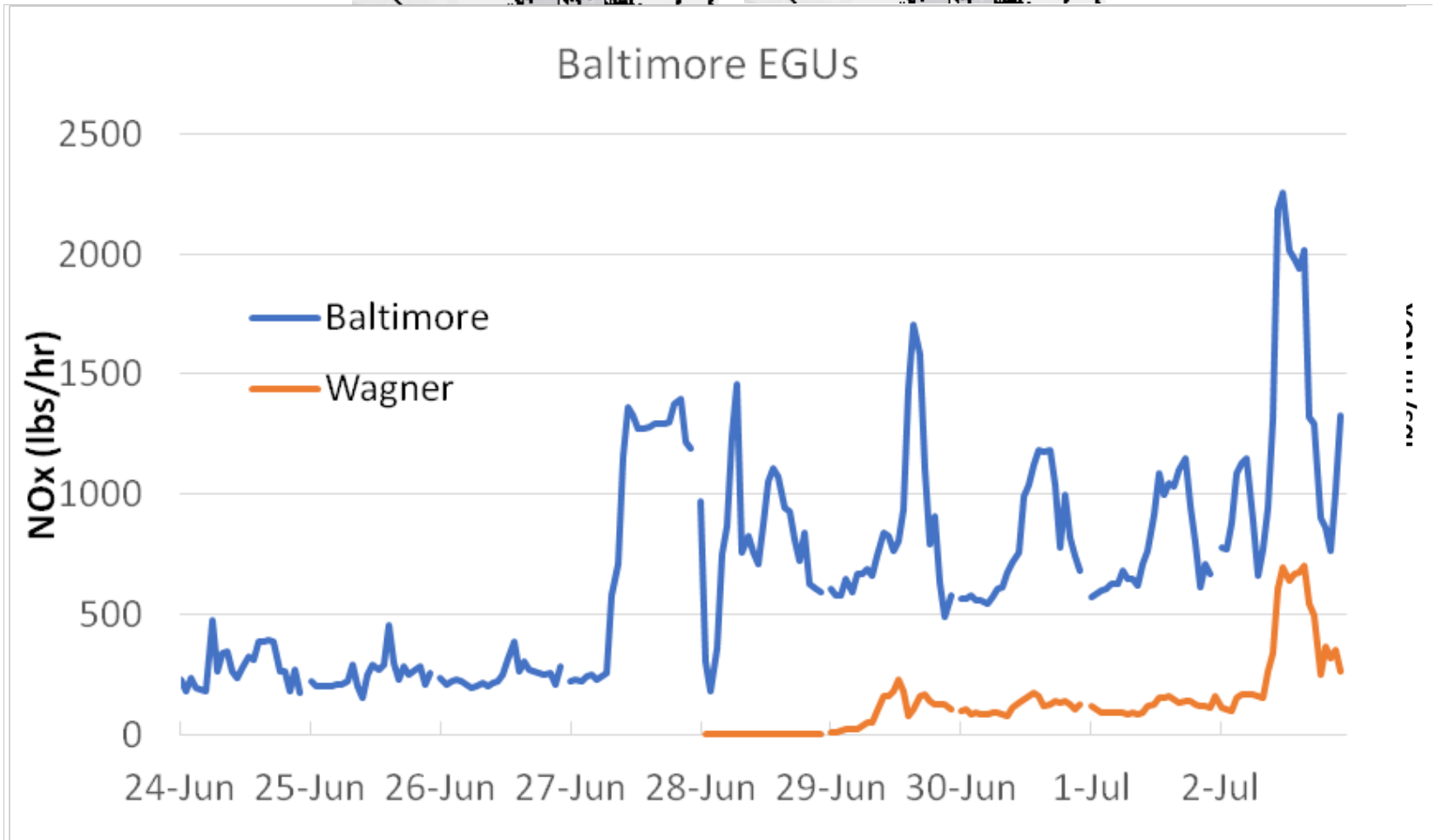
Maryland Department of the Environment

All data is considered preliminary and subject to change

Type-α: Vertical Transport







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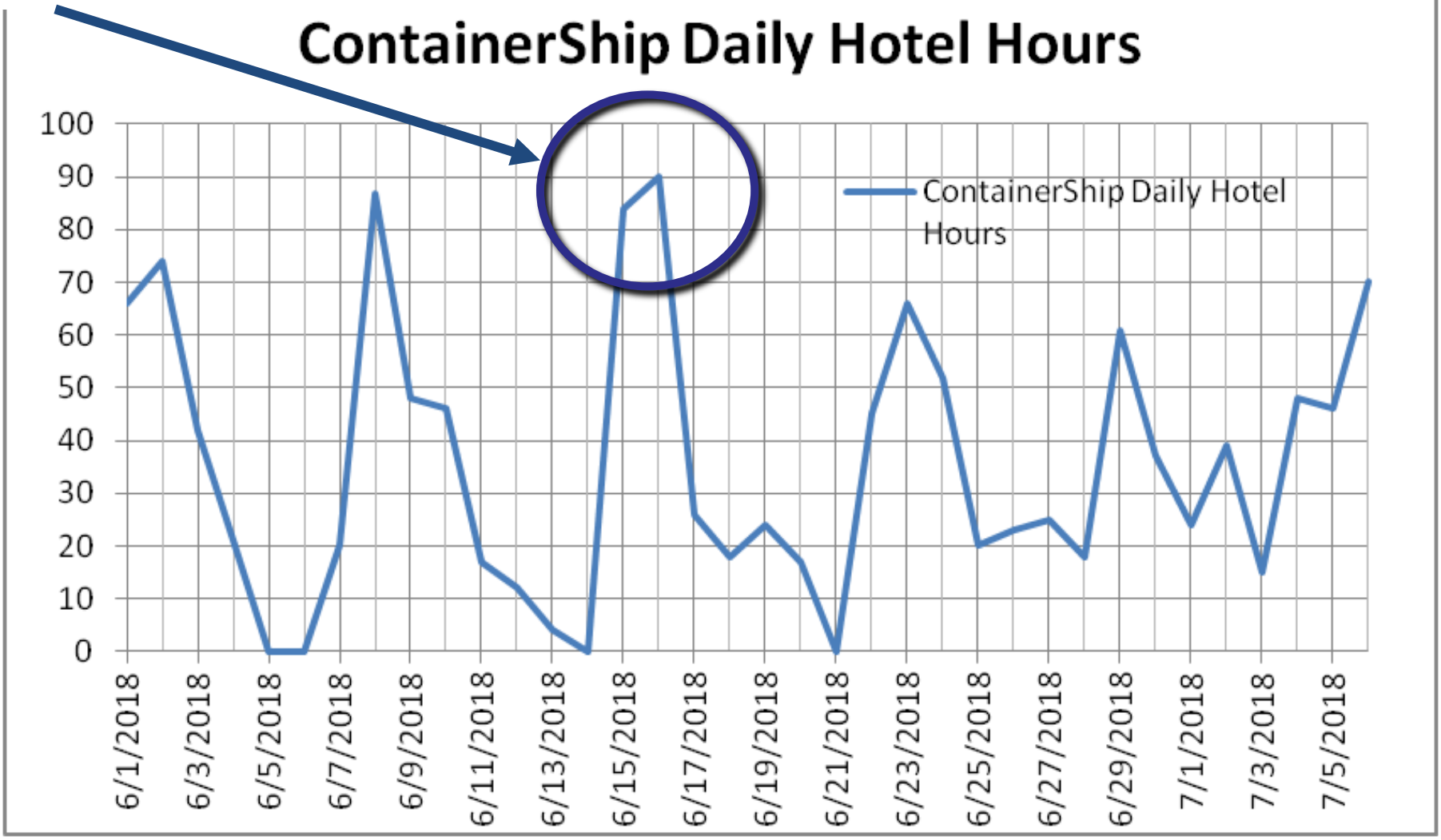
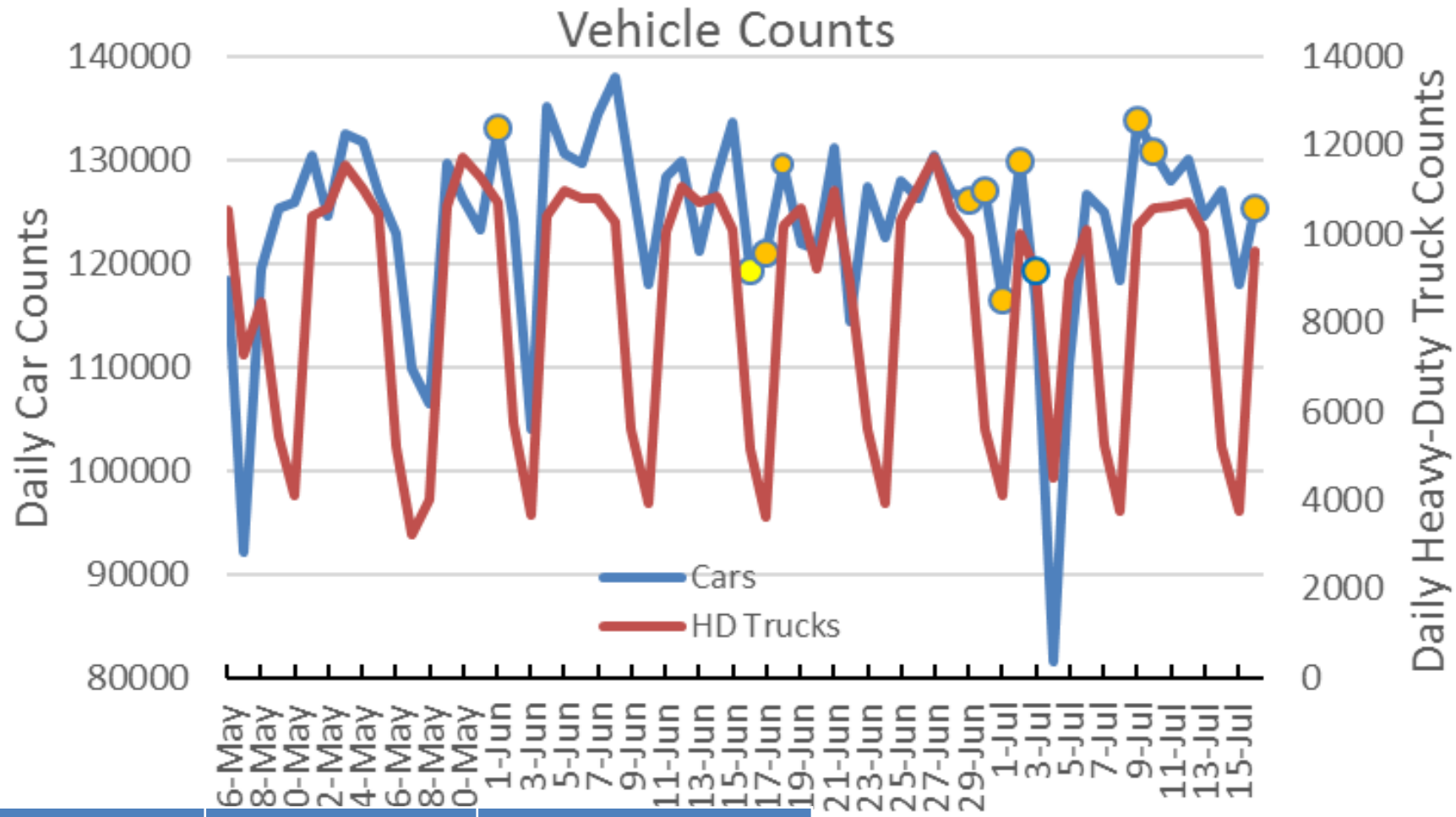
Other/Boats/Port/Industry

Port Activity – HMI observed high CO and SO2 simultaneously, transitioning to high NOx and CO



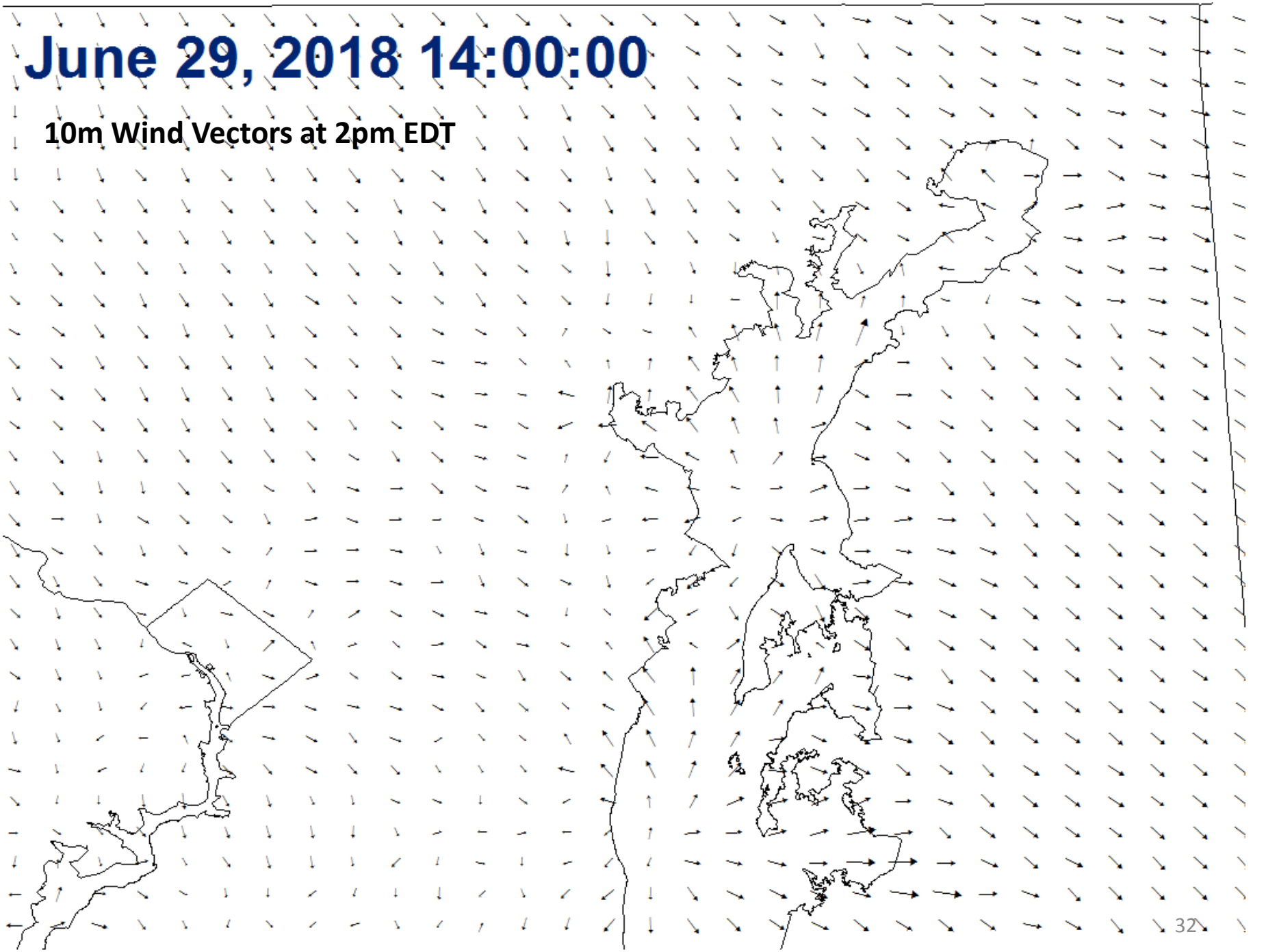


	Car	Trucks
Daily	168,658	13,575
Daily Peak 6am-6pm:	123,844 (73%)	8,477 (62%)
Weekday peak	126,411	10,336
Weekend peak	121,163	4,608
Exceedances	126,285	8,523
Weekday Ex	128,079	10,052

Vehicles

June 29, 2018 14:00:00

10m Wind Vectors at 2pm EDT



Type-β: Boats/Below???

Days with southerly winds everywhere = no transport from Baltimore to the Bay. Where does the ozone come from? TRAJECTORIES

Sunday vs Monday

Consistent with previous days with low EGUs output in 2016/17

June 17 trajectory Lidar/sonde VOCs/ozone/SO2/Hg

Morning EGU surge, afternoon high CO/NOx; low SO2; VOCs dominated by gasoline (Butene rose 900% - oil by product) but a Sunday and trajectories from the Chesapeake Bay; Lidar shows ozone at surface TOTALLY separated by ozone aloft***. First weekend in June with good weather!***

EGUs/Baltimore caused Padonia; pleasure craft and EGUs at HMI

June 18 southerly over water Lidar/sonde VOCs/ozone/SO2/Hg

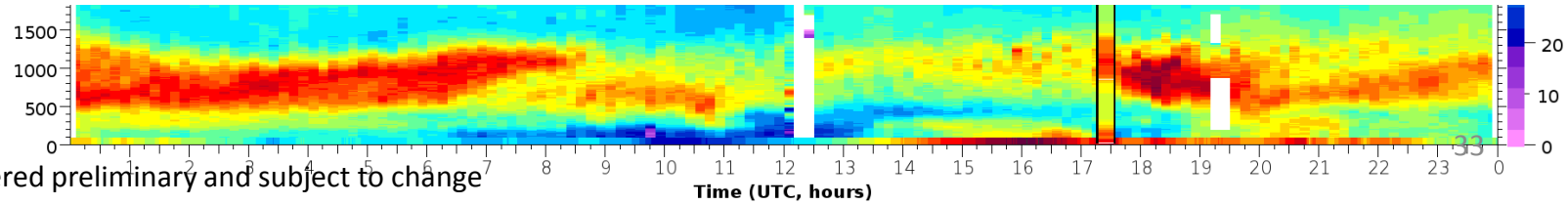
No morning surge, afternoon CO/NOx/SO2 relatively low. VOCs dominated by gasoline lower concentrations; Lidar shows ozone aloft, but not at surface. Seems to be coincident with plume from BS and/or DC area making its way over the Bay along the trough axis. Nothing in the Bay!!!

July 1 trajectory Lidar/sonde VOCs/ozone/SO2/Hg

Southerly trajectory; lidar shows layer of ozone at surface completely separate from aloft.

Starts with left over EGU air at surface…transitions to boats; higher CO with low SO2. VOCs are lower…but bay is cleaning out, so % drops are due to that. Cyclopentane still increased.

July 2 – Bay did not excxeed.



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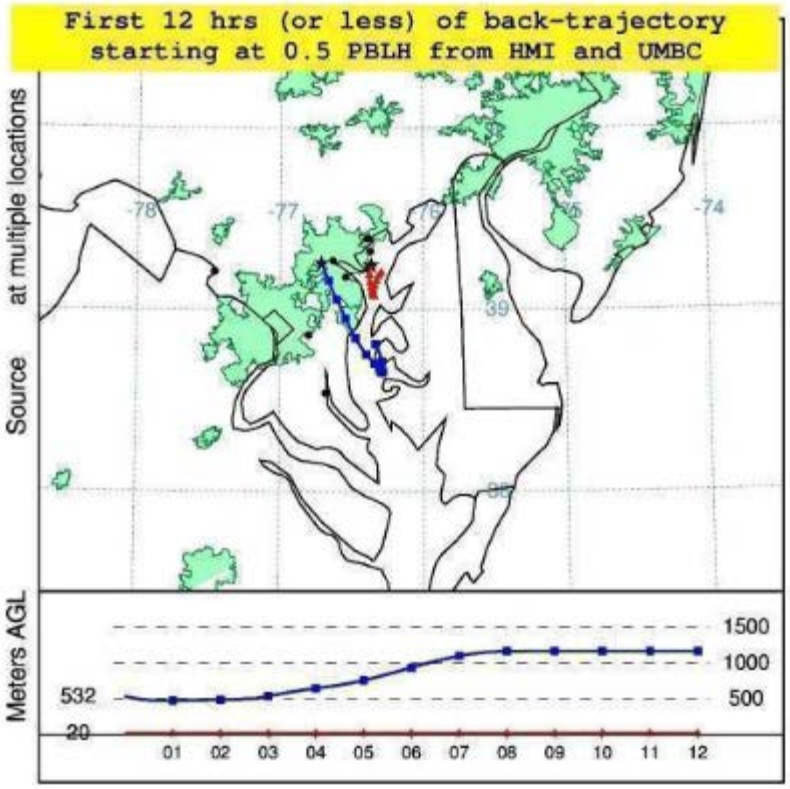

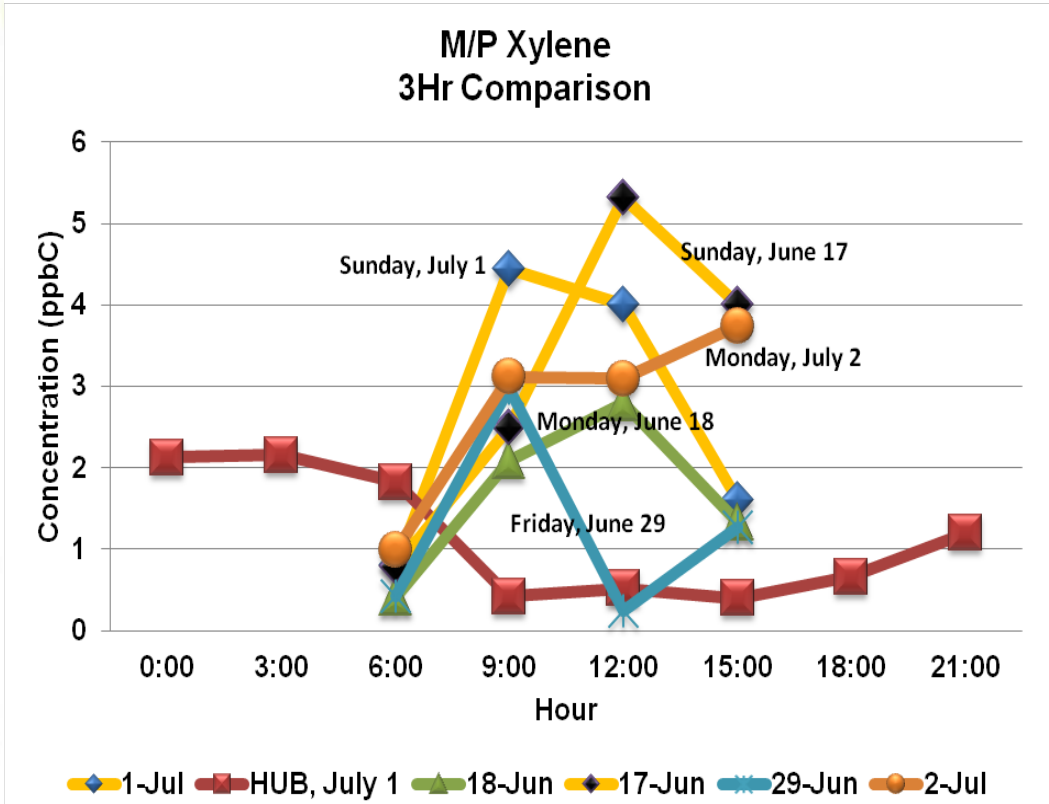

Southerly trajectories on June 17