



Ozone Water Land Environmental Transition Study



Example measurements in an attempt to provide a 4-D view of ozone in a coastal region



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**AGU Fall Meeting
December 15, 2017**

ACKNOWLEDGEMENTS:

Support was provided by: NASA Science Innovation Fund, NASA Tropospheric Composition Program, NASA TEMPO Student Collaboration Project (supported by Earth System Science Pathfinder Program), NASA Postdoctoral Program, EPA ACE Research program



Additional affiliations/contributors



LaRC Lidar team: Bill Carrion, Betsy Farris

GSFC Lidar team: Larry Twigg, Lance Nino

UAV/drone team: Eddie Adcock, Mark Motter, Ryan Hammit, Zak Johns, Ian Fenn, et al.

LaRC TEMPO student collaborators & volunteer: Lindsey Rodio, Jeremy Schroeder, Betsy Farris, Pablo Sanchez, Emily Gargulinski, Marlia Harnden

Chesapeake Bay-Bridge Tunnel Authority: Ed Spencer, Tim Holloway

Hampton University: Bill Moore, student interns: Desorae Davis, Angela Atwater

GeoTASO team: Scott Janz, Jay Al-Saddi, Matt Kowalewski, Laura Judd

SERC/GSFC Research Vessel Team: Maria Tzortziou, Ryan Stauffer, Owen Parker, Julio Roman, Lena Shalaby, Cpt Mike Goodison, Belay Demoz

SARP/Sherpa team: Sally Pusede, Glenn Wolfe, James Flynn, Jessica Munyan, Thomas F Hanisco, Don Blake, Brenna Biggs, Reem Hannun, WFF Pilots and Crew

PANDORA team: Bob Swap, Maria Tzortziou, Nader Abuhassan, Alexander Cede, Si-Chee Tsay

GSFC AERONET team: Brent Holben et al.

LaRC Website and archive: Gao Chen, Ali Aklan

VA DEQ: Dan Salkovitz, Kristen Stumpf, Brian King, John Brandt, Chuck Turner

MDE: Joel Dressen

Virginia Living Museum: Dan Summers

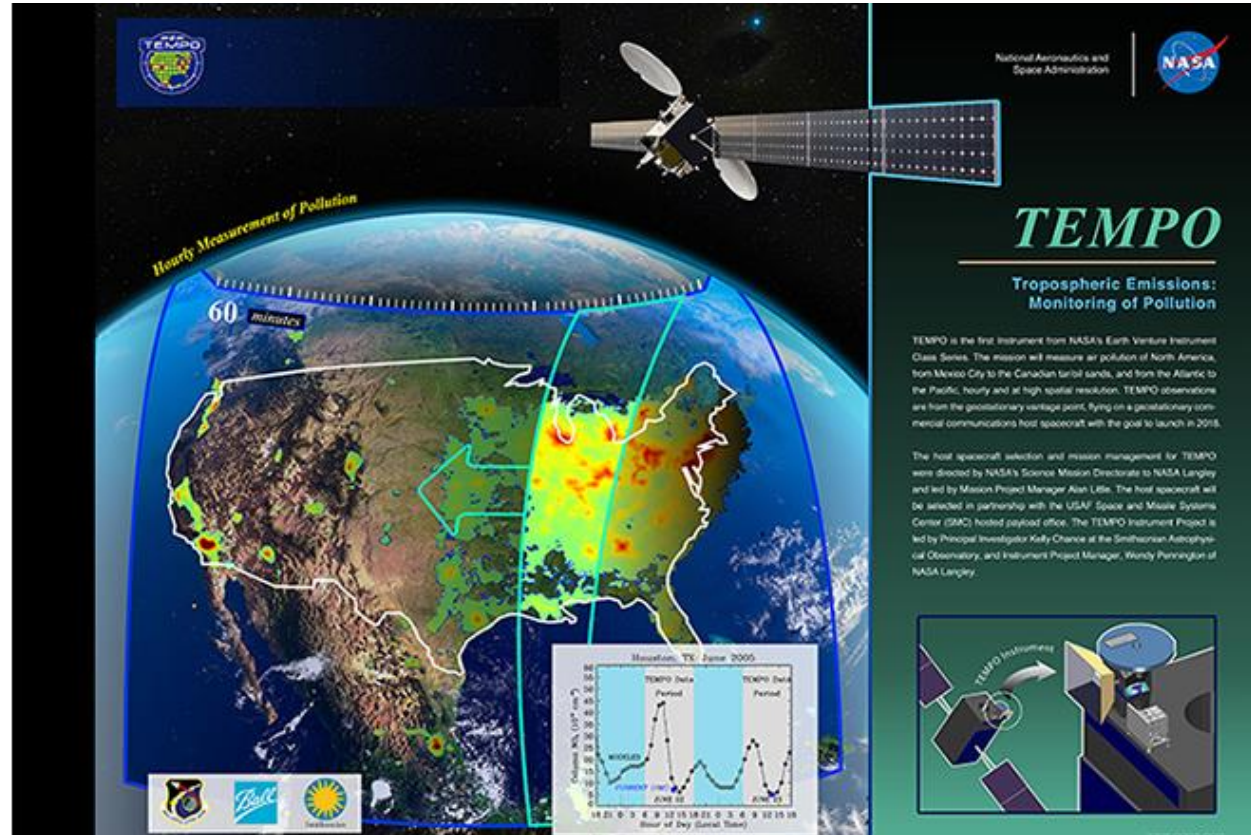
EPA: James Szykman





Motivation: NASA TEMPO Mission

- **Tropospheric Emissions: Monitoring of Pollution (TEMPO)** mission is planned for launch in 2020
- TEMPO will be the first geostationary air quality satellite for North America to provide hourly measurements throughout the U.S. for key trace gases
- TEMPO data products planned to be generated include ozone 0–2 km O_3 , free tropospheric O_3 , and the stratospheric O_3 column
- Observations of ozone and other constituents in complex coastal regions are critical for TEMPO validation and improvement in its data product retrievals
- Key OWLETS motivation was to examine AQ in a transition zone where spatial variability can be large of small distances



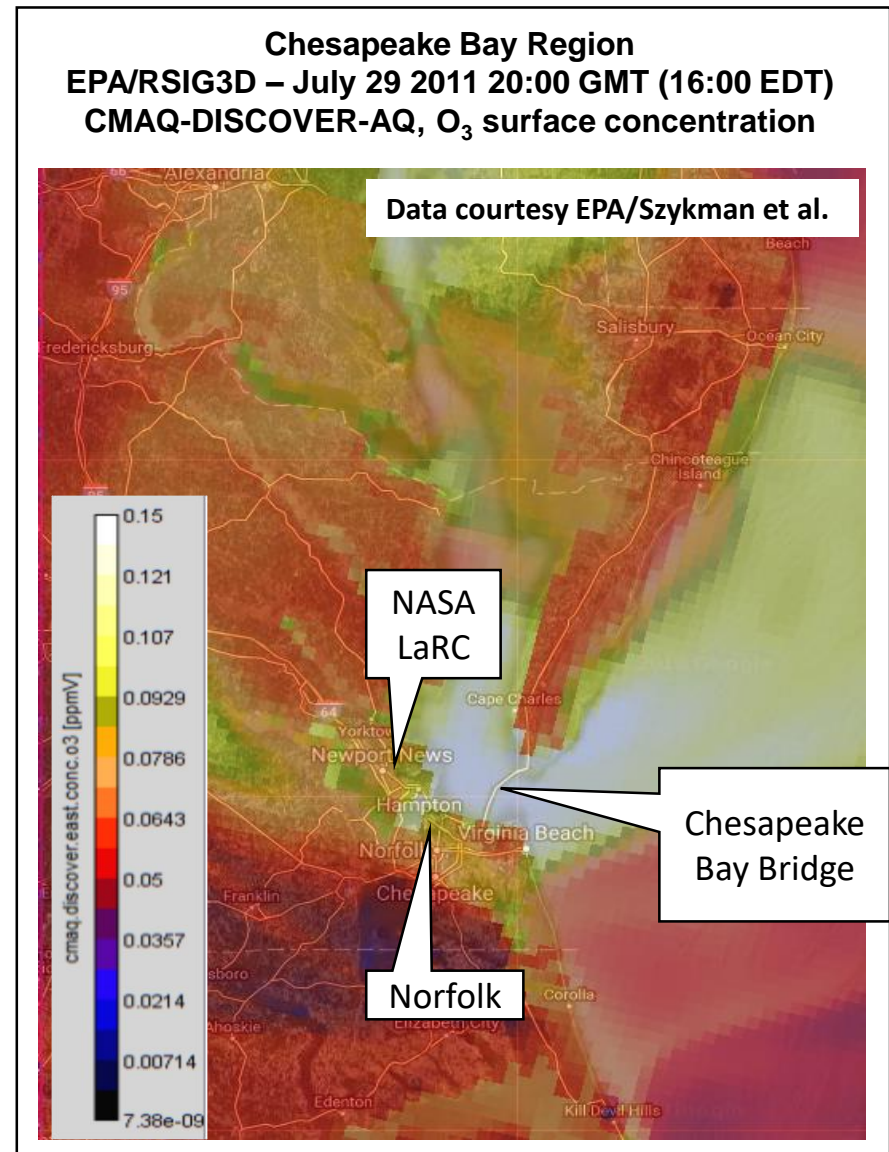
TEMPO Mission

Principal Investigator: Kelly Chance, Smithsonian Astrophysical Observatory

Instrument Development: Ball Aerospace & Technologies Corporation

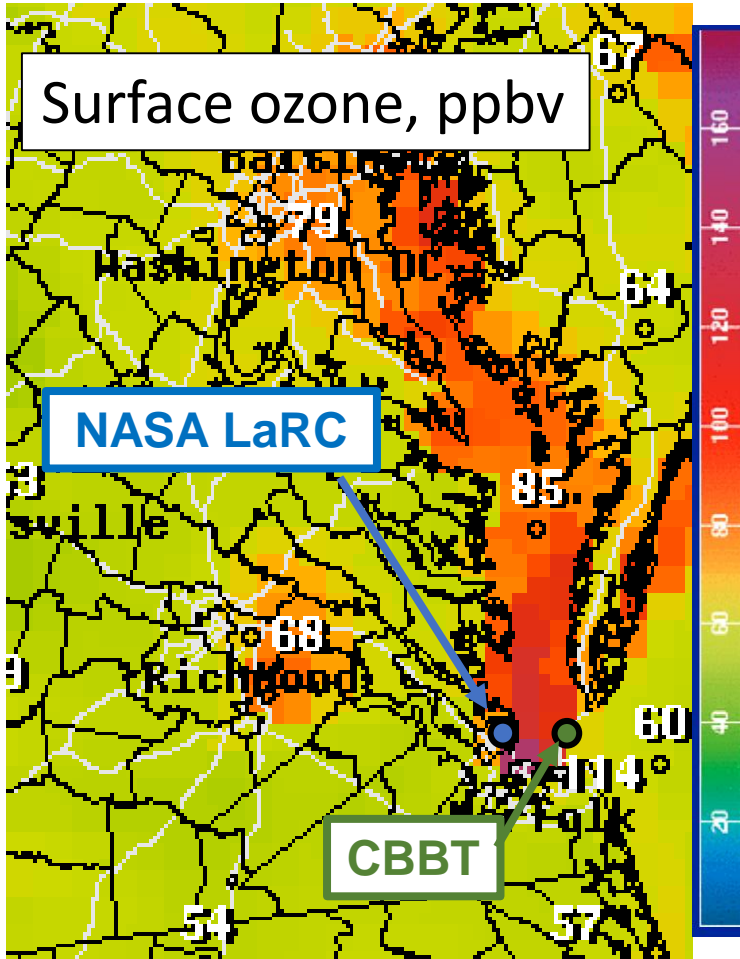
Project Management: NASA/Langley Research Center

- Significant land-water gradients in coastal regions can occur due to differences in surface deposition, boundary layer height, and cloud coverage, to the right is an EPA/CMAQ surface ozone example case from DISCOVER-AQ
- Studies have examined the Chesapeake airshed with respect to ozone including: Martins et al. 2012 (Hampton Roads region), Goldberg et al. 2014, Loughner et al. 2014, Stauffer et al. 2015 (Baltimore-DC region)
 - O₃ measurements over water are scarce!
- Vertical, horizontal, and temporal (4-D) measurements are needed to describe complex scenes to improve forecast models and air quality satellite retrievals



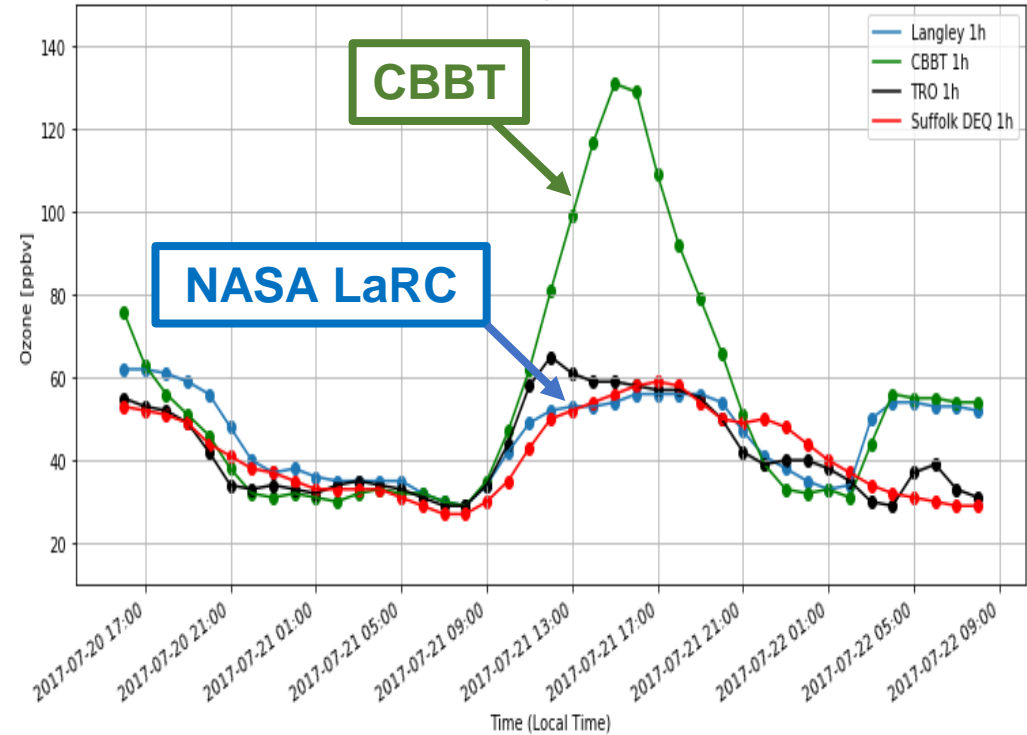


Forecast example July 20-21



Surface ozone forecast 48 hr time series

Ozone Forecast (NOAA/EPA) 2017-07-20 13:28





NAQFC 12Z forecast for hourly ozone on 07/20/17 for 07/21/17 [9am to 9pm] (airquality.weather.gov), updated 2x daily, 12 km resolution, 48 hrs

1Hr Avg Ozone Concentration(PPB) Ending Fri Jul 21 2017 3PM EDT
(Fri Jul 21 2017 19Z)

National Digital Guidance Database

12z model run Graphic created-Jul 20 12:20PM EDT



Map of measurements

original SIF award

12 days of measurements from July 7 to Aug 2, 2017

2 ozone lidars (CBBT & LaRC)

UAV/drone (CBBT or LaRC)

Simultaneous ozonesonde launches (LaRC & CBBT)

DEQ sites

CAPABLE (LaRC)

PANDORA (CBBT & LaRC)

AERONET (CBBT, Hampton U., LaRC)

Mobile Cars (2)

MPL at Hampton U

Two Ceilometers (CBBT, LaRC)

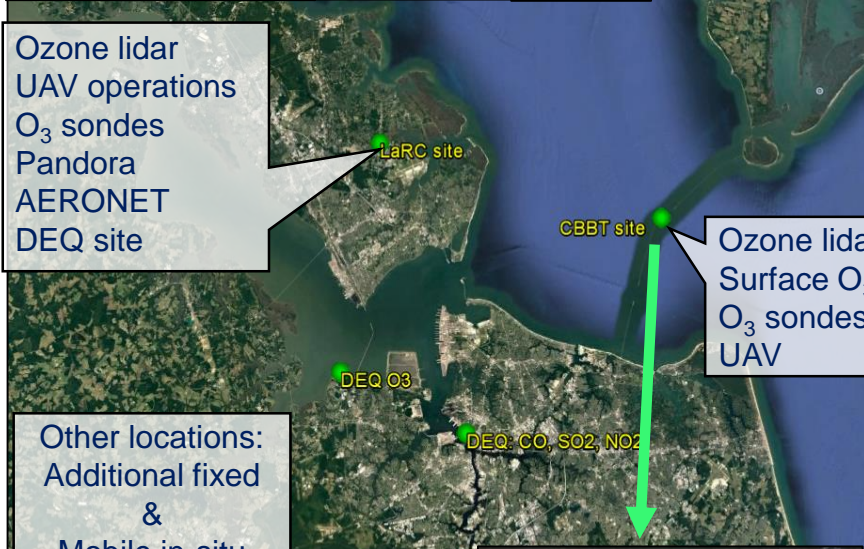
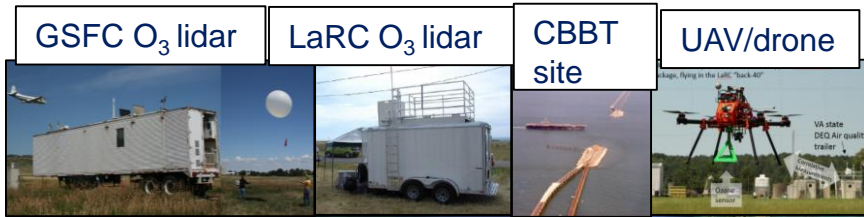
Surface NO₂ at some sites (CBBT, LaRC)

Supplemental O₃ sites (TRO, VLM)

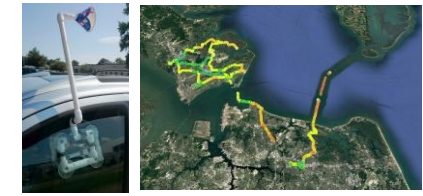
Two Sherpa flights

Three GeoTASO flights

Two days SERC research vessel



Car In-situ: 2 cars, 12 days



UC12: 3 flights July 7-8, GeoTASO



SERC research vessel July 17-18
O₃, NO₂, Pandora, Ceilometer



Sherpa aircraft: 2 flights July 19-20
O₃, NO_x, VOCs





Langley Mobile Ozone Lidar (LMOL)



Team: Guillaume Gronoff, Bill Carrion, Betsy Farris, Tim Berkoff

- DIAL technique (Two UV wavelengths)
- Small, highly mobile trailer
- Ozone and aerosol profiles up to 8 km
- Typically provide 5 minute temporal resolution
- Surface in-situ ozone (2B technologies)
- Met station (Temp, Wind speed & direction, Rel. Humidity)
- Surface radiance
- Real-time processing and display

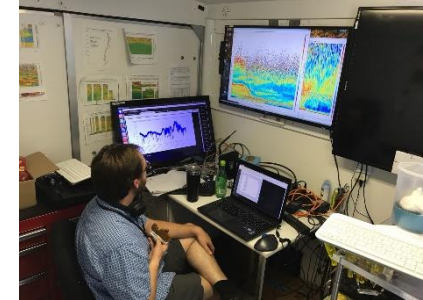
LMOL trailer located at the CBBT site



LMOL team



Real-time processing display



Instrument description: Russell De Young et al., Appl. Opt. 56, 721-730 (2017)

This was the lidar located at CBBT, 7-8 miles offshore!

Supported by NASA's Tropospheric Composition Program, Earth Science Division, NASA Headquarters through the TOLNet program
OWLETS activities also supported by NASA's Science Innovation Fund



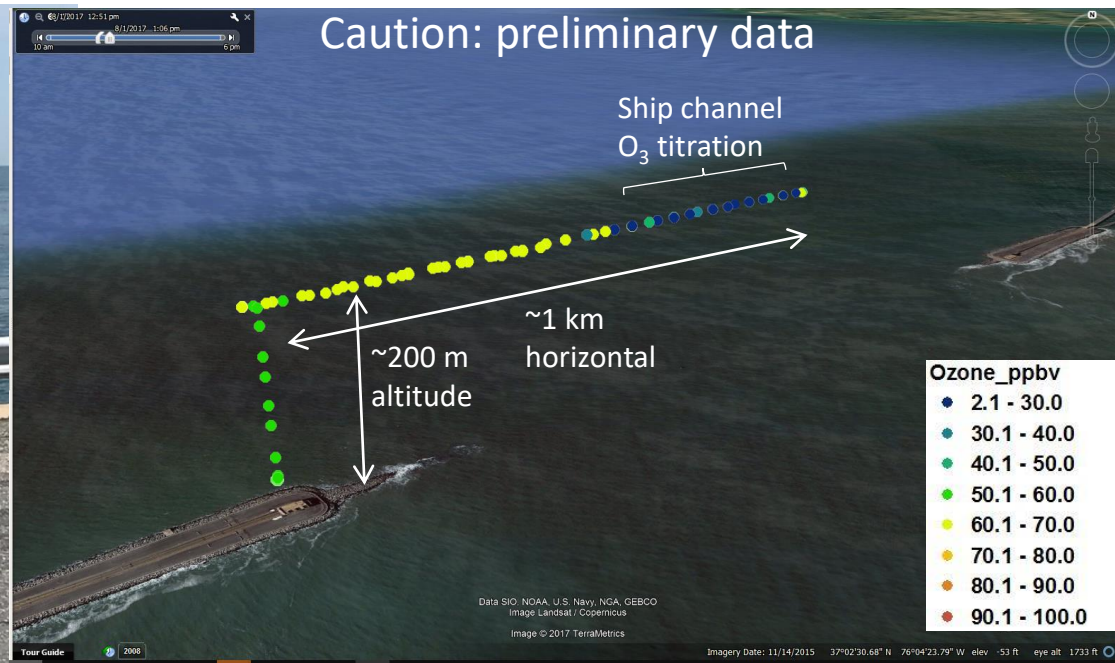
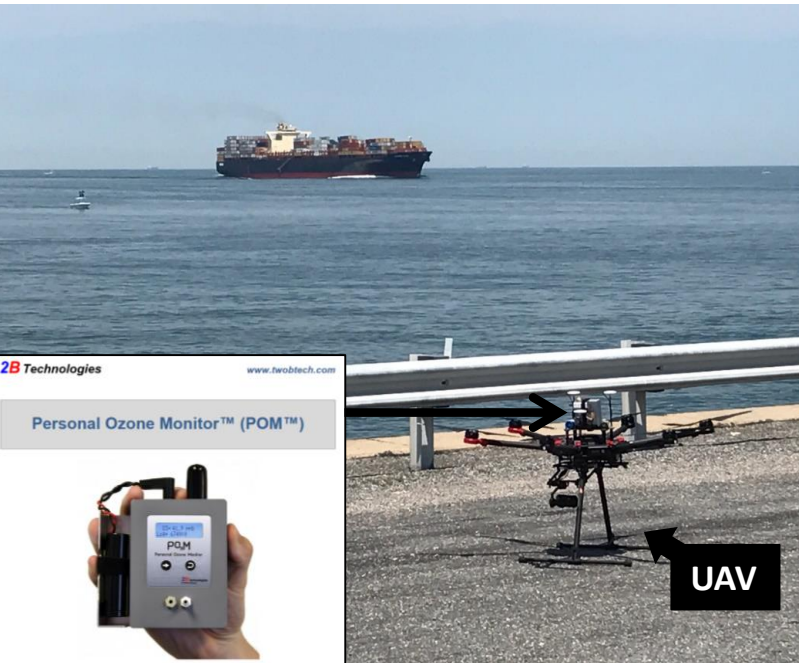


UAV/drone in-situ ozone measurements

Team members: Danette Allen, Jim Neilan, Margaret Pippin, Jeremy Schroeder, Eddie Adcock, Mark Motter, Ryan Hammit, Zak Johns, Guillaume Gronoff, Ian Fenn

CBBT site with UAV in foreground with a ship about to pass through channel

UAV August 1 flight from the CBBT third island

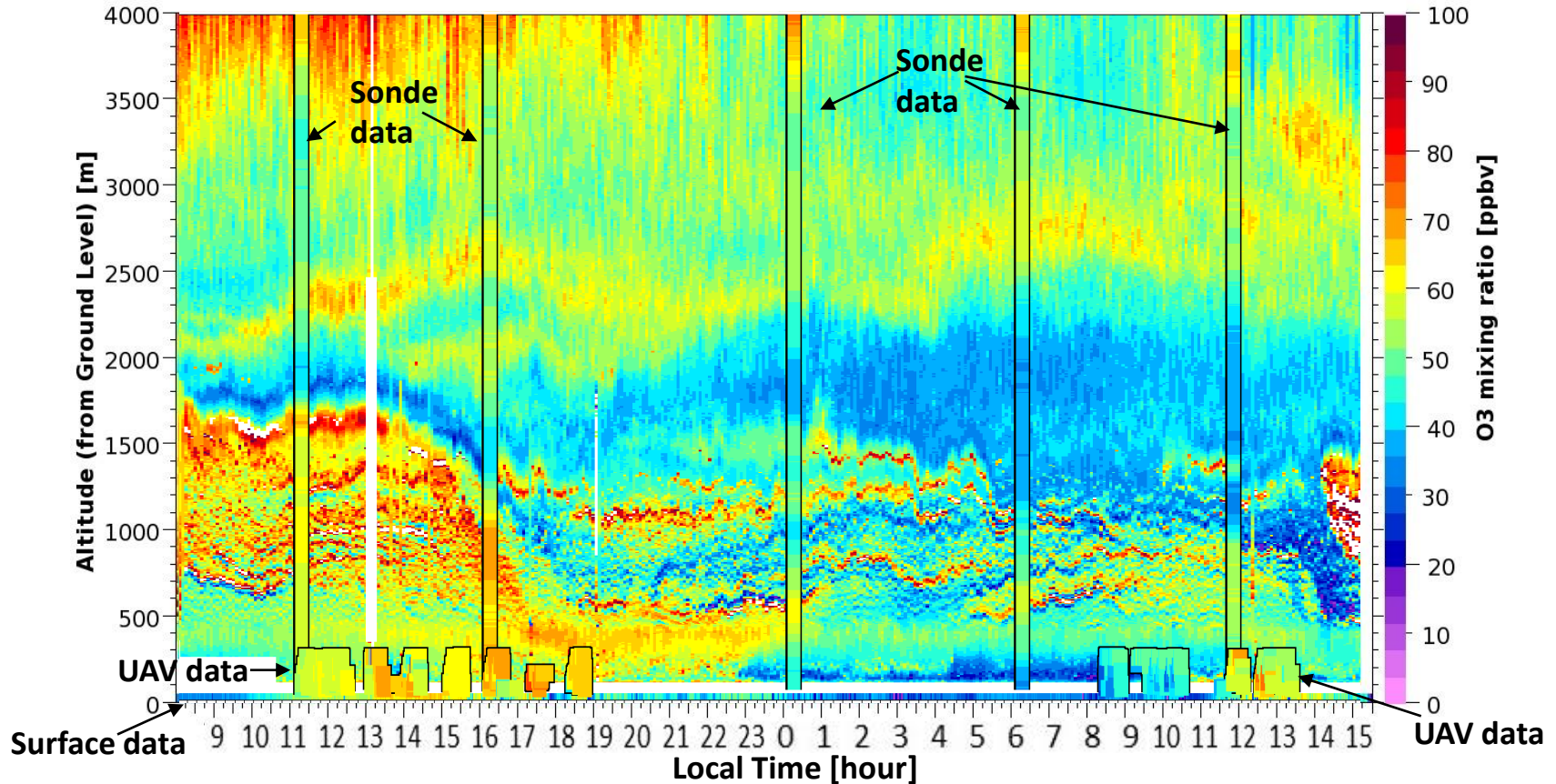


POM picture courtesy of 2B Technologies

- UAV/drone measurements conducted on five OWLETS measurement days**
- Data collected from LaRC and CBBT sites**

OWLETS UAV/Drone activities supported by NASA's Science Innovation Fund, LaRC TEMPO student collaboration, NASA LaRC Autonomy Incubator

Example Quick-look Data From The Langley Mobile Ozone Lidar: Ozone Data Obtained at the “over-water” CBBT site Aug 1-2, 2017



❖ The Langley Mobile Ozone Lidar (LMOL) on Aug 1-2 ran for 32 hours capturing diurnal cycle ozone (O₃) dynamics showing the collapse of the daytime boundary layer bringing O₃ towards the surface and the remaining complex residual layers leading into Aug 2.

❖ Ozonesonde (balloon) results and data collected by a UAV/drone carrying an in-situ O₃ sensor are also displayed. The UAV/drone sensor provided the ability to investigate near-range variability, and helped to validate the capabilities of a new near-surface lidar channel on LMOL.



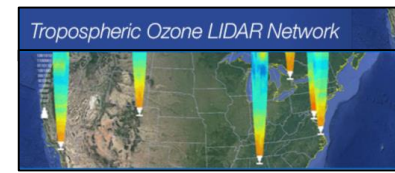
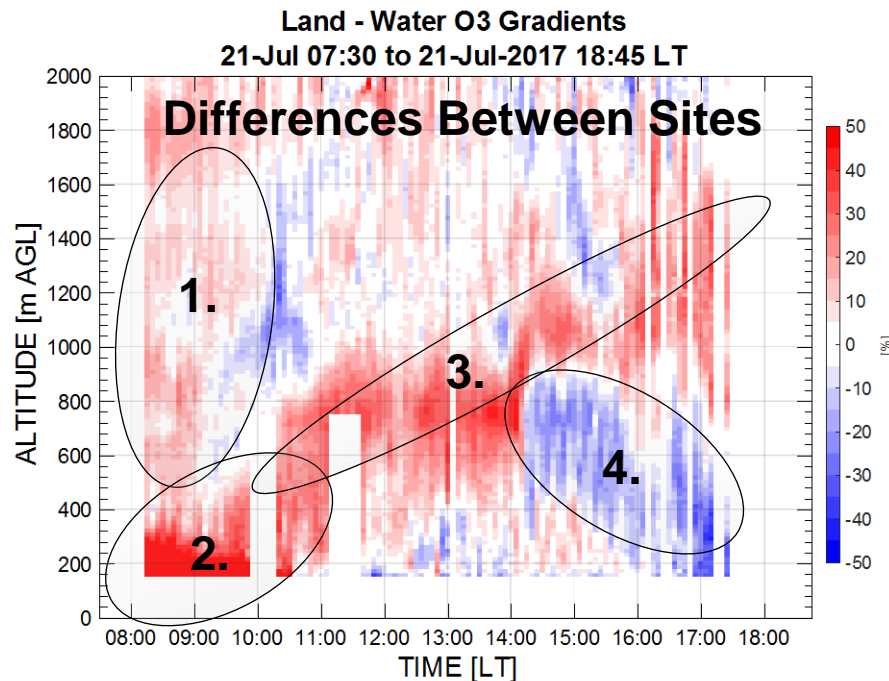
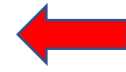
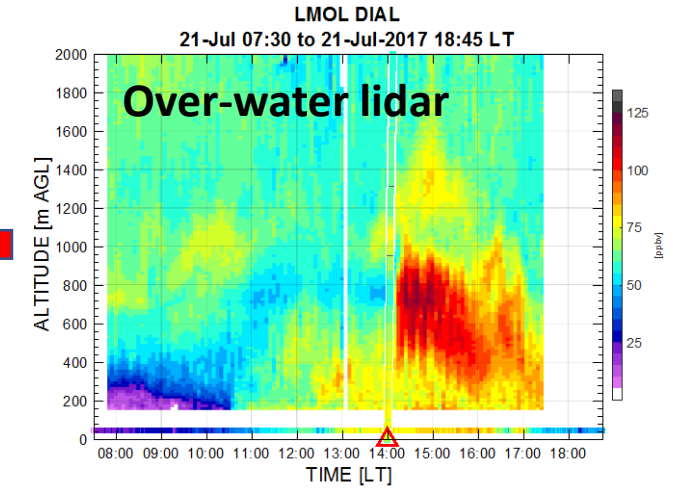
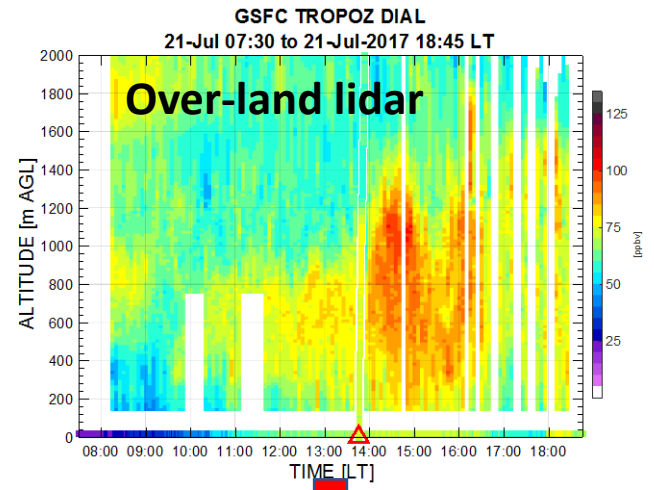
Water-Land Lidar Ozone Difference Study (Sullivan et al.)



Goddard Ozone Lidar (TROPOZ)

Team: John Sullivan, Larry Twigg, Lance Nino, Tom McGee

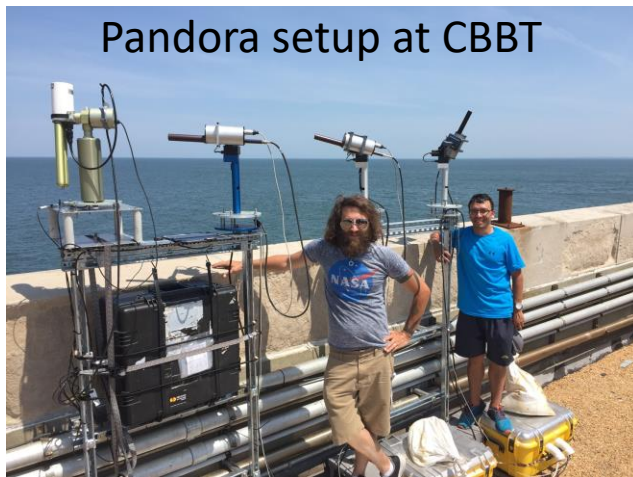
The Goddard TROPOZ was located at LaRC, the OWLETS "over land" site





Initial Pandora - Lidar Comparisons

Pandora Team members: Bob Swap, Maria Tzortiou, Nader Abuhassan, Alexander Cede, Si-Chee Tsay, *et al.*

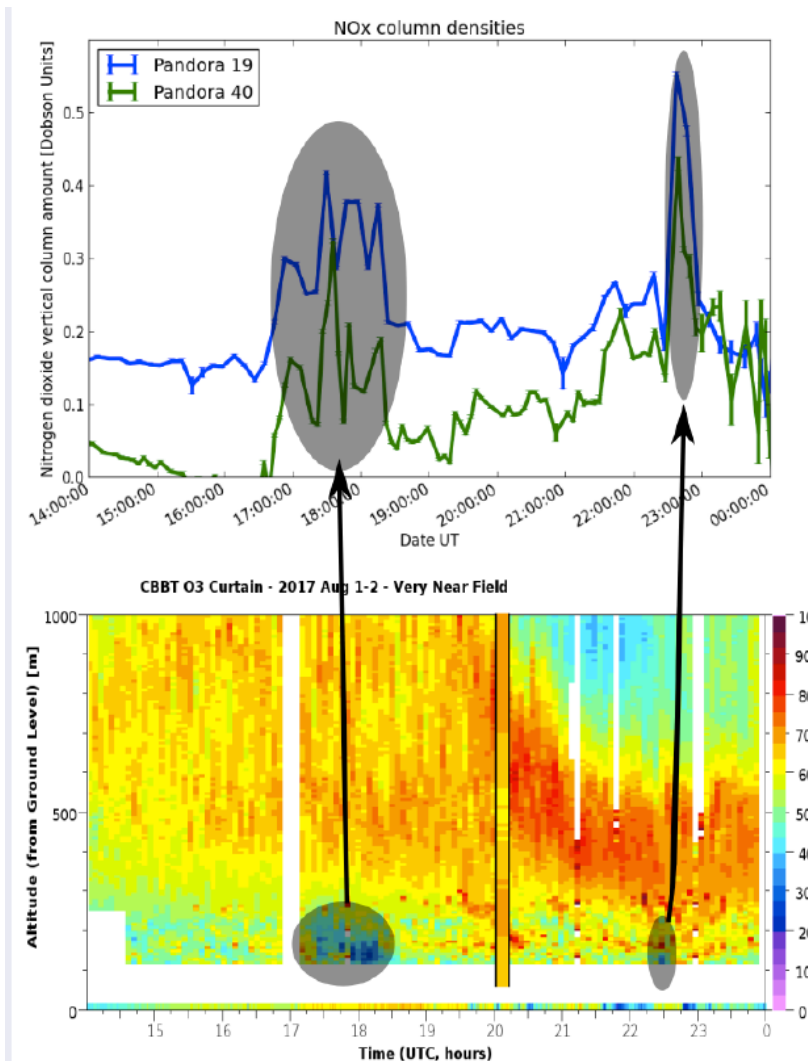


Pandora setup at CBBT



Pandora setup at CBBT

Lidar



Pandora

Locations:

LaRC, CBBT, SERC marine vessel, VCU

Data products:

Column NO₂, O₃

See poster by Gronoff et al. for columnar NO₂ features corresponding with lidar ozone depletion events



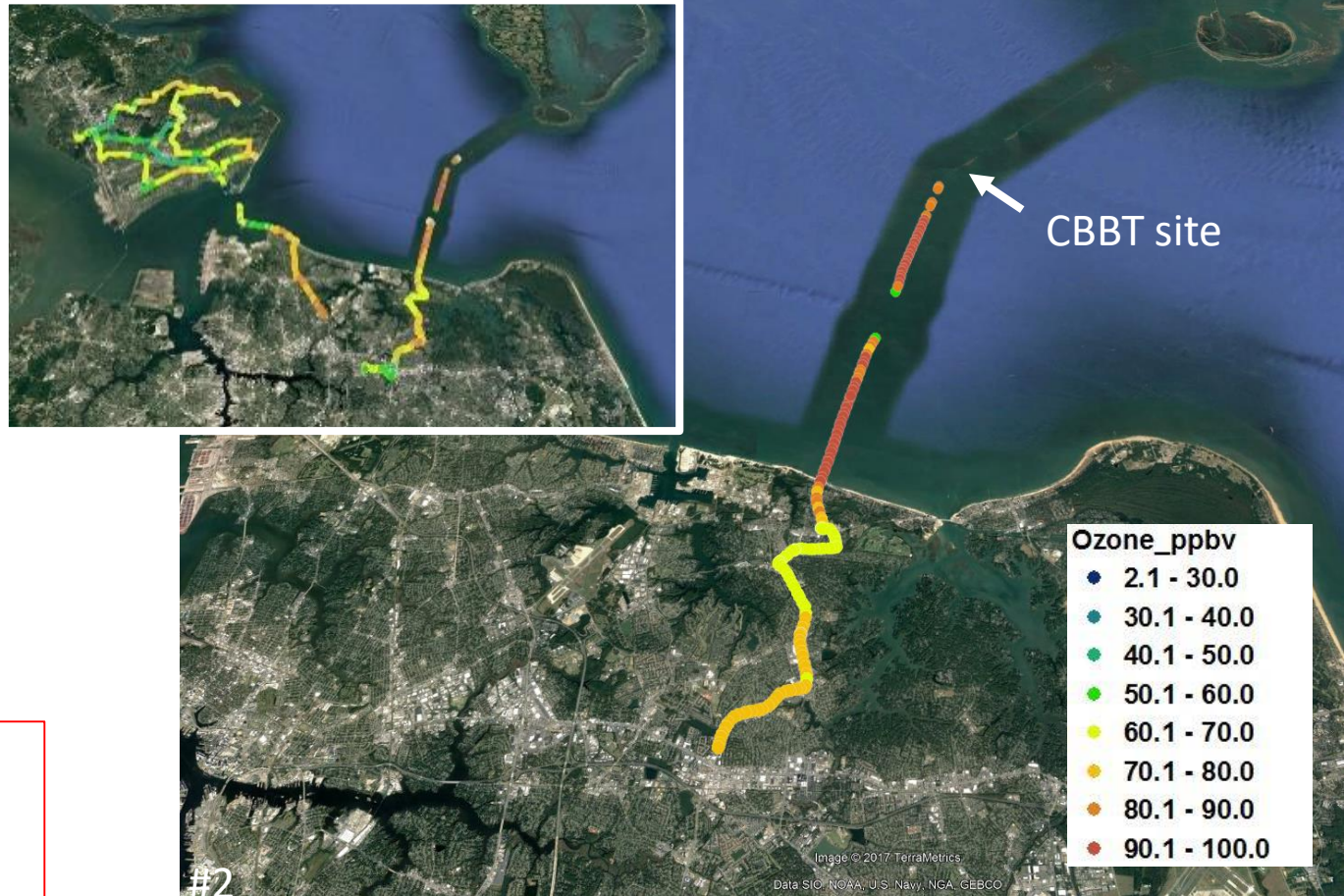
Mobile car in-situ measurements

Team members: Margaret Pippin, Jeremy Schroeder, Lindsey Rodio, Jeremy Schroeder, Betsy Farris, Pablo Sanchez, Emily Gargulinski, Desorae Davis, Angela Atwater

Example car in-situ ozone sensor data segment from July 21



Car in-situ ozone sensor Configuration

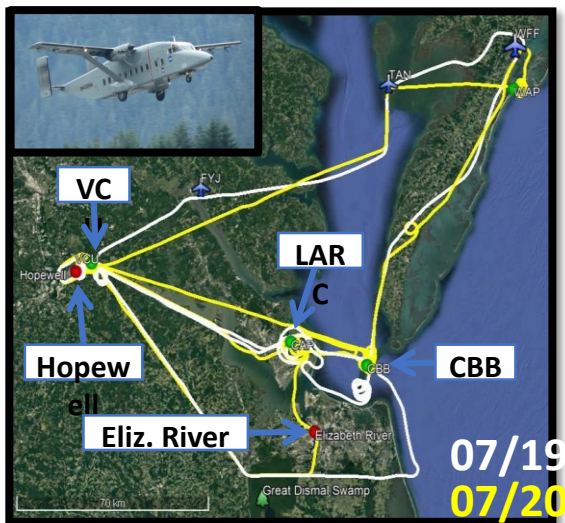


Mobile car data obtained on all OWLETS measurement days!



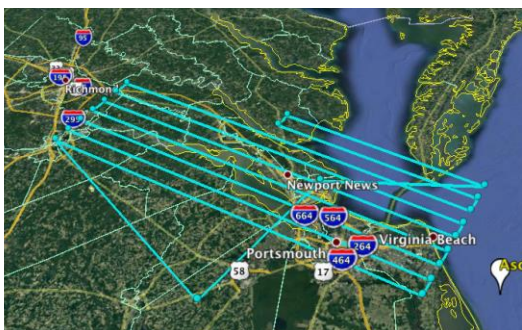
Other Mobile Platforms

SARP East C-23 Sherpa, July 19 & 20



Payload	PI, Institution
HCHO	Hanisco/St. Clair, GSFC
NO _x /O ₃	Pusede/Flynn, UVA/UH
CO/N ₂ O/H ₂ O	Pusede, UVA
VOC	Blake, UCI
CH ₄ /CO ₂ /H ₂ O	Hanisco/Wolfe, GSFC

GeoTASO UC12/King Air, July 7 & 8

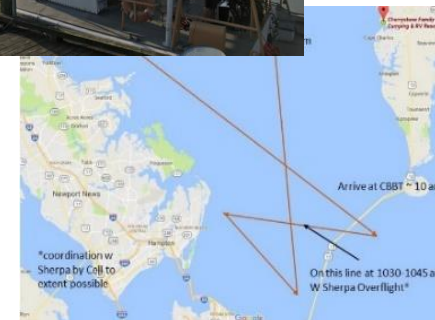


Primary data product:
NO₂ column



Team: Scott Janz, Jay Al-Saddi, Matt Kowalewski, Laura Judd

SERC Marine RV July 17,18



Instrumentation included in-situ O₃ and NO₂, Pandora (column NO₂ and O₃), and Vaisala Ceilometer



Team Members: Maria Tzortziou, Owen Parker, Julio Roman, Lena Shalaby, Ryan Stauffer, Cpt. Mike Goodison



OWLETS work-in-progress



Please contact us if you are interested in OWLETS data!

For website data archive:

www-air.larc.nasa.gov/missions/owlets/

Still at the beginning stages of OWLETS data analysis

Land-water differences: OWLETS data unambiguously show there are significant differences in surface (horizontal) and vertical measurements over extremely short distances from land to water.

Over water ozone enhancement: OWLETS observations do show elevated ozone over water with respect to land can occur under certain conditions more often when ozone levels are at their initial peak in the afternoon. For over-water afternoon peak ozone levels, the National Air Quality (NOAA/EPA) 24-hour forecasted surface enhancements over water tend to over-predict ozone levels when compared to OWLETS observations.

Over water variability: OWLETS observations have identified a high degree of over-water spatial variability in ozone concentrations.

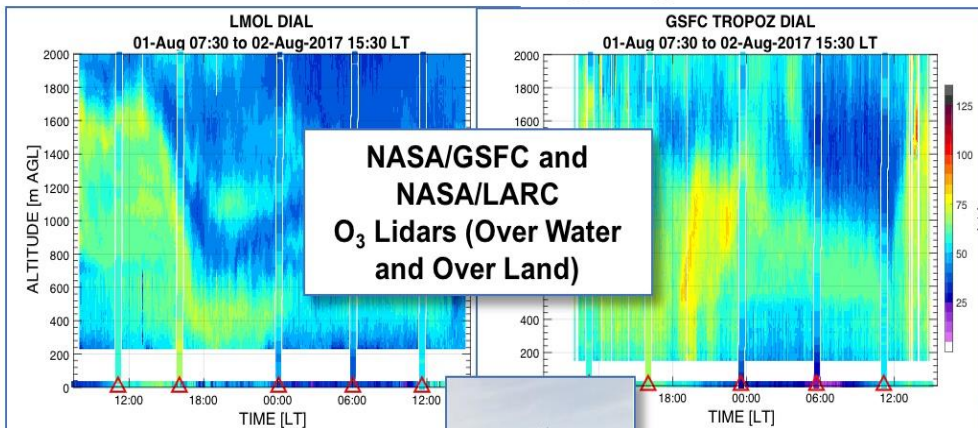


OWLETS Science Team Meeting

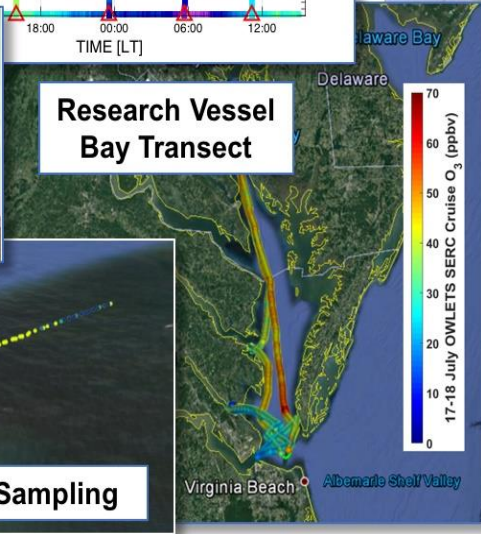
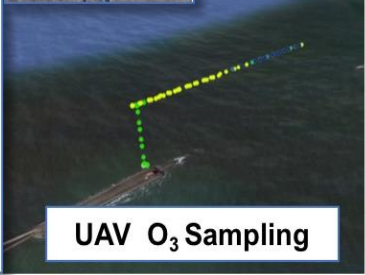
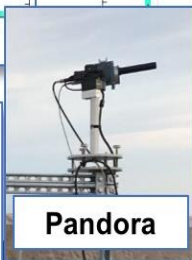
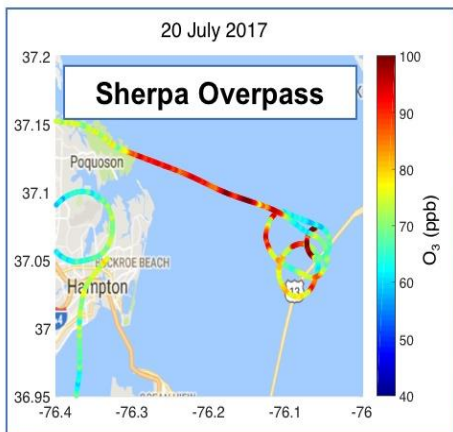
(Hosted at Maryland Department of the Environment (MDE), Oct 17-19th, 2017)



OWLETS Highlights



Over 40 attendees from NASA/GSFC, NASA/LARC, MDE, UMBC, UMD, Argonne Nat. Lab, NOAA ARL

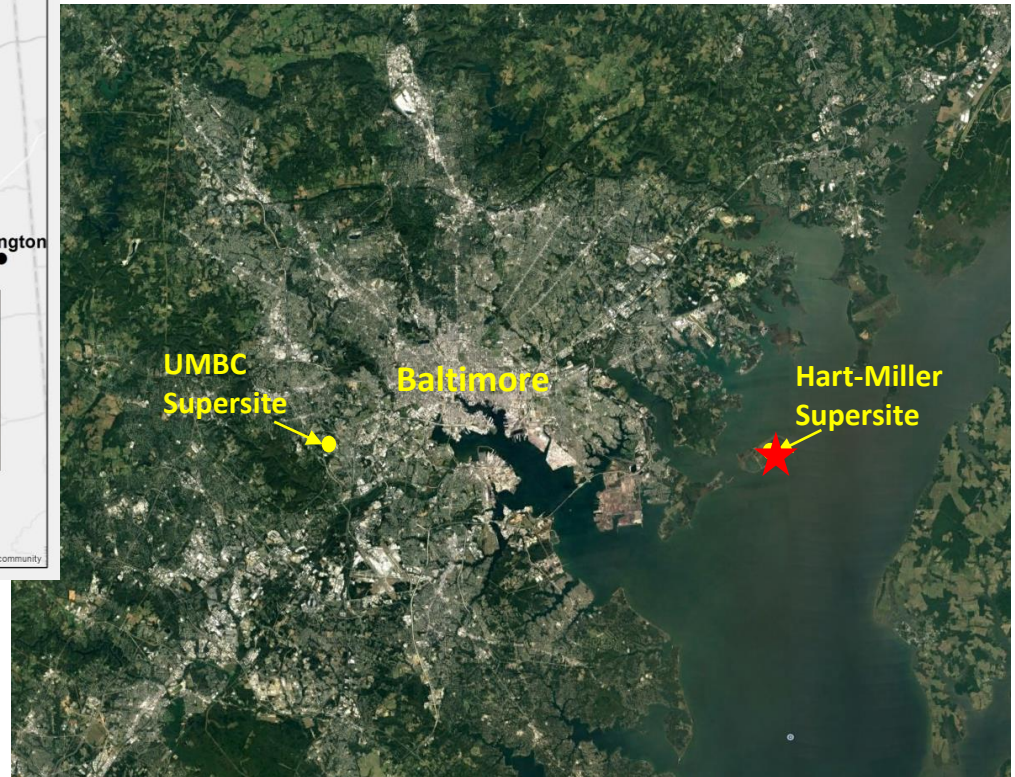
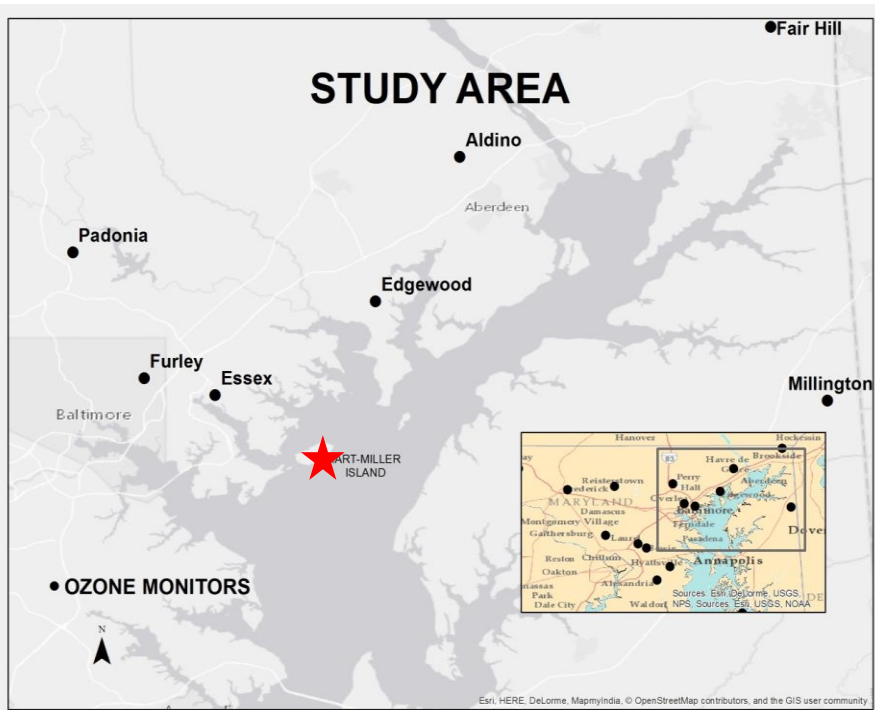


Looking towards OWLETS-2 (Baltimore, MD 2018)

- 1. Identified major ground sites.**
Both will tentatively have O₃ lidar (TOLNet), Sondes, Pandora, 24-7 surface sensors, wind profilers
- 2. Positive Support from MDE**
Continued support and infrastructure for enhanced monitoring and modeling in Baltimore (which remains as a non-attainment status)

Meeting covered presentations on existing OWLETS datasets, identification of future data analysis topics, MDE policy relevant science, and future planning for OWLETS-2

OWLETS-2 in upper Chesapeake/Baltimore region summer 2018
Tentatively planned for a May 28 to July 4 for science measurements
Two “super-sites” identified: UMBC, Hart-Miller island





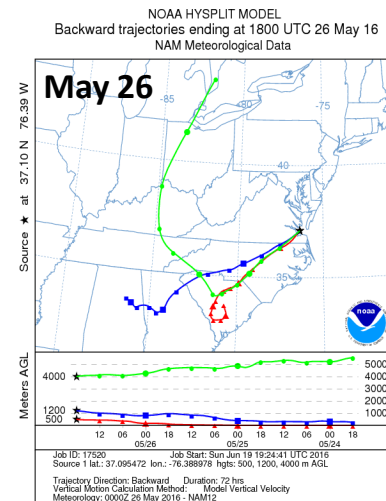
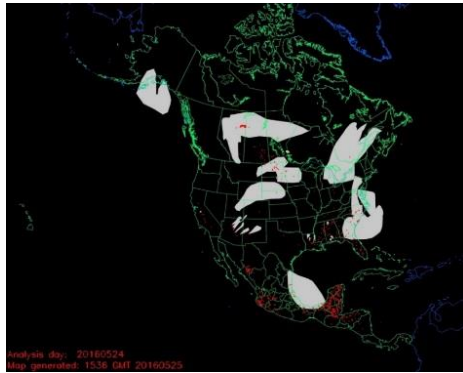
BACKUP SLIDES



Examples of elevated ozone layers: May 24 & 26, 2016 Hampton Roads

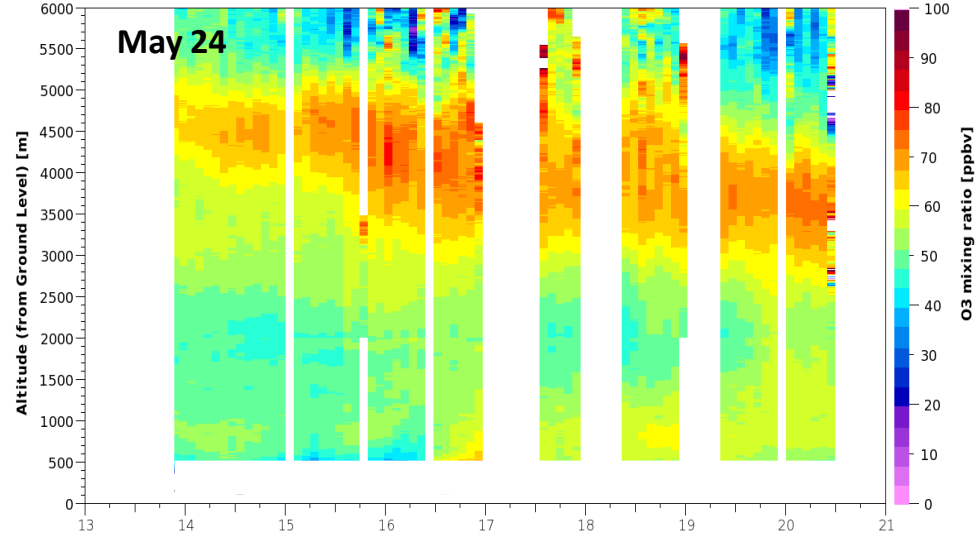
May 24 & 26: Aloft ozone layers appear to be from different sources, May 26 mixed into the boundary layer, but May 24 did not

NOAA HMS smoke product

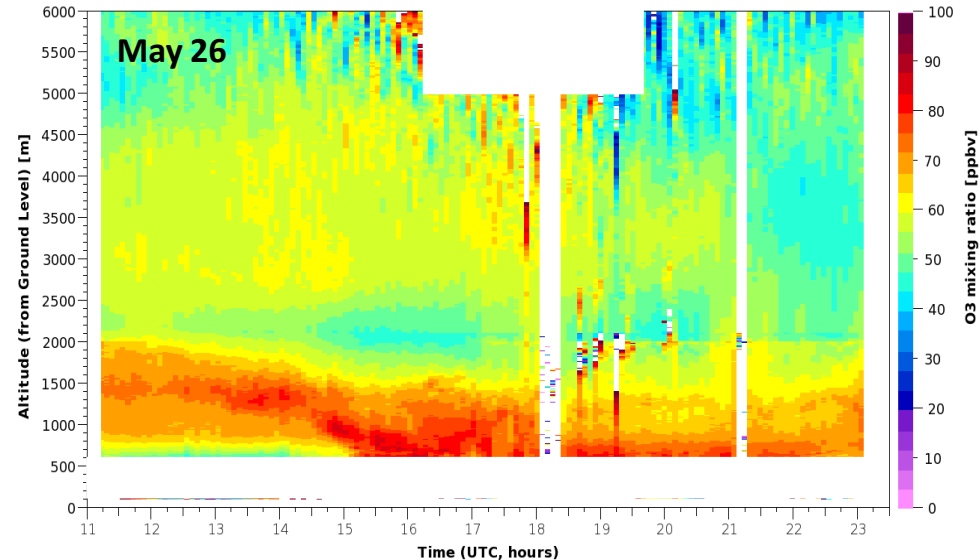


Vertical observations are needed to understand surface impacts!

Ozone curtain plot for 2016-06-24



Ozone curtain plot for 2016-05-26





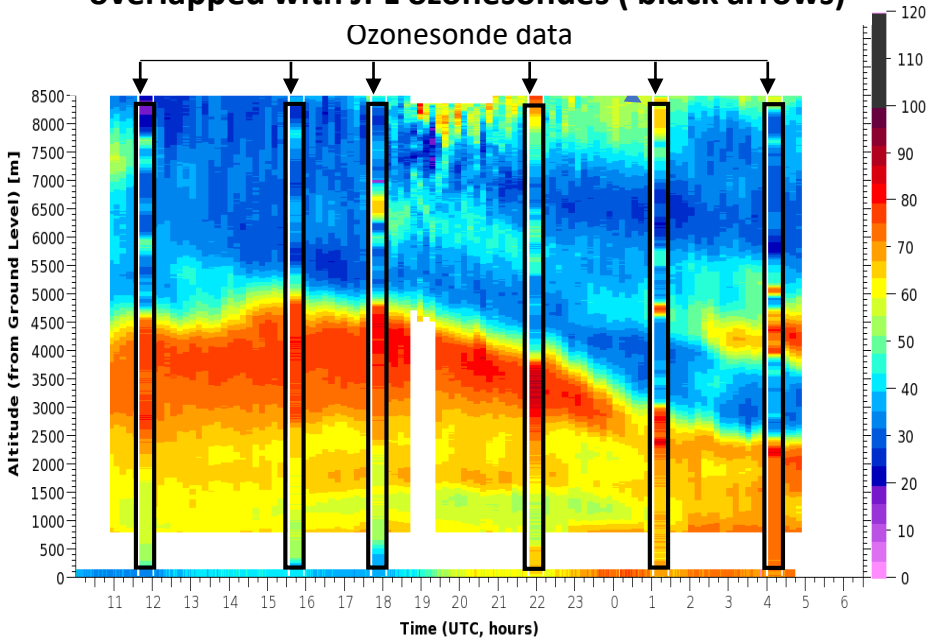
Tropospheric Ozone Lidar Network (TOLNet): Lidar Validation



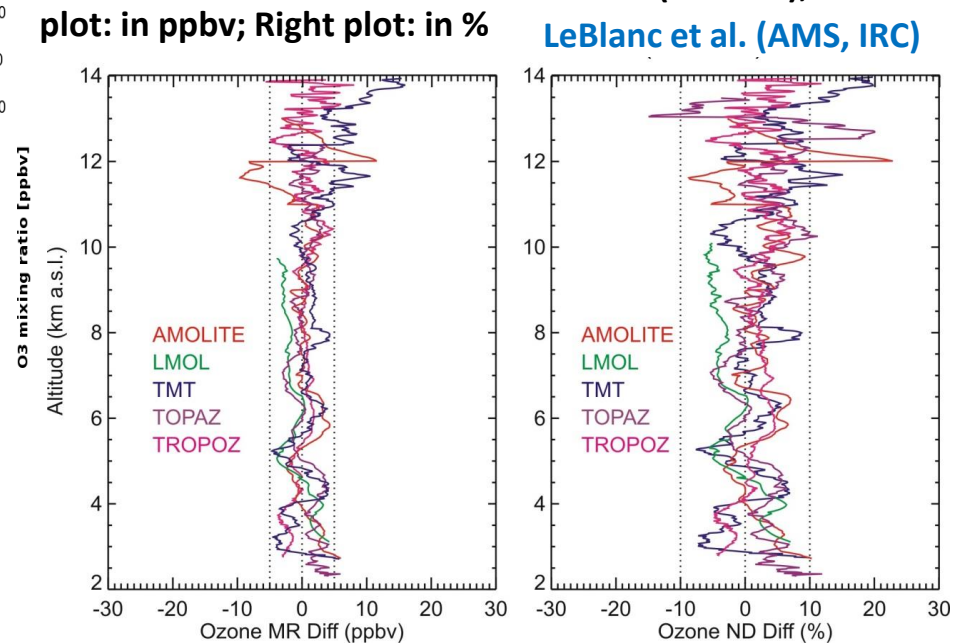
SCOOP 2016 campaign, LeBlanc et al. Five TOLNet ozone lidars together in one location!
Inter-comparisons with sondes and with each of the other TOLNet lidars

Example LMOL Data Example 2016-08-15 overlapped with JPL ozonesondes (black arrows)

Ozonesonde data



SCOOP campaign-mean of the ozone differences between the TOLNet lidars and ECC ozonesondes (ref=ECC); Left plot: in ppbv; Right plot: in %
LeBlanc et al. (AMS, IRC)



Findings:

- All lidars within +/-3 ppbv (+/-4%) of ozonesonde for alt. 2.8-13 km;
- All differences within reported ECC and lidar combined uncertainties





OWLETS Website

www-air.larc.nasa.gov/missions/owlets/



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Airborne Science Data for Atmospheric Composition

OWLETS – Ozone Water-Land Environmental Transition Study

Data Archive →

Data Archive: OWLETS 2017 

Relevant Data / Links

- Quicklook Reports
View / Upload Image s & Data :
Lidar, UAV, Ground, Mobile, etc.
- File Sharing:
Telecons, Meetings, Presentations,
etc.
- NOAA's National Weather Service
Air Quality Forecast Guidance
- ICART Data Format Document

Quick looks →


Presentations,
Etc. →

Data Upload Tools

Steps for submitting data to the Archive

- Data Submittal / Scanning 
- Help F3can
- Register PI dataDe 

Useful Tools

- Download HDFView – visual tool for browsing & editing HDF files 
- Download File Scanning SW for Windows (Requires .NET) 
- Whats New
- Download Flight Planning SW for Windows (Requires Google Earth) 

Motivation/Background

- Significant land-water gradients in coastal regions can occur due to differences in surface deposition, boundary layer height, and cloud coverage, example to right is an EPA/ACM AQ surface ozone example case
- Studies have examined the Chesapeake air-shed with respect to ozone including: Martins et al. 2012 (Hampton Roads region), Goldberg et al. 2014, Loughner et al. 2014, Stauffer et al. 2015 (Baltimore-DC region)
 - O3 measurements over water are scarce
- NASA Looking Forward: Vertical, horizontal, and temporal (4-D) measurements are needed to describe complex scenes to improve forecast models and air quality satellite retrievals
 - TEMPO/GEOSCAPE
- Key goal: provide user community high resolution vertical O3 profiles simultaneously over the land and water during various air quality events
 - Daytime, nighttime, sunset/sunrise, "poor" AQ days as well as "clean"



Quick look report page



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Date	Daily Reports	Mission Reports	Quick Look Data Reports												
			Satellite	Aircraft	Water_Craft	GSPC_Lidar	LaRC_Lidar	UAV_Drone	Surface	Mobile_InSitu	Sondes	Aerosol	Hamp_U	Pandora	
2017-07-05	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	
2017-07-06	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	
2017-07-07	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	
2017-07-08	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	
2017-07-11	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	
2017-07-12	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	
2017-07-13	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	
2017-07-16	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	
2017-07-17	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	
2017-07-18	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	
2017-07-19	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	
2017-07-20	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	
2017-07-21	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	
2017-07-25	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	
2017-07-26	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	
2017-07-30	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	
2017-07-31	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	
2017-08-01	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	
2017-08-02	Forecast	Status	X	X	X	X	X	X	X	X	X	X	X	X	

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Ceilometers!

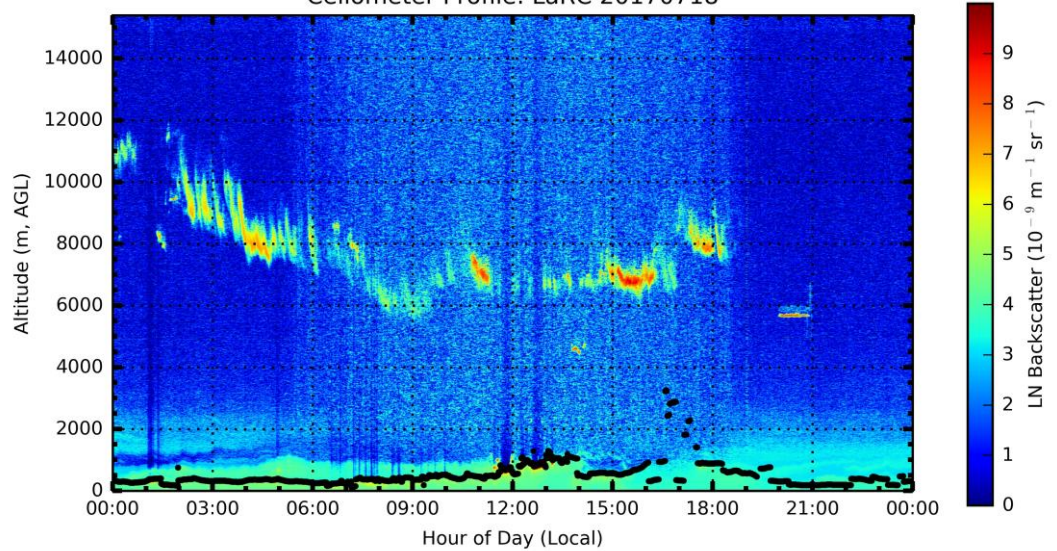
Team members: Travis Knepp, Jim Szykman, *et al.*

CBBT, LaRC, and SERC marine
research vessel

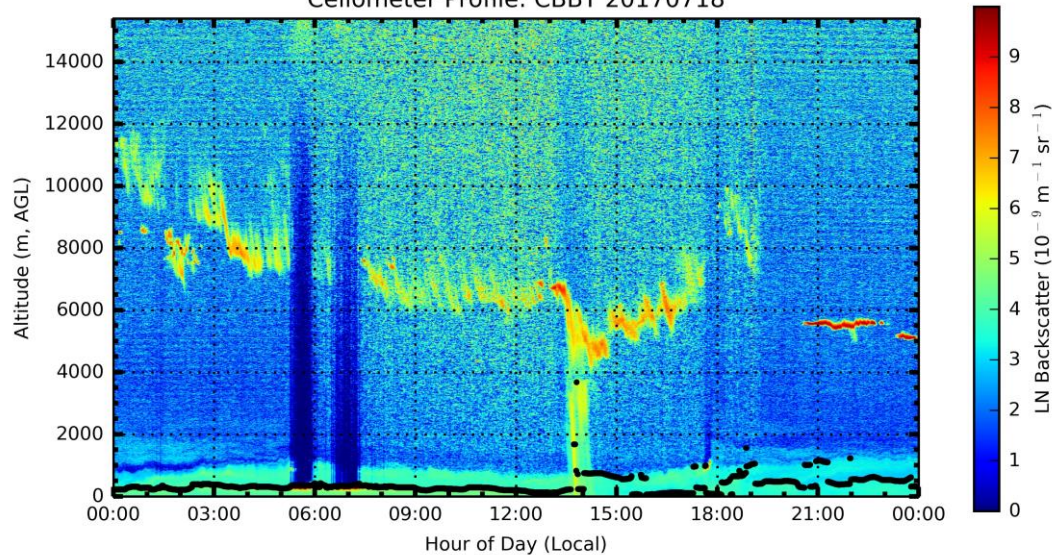
Data quicklooks and files in
archive

Attenuated backscatter signal
Mixed layer heights, cloud and
aerosol heights, cloud fraction

Ceilometer Profile: LaRC 20170718



Ceilometer Profile: CBBT 20170718





Micro-pulse Lidar at Hampton University



Team: Bill Moore, student interns: Desorae Davis, Angela Atwater

Data Products:

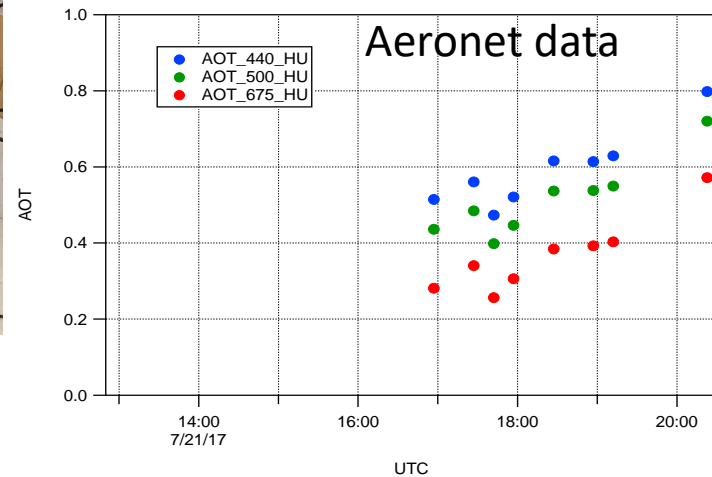
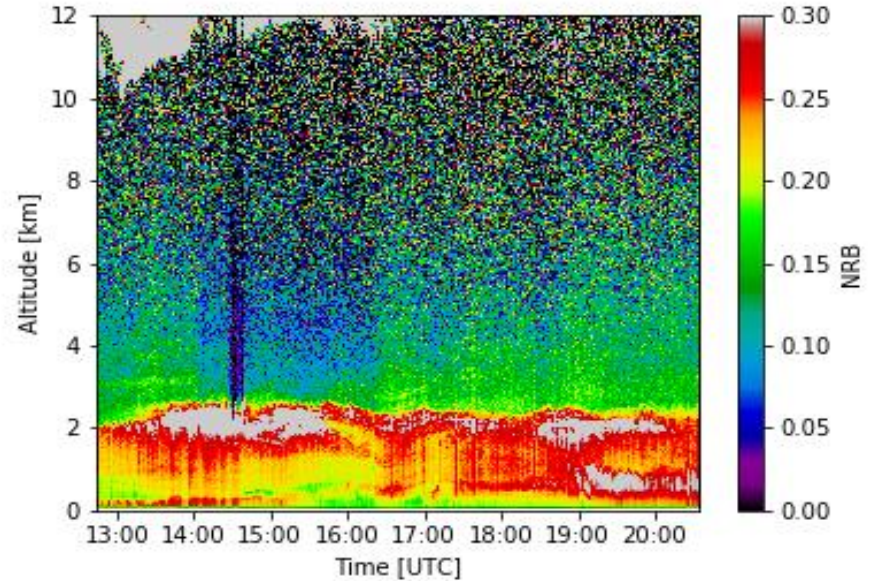
Attenuated backscatter profiles at 527 nm, Cloud and Mixed layer heights, Cloud fraction

Data collected: 8 days

MPL



July 21





In-situ surface sites

Team members: Margaret Pippin, Jeremy Schroeder, John Sullivan, Guillaume Gronoff, Travis Knepp
VA DEQ: Dan Salkovitz, Kristen Stumpf, Brian King, John Brandt, Chuck Turner

DEQ sites

NASA supplemental ozone sites (CBBT, TRO, VLM)

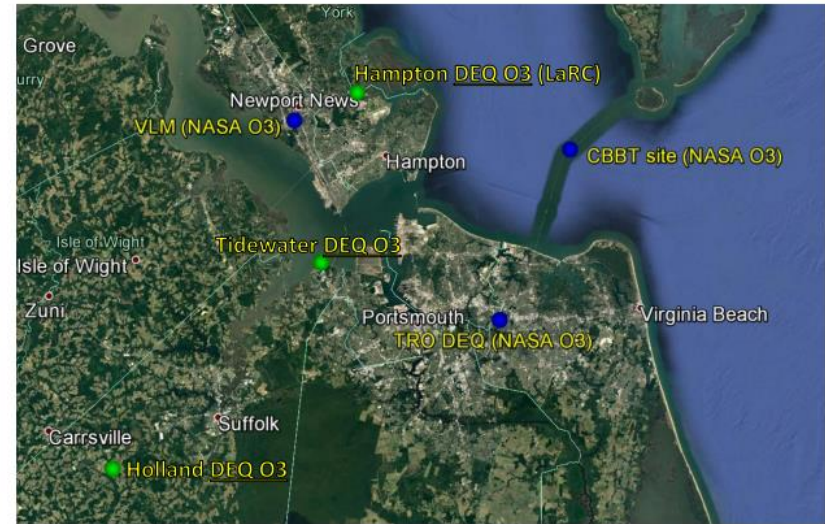
NO₂ (CBBT and LaRC)

CAPABLE trailer

Quicklooks for DEQ, but need to get NASA supplemental integrated with reports

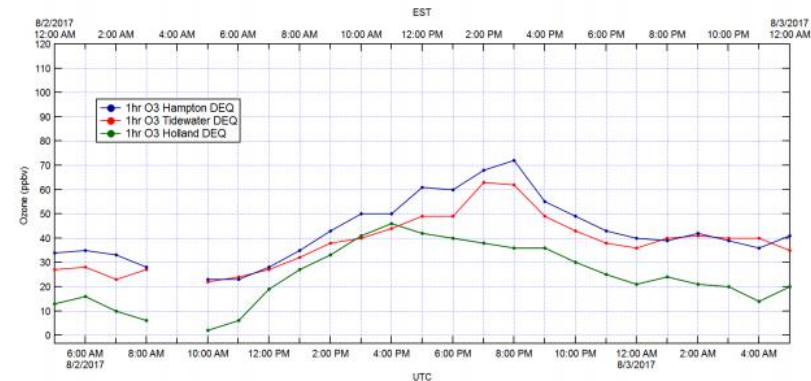
Archive: Expected in Nov

DEQ Quick Look 8/02/2017



- NASA installed 2B Model 202 Ozone Instrument
- Virginia DEQ Monitoring Station

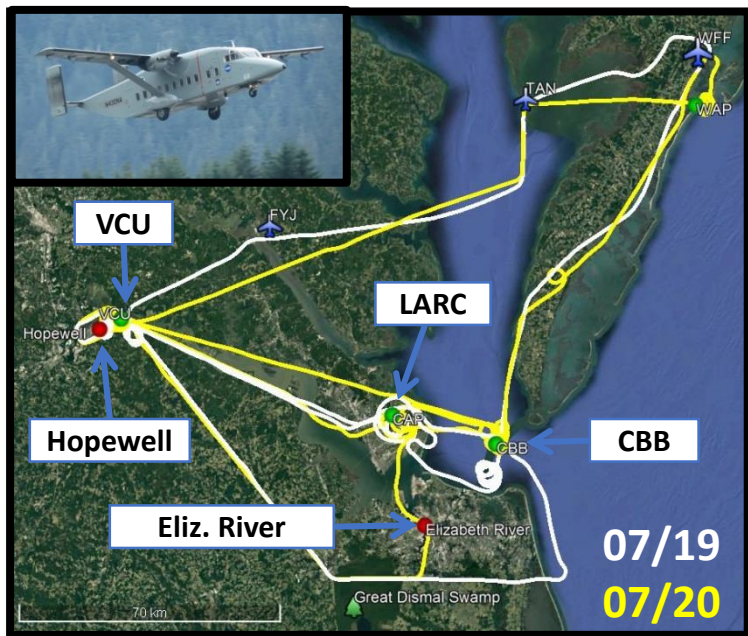
PLEASE NOTE: This data has not been verified by the Virginia DEQ and may change. This is the most current data, but it is not official until it has been certified by our technical staff. Data is collected from Virginia DEQ ambient monitoring sites and may include data collected by other outside agencies.





C-23 Sherpa (July 19 & 20)

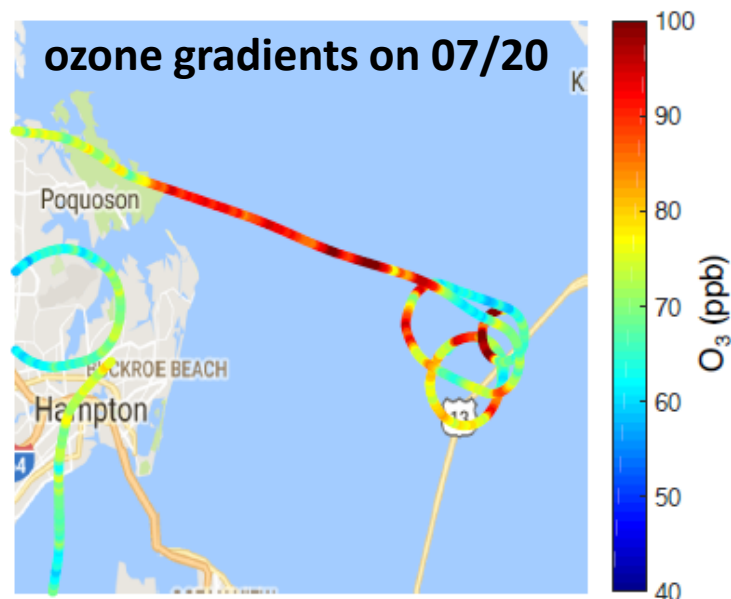
The **“SARP East” 2017** payload contained the **core measurements** needed to characterize tropospheric composition and validate retrievals of near-surface HCHO, NO₂, and O₃.



“SARP East” 2017 Objectives

1. Map land-water gradients in ozone and friends
2. Characterize vertical gradients at OWLETS ground sites for context and Pandora validation
3. Sample emissions from industrial areas at Hopewell and Elizabeth River

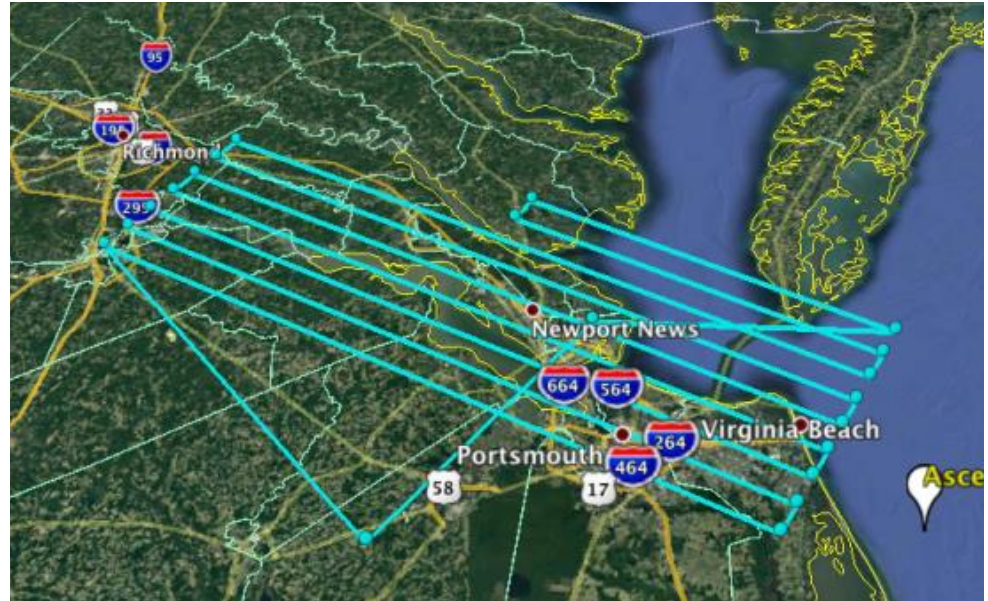
Payload	PI, Institution
HCHO	Hanisco/St. Clair, GSFC
NO _x /O ₃	Pusede/Flynn, UVA/UH
CO/N ₂ O/H ₂ O	Pusede, UVA
VOC	Blake, UCI
CH ₄ /CO ₂ /H ₂ O	Hanisco/Wolfe, GSFC





GeoTASO flights July 7 & 8 (3 flights)

Team: Scott Janz, Jay Al-Saddi, Matt Kowalewski, Laura Judd



Data product: NO₂ column

Data collected: 3 flights on two days (July 7-8)





Smithsonian Environmental Research Center (SERC) Water Vessel



Team Members: Maria Tzortziou, Owen Parker, Julio Roman, Lena Shalaby, Ryan Stauffer, Cpt. Mike Goodison

- Small research vessel sailed from Edgewater, MD to OWLETS study region on 17-18 July
- Instrumentation included in-situ O_3 and NO_2 , Pandora (column NO_2 and O_3), and Vaisala Ceilometer
- Mounted Kestrel Weather Meter provides *qualitative* T/RH measurements (no automated weather system on vessel)

Vessel at SERC Dock



SERC Team



Lena, Ryan, Owen, Julio, Cpt. Mike

CBBT Approach



Deployment supported by NASA Project #NNX13AL86G **PI: Maria Tzortziou** and Pandora Project, **PI: Bob Swap (NASA/GSFC)**, Nader Abuhassan (NASA/GSFC), Faran Haider (NASA/GSFC intern/UMBC), Belay Demoz (UMBC/JCET). Surface instrumentation from **PI Anne Thompson (NASA/GSFC)**



Tropospheric Ozone Lidar Network (TOLNet)



- Currently six ozone lidars across N. America (5 in US, 1 Canada)
- Used for air quality, satellite & model studies
- Obtain data at home site and/or deployed in field campaigns
- Although hardware is different, common algorithmic techniques, uncertainty computations
- Anticipate future field work, satellite calibration/validation, model improvements for AQ forecasting

Newchurch et al, ILRC 27 (2016)

TOLNet website:

<http://www-air.larc.nasa.gov/missions/TOLNet/>

- In addition to NASA campaigns, TOLNet lidar groups have routinely collaborated with state agencies to provide measurements for regional AQ field studies

Picture and diagram courtesy of 2B Technologies



- NIST traceable
- Federal Equivalent Method
- Small, lightweight (~ 1 lb.)
- Internal pump
- GPS
- On-board memory
- Rechargeable battery

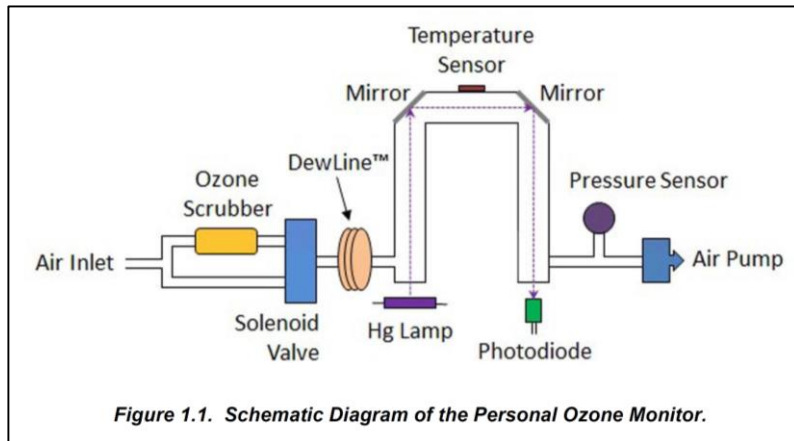
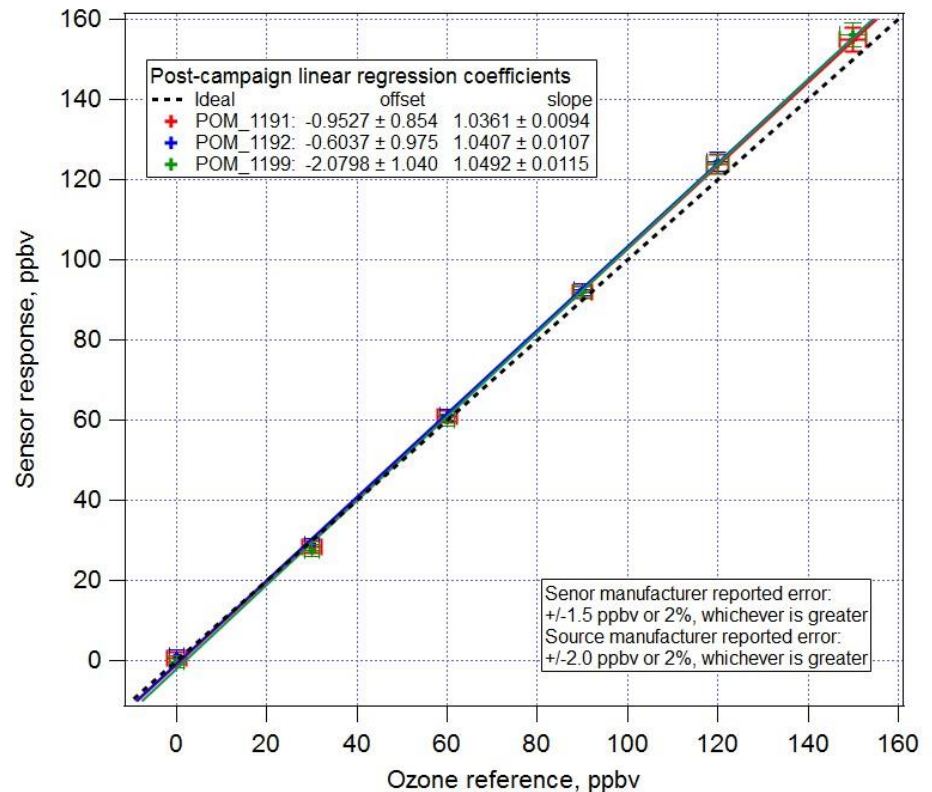


Figure 1.1. Schematic Diagram of the Personal Ozone Monitor.

The 2B POM sensor was used on the UAV platform as well as 2 mobile cars during OWLETS

In-house calibration check

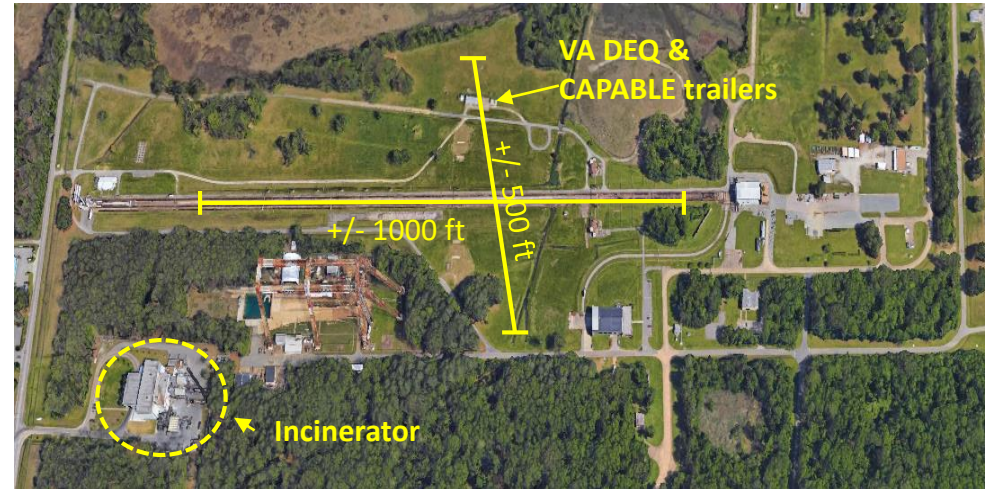




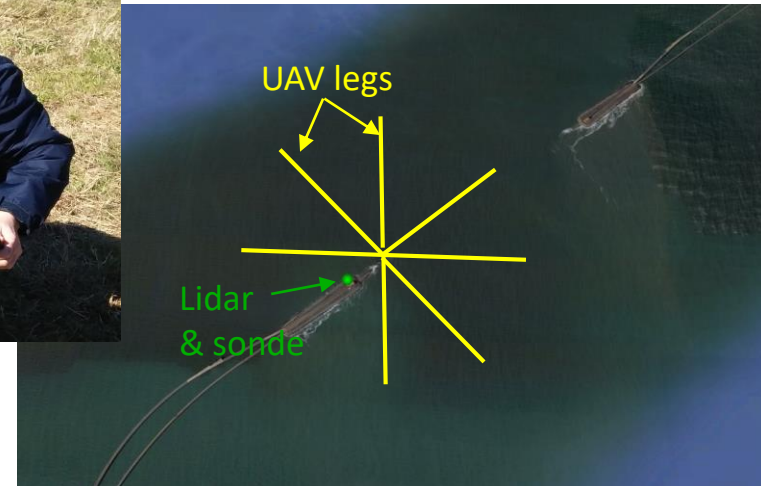
UAV/drone in-situ ozone measurements

Team members: Danette Allen, Jim Neilan, Margaret Pippin, Jeremy Schroeder, Eddie Adcock, Mark Motter, Ryan Hammit, Zak Johns, Guillaume Gronoff, Ian Fenn

LaRC “Back-40”



CBBT “over-water” site



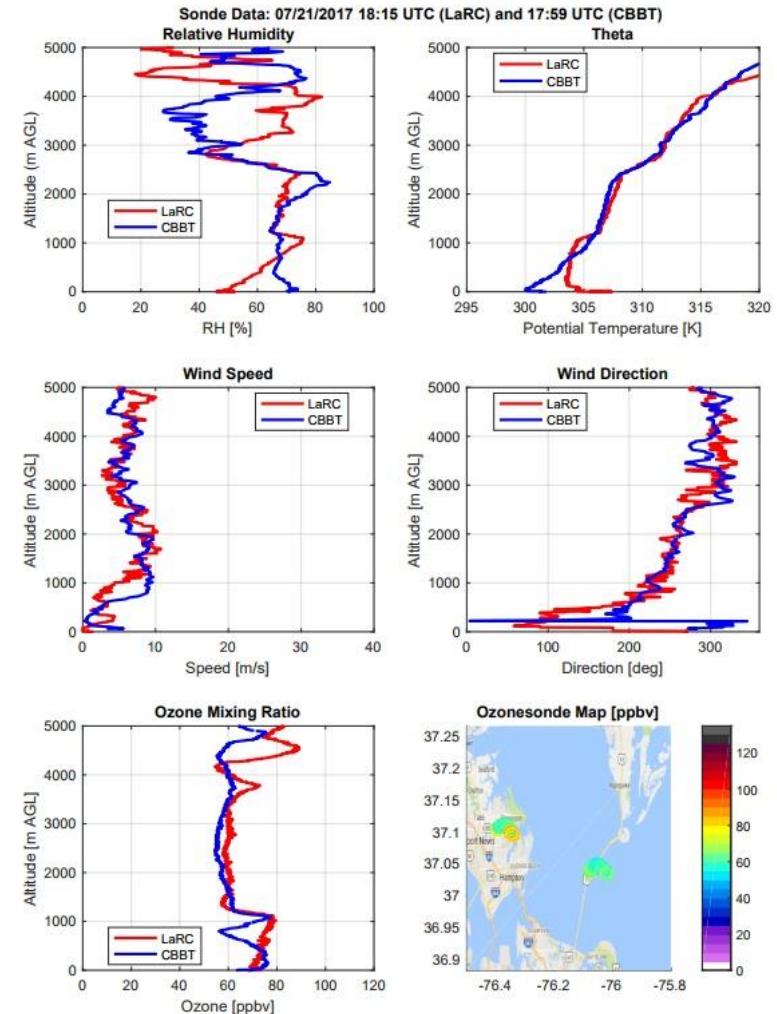
- At LaRC: 500 ft vertical, 1200 ft horizontal
- At CBBT: 700 ft vertical, 1200 ft horizontal
- Although UAV primary focus provided vertical closure between lidar and surface data, horizontal patterns were also flown to allow investigation of near-range variability, point source influences
- At LaRC line-of-site flight paths would be in close proximity to VA DEQ & CAPABLE trailers

Team: Travis Knepp, John Sullivan, Lance Nino, Emily Gargulinski

- ~35 launches
LaRC-CBBT
simultaneous
flights across 12
different days
- Data: RH, T, Wind,
Ozone
- Co-located with
lidars, providing
additional cross-
comparisons with
O₃ lidar vertical
distribution
- Measurements
include
tropospheric and
stratospheric O₃
measurements



Combined CBBT and LaRC site plots



Sonde activities supported by NASA's Tropospheric Composition Program, Earth Science Division, and Environmental Protection Agency's ACE research program

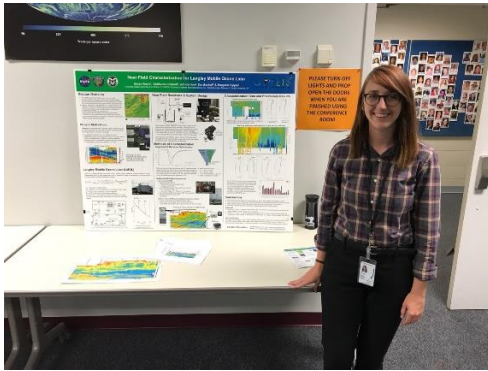


Summer Student Interns

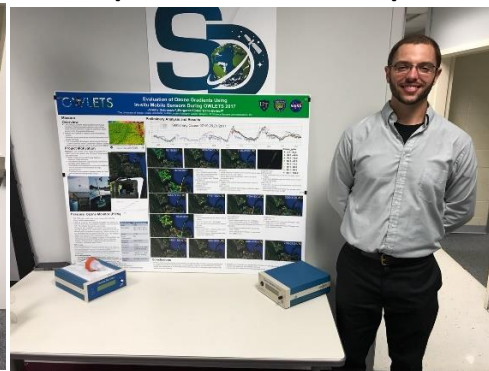


LaRC TEMPO student collaborators (Mentor: Margaret Pippin)
GSFC NIFS Program (Mentor: John Sullivan)
Hampton University NIFS Program (Mentor: Bill Moore)

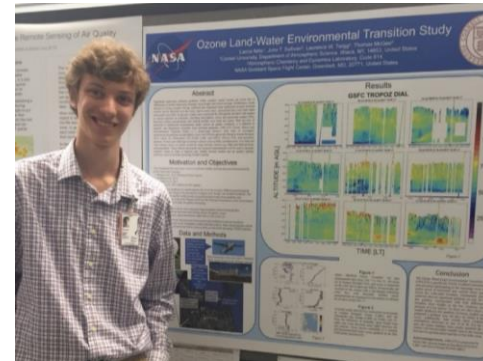
Betsy Farris (Lidar)



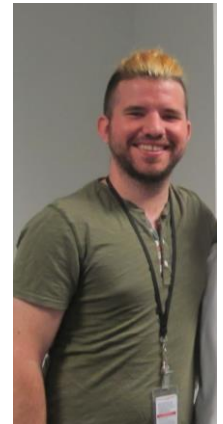
Jeremy Schroeder (UAV & Mobile Car)



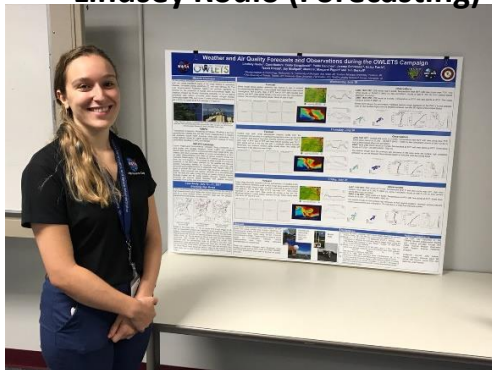
Lance Nino (GSFC lidar)



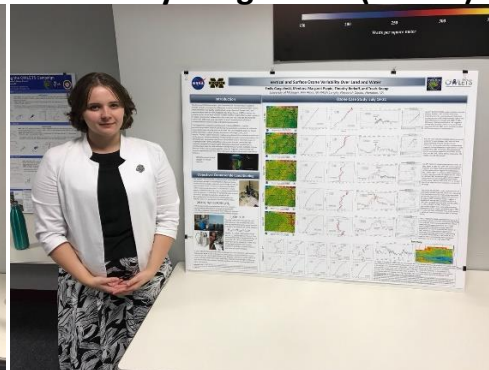
Pablo Sanchez (Aerosols)



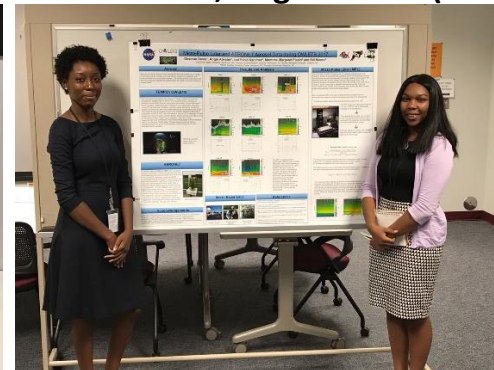
Lindsey Rodio (Forecasting)



Emily Gargulinski (Sonde)



Desorae Davis, Angela Davis (MPL)

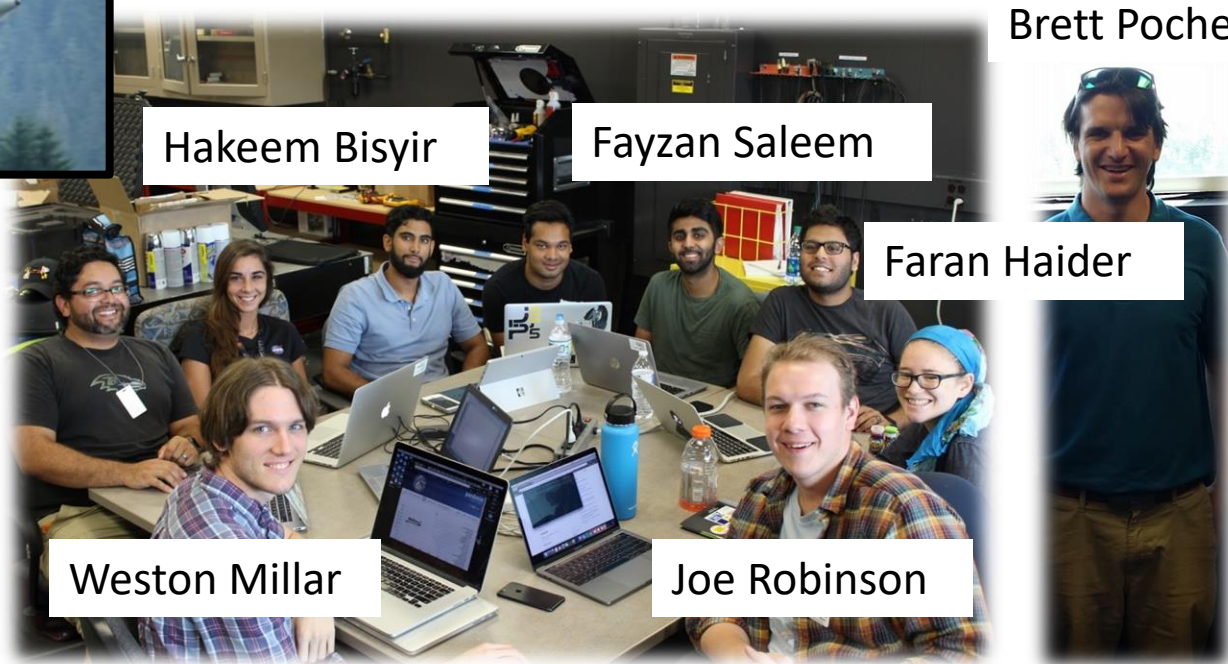




Sherpa Student Participation



6 GSFC summer interns (Swap)



Hakeem Bisyr

Fayzan Saleem

Brett Poche

Faran Haider

Weston Millar

Joe Robinson

2 Graduate Students



Jessica Munyan
UVA/Pusede Group



Brenna Biggs
UCI/Blake Group

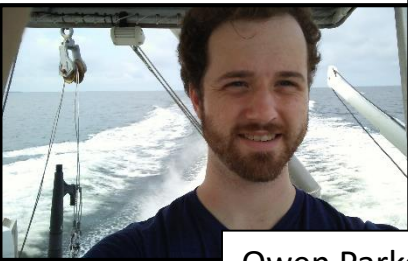


SERC R/V Student Participation



- 2 CUNY/Columbia Univ. Summer Interns (Mentor: Maria Tzortziou)
- 2 NASA/GSFC Summer Interns (Mentor: Bob Swap)
- 1 NASA/GSFC Postdoctoral Researcher (Mentor: Anne Thompson)

SERC R/V



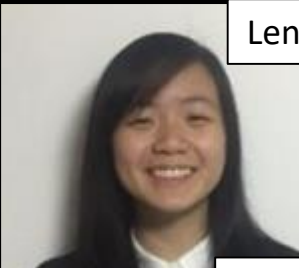
Owen Parker



Lena Shalaby



Ryan Stauffer



Rachel Li



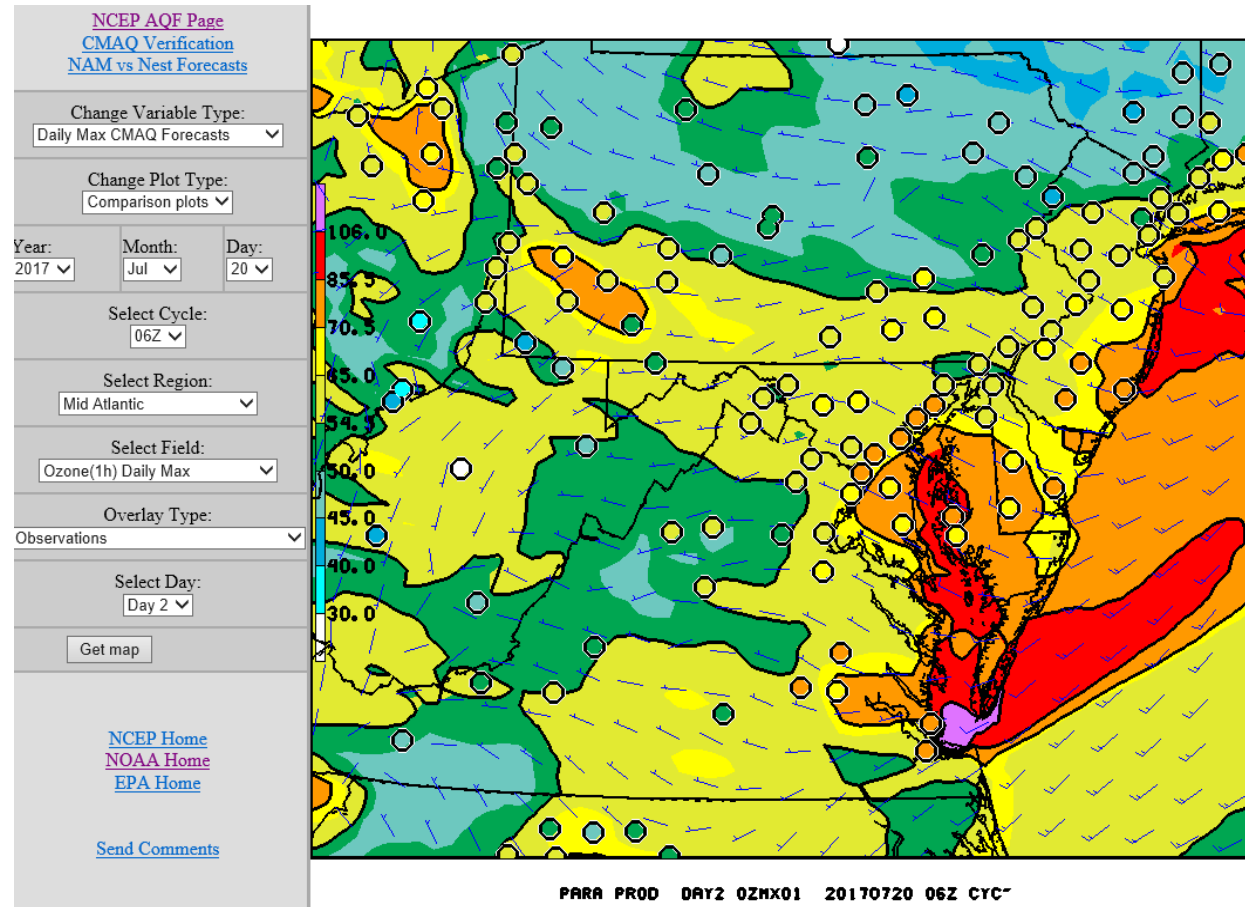
Julio Roman



Model Verification

- NOAA verification plots (link above image)
- Daily max 1-hr O₃
- 7/20/17 06Z model run
- Next day forecast
- Sharp gradient between the bay and land
 - 70+ ppb over land in Hampton Roads

From Stumpf et al., OWLETS science team meeting



From Farris et al., OWLETS science team meeting

OWLETS Data and Receiver Testing

Multi-instrument Intercomparison at CBBT (8/1-8/2), Near Field

UAV ozone data (Pippin et al.)
Sonde data (Knepp et al.)

