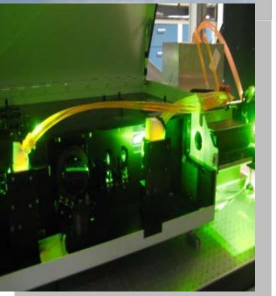
TOLNet

Tropospheric Ozone LIDAR Network



TEMPO-MAIA-TOLNet Synergy:

An Important Part of Air-Quality Understanding

Mike Newchurch with the **TEMPO, MAIA,** and **TOLNet Science Teams**

New Applications in the Use of Satellite Data Monitoring for Population Health
October 10, 2019
University of Alabama in Huntsville
College of Nursing

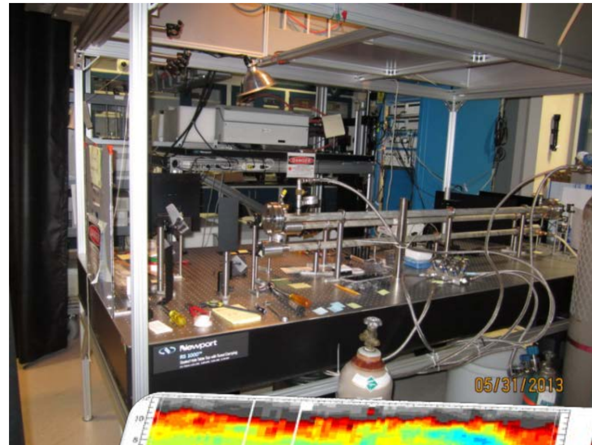
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

https://www-air.larc.nasa.gov/missions/TOLNet/

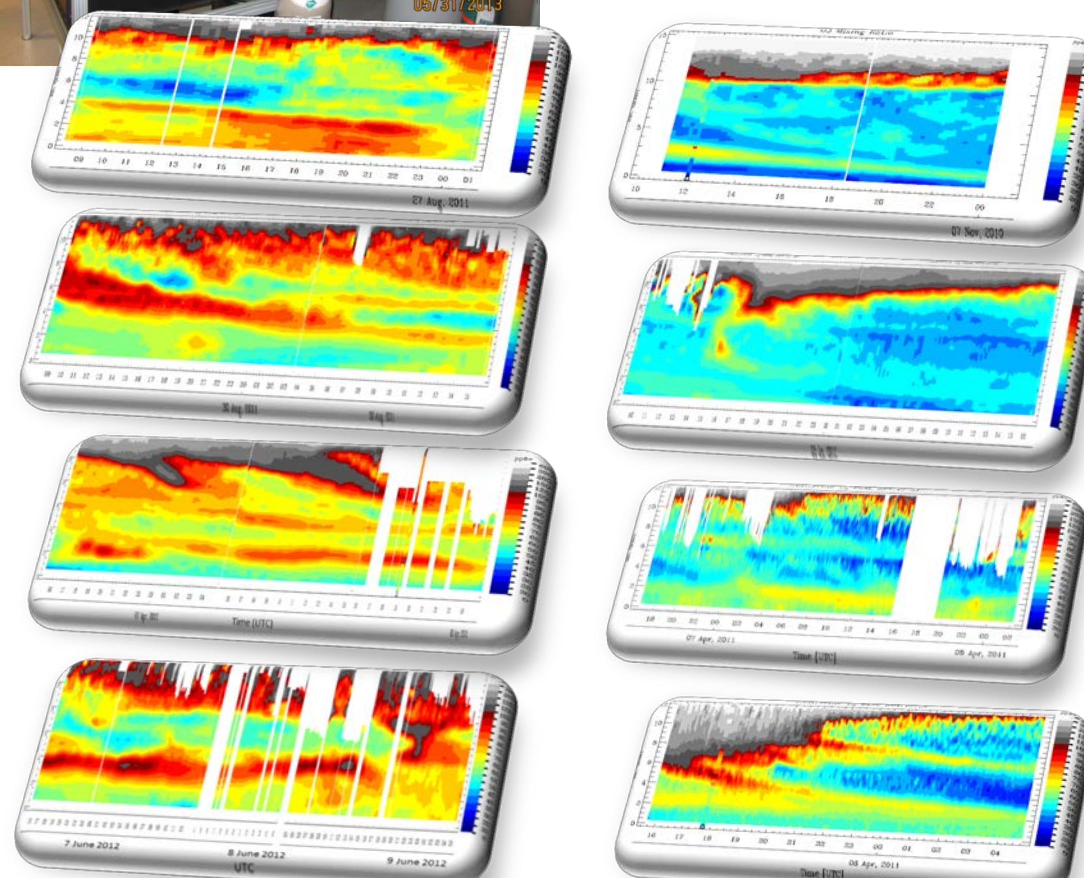
UAH Ground-based O3 lidar

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Name	**RO_3QET (Rocket-city O3 Quality Evaluation in the Troposphere) lidar**
Affiliation	UAH
Host location	Huntsville, AL
Set-up	Fixed-location
Transmitter type	Quadruple Nd:YAG pumped Raman laser
Wavelength (nm)	289, 299
Receiver size (cm)	40, 10, 2.5
Measurable range (km AGL)	0.1-12
Reference	[Kuang et al., 2011, 2013]

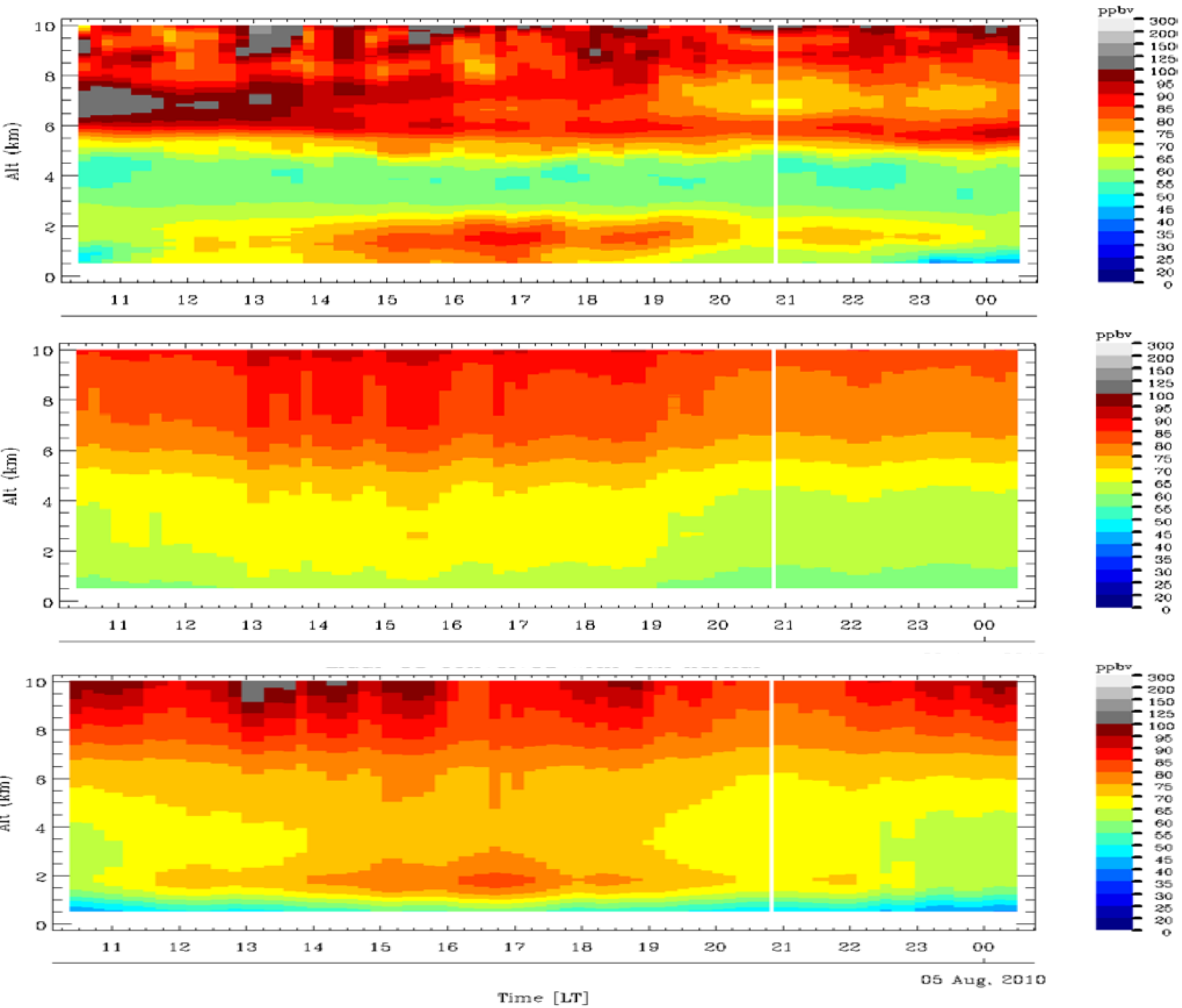


Raman shifted 289/299



Examples

High-resolution PBL lidar observation suggests both UV and Vis radiances required to capture significant PBL signal for satellite



Huntsville lidar observation on Aug. 4, 2010

Lidar obs. convolved with OMI UV averaging kernel---- unable to capture the highly variable ozone structure in PBL

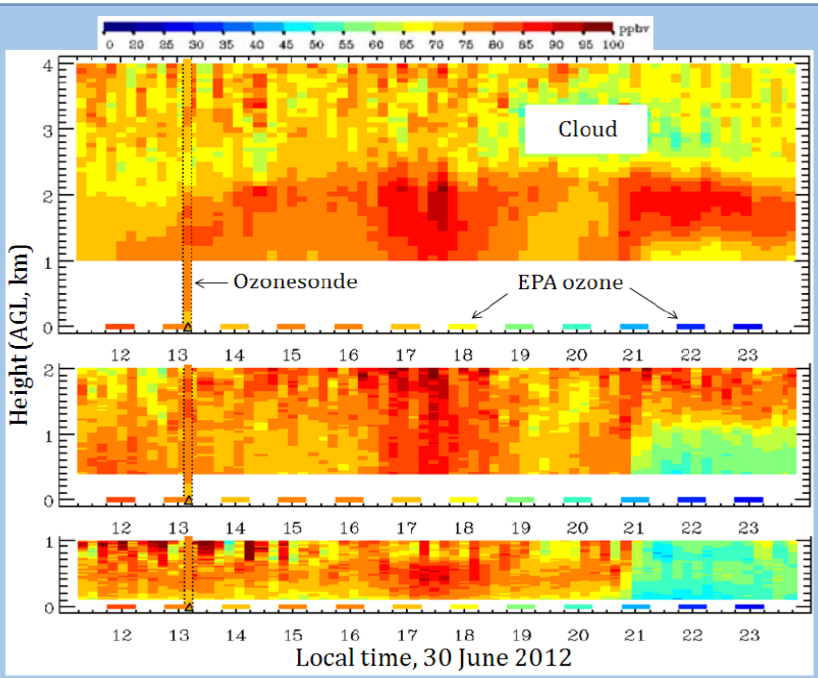
Lidar obs. Convolved with OMI UV-Vis averaging kernel----Captures the PBL ozone structure. X. Liu et al.

TOLNet lidars Measuring Ozone Below 100 m

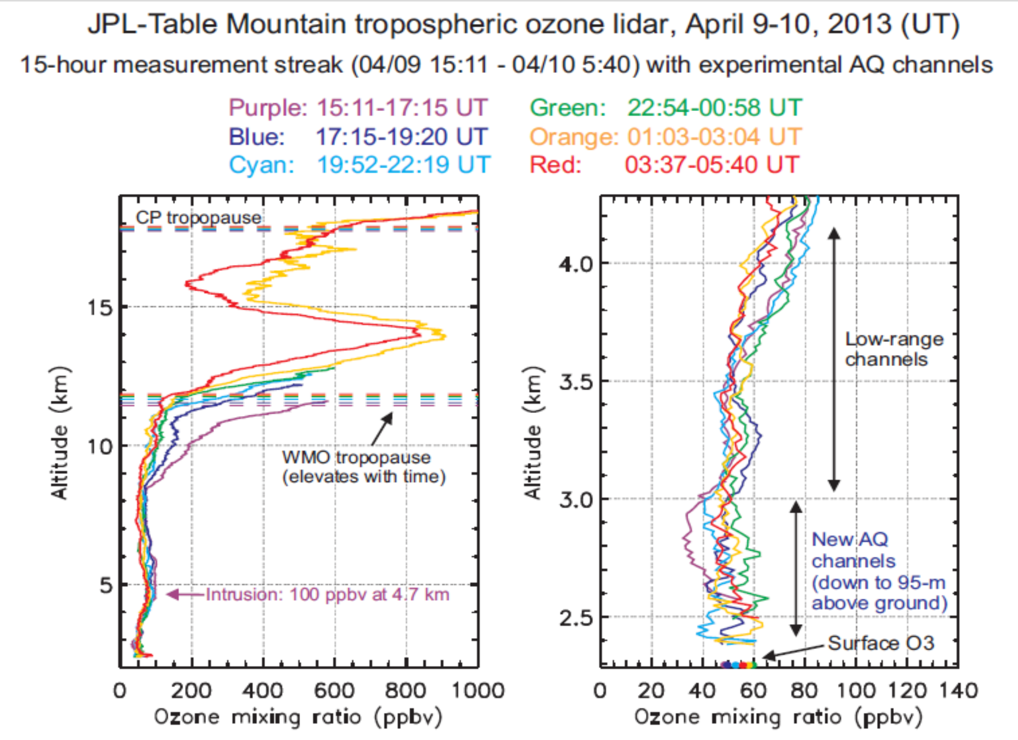
TOLNet is an emerging ground-based network making the first ozone lidar profiles from < 100 m to the stratosphere.

Mike Newchurch[1], Raul Alvarez[2], Russell DeYoung[4], Mike Hardesty[2], Shi Kuang[1], Andy Langford[2], Thierry Leblanc[5], Stuart McDermid[5] , Tom McGee[3], Christoph Senff[2], John Sullivan[3]

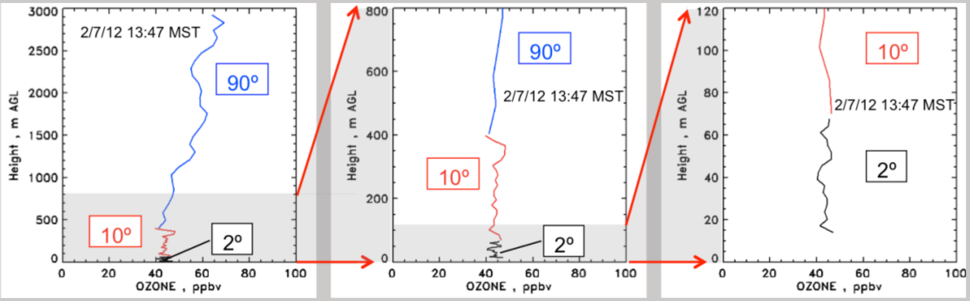
5 TOLNet Stations: *[1]UAHuntsville, [2]NOAA/ESRL, [3]NASA/GSFC, [4]NASA/LaRC, [5]NASA/JPL*



UAH Ozone lidar retrievals from the 3 lowest altitude channels compared with ozonesonde (marked by black triangle at 13:10 launch time) and EPA (~16 km away) hourly surface measurements. A 4th channel (not shown) measures the middle and upper troposphere.



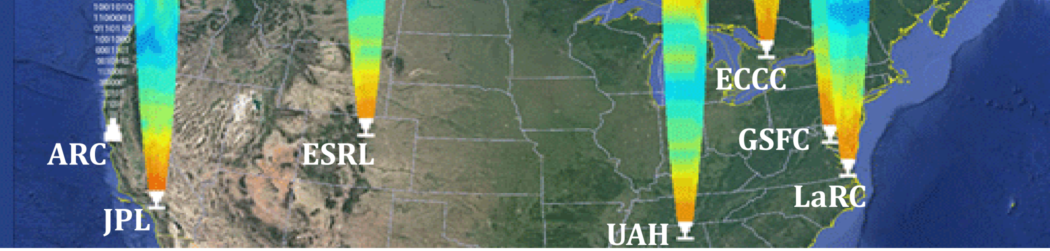
The NOAA/ESRL two-axis scanning lidar is installed in a truck. By using the scanner to direct the beam to low elevation angles, measurements are obtained to within a few meters of the surface. Azimuth scanning provides horizontal structure of ozone.



Lidar observations were made at elevation angles of 2°, 10°, 90° and pieced together to create a profile with higher vertical resolution near the surface.

TOLNET

Tropospheric Ozone LIDAR Network

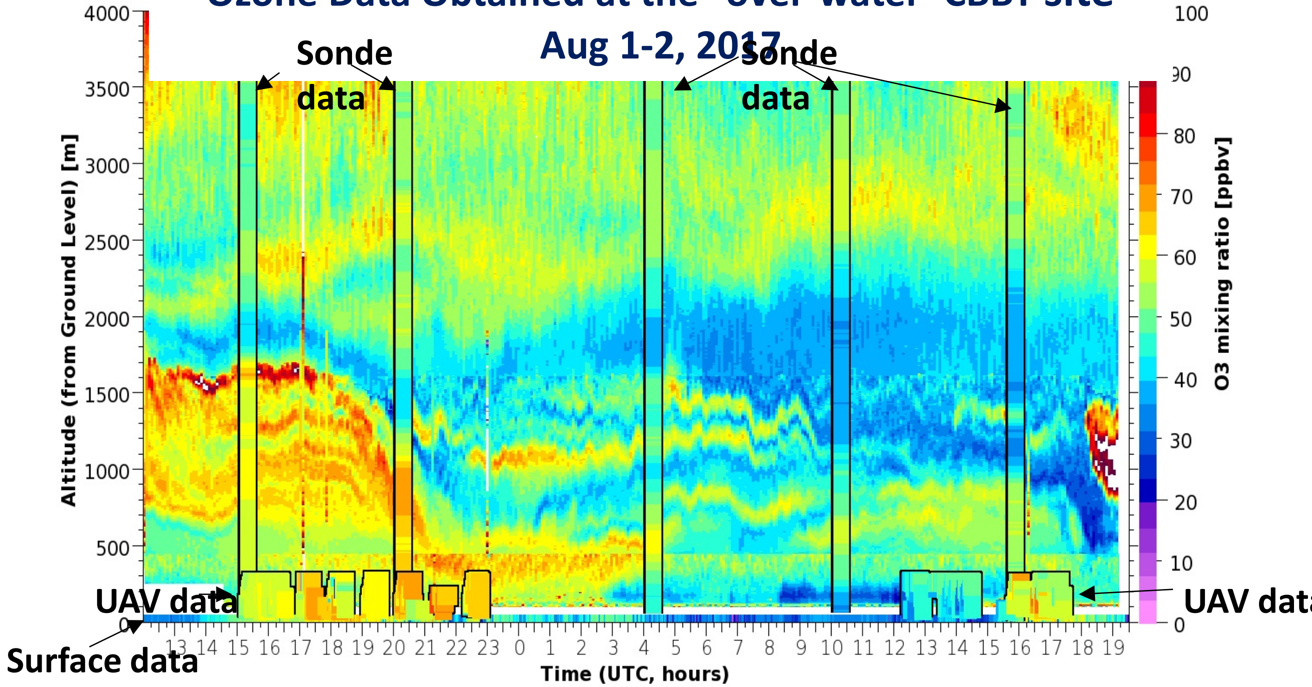


http://www-air.larc.nasa.gov/missions/TOLNet/

TOLNet Langley Mobile Ozone Lidar: Preliminary Data

Ozone Data Obtained at the "over-water' CBBT site

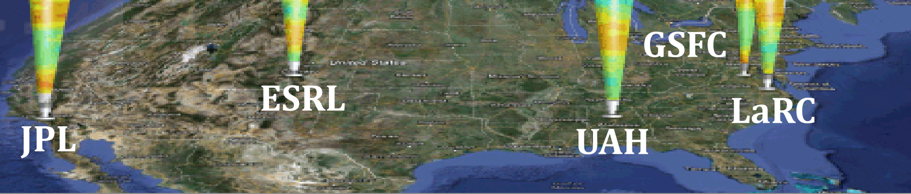
Aug 1-2, 2017



During the Summer 2017 Ozone Water Land Environmental Transition Study (OWLETS) in the Tidewater region of Southern Virginia, ozone profile data were obtained at the third island of the Chesapeake Bay Bridge Tunnel, 7.5 miles off-shore. On Aug 1-2, the Langley Mobile Ozone Lidar (LMOL) ran for 30+ hours capturing diurnal cycle ozone dynamics resulting from the collapse of the Aug 1 daytime boundary layer and resultant residual layers leading into Aug 2. Also highlighted are the ozonesonde launches and data collected by a UAV/drone carrying an in-situ ozone sensor. 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. This data when combined with other OWLETS measurements will help evaluate ozone transition behavior from land to water in complex coastal scenes where large gradients in ozone can occur.

TOLNET

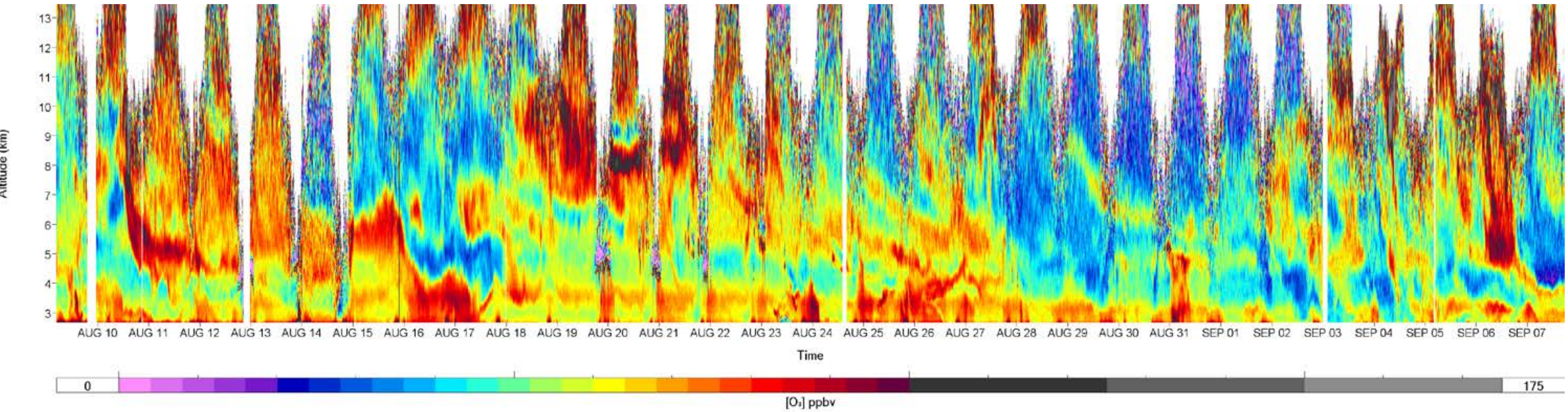
Tropospheric Ozone LIDAR Network



ECCC continuous, autonomous observations at SCOOP:

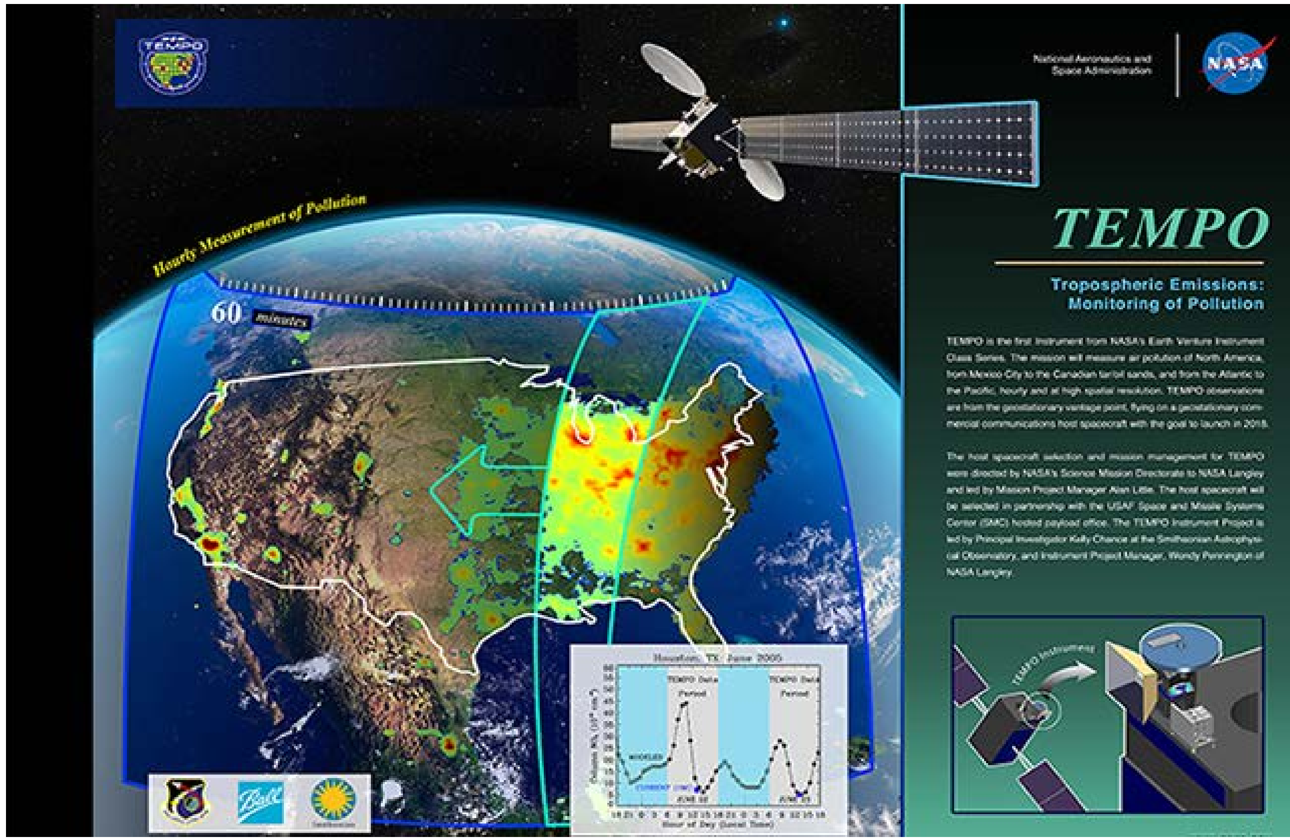
31 days including the BlueCut fire TMF evacuation

Courtesy of K. Strawbridge



OWLETS Motivation: Satellite evaluation

- Tropospheric Emissions: Monitoring of Pollution (TEMPO) mission is planned for launch in 2022
- 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 over small distances



TEMPO Mission

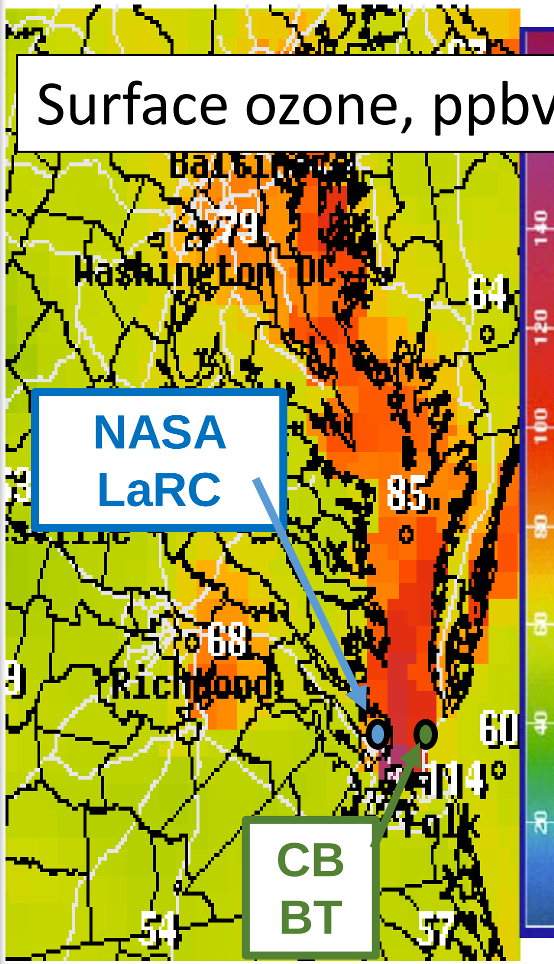
Principal Investigator: Kelly Chance, Smithsonian Astrophysical Observatory

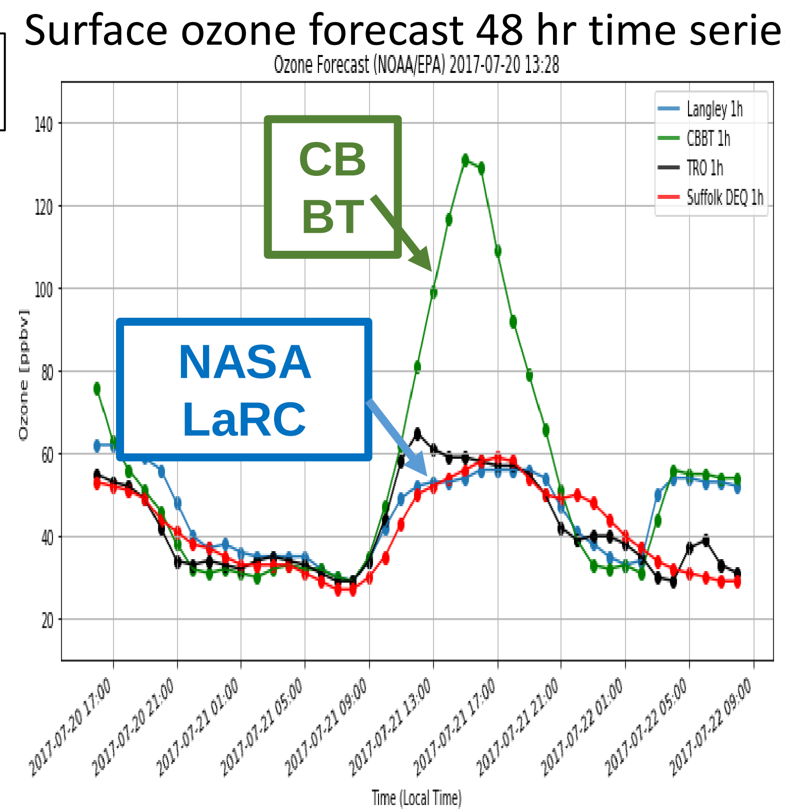
Instrument Development: Ball Aerospace & Technologies Corporation

Project Management: NASA/Langley Research Center

OWLETS-1 Motivation

- 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 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)
- Vertical, horizontal, and temporal (4-D) measurements are needed to describe complex scenes to improve forecast models and air quality satellite retrievals





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

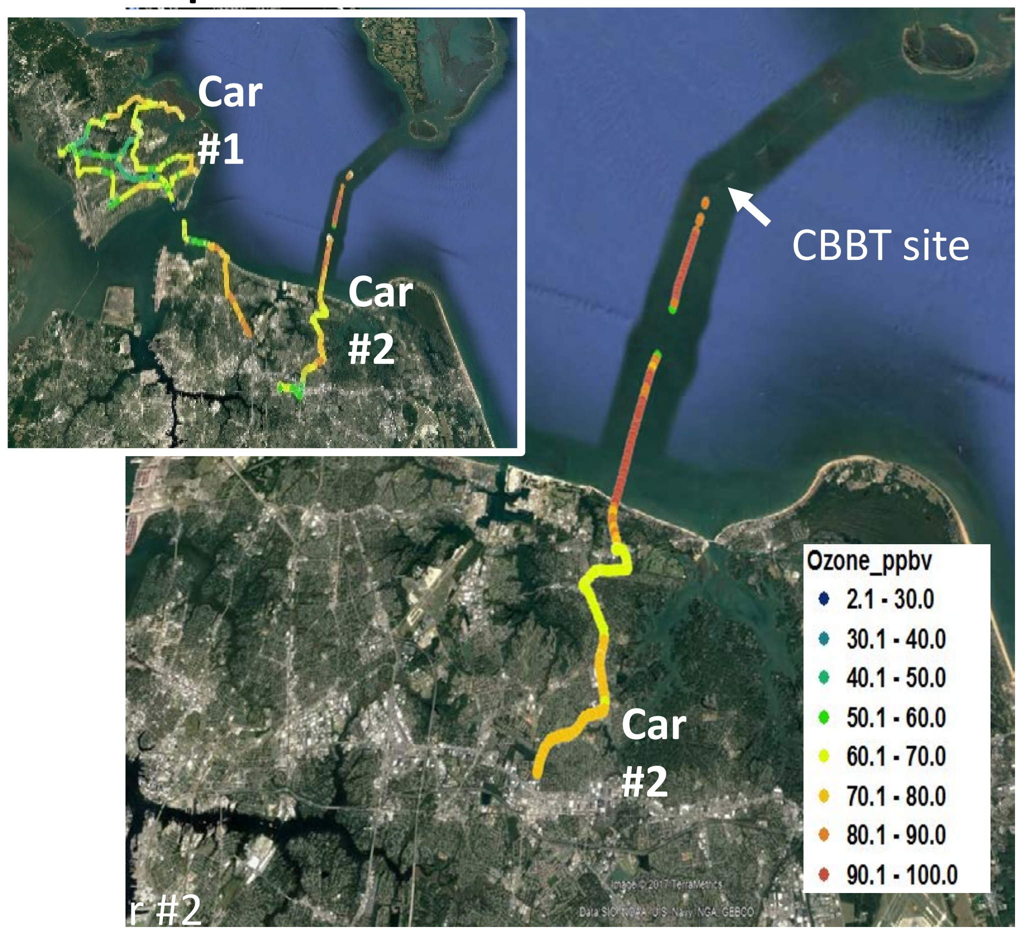
1Hr Avg Ozone Concentration(PPB) Ending Fri Jul 21 2017 3PM EDT
(Fri Jul 21 2017 19Z)
National Digital Guidance Database
12z model run Graphic created-Jul 20 12:20PM EDT

OWLETS-1 Mobile car in-situ measurements

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

Car sensor setup

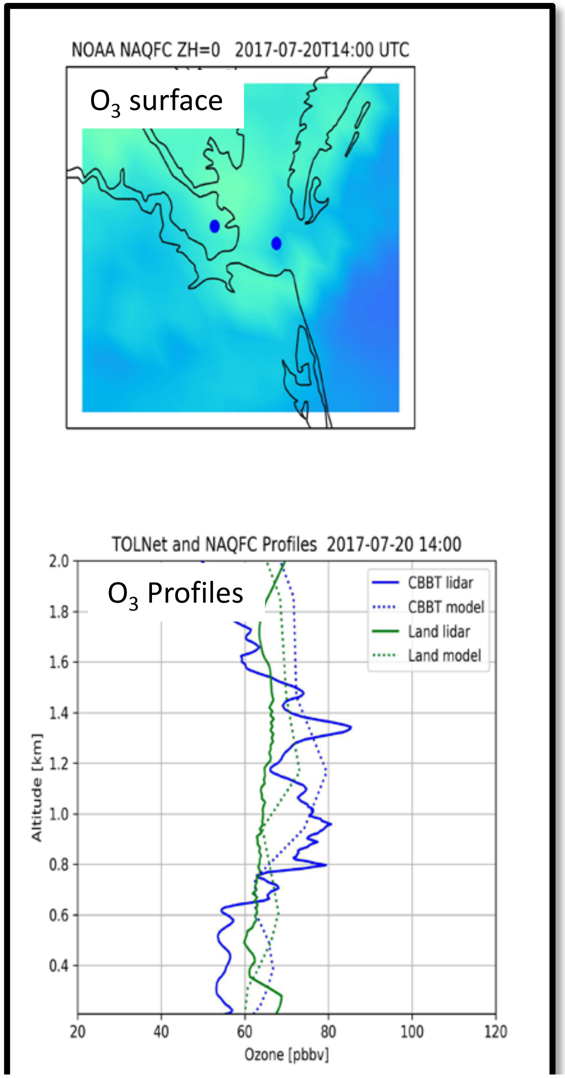
Example car in-situ ozone sensor data



Mobile car data obtained on all OWLETS measurement days

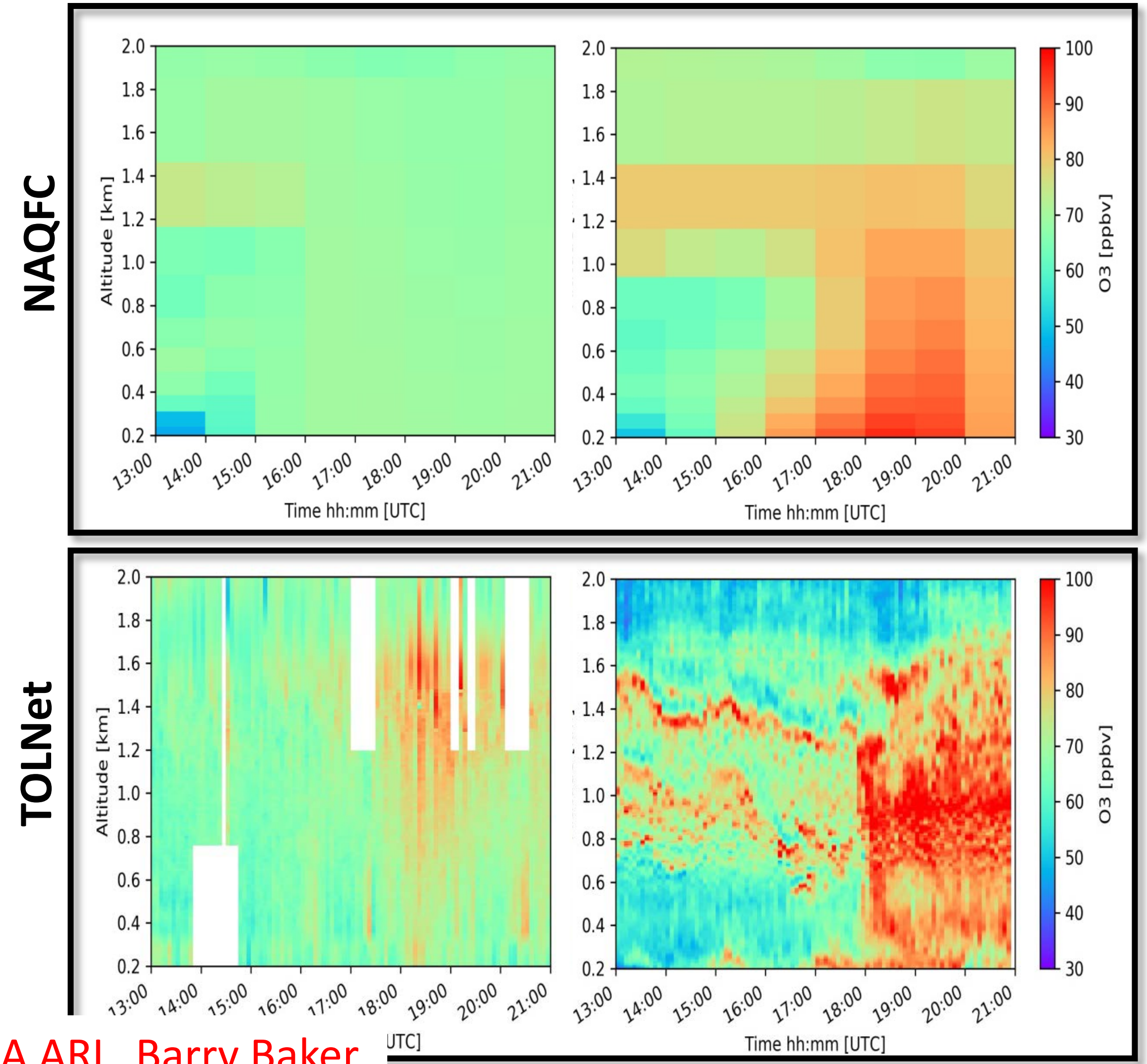
PRELIMINARY OWLETS-1 July 20, 2017
TOLnet lidar comparison to NAQFC forecast example

July 20, 2017



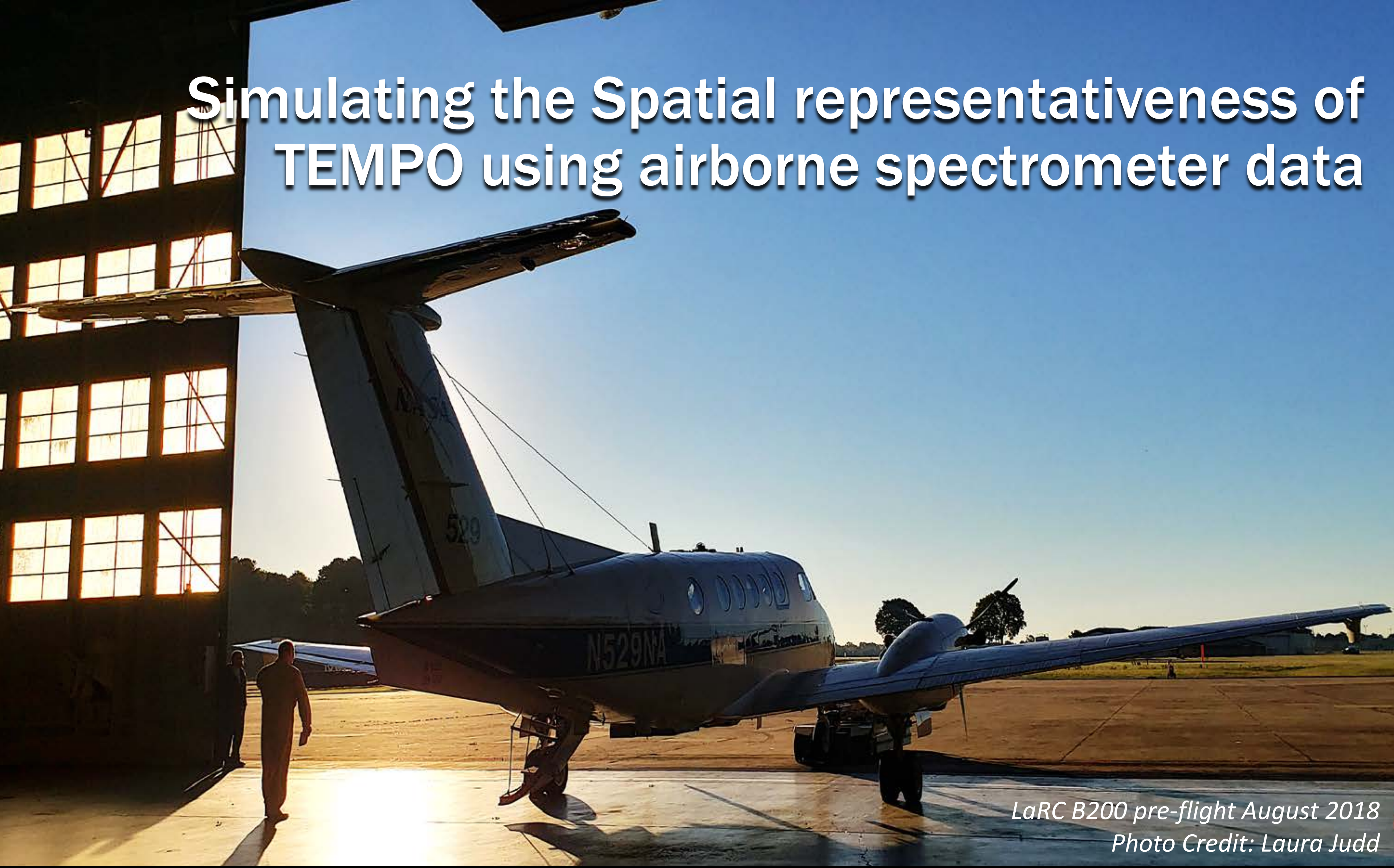
Ozone profiles July 20, 2017

Over land (LaRC) **Over water (CBBT)**



NAQFC Data Courtesy of NOAA ARL, Barry Baker

Simulating the Spatial representativeness of TEMPO using airborne spectrometer data



LaRC B200 pre-flight August 2018
Photo Credit: Laura Judd

Presented at the 2019 TEMPO Science Team Meeting
by Laura Judd, NASA Postdoctoral Fellow at LaRC

Jay Al-saadi, Scott Janz, Matt Kowalewski, Jim Szykman, Luke Valin,
the Pandora/Pandonia teams, LMOS Science Team, LISTOS Science Team, Harvard SAO

Airborne Mapping Spectrometers: LaRC/GSFC Partnership

Scott Janz, NASA GSFC Instrument PI; LaRC Aircraft and Science

GeoTASO

- <u>Geo</u>stationary <u>T</u>race gas and <u>A</u>erosol <u>S</u>ensor <u>O</u>ptimization
- Flown during all Studies
- UV-VIS
- Large—300+lbs

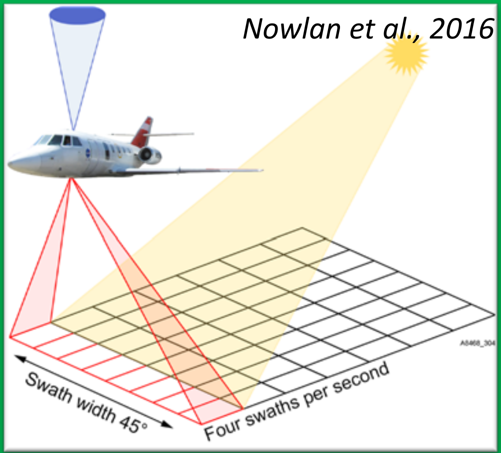
GCAS

- <u>GEOC</u>APE <u>A</u>irborne <u>S</u>pectrometer
- Flown during LISTOS
- UV-VIS-NIR
- Small— ~100 lbs
- Co-located with HALO

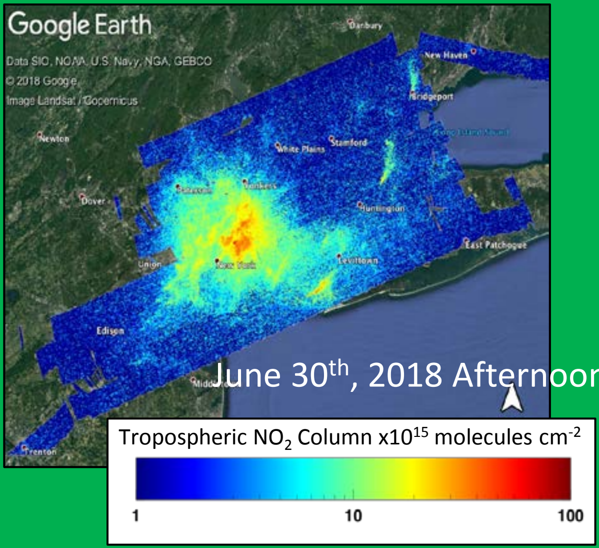
Used to improve and validate retrievals for future geostationary observations of air quality (e.g. TEMPO)

Both operate in a push-broom mode recording high spectral resolution visible spectra for NO_2 retrievals at ~250 x 250 m resolution

Also capable of retrieving HCHO

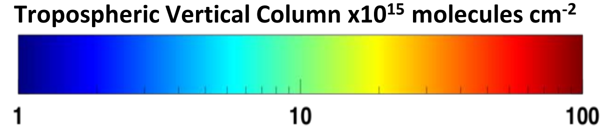


Gapless mapping strategy: 1.5-4 hours

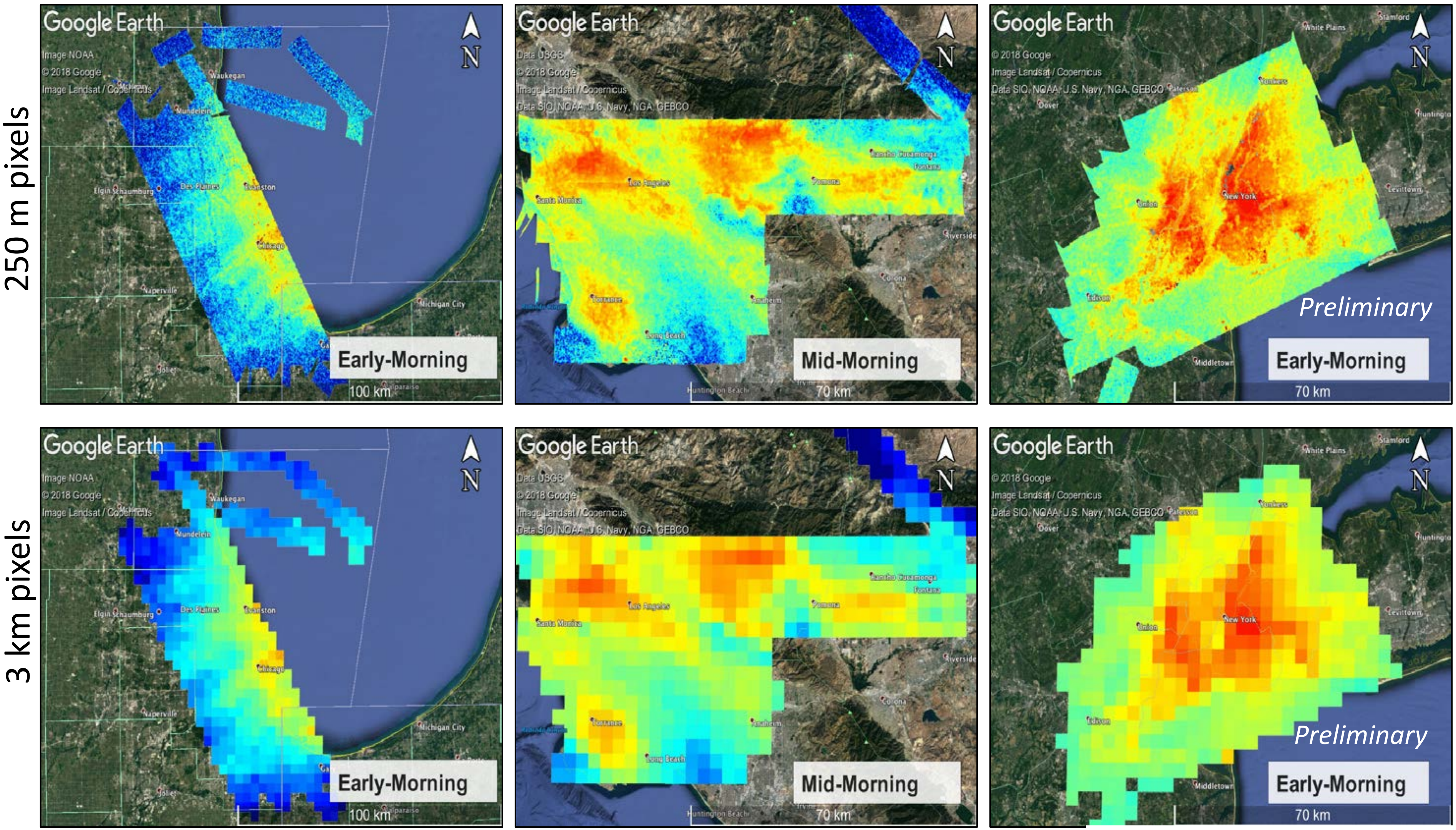


Slide provided by Laura Judd, LaRC

Simulating TEMPO spatial scale observations



May 22nd, 2017 | June 27th, 2017 | July 20th, 2018

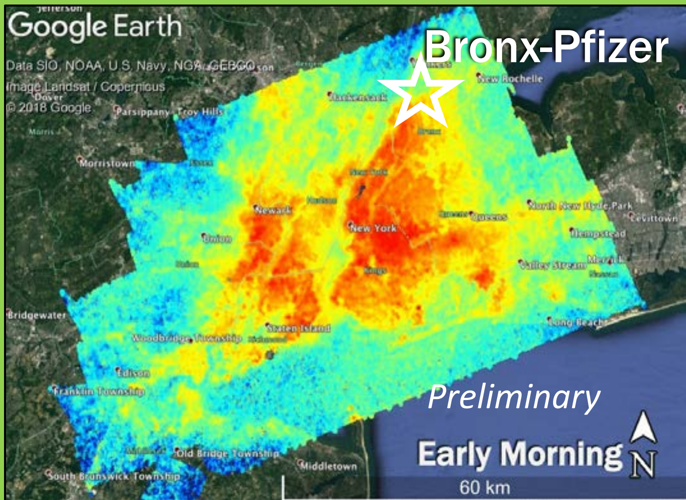


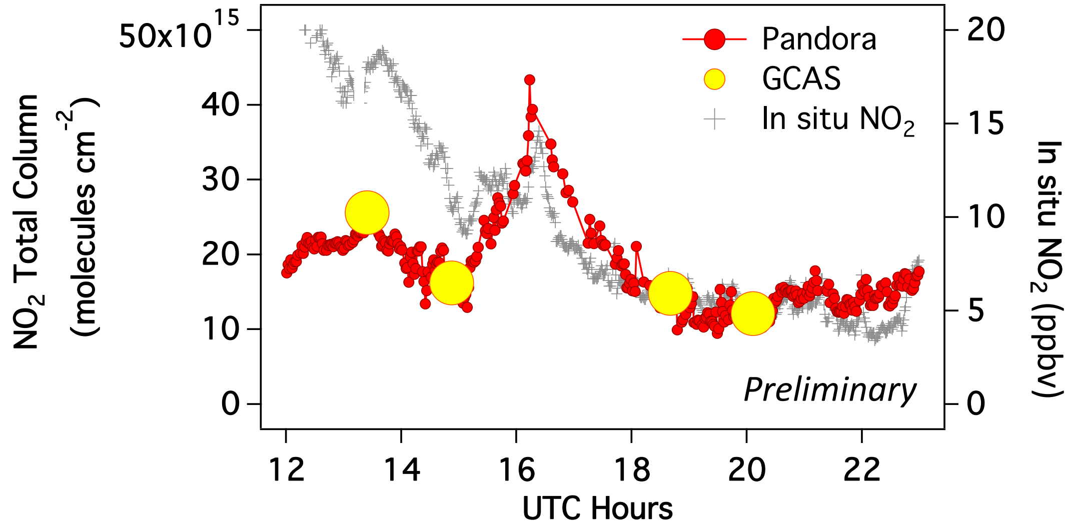
Zoogman et al. (2017) reports TEMPO resolution as 2.1 km x 4.4 km (9.24km^2)

Slide provided by Laura Judd, LaRC

Connecting a Ground site (Bronx) to the Raster image:

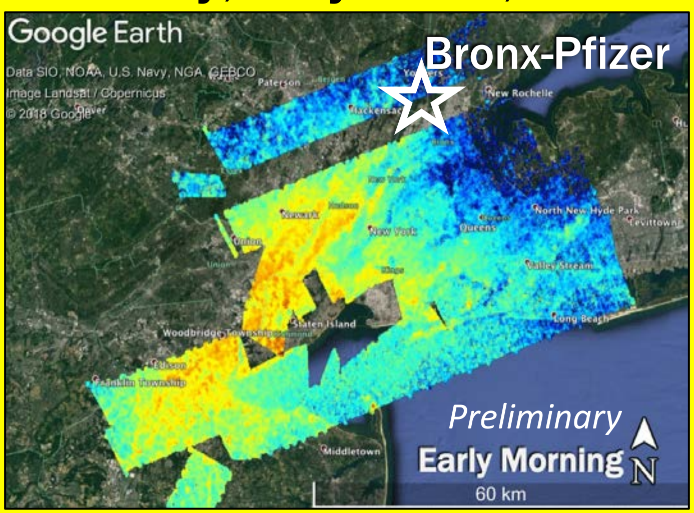
Friday, July 20th, 2018

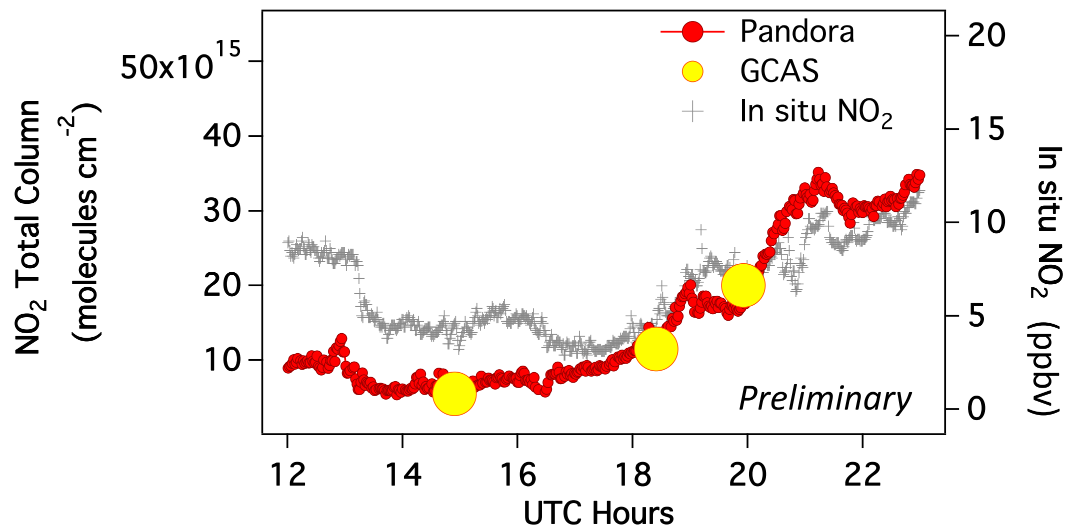




Preliminary 1 minute ground in situ NO_2 data credit to NYSDEC staff

Thursday, July 19th, 2018



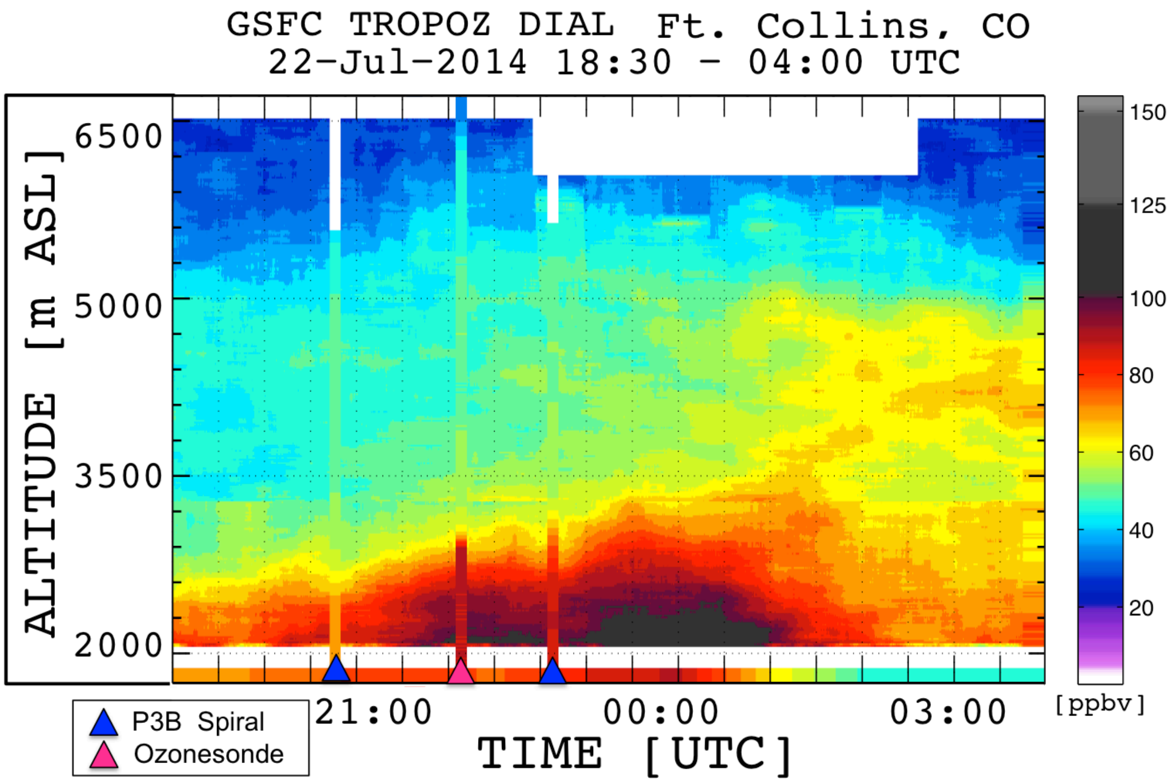


Slide provided by Laura Judd, LaRC

TOLNET

Tropospheric Ozone LIDAR Network

GSFC TROPOZ Observations from DISCOVER-AQ July 22-23 2014 at Ft. Collins, CO



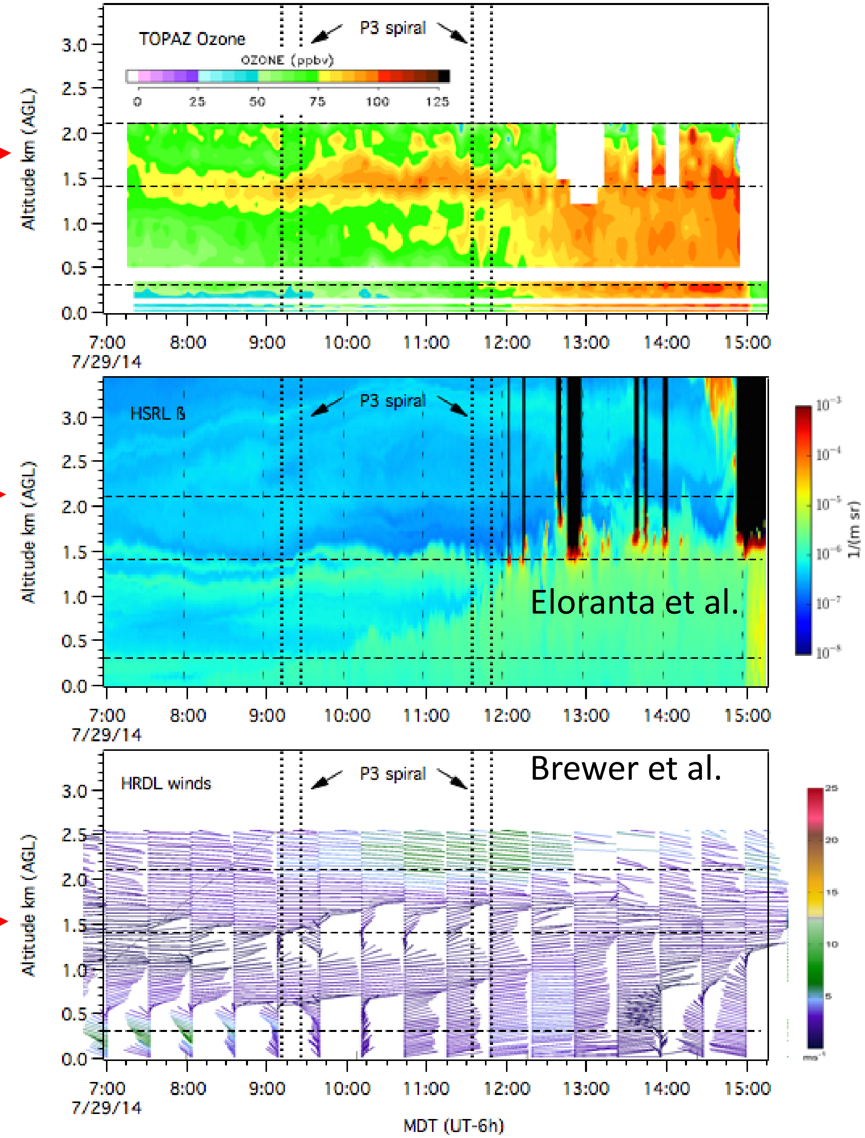
- GSFC TROPOZ DIAL observations on July 22 and 23 2014 compare well with the NASA P3B Spiral-down and co-located ozonesondes.
- The surface monitor is shown in the lowest bin of the figure, which indicates the greatest enhancement near 0 UTC (18 MDT) and quickly becomes less polluted at the surface.
- However, aloft ozone concentrations remain elevated and are characterized with extended TROPOZ measurements

- This **elevated ozone event** was delayed from the typical diurnal maximum during the DISCOVER AQ campaign period by several hours.
- Further analysis has shown that the increase in near surface (1570m ASL) ozone was correlated with a convectively driven upslope – downslope flow transition, which subsequently converged over Ft. Collins, CO.

Multiple lidar probing of wave dynamics and entrainment of the morning residual layer (RL) at the Boulder Atmospheric Observatory (BAO) during DISCOVER-AQ/FRAPPÉ: An example from July 29, 2014.

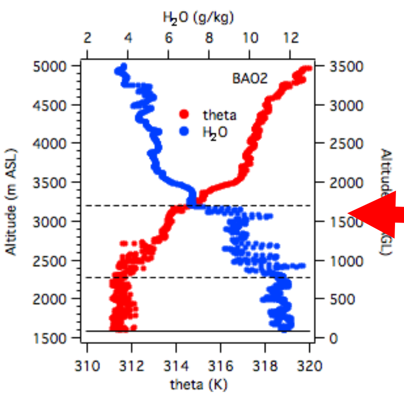
Measurements from the NOAA TOPAZ lidar show a narrow morning RL with 75-90 ppbv of O_3 that is enveloped by the growing convective boundary layer (CBL) near midday.

The P3 showed this RL extending over a large area. The observations were ended by T-storms near 1500 MDT.



The aerosol distribution from the collocated U Wisc HSRL (High Spectral Resolution Lidar) shows similar structures with gravity wave (GW) activity in the RL between 1000 and 1200 MDT.

The water vapor profile from the second BAO spiral also show this wave activity.



NOAA HRDL (High Resolution Doppler Lidar) located nearby shows predominately easterly winds with directional shear in the RL during late morning that may have triggered GWs. T-storm outflow causes low level winds to rotate to WNW in afternoon.

A.O. Langford, NOAA ESRL ARS

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

OWLETS-2 Science Team Meeting

May 6-7, 2019

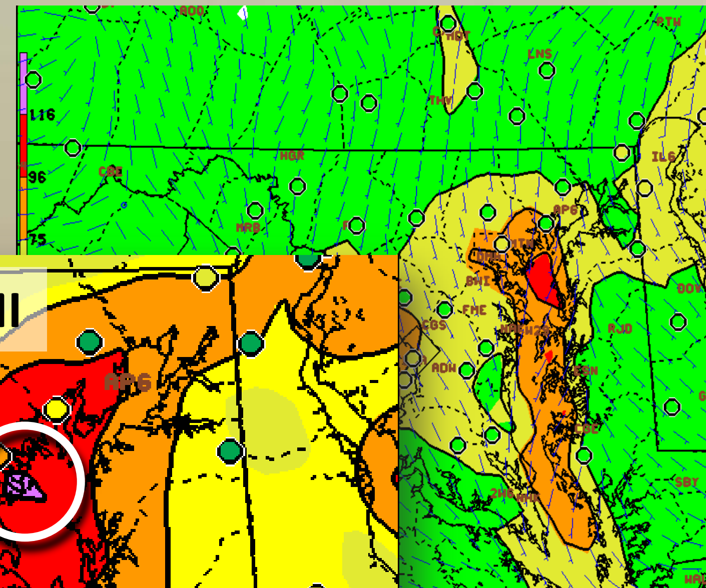
OWLETS-2 Ozone Water-Land Environmental Transition Study

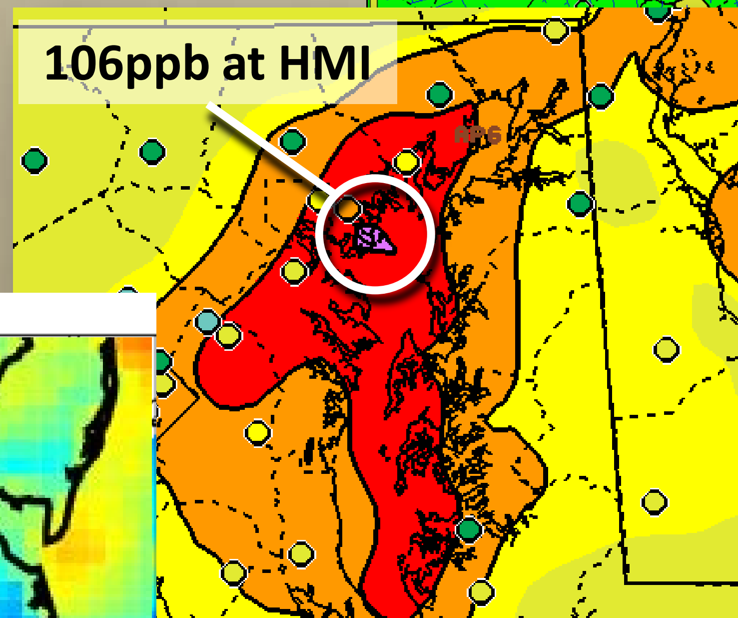
Maryland Department of the Environment

Chesapeake Bay Ozone Background

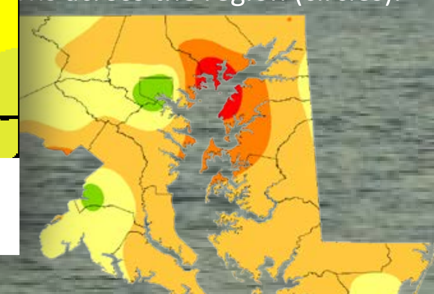
Maryland "Water Issues"

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

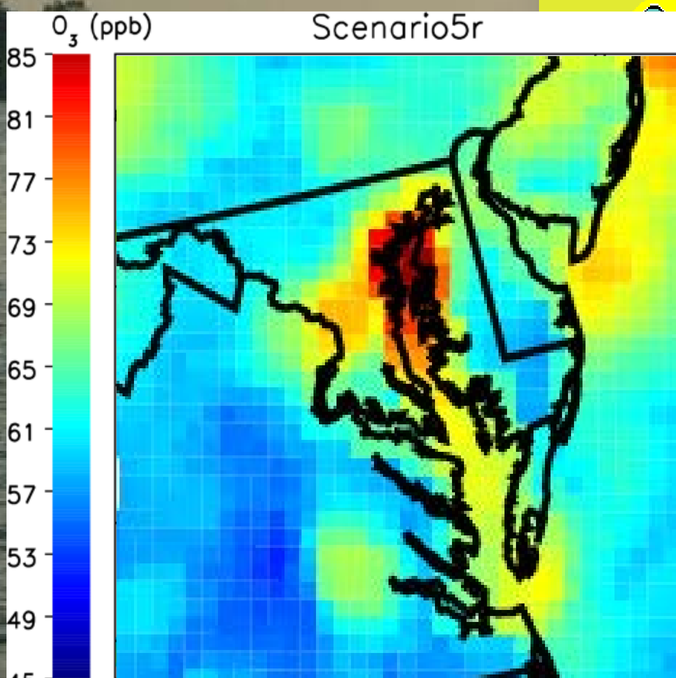




Forecast 8-hour maximum ozone averages July 6, 2016 [06z run]



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



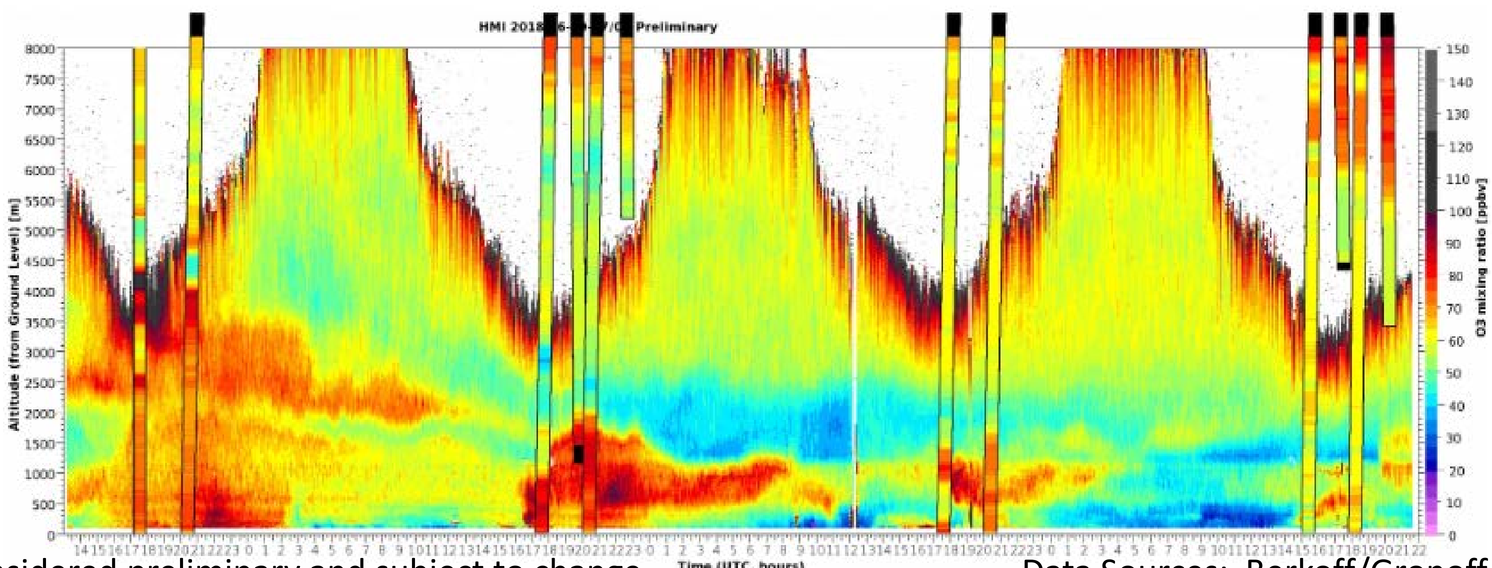
Tim Canty, PhD, UMD

How do we verify any of this?

Picture: Chesapeake Bay, July 20, 2017

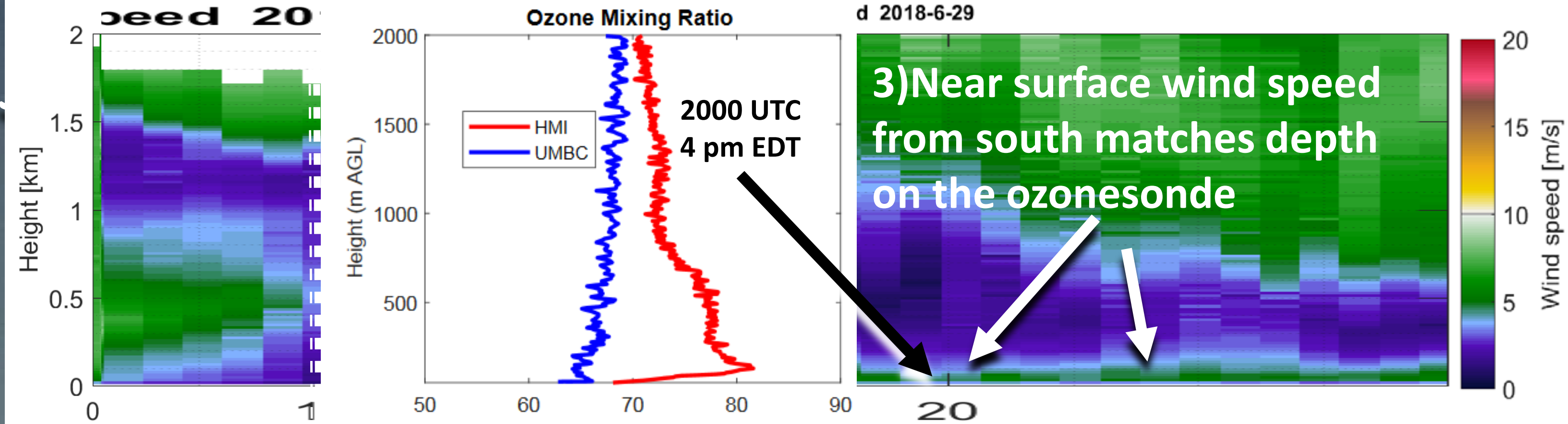
Types of Exceedances at Hart-Miller Island

- 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



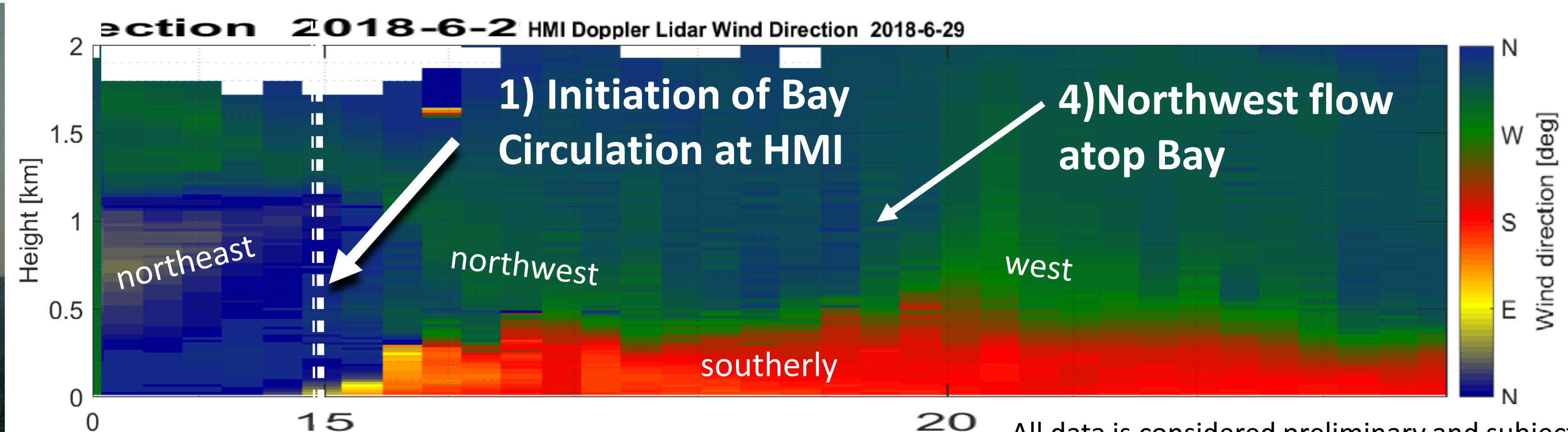
All data is considered preliminary and subject to change

Data Sources: Berkoff/Gronoff, NASA; MDE



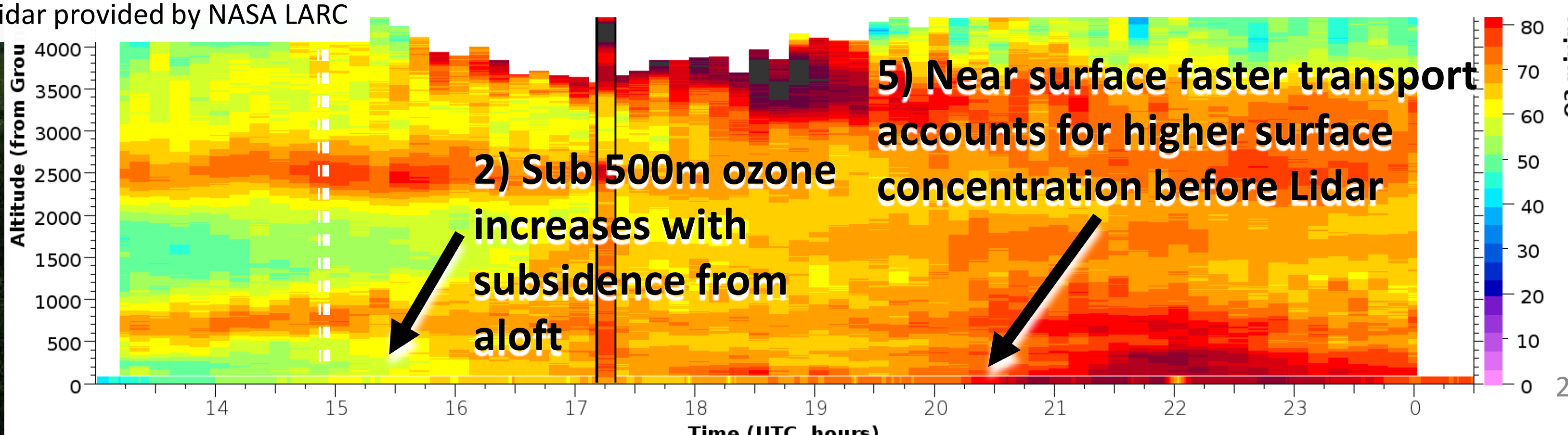
Wind Lidar provided by UMBC: Delgado

All data is considered preliminary and subject to change



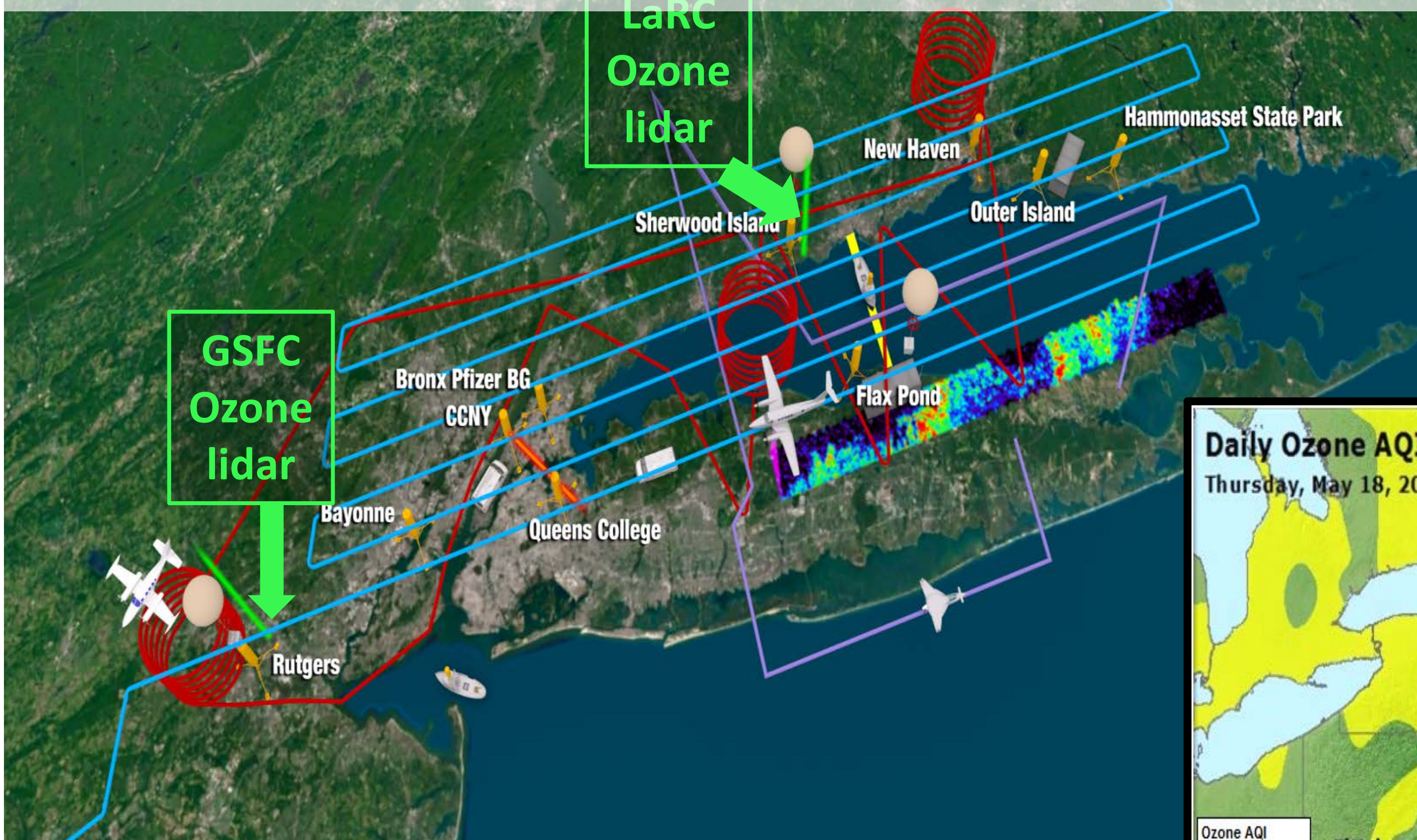
All data is considered preliminary and subject to change

Ozone Lidar provided by NASA LARC



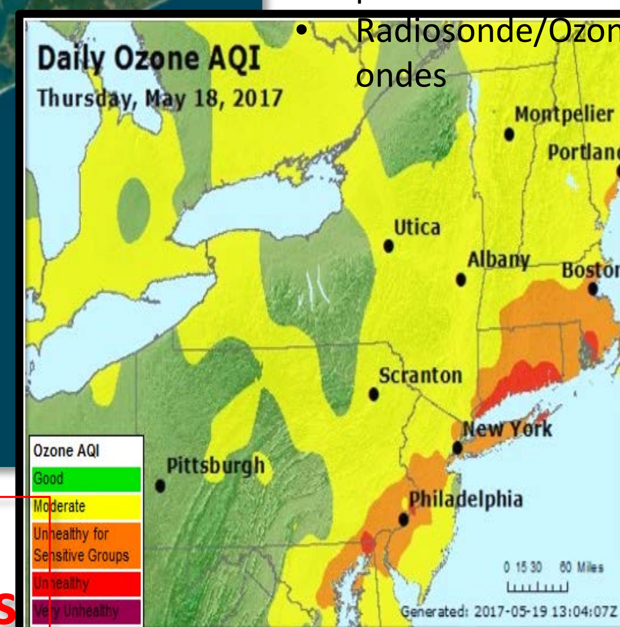
Long Island Sound Tropospheric Ozone Study (LISTOS)

Miller et al., "Overview of the Long Island Sound Tropospheric Ozone Study (LISTOS)", AGU Fall Meeting, 2018



Summer 2018:

- Multiple aircraft
- Marine vessels
- Automobiles
- Ground lidars
- Sounding systems
- In-situ sensors
- Pandora sun-spectrometers
- Aeronet sun-photometers
- Radiosonde/Ozonesondes



Campaign description website:

http://www.nescaum.org/documents/listos

Ozone production in the Soberanes Fire plume: impact on air quality in the San Joaquin Valley during the California Baseline Ozone Transport Study (CABOTS)

Andrew O. Langford

2019 OWLETS/TOLNet Annual Science Team Meeting

College Park, MD May 6-8, 2019

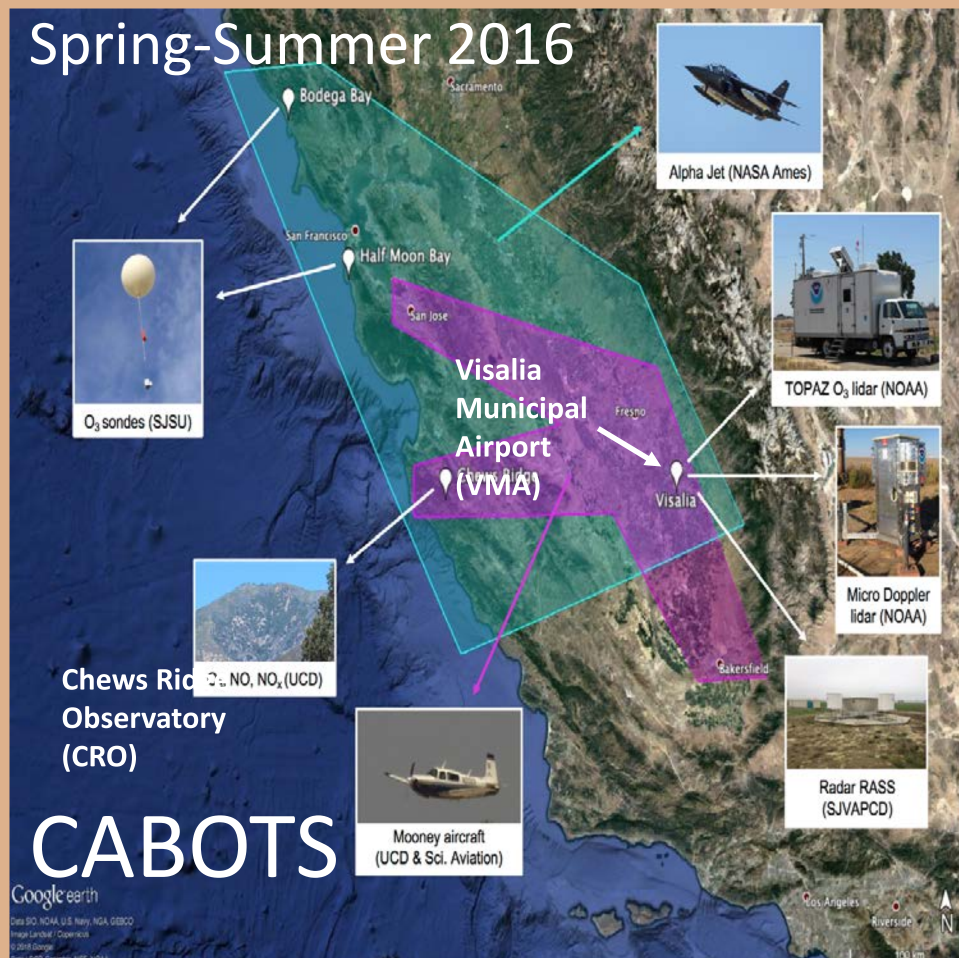
San Joaquin Valley Air Basin is an 'Extreme' non-attainment area.

How much does transported O_3 contribute to the high surface concentrations in the San Joaquin Valley (SJV)?

STT?

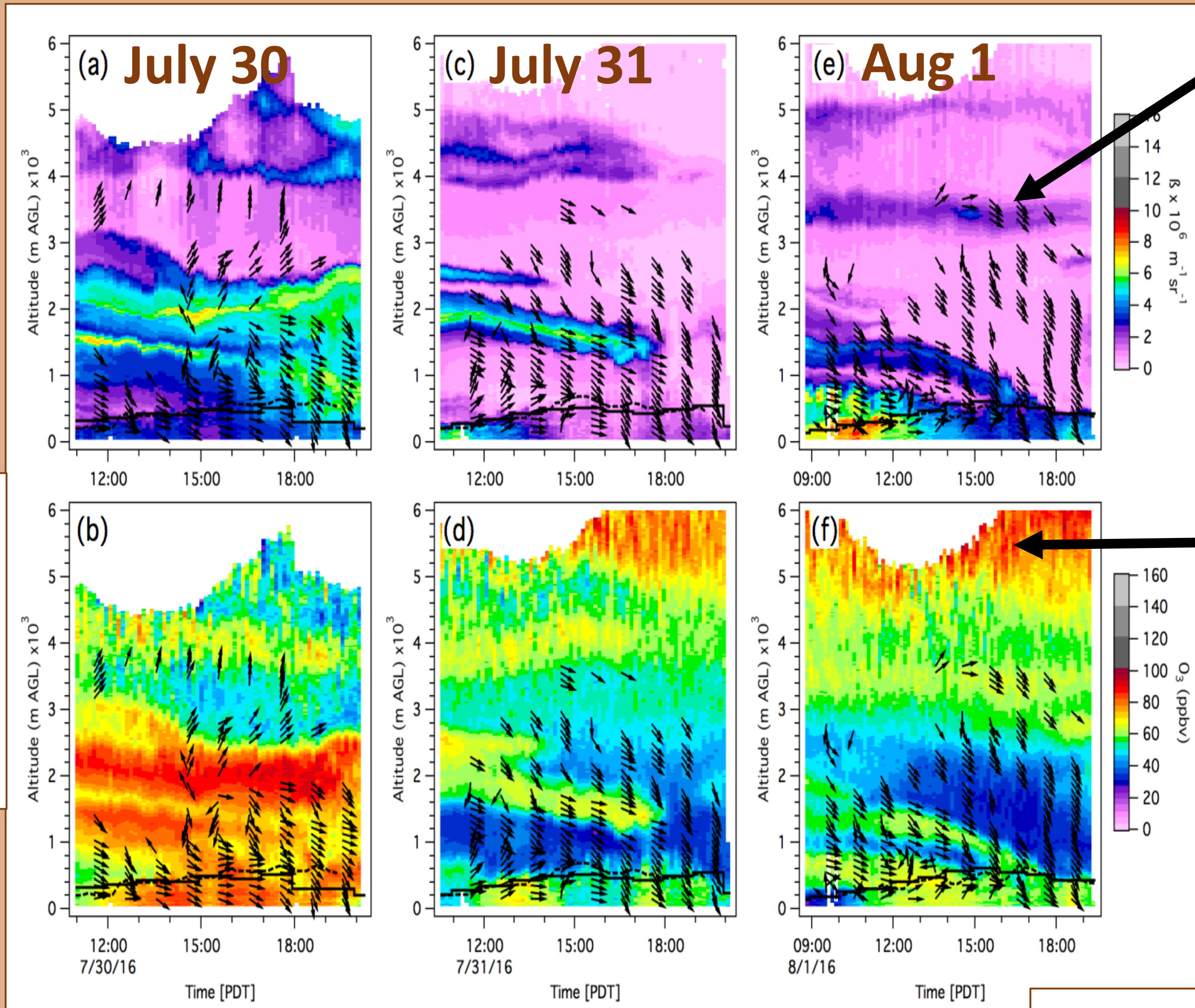
Asia?

Wildfires?



Langford TOLNet 2019

High altitude plumes (July 30-Aug 1)



Elevated backscatter is mostly from Goose Fire

SW winds at coast push Soberanes plume into northern SJV on July 31

Asian transport layer aloft

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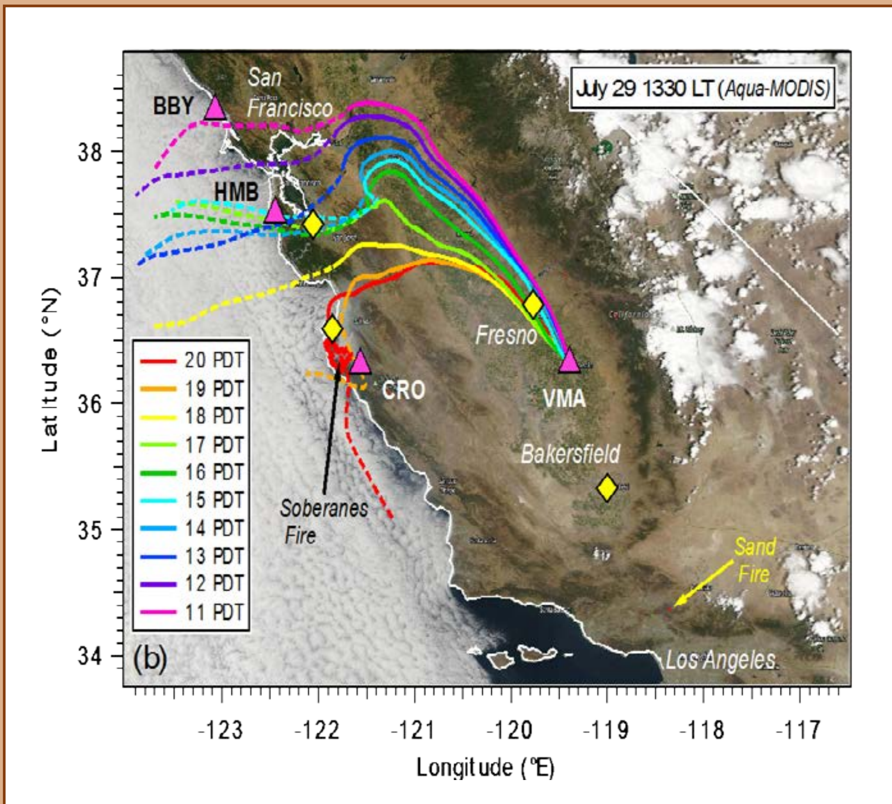
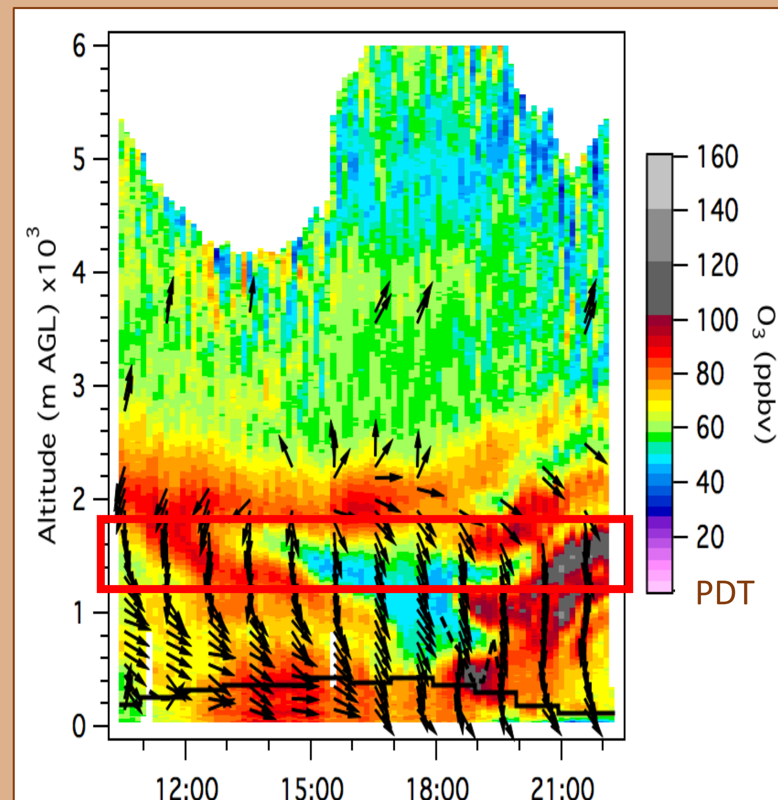
NOAA/ARL HYSPLIT 48-h back trajectories at 1.5 km

July 29, 2016





Highest ß and O_3 came directly from fire (32 h)

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TOLNet
Tropospheric Ozone LIDAR Network

Conclusions

1. The spatio-temporal characteristics of prevalent atmospheric trace gas and aerosol structures exhibit substantial variability.

2. Lidars can measure this spatio-temporal structure in a few places over limited times.

3. Space-borne sensors can measure these structures in lower resolution hourly across the North American continent.

4. The synergy of space-borne sensors with ground based (and aircraft) lidars and other sensors afford the best approach to measuring and diagnosing important air-quality structures and processes in a modeling framework.

5. The challenge for the health and air-quality communities is to define the intersection of air-quality measurements and health effects.

TOLNet

Tropospheric Ozone LIDAR Network

6th Annual TOLNet Meeting
with
2nd Annual OWLETS
6-8 May 2019
College Park, MD USA