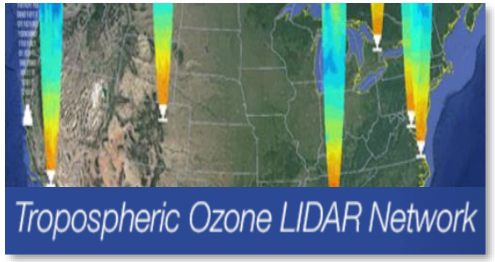
A21E-02: Comparison of tropospheric ozone vertical profiles between NASA ozone lidars and NOAA's National Air Quality Forecasting Capability (NAQFC) model



Timothy Berkoff NASA Langley Research Center
Guillaume Gronoff NASA Langley/SSAI
Barry Baker NOAA Air Resources Laboratory
Pius Lee NOAA Air Resources Laboratory
John Sullivan NASA Goddard Space Flight Center

Acknowledgements

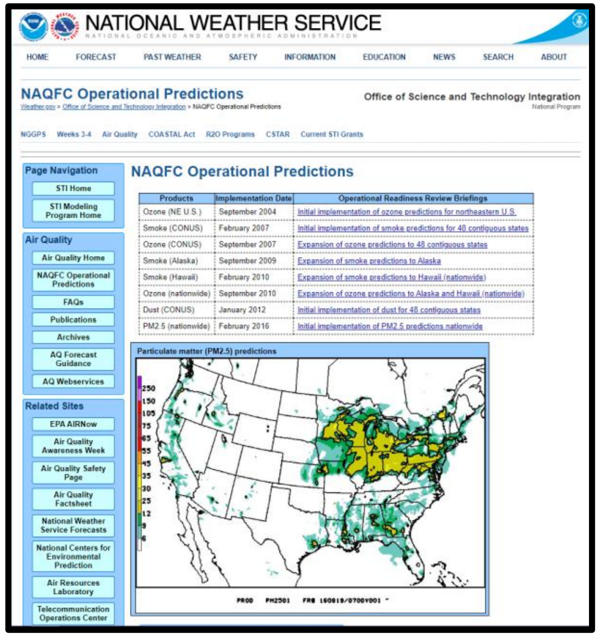
Additional contributors: Bill Carrion, Betsy Farris, Joey Sparrow, Larry Twigg

Funding: NASA Science Innovation Fund & NASA Headquarters Tropospheric Composition Program

National Air Quality Forecast Capability (NAQFC) Model

- Initial joint EPA and NOAA development, NAQFC forecasts include fine particulate matter (PM2.5), ozone and other trace gases
- NOAA ARL & NCEP develop upgrades for the NAQFC forecast system
- NAM 12 km meteorology coupled to the EPA Community Multiscale Air Quality Model (CMAQ) version 5.0.2
- 48-hour forecast run at 4 cycles per day, (0, 6, 12 and 18 UTC)
- Includes 35 vertical levels from 0-16 km

https://www.weather.gov/sti/stimodeling_airquality_predictions



National Air Quality Forecast Capability Model	
Chemical transport model	CMAQ5.0.2
Meteorology	NAM 12 km horizontal
Chemical mechanism	CB05 and aero6 inside CMAQ
PBL scheme	ACM2 - Jon Pleim's (2007)
Deposition scheme	Dry: resistance scheme by parallel circuit analog; Wet: scavenging & wash-out
Emissions inventory	2014 NEI for area and mobile sources and CEM 2016 with 2017 DoE energy projection
Wildfire emissions	HMS from NESDIS
Lightning NO	Not included

In this study:

12UT prior day forecast used for the next 24 hour UT day

2-D linear interpolation was applied to each vertical level to a ~0.7x0.7 km horizontal resolution grid

Lidar measurements were re-gridded and aggregated to match NAQFC temporal and altitude intervals

While several studies exist comparing NAQFC skill in predicting surface concentration, studies comparing vertical distribution are limited

Tropospheric Ozone Lidar Network (TOLNET) systems

- TOLNet is a network of 7 operational ozone lidar systems across N. America
- Two NASA systems (LMOL & TROPOZ) obtained data during OWLETS 1 & 2, and LISTOS campaigns
- Based on DIAL technique using two UV wavelengths (“on” and “off” O_3 absorption)
- Ozone vertical profiles from 0.1-4 km daytime, 8+ km nighttime at 5 minute temporal resolution
- Data files include O_3 mixing ratio and number density as well as standard uncertainties
- TOLNet network data provides standardized data products across instruments & extensively validated (e.g. SCOOP campaign)

TOLNet O_3 lidars utilize common approach for processing and error propagation, enabling lidar intercomparisons. SCOOP 2016 campaign: TOLNet O_3 lidars < 4% differences when compared to each other and ozonesondes

NASA Langley Mobile Ozone Lidar (LMOL)

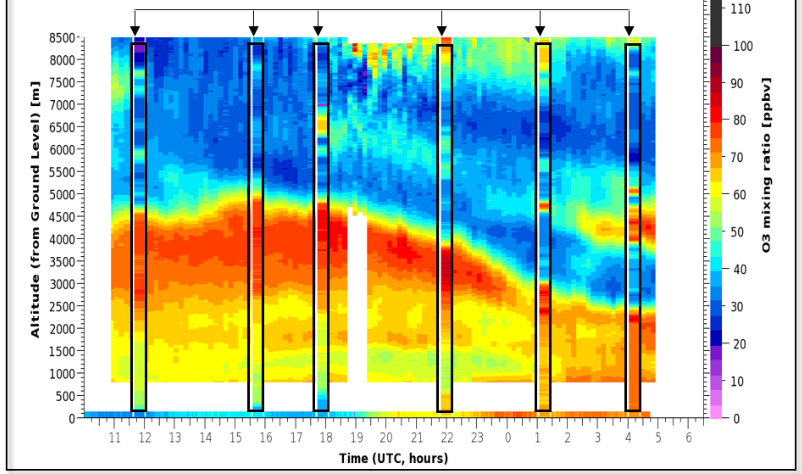
PI. T. Berkoff *De Young et al.,Appl.Opt.(2017)*

NASA Goddard Tropospheric Ozone Lidar (TROPOZ)

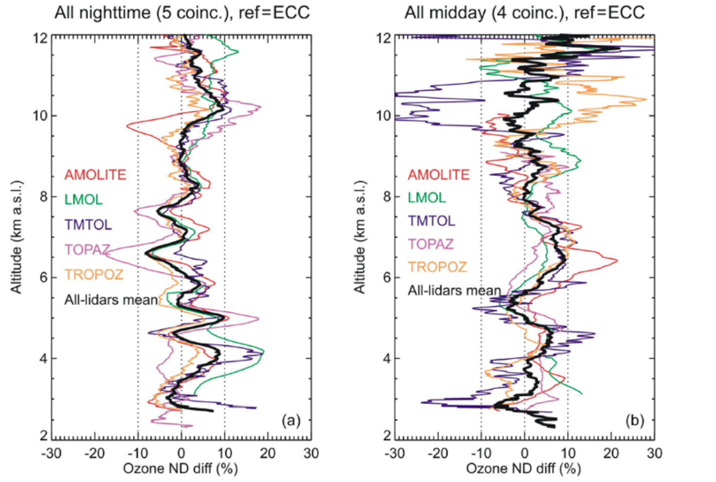
PI. J. Sullivan *Sullivan et al., AMT (2014)*

Southern California Ozone Observation Project (SCOOP campaign, 2016) **See *Leblanc et al. AMT 2018***

Example LMOL O_3 curtain data overlapped with JPL ozonesondes (black arrows)



Five TOLNet O_3 lidars in one location!



Ozone Water Land Environmental Transition Study (OWLETS-1) Hampton Roads Region 2017

Sullivan et al., "The Ozone Water–Land Environmental Transition Study", BAMS 2019

OWLETS
Ozone Water-Land Environmental Transition Study

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

- **Two TOLNet ozone lidars (CBBT & LaRC)**
- **UAS/drone (CBBT or LaRC)**
- **Simultaneous ozonesonde launches (LaRC & CBBT)**
- **Mobile Cars (2)**
- **VA DEQ sites**
- **PANDORA (CBBT & LaRC)**
- **Surface in-situ measurements**
- **Two Sherpa aircraft flights (July 19, 20)**
- **Three GeoTASO aircraft flights (July 7, 8)**
- **Two days SERC research vessel (July 17, 18)**

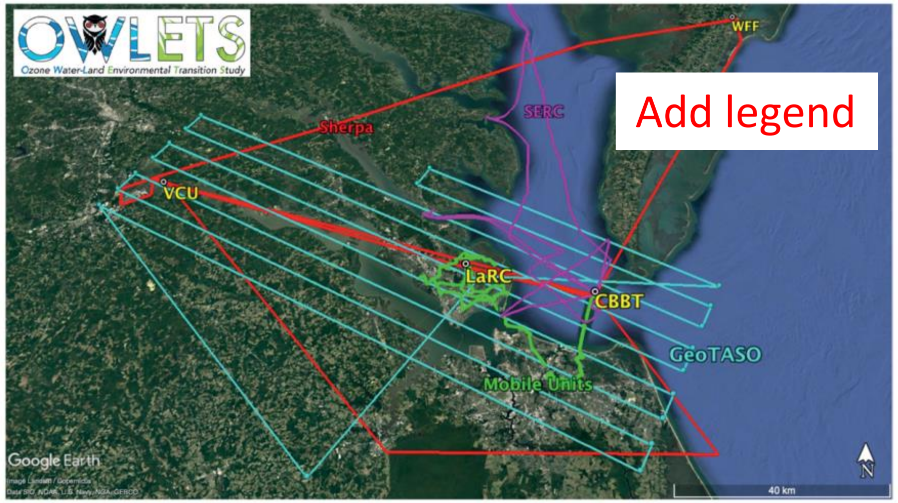
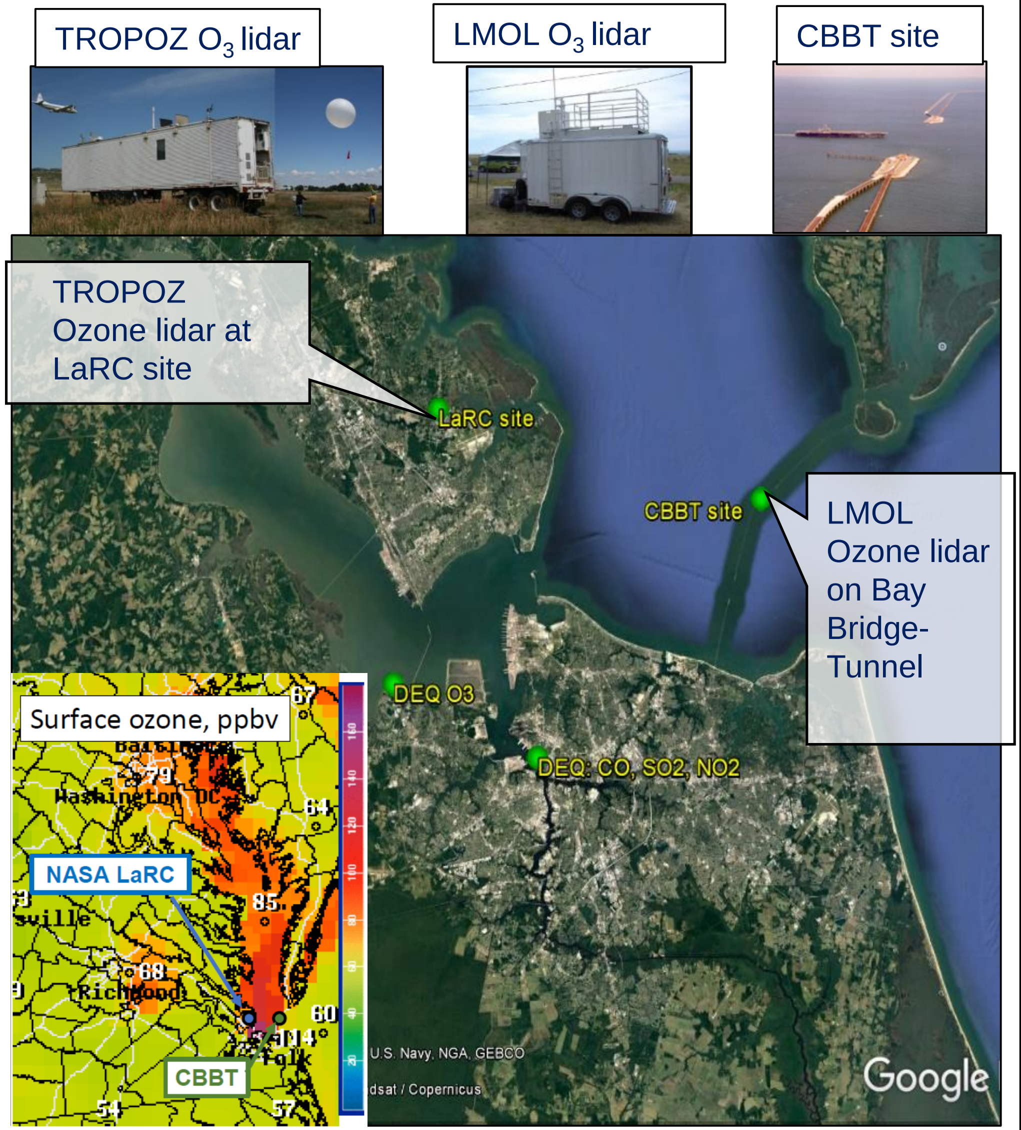


Fig. 1. Overview of OWLETS ground sites, mobile unit pathways, research cruise routes, and aircraft sorties.

OWLETS data archive:
https://www-air.larc.nasa.gov/missions/owlets/index.html



Initial seed funding for OWLETS-1 provided by NASA Science Innovation Fund Award

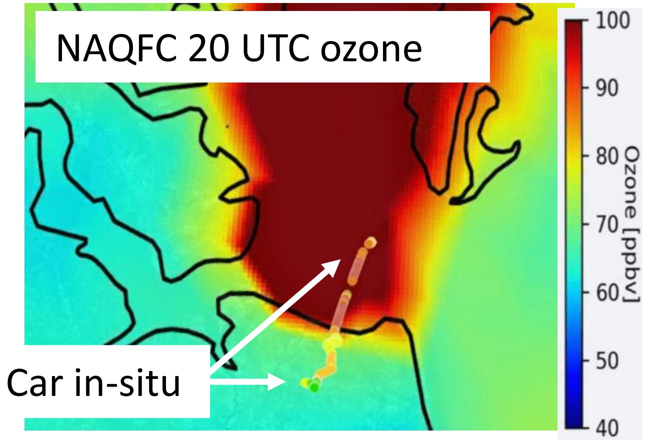
OWLETS-1 Over-water O_3 enhancement examples

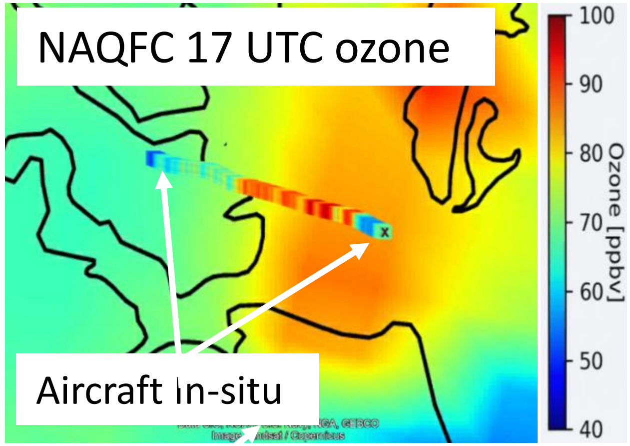
- In understanding water-land transition boundary ozone, July 20 & 21 were of particular interest during the OWLETS campaign
- Two mid-level highs (Gulf Coast & Atlantic) caused stagnation of air over region; some evidence of sea-breeze circulation
- High over water values forecasted >90 ppbv
- Morning stagnant/light SW winds that shifted to SE winds over the bay in the afternoon
- Max afternoon surface measurements O3: 85-90 ppbv
- In addition to O_3 lidars, Sherpa aircraft in-situ(July 20), Mobile cars with in-situ O3, synchronized land, water ozonesonde launches

In-situ measurements in relation to NAQFC forecast

Car Mobile Data July 21, 2017

Aircraft Data July 20, 2017

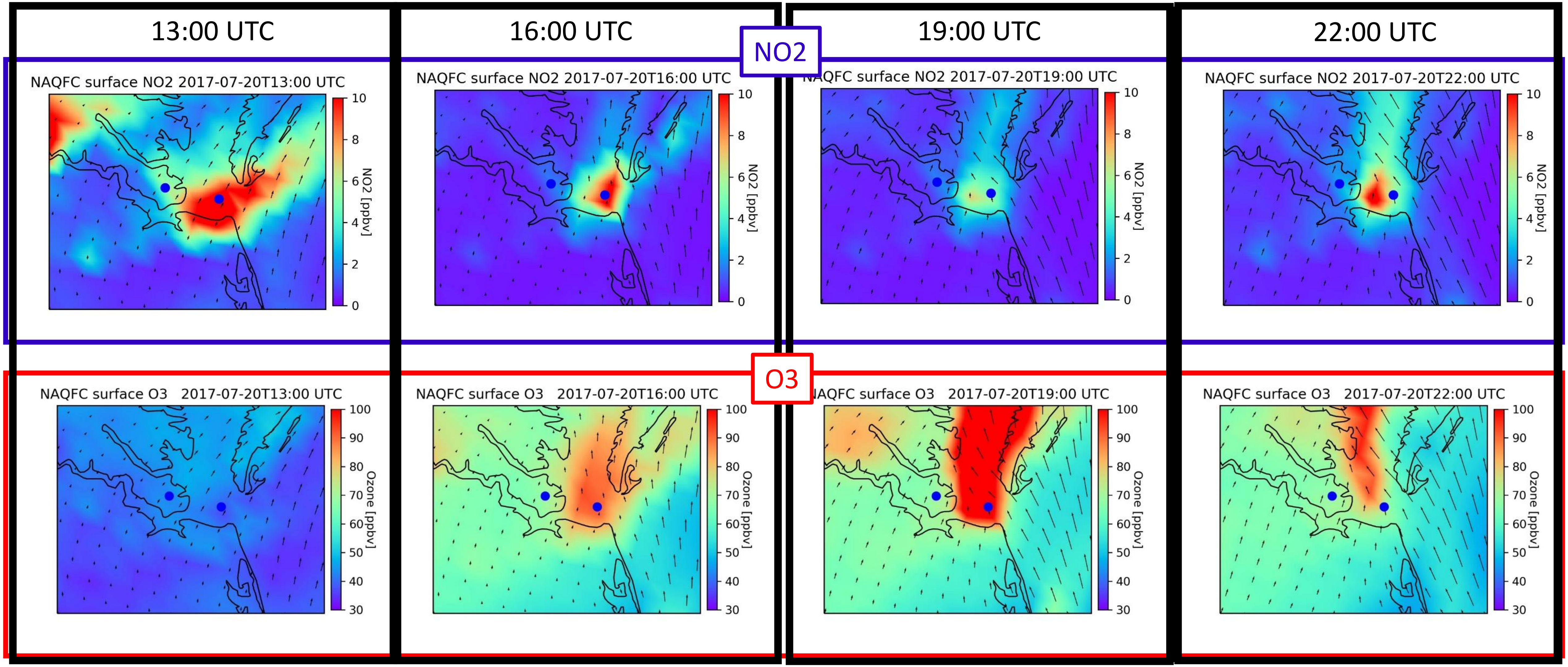




In-situ & aircraft analyses: J. Schroeder, Mobile Car Measurements, Masters Thesis, in prep.; M. Buzanowicz, AMS 2019; L. Rodio AMS 2019

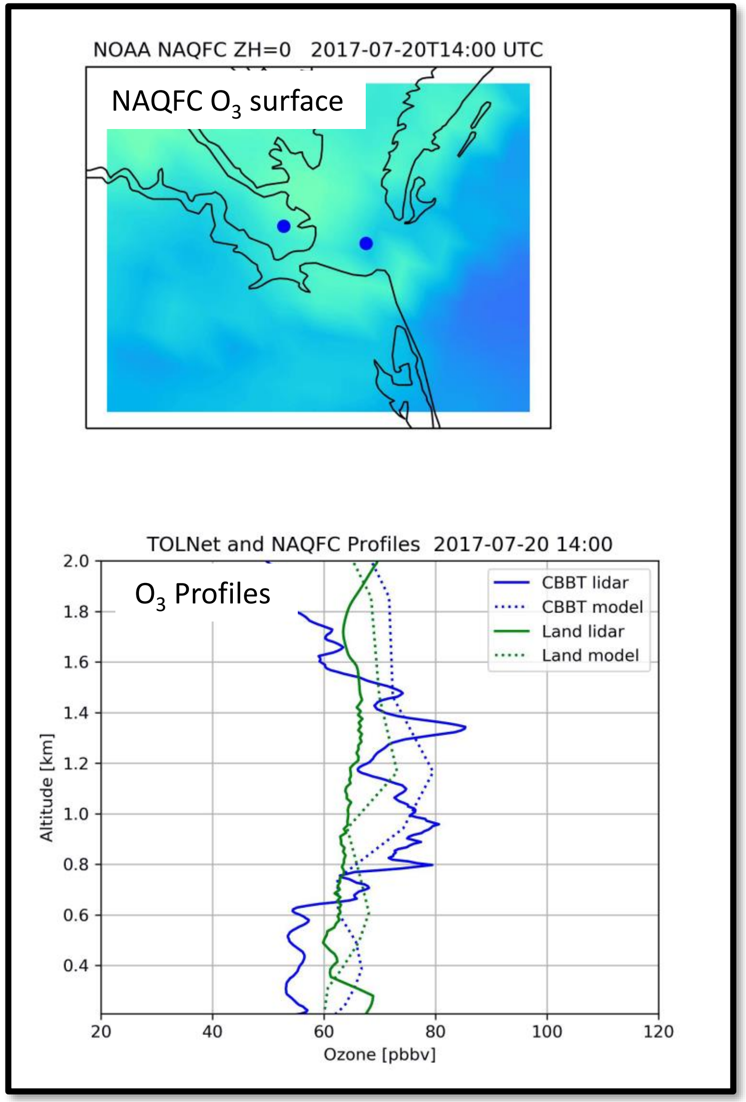
Surface NAQFC NO_2 & O_3 forecast July 20, 2017

Forecast time sequence: Morning to Evening, 3 hour steps

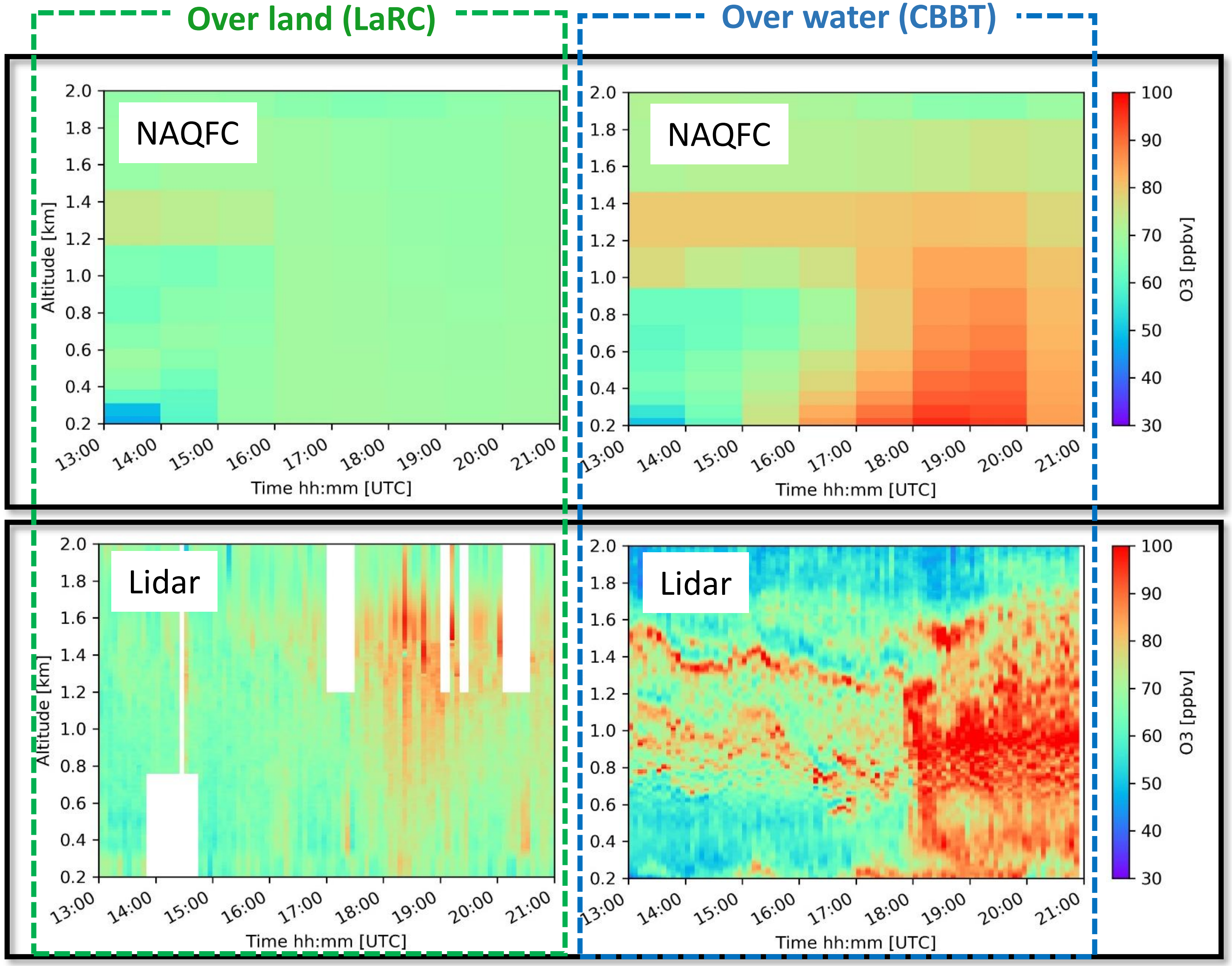


July 20, 2017 NAQFC & Lidar Ozone Inter-comparison

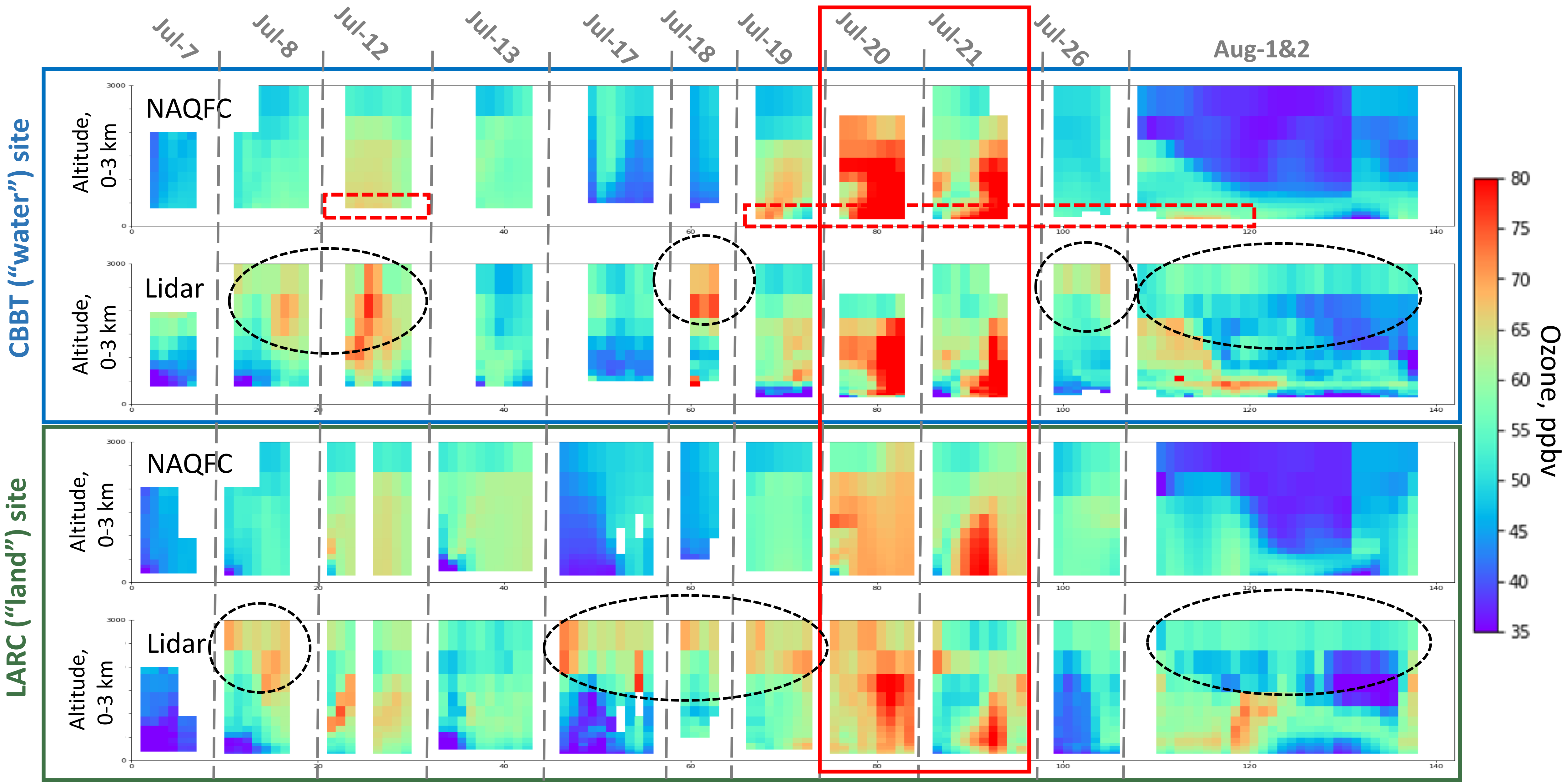
July 20, 2017



Ozone profiles July 20, 2017



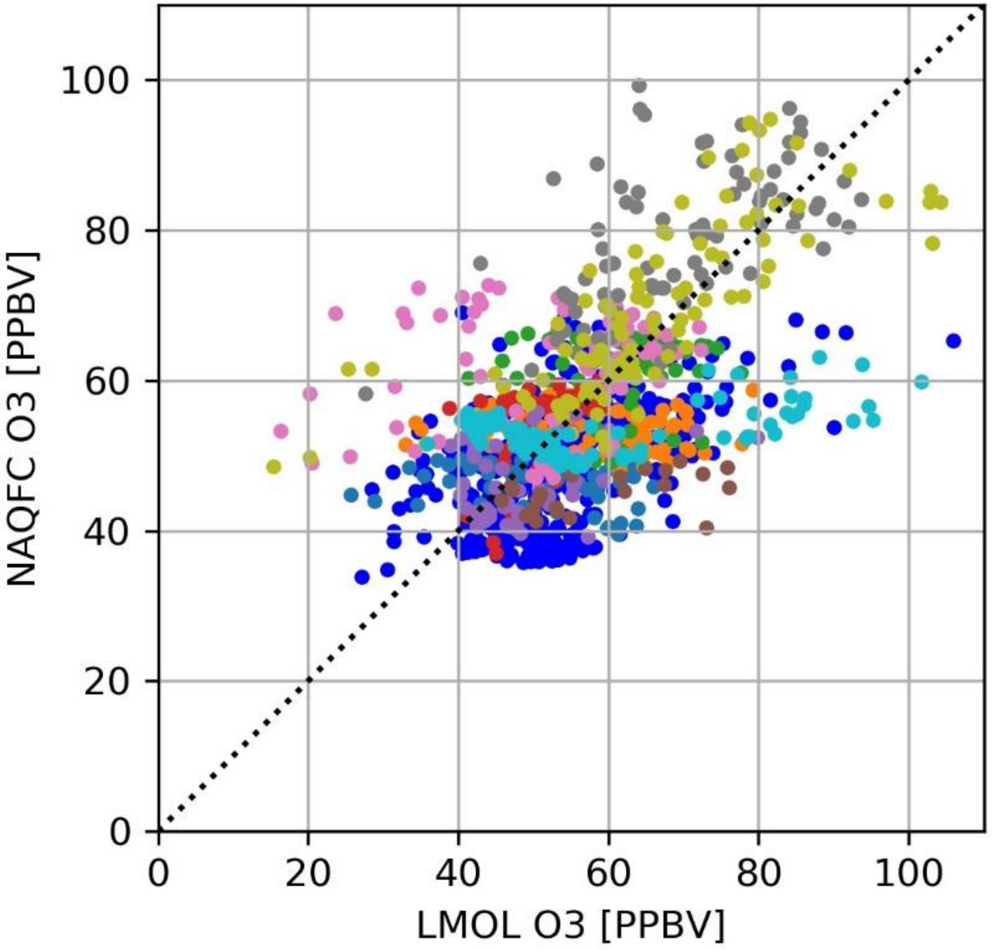
NAQFC & Re-gridded Lidar O_3 Time Series: all OWLETS days



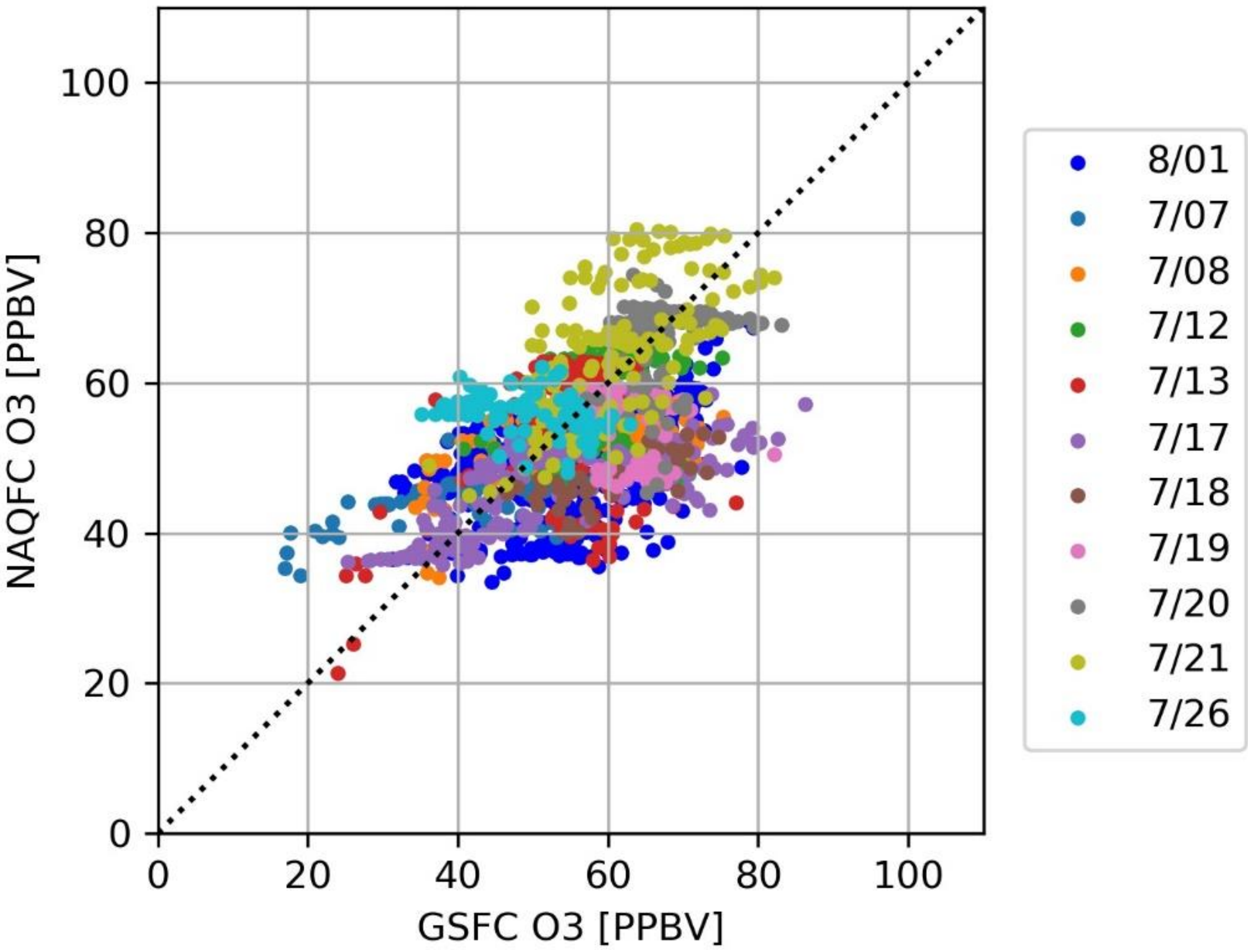
NAQFC versus Re-gridded Lidar O_3 Correlation Plots

OWLETS-1 data all times & altitudes, colored by day

CBBT ("over water") site

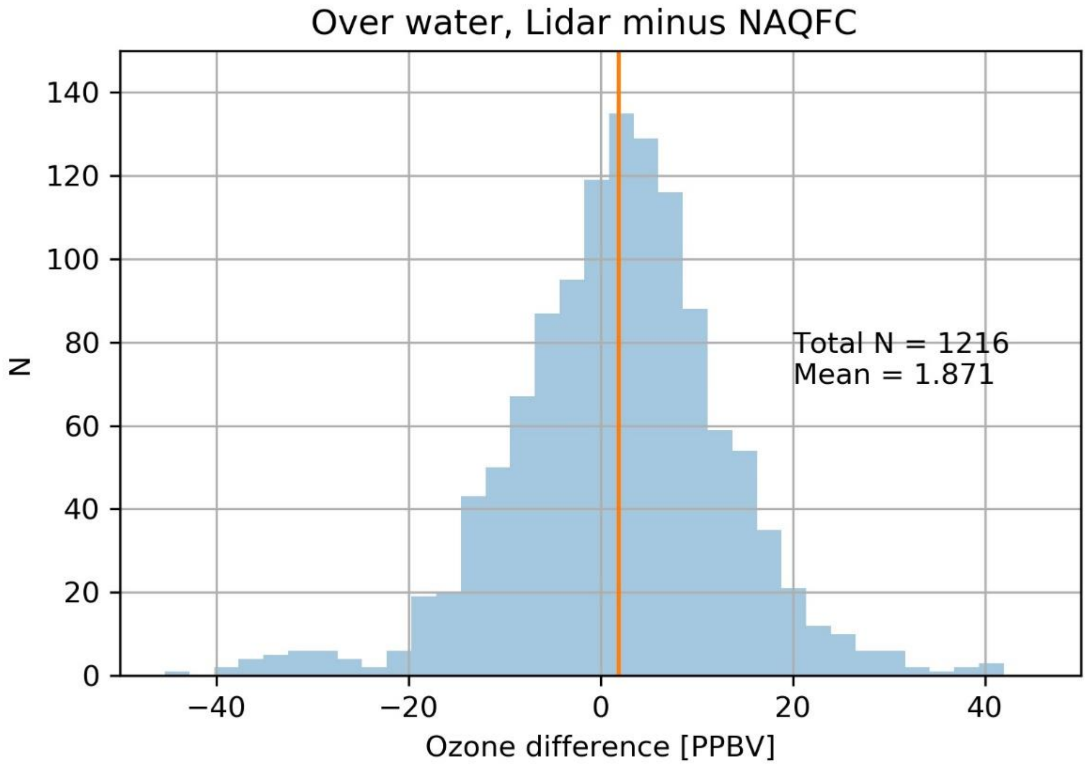


LaRC ("over land") site

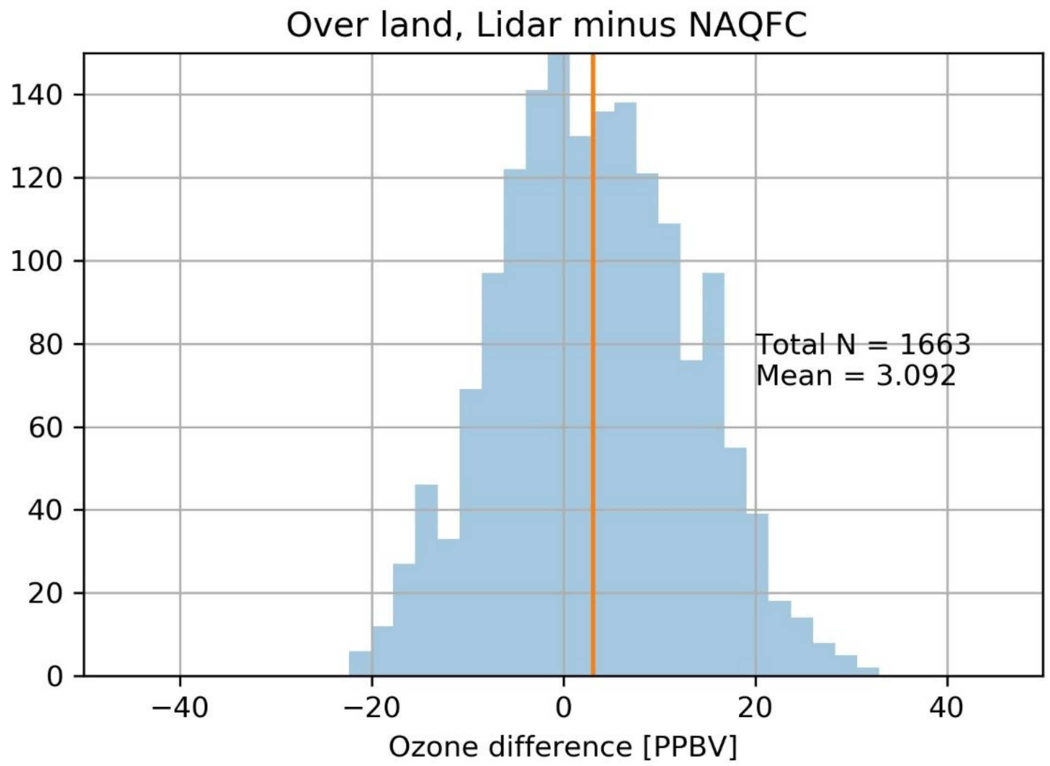


OWLETS-1 Lidar minus NAQFC O_3 Difference Distribution

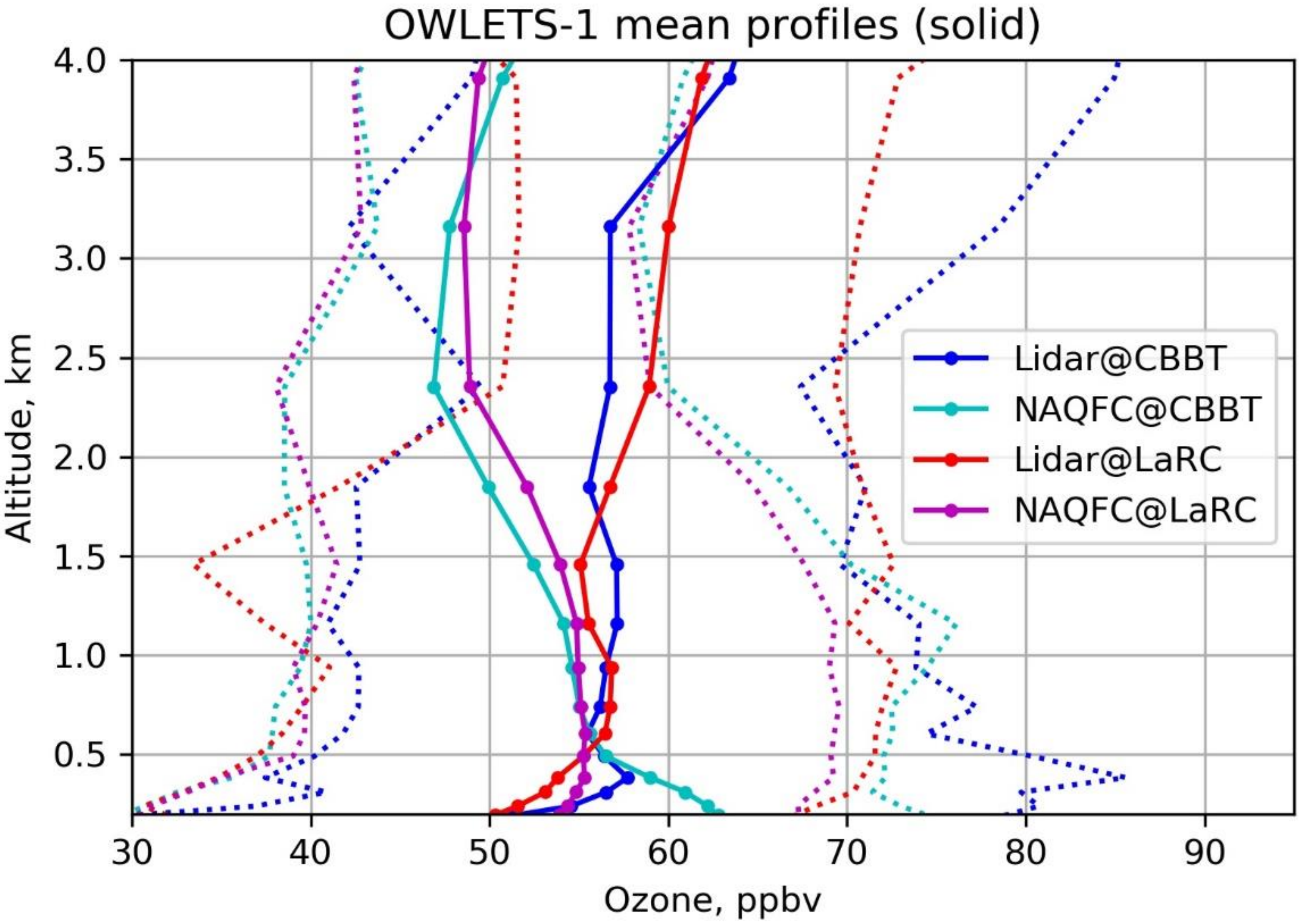
CBBT (“over water”) site



LaRC (“over land”) site

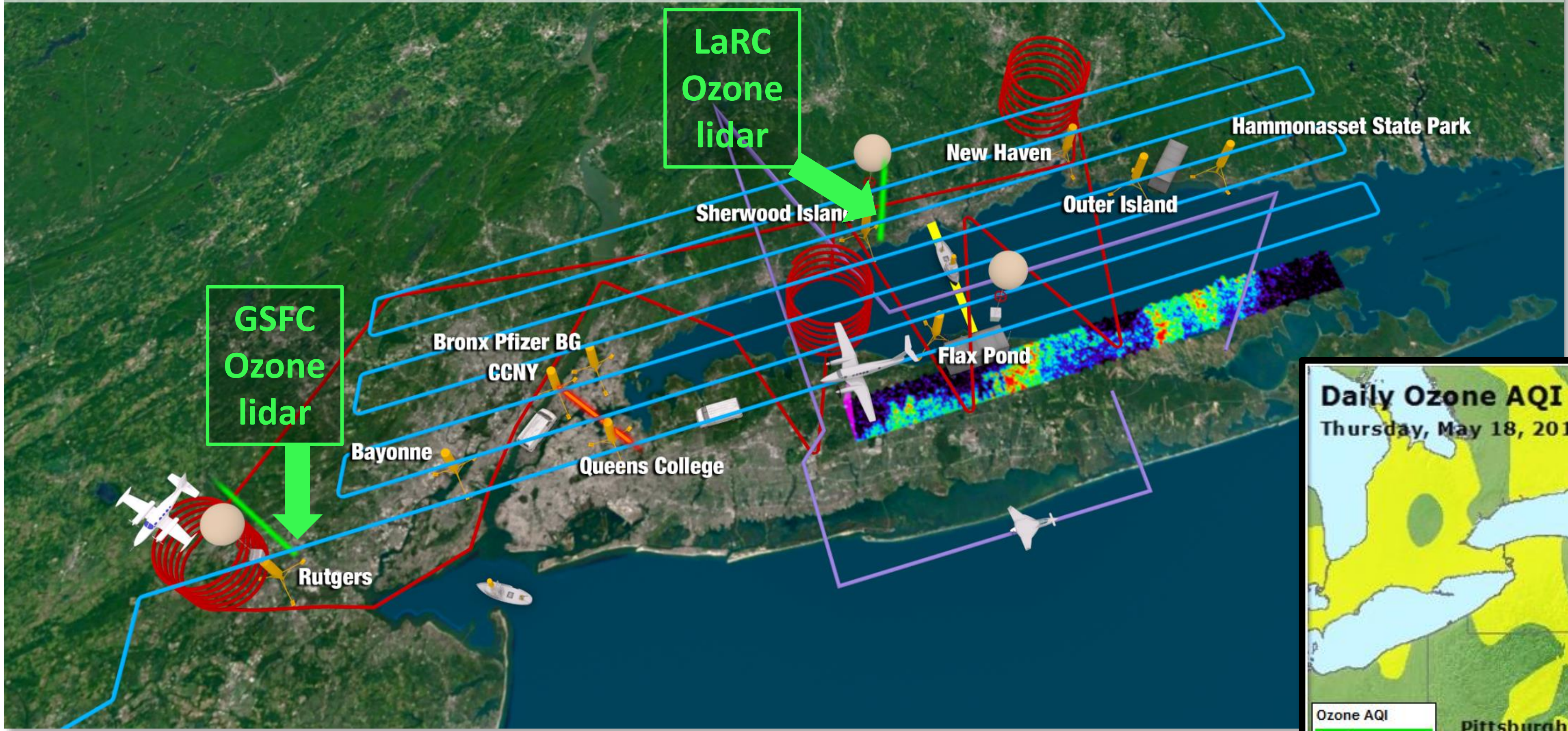


OWLETS-1 Mean Profiles (solid)
5%, 95% percentiles (dashed)



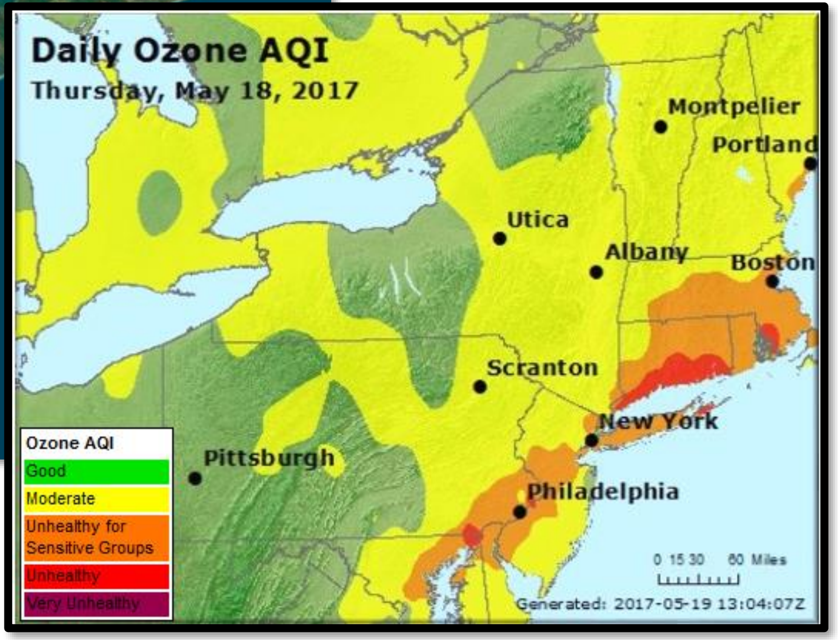
Long Island Sound Tropospheric Ozone Study (LISTOS)

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

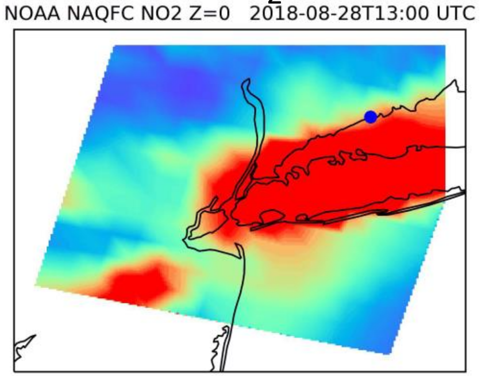


Campaign description website:
http://www.nescaum.org/documents/listos

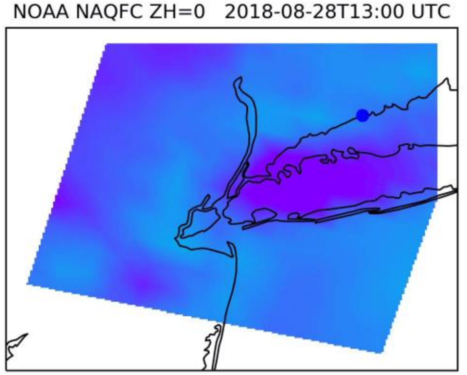
Aug 28, 2018 Inter-comparison with NAQFC forecast model

NOAA NAQFC surface forecast

NO_2



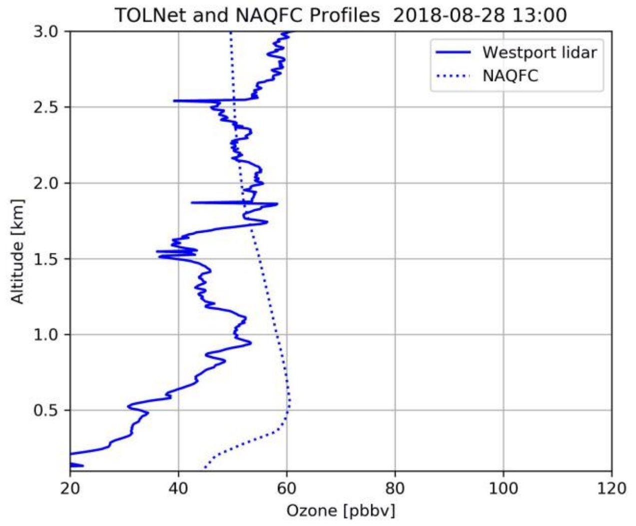
O_3

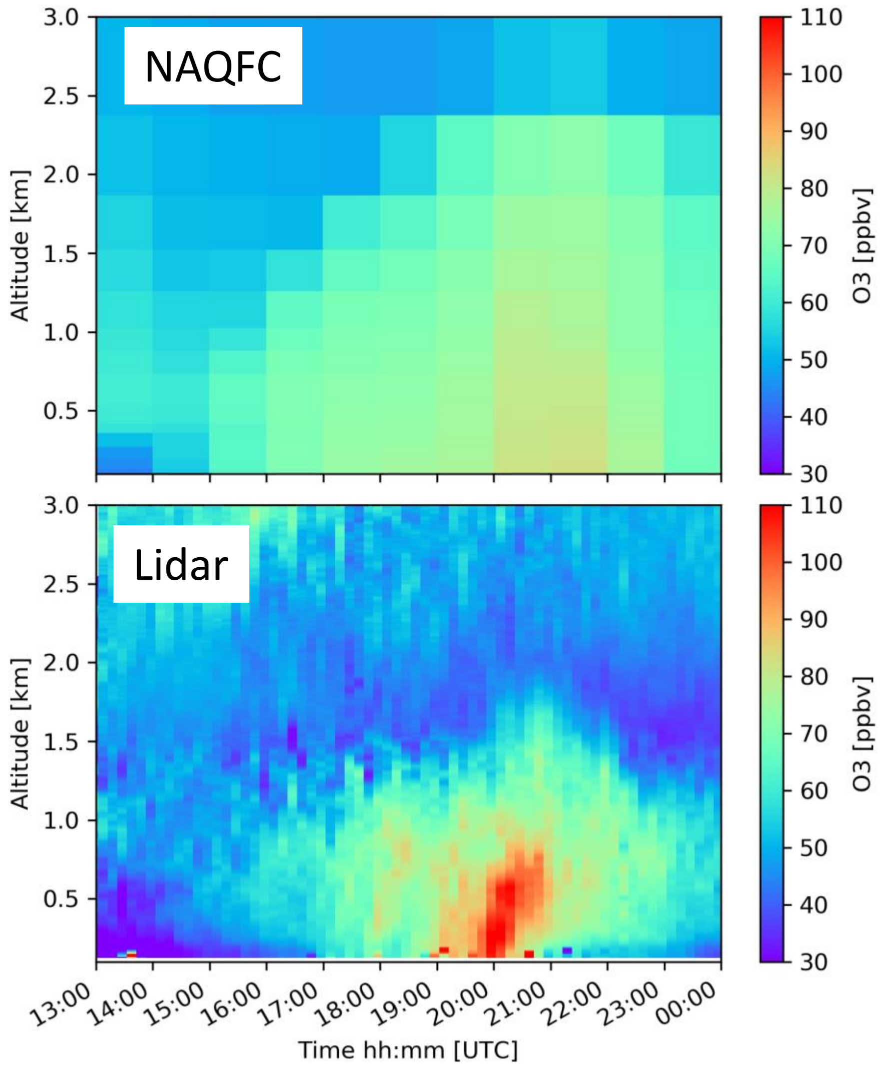


O_3 Vertical Profiles Westport, CT

PRELIMINARY

TOLNet (solid), NAQFC (dashed)





SUMMARY

OWLETS-1 results:

- NAQFC captured major features in the boundary layer observed by lidar, showing significant differences in O_3 vertical profiles over land and water
- Both NAQFC and Lidar vertical distributions indicate high degree of variability and occurrence of higher ozone values over water when compared to land
- Mean difference (Lidar minus NAQFC) for all times and altitudes is small (<3 ppbv) for both land and water sites
- During OWLETS, mean lidar profiles indicate a ~10 ppbv high bias in the free troposphere (1.5 to 4 km) to NAQFC, possibly due to background and/or elevated transport, will require further study
- Values in the boundary layer (<1.5 km) on average have relatively close agreement
- At 0-400 m altitude, NAQFC over-water biases high compared to lidar, bias increases in amplitude closer to surface, this bias is not apparent over land during OWLETS

Future work: Similar NAQFC analyses for OWLETS-2 and LISTOS campaigns!

TOLNet lidar and model intercomparison studies		
Dacic et al.	NASA GSFC	GEOS-CF & MERRA2-GMI
Torres-Vazquez et al.	EPA	WRF-CMAQ
Wang et al.	U. of Alabama/Huntsville	NCAR ACOM model
McDonald et al.	U. of Colorado/NOAA	WRF-Chem
Rodio et al.	U. of Maryland	F0OM Box & TerpWRF
Gronoff & Knowland et al.	NASA LaRC & GSFC	GEOS-CF
Johnson et al.	NASA AMES	GEOS-CF
Bernier et al.	U. of Houston	WRF-GC & CMAQ

To understand surface O_3, you need to understand the vertical distribution. TOLNet lidars provide a unique capability to support model validation efforts and satellite retrieval studies

Contact info: Timothy Berkoff, timothy.a.berkoff@nasa.gov, 757-864-3684