

### Part 4 Questions & Answers Session

Please type your questions in the Question Box. We will try our best to get to all your questions. If we don't, feel free to email Melanie Follette Cook (melanie.cook@nasa.gov) or Carl Malings (carl.a.malings@nasa.gov). Please also refer to the <u>TOLNet Website</u> for more information.

# Question 1: Do O $_3$ measurements with balloons allow us to detect only the vertical distribution? Or can you somewhat monitor them to also detect the horizontal distribution?

Answer 1: Ozonesondes can detect horizontal variability, but only along the balloon trajectory, which might make it hard to interpret without additional supporting measurements.

#### Question 2: What is the basic concept of LiDAR?

Answer 2: Lidar or LiDAR (Light Detection And Ranging). In a LiDAR system, light is emitted from a rapidly firing laser. You can imagine light quickly strobing (or pulsing) from a laser light source. This light travels to the ground and reflects off of thi ngs like buildings and tree branches or in this case, the atmosphere. The reflected light energy then returns to the LiDAR sensor where it is recorded and used to retrieve physical quantities of the atmosphere.

### Question 3: What is the frequency and accuracy of LiDAR? How deep can LiDAR detect? Does LiDAR work at night/without GPS/underwater?

Answer 3: LiDARs for ozone measurements typically operate in the UV region of the electromagnetic spectrum because we rely on the absorption by ozone to operate. There are some ozone LiDARs that operate in the IR around 10 um (another ozone absorption band ), but they are less common.

With enough signal to noise, LiDAR can be very accurate. Depending on how quickly you want to measure or how long you want to average the signal, you can increase or decrease your accuracy with a potential trade -off in vertical resolution or altitude of detection. Unlike passive sensors, TOLNet measures during the day and night because it produces its own laser light.



Yes, ozone LiDARs do not require GPS to operate. Ozone LiDARs do not operate underwater. TOLNet does not measure any underwater properties. Lidars can work underwater with appropriate wavelength selection to complement water absorption.

### Question 4: The measurements reached 4 km only as shown in the figure. Can it reach higher altitudes?

Answer 4: The altitude coverage of TOLNet depends on laser signal detected, solar background contamination, averaging of the data, and the atmosphere itself (presence of ozone, aerosol, and clouds). The highest altitudes are achieved in clear nighttime skies.

### Question 5: How do I join the TOLNet of NASA?

Answer 5: Feel free to reach out to John Sullivan: john.t.sullivan@nasa.gov.

# Question 6: Can you discuss more about the requirements for the instrument SMOL? For example, in our community, will your team provide tech assistance and data support?

Answer 6: We are in the process of building and deploying more SMOL LiDARs for community use. We expect in the future to have the ability to provide similar technical and data support to the previous networks described in this training. We are trying to do our best to make SMOL available to the community. Size: 3x4x6ft and requires 2 - 2.5kW.

Question 7: With how much accuracy, the absorption cross -sections (sigma) are calculated because this parameter is highly variable with ambient meteorological parameters?

Answer 7: The ozone absorption cross-section is measured in the lab for different temperature and pressure conditions. The impact of the ozone absorption cross - section depends on the wavelength selection. Further information about the impact of absorption cross section on lidar retrieval can be found in <a href="https://amt.copernicus.org/articles/9/4051/2016/">https://amt.copernicus.org/articles/9/4051/2016/</a> (Sec. 4.4).

### Question 8: What is the ON and OFF wavelength difference in the Compact Ozone LiDAR?



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Answer 8: 289 nm, 299 nm are the main wavelengths. 266, 316, and 341 nm can also be used in certain situations.

Question 9: Can the SMOL be operated in a mobile format to understand tropospheric distributions across smaller geographic areas (e.g., Western Lake Michigan shoreline) or are there limitations in the measurement principle that prevent this capability? See ms like an interesting use case for studies such as the Lake Michigan Ozone Study in 2017.

Answer 9: The SMOL systems can be deployed across small geographic areas and can even be installed side by side. Cross-talk between different instruments can be avoided by synchronizing them using a common timing source.

# Question 10: How do you produce the OFF wavelength besides the principal wavelength of the laser in the DIAL? Or you will use separate lasers for ON and OFF wavelengths to get better accuracies?

Answer 10: Different techniques exist to generate the wavelengths used for ozone DIALs. The most common ones are stimulated Raman scattering, optical parametric oscillators (OPOs), and other types of tunable lasers.

### Question 11: What is the type of relationship you observe between AOD and Ozone Optical depth?

Answer 11: Generally speaking there is no physical correlation between both, but there are many cases where a positive correlation between the two are commonly observed (e.g., urban environments and smoke plumes from forest fires).

### Question 12: Do you know of some TOLNet potential applications for Sulfur Dioxide monitoring?

Answer 12: Ozone is generally in the ~60 ppbv background level, sulfur dioxide is in much smaller concentrations (~few ppb). Therefore, this is much more challenging for LiDAR, unless in specific situations where there may be stronger gradients, such as near volcanic activity. Certain TOLNet LiDARs could be augmented to measure SO<sub>2</sub> in an experimental mode but it has not been a standard product.

### Question 13: How often do you observe the homogeneous/heterogeneous chemistry effects in your data?



Answer 13: Generally, we see much more vertical variability in the morning hours or nighttime hours before/after the atmosphere is convectively mixed.

#### Question 14: In slide 25 you mentioned the term, "afternoon ozone build -up". Could you elaborate on this process, and local sources?

Answer 14: To understand ozone enhancements, it is challenging to only look at the ozone lidar data. For more context, we will generally use atmospheric chemical transport models and forecasts to understand the sources and transport of ozone.

Question 15: Are you using any Raman Cell technique for producing OFF wavelength in your DIAL?

Answer 15: Yes, some of the TOLNet LiDARs use Raman cells to generate on and off wavelengths for the DIAL. The most common gases used are hydrogen, deuterium, and carbon dioxide.

Question 16: The measurements of wind speed and direction are vital to determine the nocturnal enhancement of ozone, are they available in TOLNET? Answer 16: Yes, this is an important point. TOLNet does not measure winds, however we typically try to co -locate these measurements with existing wind profiling measurements.

#### Question 17: Are there any TOLNet data for India? Or Africa?

Answer 17: No. There have been some deployments of TOLNet outside North America (e.g., to Europe and Korea). Please contact the TOLNet team if you would like to discuss opportunities for field deployments.

Question 18: Are you using the path -averaged approach besides the range - resolved approach to measure the ozone amount time series for trends and variability analyses?

Answer 18: We are currently only using range-resolved approaches to the data. Many of these LiDARs have been in a 'campaign mode' and not a single location, therefore trend analyses may be challenging.

NDACC – Network for the Detection of Atmospheric Composition Change: <u>https://ndacc.larc.nasa.gov/about</u>



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TOAR – Tropospheric Ozone Assessment Report: https://igacproject.org/activities/TOAR

### Question 19: Is it possible to examine the effect of GHGs on the ozone from the LiDAR data?

Answer 19: The interaction between ozone and GHGs is complex and dependent on the particular GHGs.

### Question 20: In the graph of ozone from the LiDAR, why are there some dates/times which appear empty?

Answer 20: TOLNet is not a 24-7 measurement, although we are moving that way. Data gaps are generally due to instrument issues or not having an operator present.

## Question 21: Are any of these networks located at the same sites as EPA or state operated AQ sites, so that we can evaluate the vertical profile in addition to the surface -level $O_3$ concentration?

Answer 21: We deployed several TOLNet instruments at or near EPA or state-operated AQ sites during field campaigns. The most recent case was the deployment of two SMOL LiDARs during the USOS campaign in Utah (e.g.,

https://csl.noaa.gov/groups/csl7/measurements/2024usos/).

### Question 22: Can we get spectral effective beam absorptance, transmittance, scattering within the BL (esp z < 300 m)?

Answer 22: Yes, although there may be other practical measurement strategies depending on the optical or bulk properties of interest.

### Question 23: Would you mind please explaining the absorption by wavelength and how it is interpreted?

Answer 23: The individual photons generated by the LiDAR are absorbed by the ozone molecule. This results in a reduction in return signal attributed to absorption, which we can then quantify as physical amounts of ozone in the atmosphere at specific altitu des.

### Question 24: Do we have an option for other LiDAR observations to be involved with TOLNET?

Answer 24: There may be other networks or repositories for this type of data. Please reach out to John Sullivan (john.t.sullivan@nasa.gov).



## Question 25: Is it possible to use the TOLNet data to measure other trace gases such as CO $_2$ and Formaldehyde?

Answer 25: These may be more challenging to measure with the existing TOLNet wavelengths (< 300 nm), especially for  $CO_2$  which is more active in the absorption region in the infrared.

## Question 26: What is the spatial coverage of TOLNET including campaign observations?

Answer 26: The LiDARs in deployment mode are generally placed to better understand chemical transport patterns. We will utilize chemical transport models and surface measurements to understand these processes further.

Question 27: I'm sorry this is a question about PANDORA. I would like to know if there is any GitHub code you could recommend to us where it is shown how to open PANDORA data. I tried but couldn't do it. Specifically, I would like to be able to open the sp ectral irradiance data from measurements at ground level, because I would like to model spectral irradiance and compare it to the one from PANDORA.

Answer 27: We do not have file readers available for this application, but L1 irradiance data are available in .txt format on the PGN server. There are standard codes and functions for importing these data, for example in MATLAB or Python. The file header specifies which data columns are L1 data (i.e., irradiances) as well as associated uncertainties. The L1 irradiances are recorded in pixel space but the nominal wavelengths for each pixel are included as a line in each L1 file header.

### Question 28: How close to the laser source can the TOLnet ground -based LiDARs probe? Can that parameter be adjusted?

Answer 28: This is dependent on the physical properties of the laser system.

### Question 29: Are there any applications that use LiDAR data for real -time flood mapping?

Answer 29: TOLNet would not be the best resource for this information. NASA has some other resources such as synthetic aperture radar which are typically used; please refer to this previous ARSET training on monitoring and modeling floods using Earth observations.



### Question 30: Are the ozonesondes launched during field campaigns used just for comparison/validation or also some kind of calibration?

Answer 30: Ozonesondes are not needed for calibration, just for comparison and validation.

### Question 31: Would you mind please explaining what is delta sigma in the gas profile concentration profile of the ozone equation?

Answer 31: Delta sigma in the gas equation was explained in the previous slide showing the EM spectrum. This is the difference in the ozone absorption cross section between the two wavelengths used (typically called on and off, more and less absorbed).

### Question 32: Have you tested the ozone data acquired from TOLNET during dusty conditions?

Answer 32: We have several instances of TOLNet data being acquired during long range transport of dust events. One example can be found here: https://acp.copernicus.org/articles/22/1707/2022/acp -22-1707-2022.html.

Question 33: How does the GSFC TROPOZ DIAL system optimize its transmitter and receiver components to accurately measure tropospheric ozone levels, and what measures are in place to enhance signal quality and prevent detector saturation?

Answer 33: Narrowband interference filters are critical for this. The detector field of view and beam size can also be optimized to enhance signal quality. Electronic gating or choppers can be used to reduce near field saturation levels.

### Question 34: Can satellite measurements measure tropospheric ozone and how accurate is it compared to TOLNET?

Answer 34: Due to the high concentration of ozone in the stratosphere, measurements of tropospheric ozone from satellites are difficult. TOLNET measurements would likely be much more accurate, and would be used to compare with any satellite measurements, for example, data products on near -surface ozone which are being developed for the TEMPO satellite instrument.



## Question 35: What is the spatial representativeness of any single observation, the observation footprint representation (ignoring wind effects).

Answer 35: This would take some thoughtful analysis to respond to. There are instances where a single point would be quite representative of a region and other times when it would not. Using chemical transport models and satellite data would help with the interpretation.

#### Question 36: You mentioned something about an FAA requirement for operators. What are the requirements for deploying a TOLNET observation?

Answer 36: Most TOLNet LiDARs are eye-safe or nearly eye-safe. You would generally want to sight them somewhere where you could not look directly into the beam. We encourage you to reach out to the TOLNet team if you are interested in learning more about this.