Plein ecran

O_3 Titration from a Nearby Point Source: The Wonders of the Very Near Field (OWLETS Campaign)

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OWLETS was funded by NASA / NASA LaRC SIF
We are extremely indebted to the CBBT team for hosting us and being very welcoming
Some data are courtesy of the Pandora team. From Pandonia website
Special thanks to J. Sullivan.

TOLNet/NDACC joint meeting, May 2018

The LMOL Lidar

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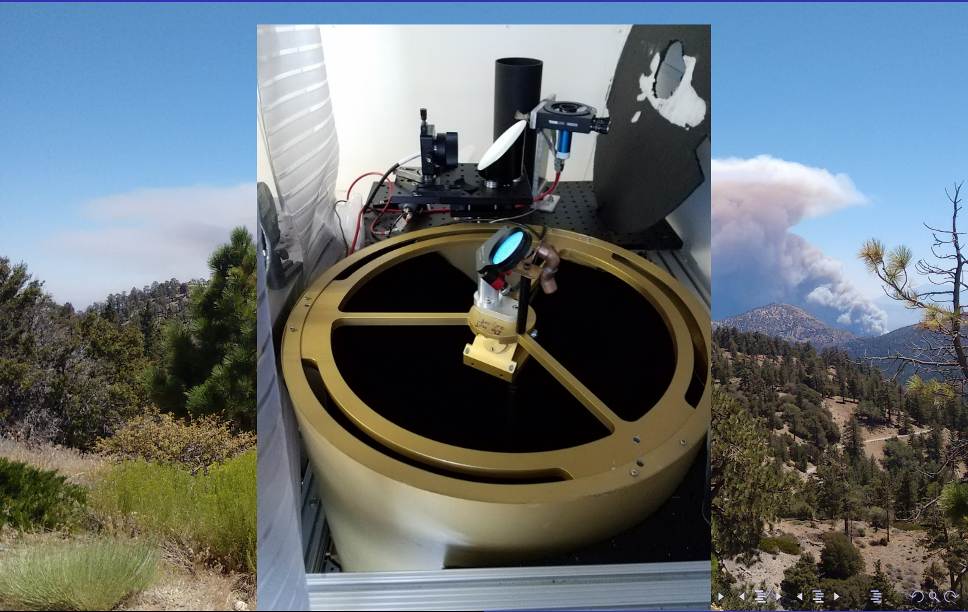
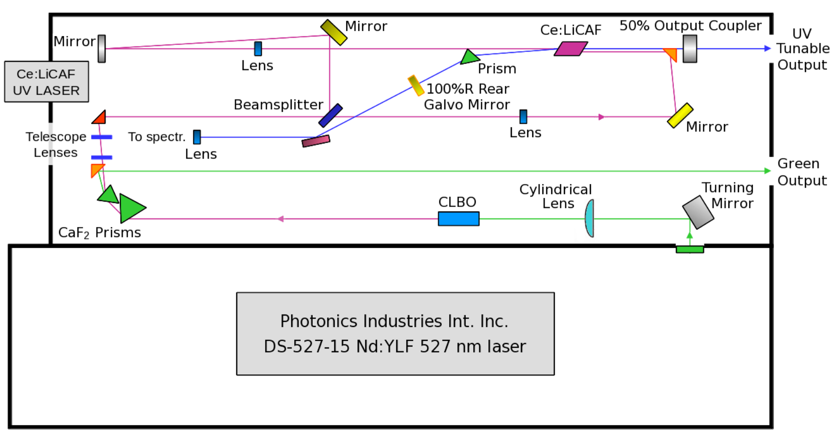


The LMOL Lidar



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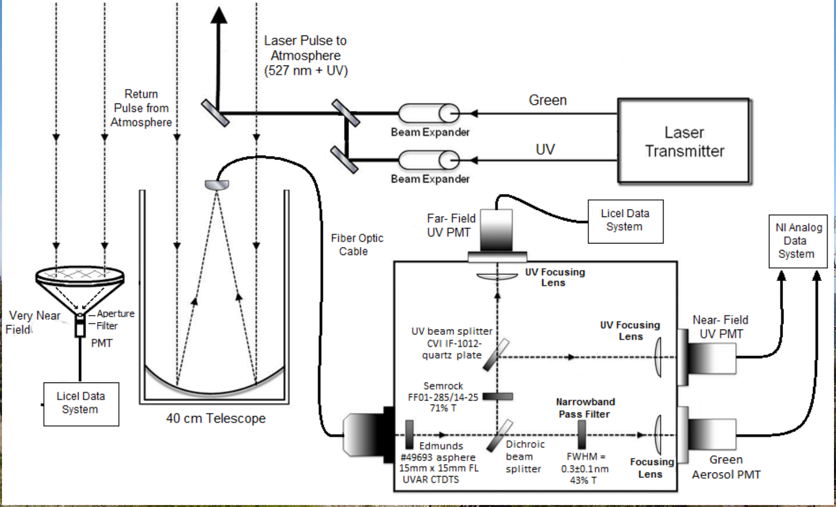
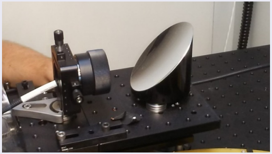
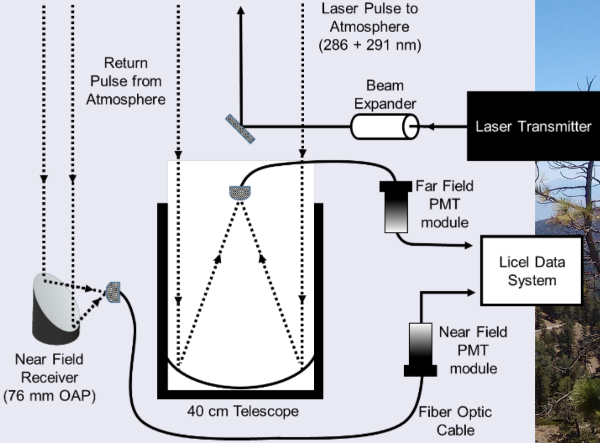


The LMOL Lidar

New receiver





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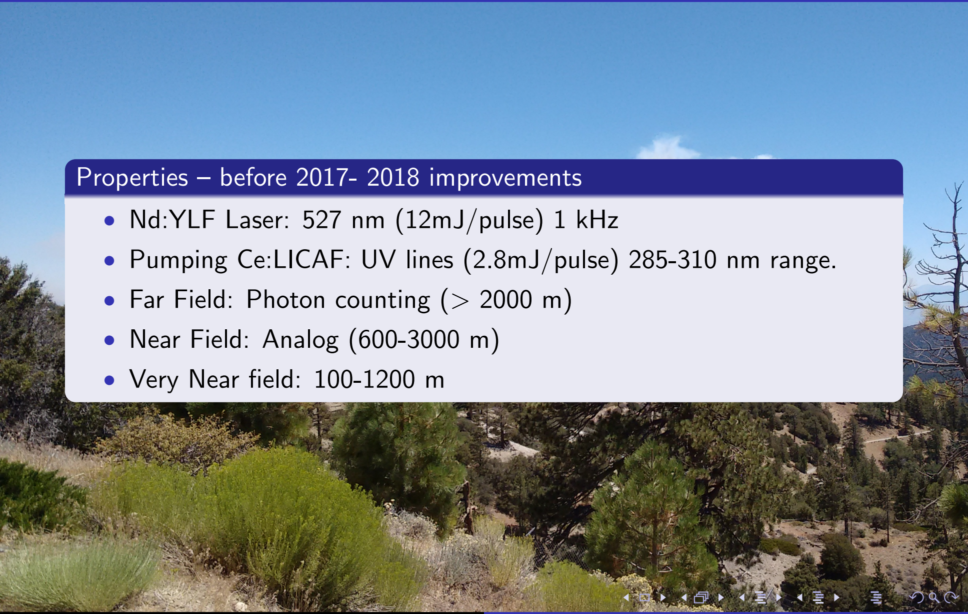
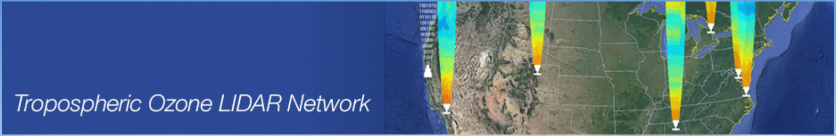


Properties – before 2017- 2018 improvements

- Nd:YLF Laser: 527 nm (12mJ/pulse) 1 kHz
- Pumping Ce:LICAF: UV lines (2.8mJ/pulse) 285-310 nm range.
- Far Field: Photon counting ($>$ 2000 m)
- Near Field: Analog (600-3000 m)
- Very Near field: 100-1200 m

Data validation, control, and standardization

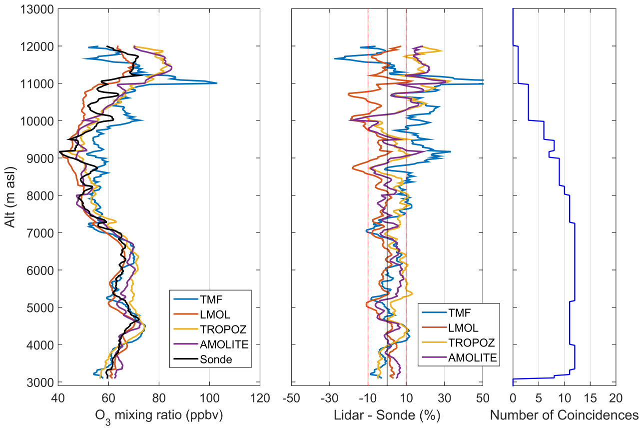


TOLNet validation

- Intercalibration of Lidars –including LaRC/LMOL and GSFC/TROPOZ–
- Validation of lidars against ozonesondes.
- Definition of common algorithmic techniques (vertical resolution, temporal resolution, uncertainty computations).
- Definition of common parameters (O_3 absorption cross sections, O_2 mixing ratio . . .) across TOLNet and NDACC.

Data validation, control, and standardization

For those who were not there: TOLNet validation: Intercomparison with sondes during SCOOP. Courtesy Thierry Leblanc (JPL)



Validations and Campaigns

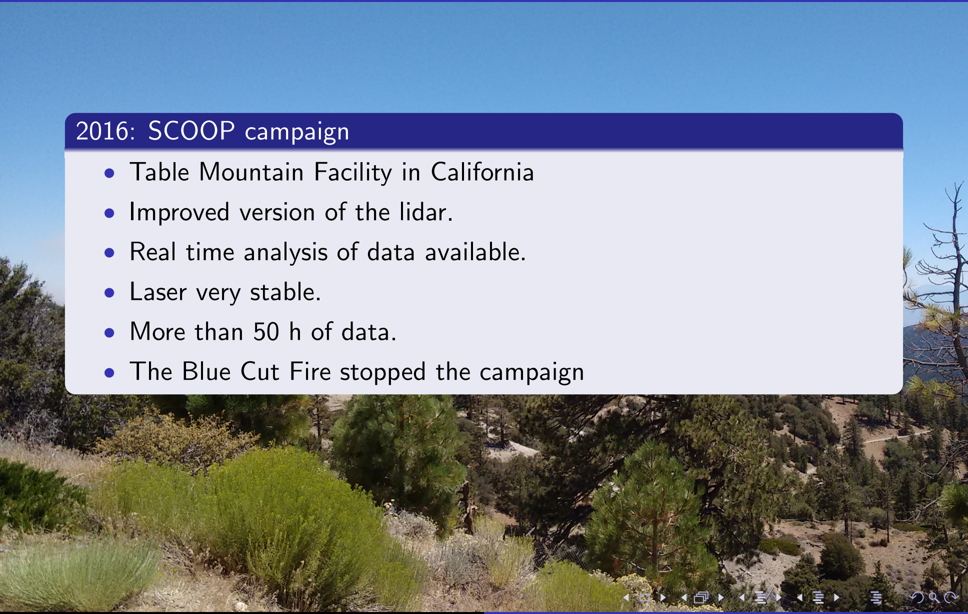
2014: DISCOVER-AQ Campaign

Boulder, Co
First version of the Lidar.
Still some technical problems.
Intercomparison with the other TOLNet lidars, and P3B plane.
(I was not present for that campaign.)

Warning on DAQ results

This was the first deployment of LMOL. The instrument has been dramatically improved since.

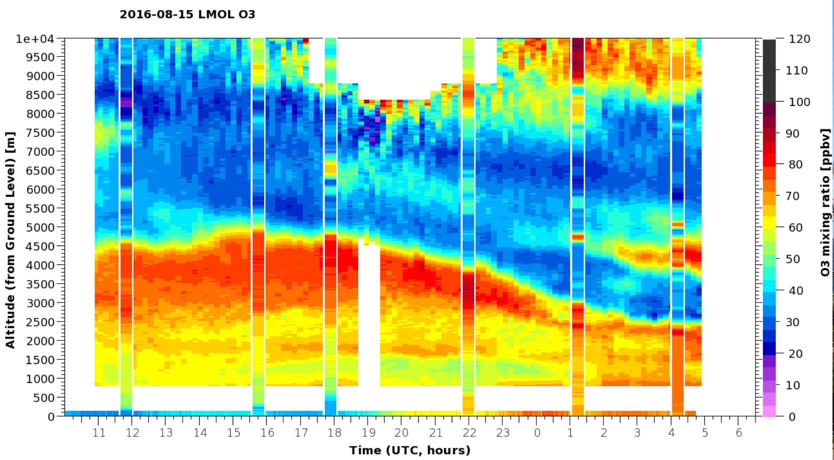
Validations and Campaigns



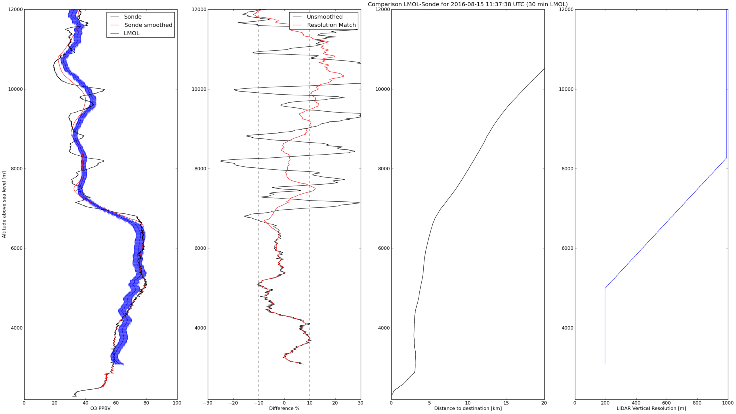
2016: SCOOP campaign

- Table Mountain Facility in California
- Improved version of the lidar.
- Real time analysis of data available.
- Laser very stable.
- More than 50 h of data.
- The Blue Cut Fire stopped the campaign

Validations and Campaigns



Validations and Campaigns



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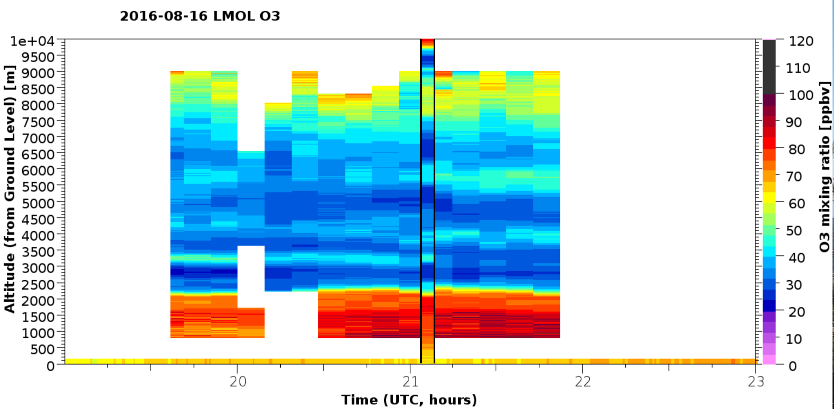


Validations and Campaigns

Conclusion of the SCOOP campaign

- The LMOL laser is stable and able to run for hours at a time.
- The configuration of the system is stable and gives consistent results.
- LMOL has been successfully inter-compared with other TOLNET lidars: all lidars retrievals differs by values inferior to their uncertainties.
- LMOL has been successfully compared with ozone sondes.
- The LMOL retrieval system computes uncertainties following the recommended techniques by **Leblanc et al. 2016 (AMT)**.

LMOL is validated for ozone observation campaigns.

Validations and Campaigns

LMOL publications

- “Langley mobile ozone lidar: ozone and aerosol atmospheric profiling for air quality research” R De Young, W Carrion, R Ganoe, D Pliutau, G Gronoff...- Applied Optics, 2017
- “Quantifying TOLNet Ozone Lidar Accuracy during the 2014 DISCOVER-AQ and FRAPPÉ Campaigns”, Wang, L., Newchurch, M. J., Alvarez II, R. J., Berkoff, T. A., Brown, S. S., Carrion, W., De Young, R. J., Johnson, B. J., Ganoe, R., Gronoff, G., Kirgis, G., Kuang, S., Langford, A. O., Leblanc, T., McDuffie, E. E., McGee, T. J., Pliutau, D., Senff, C. J., Sullivan, J. T., Sumnicht, G., Twigg, L. W., and Weinheimer, A. J.: Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2017-106, accepted, 2017.
- Leblanc et al. SCOOP intercomparison (in prep)

The next slides are the first results of the OWLETS campaign. They are preliminary. Publication based on this work are in preparation/under review

The OWLETS campaign

The OWLETS campaign

Motivations

- Primary: understanding the land/sea O_3 gradient
- Low altitude observations ($<$200 m – 500 m)
- Performing lidar/UAV intercomparisons

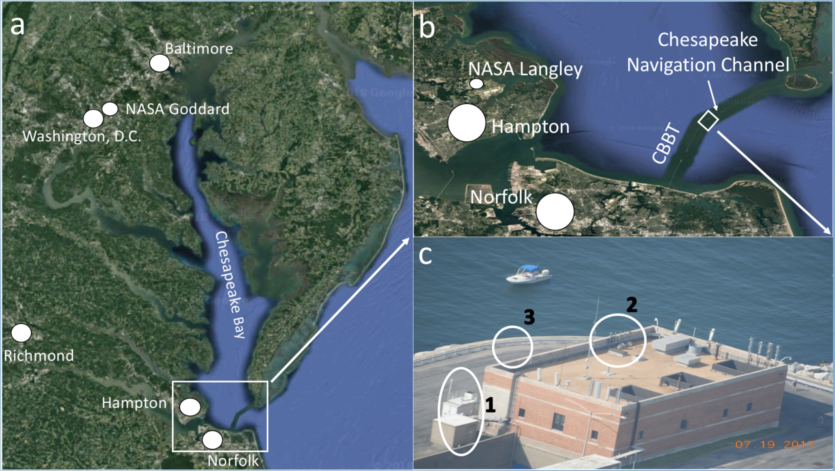
LMOL role for owlets

- observation at the 3rd island of the cbbt: "on-water" lidar
- record of ground O_3, NO_x
- secondary: performing lidar/uav intercomparisons

Achievements

- Observations on every campaign days: 14 days
- LMOL record of over 30 hours observations
- Minimum altitude of $\approx$ 110 m
- All data have been archived with resolution/time optimized for comparison with TROPOZ

The OWLETS campaign



The OWLETS campaign

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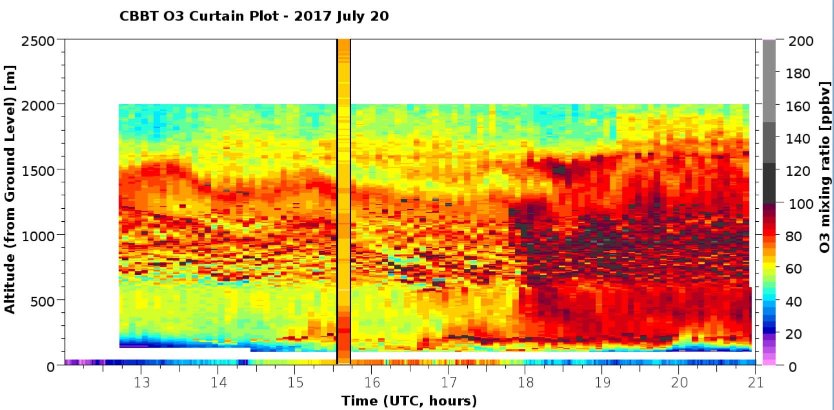
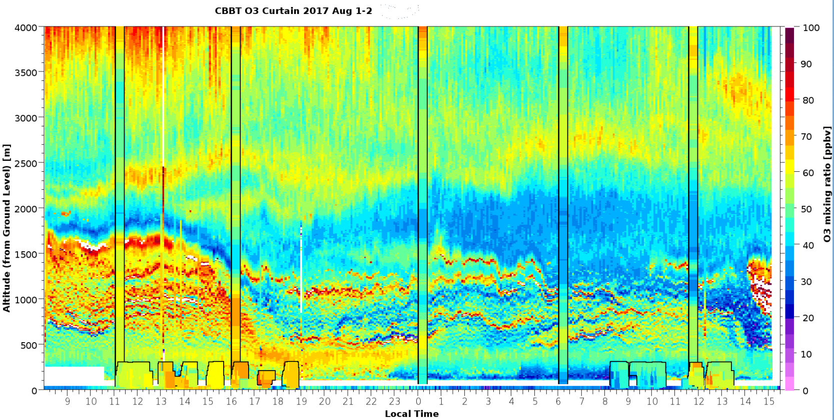


The OWLETS campaign



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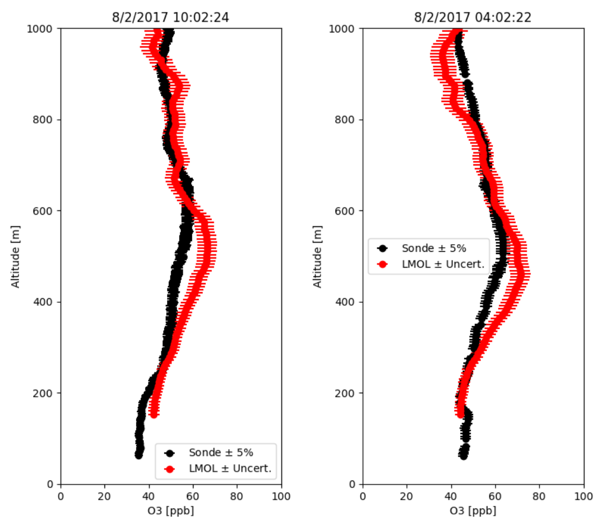

The OWLETS campaign: Observation of O_3 titration due to a ship

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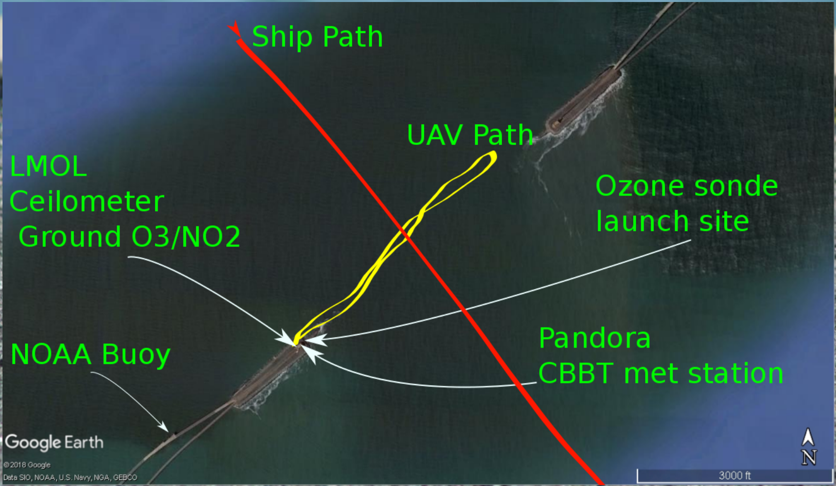

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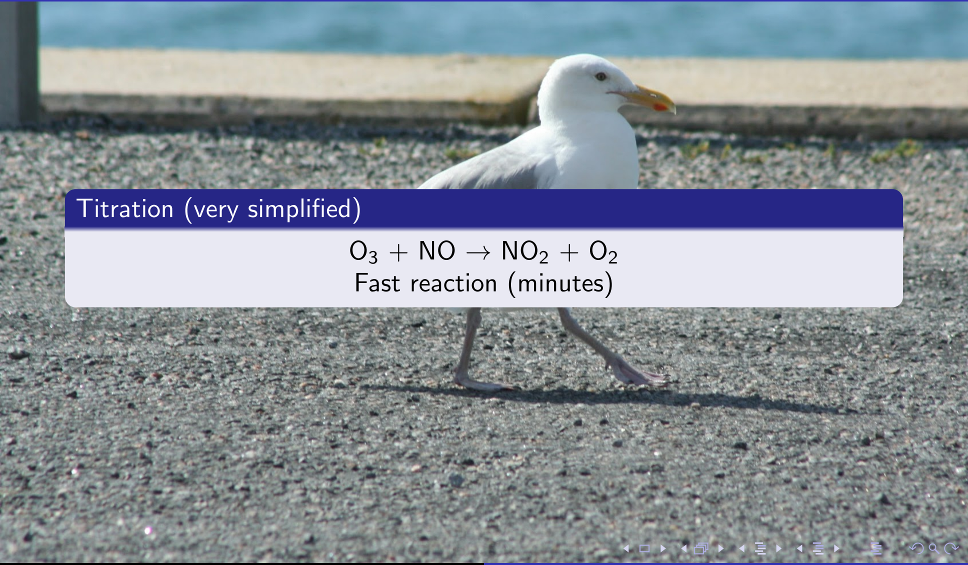
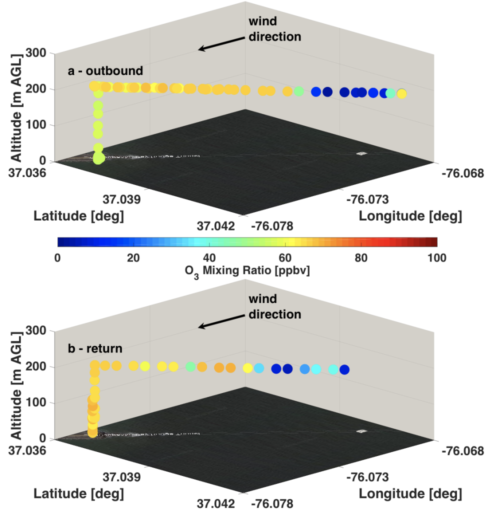


Titration (very simplified)

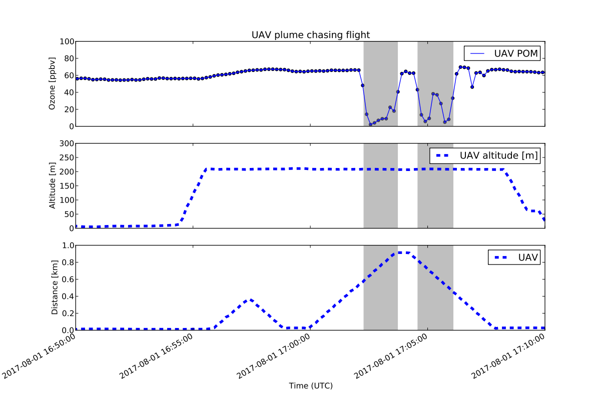
$$O_3 + NO \rightarrow NO_2 + O_2$$

Fast reaction (minutes)

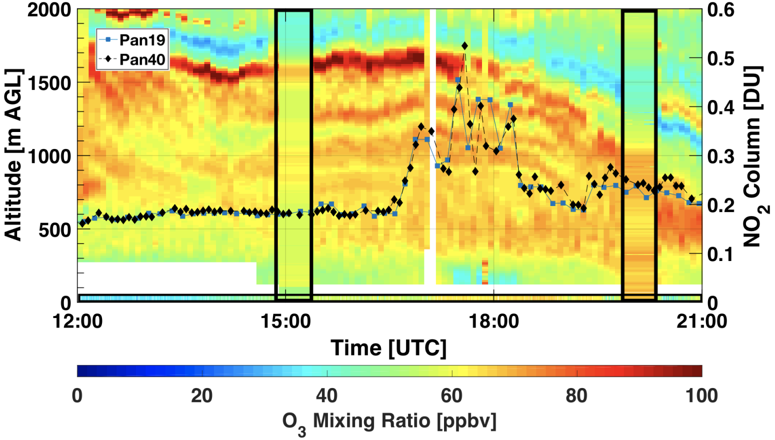
The OWLETS campaign: Observation of O_3 titration due to a ship



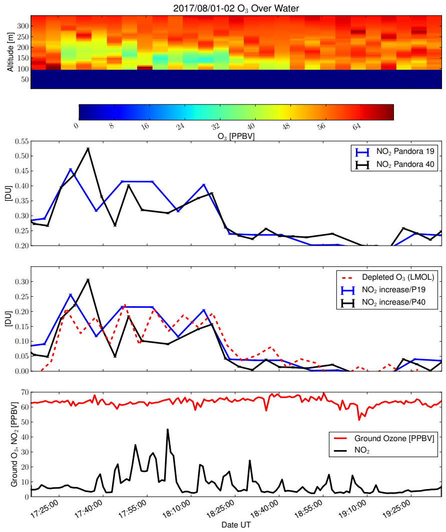
The OWLETS campaign: Observation of O_3 titration due to a ship



Pandora / LMOL intercomparison



Pandora / LMOL intercomparison



Pandora / LMOL intercomparison

- O_3 + NO → NO_2 + O_2 verified
- The ship emitted mainly NO, the NO_2 coming from the titration
- NO_2 leads to reaction that can make more O_3 than initially present in the long term (hours)
- The plume was aloft
- The multi-instrumental observation was crucial to diagnose the event
- Ring et al. 2018: the vertical structure of the ship plume has impact on TROPOMI-like observations of the Chesapeake region.

Submitted to AMT

To be on AMTD soon.

TROPOMI Overpasses / Preparation for OWLETS II

LMOL recent improvements and validation

- Improved PMT (reaching ≈9 km with a 5min averaging during the night.
- Off axis system / window (to prevent rainwater)
- Autonomy / remote control
- Eye Safe System (for safety and aviation regulation)

TROPOMI Overpasses

- Observation around 12-15h
- A few ozonesondes launched during that window (T. Knepp)
- Real time preview

TROPOMI Overpasses / Preparation for OWLETS II

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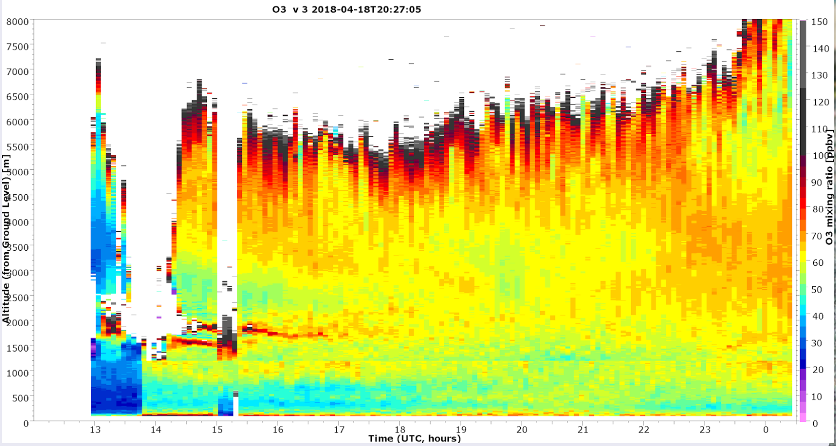
TROPOMI Overpasses / Preparation for OWLETS II

PRELIMINARY - REAL TIME VIEW (not optimized)



TROPOMI Overpasses / Preparation for OWLETS II

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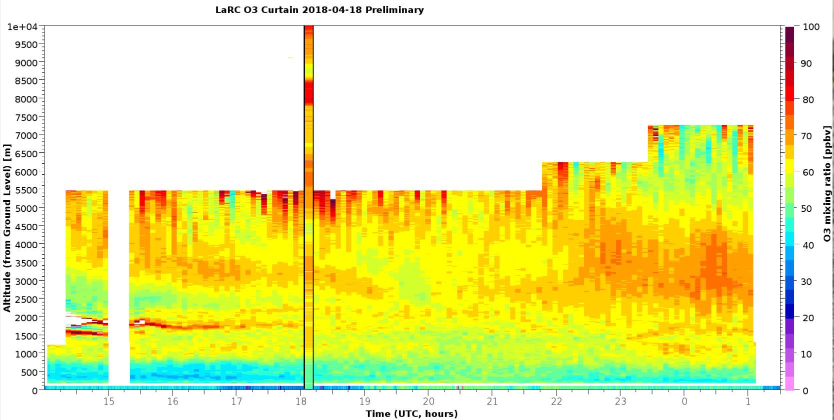
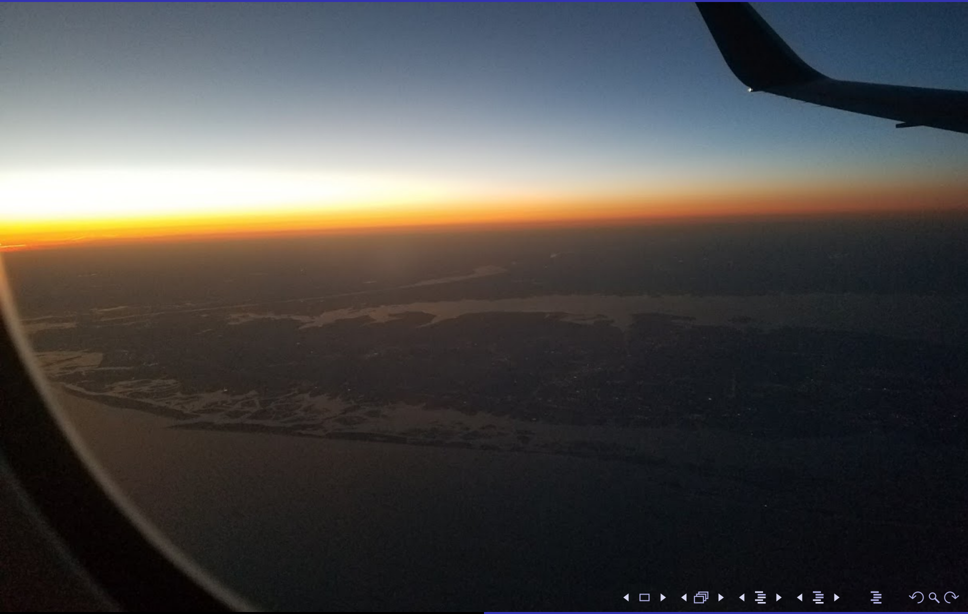


TROPOMI Overpasses / Preparation for OWLETS II

Conclusions



Conclusions

LMOL

- Mobile Lidar for Aerosols and O_3 measurements, part of the TOLNet network.
- Inputs parameters, outputs parameters, uncertainty validatation, etc, validated by the network.
- Adapted to study evolution of O_3.
- Available to support calibration/validation of satellites (TROPOMI, TEMPO)
- In Constant evolution.
- Strong collaboration with Pandora / measurements complementary.
- Next Step: 2018 campaigns. OWLETS-2 / LISTOS

Conclusions

Unique LMOL capabilities

- Mostly Autonomous
- Typical resolution: 5 min, 20 m – 1000 m (vertical).
- Capabilities: 100m – 6/7 km altitude (day), 10 km (night)...and improving!
- Smallest TOLNet Lidar / most mobile.
- EYE SAFE!

LMOL can be shipped internationally for campaigns

It is based on published laser/techniques, and therefore not a problem for export.

Stay tuned for Owlets II

Appendix 1: The DIAL method

Lidar equation

$P_\lambda R^2 = \gamma_\lambda B_\lambda e^{-2\int_0^R \beta_{aero,\lambda(r)} + \beta_{Rayleigh,\lambda(r)} + N_{O_3}(r)\sigma_{O_3,\lambda} + \sum_{sp} \sigma_{sp(z),\lambda} N_{sp}(r) dr}$.

N_{sp}: the density for species sp

P the lidar power. z the altitude. R: the range.

λ the lidar wavelength (on: the wavelength the most absorbed by O_3, off: the least absorbed by O_3).

γ_λ: the lidar constant for the specified wavelength.

$\sigma_{sp(z),\lambda}$: the cross section

$\Delta\beta_{aero} = \beta_{aero,off} - \beta_{aero,on}$

$\Delta\sigma_{sp(z)} = \sigma_{spz,on} - \sigma_{spz,off}$

$\Delta\lambda = \lambda_{off} - \lambda_{on}$

B : the total backscatter. Rayleigh scattering + aerosol scattering

β_{sp}: the absorption by the species sp.

Appendix 1: The DIAL method

Lidar equation

By deriving the logarithm of ratio P_{off}/P_{on}, we get:

$$N_{O_3(z)} = \frac{1}{\Delta\sigma_{O_3(z)}}\left(\frac{1}{2}\frac{\partial}{\partial z}\left(\ln\left(\frac{P_{off}}{P_{on}}\right) - \ln\left(\frac{B_{off}}{B_{on}}\right) - \underbrace{\ln\left(\frac{\gamma_{off}}{\gamma_{on}}\right)}_{If\ \ variation\ \ with\ \ z}\right)\right.$$
$$\left. + \underbrace{\Delta\beta_{aero}}_{Aerosol\ \ extinction} - \underbrace{\Delta\sigma_{M(z)}N_a(z)}_{Rayleigh\ \ extinction} - \sum_{sp}\Delta\sigma_{sp(z)}N_{sp}(z)\right) \quad (1)$$

The aerosol corrections appears on two parts: the backscatter correction $\left(\ln\left(\frac{B_{off}}{B_{on}}\right)\right)$ and the extinction correction $(\beta_{aero,off} - \beta_{aero,on})$.

Appendix 2: The Aerosol retrieval

Retrieving the Aerosol content

$P_\lambda R^2 = \gamma_\lambda B_\lambda e^{-2\int_0^R \beta_{aero,\lambda(r)} + \beta_{Rayleigh,\lambda(r)} dr}$.

- $\mathrm{B}_{Rayleigh} = \frac{3}{8\pi}\beta_{Rayleigh}$
- $\mathrm{B}_{Aerosols} = \frac{\beta_{Aerosols}}{S_\lambda}$: this is the biggest unknown S=20 to 50.
- We know $\mathrm{B}_{Rayleigh}$ from the atmosphere, and the cross sections.
- The Green channel allows us to retrieve the ratio $\frac{B_{Rayleigh}}{B_{Aerosols}}$ at 527 nm , with the uncertainty from the aerosol absorption factor S.
- The 2 UV channels allows us to retrieve this ratio in the UV, which is different, but varies accordingly. (Browell et al. 1985 for the technique).

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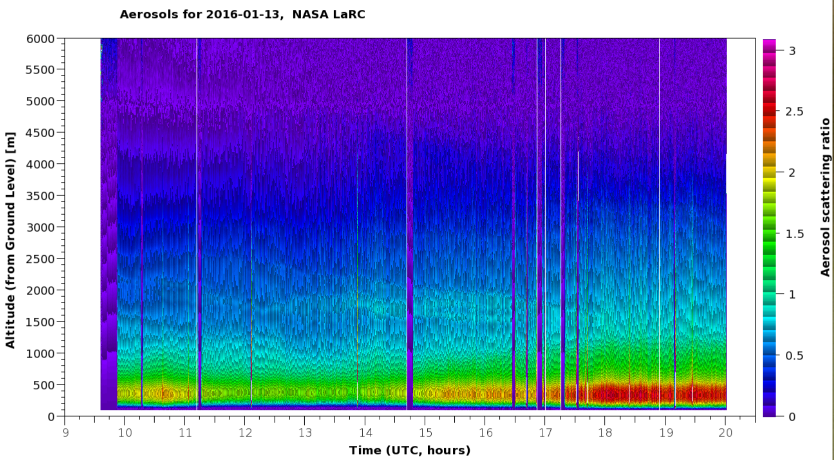

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