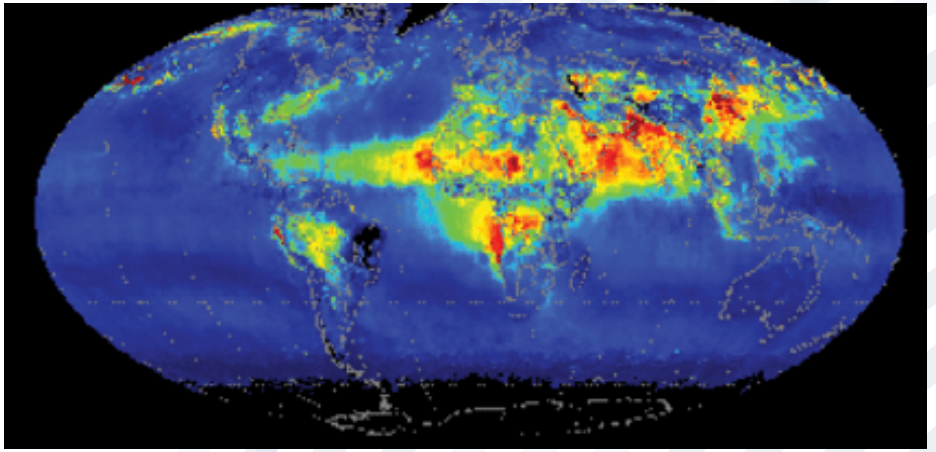
Current developments for remote sensing mobile observations

Ioana Popovici, Philippe Goloub, Luc Blarel, Benjamin Torres, Maria Fernanda Sanchez Barrero, Thierry Podvin, Rodrigue Loisil, Cyril Delegove, Gaël Dubois, Eric Bourrianne, Qiaoyun Hu, Fabrice Ducos, Bhagyashree Patra, Stéphane Victori, Lélia Proniewski

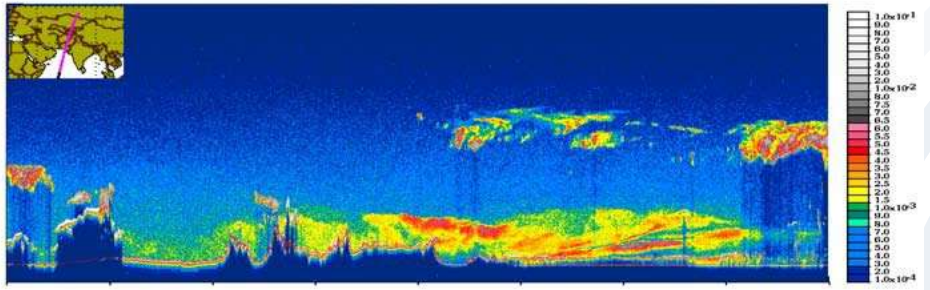
1st ACTRIS Science Conference, May 11-13, 2022

Context and interest of mobile observations

- About 500 fixed and terrestrial sites (photometers)
- No measurements over the oceans despite good occupation of the islands
- Few aircraft measurements except dedicated campaigns (no routine observations)
- Need for satellite validation over the oceans and in some difficult regions (mountains, volcanoes etc)
- Complete the observational gaps



MODIS AOD at 550 nm, DJF 2005



CALIOP backscatter over Pakistan and Arabian Sea

(Lau et al., WMO Bulletin, 2009)

AGORA Lab

Mobile observations strategy

AGORA-Lab

- Observations during vector's movement
- Movement type: slow (<12 m/s)
- Movement type: fast (aircraft, high-speed train)
- Automatic
- Near Real-Time (NRT)
- AERONET compatible: AOD (sun, moon), radiances
- Modular, standard concept → network objective
- Project of fast instrument deployment (3MIP photometer)





AGORA Lab

Mobile observations capabilities

MAMS (Mobile Aerosol Monitoring System)

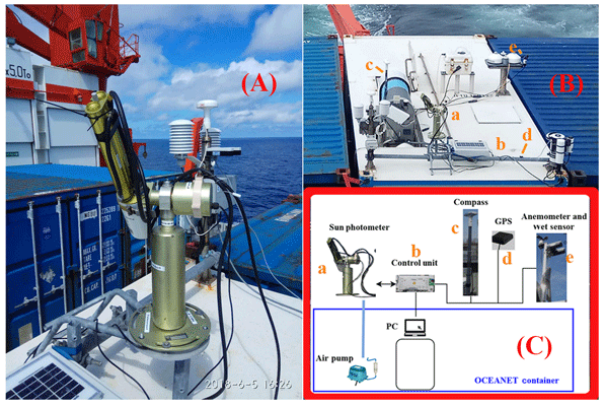
(Popovici et al., AMT, 2018)

PLASMA photometer

(Karol et al., AMT, 2013)

TRL 3

CIMEL CE318 shipborne photometer



TRL 7

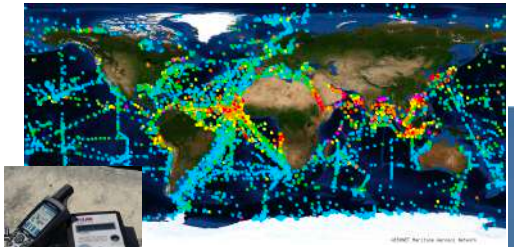
(Yin et al., AMT, 2019)

CIMEL CE376 micro-LIDAR

(poster ACTRIS, R2P18)

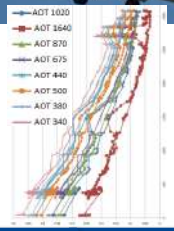
TRL 5

Mobile photometer developments



MAN Network
(AERONET)

PLASMA 2
FALCON 20



CE318-T
RV POLARSTERN

MOSAIC/Arctic
CE318-T

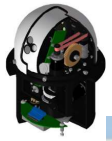
Sea2Cloud
New Zealand
CE318-T

Marion Dufresne
CE318-T

+ SKY Radiances
+ MOON

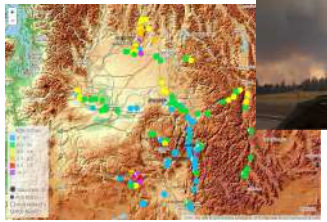
2004 | 2013 | 2017 | 2017 | 2018 | 2019 | 2019 | 2020 | 2020 | 2021 | 2021 | 2022

PLASMA 1
(dev. LOA)
Aircraft, ULM, car



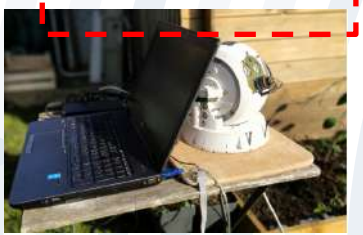
AQABA campaign
CIMEL CE318
RV Kommandor Iona

FIREX campaign
CE318-T on car



CE318-T
Boulogne sur Mer
GPS improv.

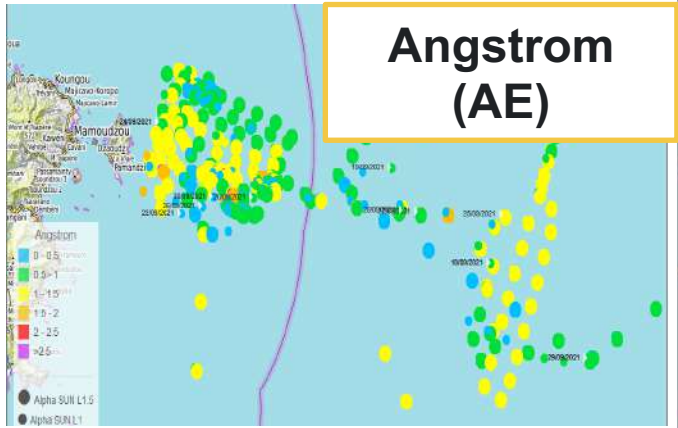
PLASMA 3D
Hybrid Plasma/CE318-T

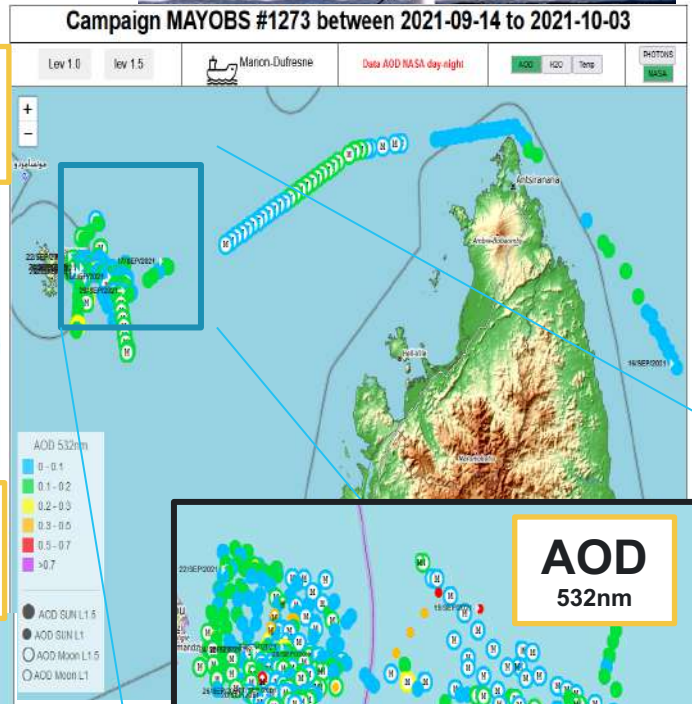


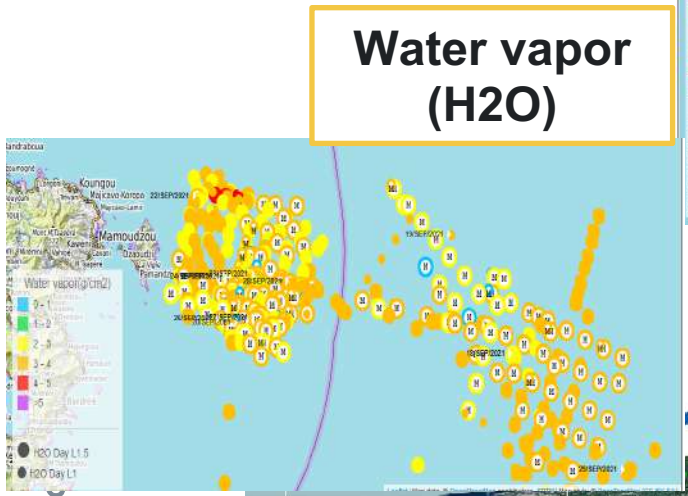
NOAA
RV Ron H Brown

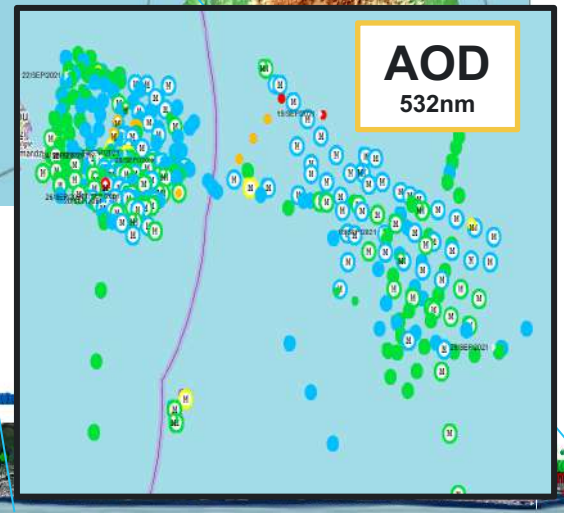
CE318-T on RV Marion Dufresne Around Madagascar

- Photometer in permanent operation since 2021, continuous, without any problems





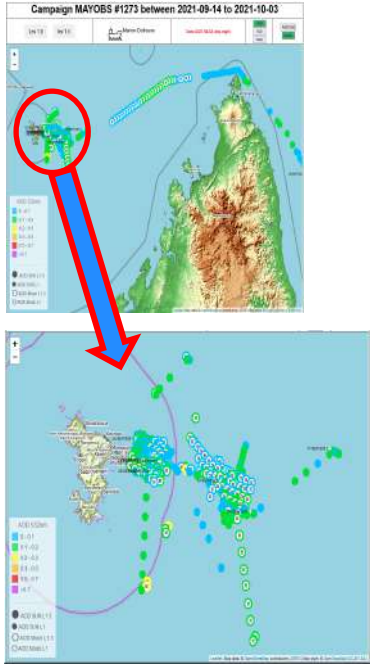


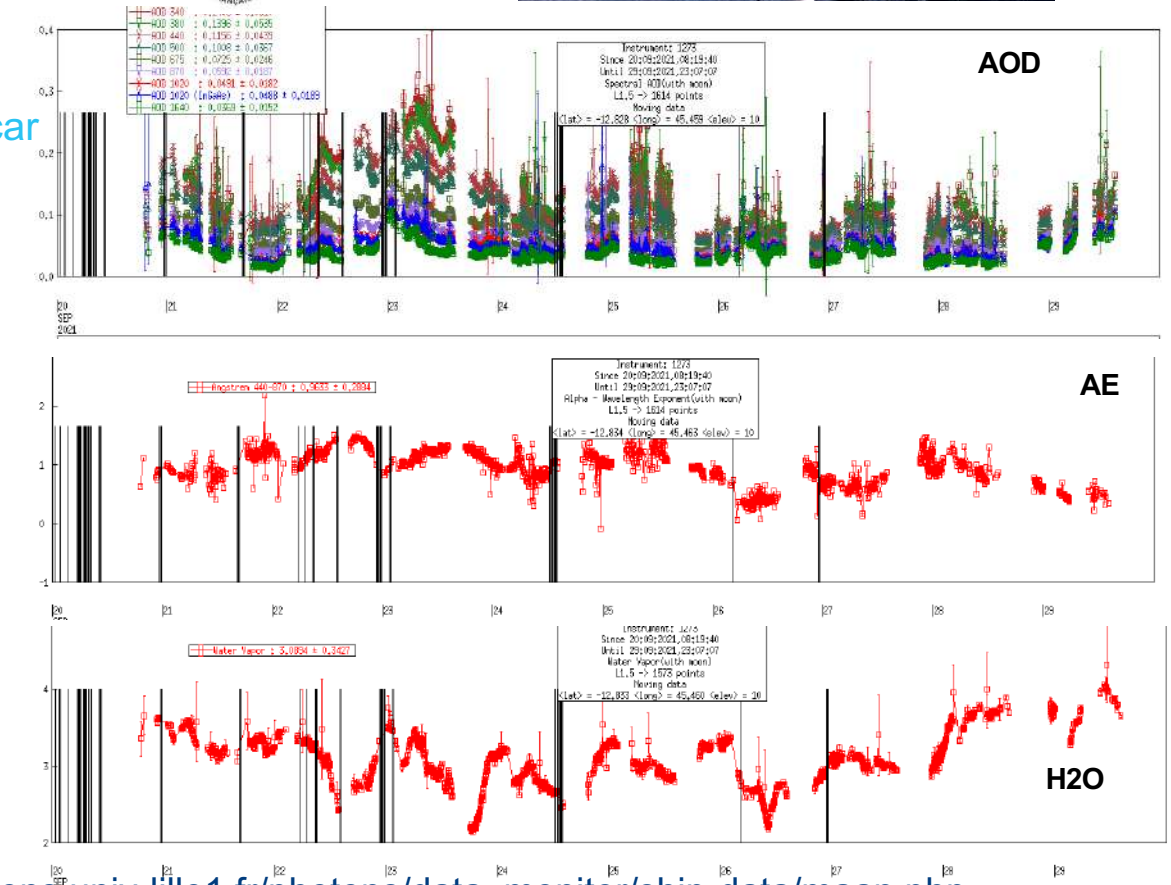


Time series (AOD, AE, H2O)

Day & Night

MAP-IO Around Madagascar

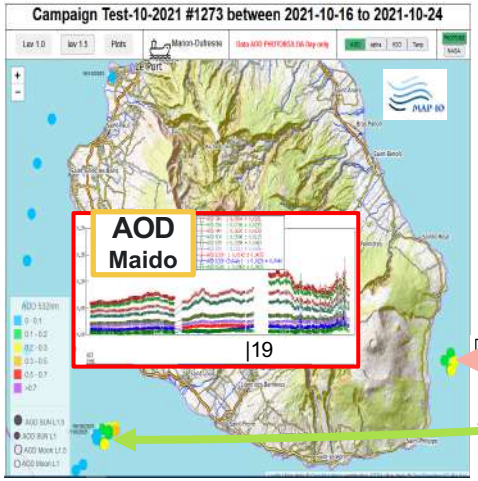


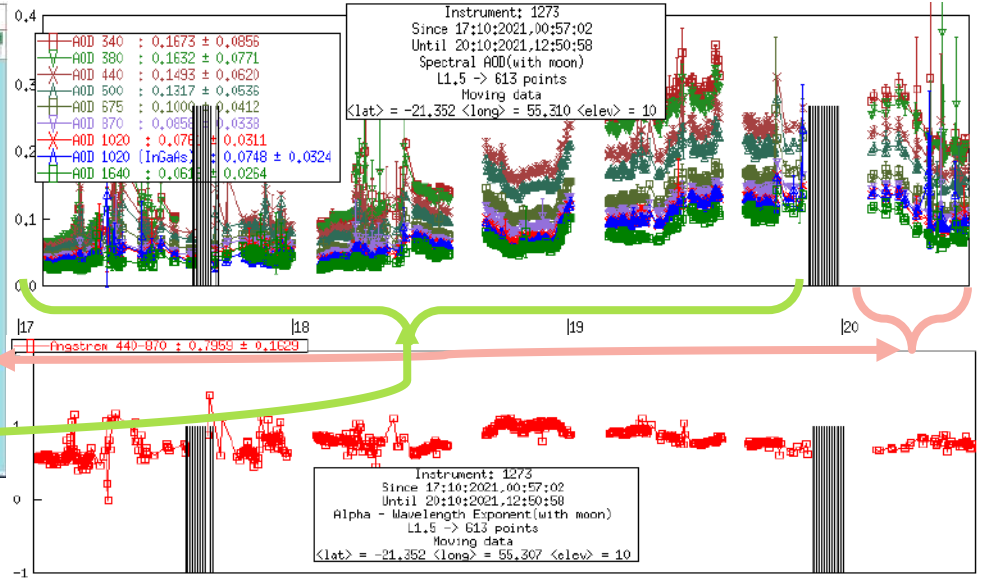


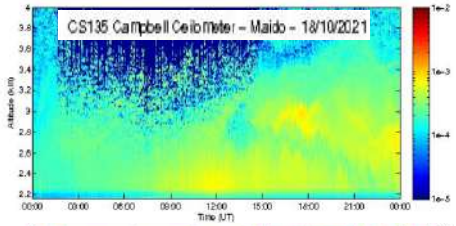
Data access: http://loaphotons.univ-lille1.fr/photons/data_monitor/ship-data/maan.php

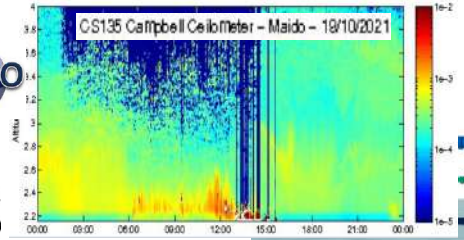
News: https://earth.esa.int/eogateway/news/monitoring-aerosol-properties-in-the-indian-ocean

Reaching La Réunion Island (2021)
Piton de la Fournaise volcano









esa QA4EO

AGORA Lab

Advanced PLASMA (version 3)

- Compact / Waterproof / GPS inertial unit
- 100% AERONET Compatible
- AOD uncertainty = AERONET master
- Easy maintenance
- Application of GRASP-inversion

} CE318T photometer head

+

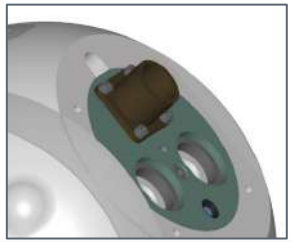
Plasma1/2

Expected measurements:

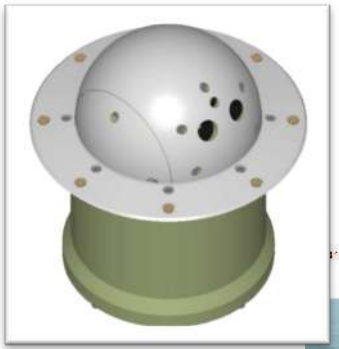
- AOD for the 9 standard filters (1640, 1020, 870, 670, 500, 440, 380, 340, 940)
- SKY measurements of almucantar type with option for some filters
- Possibility to perform AOD measurements at certain wavelengths, to accelerate the acquisition
- Night-time AOD measurements

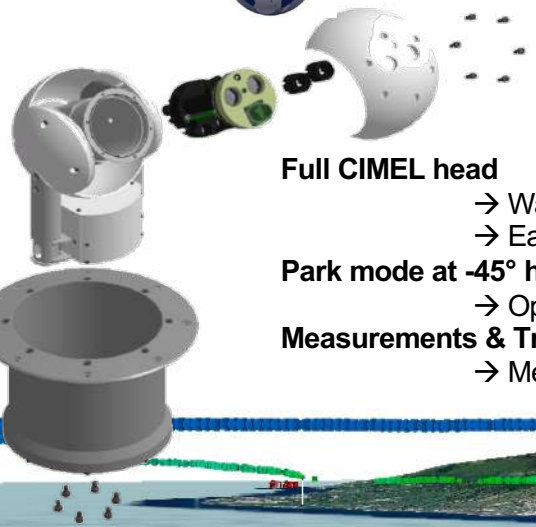
esa QA4EO

Artist vue Rodrigue LOISIL



PLASMA 3 Final Version





Full CIMEL head

→ Waterproof guarantee
→ Easily interchangeable

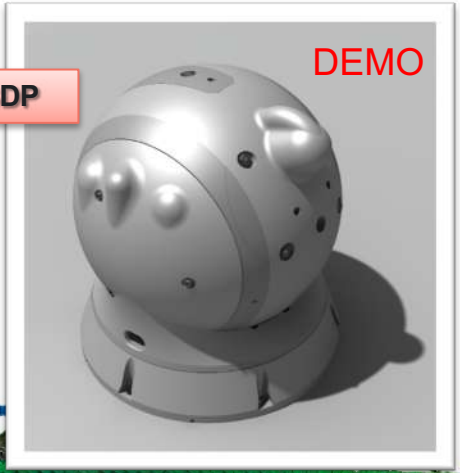
Park mode at -45° horizontal

→ Optics protection

Measurements & Track: Horizon-20° to Horizon-10°

→ Measuring range = 210°

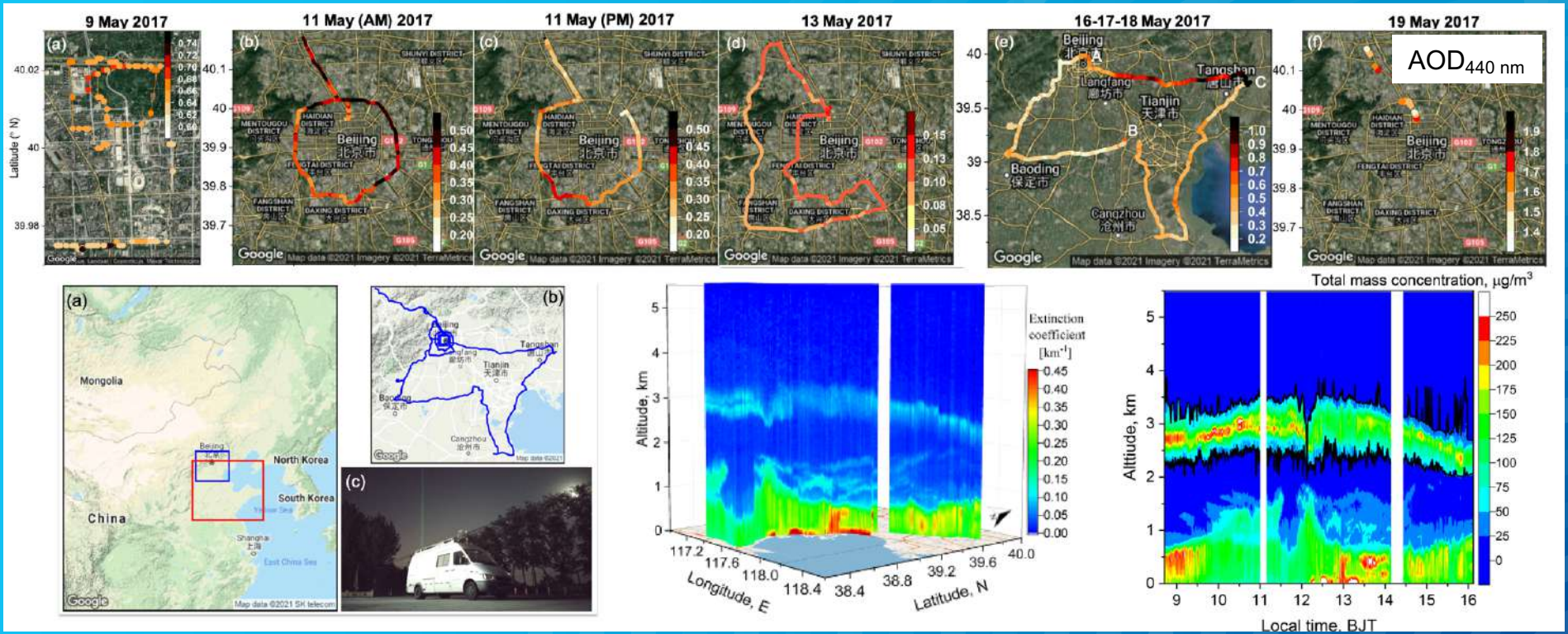
PLASMA 3DP



Mobile LIDAR
CIMEL CE376

LiDAR-photometer mobile measurements

Spatial and vertical variability in North China Plain, 2017

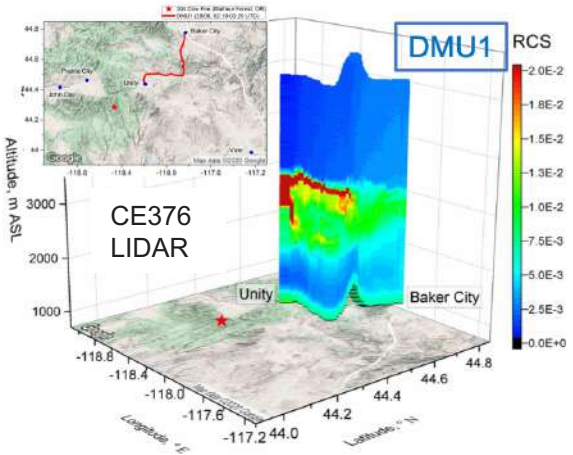


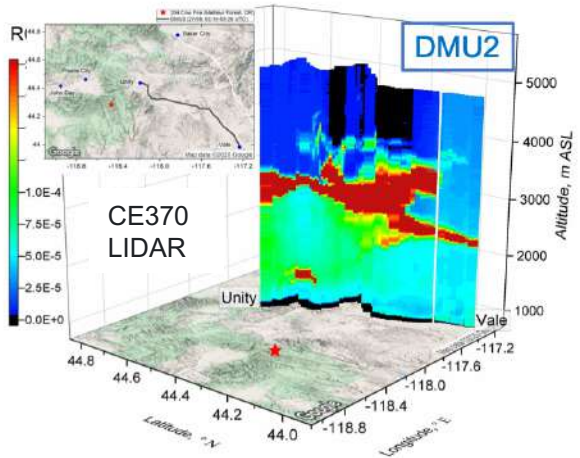
With CIMEL CE370 micro-LIDAR

(Popovici et al., Atmosphere, 2022)

FIREX-AQ campaign in western US, 2019

- FIREX-AQ experience proved that we are able to embark compact remote sensing instruments and install them quickly on site to access harsh environments and get close to fires sources, which has not been done before
  - First time a LIDAR reaches close to fire sources in a mountainous region
    - Spatial information, useful for smoke dispersion models



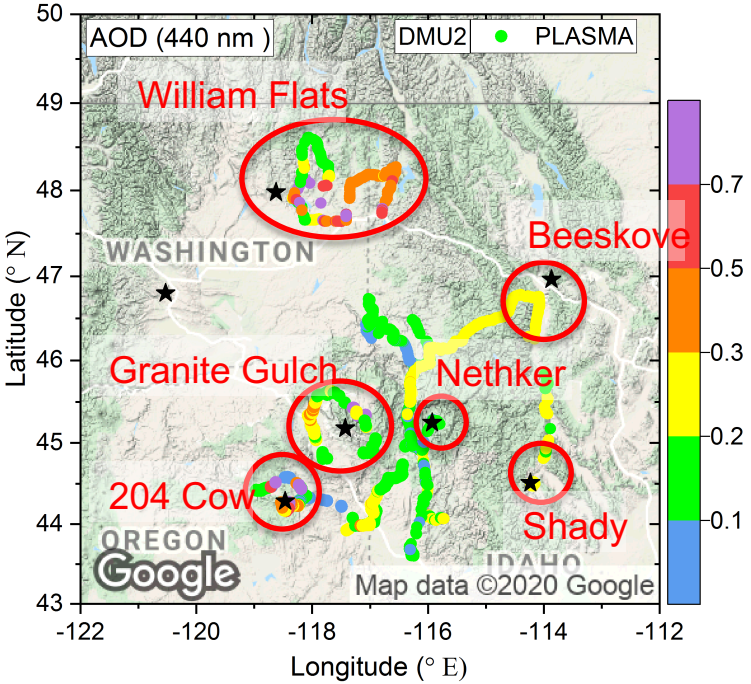


FIREX-AQ campaign in western US, 2019

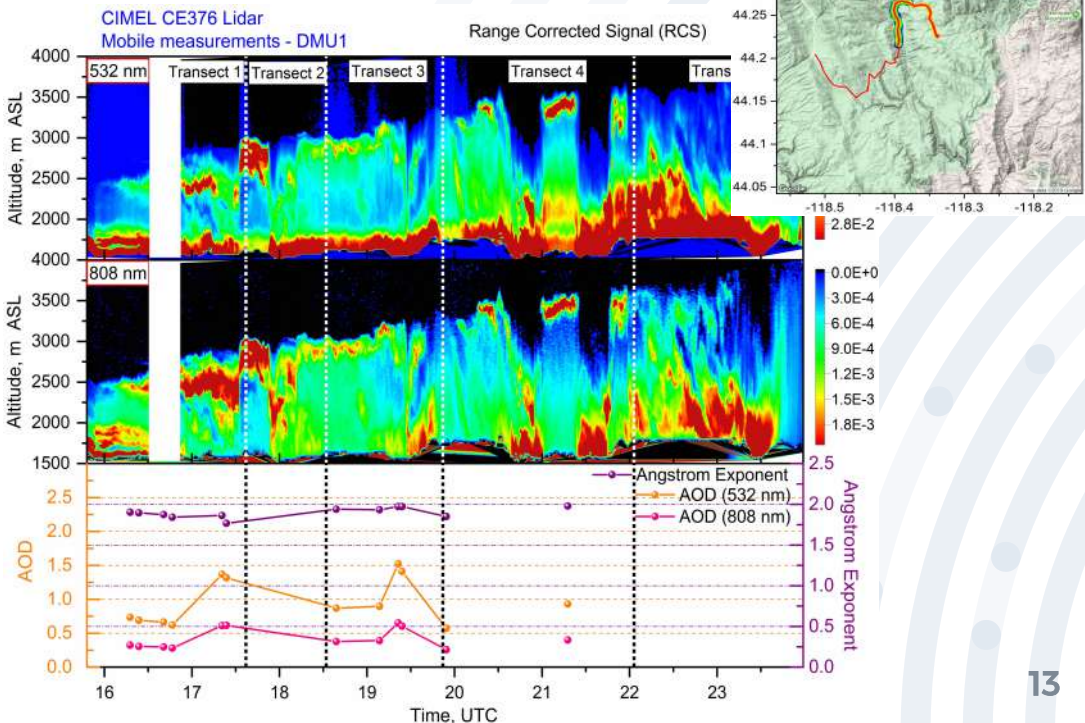
https://aeronet.gsfc.nasa.gov/new_web/DRAGON-FIREX-AQ_2019.html

- Mapping of smoke vertical and spatial dispersion thanks to mobile LIDAR and photometer measurements

PLASMA photometer



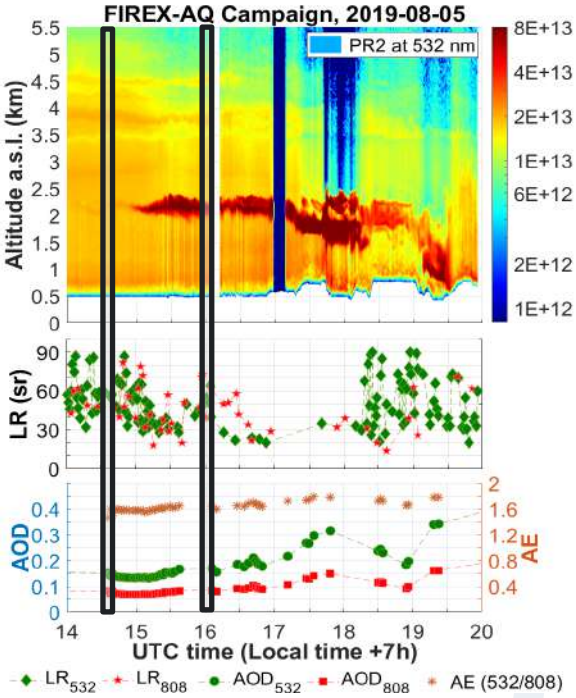
CE376 LIDAR

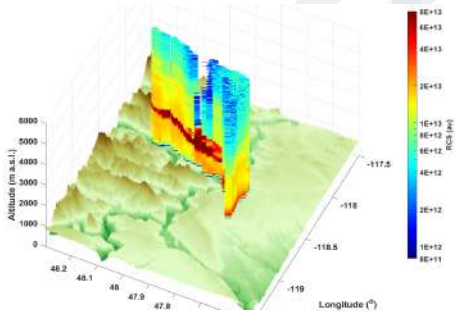


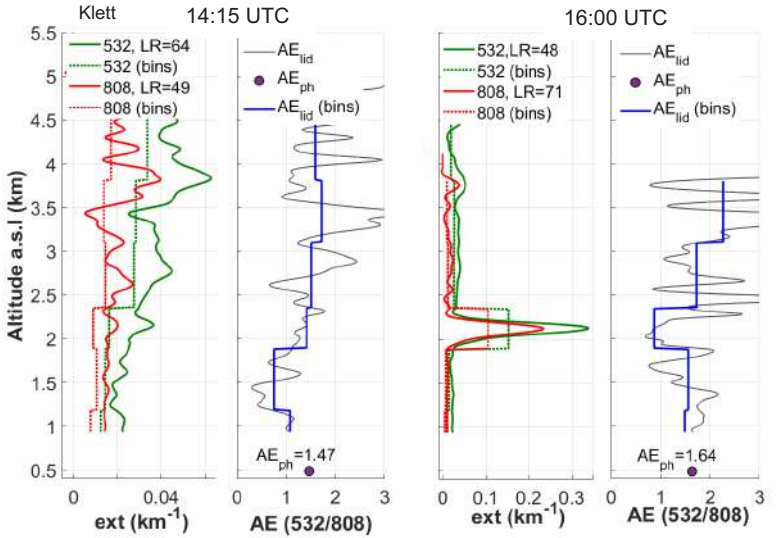
FIREX-AQ campaign in western US, 2019

- The synergy of the mobile photometer with the CE376 lidar allows profiling the extinction at 2 wavelengths (532, 808 nm) and of the Angstrom Exponent (AE)

- The AE vertical profile and the depolarization capabilities of the CE376 allow identifying the aerosol type (fine/coarse)



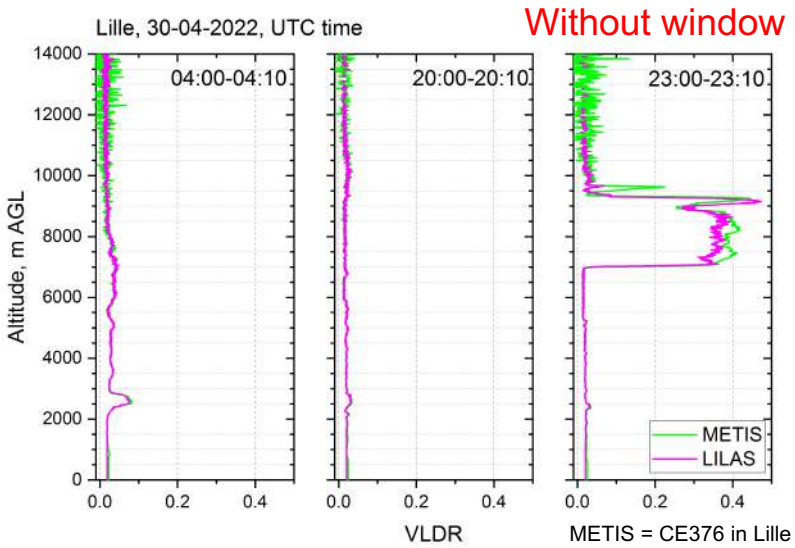




*CE376 before some mechanical improvements

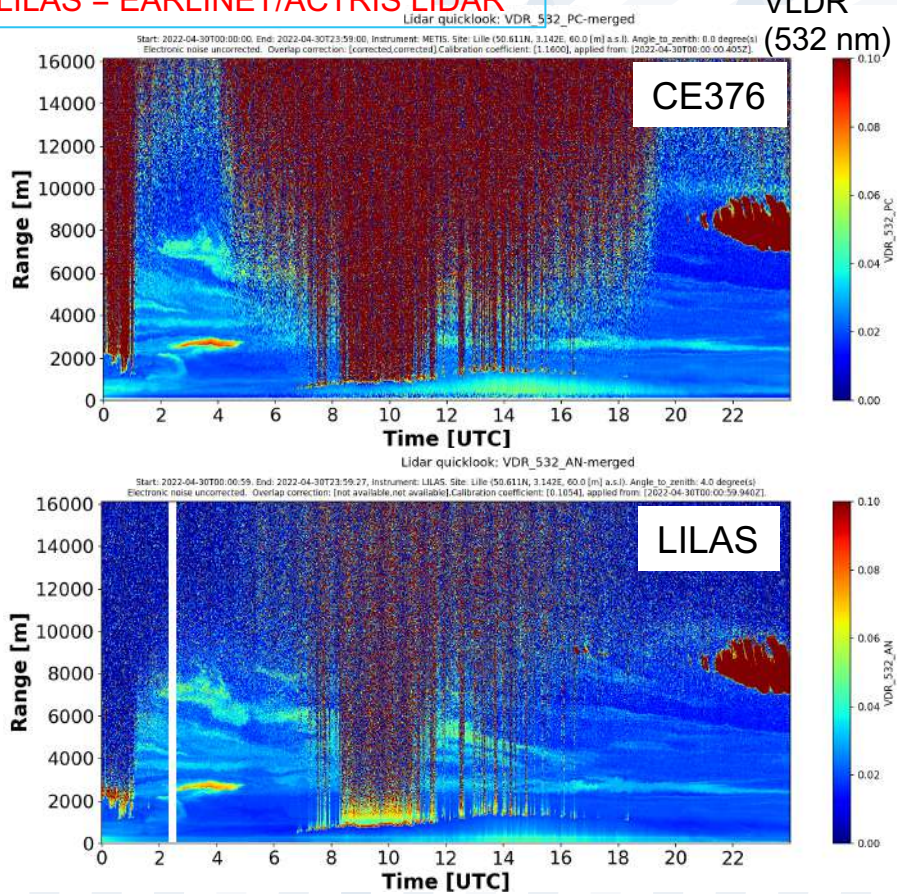
(Sanchez Barrero et al., in prep., 2022)

CIMEL CE376 lidar is checked against LILAS



LILAS = EARLINET/ACTRIS LIDAR

VLDR (532 nm)



- The CE376 LIDAR characterization and validation is done at ATOLL (Atmospheric Observatory of LiLE) platform, located at LOA, University of Lille/CNRS, France, where EARLINET QC/QA procedures are followed

- The agreement of the VLDR is excellent, with relative differences of 9%

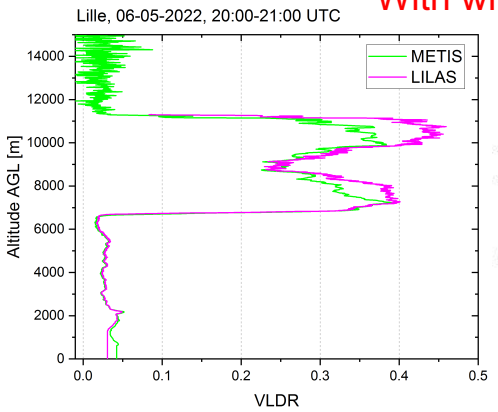
AUSTRAL processing

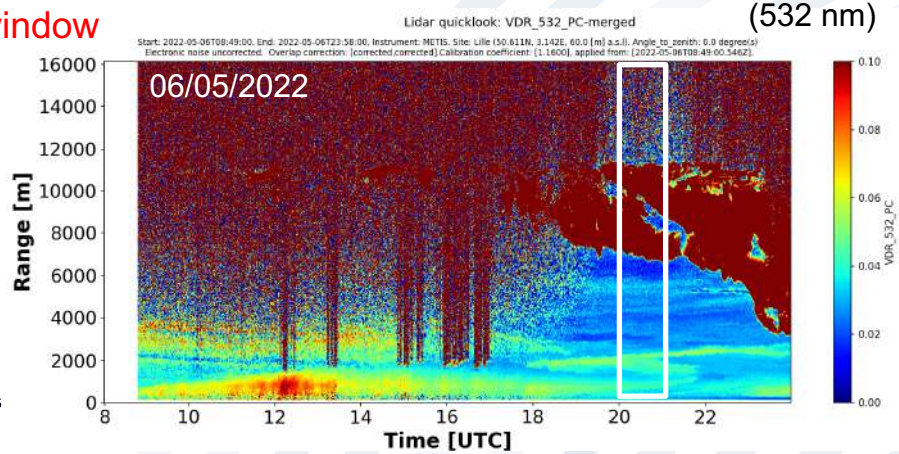
CIMEL CE376 lidar is checked against LILAS

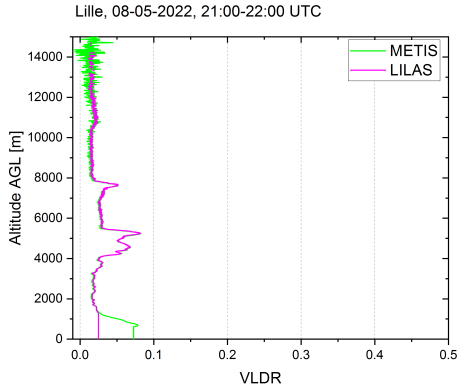
- 24/7 LIDAR records possible thanks to window in the ATOLL platform
- The window does not perturb the depolarization measurements (comparison with LILAS)
- Excellent agreement with LILAS (relative differences of 8% and 11% for cirrus case)

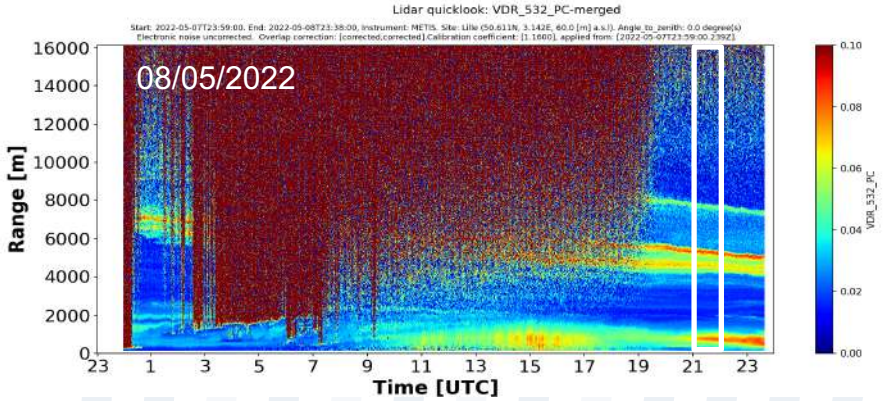
With window

VLDR (532 nm)



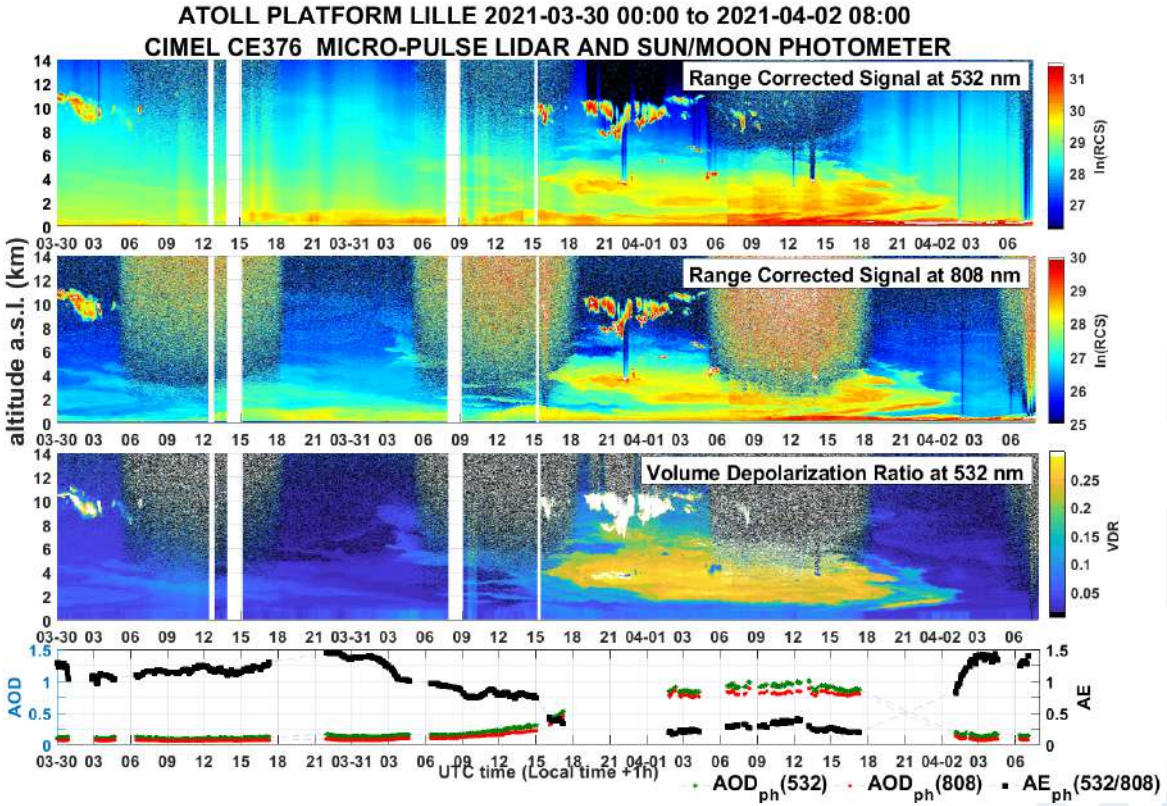






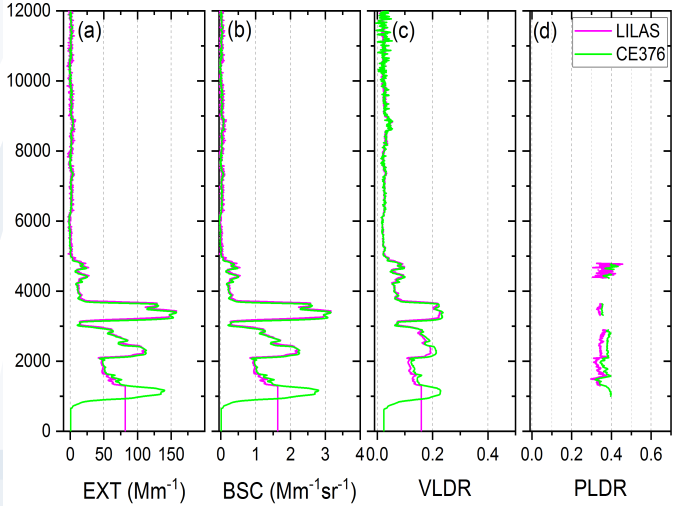
AGORA Lab

CIMEL CE376 lidar data quality



(Sanchez Barrero et al., in prep., 2022)

- The comparison with LILAS EARLINET/ACTRIS lidar shows the quality of the CE376 lidar (extinction derived with Klett, LR of 50 sr): 10% differences for extinction (EXT) and backscatter (BSC) profiles and 7% for VLDR and PLDR.



Future design of CE376 lidar

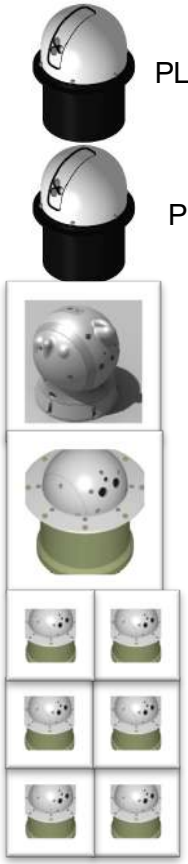
- Mechanical improvements (*robustness, stability*)
- Pre-aligned emission-reception modules, easily replaceable
- Reduction of electronic cards
- Temperature control
- One-axis blocs, optics protection
- Tests

AGORA Lab

ATMO-TECH project submitted to H2020 / INFRA-TECH call

Processing tools for photometers (STrAP)

STrAP (System for the Treatment of AOD PLASMA) is a processing framework for the treatment, filtering and visualization of PLASMA photometer AOD and radiances data



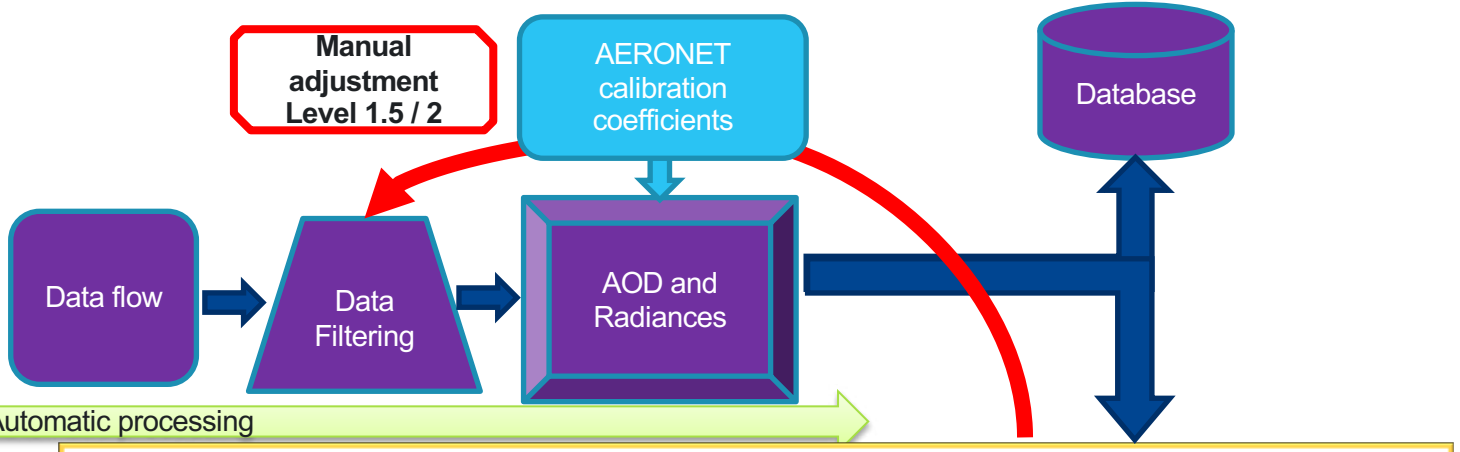
PLASMA1

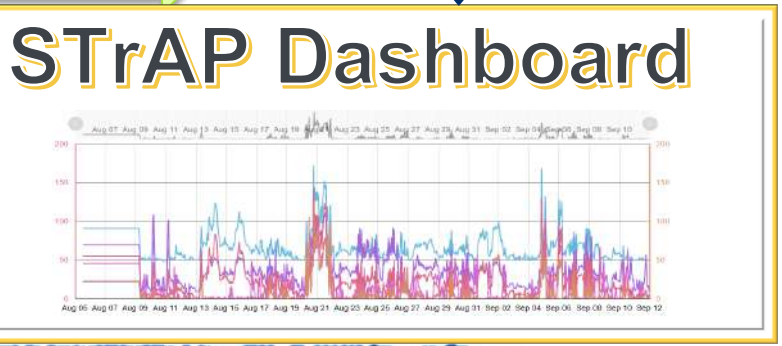
PLASMA2

PLASMA3D

PLASMA3

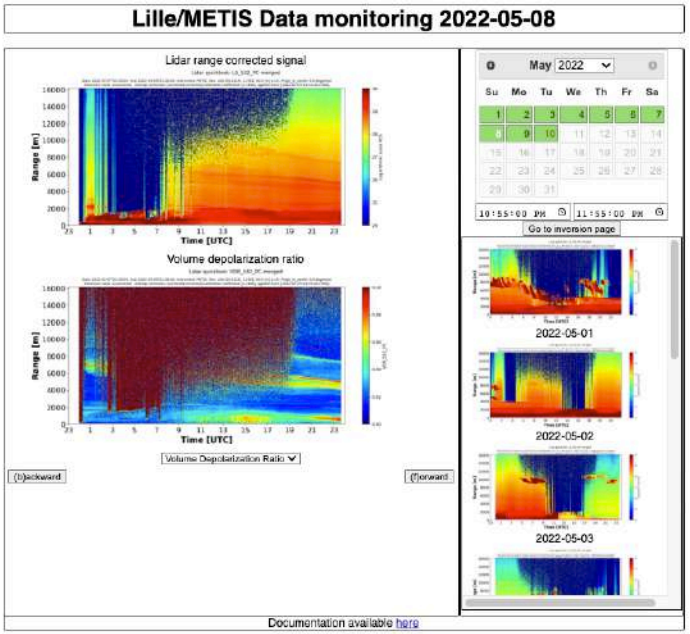
PLASMAx



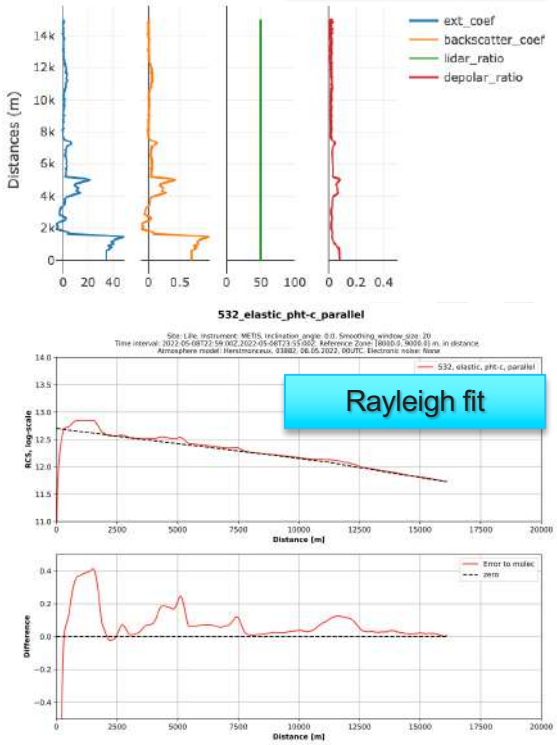


Processing and retrieval framework for LIDAR (AUSTRAL)

AUSTRAL (AUtomated Server for the TReatment of Atmospheric Lidars) processing framework allows the treatment, retrieval and visualization of lidar data (incl. CIMEL CE710 and CE376). It was developed by LOA in the framework of AGORA-Lab.

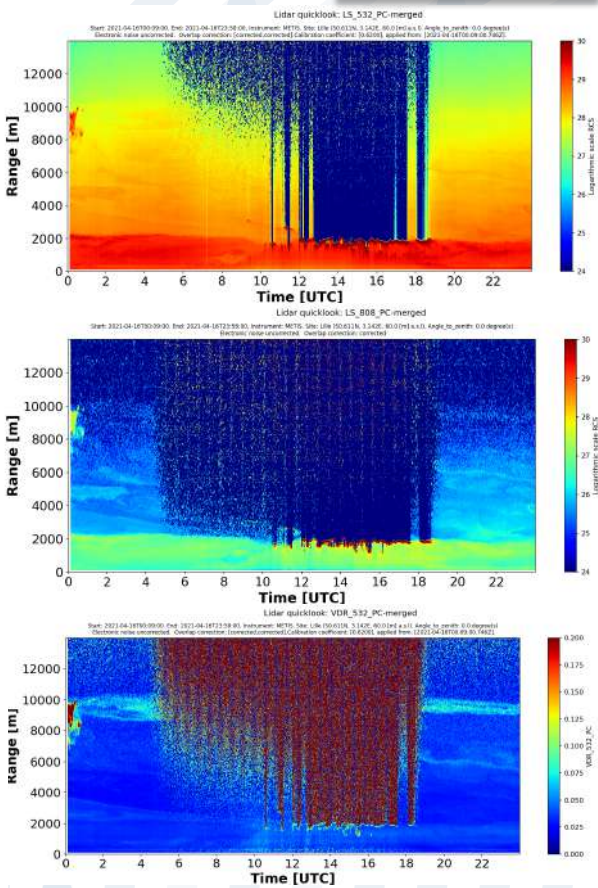


Inversion



CE376 lidar

Quicklooks



Perspectives

https://www.agora-lab.fr/

AGORA Lab

- Future developments on mobile Photometer:
  - continue on PLASMA 3 and 3DP
  - ship-borne CE318-T: analyse radiances data and improve
- Future developments on mobile LIDAR:
  - improve robustness to mechanical stress (vibrations, acceleration)
  - response to harsh environments (sea-spray, temperature variations and extremes)
- Projects
  - OBS4CLIM/ACTRIS-FR (2021-2028): 4 CE376 lidars (incl. 1 on TGV) + 1 CE710 LiDAR (LIFE), *(just started)*
  - ATMO-TECH (H2020/INFRA): improvement and test of new CE376 on different mobile platforms (ship, train, car, aircraft), (submitted)
- Campaigns
  - Shipborne photometer on NOAA's RV Ronald H Brown (2022)
  - Integration of shipborne photometer on mobile platform TBD (ESA/QA4EO program)
  - Integration of CE376 lidar on POLAR-POD fleet around Antarctica (2023, …)
  - Transect La Reunion Island-Cayenne (2023), AMARYLLIS campaign with CE376 lidar
  - Ground-based and aircraft measurements (AERO-HDF, France)

=> New generation of state-of-the-art scientific instruments to fill atmospheric observational gaps, enabling new scientific breakthrough and industrial applications

=> Preparation of new services (instrument, processing, data) for supporting satellite observation mission needs, etc.

References

- Karol, Y.., Tanré, D., Goloub, P., Vervaerde, C., Balois, J., Y., Blarel, L., Podvin, T., Mortier, A. and Chaikovsky, A., (2013). Airborne sun photometer PLASMA: concept, measurements, comparison of aerosol extinction vertical profile with lidar, *Atmos. Meas. Tech*, 6, 2383–2389.
- Popovici, I.E., Goloub, P., Podvin, T., Blarel, L., Loisil, R., Unga, F., Mortier, A., Deroo, C., Victori, S. Ducos, F., Torres, B., Delegove, C., Choël, M., Pujol-Söhne, N. and Pietras, C. (2018). Description and applications of a mobile system performing on-road aerosol remote sensing and in situ measurements, *Atmos. Meas. Tech*, 11, 4671–4691.
- Yin, Z., Ansmann, A., Baars, H., Seifert, P., Engelmann, R., Radenz, M., Jimenez, C., Herzog, A., Ohneiser, K., Hanbuch, K., Blarel, L., Goloub, P., Dubois, G., Victori, S. and Maupin, F. (2019) Aerosol measurements with a shipborne Sun-sky-lunar photometer and collocated multiwavelength Raman polarization lidar over Atlantic Ocean, *Atmos. Meas. Tech.*, 12, 5685–5698.
- Popovici, I.E., Deng, Z., Goloub, P., Xia, X., Chen, H., Blarel, L., Podvin, T., Hao, Y., Chen, H., Torres, B., Victori, S. and Xuehua, F. (2022). Mobile On-Road Measurements of Aerosol Optical Properties during MOABAI Campaign in the North China Plain, *Atmosphere*, 13, 21.
- https://earth.esa.int/eogateway/news/monitoring-aerosol-properties-in-the-indian-ocean

Acknowledgements

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