



EXPLORE THE CLIMATE

**ADVANCES IN GROUND-BASED  
OPTICAL REMOTE SENSING  
INSTRUMENTATION**

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ASAE, September 2024



# CHALLENGES OF GROUND-BASED REMOTE SENSING

# Ground based remote sensing

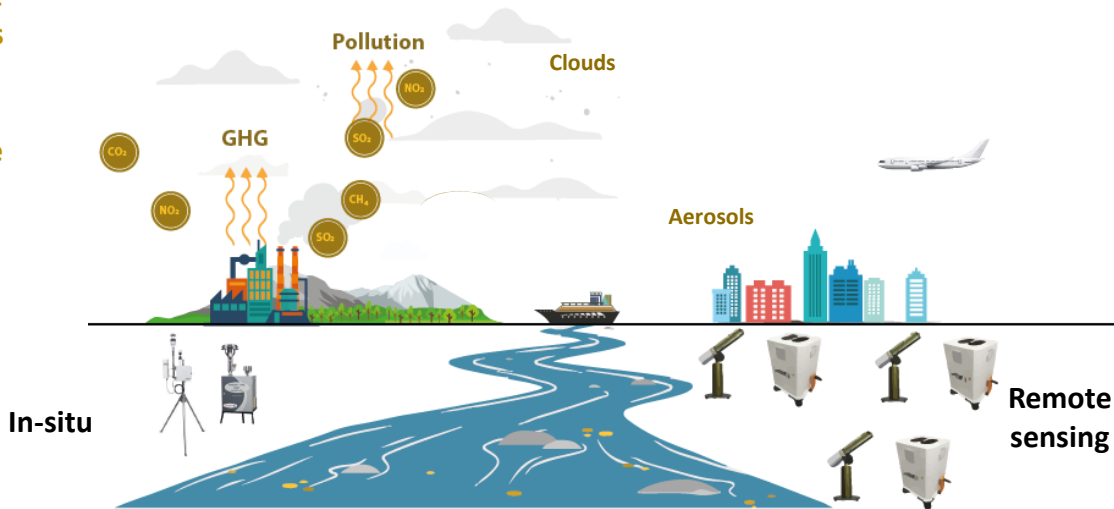
## Multiple missions



Atmosphere components

Atmosphere properties

Surface properties



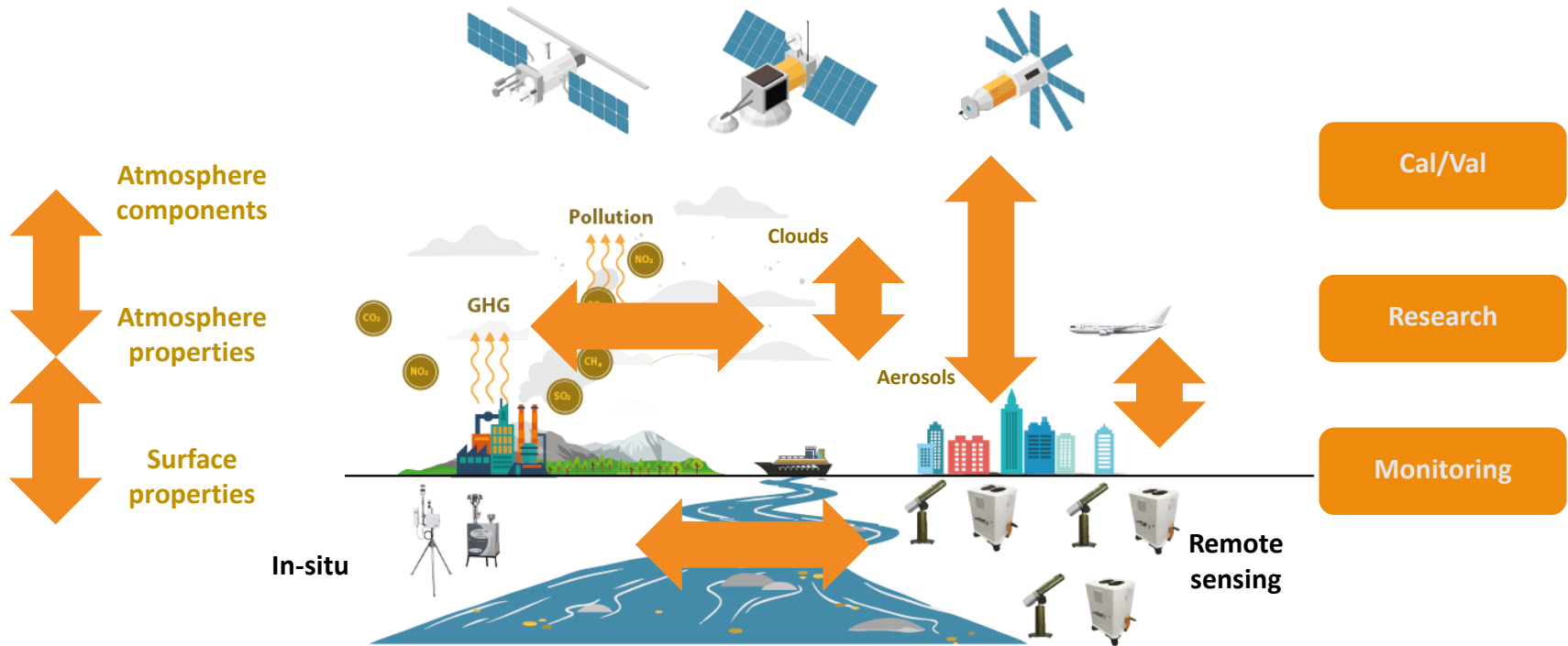
Cal/Val

Research

Monitoring

# Ground based remote sensing

## Multiple data synergies



# Ground based remote sensing

## Each instrument must support multiple usages

- Reference instruments
  - High metrological performances
  - Traceable calibration
- Network instruments
  - Low maintenance
  - Durability and cost efficiency
- Global and local
  - Automatic operations
  - Under all environmental conditions
- Campaigns or isolated sites
  - Low power consumption
  - Telecommunication
  - Fixed or mobile

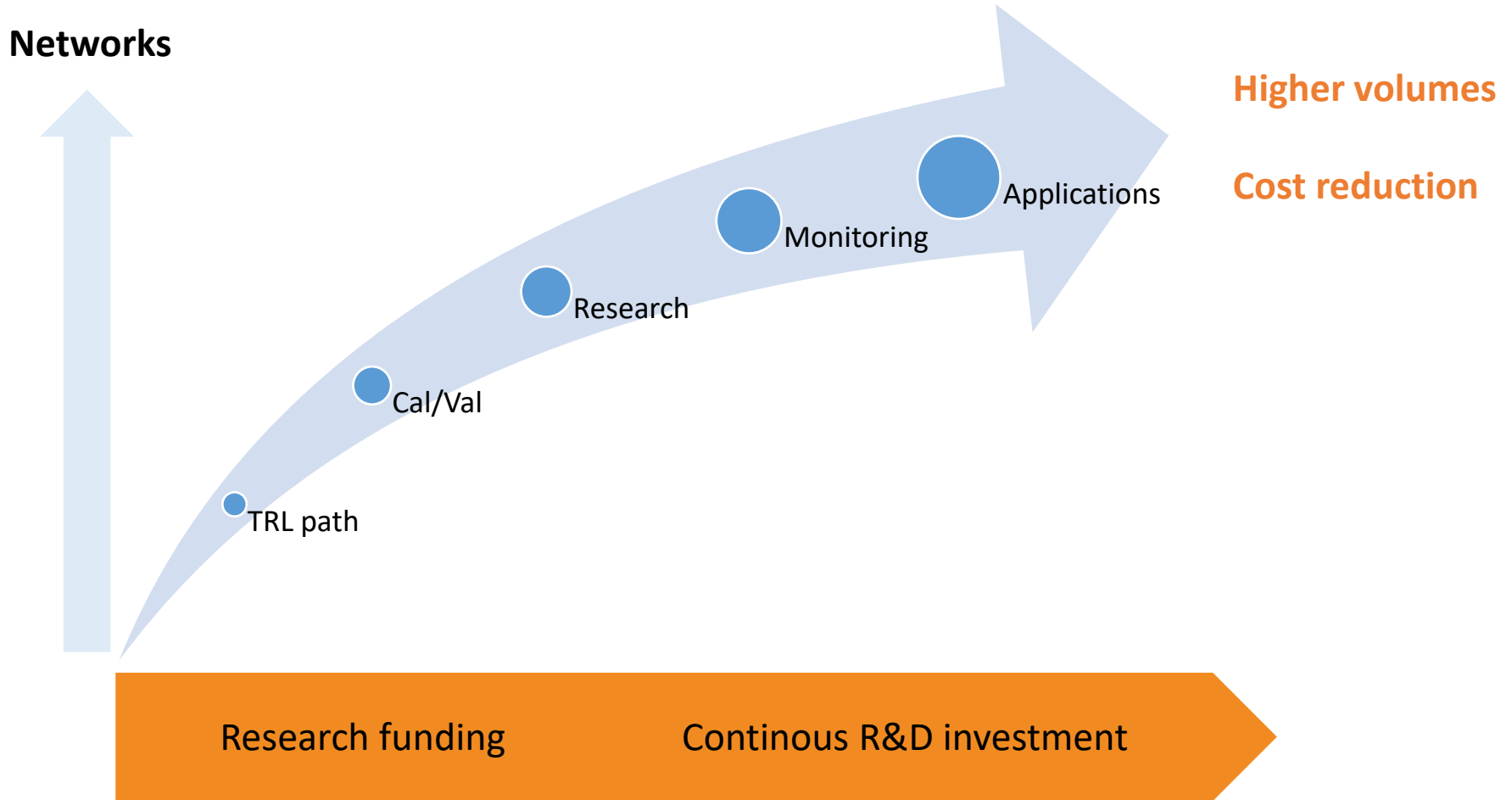
# Ground based remote sensing

## Antithetical exigences

Research	Monitoring
State-of-the-art	Operational
Innovation	Continuity
Hi-Tech	Cost efficient
Up-to-date	Long life
Customized	Standardized

# Ground based remote sensing

A long and uncertain journey towards « democratization »



# The challenge

Technological instrumental progress must be leveraged both towards innovation and “democratization”

The AERONET network is at the junction.

**The history of the CE318 photometer shows that it is possible !**



# CIMEL'S MANUFACTURER MISSION



# THE **PURPOSE** OF OUR ACTION

Measuring the Earth's **atmosphere** and **surface** for a sustainable world



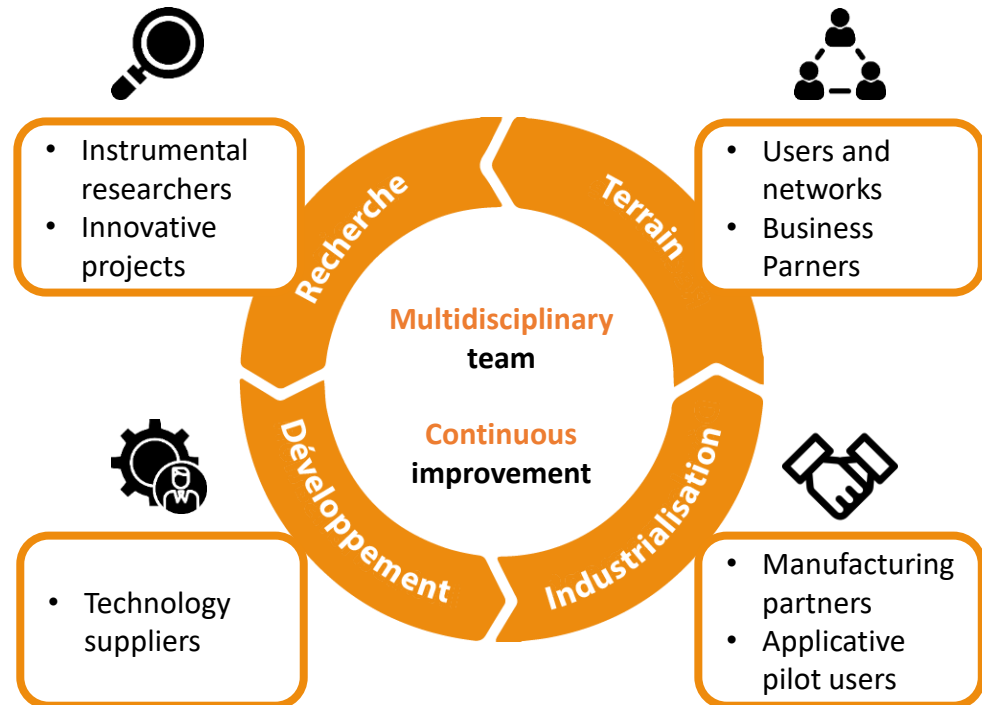
Combining technology with science,  
CIMEL creates **optical remote sensing instruments** for the atmosphere and surface  
that help understand the Earth system and adapt human activities to the environment.

30 people

> 50 years experience

# How we do it

- **Nurture partnerships**
  - With researchers, suppliers, users
  - Support users and learn from feedbacks
- **Reinforce internal competences**
  - Master the full product life cycle
  - Build the full palet of competencies
- **Continuous improvement**
  - Technological watch and innovation
  - Build confidence through transparency
- **Long term engagement**
  - Follow product lines
  - Capitalize the know-how



# Product life management process

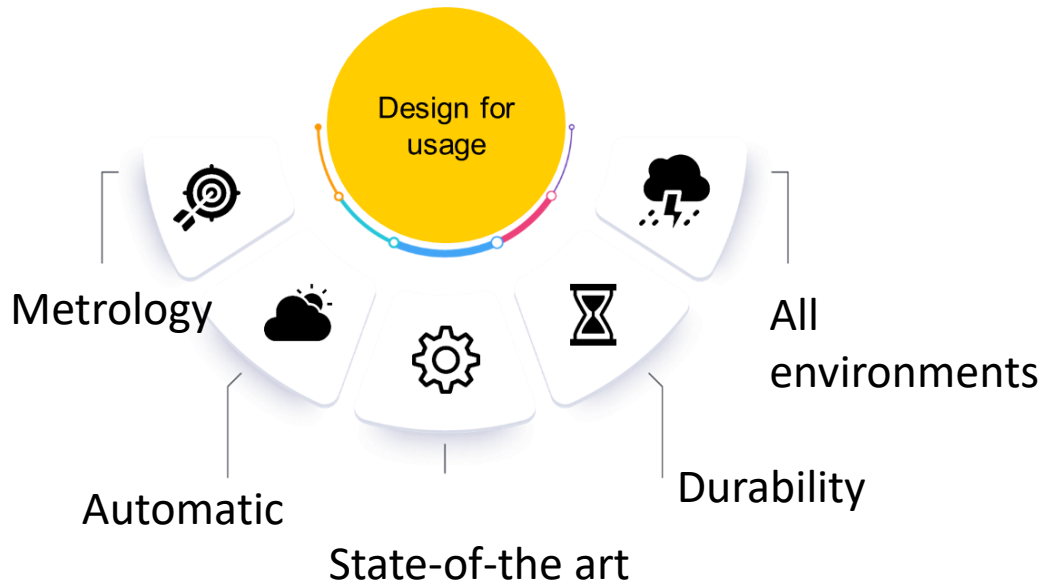
## Transversal organization

Long term commitment

Life Cycle	Scientific	Product Mgmt	Technical	Production	Marketing
Research	Dark Orange	Light Blue	Light Blue	Light Blue	Light Blue
Product definition	Light Orange	Dark Orange	Light Orange	Light Orange	Light Orange
Prototyping	Light Orange	Light Blue	Dark Orange	Light Orange	Light Blue
Scientific validation	Dark Orange	Light Blue	Light Orange	Light Blue	Light Blue
Industrialization	Light Blue	Light Orange	Dark Orange	Light Orange	Light Blue
Production	Light Blue	Light Blue	Light Blue	Dark Orange	Light Orange
Commercialization	Light Blue	Light Orange	Light Blue	Light Blue	Dark Orange
Commissioning	Light Blue	Light Blue	Light Blue	Light Orange	Dark Orange
Technical support	Light Orange	Light Blue	Light Orange	Light Orange	Dark Orange
Maintenance	Light Blue	Light Blue	Light Orange	Dark Orange	Light Orange

# Integrate all constraints in design

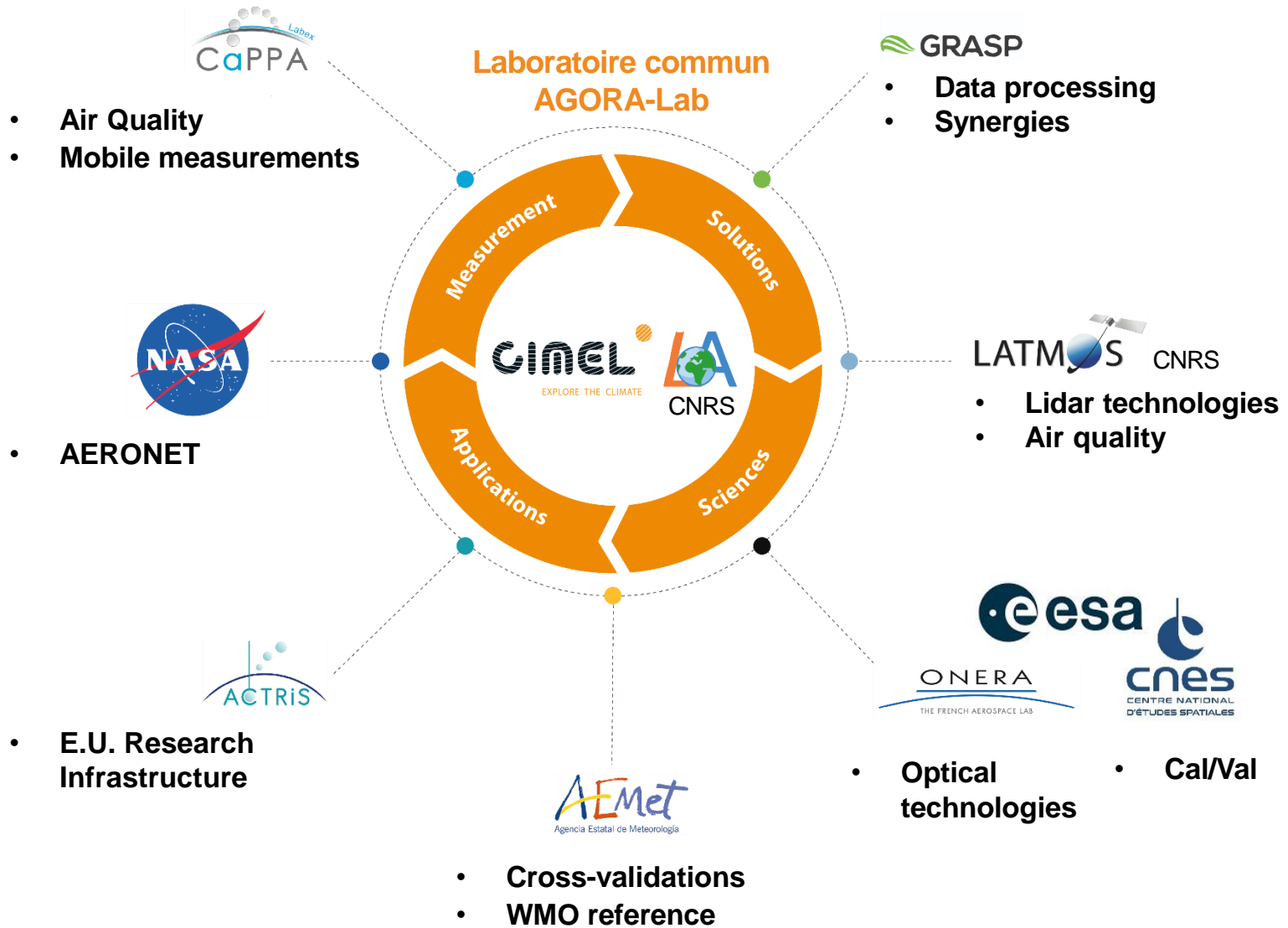
- Initial design



- Long term follow-up

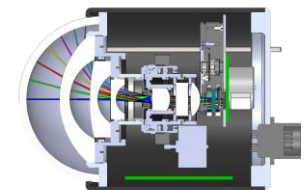
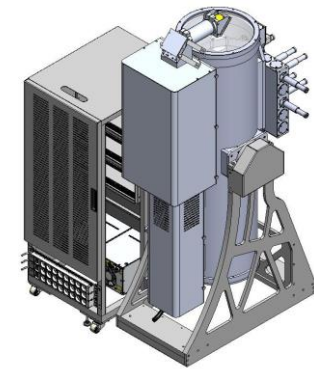
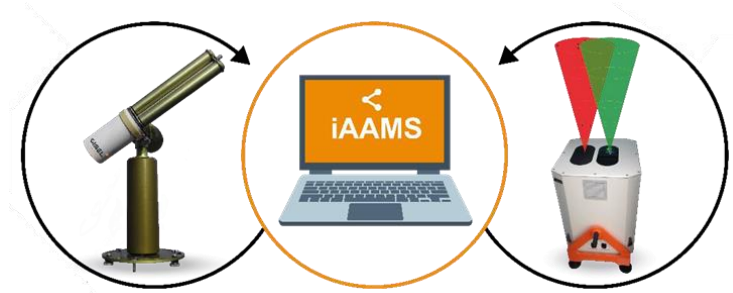
- Ensure retro-compatibility of evolutions
- Easy on site maintenance and up-grades
- Ensure spare parts availability

# RELY ON A STRONG ECOSYSTEM



# CIMEL'S OFFER

- A range of commercial solutions
  - Dedicated to both research and monitoring
  - Synergistic software
  - Free remote support
  - Constantly improving with technology
- Specific developments
  - New applications of existing products
  - Development of prototypes



# THE CE318-T PHOTOMETER





# THE CE318-T PHOTOMETER

## CE318-T Sun-Sky-Lunar



Aerosol quantification (AOD)



Atmospheric analysis & climate studies



Satellite calibration & data validation



Site validation of solar power plants

Day and night AOD measurements

Complementary to the LiDAR

Fully autonomous & user-friendly

Harsh environmental conditions

Customisable (filters, scenarios...)

## Several models

- TS9: Standard
- TP9: Polarised
- TV12: Ocean and Lake Color (12 filters)
- TU12: "BRDF" (12 filters)
- TL9: Laser communications with satellites
- Heating option for very cold weather

# The CE318-T: improvements

- Lunar measurements at nighttime (from 1<sup>st</sup> to 3<sup>rd</sup> quarter)
- Hybrid scenario (Sky) → more scattering angles
- Polarization angles characterized in factory
  
- Improved electronic stability of the high gain
- Improved electronic stability of dark signal
- Gain ratios controlled in factory
  
- Virtually unlimited data storage
- Telecom 2G/GPRS/3G/4G + Internet link (FTP/HTTPS)
- LAN connection : converter serial/IP
- GPS : automatic time and location
- Custom launching of standard scenarios from a script on a PC
  
- Low power : on solar panel (continuity, campaigns and isolated sites)
- Resistance to aggressive environment (marine)

# The CE318-T: 10 years already and **more to come !** > **600** photometers manufactured

- Parts are no longer available for previous versions
- Cooperation with Aeronet : NASA and LOA
  - Technical meetings : REX, issue solving, improvements, research, information sharing, prioritization of evolutions
- Improvements to come
  - Improved connectics and cables robustness
  - Initial temperature dependance calibration at factory
  - New long life rain detector
  - Possibility of simultaneous transfer to AERONET and to iAAMS (GRASP)
- On-going research
  - FOV characterization for vicarious calibration
  - Mobile version (ship and airborne/PLASMA) (LOA)
    - ➔ *see B. Torres' presentation*
  - UV extension (NASA, ESA ?)
  - Aerosol profiling (NASA)

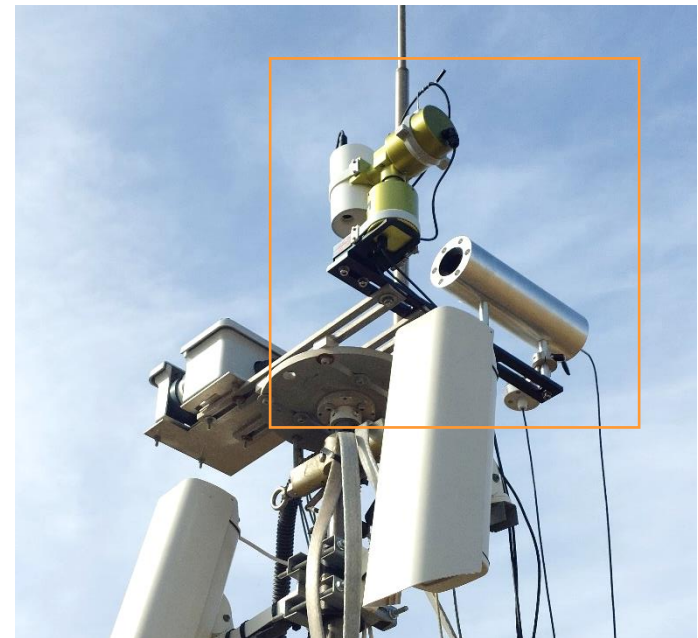
# CIMEL'S CURRENT RANGE OF INSTRUMENTS



# CE312 Thermal Infrared Radiometer

- Only commercial multi-spectral TIR radiometer
  - New model with memory and 4G communication
- Applications:
  - Cal/Val of land, water, aerosols, clouds

➔ New robotised solution developed for the CNES



*CE312 robotised - Prototype at La Crau for CNES*

# Automatic aerosol LiDAR – CE376



## Micro-pulse LiDAR

- 2 wavelengths
- Polarization (532)
- Eye-safe
- Compact
- Robust for mobility
- Real time & continuous

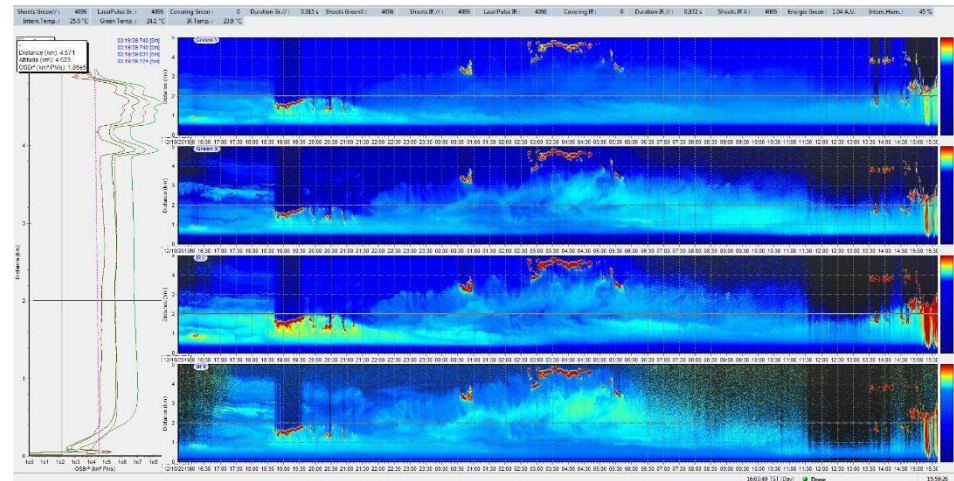
## Technical specifications

<b>Laser</b>	Green: frequency doubled Nd:YAG NIR: pulsed laser diode
<b>Wavelengths</b>	Green: 532 nm NIR < 850 nm
<b>Temperature</b>	+15°C to +25°C without thermal enclosure -20°C to +45°C with thermal enclosure
<b>Dimensions</b>	710 x 450 x 650 mm
<b>Weight</b>	35 kg

## Up to 12 km by daytime

## Applications

- ✓ Research
- ✓ Meteorology
- ✓ Air Quality
  - Natural sources
  - Urban pollution
  - Industrial sites monitoring

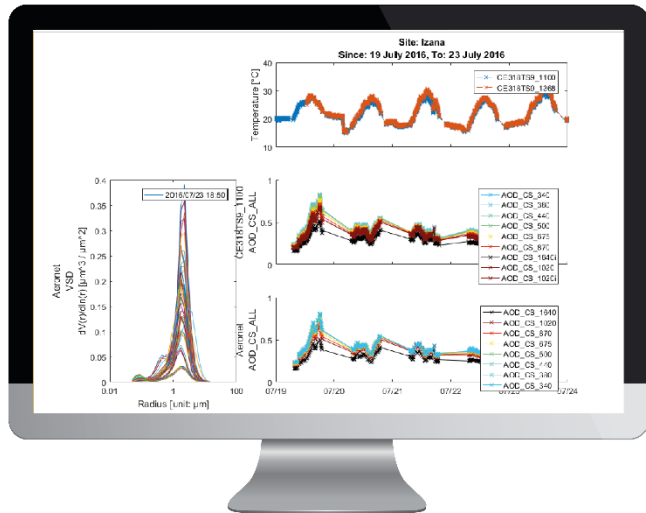
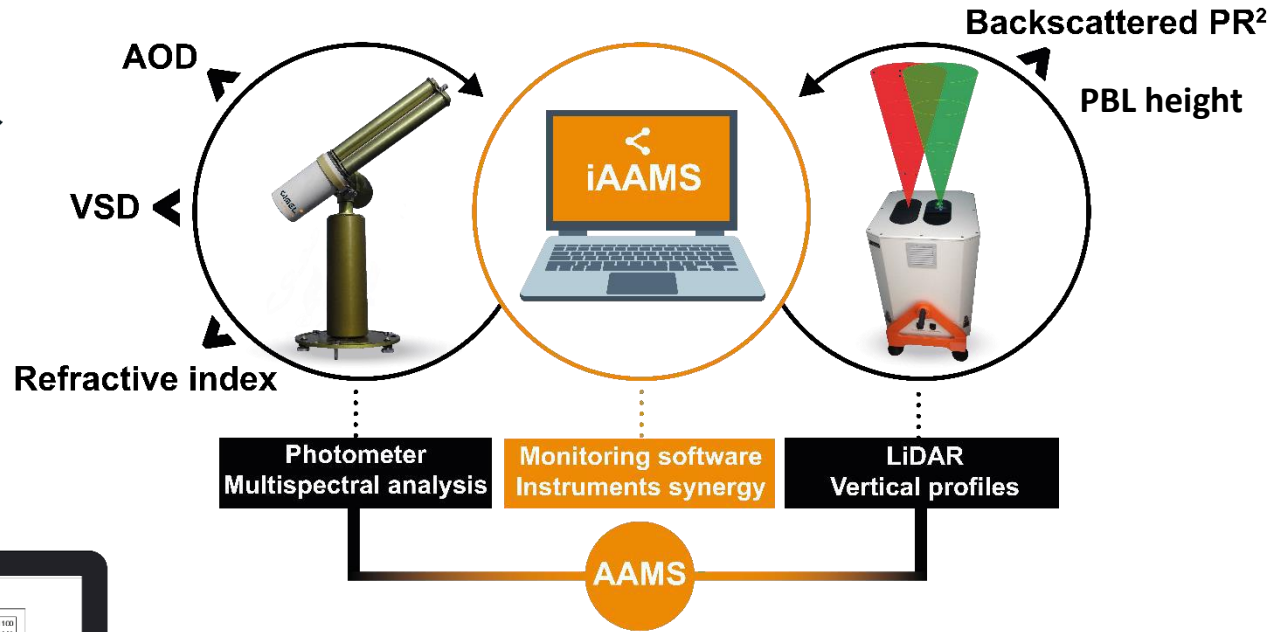


Aerosol vertical profile quicklook (PR2) - iAAMS monitoring software

# AAMS Complete Solution

## AAMS: Automatic Aerosols Monitoring System

- Continuous measurement (Day & Night)
- Real time data analysis
- Automatic & integrated system
- Easy to install / Mobile
- Turnkey solution

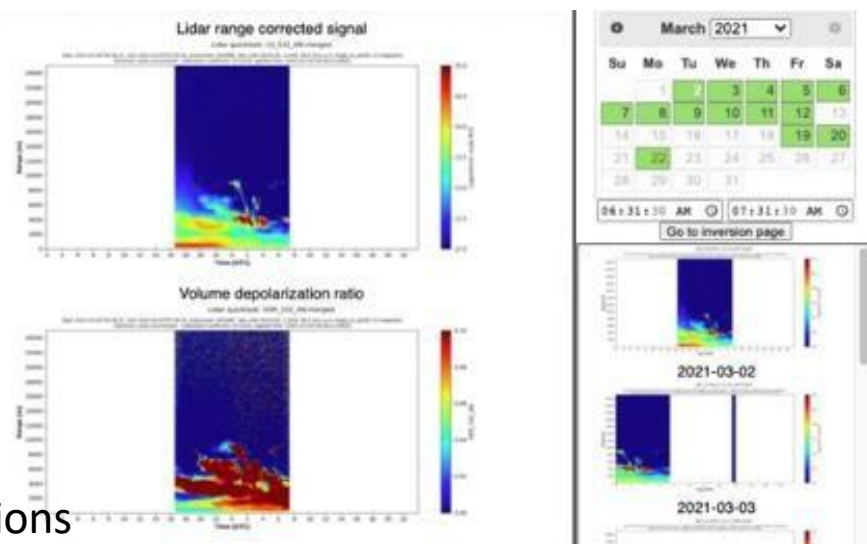
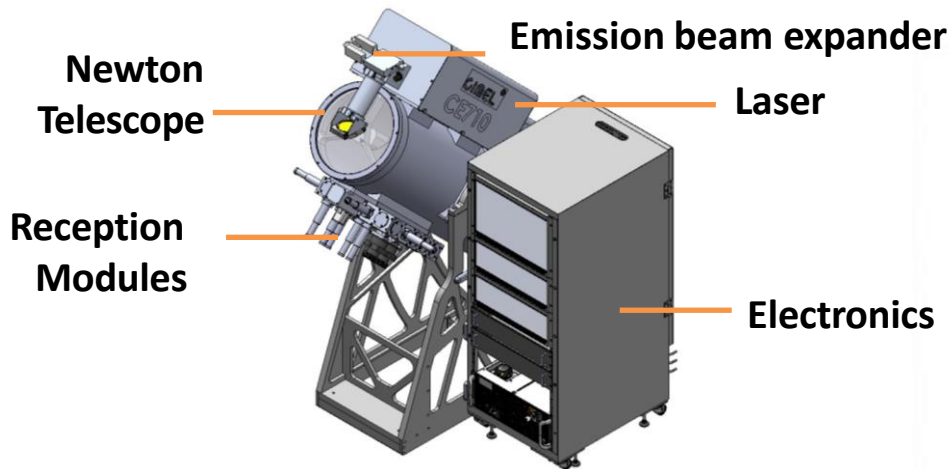


- Characterisation of aerosols types
  - Extinction & Backscatter profiles
  - Vertical profile of Mass concentration
- Integrating GRASP inside*



# High Power Mie-Raman Fluorescence LiDAR - CE710

*AUSTRAL processing*



*Developed by LOA in AGORA-Lab*

- Fully Modular System for all specific applications
- Multi-channel (up to 15 depending on lasers and wavelengths)
- Automatic operation and calibrations
- Telescope: 40 cm diameter
- Depolarization options: 355, 532 and 1064 nm
- Enhanced Fluorescence capabilities
- Height resolution : 3.75 - 15 m / Time resolution: 10-30 s

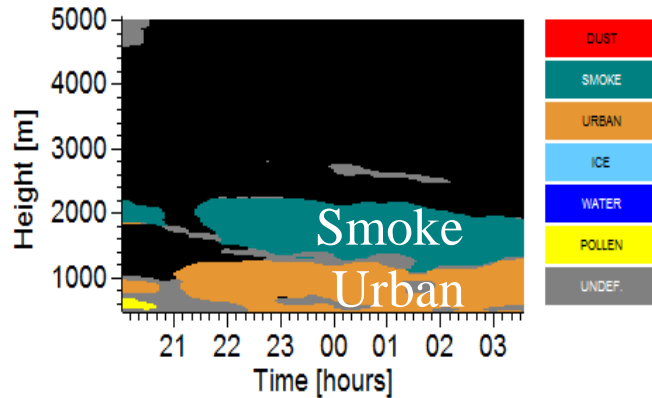




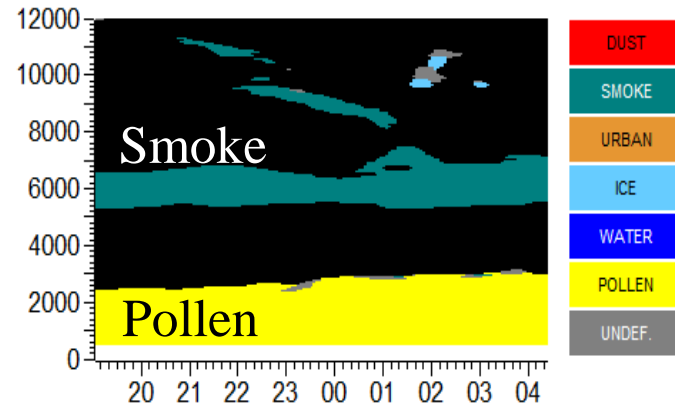
# Classification of aerosol types

→ Distinctive fluorescence signatures, unique to different types of aerosols, facilitate selective detection and discrimination.

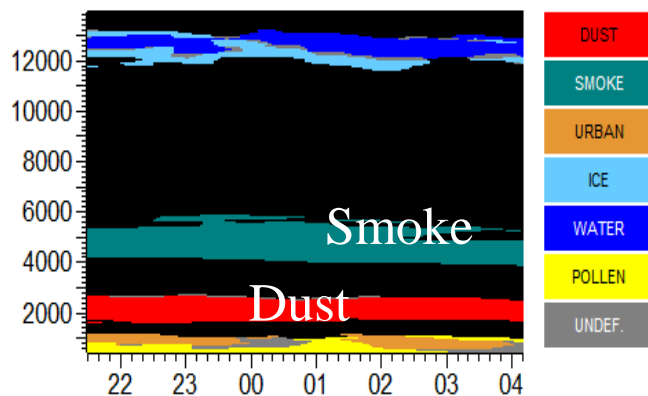
11 August 2021. Smoke and Urban



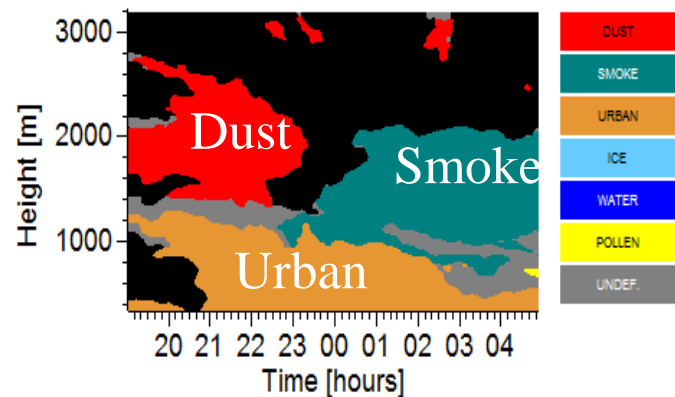
14 September 2020. Smoke and Pollen



7 September 2021. Smoke and Dust



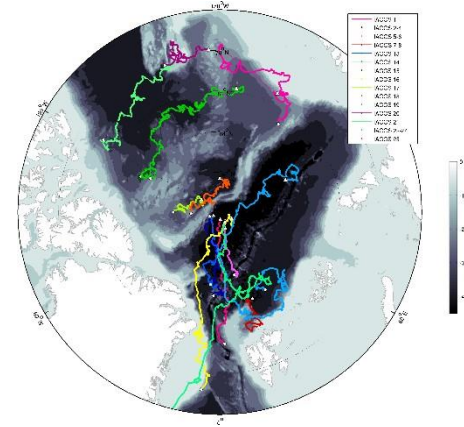
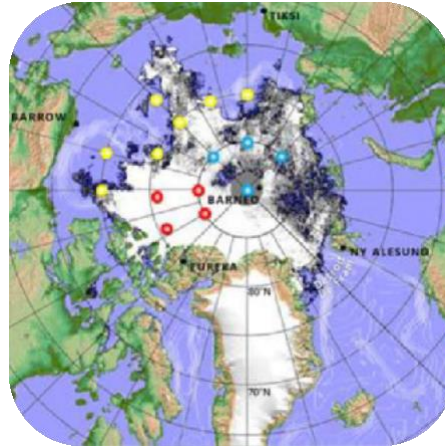
27 March 2022. Three types of aerosol



# Some custom developments



# IAOOS project: arctic micro-LiDARs



→ Development of an integrated floating system collecting real-time observations of the ocean, ice, snow and atmosphere in the Arctic area

## CIMEL's challenges

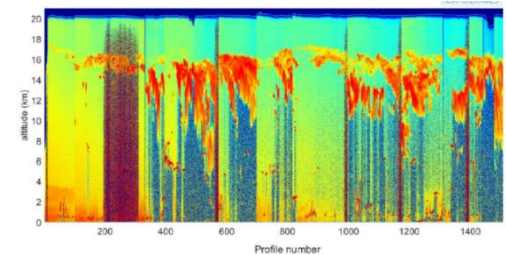
- Miniaturization of LiDAR
- Autonomous for 2 years on batteries (No solar panel)
- Harsh environmental conditions
- Very low power consumption (10 W)
- Up to 3 km range



- Integration of the Lidar on the multi-instrumented buoys
- Deployment of a network of 20 floating platforms

# BeCOOL: Micro-LiDAR below a stratospheric balloon

- Objective: measure cloud top heights in the tropics
  - CIMEL's challenges
    - Harsh environmental conditions
    - Micro-pulse LiDAR under 7 kg
    - Up to 22 km altitude
- ➔ Already several successful flights of a few months



# OUR UPCOMING CHALLENGES



# Hyperspectral photometer



- Objective: high resolution from 350 to 2500 nm
  - Application: Cal/Val of land and ocean
- Approach: 3 lines (incl. extended NIR)
  - Breakthrough : detectors and design for metrological stability
- Collaboration
  - Spectrometer manufacturer
  - CNES: Cal/Val prototype
  - ESA: advanced resolution

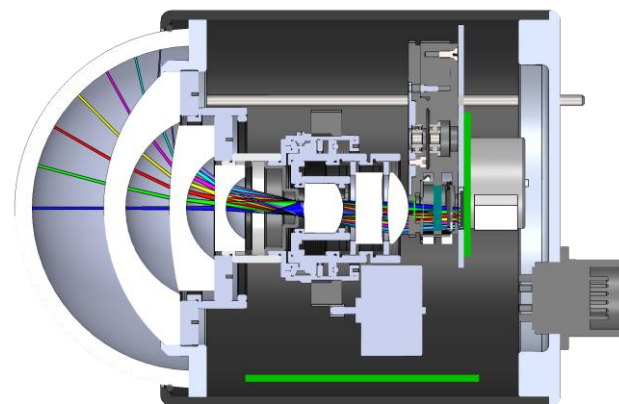


➔ Prototype test at La Crau in S1 2025 (TRL 6)

# Multispectral Hemispherical Radiometric Camera

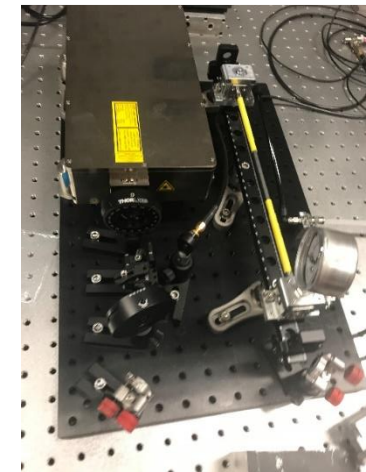
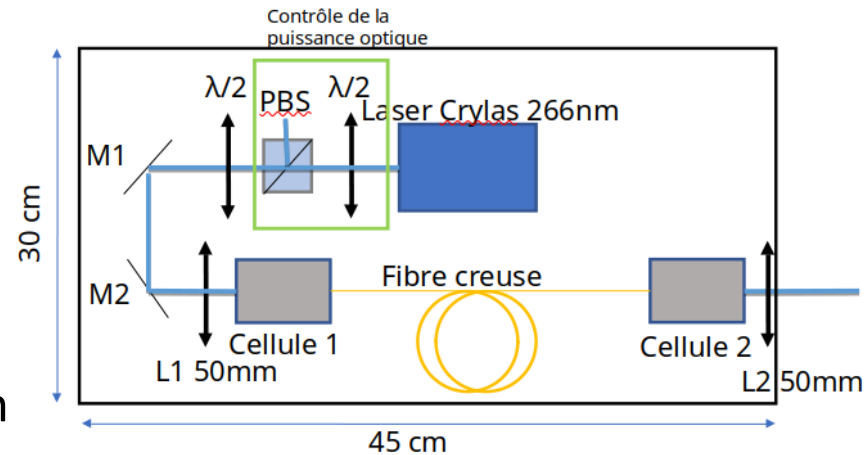


- Objective: Aerial/submarine, mobile, cost-efficient
    - Applications:
      - CalVal for land, water, aerosol, cloud masks
      - Earth Energy balance
      - Air quality, Night pollution
  - Approach: Filter wheel camera
    - Breakthrough: thermal stability
  - Collaboration
    - JRC Marine Optical Laboratory: metrological characterization
    - Cal/Val campaigns: tests
- ➔ Cal/Val tests on prototype in S2 2025 (TRL 6)



# Ozone Micro-LiDAR

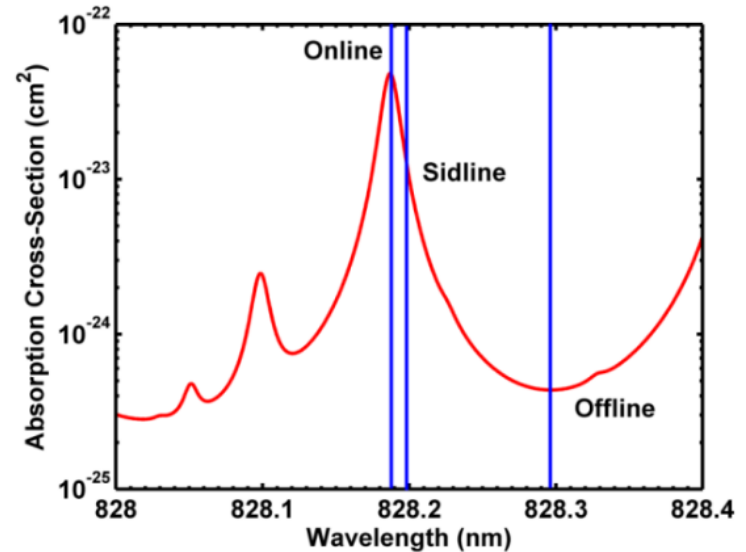
- Objective : Ozone LiDAR for monitoring networks
    - Application : air quality monitoring and forecasting
  - Approach : DIAL 266 -289 nm
    - ➔ Breakthrough : UV source at 289 nm
  - Collaborations
    - Manufacturer of UV source
    - LATMOS : data processing
- ➔ LiDAR POC in S1 2025 (TRL 3)





# Water Vapor Micro-LiDAR

- Objective : WV LiDAR for operational networks
    - Application : meteorology, prediction of heavy rains
  - Approach : DIAL at 828 nm
    - ➔ Breakthrough: powerful NIR source
  - Collaborations (Paris)
    - LCF: source technology
    - LATMOS: data processing
- ➔ LiDAR POC in 2024 (TRL 3)



# CH4/CO2 Hyperspectral radiometer

- Objective : Affordable Cal/val of Total Column

- Application:

- Quantification of GHG emissions sources and sinks
    - Cost efficient extension of Cal/Val network

- Approach: very high resolution spectro-radiometer

- ➔ Breakthrough: new ultra-fine detection technology

- Collaboration

- Manufacturer of detection technology

- ➔ Theoretical concept validation in 2024 (TRL 2)



# CONCLUSION

# Takeaway

- **Ground-based Remote Sensing**
  - A crucial link for numerous synergies in data processing
  - New technologies should be harnessed from innovation towards « democratization »
- **CIMEL**
  - We develop a range of commercial instruments and synergistic solutions for both research and monitoring
  - **AERONET-CIMEL long-term cooperation is the emblematic example of succesful technological evolution over >30 years**
  - We welcome innovative projects for future instruments !
- **We need your feedbacks on your needs, expectations and user experience on the field**
  - ➔ *Please contact me or Stéphane Victori, head of Scientific Department*