Optical measurements of atmospheric properties by CMAX-DOAS and LIDAR at Concepcion, Chile

Rodrigo Fuentes-Inzunza[(1),*], E. Montilla-Rosero [(1)], A. Silva[(1),(4)], C. Jiménez[,(3)], Rolando Hernández[1,2] and Carlos Saavedra[1,2]

[1] Center for Optics and Photonics, Universidad de Concepción, Casilla 4016, Concepción, Chile.

[2] Departamento de Física, Universidad de Concepción, Casilla 160-C, Concepción, Chile.

[3] Now at, Leipzig, Germany.

[4] Now at Universidad de la Frontera, Temuco, Chile.

[*] email: *rodrigo.fuentes@cefop.udec.cl*

Outline

1.- Instrumentations: CEFOP (UdeC) LALINET station

- Sunphotometer AERONET
- LIDAR System
- DOAS System

2.- CMAX-DOAS Instrument and AMIS acquisition

- Instrument Capabilities.
- The Optical Head and Tripod.
- The Fiber Optics: Five Track Fiber Bundle.
- The Atmospheric Monitoring Image Spectrometer (AMIS)

3.- Retrieval Aerosol Properties from oxygen dimer O_4 Absorption

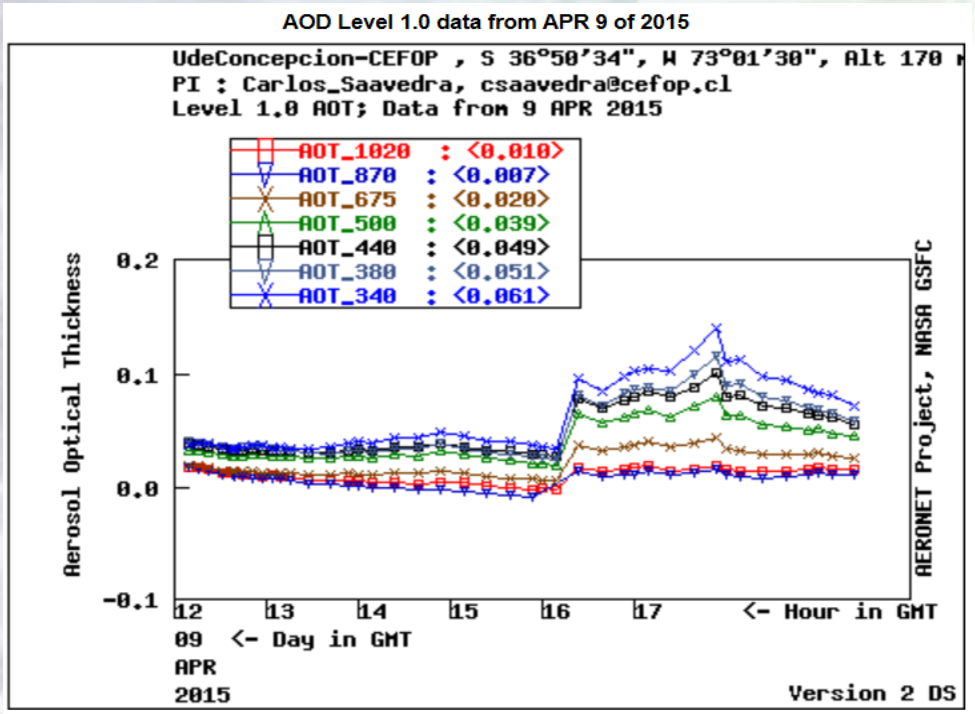
- Molecular identification of trace gases.
- Aerosol optical properties.

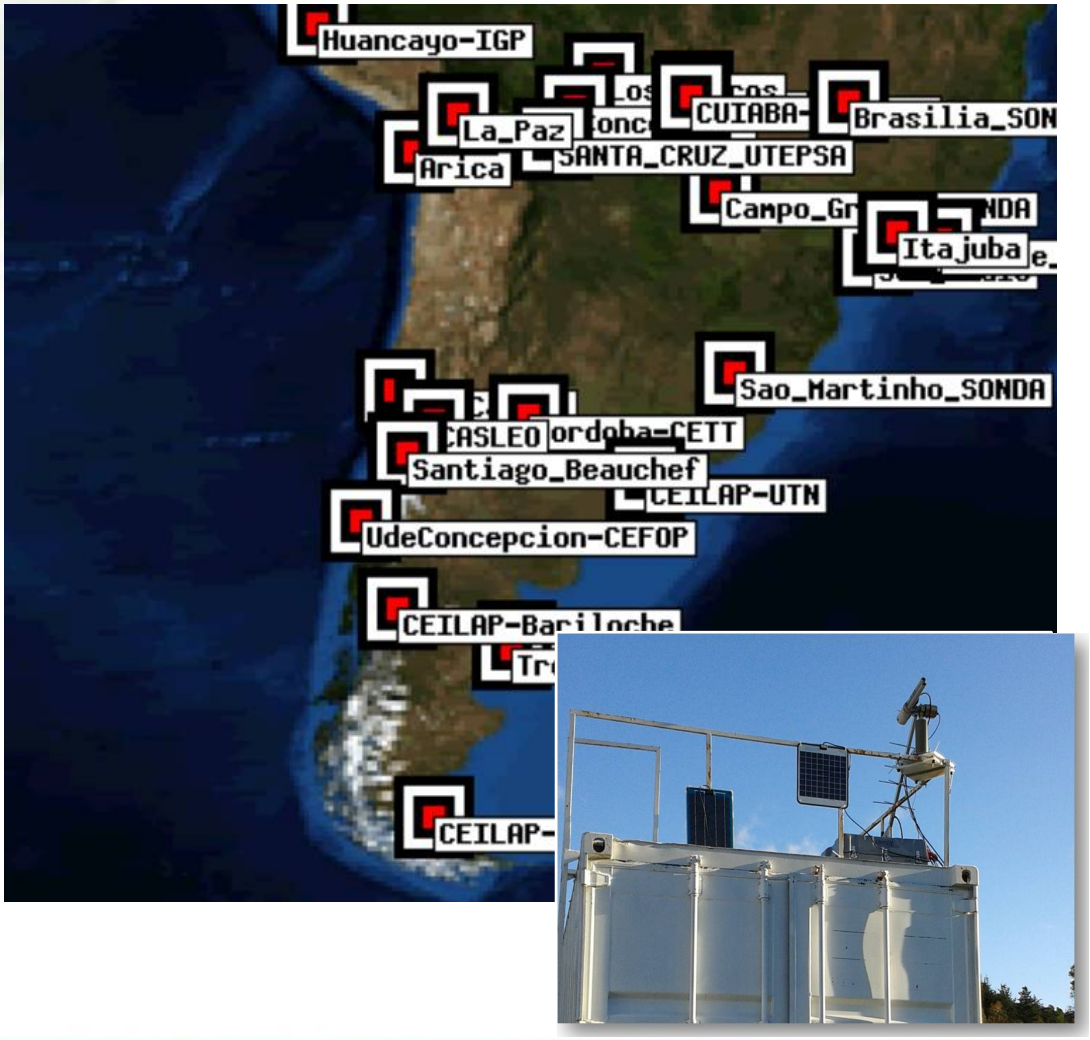

36.82°S, 73.05°W, 170 m.
Pacific Ocean
Concepción
UdeC
LIDAR-CEFOP
Bio Bio River

1.- Instrumentations: CEFOP (UdeC) ALINET station

Emphasis on tropospheric aerosols, water vapor mixing ratio in lower troposphere, trace gases, radiative transference calculation.

Sunphotometer AERONET



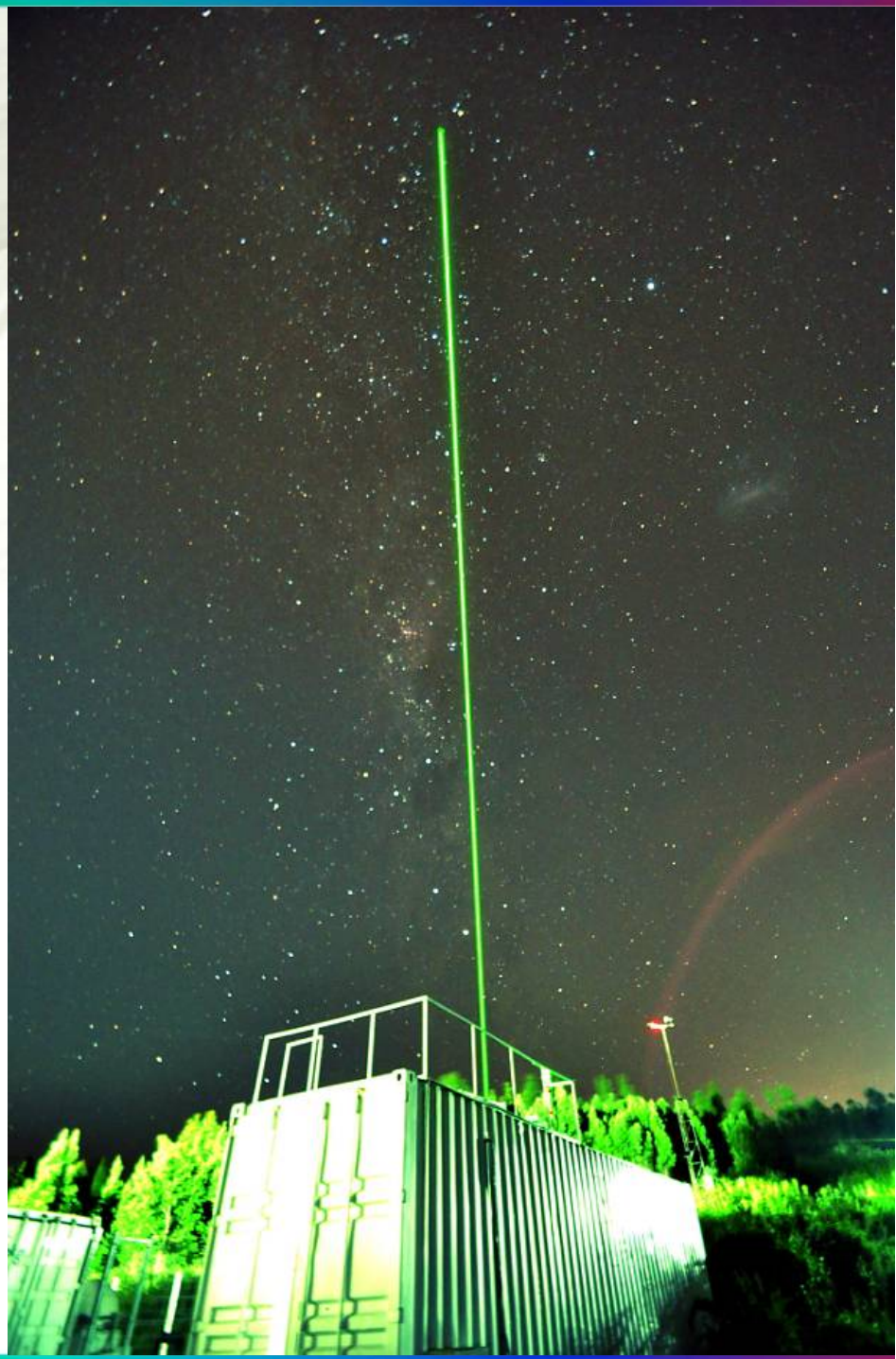


Instrumentations:

Emphasis on tropospheric aerosols, water vapor mixing ratio in lower troposphere, trace gases, RTC.

LIDAR System

Elastic LIDAR
532, 355nm
Raman LIDAR
387, 407nm



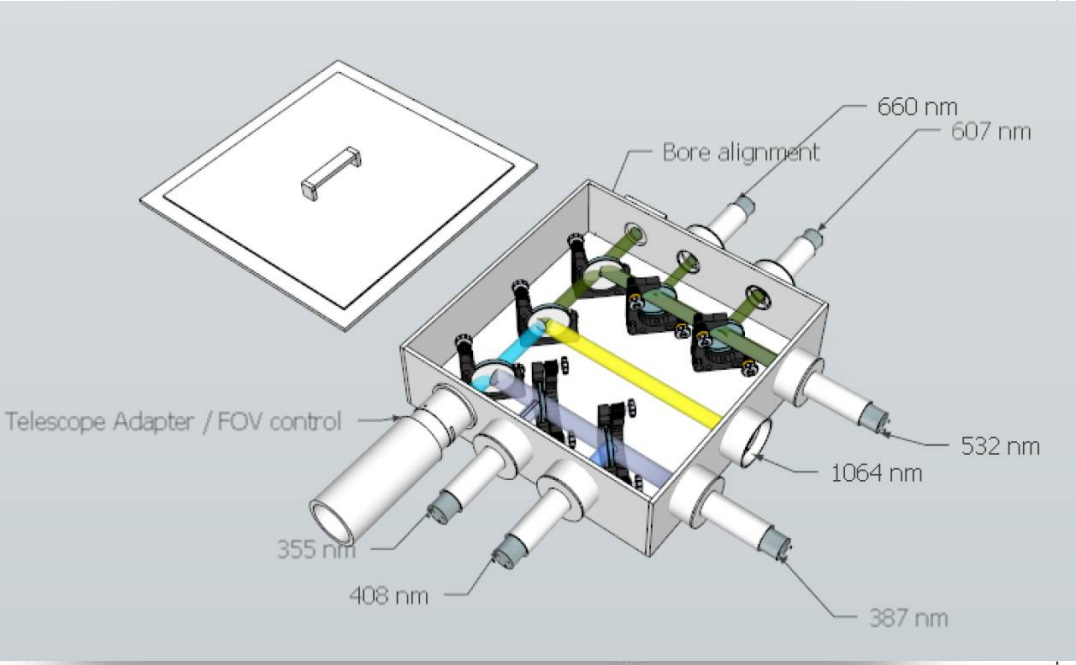
Instrumentations:

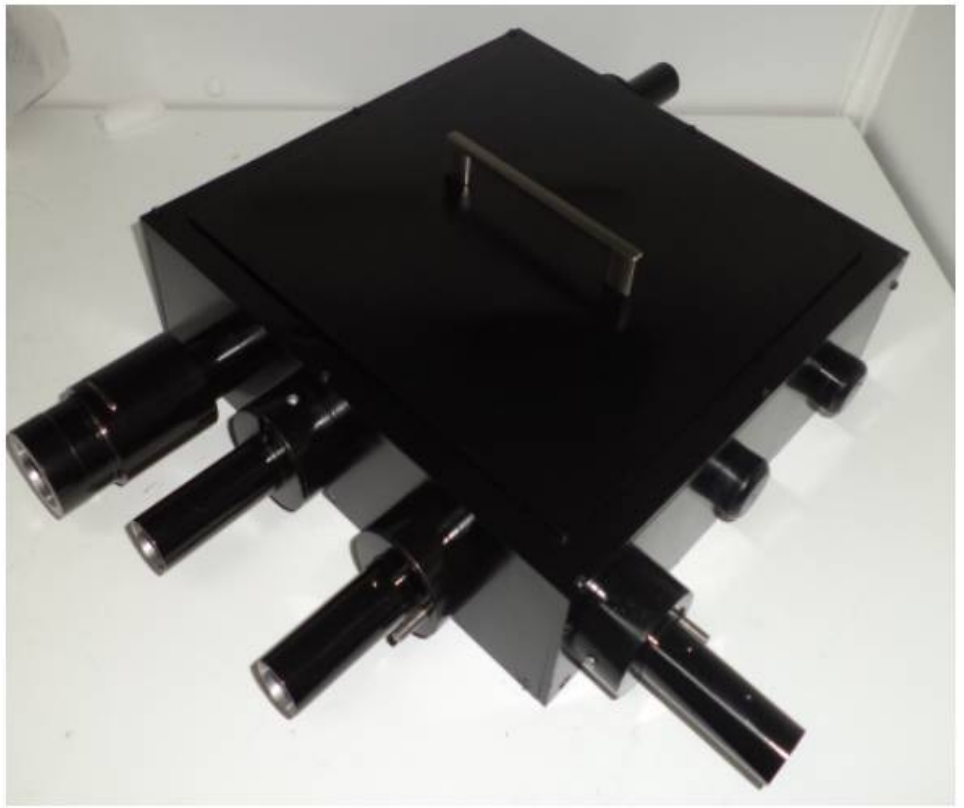
Emphasis on tropospheric aerosols, water vapor mixing ratio in lower troposphere, trace gases, RTC.

DOAS System

Multiple Telescopes
3, 5, 10, 15 y 90 degree

2.- LIDAR – CEFOP System: Polychromator



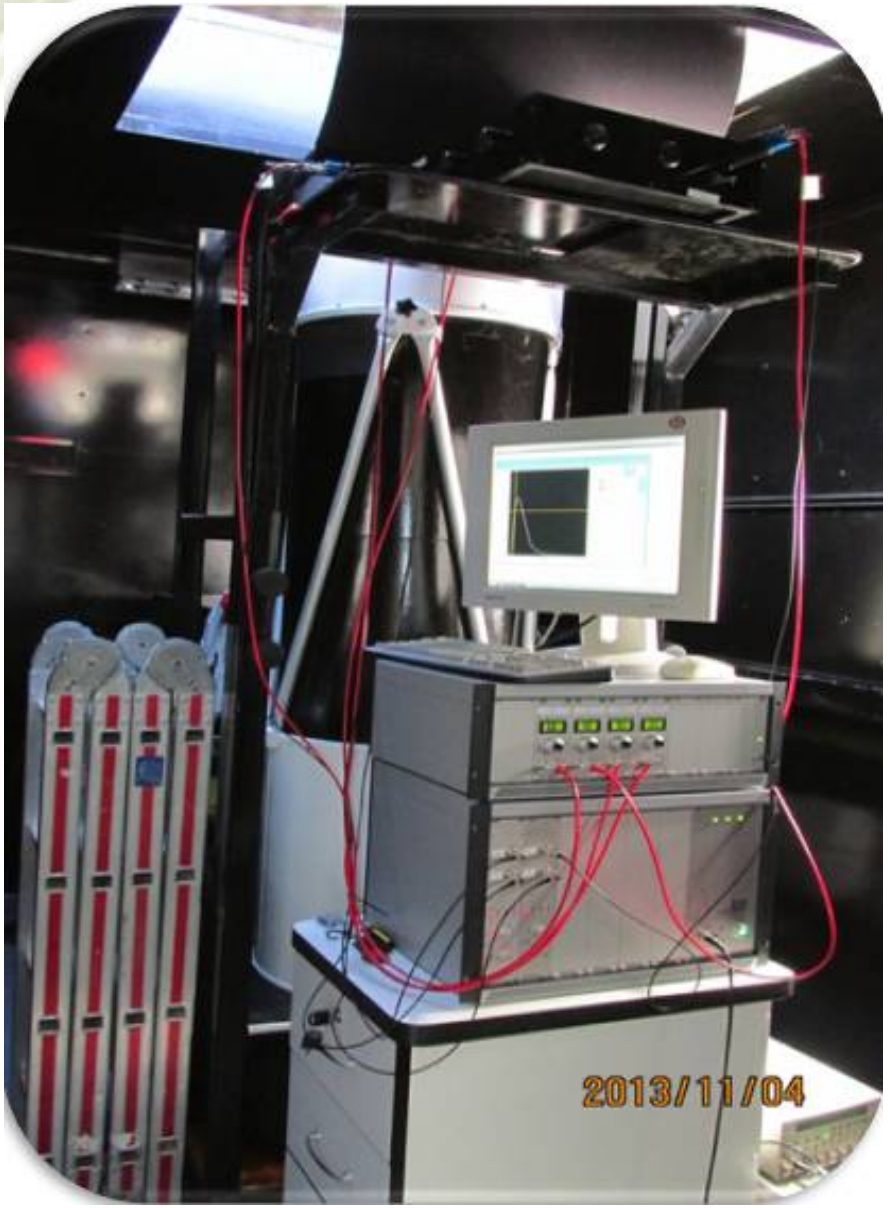


Actually: Elastic 532, 355 nm
Raman 387nm N_2, 407nm H_2O

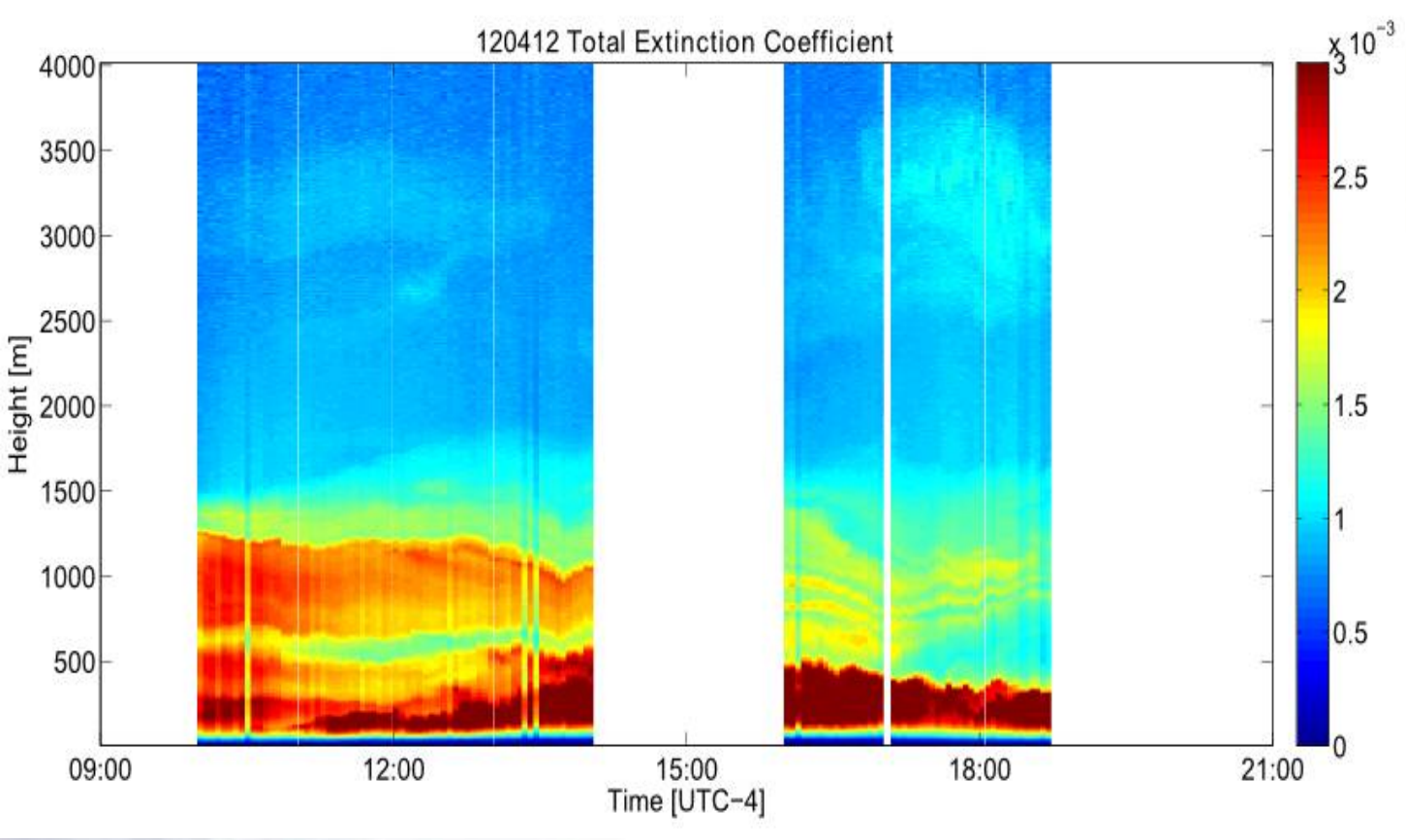
Optical Design
Mr.Sc. Cristofer Jiménez

LIDAR – CEFOP System: Specification

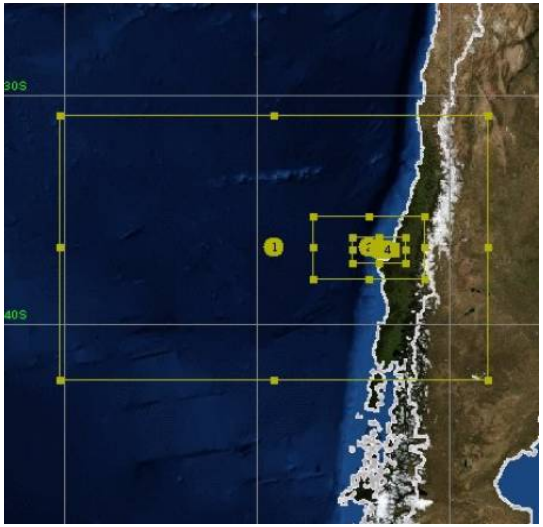
Laser	Q-switched Nd:YAG
Laser wavelengths emitted	1064 nm, 532 nm & 354.7 nm
Maximum energy/pulse	850 mJ (@1064)
	400 mJ (@532)
	185 mJ (@354.7)
Pulse	5 ns; 10 Hz
Telescope type	Newtonian
Focal length	182.9 cm
FOV	1.6 mrad
Detector	PMT (300 -900 nm) 4 channels
Data Acquisition	2 LICEL transient recorder
	20 MHz/12 bit
Range resolution	7.5 m



LIDAR – CEFOP: measurements algorithm reduction



PBL height evolution, Extinction and Backscattering Coefficients

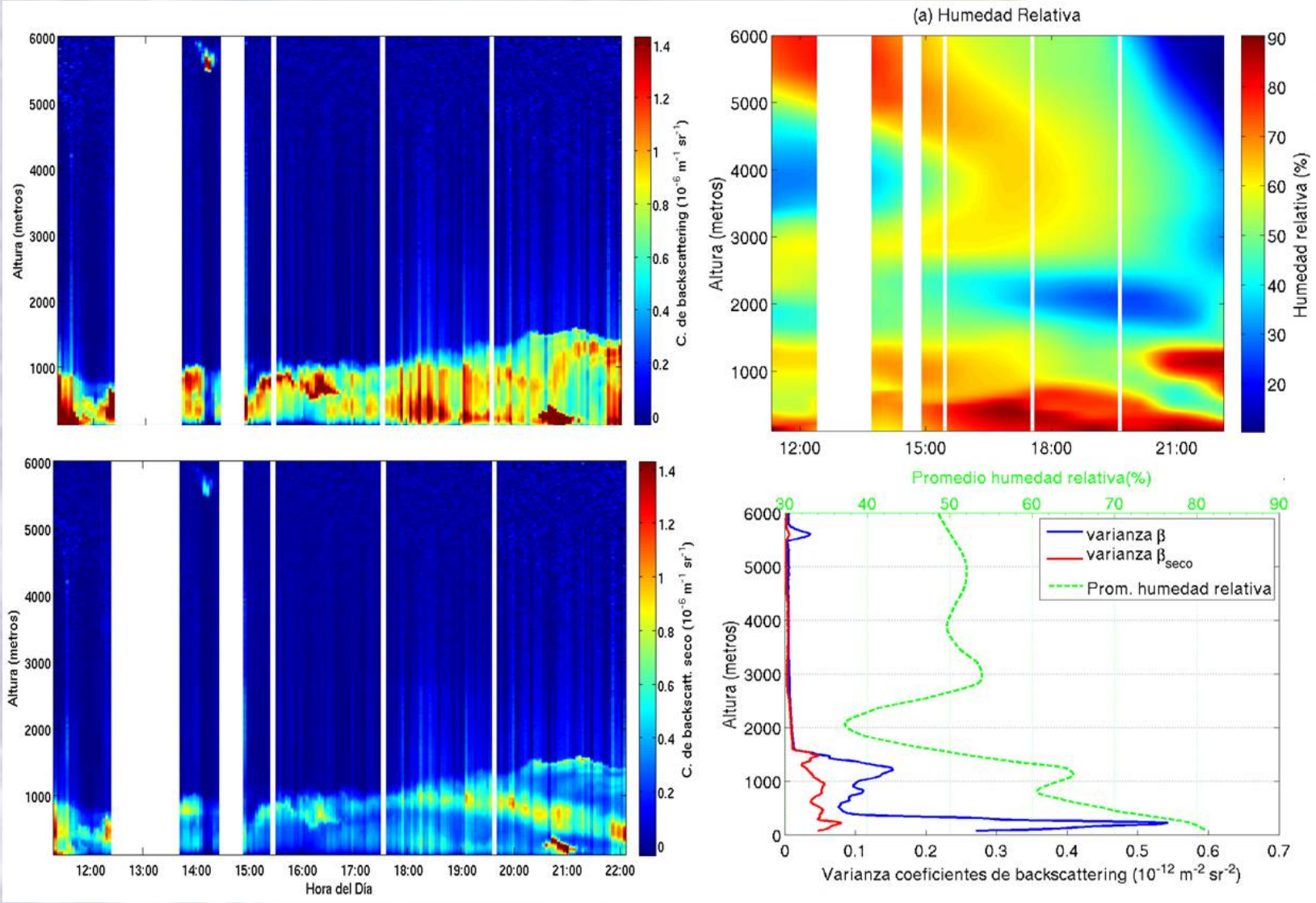


Mesoscale numerical weather prediction model => WRF

Optical Characterization of low tropospheric aerosols by elastics Lidar measurements (Concepción, Chile)

Dra. (C) Antonieta Silva

LIDAR – CEFOP Humidity effect

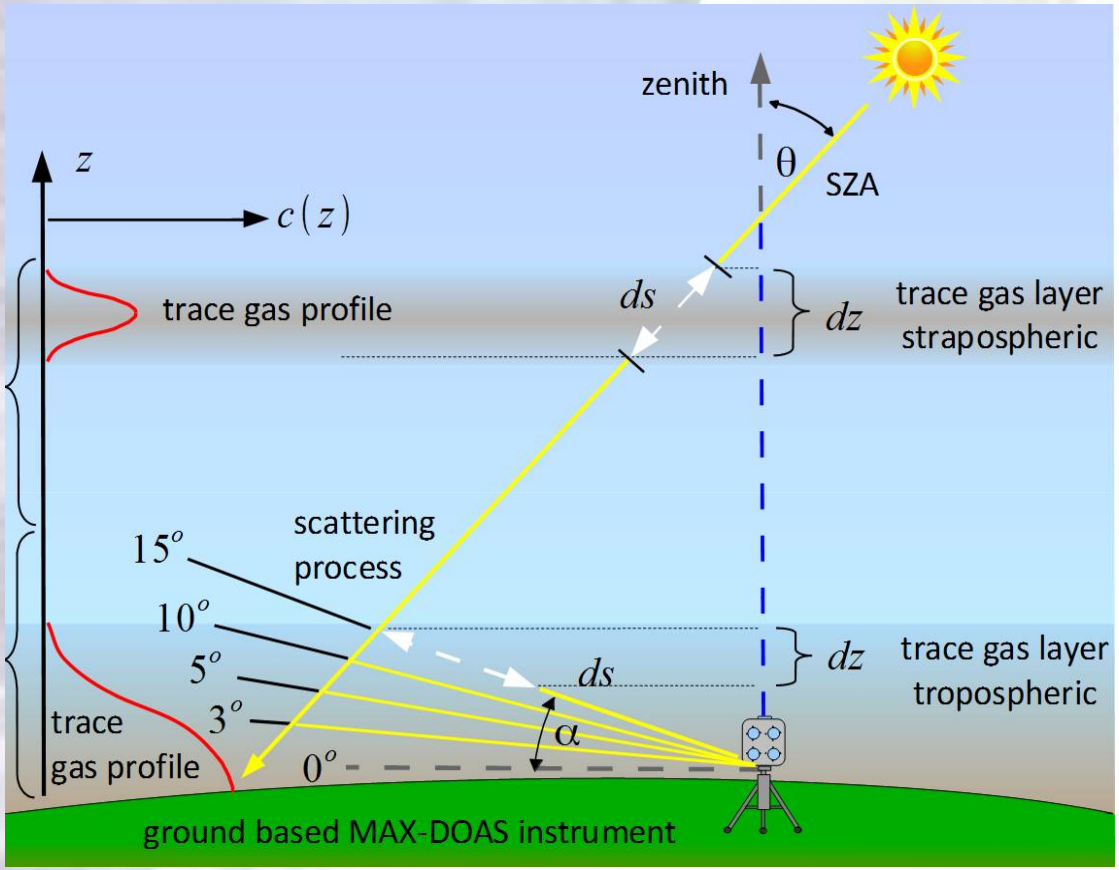


Master Thesis
Sr. C. Jiménez

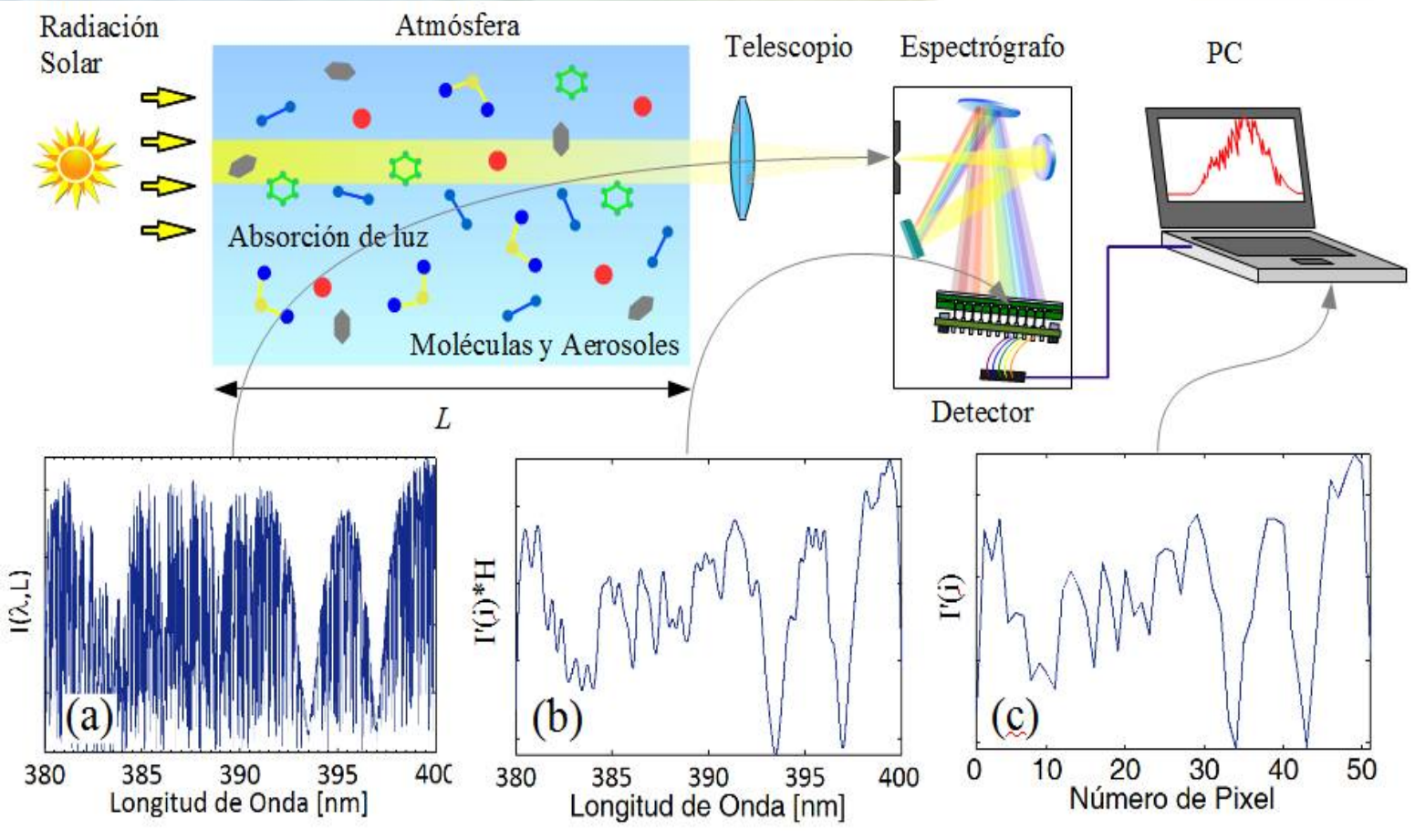
Humidity effect on Aerosol Backscattering coefficient for April 12th, 2012.

DOAS: Differential Optical Absorption Spectroscopy

The MAX-DOAS technique identifies and quantifies the trace gas abundances with narrow band absorption structures in the near UV and visible wavelength region in the open atmosphere using scattered sunlight collected by different viewing directions.



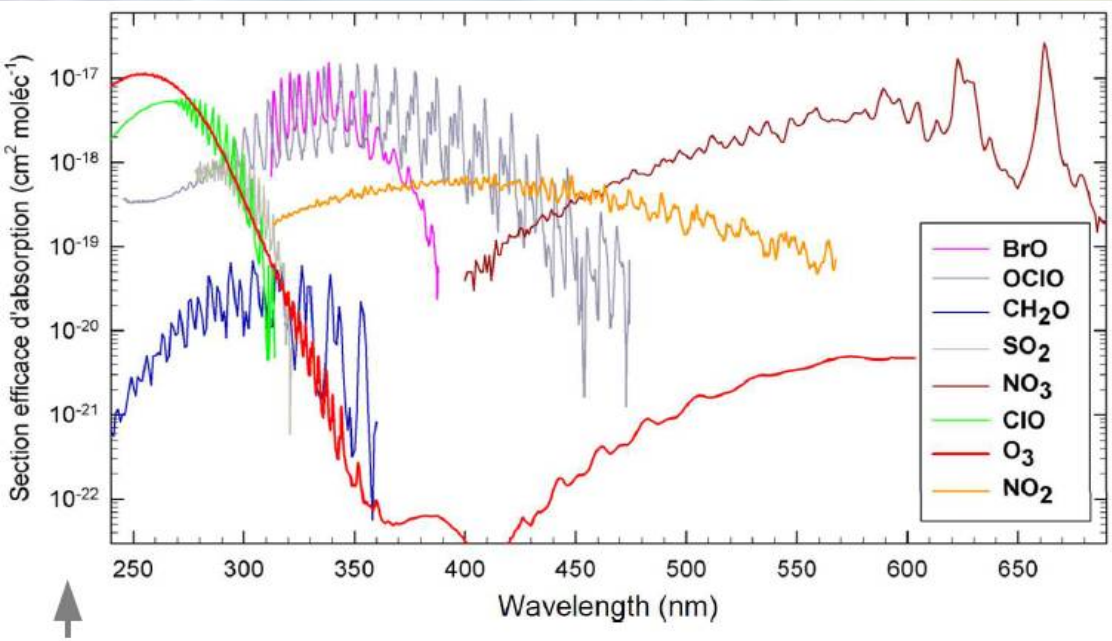
DOAS: Differential Optical Absorption Spectroscopy



Ley de Beer -Lambert para la absorción óptica

$$I(\lambda) = I_0(\lambda) \cdot \exp\left[- L\left(\sum_i \left(\sigma_i(\lambda) c_i\right) + \varepsilon_R(\lambda) + \varepsilon_M(\lambda) \right) \right] \cdot A(\lambda)$$

Pasive DOAS Especies medibles

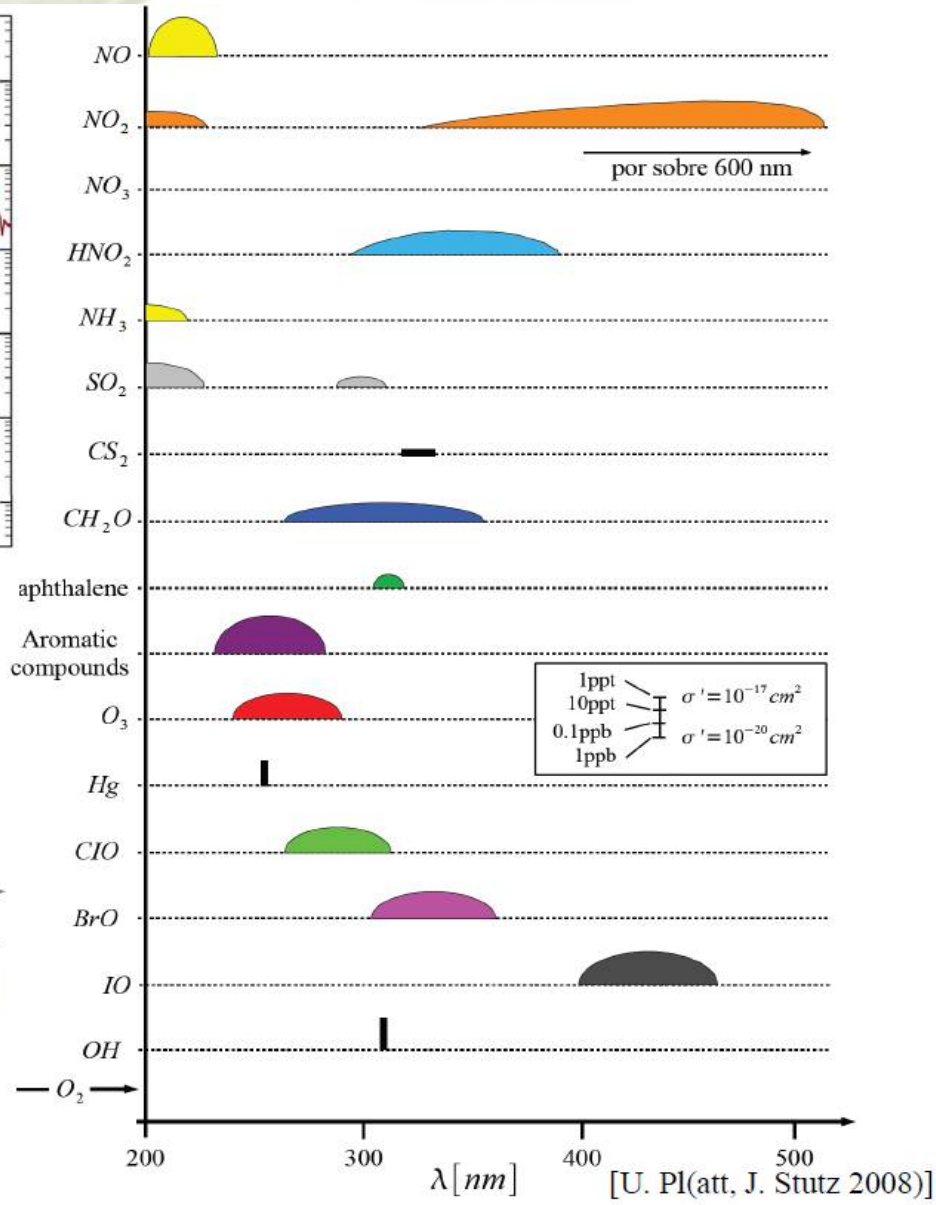


SECCIONES TRANSVERSALES DE ABSORCIÓN

de un número de especies contaminantes presentes en la atmósfera como una función de la longitud de onda [nm]. Note que cada espectro es único para cada especie.

SECCIONES TRANSVERSALES DE ABSORCIÓN →

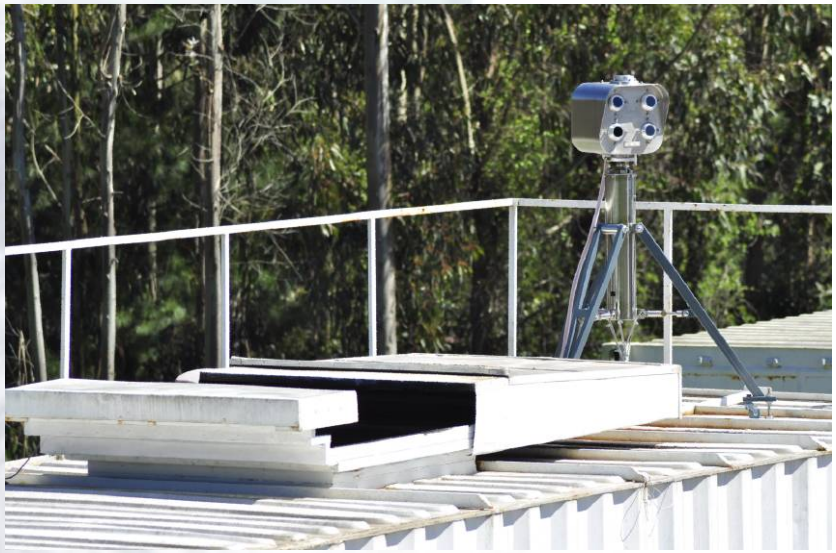
simplificada en el rango espectral UV y visible, útil para la detección de trazas de gases en la tropósfera. La escala vertical para cada especie está dada por el logaritmo de la sección transversal de la molécula entre 10^{-20} a $10^{-17}[cm^2/moléculas]$. También se muestra el límite de detección para una longitud de camino óptico de 10km desde un 1ppt a 1ppb.



[U. Pl(att, J. Stutz 2008)]

CMAX-DOAS: Instrument Capabilities

The CMAX-DOAS (Concurrent Multi-Axis Differential Optical Absorption Spectroscopy) technique identifies and quantifies the trace gas abundances with narrow band absorption structures in the near UV and visible wavelength region in the open atmosphere using scattered sunlight collected by different viewing directions.



Instrument Capabilities:

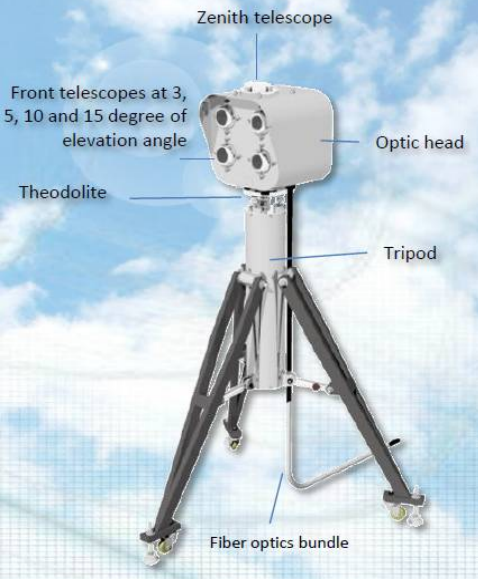
- High sensitivity to measure the total column densities of several trace gases constituents of the troposphere and stratosphere: O3, O4, NO2, NO3, BrO, HCHO, IO, OClO, H2O and others.
- Five simultaneous measurements at different viewing directions, allowing a enhancement of the temporal resolution (typical 30 s).
- Validation of radiative transfer model, measuring the absorption of O4 and H2O. Being possible to recognize cloud, fog and aerosol.
- Inversion methods for the reconstruction of vertical profiles of trace gases and aerosols. AOD aerosol Total Optical Depth, Aerosol extinction Coefficient.
- Easy installation, allowing automation for long periods of time without absolute radiometric calibration and technical assistance.

CMAX-DOAS: Instrument Capabilities

The Optical Head and Tripod.

Optical Head:

- Five refractor telescopes, UV Silica 180-1100 nm, 7 arcmin FOV with external UV Silica flat windows for environmental protection.
- Telescopes pre configured in 3, 5, 10, 15 and 90 of elevation angles.
- Waterproof construction, stainless steel, aluminum, brass
- Accurate leveling theodolite.



Universidad de Concepción

Centro de Óptica y Fotónica

CEFOP - Center for Optic and Photonics
Esteban Iturra St. 6th Floor, Faculty of Physical Sciences and Mathematics,
Universidad de Concepción, Chile
Telephone : 56 - 41 - 2204740.

The Fiber Optics: Five Track Fiber Bundle.

Optical Fiber:

- Five Track Fiber Bundle.
- High UV Silica transmission, 180-1100nm.
- 200um core diameter, NA = 0.22, 8m total length.
- Single SMA connector / Linear array connector with interspace of 1.5 mm.

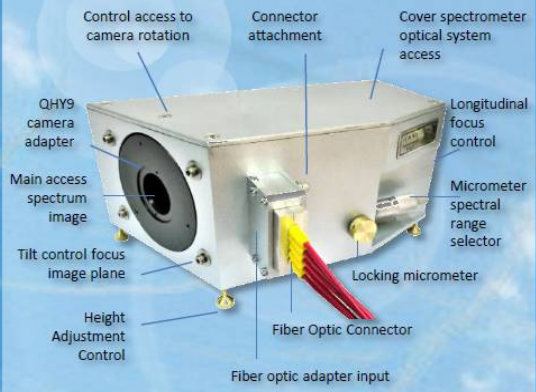
Complete CMAX-DOAS Instrument

CMAX-DOAS

The Atmospheric Monitoring Image Spectrometer

Image Spectrometer:

- Middle resolution Littrow image spectrometer FWHM 0.42nm, 0,08nm/pixel.
- Manual selection of wide spectral range, 340-1050nm. (280nm spectral range).
- Optical aspheric off-axis parabolic mirror.
- Multiple objects input, five maximum sources.
- Slit 20 microns.
- Lamps reference kit for spectral wavelength calibration. (Ne, Ne-Kp, Ne-Ar, Ne-Hg).



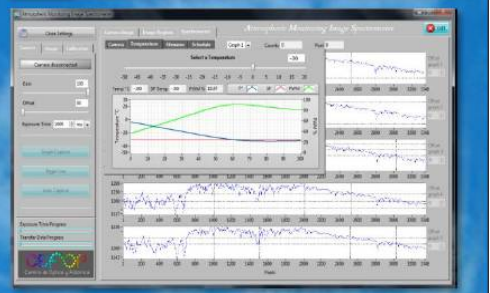
To request more information, please contact to:
Dr. Rodrigo Fuentes Inzunza
Mail: rodrigo.fuentes.inzunza@cefop.udec.cl
Telephone : 56 - 41 - 2661371

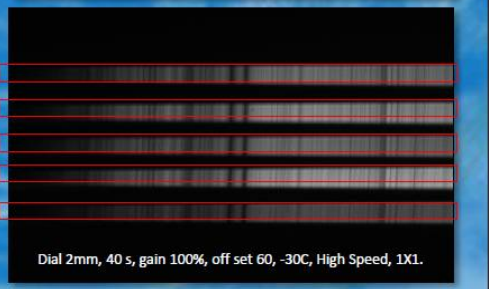
The Atmospheric Monitoring Image Spectrometer (AMIS)

AMIS Software:

- Camera Monochrome, 16-bit, 3326x2504 pixels.
- Spectral response 340 nm to 1050 nm.
- Internal Shutter (noise calibration : Dark, Flat, Bias).
- Temperature Stabilization, (Thermo Electric Cooler) -50 Celsius degrees below ambient .
- Line Curve correction, Wavelength Calibration, configurable auto-save schedules.
- Communication port USB 2.0, OS Win7, Win 8.

AMIS Software for control spectrometer and the data acquisition.

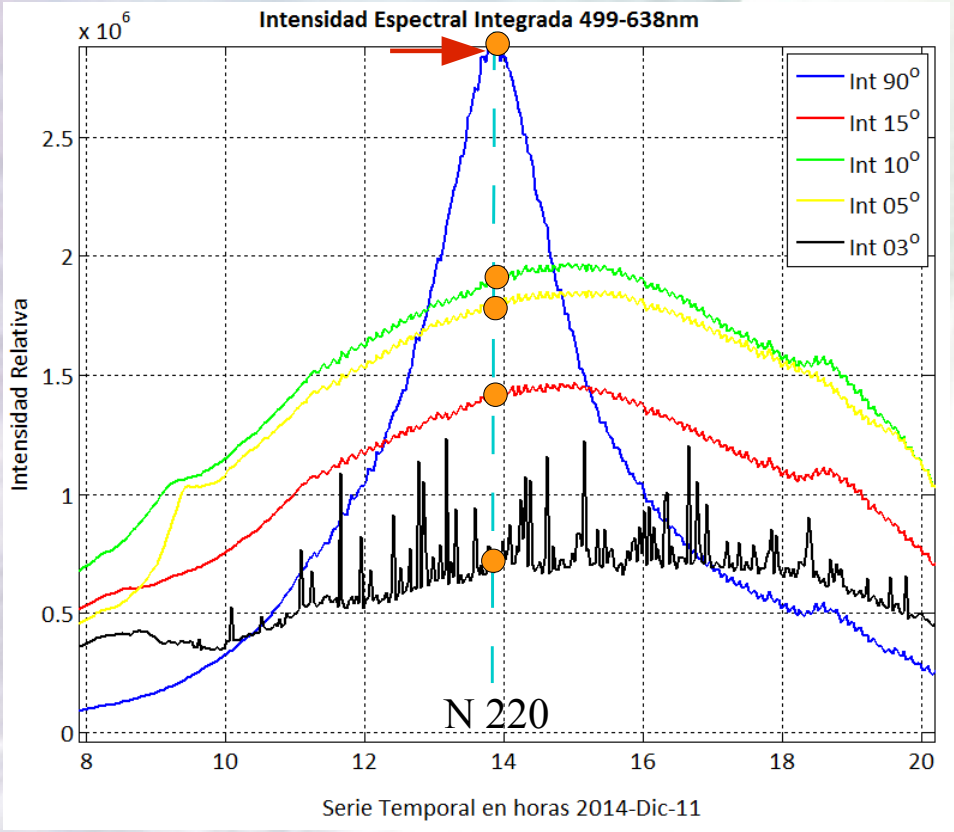


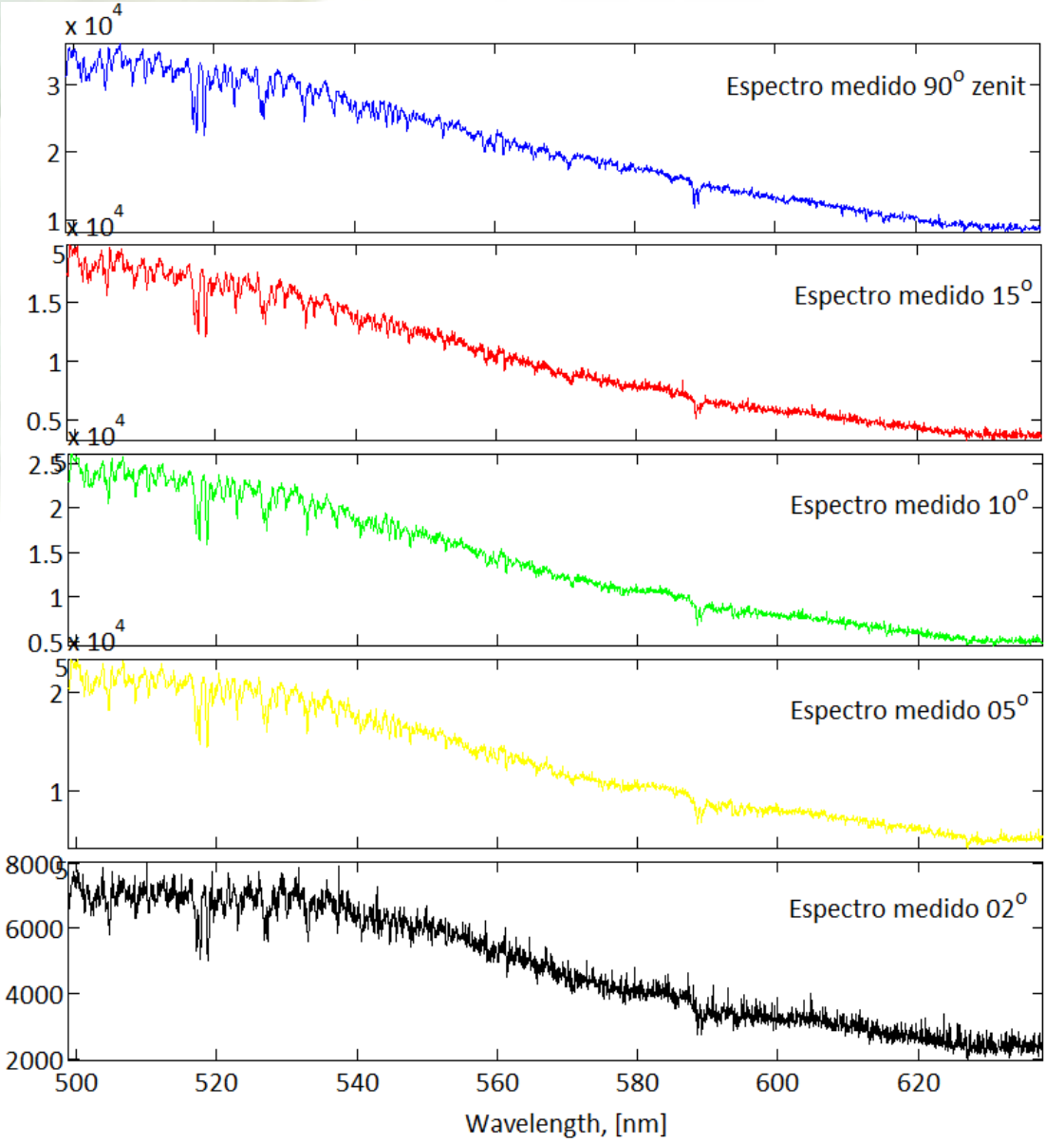


Typical image converted to five scattered sunlight spectrums

CMAX-DOAS: Measurements

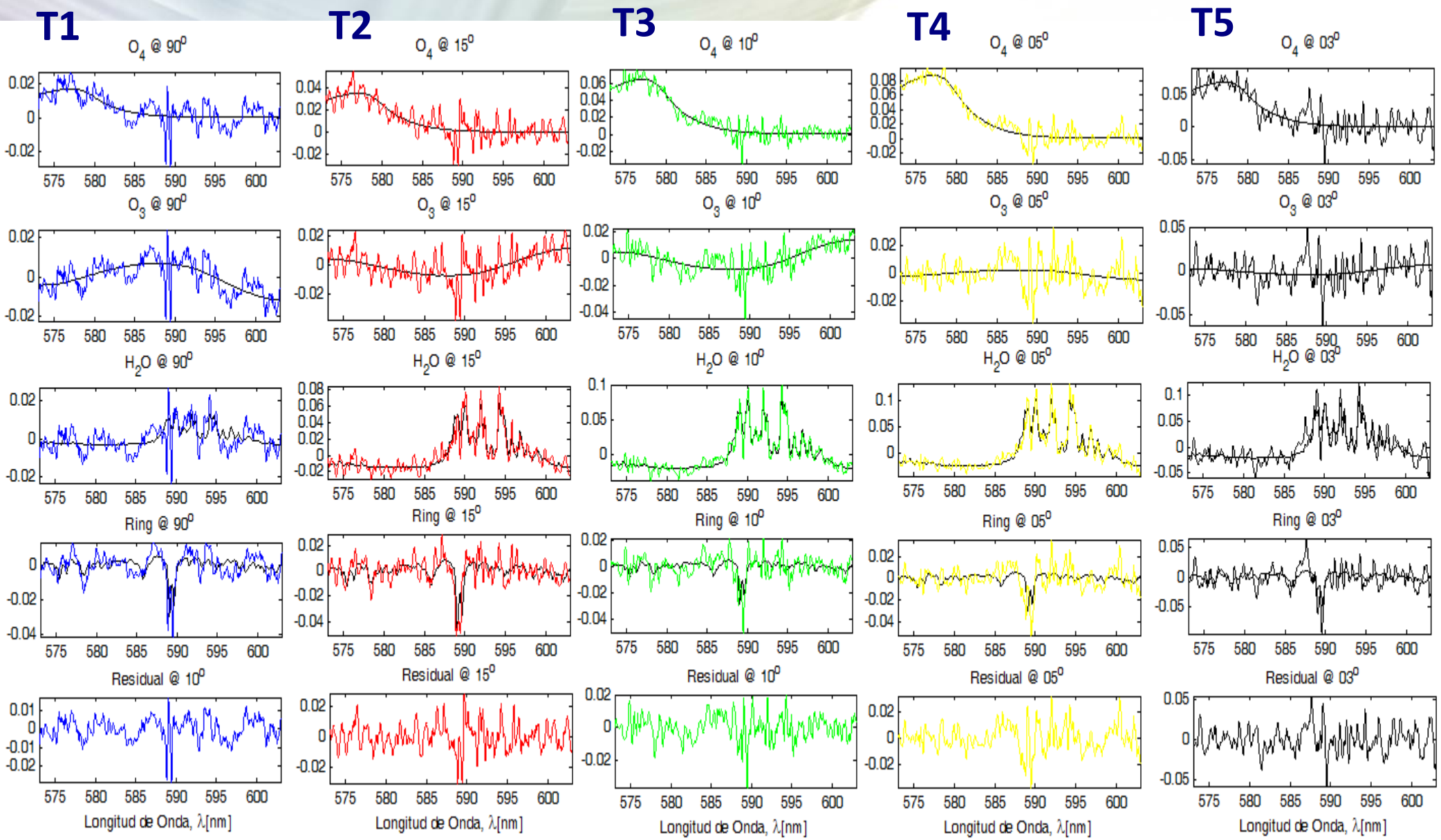
Dinamic evolution (11/Dic/2014)
Clear sky, 577nm





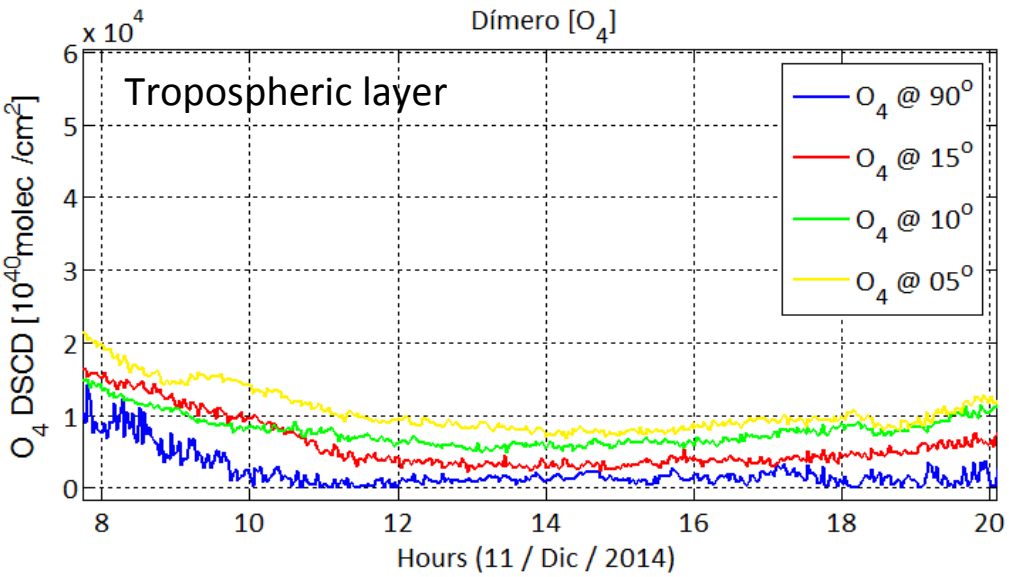
CMAX-DOAS: Measurements

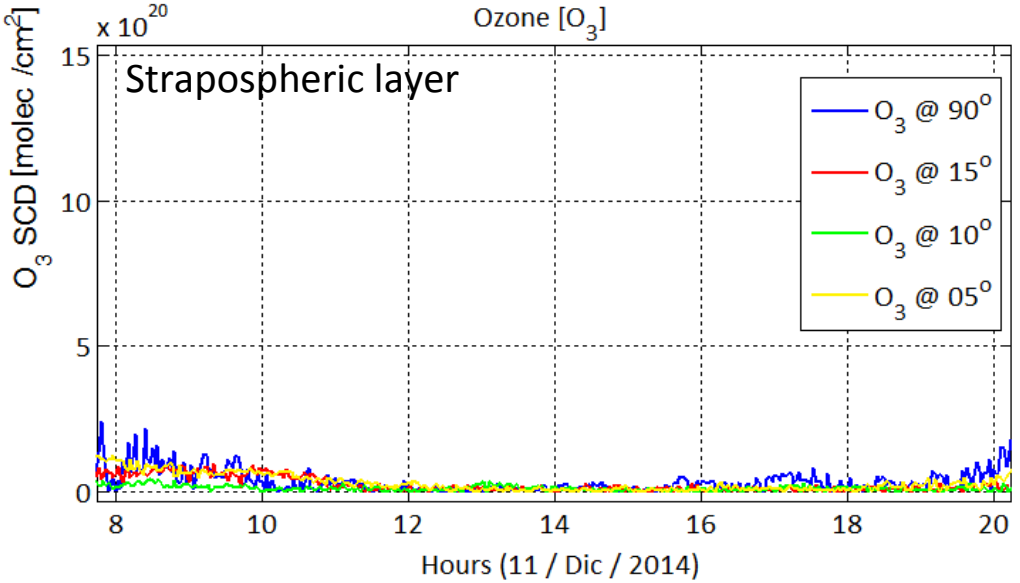
Dinamic evolution (11/Dic/2014)
Clear sky, 577nm

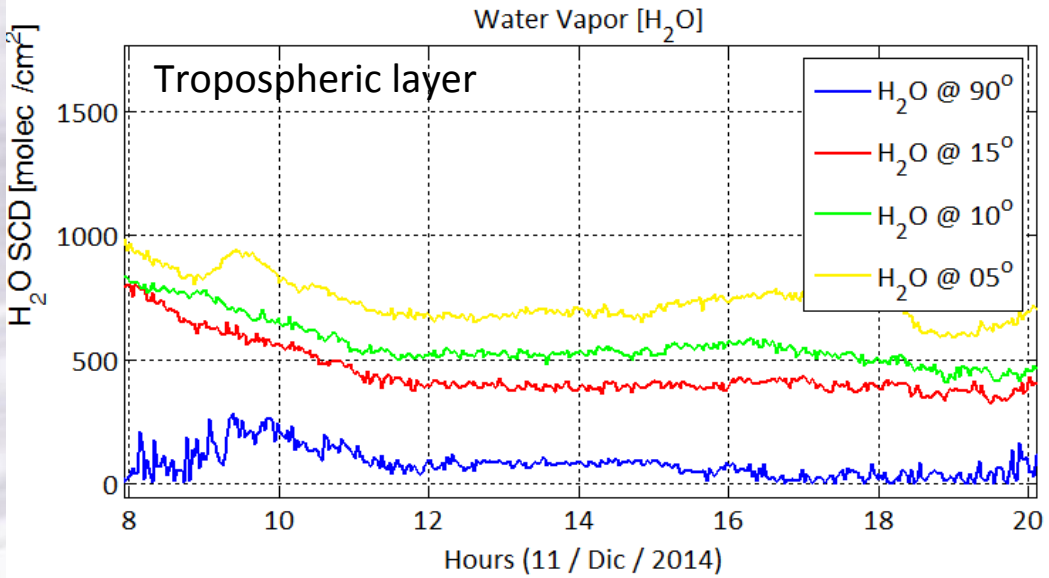


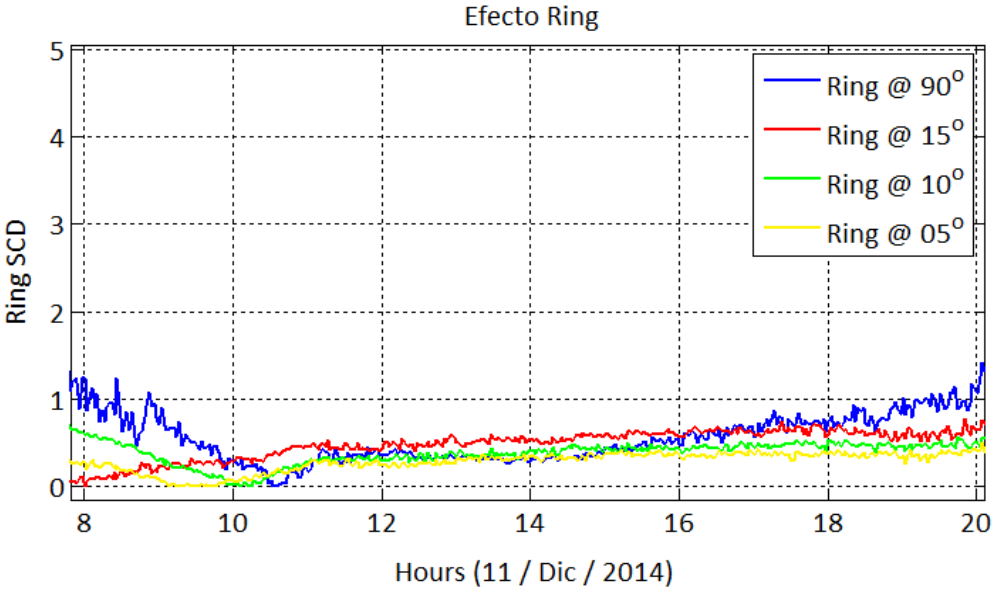
CMAX-DOAS: Measurements

Dinamic evolution (11/Dic/2014)
Clear sky, 577nm



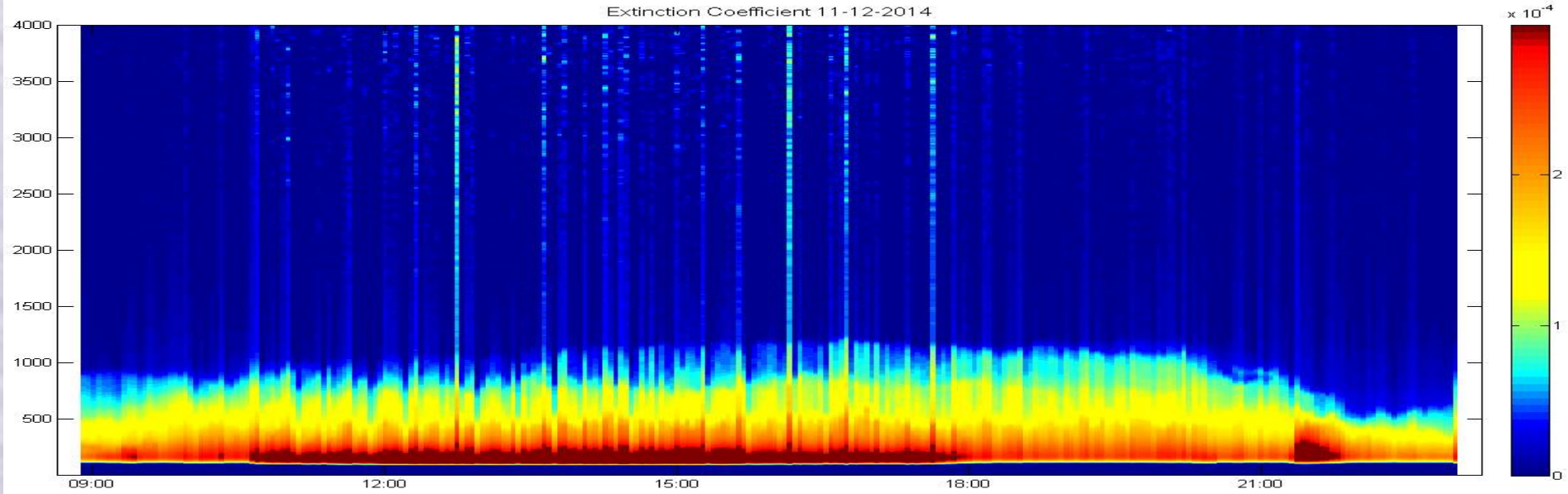


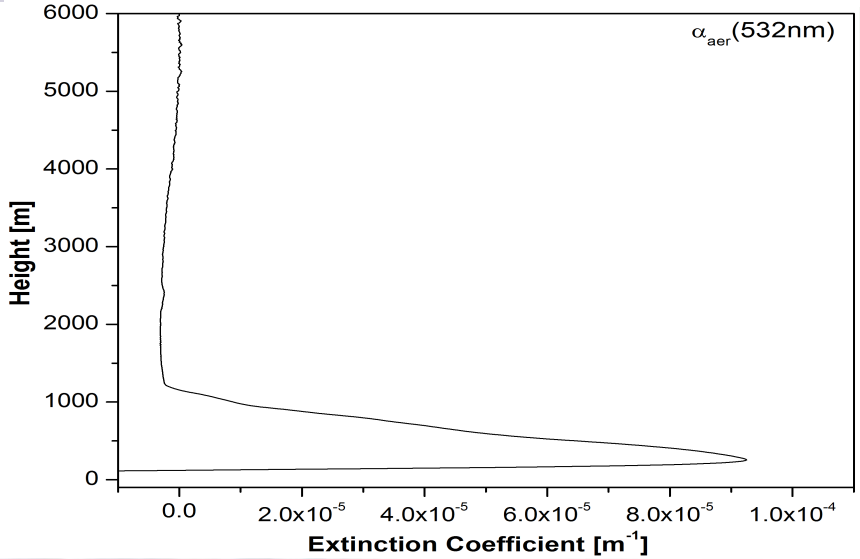


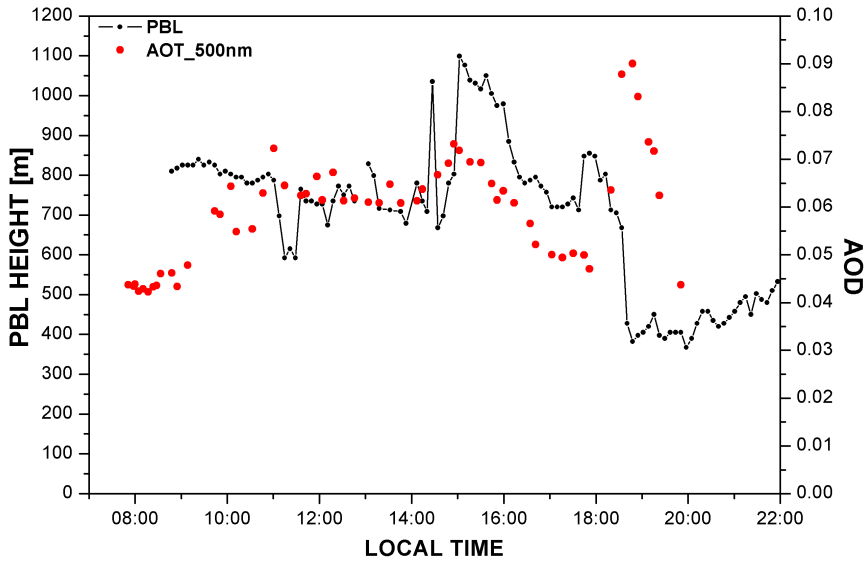


CMAX-DOAS: Measurements

Dinamic evolution (11/Dic/2014)
Clear sky, 577nm





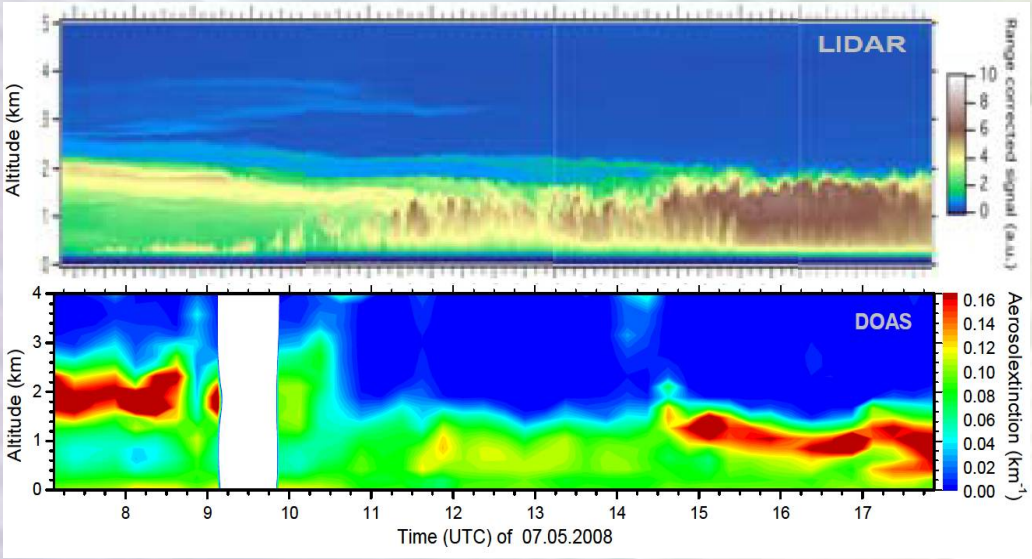


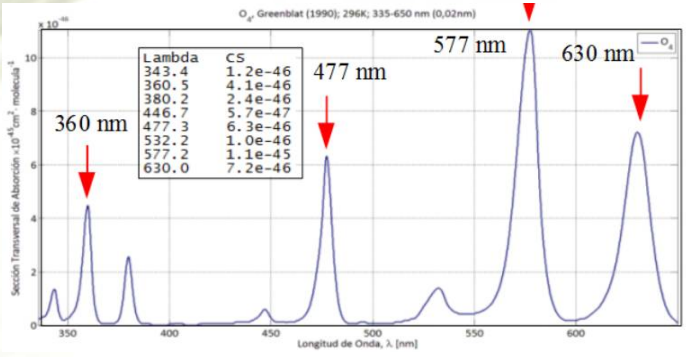
2) .- Aerosol extinction profile

1) .- Aerosol Optical Depth (AOD)

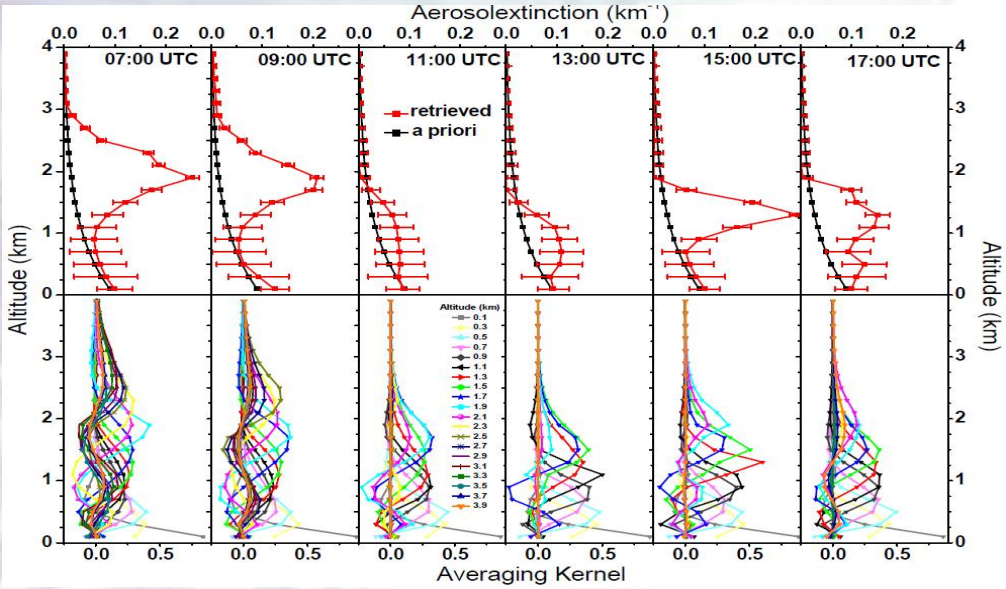
CMAX-DOAS: Measurements

Dinamic evolution (11/Dic/2014)
Clear sky, 577nm

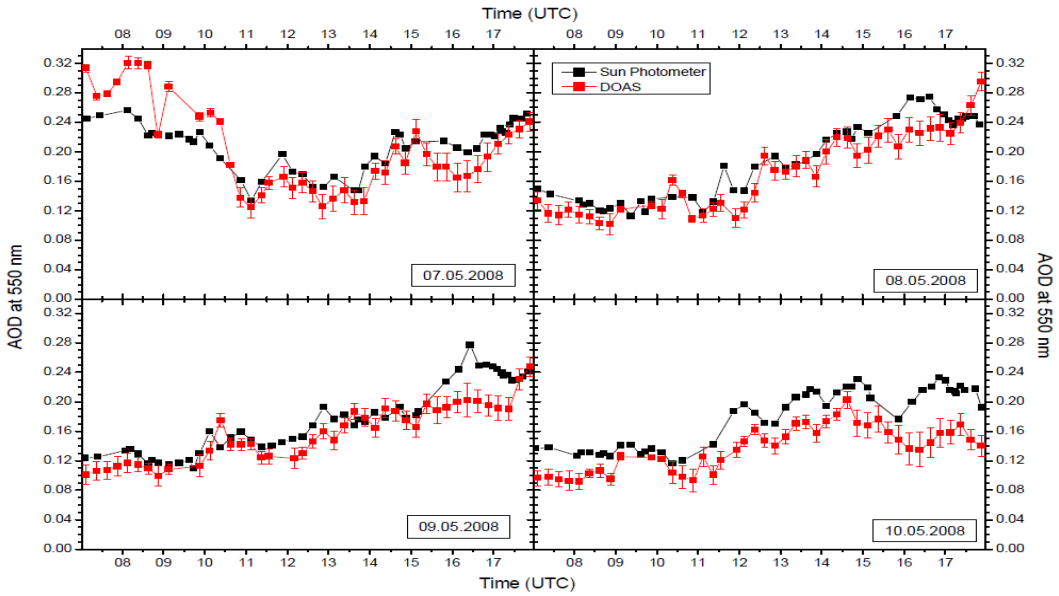




$$c_{(O_4)} = k_{eq}\left(0{,}21\, c_{air}(z)\right)^2$$



2) .- Aerosol extinction profile

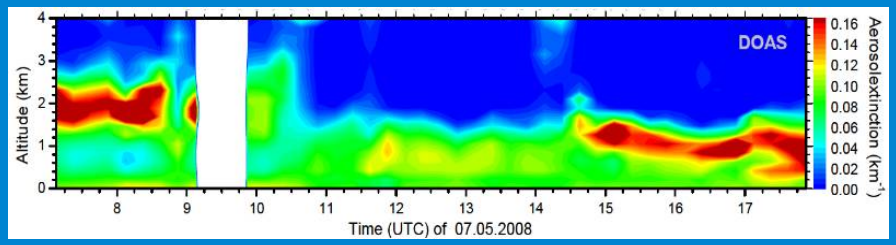


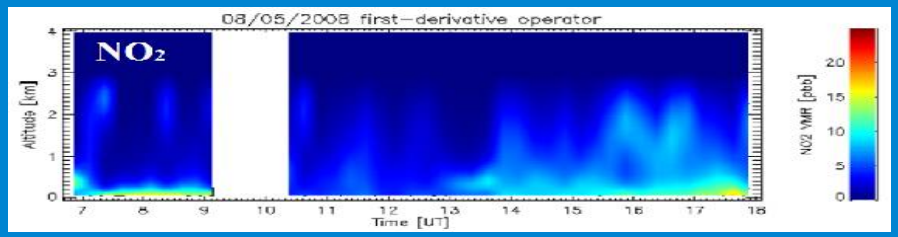
1) .- Aerosol Optical Depth (AOD)

Selami Yilmaz, Thesis Dissertation [2012]

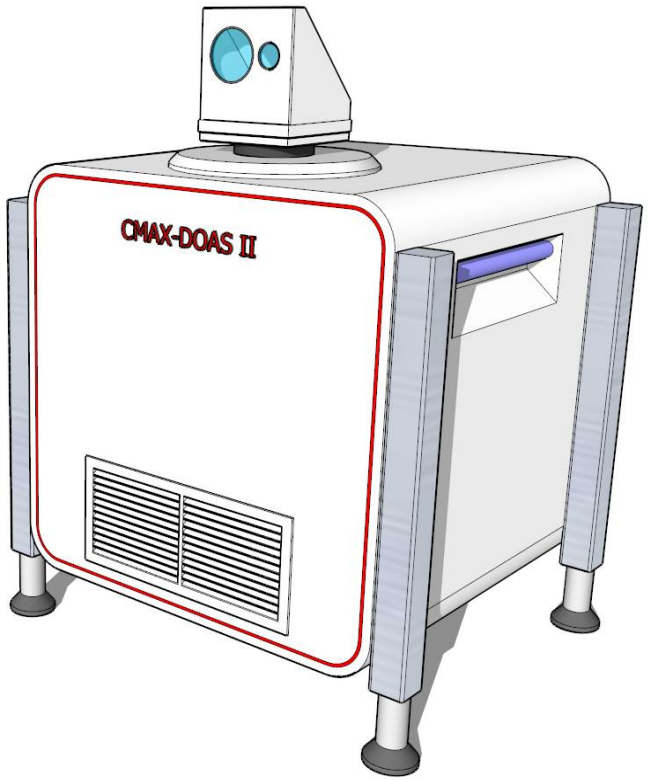
CMAX-DOAS 2da Generación

Aerosols and gas vertical stratification



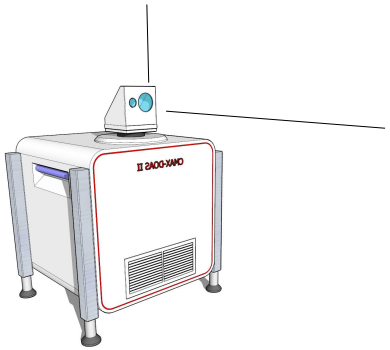


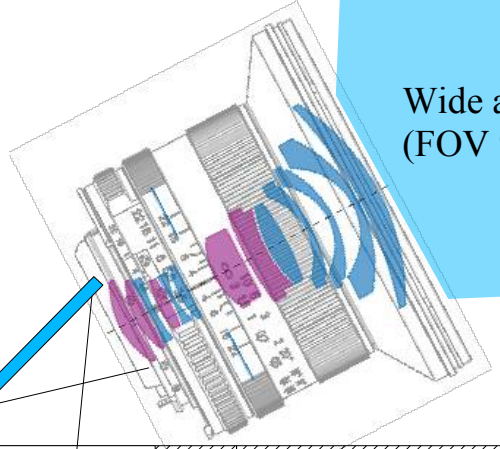
CMAX-DOAS
1era Generación
5 Telescopios
resolución 200m



Objetivo:
Reconstrucción de perfiles verticales de O_3, O_4, H_2O, NO_2, NO_3, y aerosoles con resolución inferior a 20 metros desde 0-4 km de altitud. Similar a sistemas LIDAR.

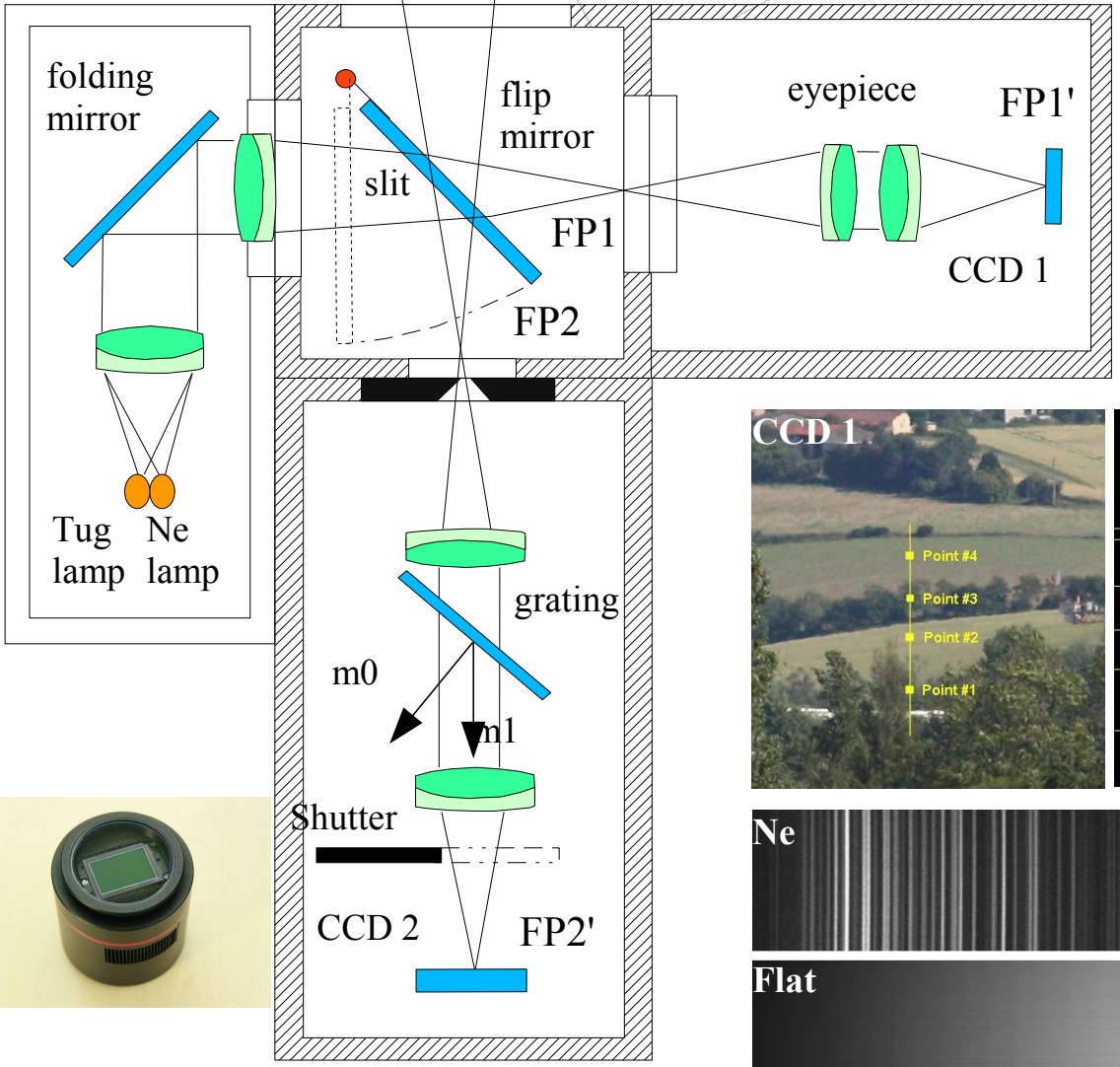
Rango espectral = 300-700nm
Resolución espectral FWHM = 0,5nm,
Resolución por píxel = 0,1nm/piíxel

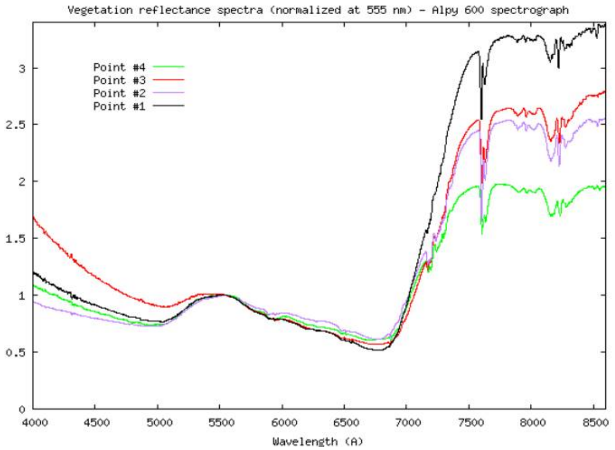


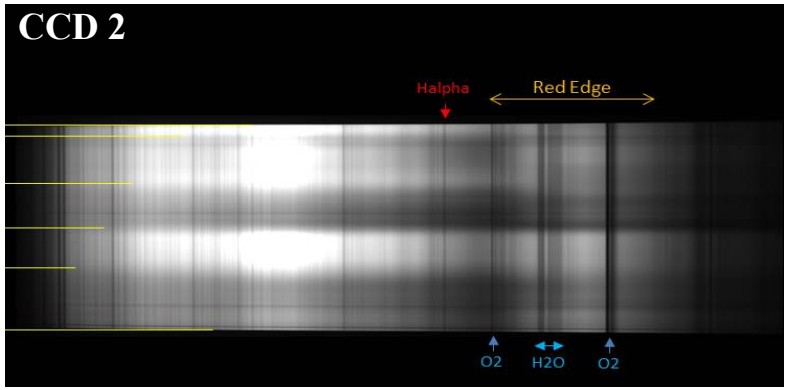


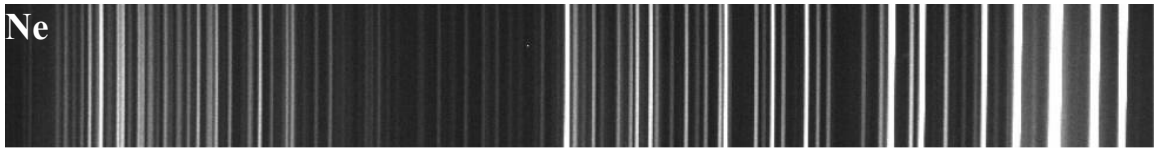
Wide angle lens 18mm
(FOV 90 degree)

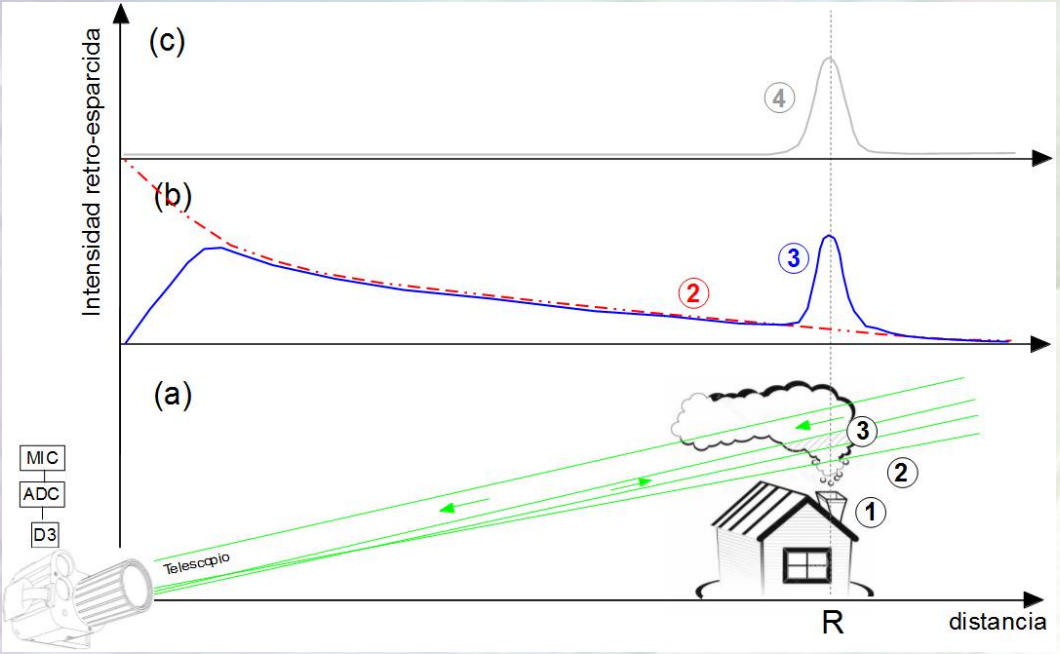
CCD 1

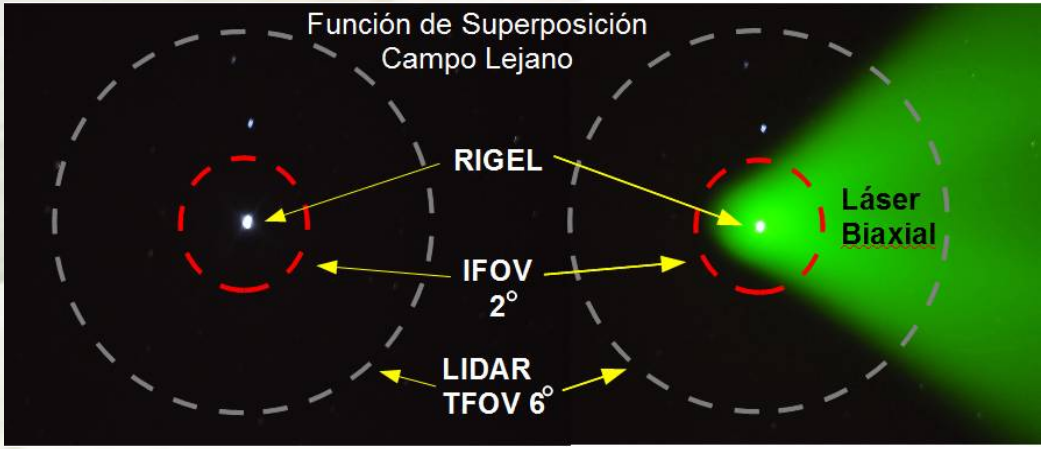




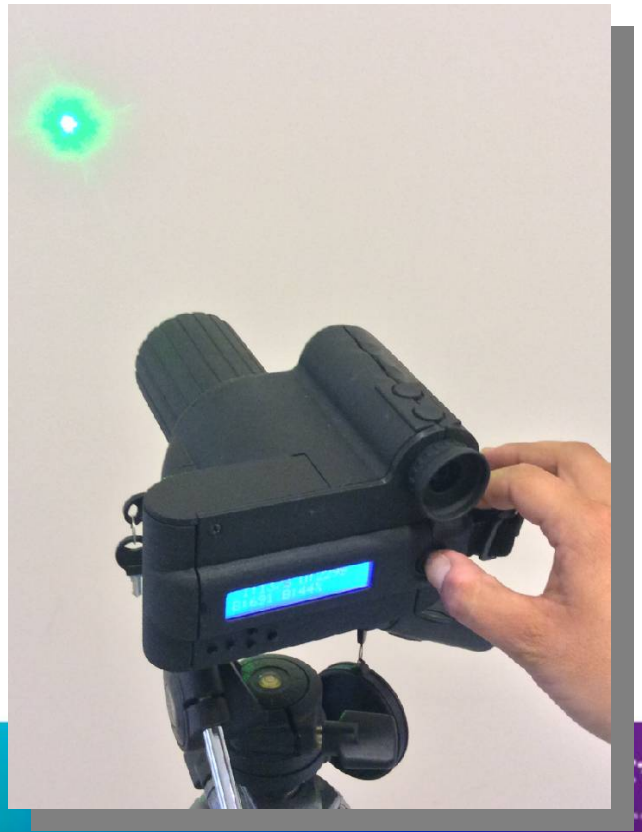


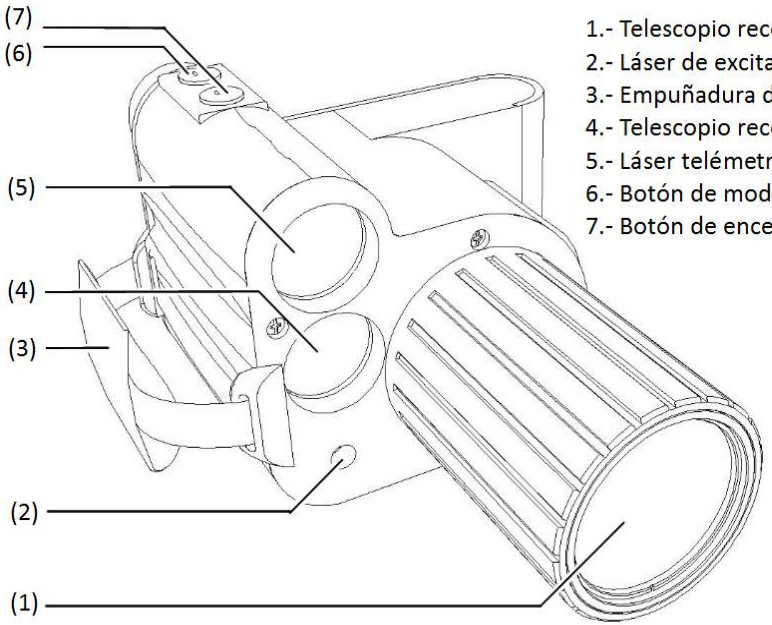






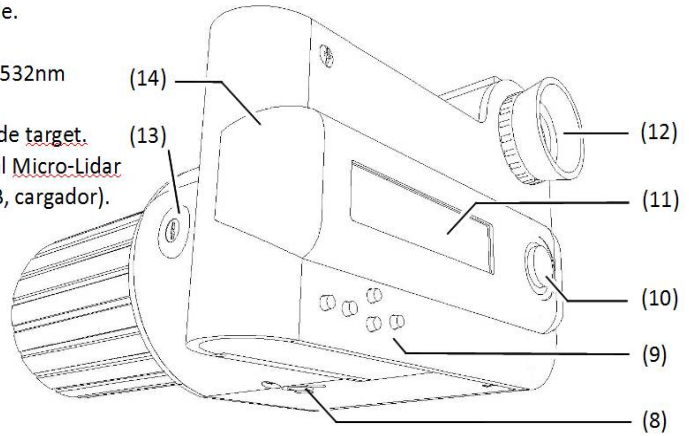
Título: Un dispositivo óptico micro-LIDAR transportable para la detección activa de material particulado emitido en chimeneas y calderas alimentadas con biomassa. U.P.I. No 03574-2014, 30 Dic. 2015.



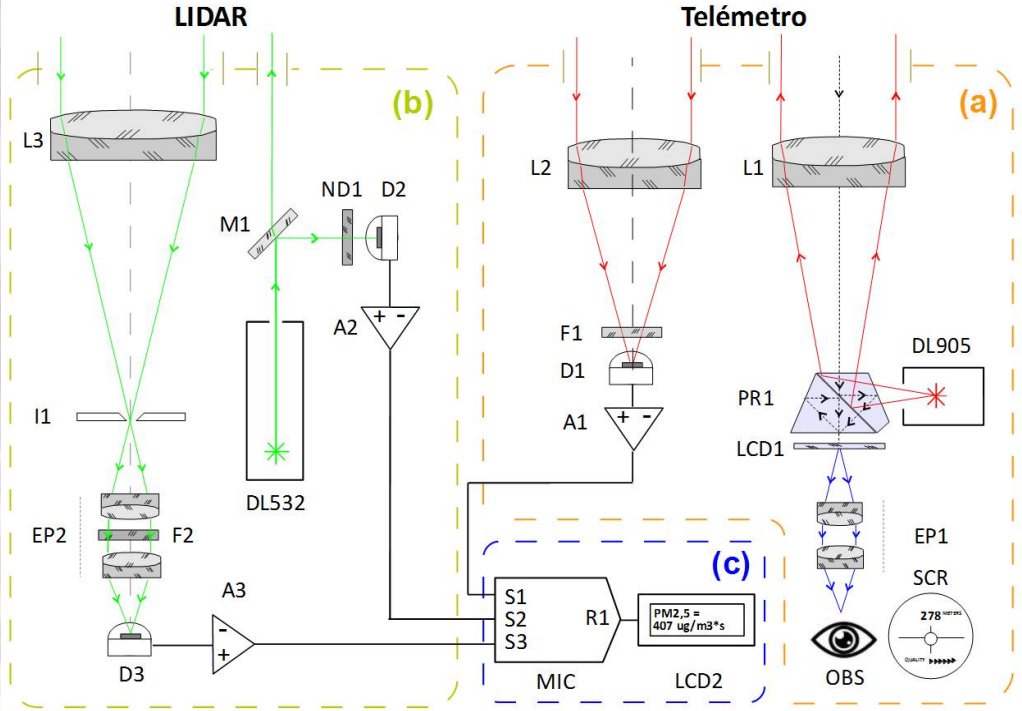


1.- Telescopio receptor de LIDAR, 50mm.
2.- Láser de excitación Visible 532nm (Láser 2).
3.- Empuñadura de sujeción manual.
4.- Telescopio receptor telémetro .
5.- Láser telémetro IR 905nm (Láser 1).
6.- Botón de modo de medición telémetro.
7.- Botón de encendido y disparo telémetro.

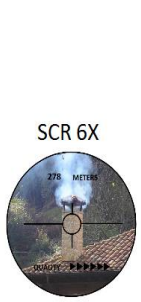
8.- Rosca de sujeción 1/4-20 para trípode.
9.- Botonera de control Micro-LIDAR
10.- Botón pulsador para emisión Láser 532nm
11.- Pantalla LCD de visualización
12.- Mira telescópica 6X para buscador de target.
13.- Sistema de seguridad a control total Micro-Lidar
14.- Periféricos (memoria micro-SD, USB, cargador).

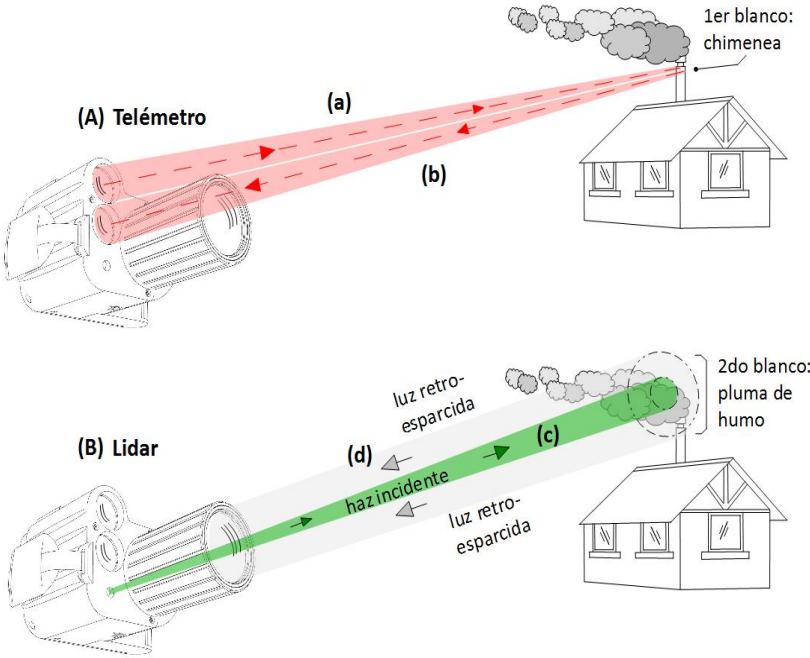


Configuración Electro-Optica de Micro-LIDAR



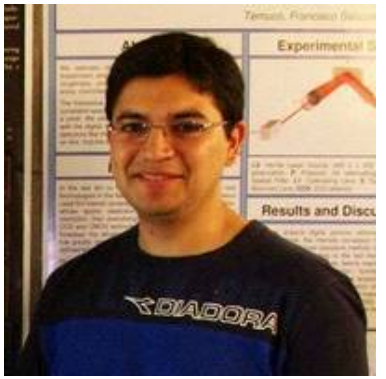
Control Electrónico





TEAM LIDAR-CEFOP Obervatory

Dra. Elena Montilla
Researcher



Dr. Rodrigo Fuentes
Researcher

M.Sc. Cristofer Jimenez
* Now at
Leipzig (Germany)

Dra. (C) Antonieta Silva
* Now at
UFRO University

Catherine Espinoza
Automation Eng.
Student

CONCLUSIONS

The potencial of the MAX-DOAS developed can serve to determine the atmospheric aerosol optical properties, such as LIDAR and sun photometers optical systems.

- A Radiative Transfer Model have to do implementated.
- Aerosol extinction profile at several wavelength (360, 447, 477, 577 and 630 nm)
- Aerosol Optical Thickness (AOT)

The two major advantages of this method are:

- It does not require absolute radiometric calibration, because use differential oxygen dimer absorption structures.

- A Better resolution can be achived changed the telescopes by pixels in a CCD array.

THANK YOU