UTLS Observations at Reunion Island

V. Duflot

Vérèmes H., Payen G., Portafaix T., Bègue N., Posny F., Keckhut P., Baray J.-L., Godin-Beekman S., Vernier J.-P., Renard J.-B., Clarisse L., Marquestaut N., Cammas J.-P.

Observatoire de Physique de l'Atmosphère de la Réunion

Objectives:

To build long term series of essential climate variables in the tropical southern hemisphere

- **Meet the standards of large international research networks and european infrastructures**
- **Open data access policy**

To participate to satellite calibration & validation exercises. Examples:

- **ADM-Aeolus**
- **CALIPSOv4/EarthCARE**
- **TROPOMI**

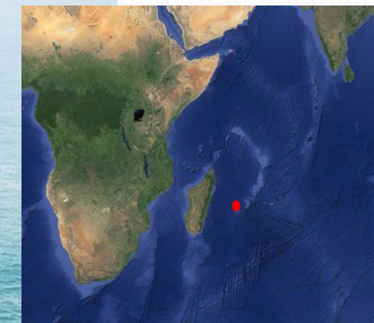
To conduct research on climate and regional-scale processes

- **International research**
- **Local S3 strategy: natural risks (volcanoes, cyclones)**

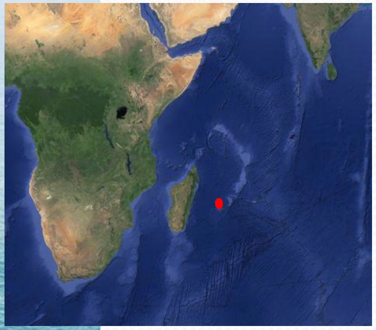
To promote transnational access for research scientists

- **Foster the scientific collaborations with international cutting-edge research units**
- **Support operational costs of the observatory**

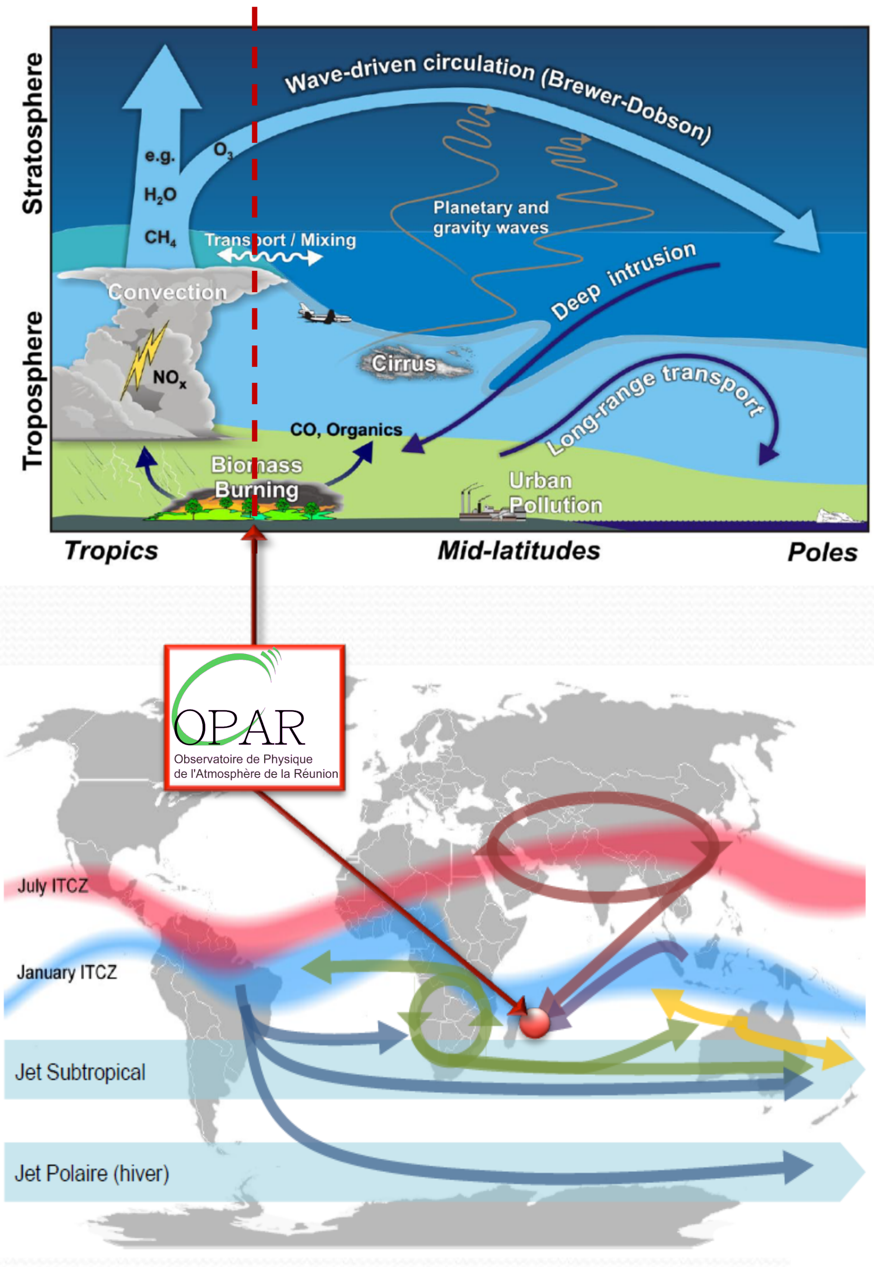
Advertising



Advertising



Reunion Island UTLS Geophysical Context

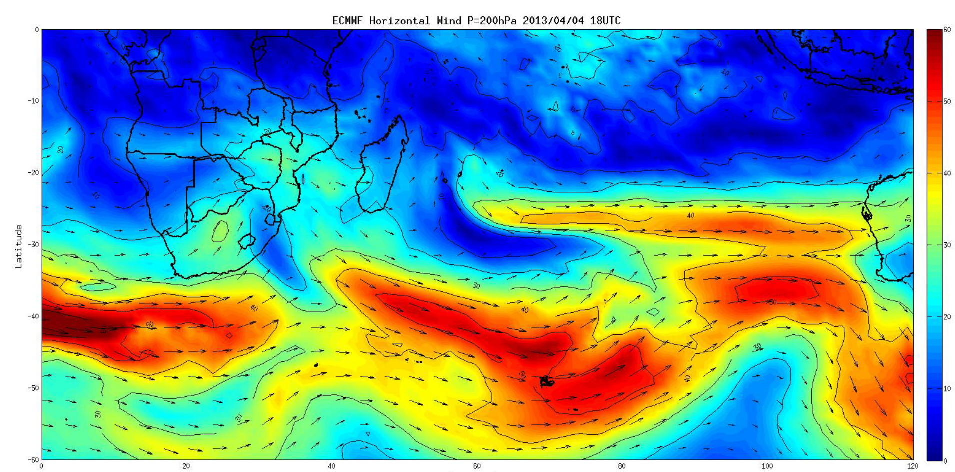


Convection (ITCZ)
- **Cirrus**
- **Stratosphere (WV) feeding**

STE
- **Rossby wave breaking (subtrop jet)**
- **Mid-lat isentropic transport**

Biomass burning season
- **GHGs, O3 and aerosol transport**

Asian Monsoon Anticyclone
- **Inter-hemispheric transport**



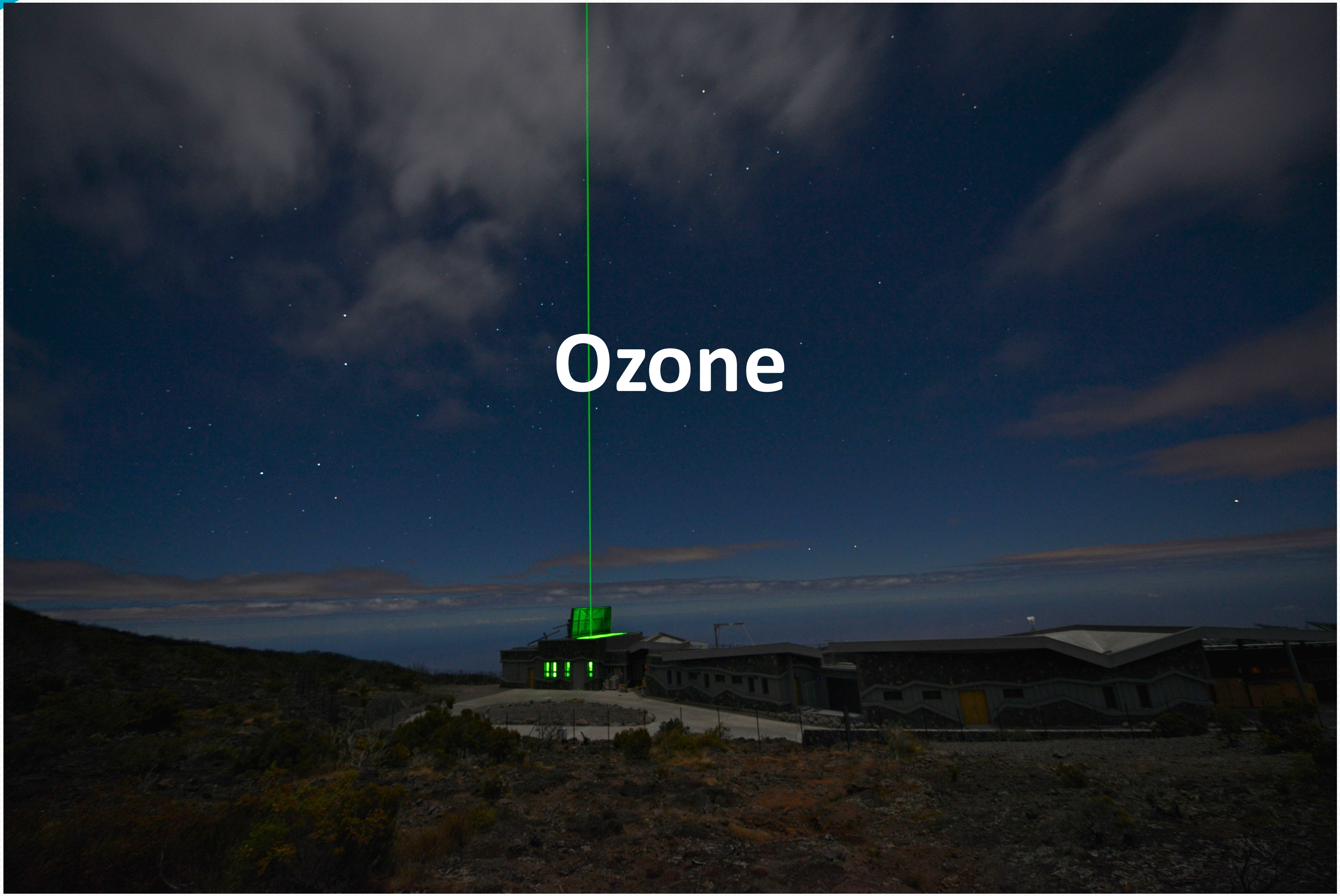
Instrumental array

Obs. du Maïdo	
Lidar O3S	Lidar Vent
Lidar O3t	Scanotron
Lidar 1200	OPS 3330
FTIR	Aethalomètre
Radiomètre IRT	Filtres chimiques
WIRA-C	CPC 3776
GPS	Analyseur Nox
Caméra TLE	Analyseur O3
All-Sky	Analyseur SO2
Antenne WWLNN	Picarro 4 gaz
Station infra-son	Picarro isotope de l’eau
ODS	Prélèvement de pluie
Station météo	Caméras visible
Sondes Cobald	Sondes CFH

Moufia	
FTIR	Spectro UV
Picarro 3 Gaz	Mini-SAOZ
Disdromètre	SAOZ
MARLEY	CIMEL
Microtops	BASTA

Gillot	
GNSS	Sondes LOAC
Sondes M10 – ECC Ozone	

Le Port	
MAX-DOAS	Sonde POPS


Ozone

UTLS Ozone Lidar Observations

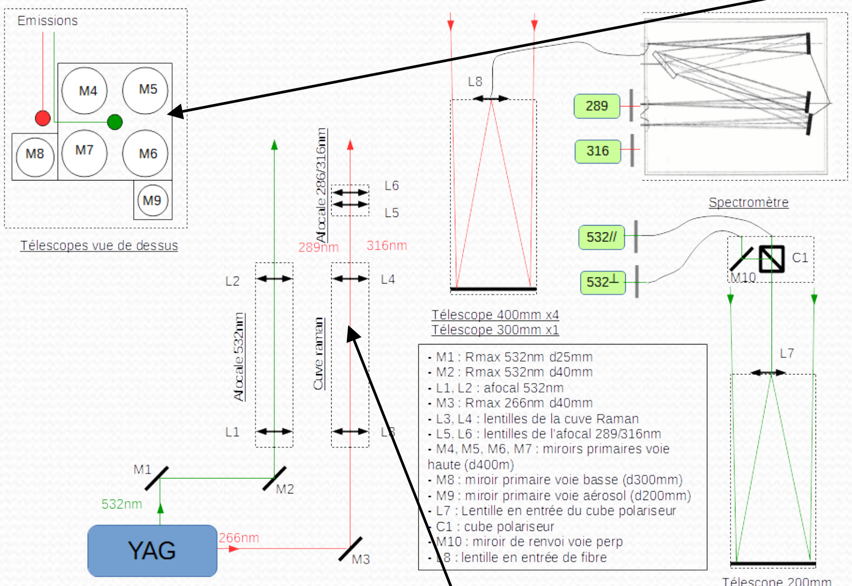
Technical Features

Tropospheric O3 lidar

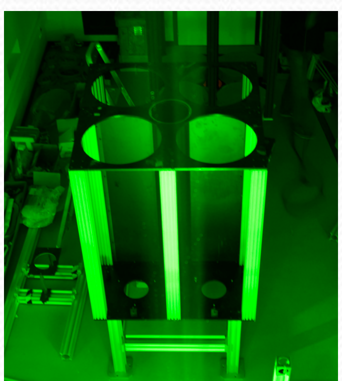
2 DIAL lidars dedicated to O3 measurements

Stratospheric O3 lidar

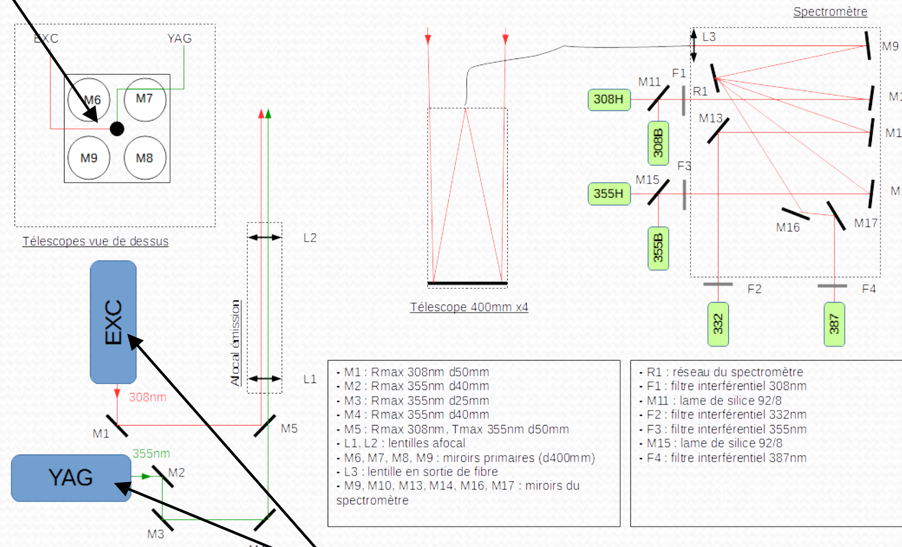
4x400mm mirrors mozaic



Raman cell (316 & 289nm)



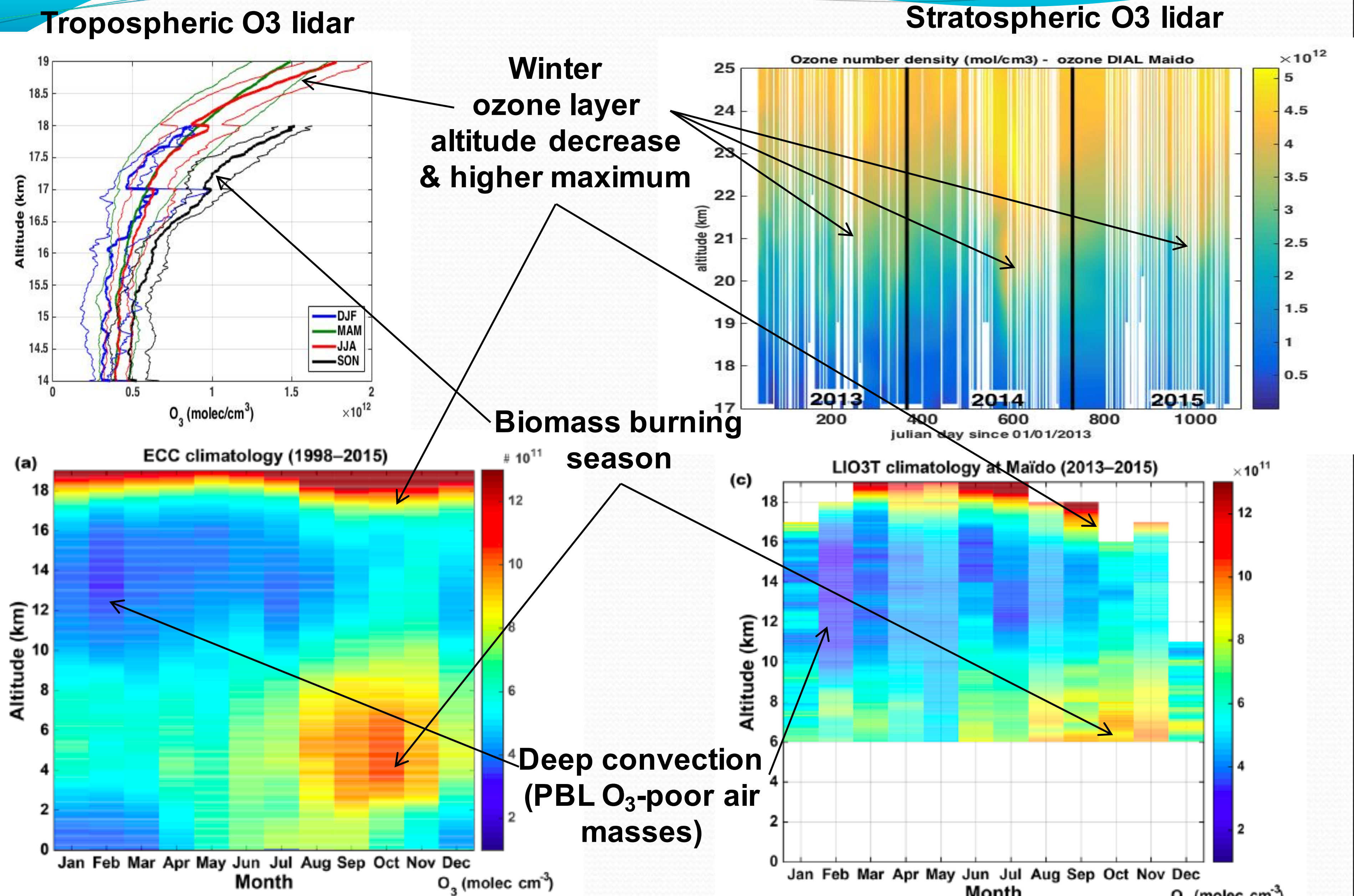
Covered range : 6-19km



2 lasers (355 & 308nm)

Covered range : 17-45km

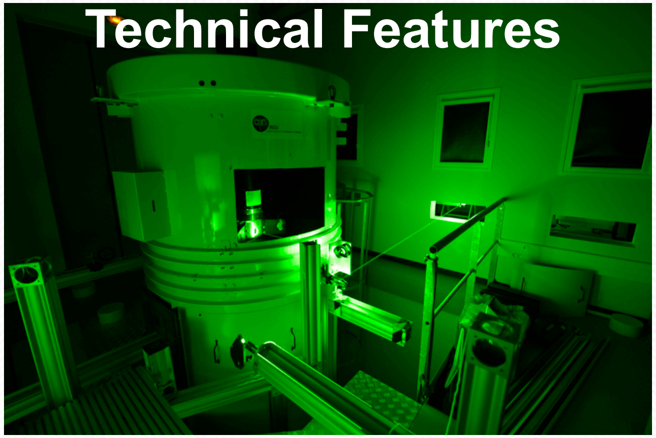
UTLS Ozone Lidar Observations



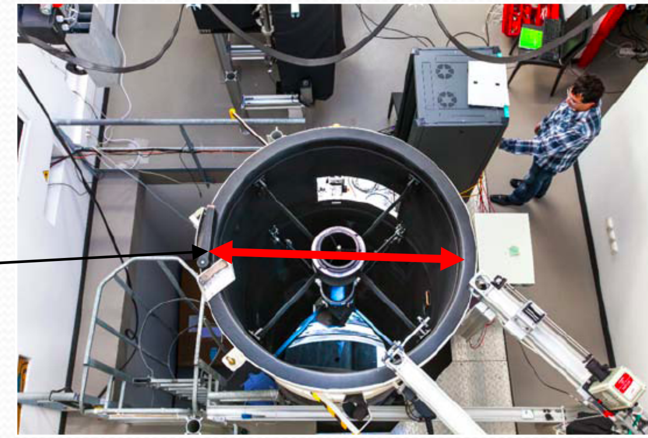
Duflot et al., **AMT2017**

Water Vapor

UTLS Water Vapor Lidar Observations



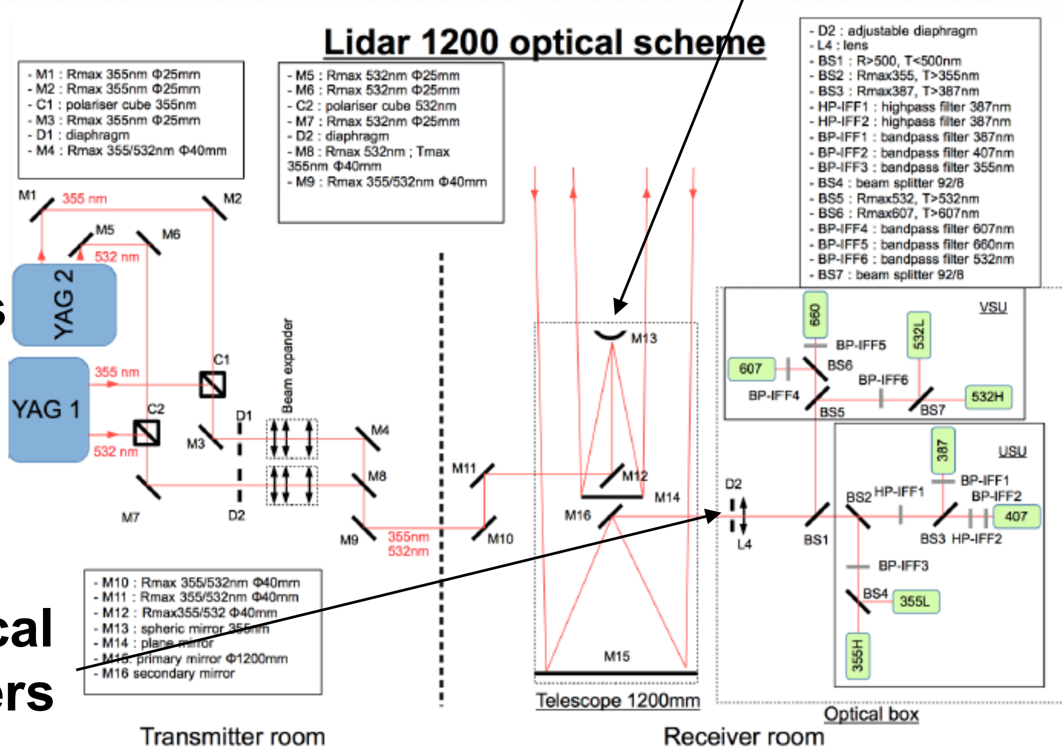
1.2m telescope



Coaxial emission/reception

2 lasers

No optical fibers

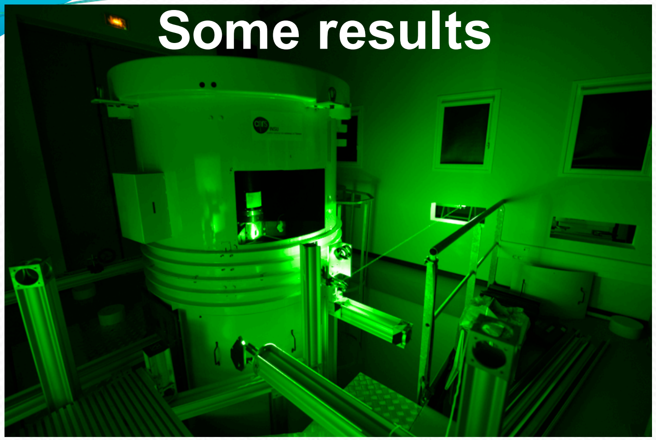


Calibrated through GNSS IWV

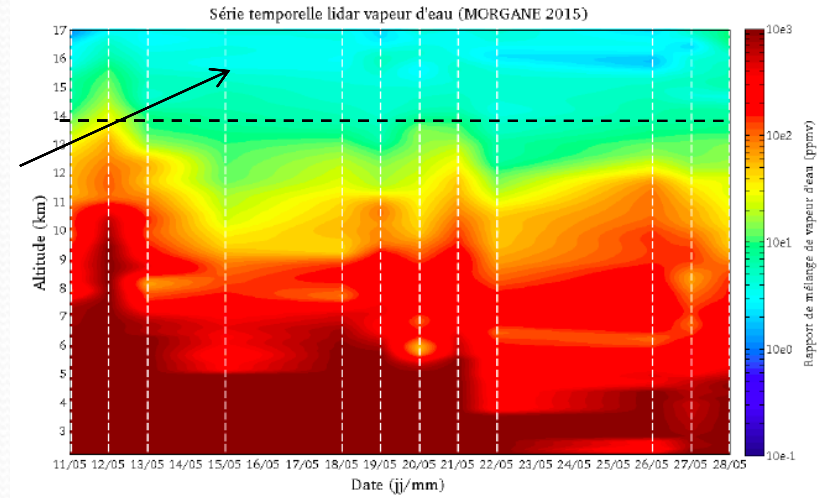
GRUAN (for trend detection)	UT	LS
Vertical Resolution	<1km (600m)	<1km (750m)
Total uncertainty	<60% (<25%)	<20% (<15%)
Time resolution	<1h (40min)	- (47h)

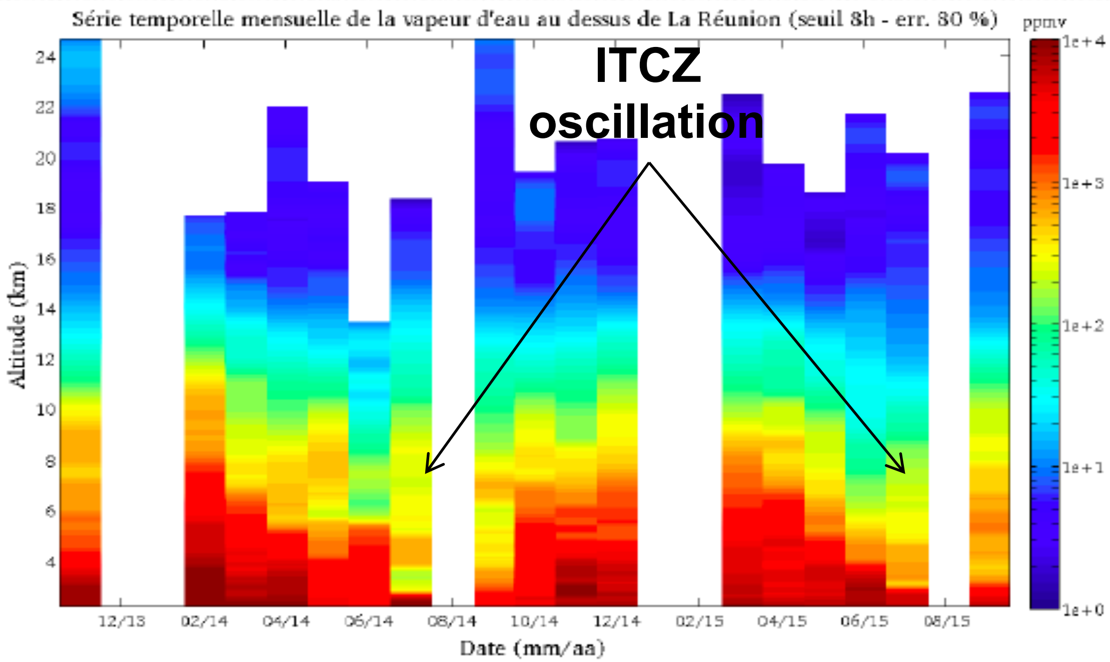
UTLS Water Vapor Lidar Observations

Some results

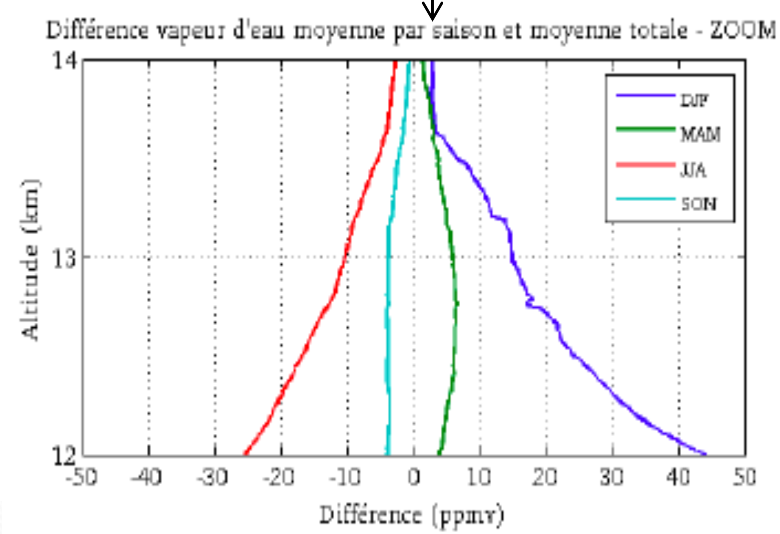


MORGANE Time serie: visible structures in the UT



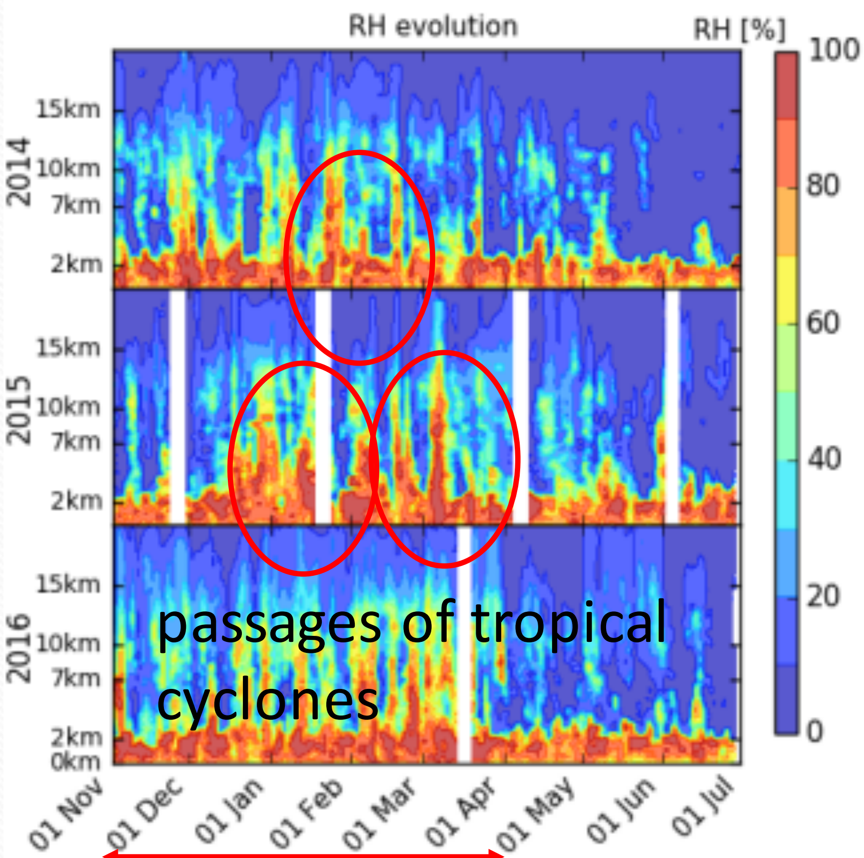


Free troposphere - upper troposphere WV continuum ?

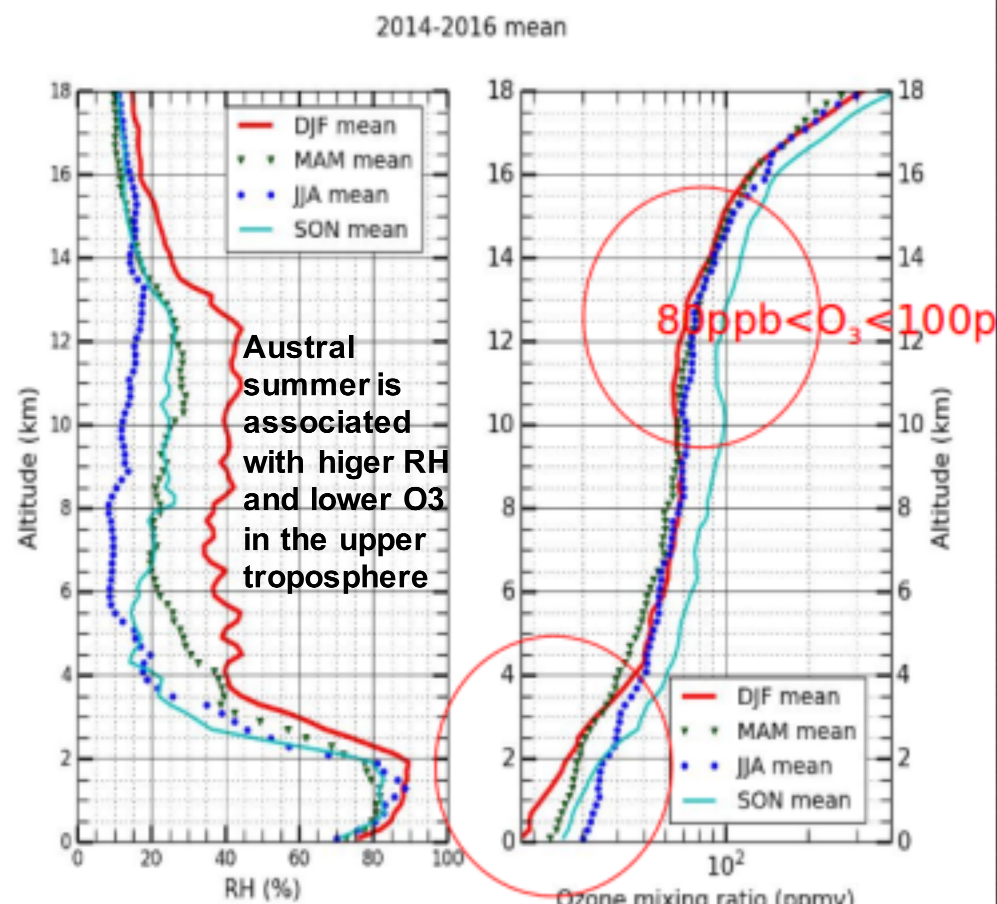


Vérèmes et al., **AMTD2017**

Impact of deep convection on the chemical budget (H_2O/O_3) of the upper troposphere over Réunion Island



Time series of RH measured by the M10 radiosonde (daily Météo-France launch at 12UTC from the airport)



20ppb<O_3<30ppb

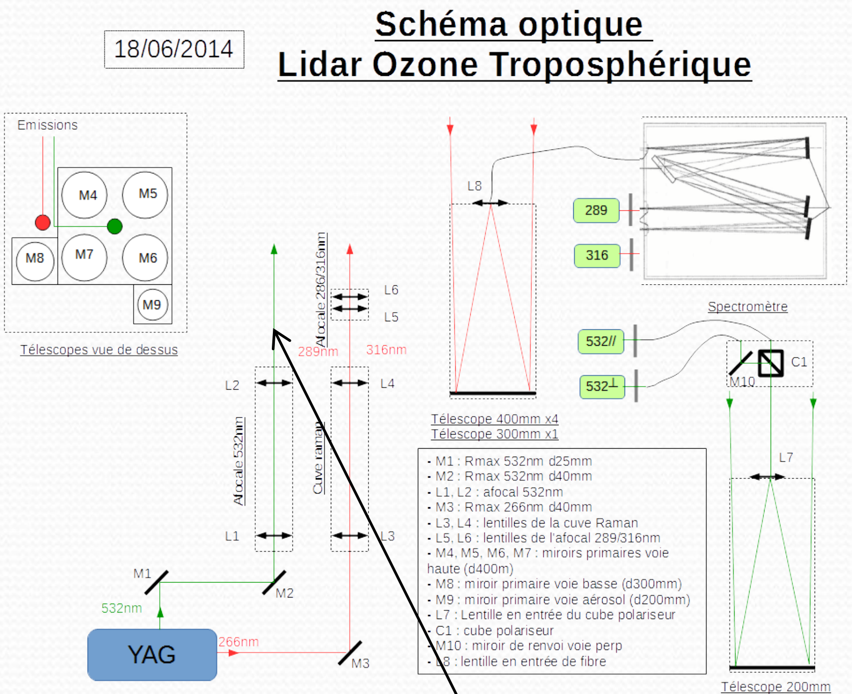
***Héron et al.*, in prep.**


Aerosols

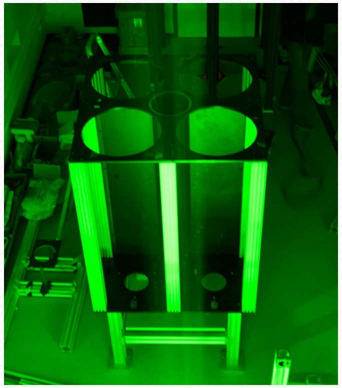
UTLS Aerosols Lidar Observations **Technical Features**

Use of the O3 lidars for UTLS aerosols detection

Tropospheric O3 lidar

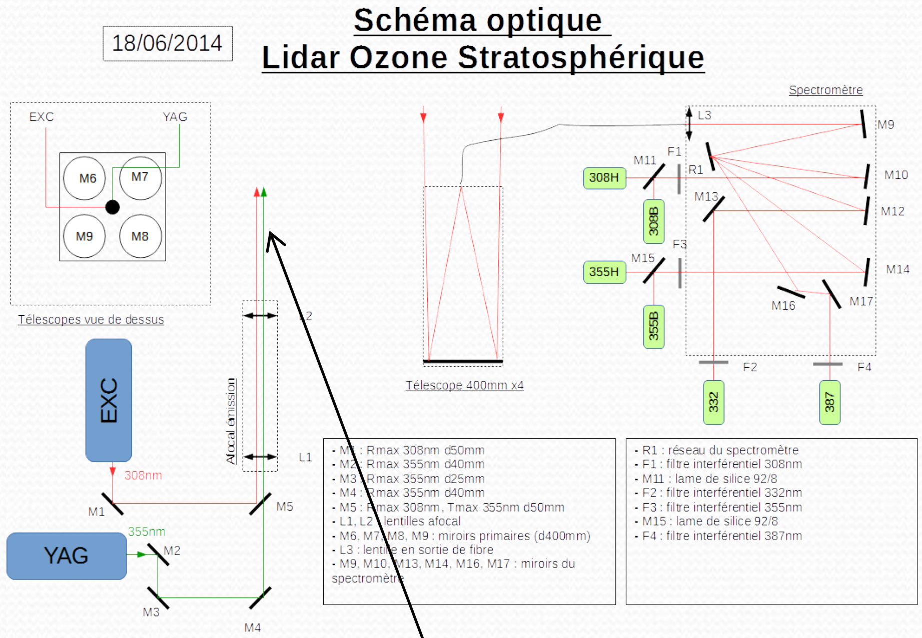


532nm signal



Covered range : 8-20km

Stratospheric O3 lidar



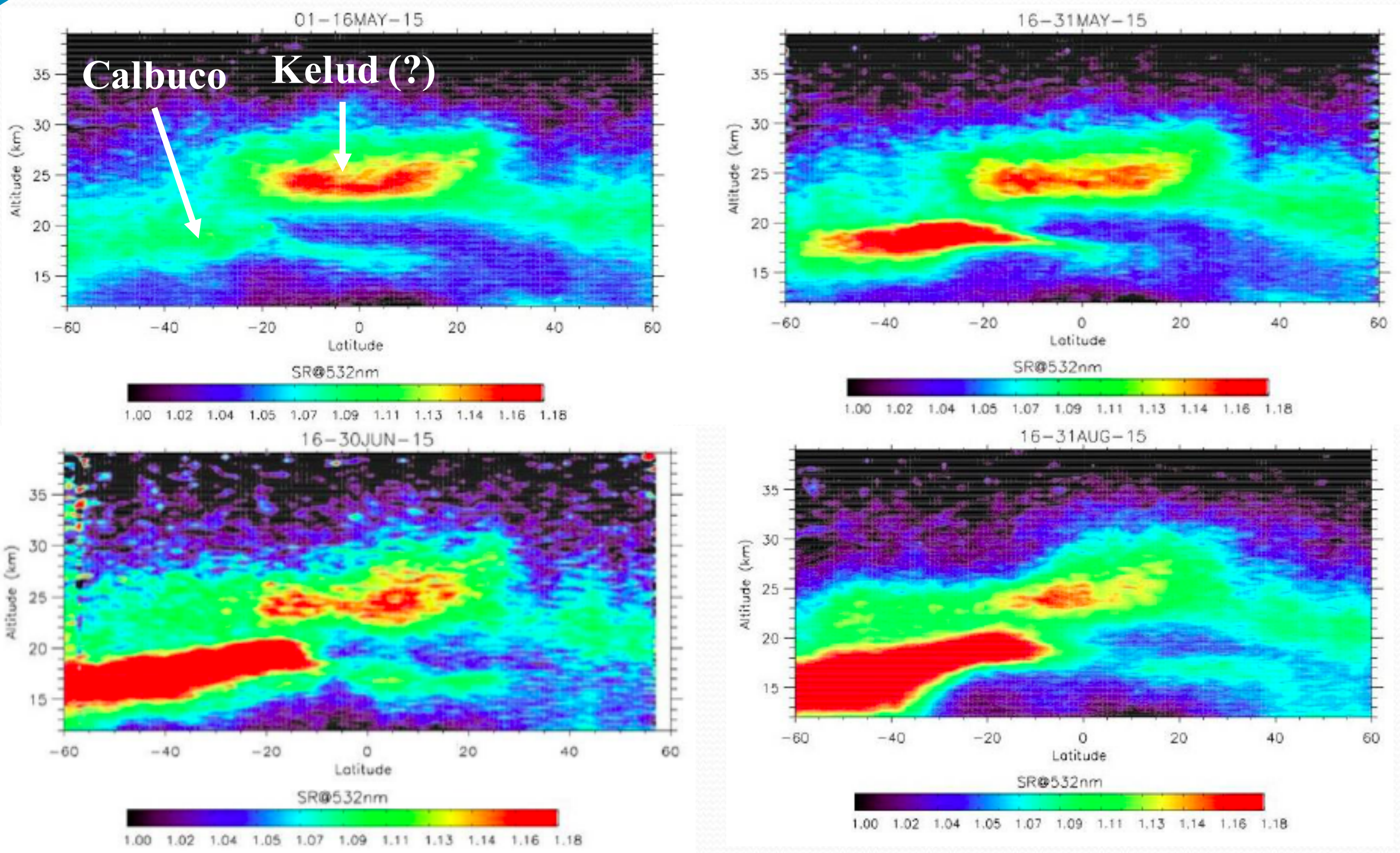
355nm signal

Covered range : 17-45km

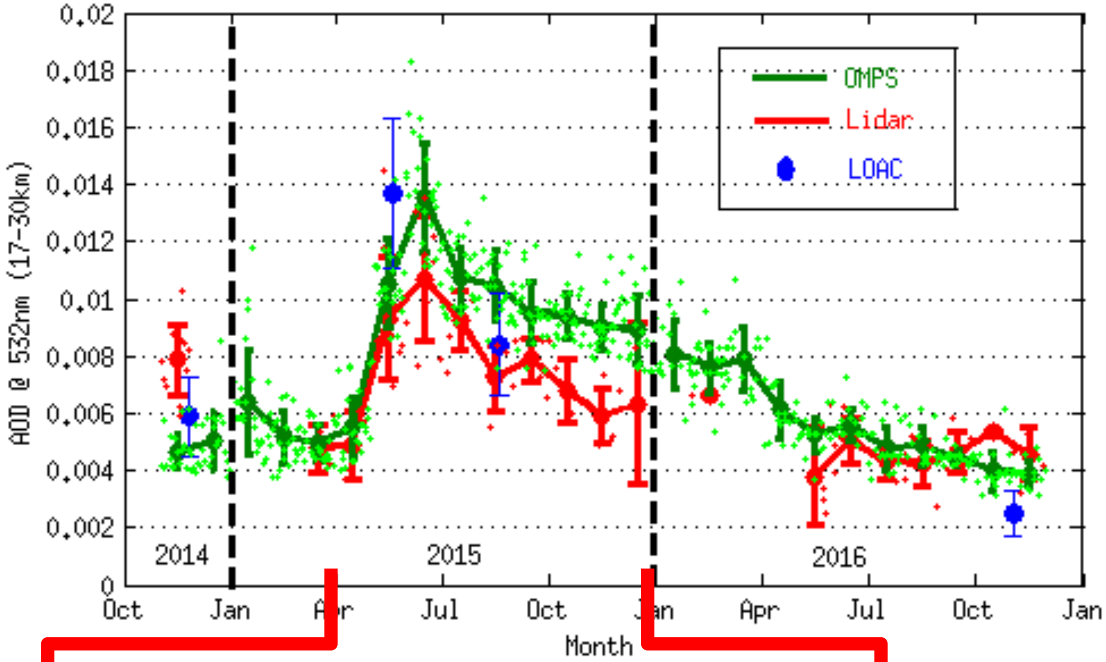
Calbuco eruption

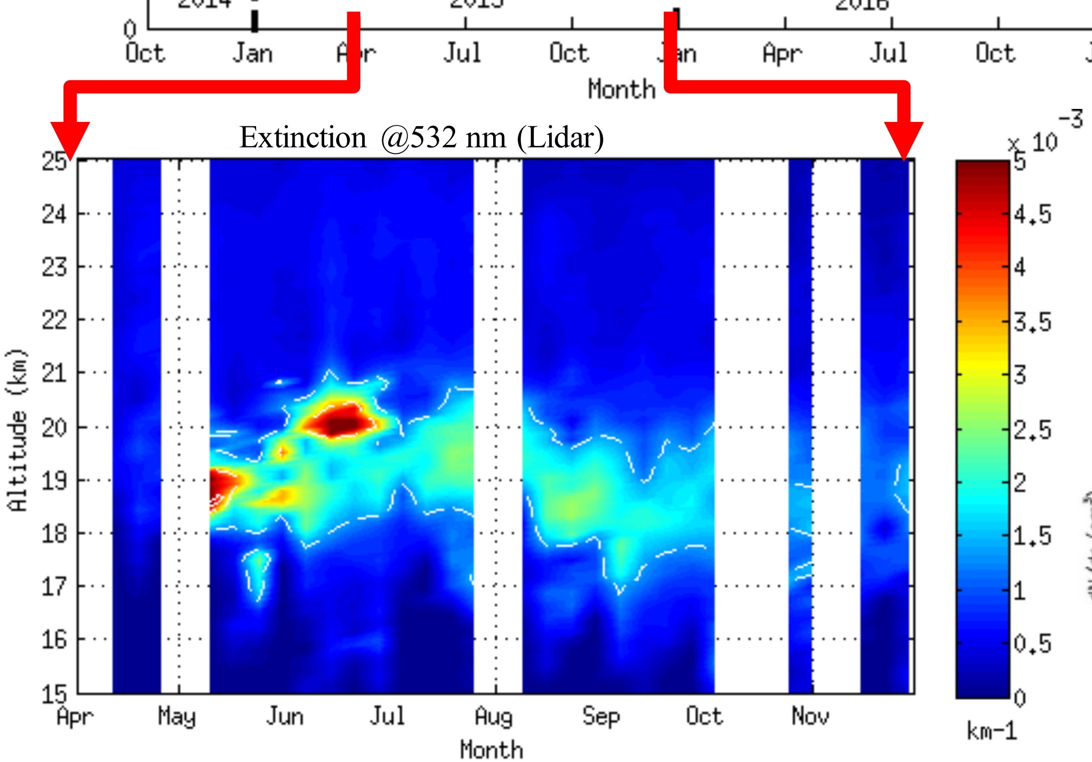
22 April 2015

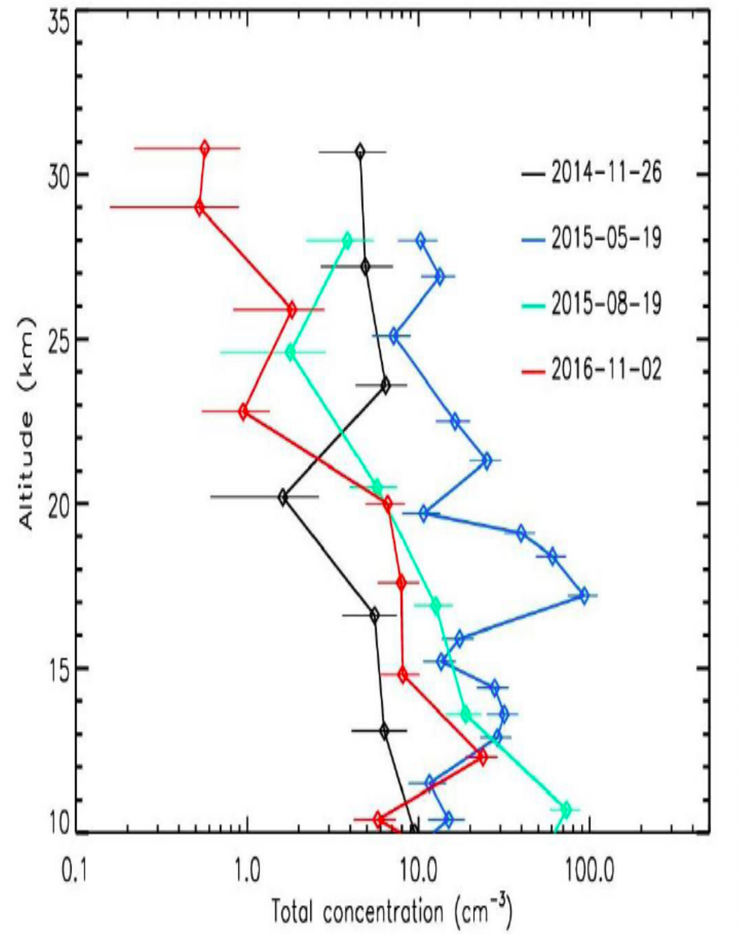
Calbuco eruption: low stratosphere observations

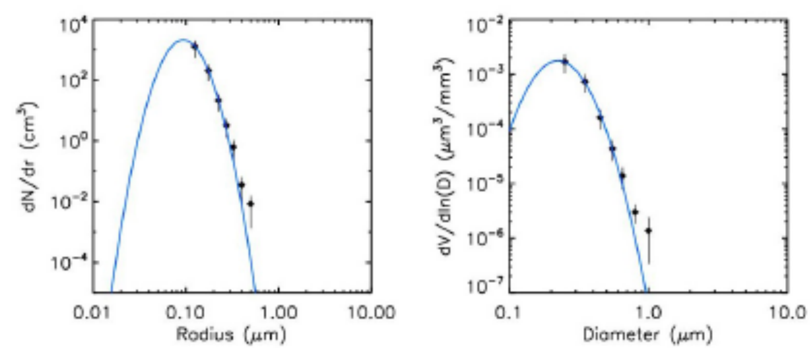


Calbuco eruption: low stratosphere observations



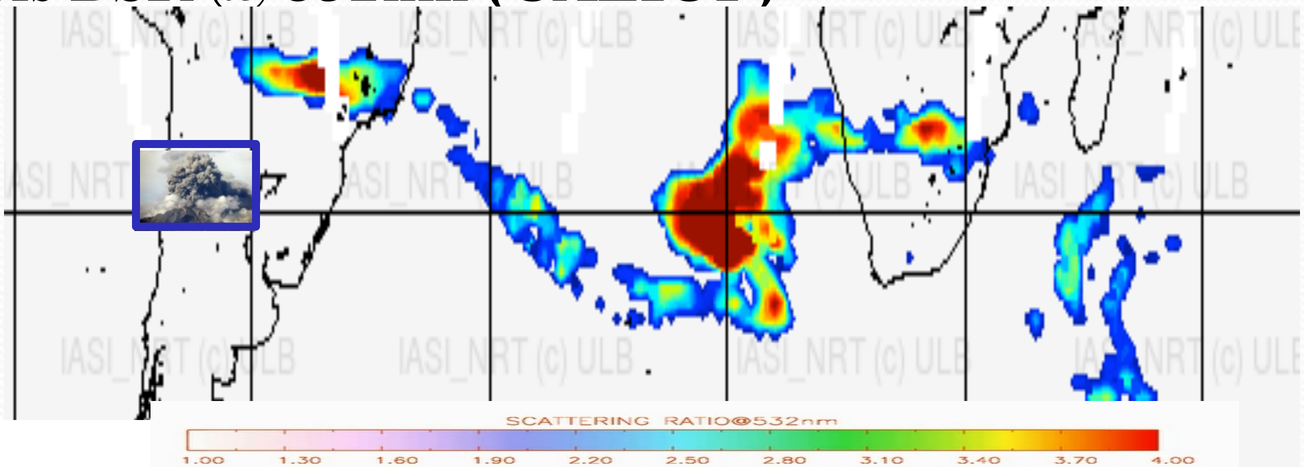


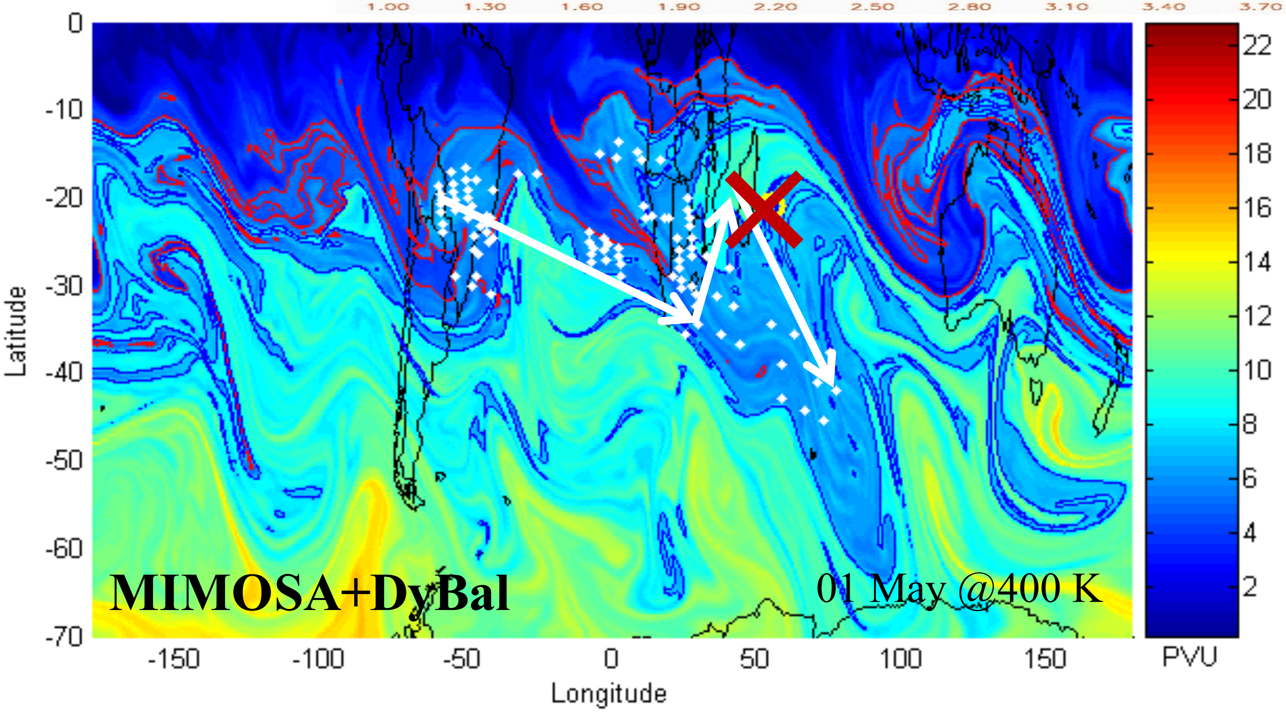




Calbuco eruption: low stratosphere observations

Aerosols BSR @ 532nm (CALIOP)



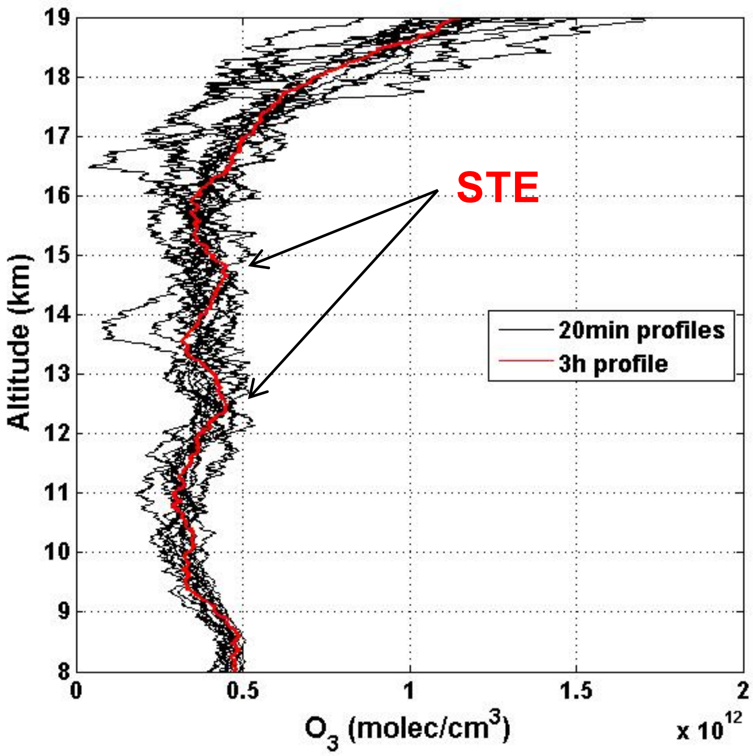


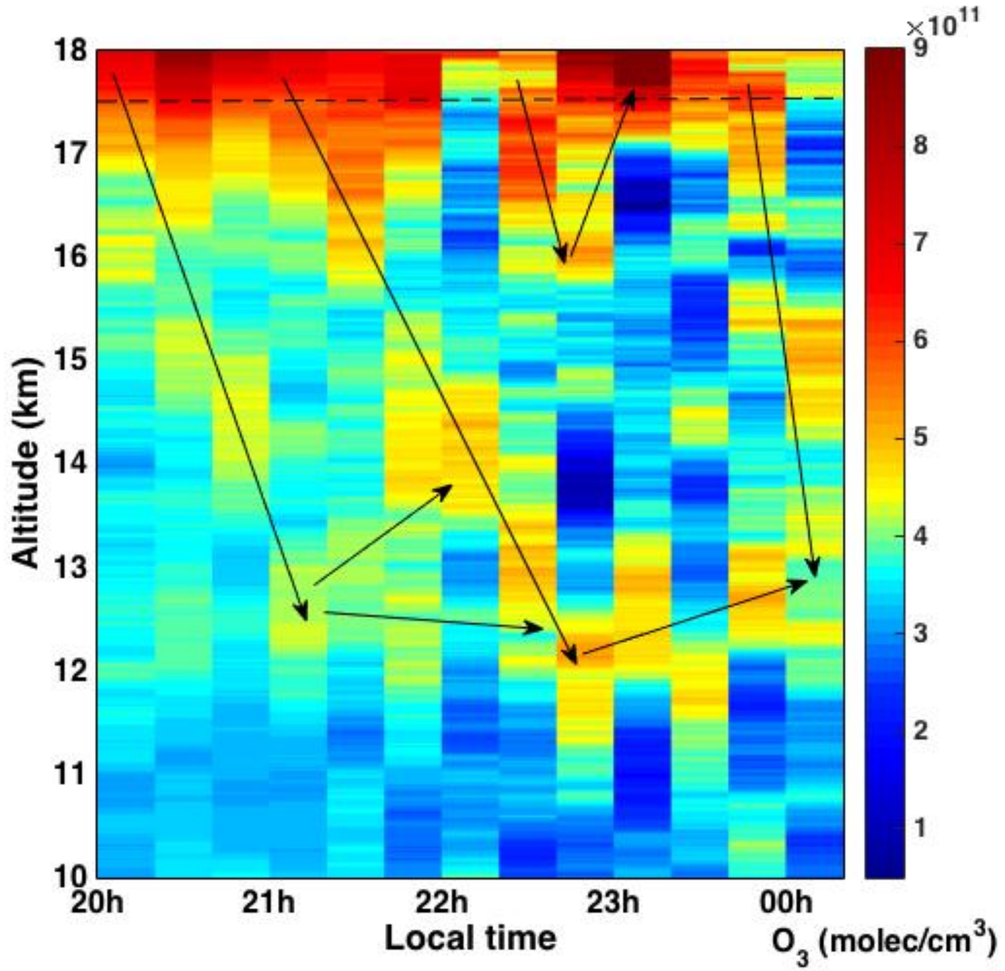
The dynamical barriers (subtropical and polar vortex) act as a channel

***Bègue et al.*, ACP 2017**

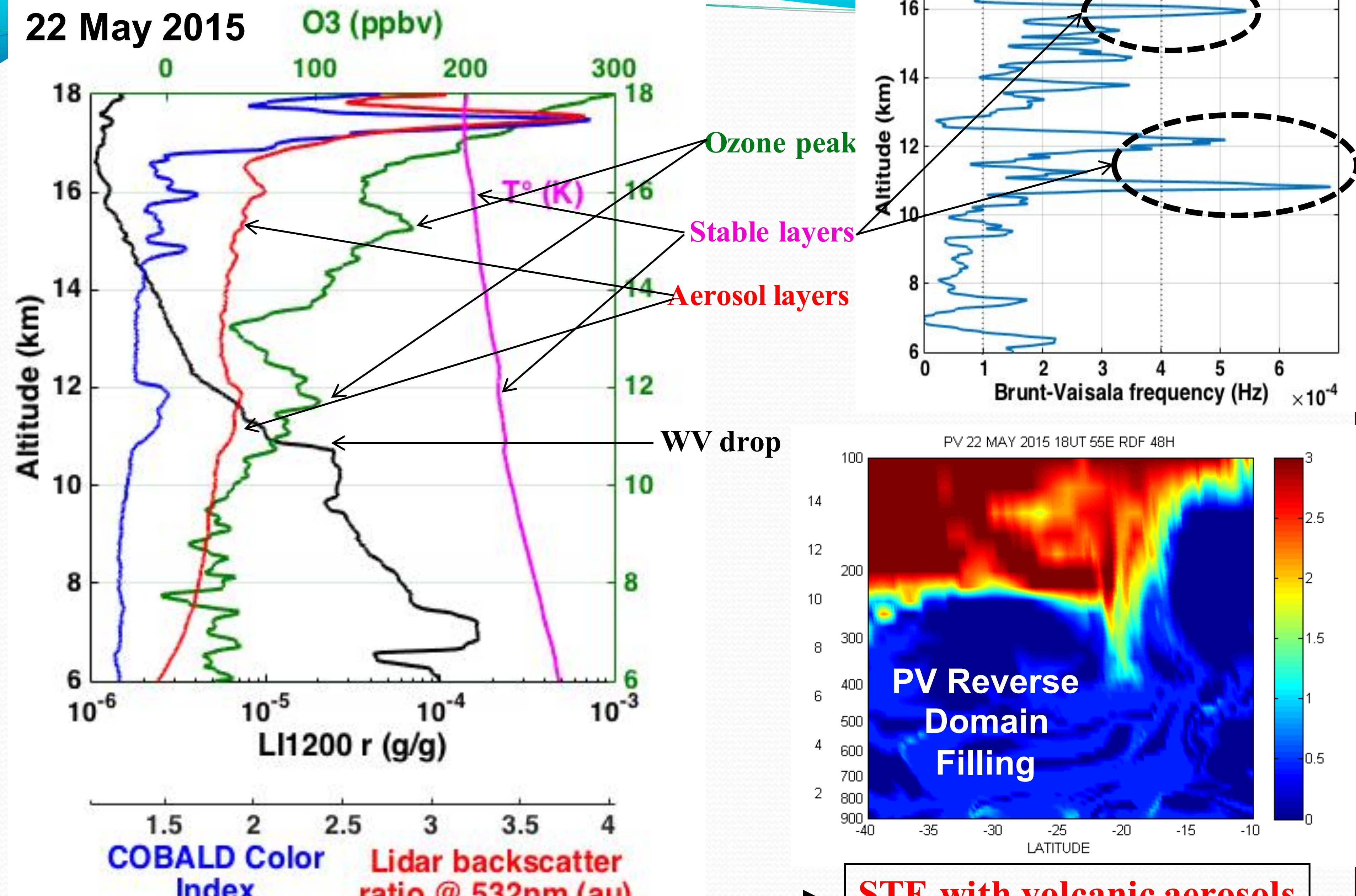
Calbuco: troposphere observations: STE

11 May 2015



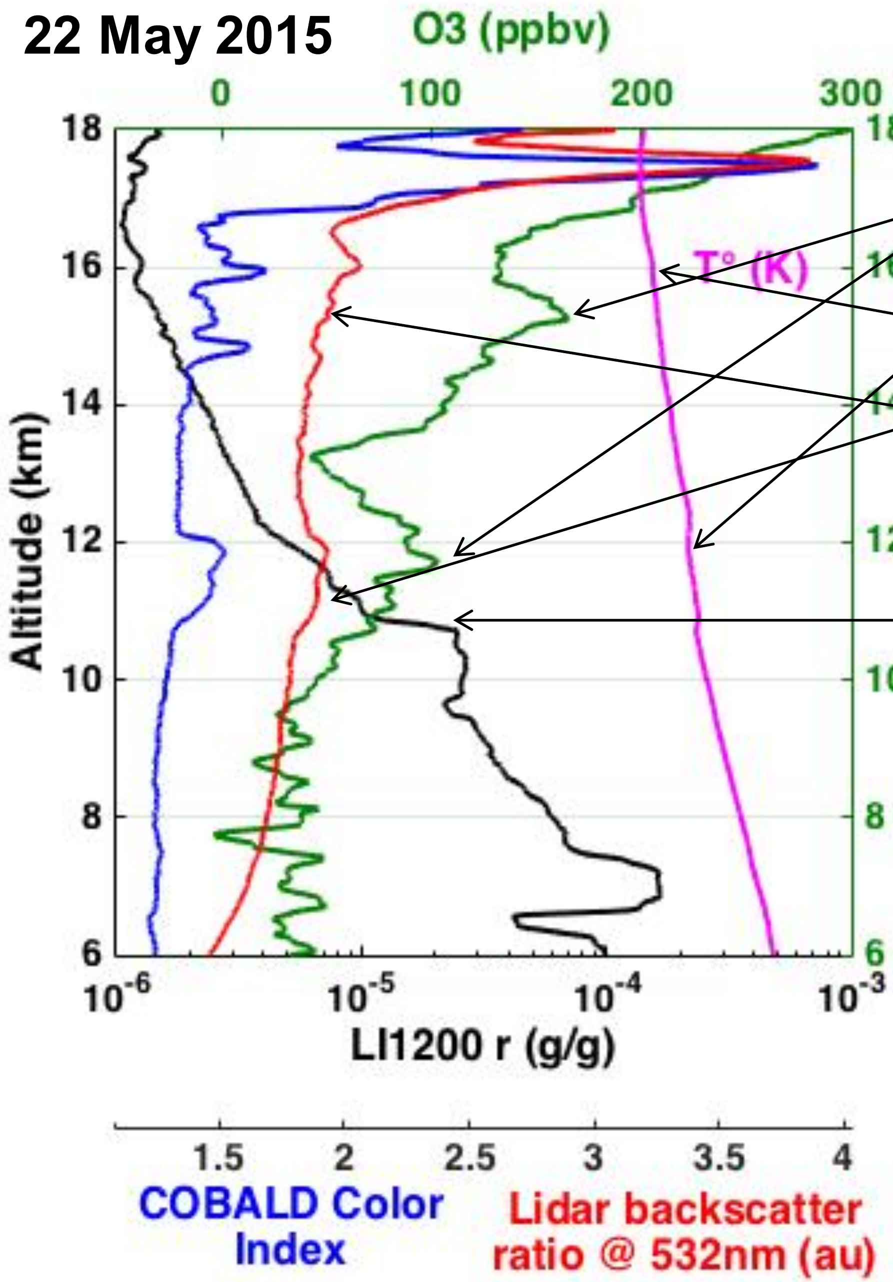


Calbuco: troposphere observations: STE



STE with volcanic aerosols

Calbuco: troposphere observations: STE

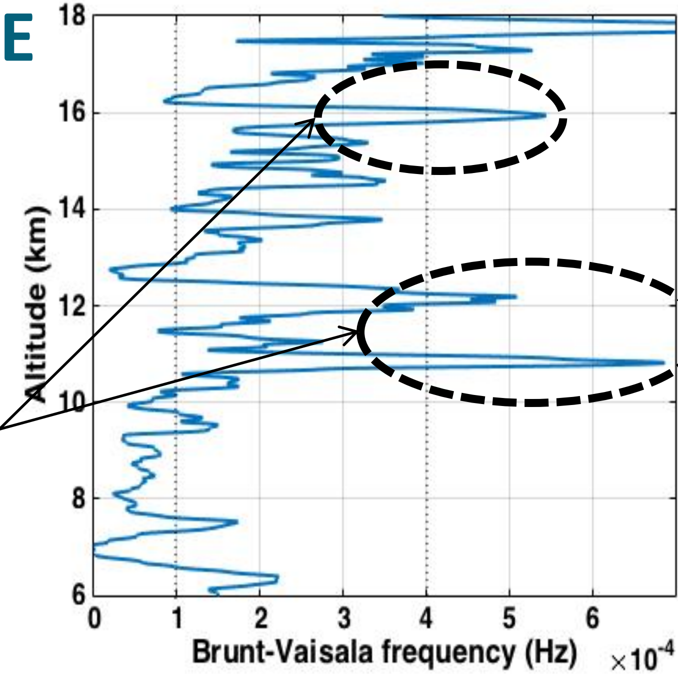


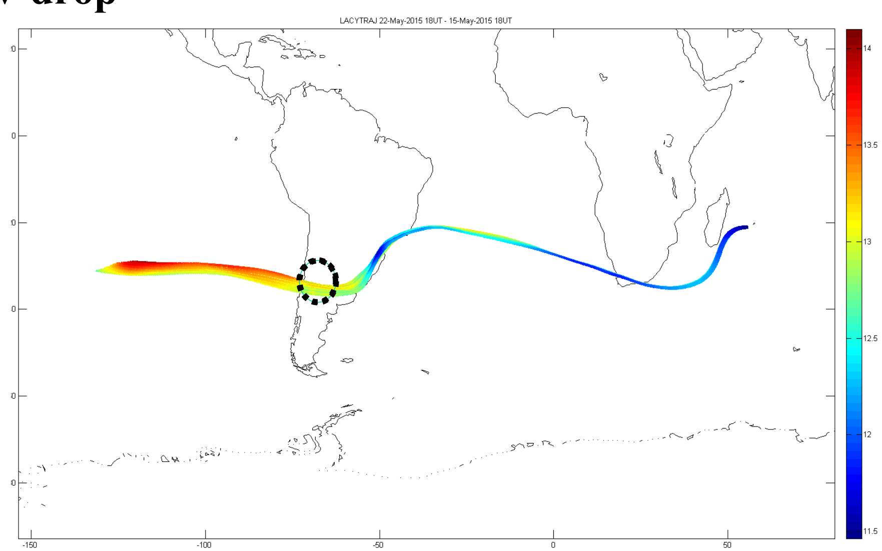
Ozone peak

Stable layers

Aerosol layers

WV drop

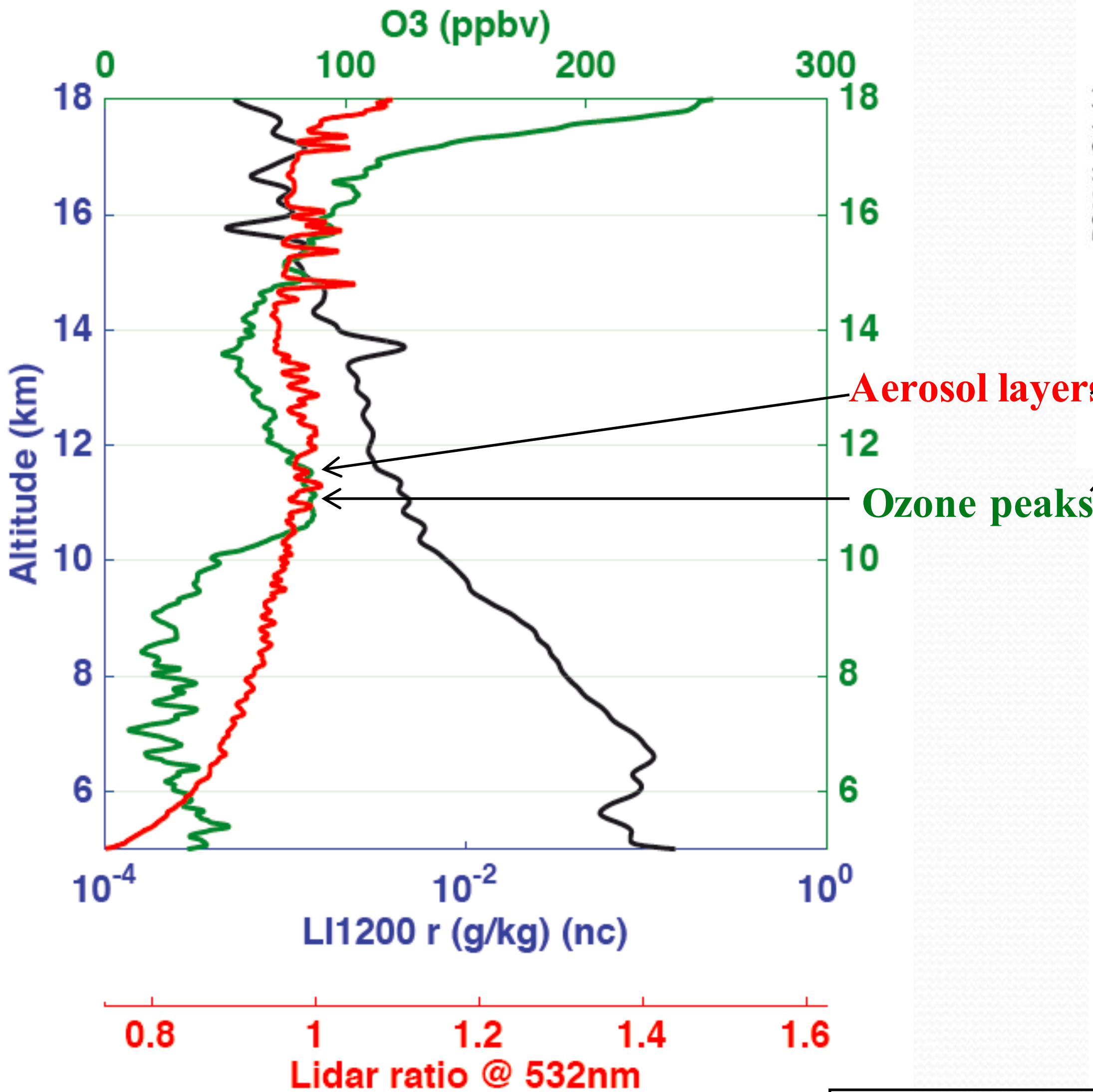


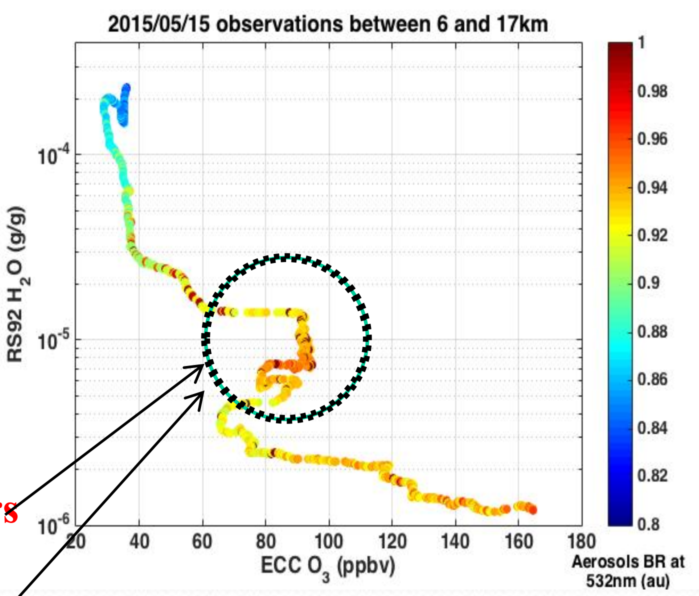


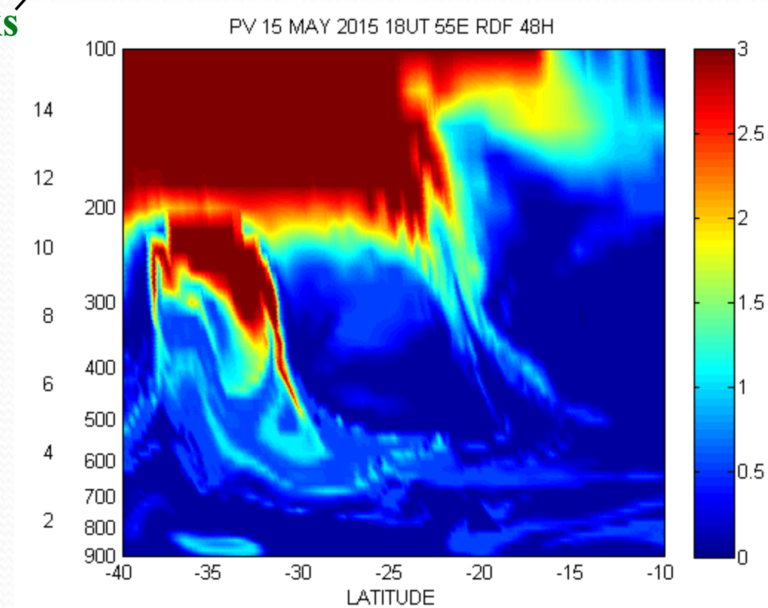
STE with volcanic aerosols

Calbuco: troposphere observations: STE

15 May 2015



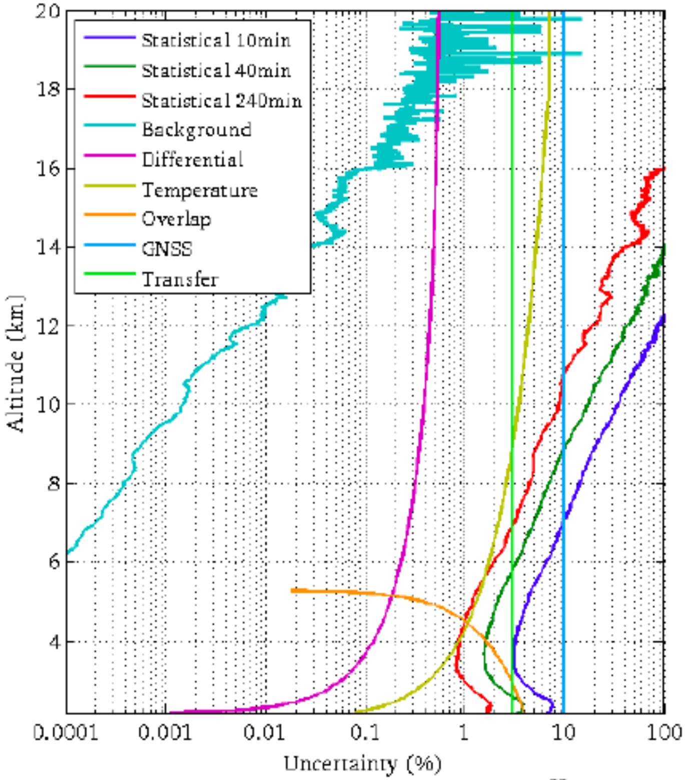


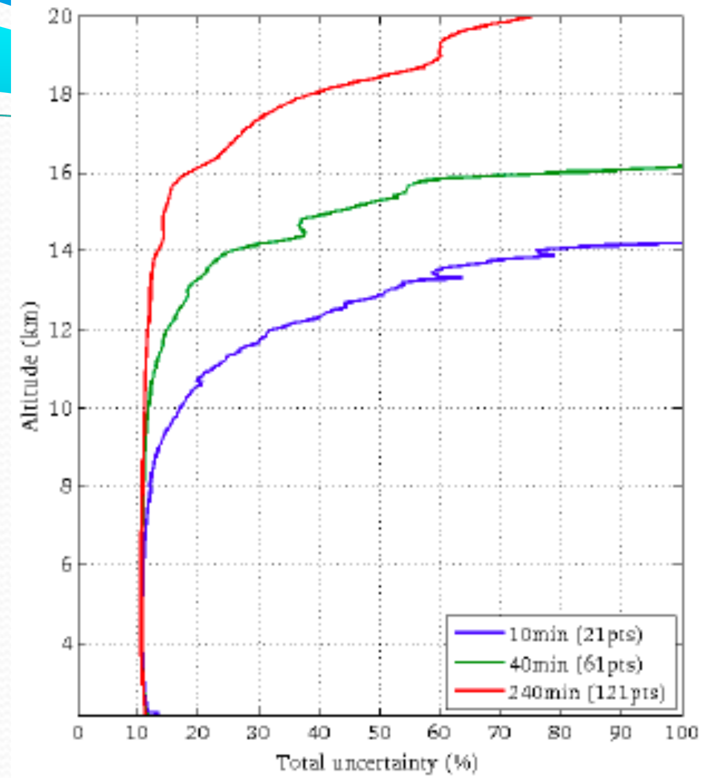


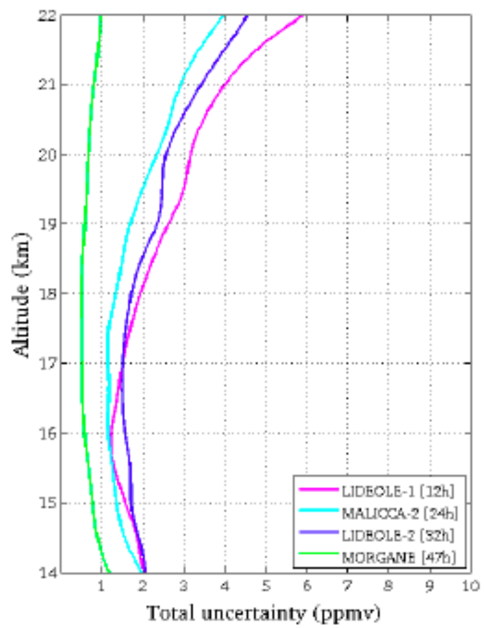
Duflot et al., in prep.

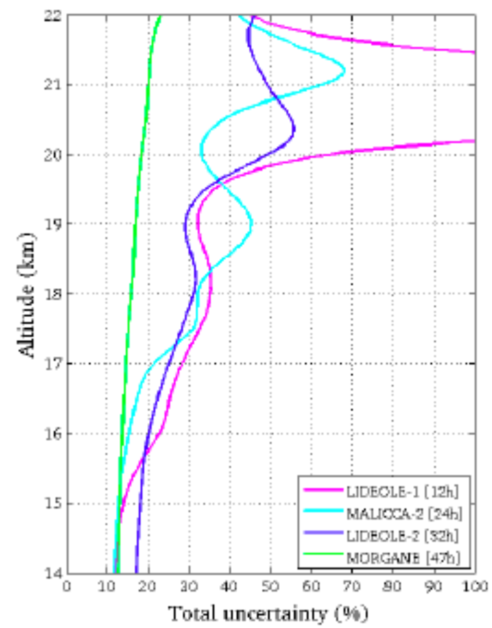
To which extent are STE a sink for volcanic stratospheric aerosols?

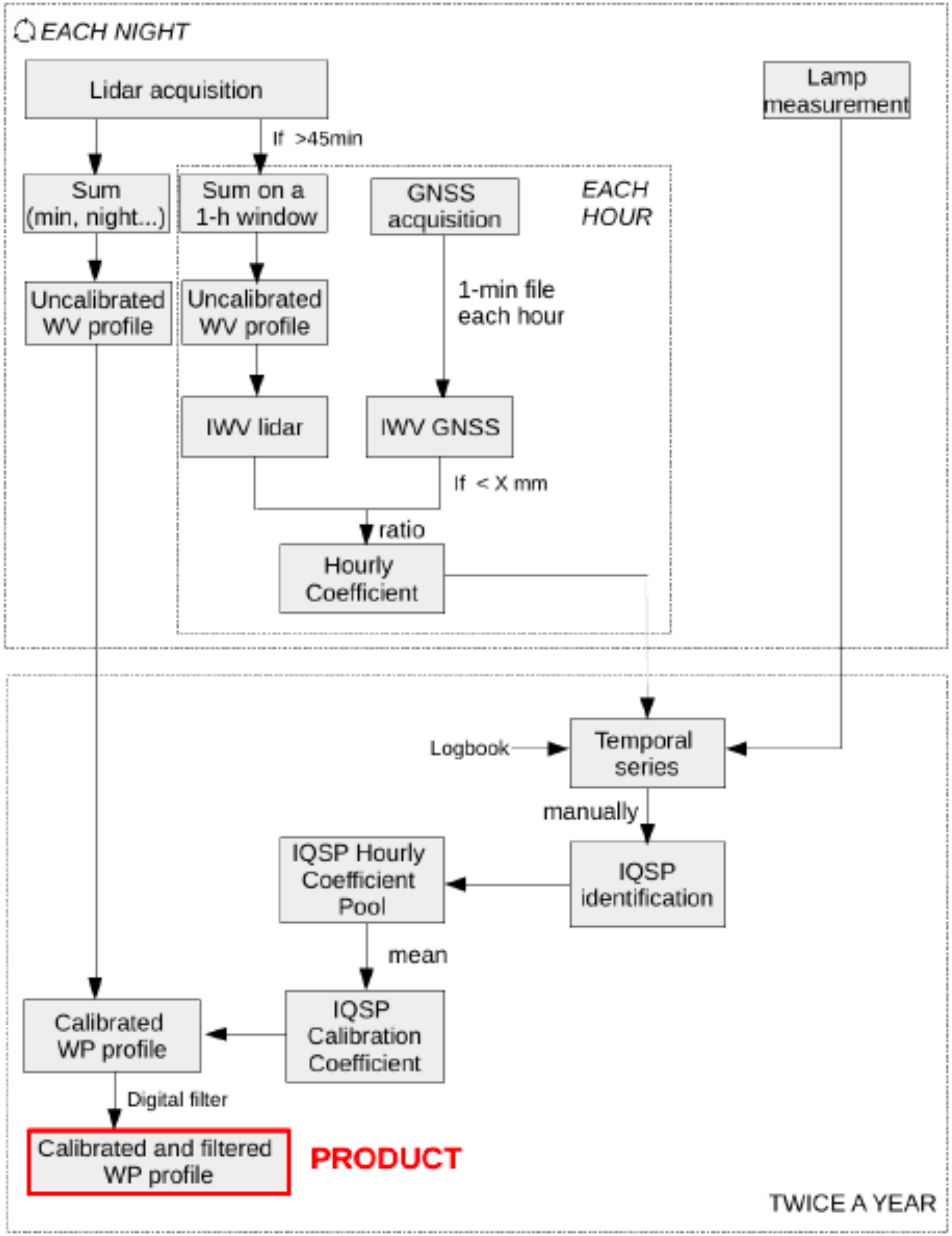
More slides

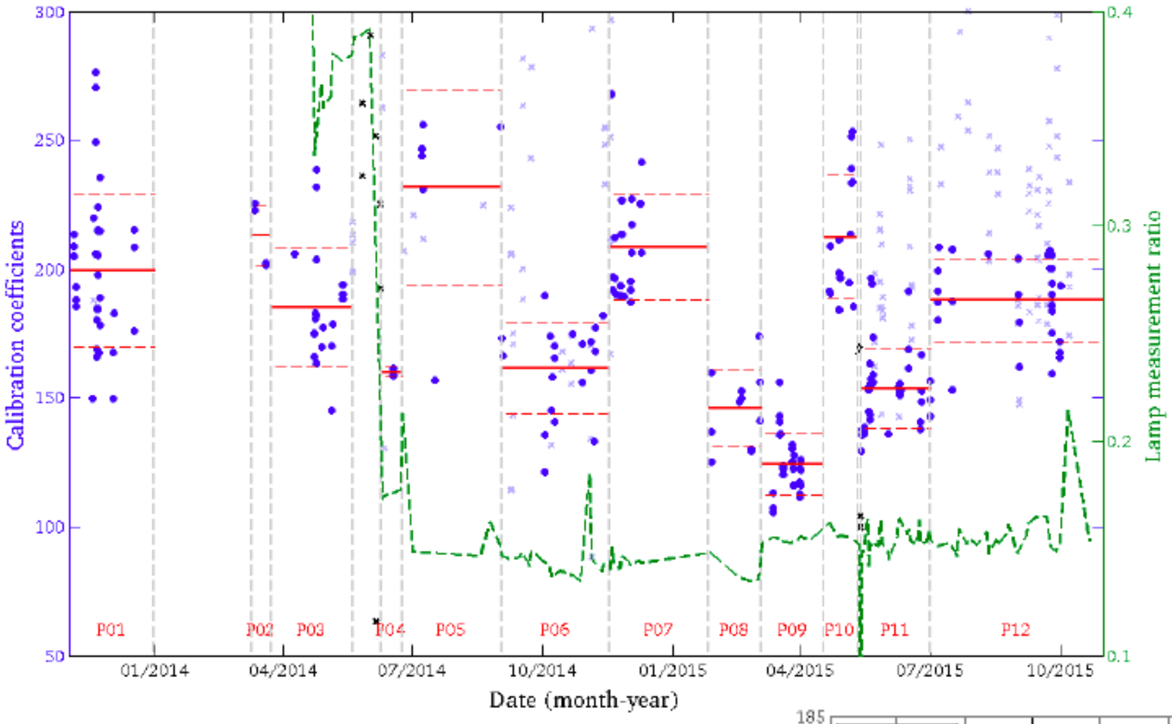

Statistical 10min
Statistical 40min
Statistical 240min
Background
Differential
Temperature
Overlap
GNSS
Transfer
Altitude (km)
Uncertainty (%)
0.0001
0.001
0.01
0.1
1
10
100

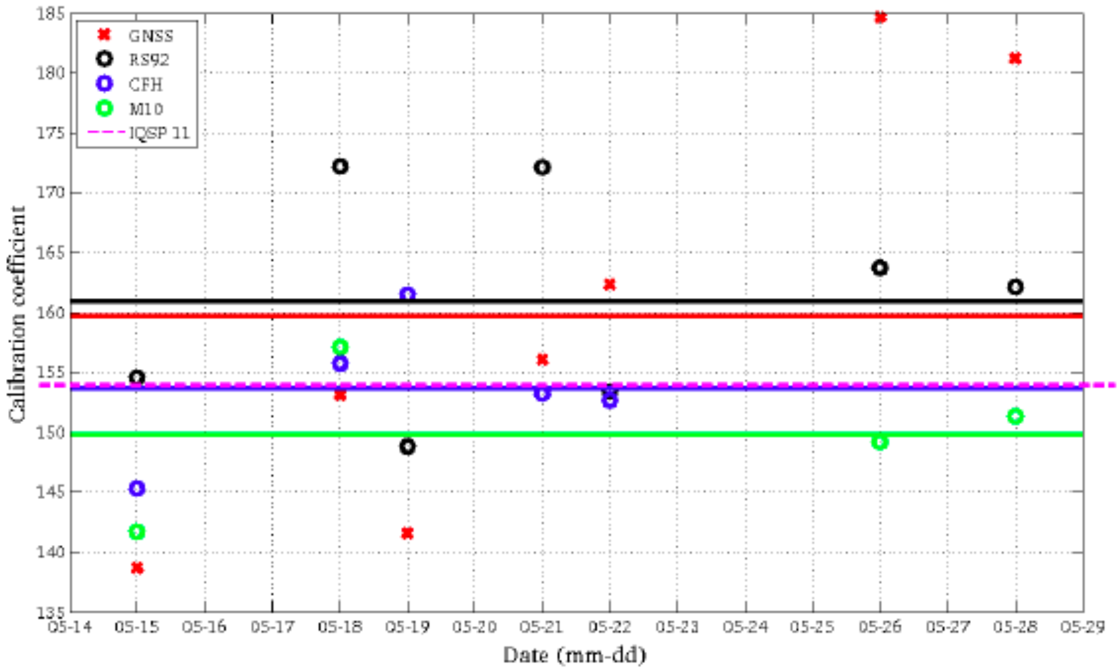

10min (21pts)
40min (61pts)
240min (121pts)
Altitude (km)
Total uncertainty (%)

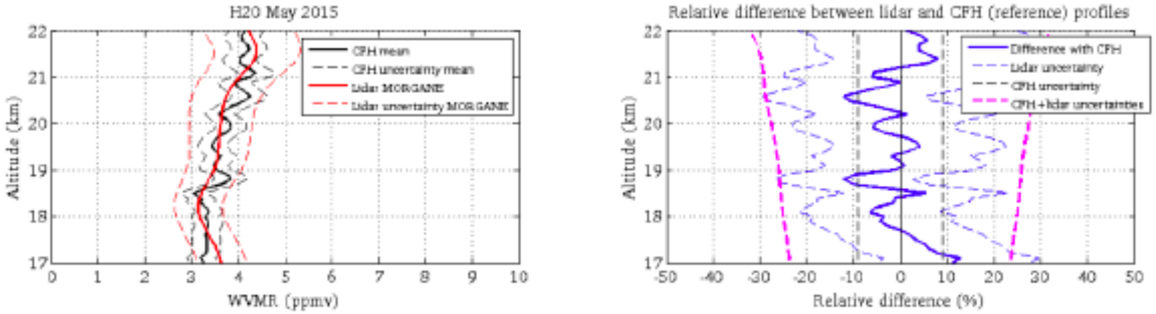

LIDEOLE-1 [12h]
MALICCA-2 [24h]
LIDEOLE-2 [32h]
MORGANE [47h]
Altitude (km)
Total uncertainty (ppmv)


LIDEOLE-1 [12h]
MALICCA-2 [24h]
LIDEOLE-2 [32h]
MORGANE [47h]
Altitude (km)
Total uncertainty (%)

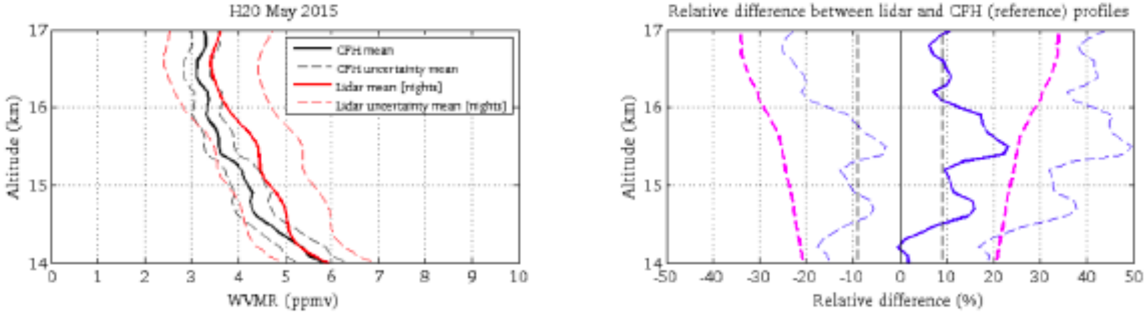

EACH NIGHT
Lidar acquisition
Lamp measurement
If >45min
Sum (min, night...)
Sum on a 1-h window
GNSS acquisition
EACH HOUR
Uncalibrated WV profile
Uncalibrated WV profile
1-min file each hour
IWV lidar
IWV GNSS
If < X mm
ratio
Hourly Coefficient
Logbook
Temporal series
manually
IQSP Hourly Coefficient Pool
IQSP identification
mean
Calibrated WP profile
IQSP Calibration Coefficient
Digital filter
Calibrated and filtered WP profile
PRODUCT
TWICE A YEAR


Calibration coefficients
Lamp measurement ratio
Date (month-year)
P01
P02
P03
P04
P05
P06
P07
P08
P09
P10
P11
P12
01/2014
04/2014
07/2014
10/2014
01/2015
04/2015
07/2015
10/2015

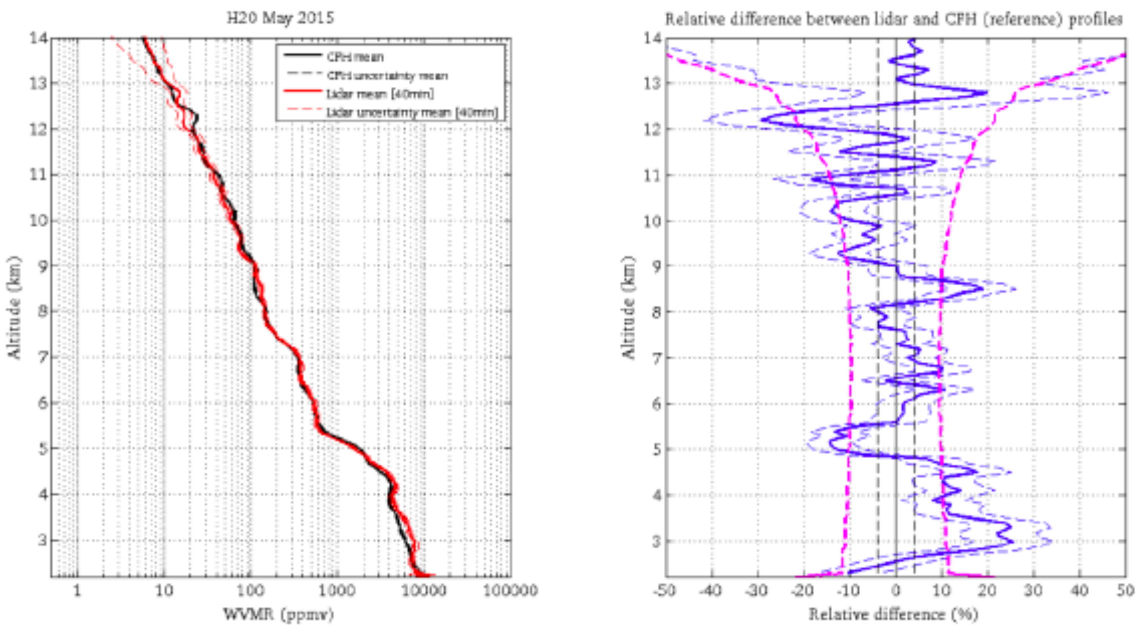

GNSS
RS92
CFH
M10
IQSP 11
Calibration coefficient
Date (mm-dd)


H20 May 2015
CFH mean
CFH uncertainty mean
Lidar MORGANE
Lidar uncertainty MORGANE
Altitude (km)
WVMR (ppmv)
Relative difference between lidar and CFH (reference) profiles
Difference with CFH
Lidar uncertainty
CFH uncertainty
CFH+lidar uncertainties
Relative difference (%)

B)


H20 May 2015
CFH mean
CFH uncertainty mean
Lidar mean [nights]
Lidar uncertainty mean [nights]
Altitude (km)
WVMR (ppmv)
Relative difference between lidar and CFH (reference) profiles
Relative difference (%)

C)


H20 May 2015
CFH mean
CFH uncertainty mean
Lidar mean [40min]
Lidar uncertainty mean [40min]
Altitude (km)
WVMR (ppmv)
Relative difference between lidar and CFH (reference) profiles
Relative difference (%)

ATTRIBUTE	TREND DETECTION		PROCESS STUDIES
	Upper Troposphere	Lower Stratosphere	
Vertical resolution	< 1 km	< 1 km	10-100 m
Systematic error	5-10%	5-10%	10%
Random error	up to 50%	< 10%	< 10-25%[1]
Stability	no data	no data	N/A
Temporal resolution	< 1 h	no data	1 min

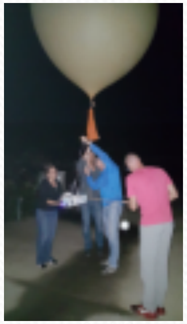
ALTITUDE RANGE (km asl)	TEMPORAL RESOLUTION (min)	FILTER (number of points at 21 km)	VERTICAL RESOLUTION (m)	SYSTEMATIC UNCERTAINTY (%)	STATISTICAL UNCERTAINTY (%)	TOTAL UNCERTAINTY (%)
2.2-10	10	21	65-90	10-15*	2.5-15**	< 20**
2.2-14	40	61	100-300		2-25**	< 25**
2.2-17	240-480	121	100-650		1-25**	< 30**
2.2-22	~2800	201	150-1300		< 20**	< 25**

UTLS Water Vapor Observations

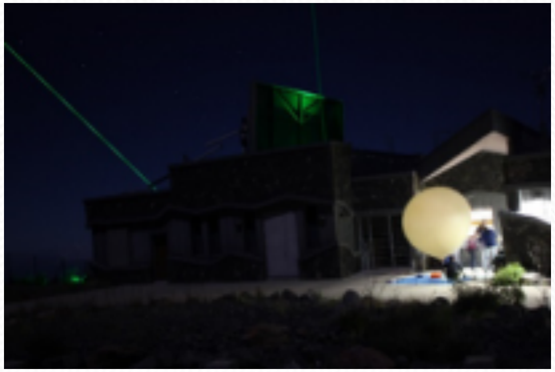
Nov 2014 TNA-ACTRIS
CFH+M10+RS92+Lidar

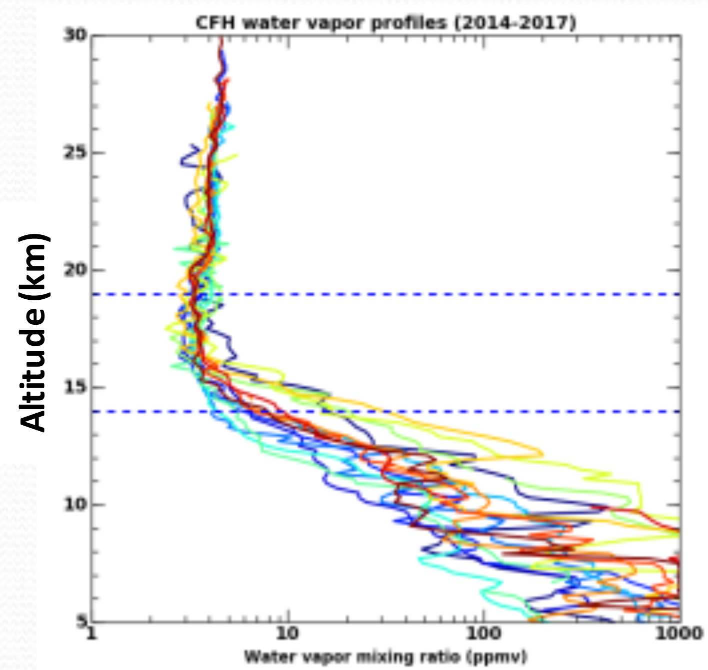
May 2015: MORGANE campaign
CFH+M10+RS92+Lidar

Jan/Mar 2016
HAIC campaign
+ TNA ACTRIS
CFH+M10+Lidar



Mar/May 2017 TC Enawo
+ TNA ACTRIS
CFH+M10+Lidar





3 years of CFH (13 profiles) + Lidar water vapor data for (2014-2017) available

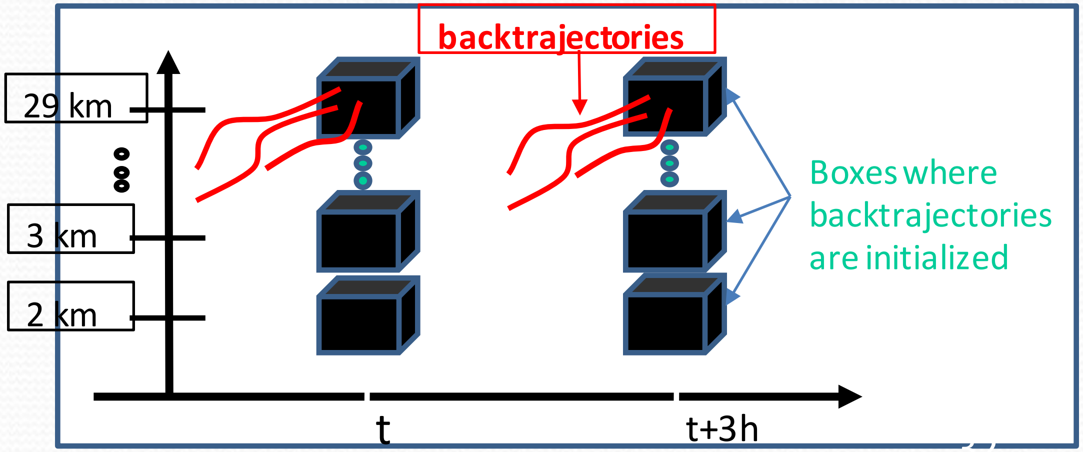
ORIGIN OF CONVECTIVE OUTFLOW MEASURED AT REUNION ISLAND

FLEXPART lagrangian driven by 0.15x0.15 degree ECMWF over the Southern Indian Ocean, and 0.5x0.5 degree at global scale.

20000 Backtrajectories calculated over 1 week from each "box"
Each set of trajectories is released every 1km from 2km to 29km alttiude, and every 3 hours.

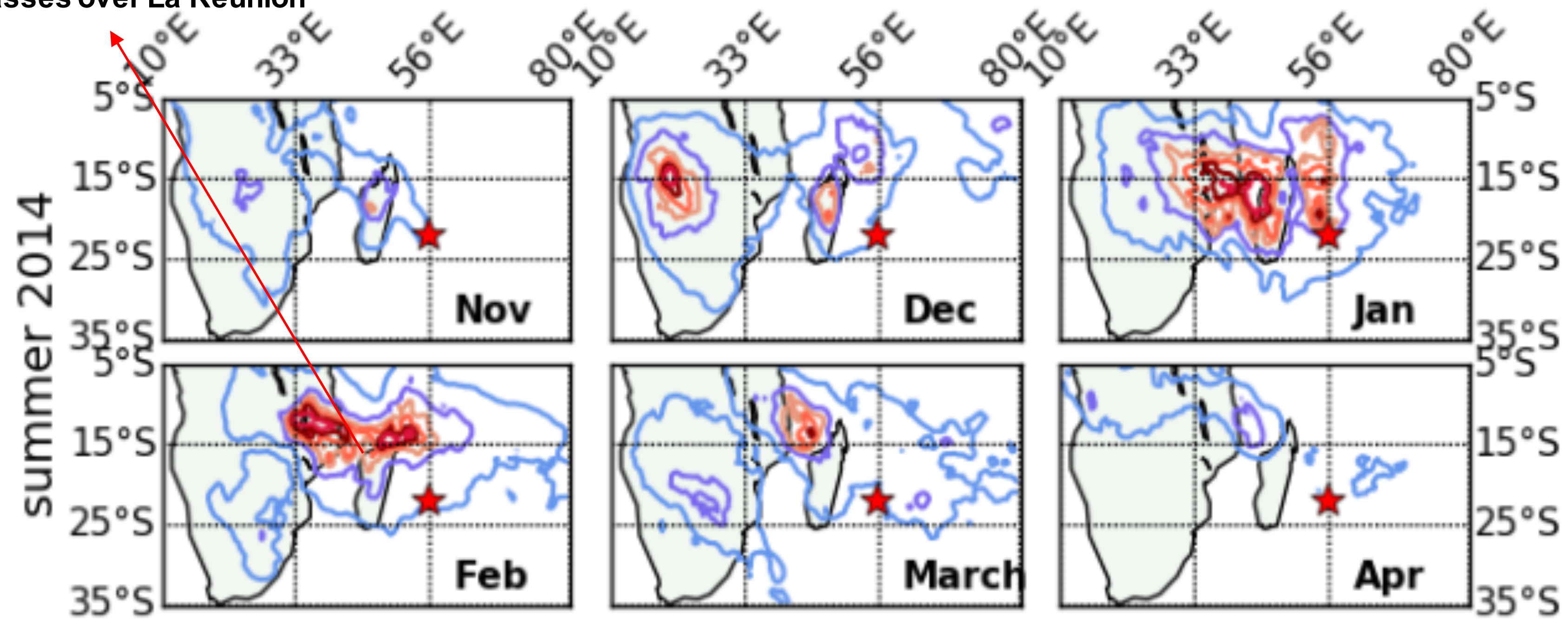
FLEXPART model output:

- Percentage of tropospheric, stratospheric and boundary layer air origin
- Probability density function of origin in the lower troposphere



ORIGIN OF CONVECTIVE OUTFLOW MEASURED AT REUNION ISLAND

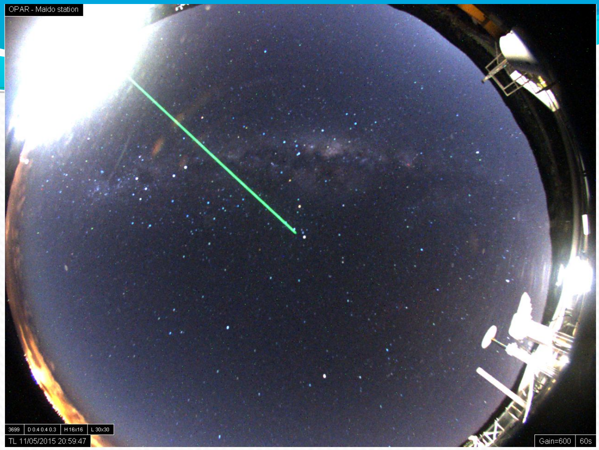
The contours correspond to the probability of convective origin for upper tropospheric air masses over La Réunion



The convective influence (inferred from FLEXPART trajectories+METEOSAT 7 images) varies in time, with maximum of influence in Jan-Feb associated with deep convection over Madagascar/the Mozambique Channel

Courtesy S. Evan

The Maïdo Observatory



25 instruments in total

12 in situ instruments

5 lidars:

- **Wind**
- **Mobile aerosols (PBL and free troposphere)**
- **Water vapor, T°**
- **DIAL tropospheric O3 (+aerosols)**
- **DIAL stratospheric O3 (+aerosols)**

Nighttime measurements

Routinely operated twice/week (+ campaigns)