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REMOTE SENSING
for
UNDERSTANDING – regional air pollution
and
MONITORING – climate change related parameters

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Classical Analytic Techniques vs. Remote Sensing

Classical Analytical Techniques

Remote sensing

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UNDERSTANDING ~ regional air pollution

COMPLEX

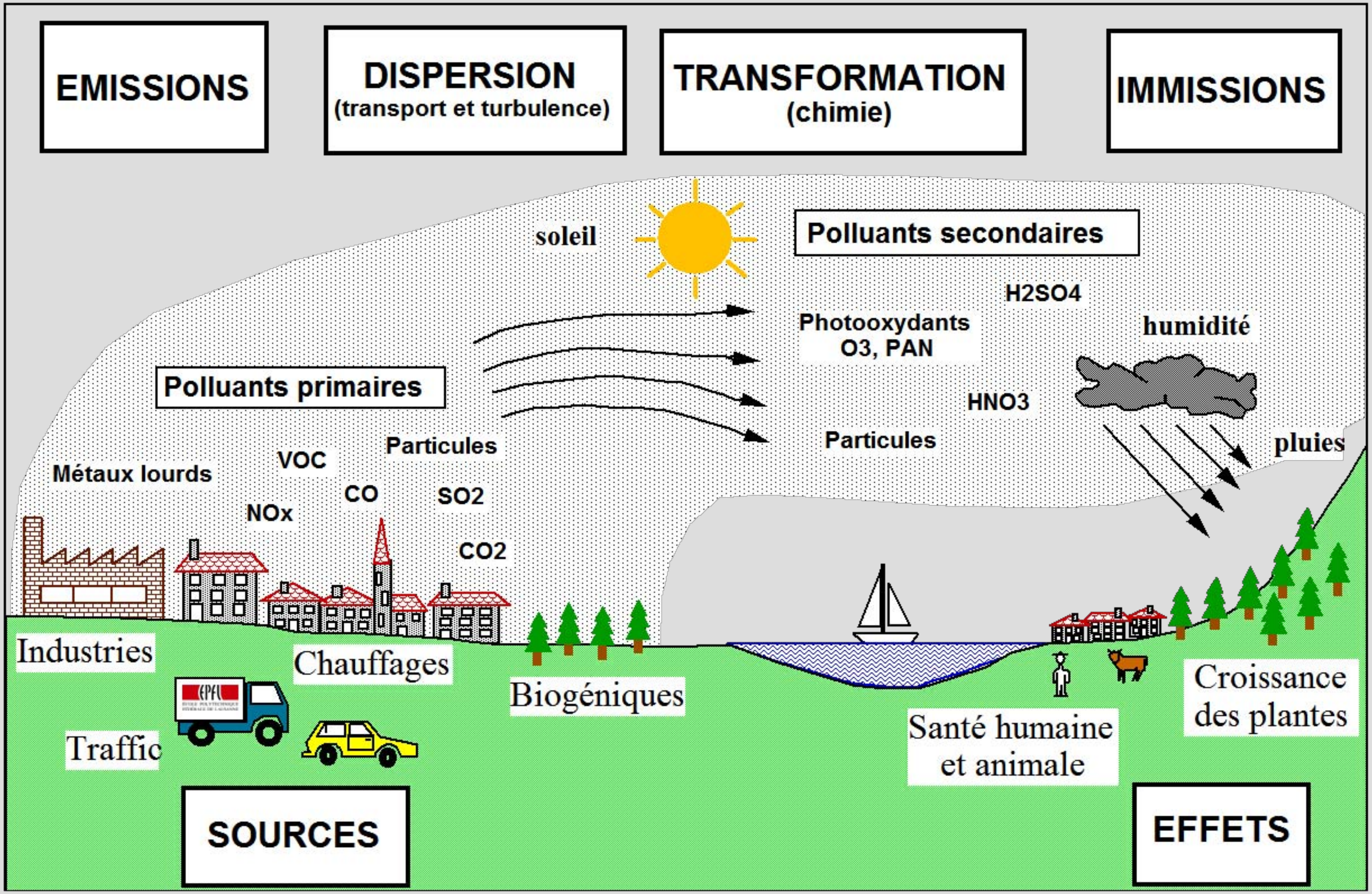
TRANSPORT

CHEMISTRY

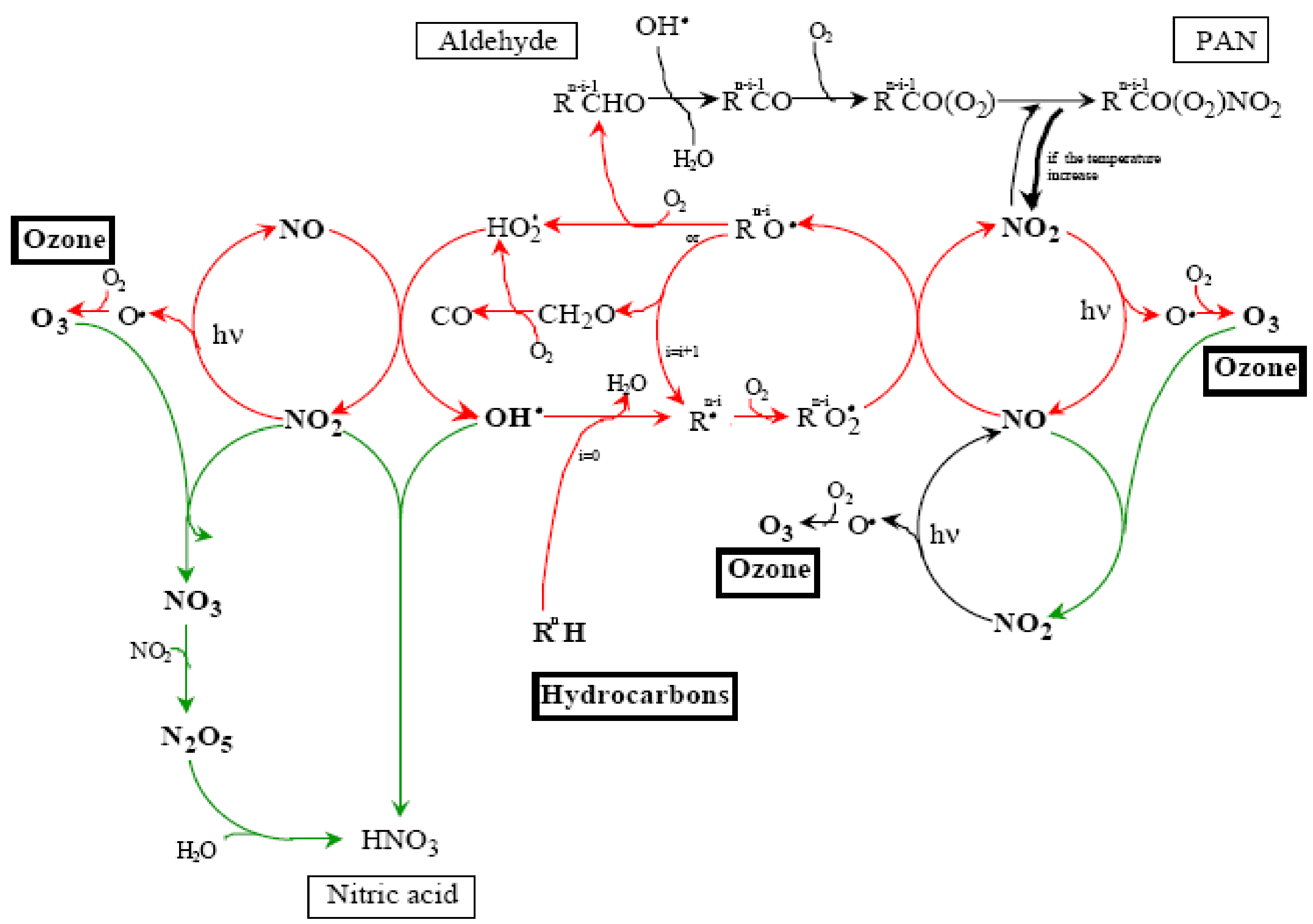
OZONE

METEO

EFFECTS

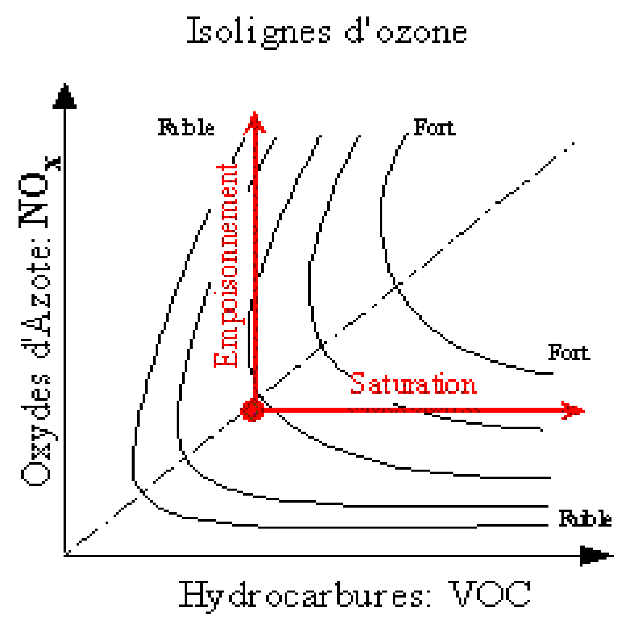


Tropspheric Ozone Formation: a complex chemistry



Tropspheric Ozone Formation: A non linear problem

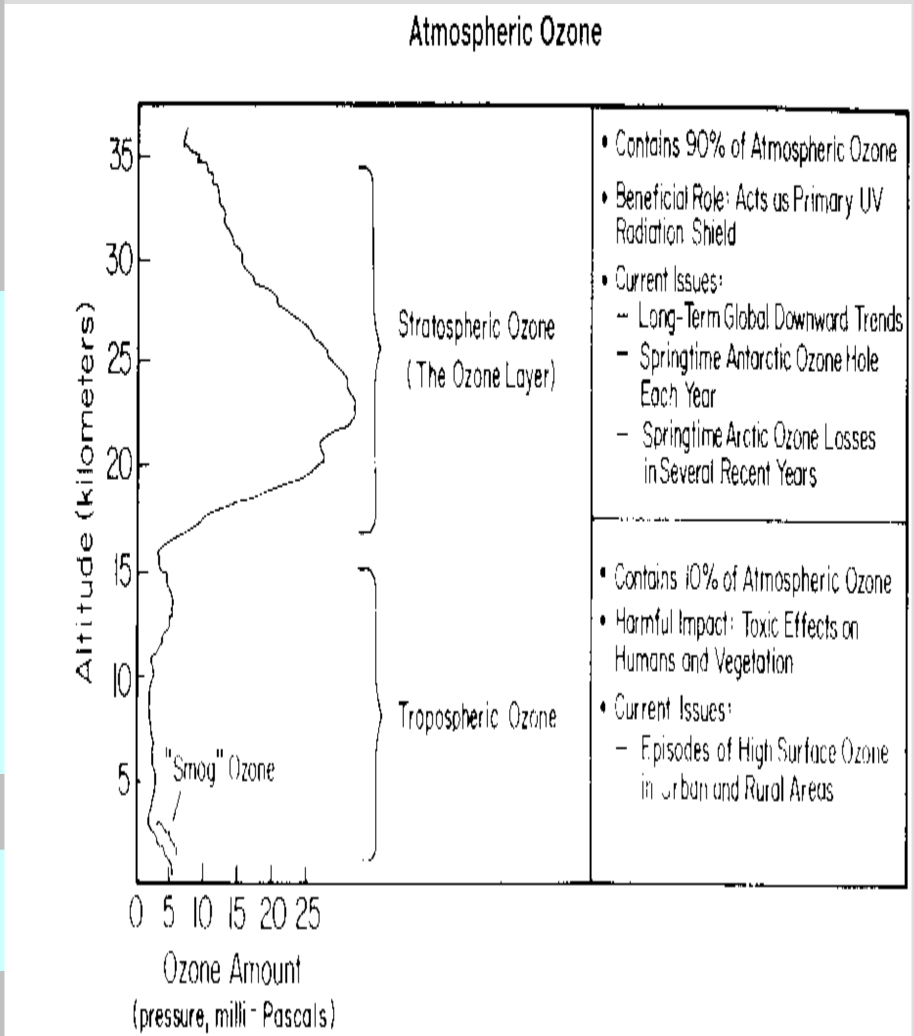
$$NO_x + VOC \longrightarrow O_3$$

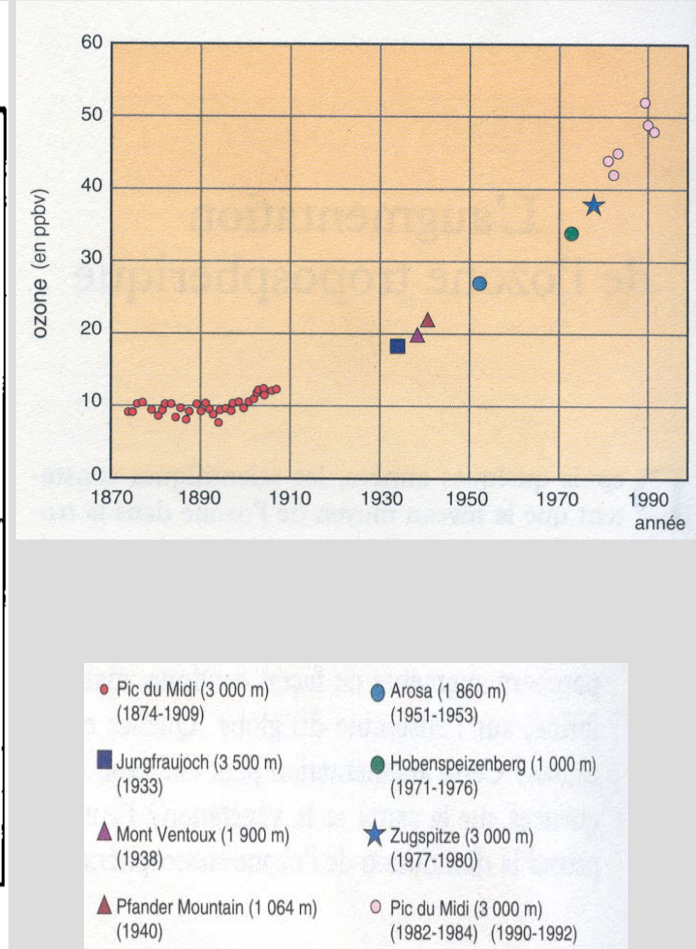


NOX and VOC simple reduction may give WORSE

Identification of VOC & NOX limited regimes ?!

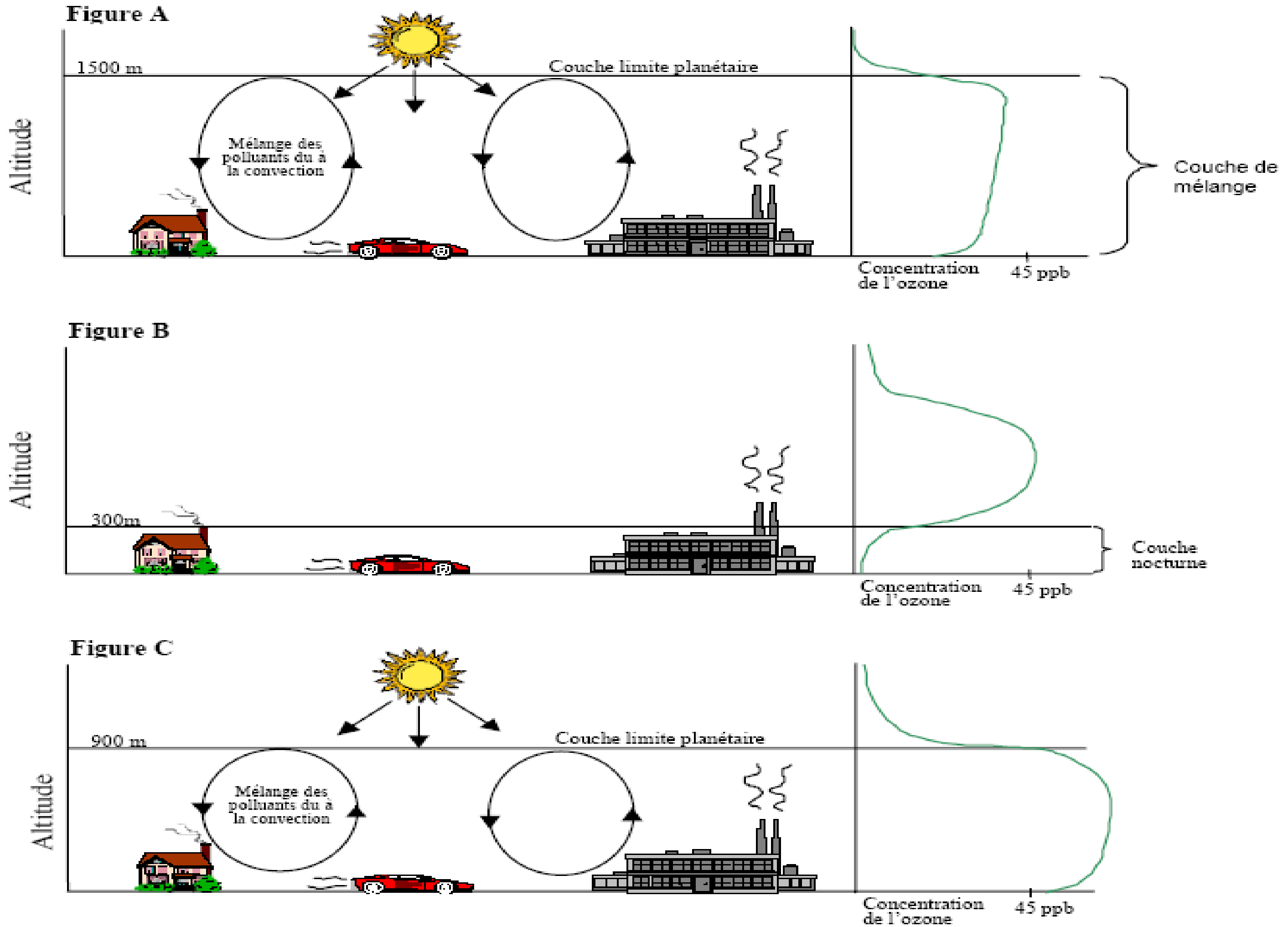
Ozone: The Good & The Bad Ones





Planetary Boundary Layer: Dynamics & Processes

COMPLEX
DYNAMIC
CHEMISTRY
OZONE
METEO
EFFECTS



Regional Air Pollution Modeling: Euler Scheme

3D MODEL

METEO

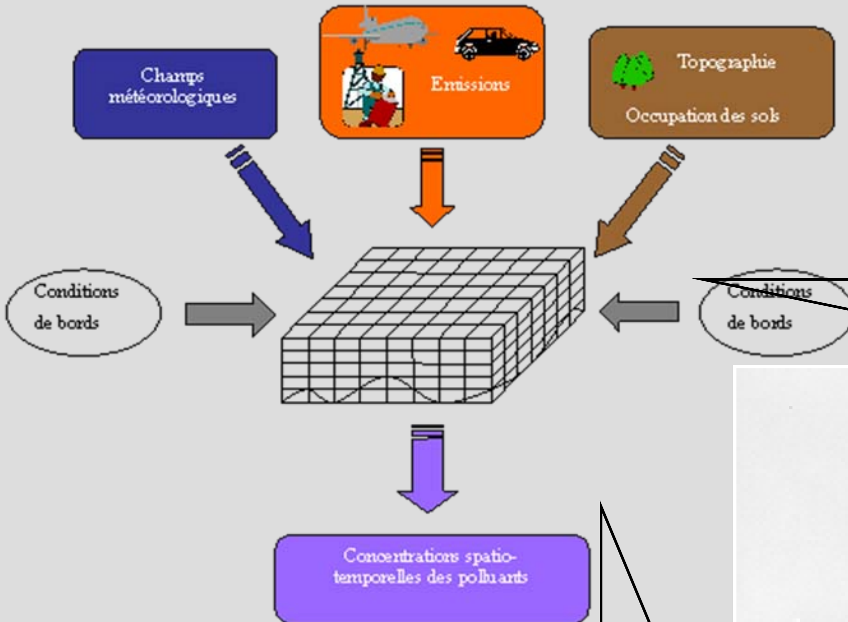
EMISIONS

TOPO

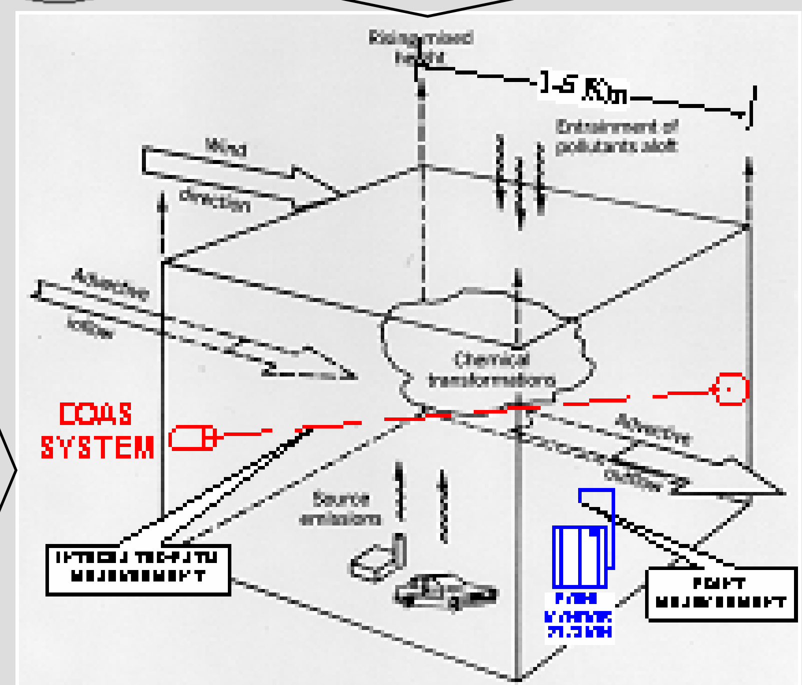
LIMIT Conditions

Meteo & Pollution

f (time, space)



Need of 3D Representative Measurements



DOAS

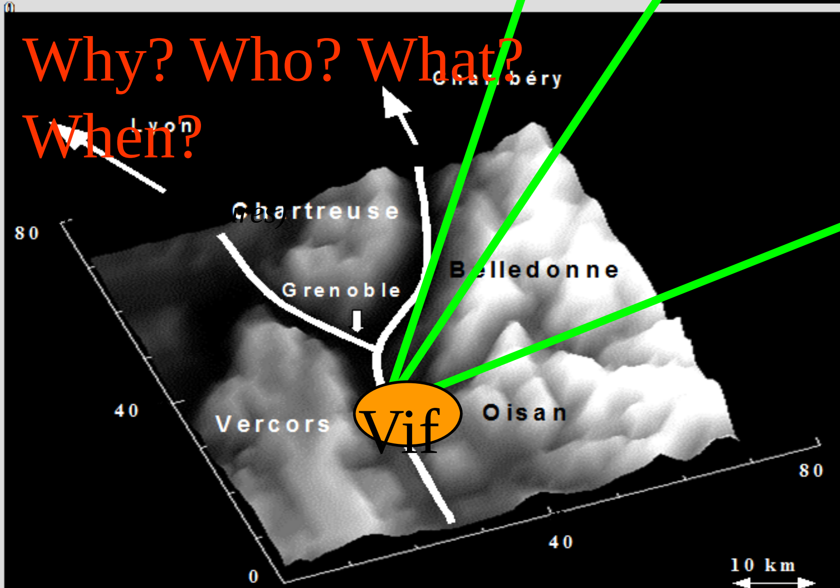
LIDAR,

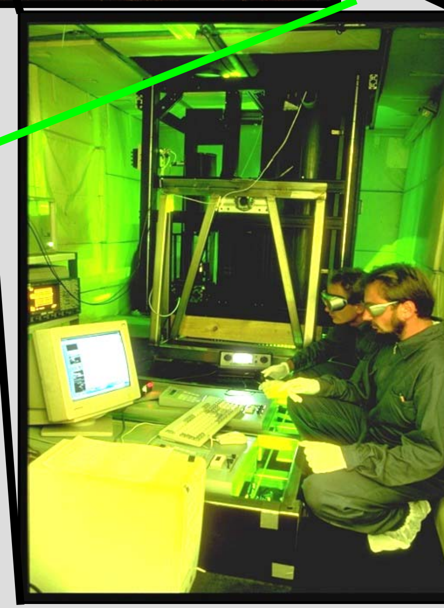
WindProfiler,

RadioSounding

Un instrumented site in GRENOPHOT99

VIF: a measurement site in a village situated in the rural area at 20 km South of Grenoble ?





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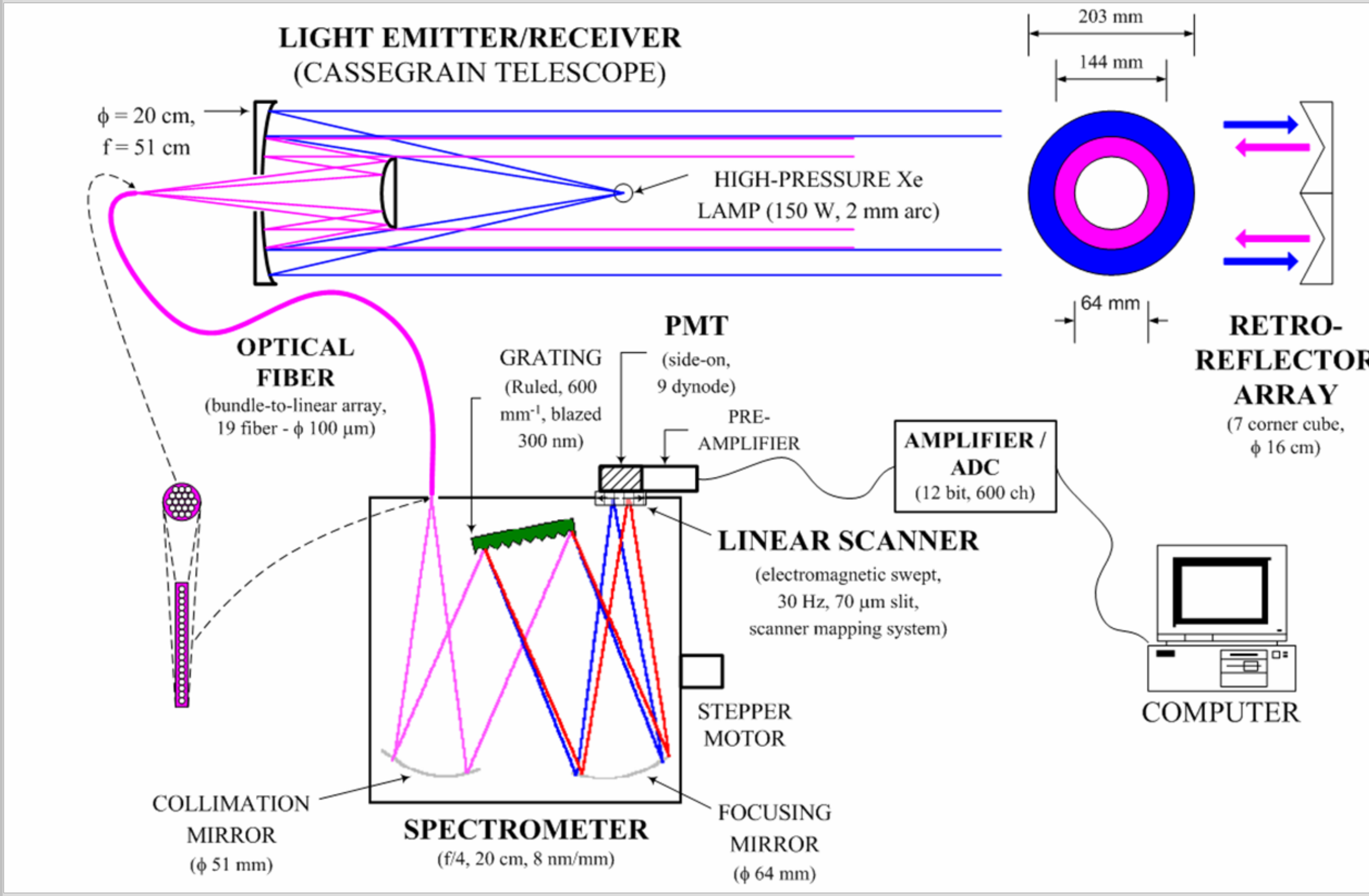
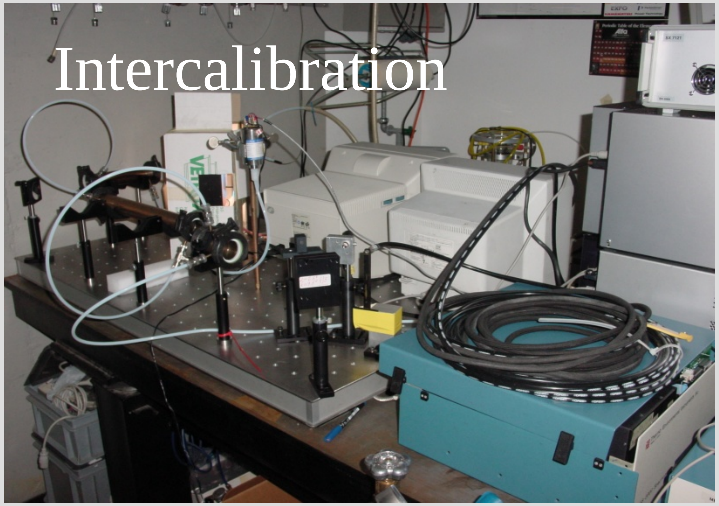
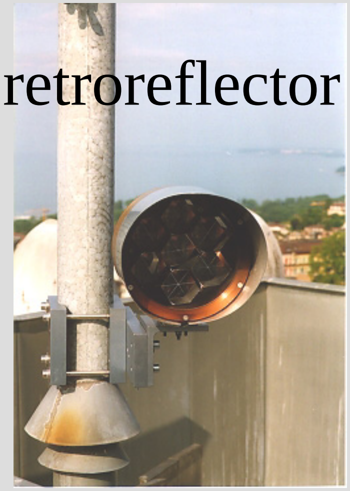
DOAS SYSTEM : Optical Layout



DOAS: Differential Optical Absorption Spectroscopy

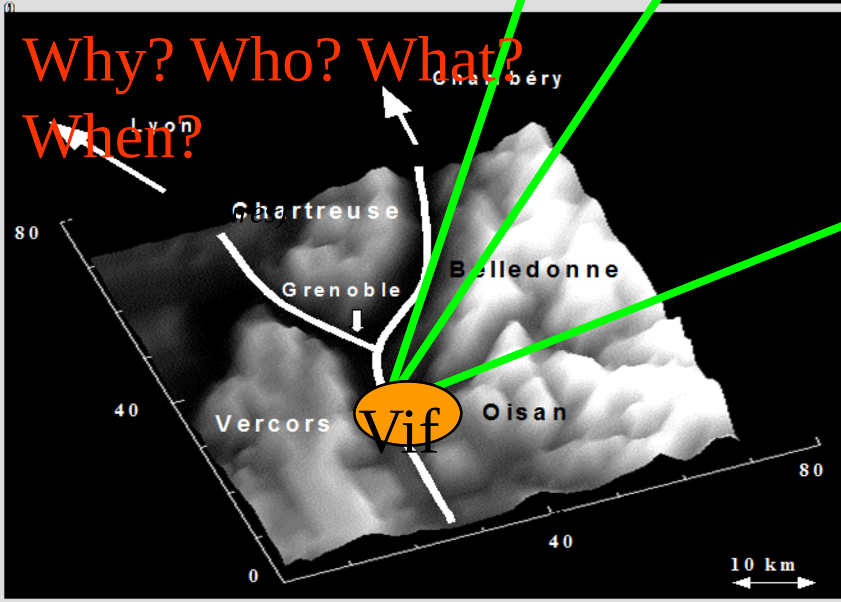


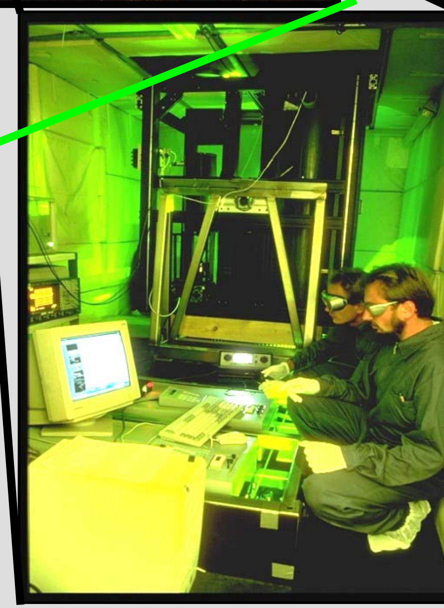


Un instrumented site in GRENOPHOT99

VIF: a measurement site in a village situated in the rural area at 20 km South of Grenoble ?

Why? Who? What? When?





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Ozone DIAL-LIDAR : the setup used on the

O3 DIAL LIDAR

O3 Profiles

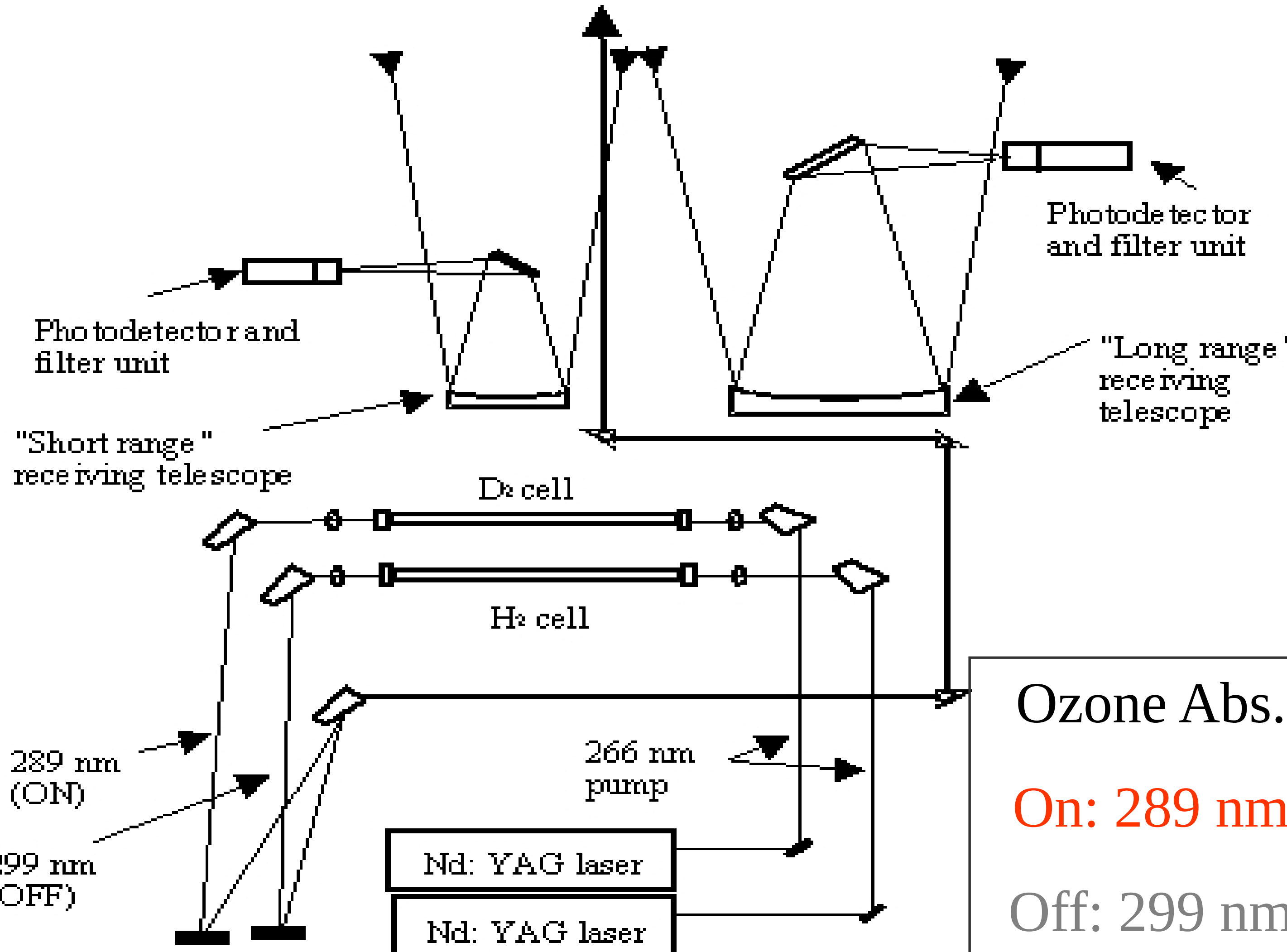
PBL

Aerosols

0.5 – 4 Km

0- 3.5 days

R: 75m/30min

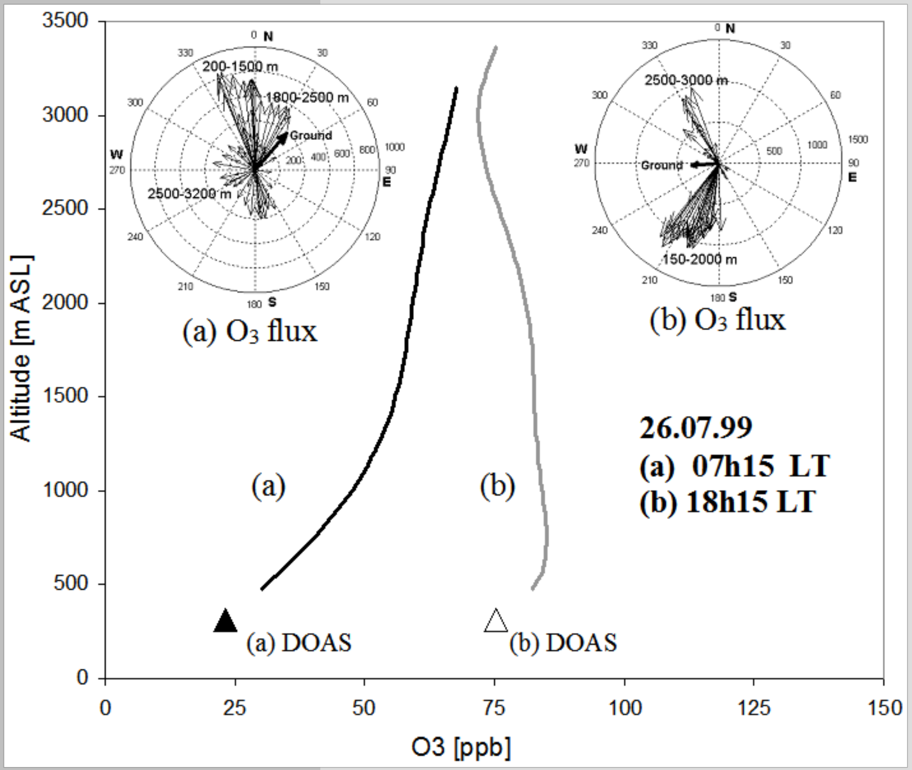


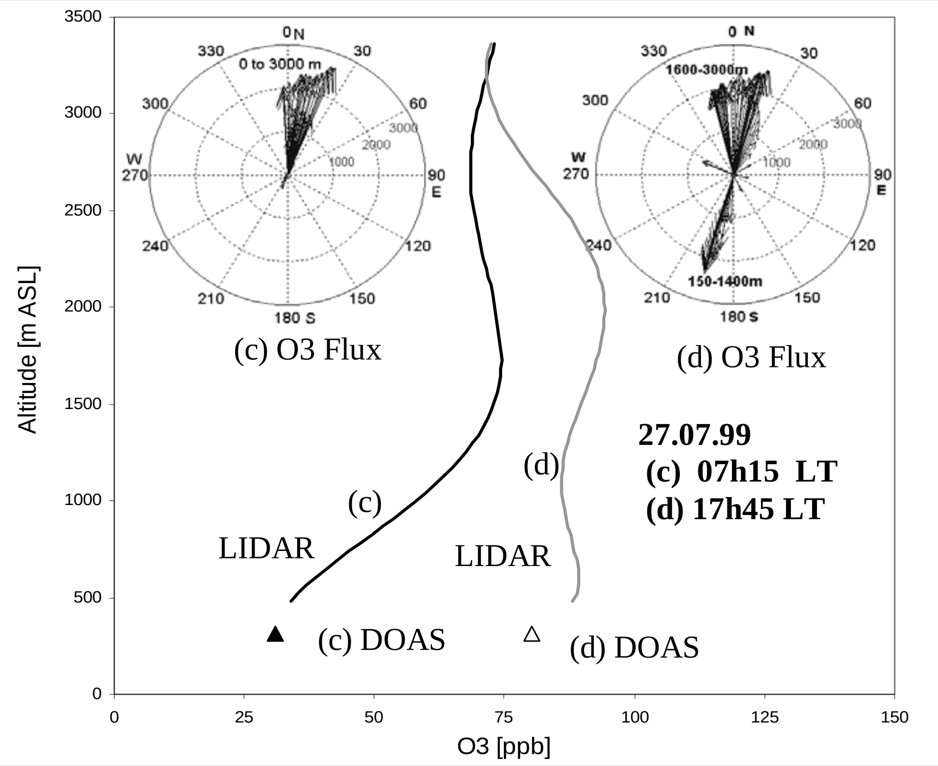
Ozone Abs.

On: 289 nm

Off: 299 nm

Ozone Fluxes & Profiles: METEO Regimes





anticyclone : North ozone flux + 50-60 ppb photochemical production/ 10h

cyclone: South ozone + stop photochemistry, complex turbulent mixing

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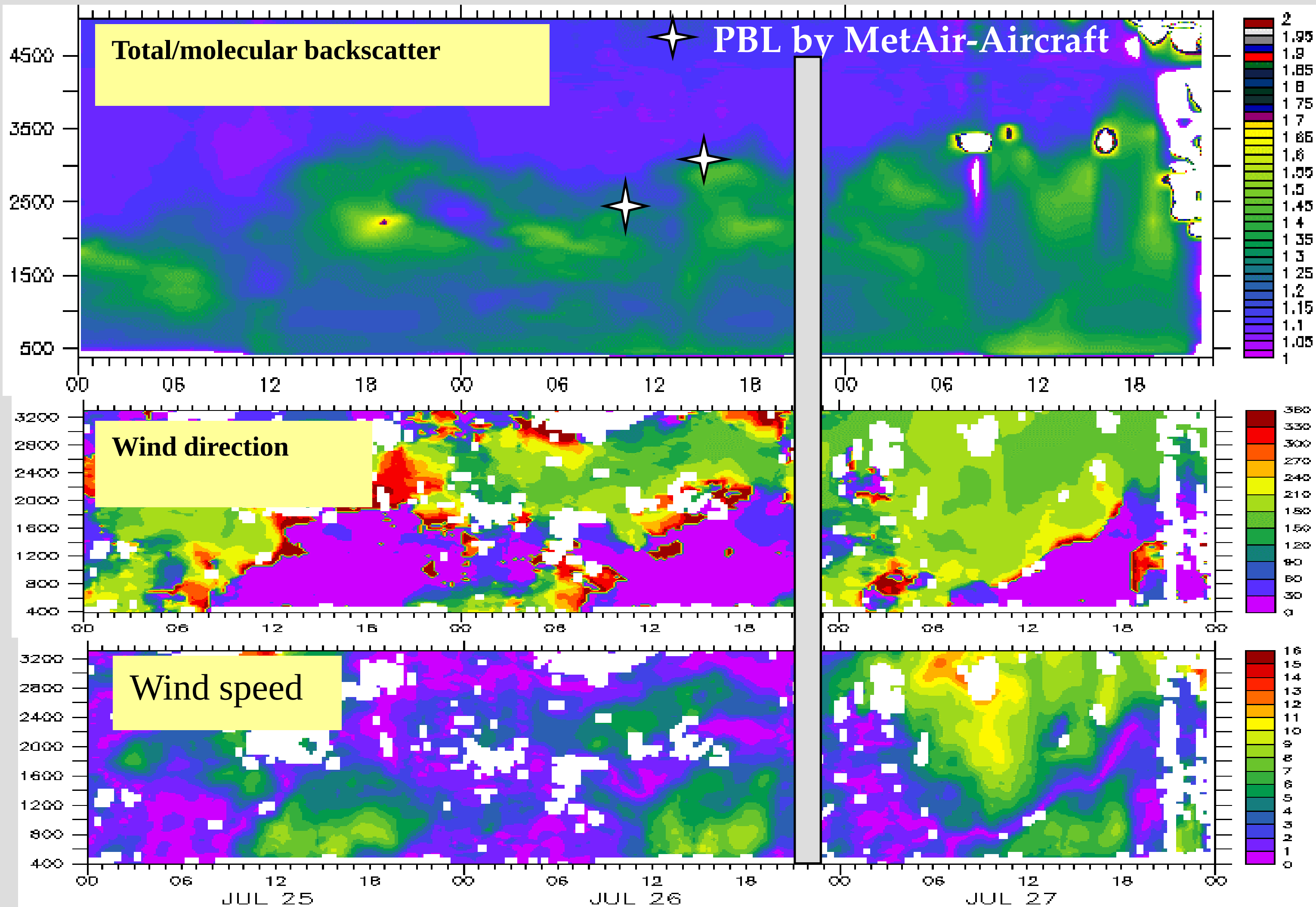
ESYCH

PBL & Meteo: Wind Profiler & LIDAR

- Validations Comparisons
- Aerosols Load
- METEO Regimes
- PBL Markers
- Interpretation Treatment



ESYCH-PSE-EPFL,

ESYCH

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EPFL-LPAS instrumented site : ESCOMPTE2001

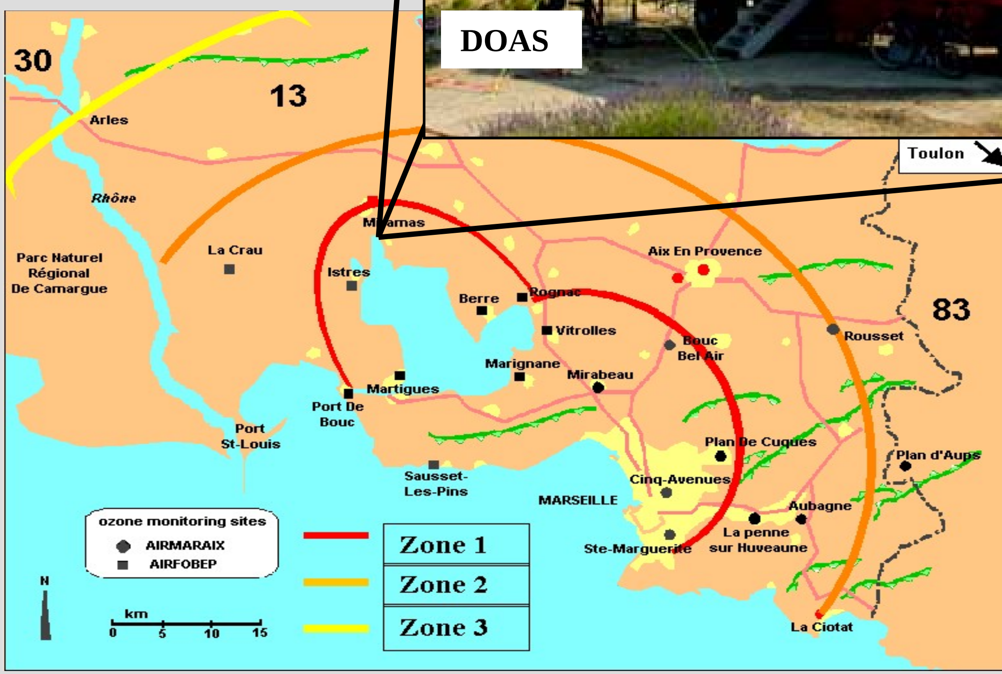
Site Choice

METEO Regimes

LIDAR Ozone

DOAS PointMonitor

IOPs Coordination



PM: (O_3, SO_2, NO_x, PAH, BC, Wind, Temp, RH, Rad)

DOAS: (O_3, SO_2, $NO_{x,}$, BTEX)

LIDAR: O_3 (100-7000m agl)

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OZONE LIDAR: 2001 ESCOMPTE Configuration

O3 TRIAL LIDAR

O3 Profiles

PBL

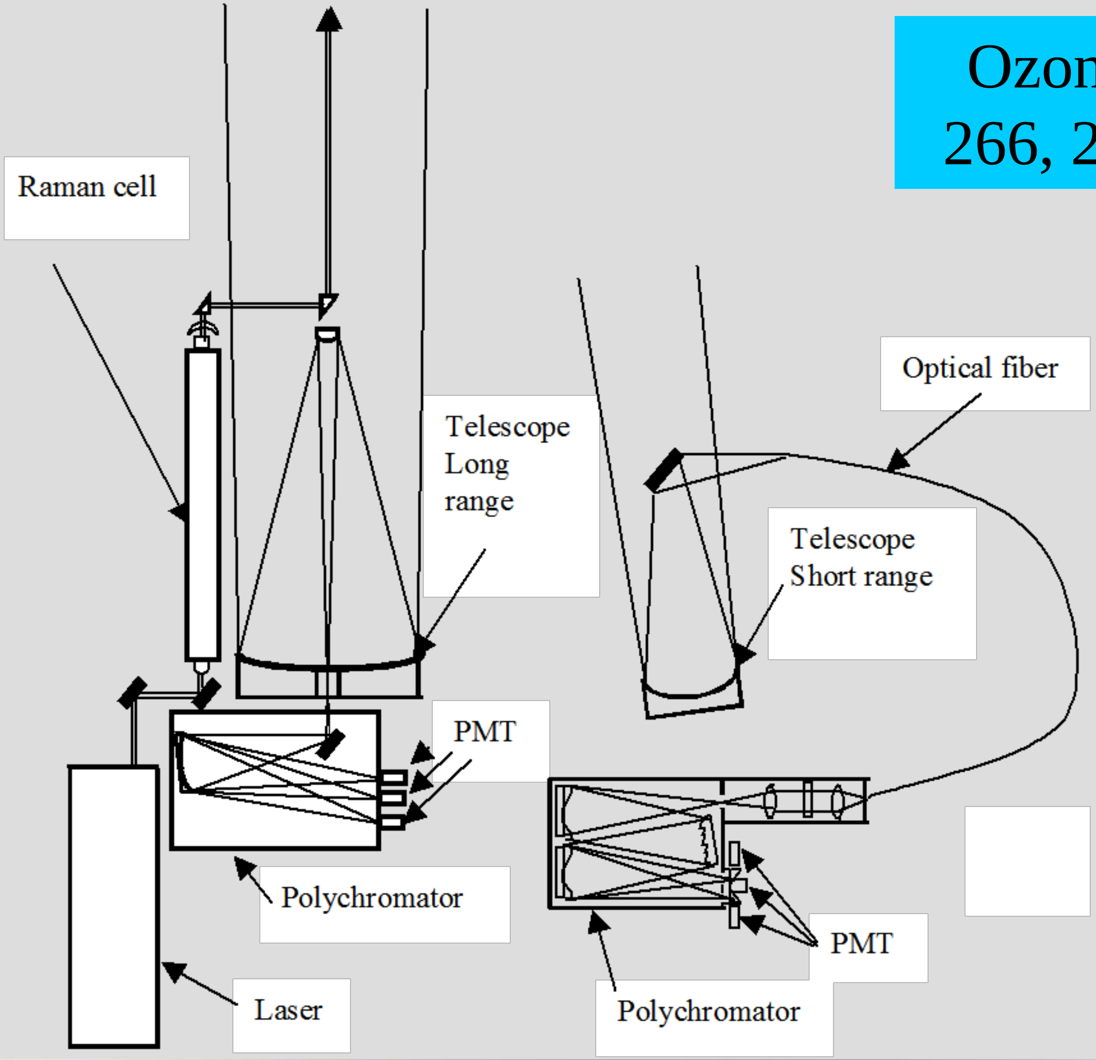
Aerosols

0.2 – 7 Km

0- 6 days

R: 75m/30min

Ozone « TRIAL »
266, 283 et 304 nm



OZONE & AEROSOLS : ESCOMPTE 2001

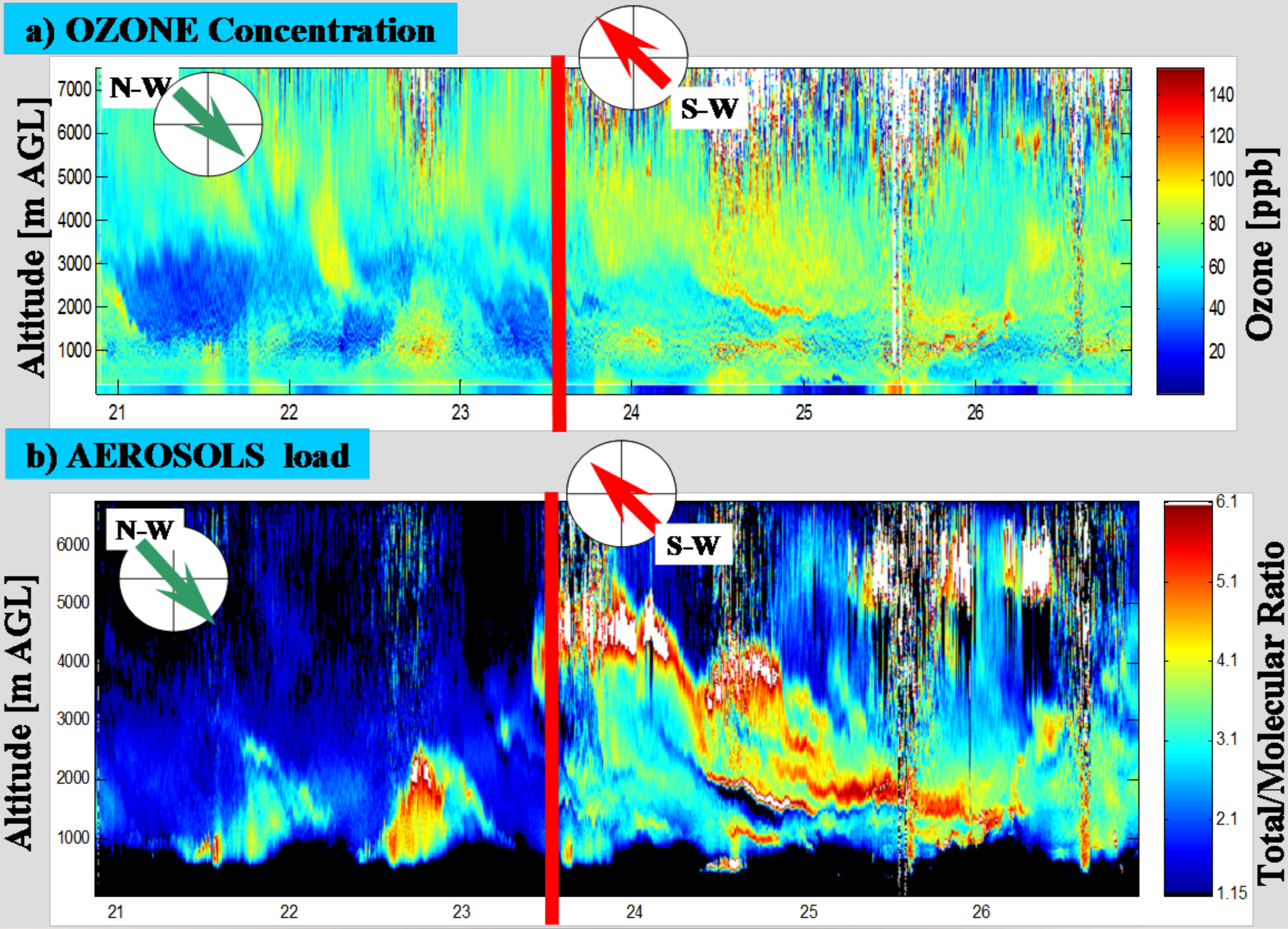
METEO

Regimes !!!

0.2 – 7 Km

0- 6 days

R: 75m/30min

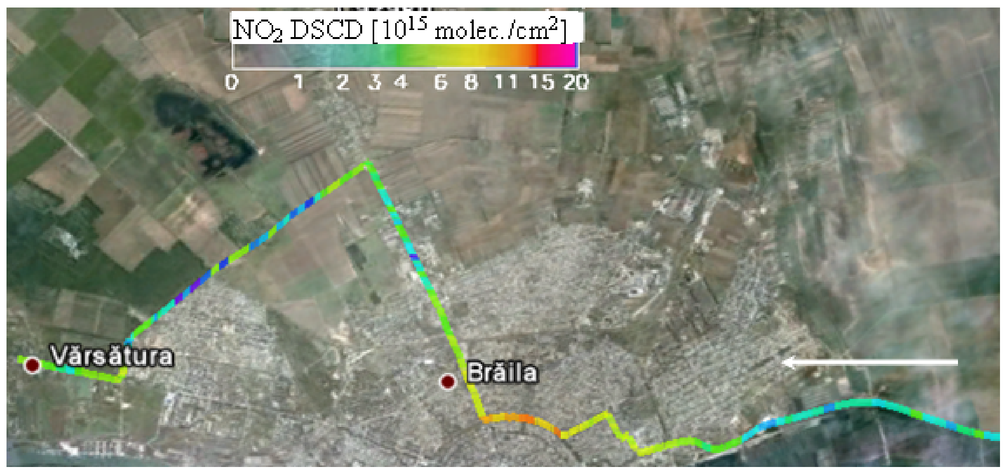


DOAS MOBILE PLATFORMS

CAR

GLIDER

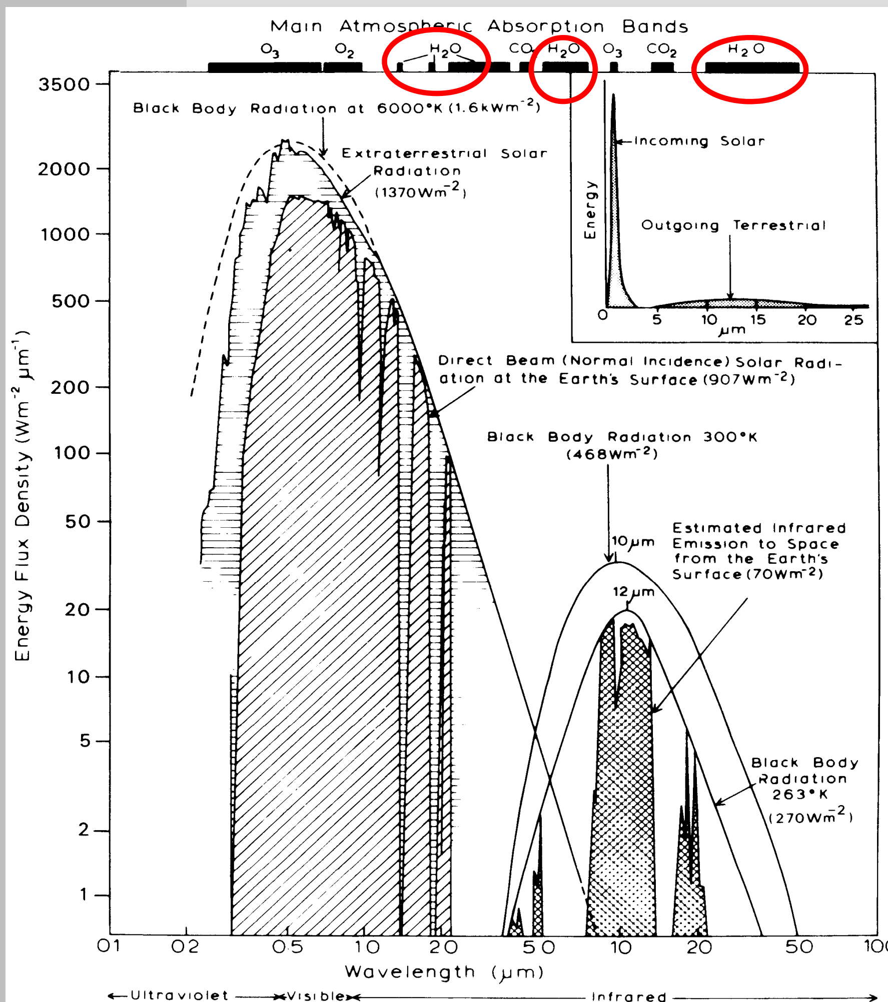
UAV



NO2 DSCD FROM CAR-DOAS MEASUREMENTS

PURPOSE: IDENTIFICATION /QUANTIFICATION OF POLLUTED AREAS AND SATELLITE DATA VALIDATION FOR OMI, GOME AND SCIAMACHY INSTRUMENTS

MONITORING ~ climate change related parameters



$$\Delta F = S_{\downarrow} - S^{\uparrow} = \lambda_0 \Delta T_e$$

CO_2: +1.46 Wm^{-2}

CH_4 : +0.48 Wm^{-2}

CFC: +0.34 Wm^{-2}

N_2O: +0.15 Wm^{-2}

O_3 stratospheric ↓ : -0.15 Wm^{-2}

O_3 tropospheric ↑: +0.35 Wm^{-2}

H_2O ???

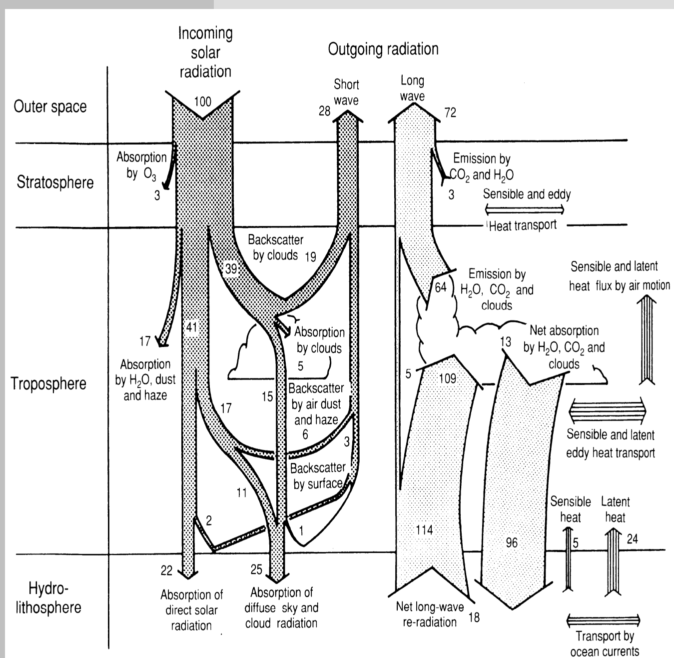
- high time-space variability
- positive feedback
- clouds processes involved

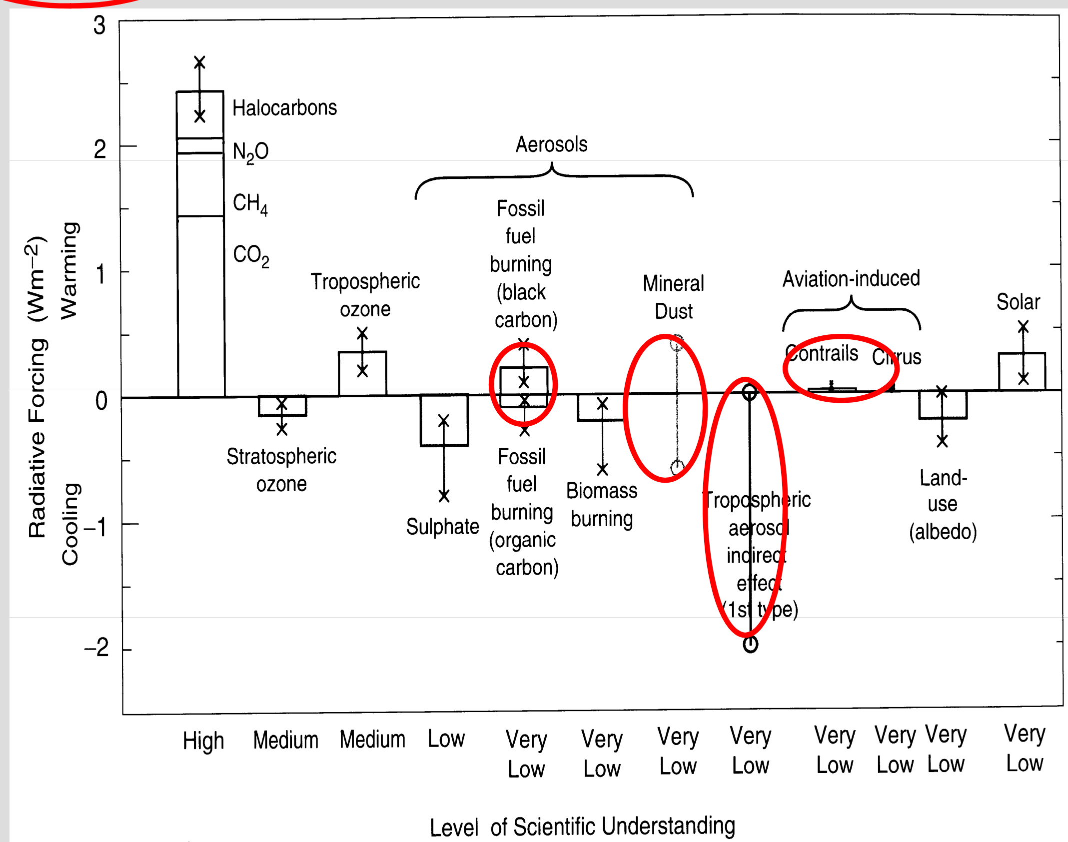
Greenhouse Effect : Other Factors ? YES

Te ~ 5°C (no Earth atm&albedo)
Te ~ -18°C (no atm. with albedo)
Te ~ 30°C (with atm. with albedo)

~ 12-15°C

$$S\frac{(2-f)(1-\omega_0-a_s)+a_s}{2-a_l}=\sigma T_e^4$$



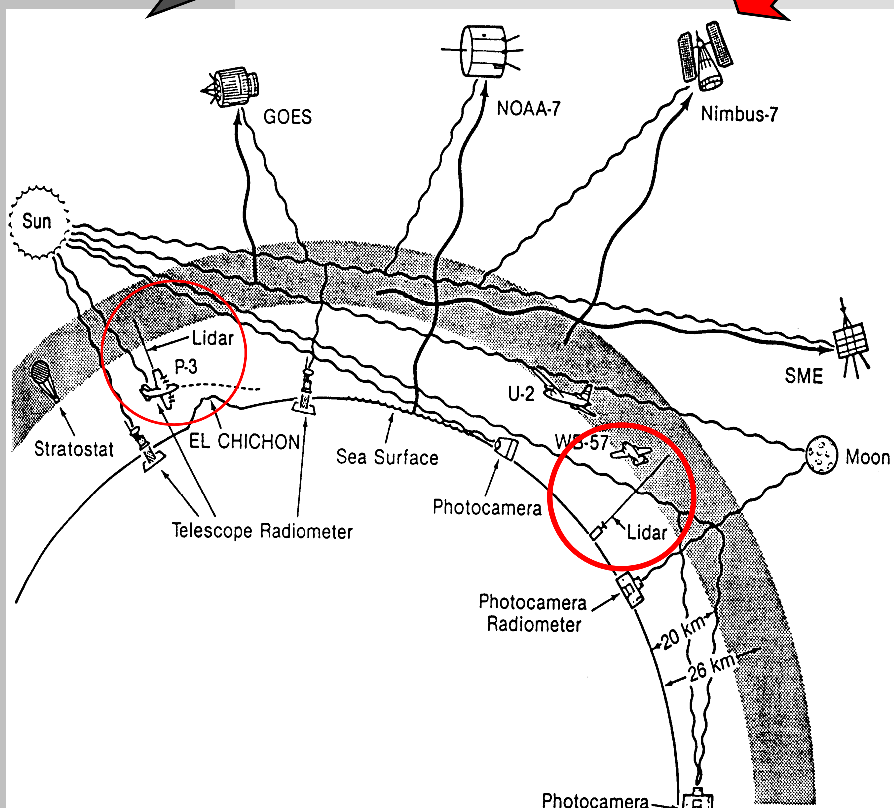


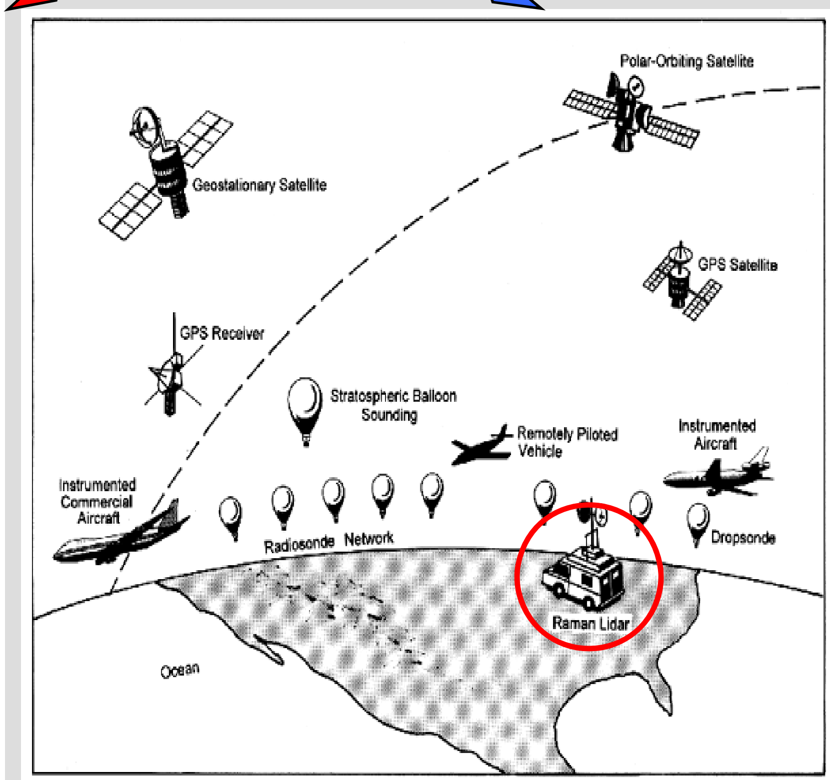
Measurements Approaches

Aerosols

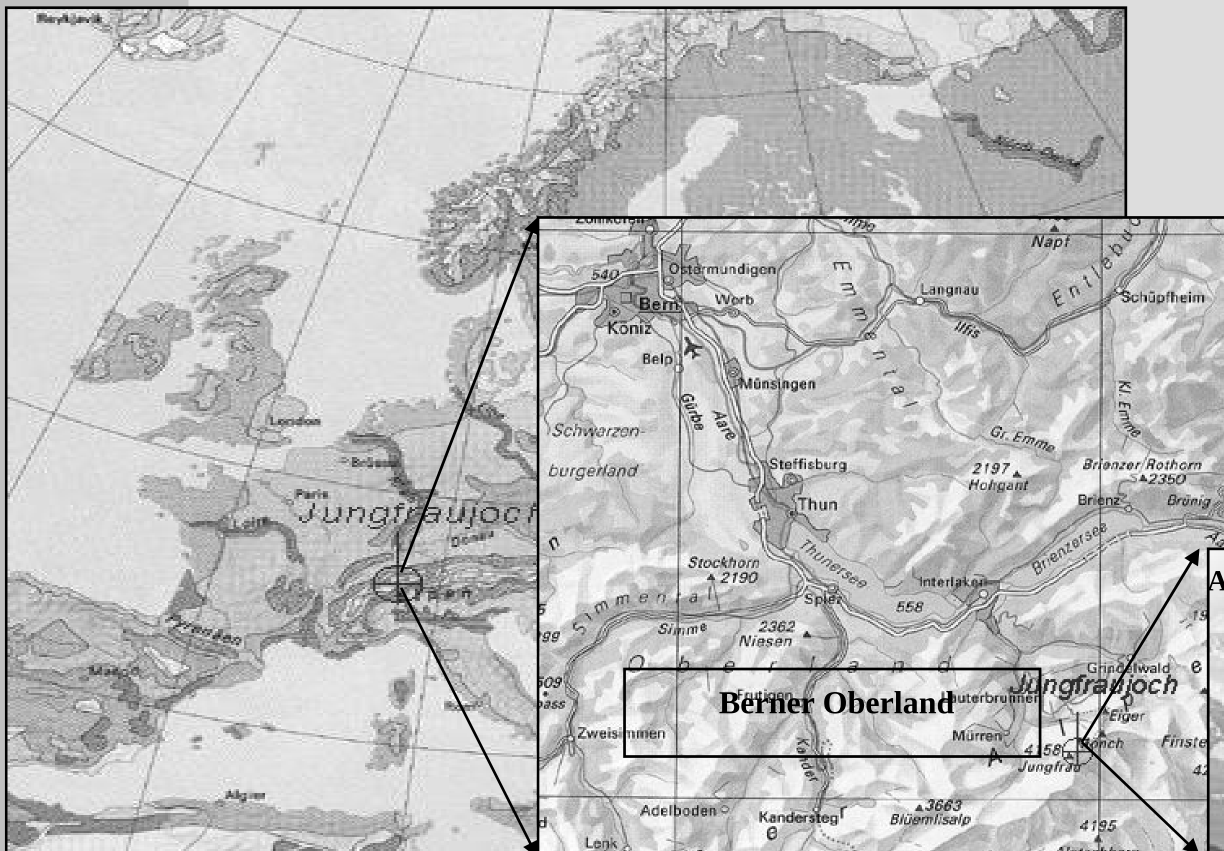
Temperature

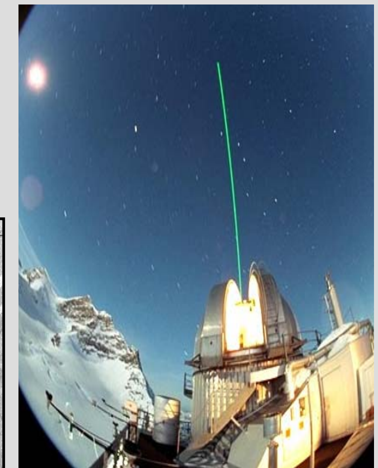
Water Vapor



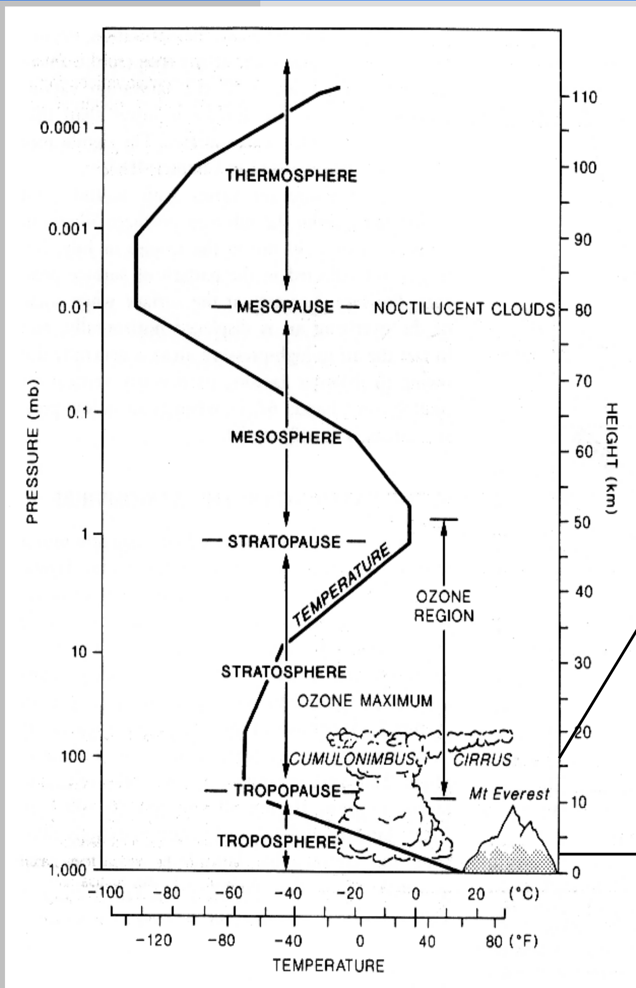


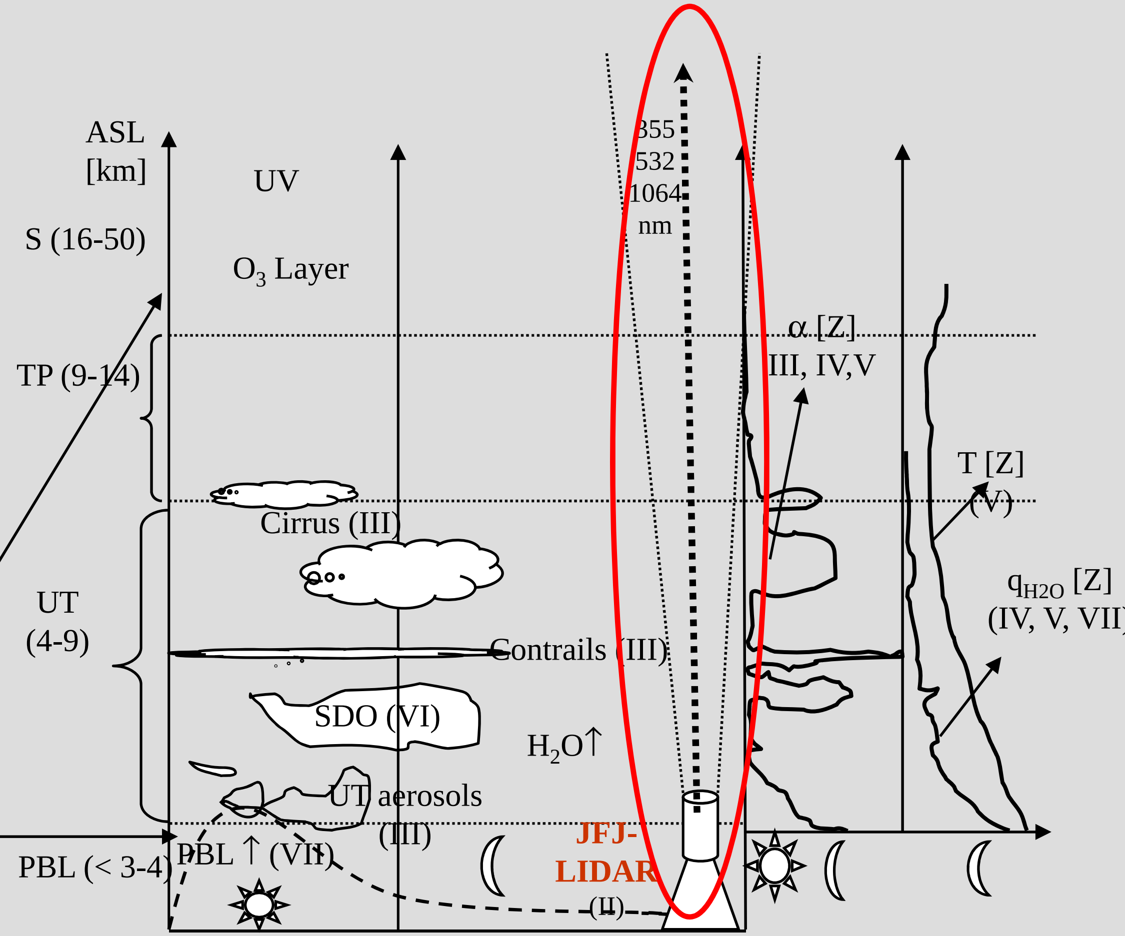
Jungfraujoch observatory (3580 m ASL, 46°33' N, 7°59' E)





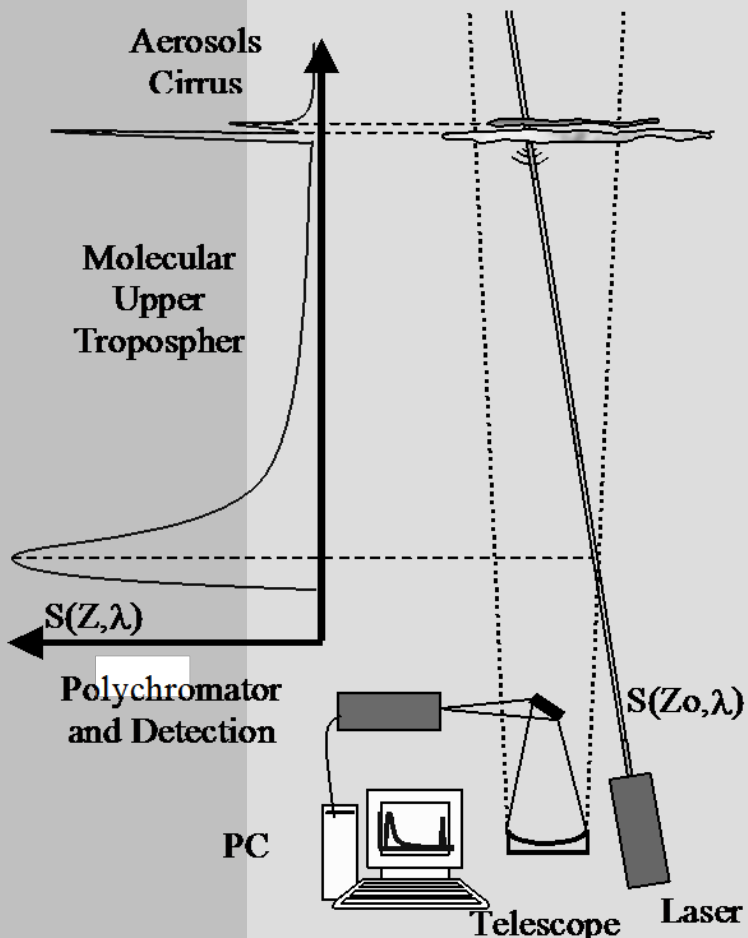
Research Objectives





LIDAR Methodology Principle & Equation

$$S(Z,\lambda_D)=S(Z_0,\lambda_L)\cdot C_S(Z)\frac{A_0}{Z^2}\delta Z\cdot\beta_{atm}(Z,\lambda_D,\lambda_L)\cdot T_{\rightarrow}(\lambda_L,Z)\cdot T_{\leftarrow}(\lambda_D,Z)$$



$S(Z, \lambda_D)$- intensity of detected radiation from altitude Z at λ_D

$S(Z_0, \lambda_L)$- intensity of emitted laser radiation

$C_s(Z)$ -lidar instrument function

A_0 - area of telescope collector mirror

$$\delta Z=\frac{c\left(\tau_D+\tau_L+\tau_P\right)}{2})$$ vertical resolution

$c \sim 3x10^8\ ms^{-1}$ and $\tau_D \sim 5x10^{-7}$ s $\rightarrow$ 7.5 m

($Z_i = i\ \delta Z$, i = 0…# digitizer channels : 3000 $\rightarrow$ 26 km ASL

$$T_{\rightarrow}(\lambda_L,Z)=\exp\left[-\int_{Zo}^{Z}\alpha_{atm}(\lambda_L,z)dz\right]$$

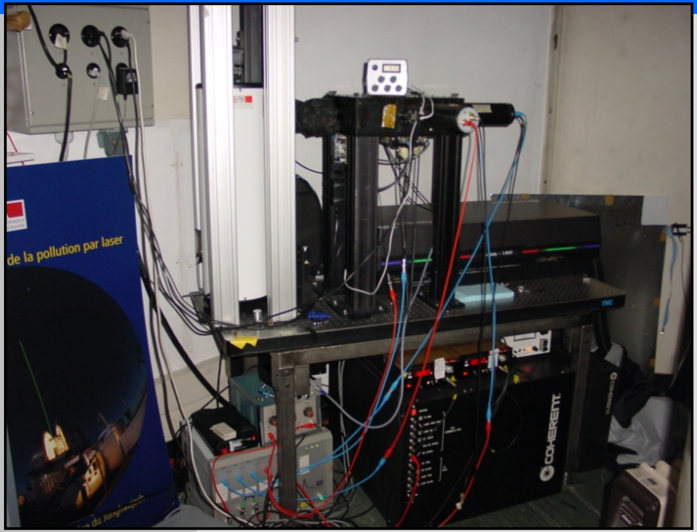
$$T_{\rightarrow}(\lambda_D,Z)=\exp\left[-\int_{Zo}^{Z}\alpha_{atm}(\lambda_D,z)dz\right]$$

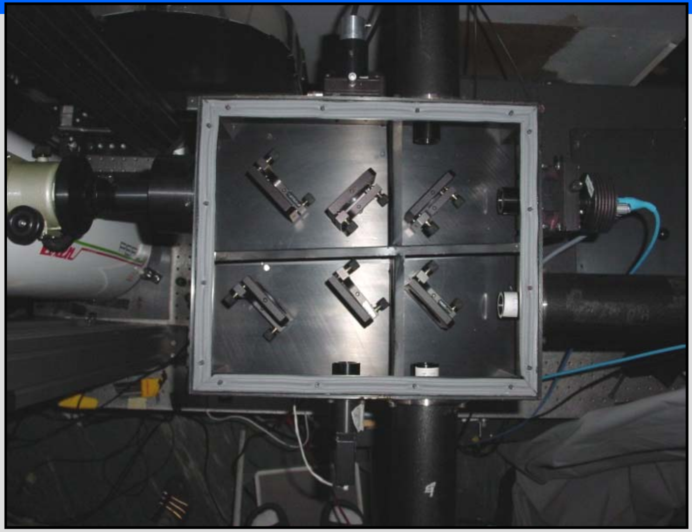
atmospheric transmissions

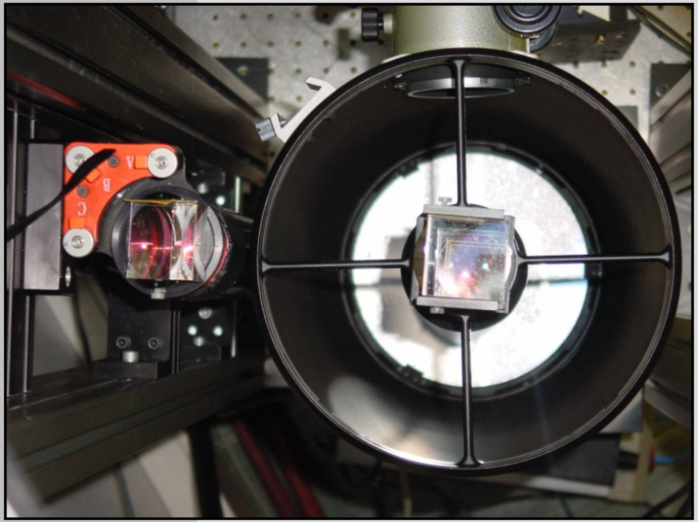
$\beta\ [m^{-1}\ sr^{-1}]$ and $\alpha\ [m^{-1}]$

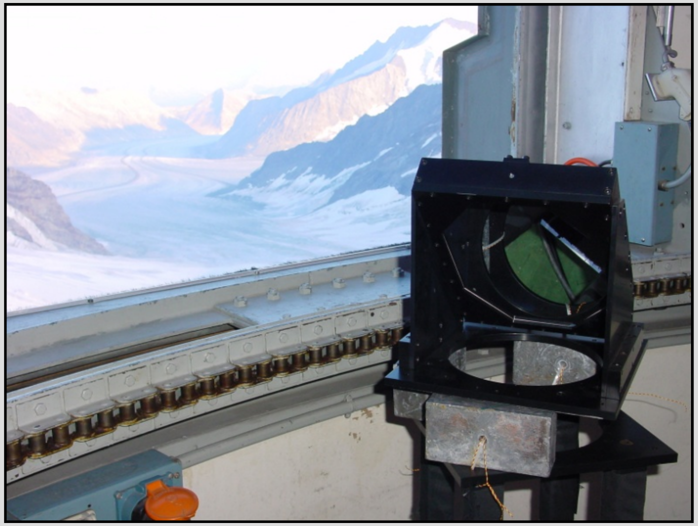
backscatter and extinction coefficients

JFJ - LIDAR System … in some pictures

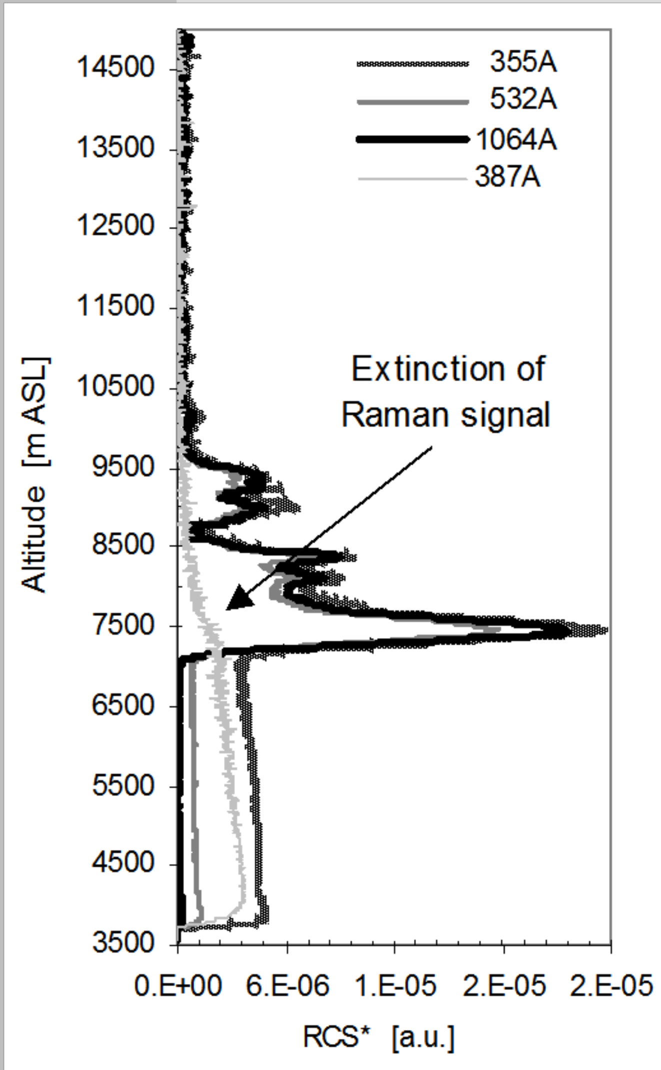


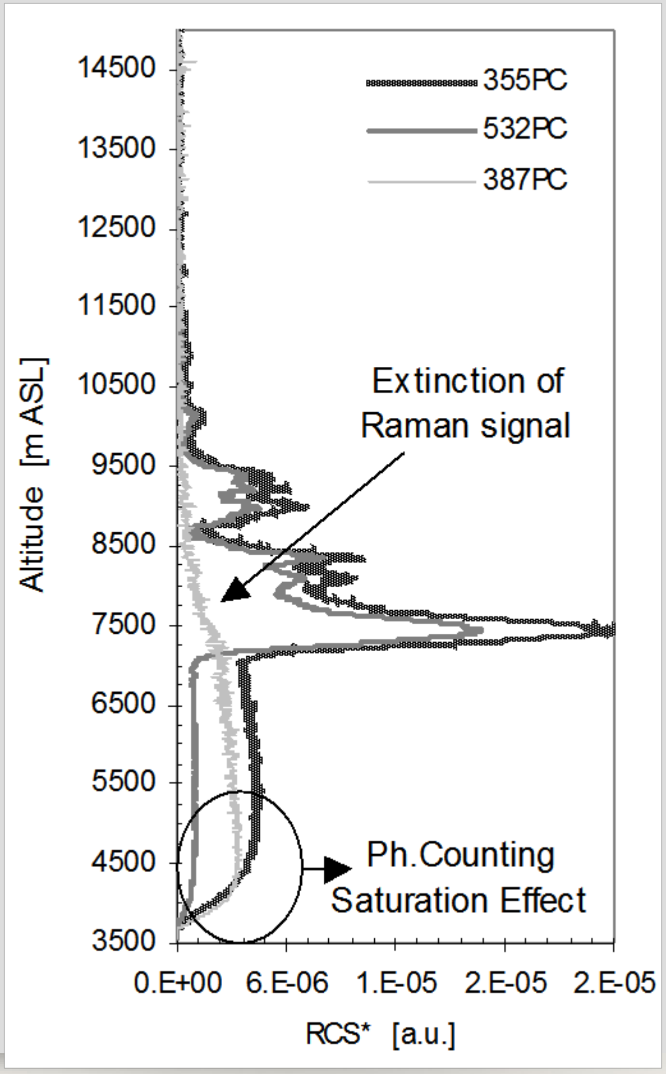




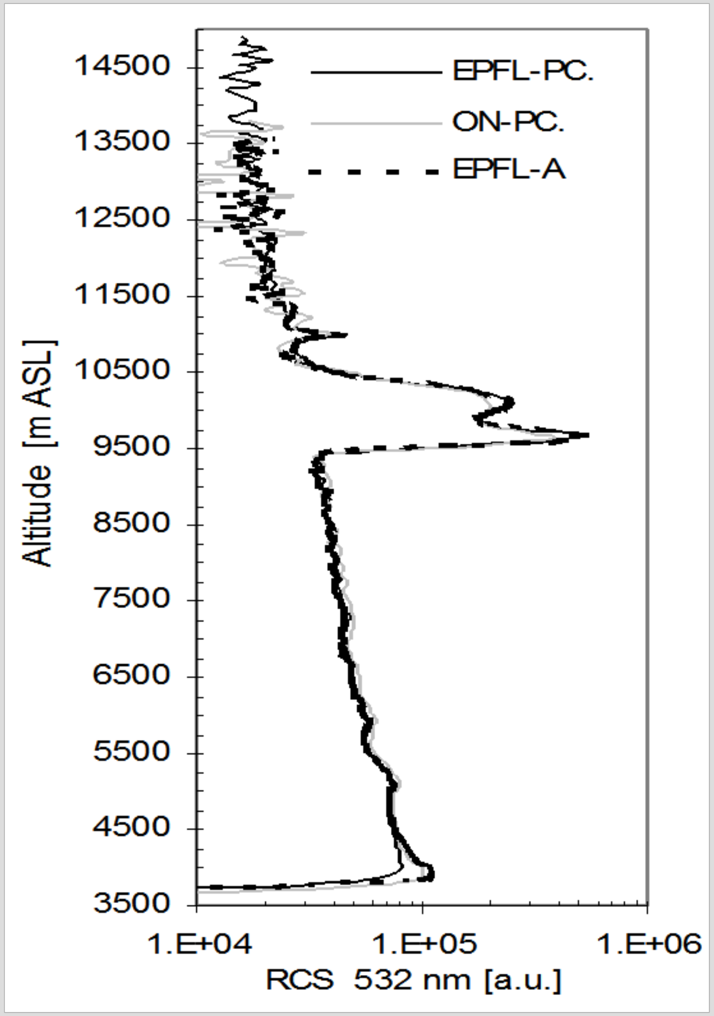


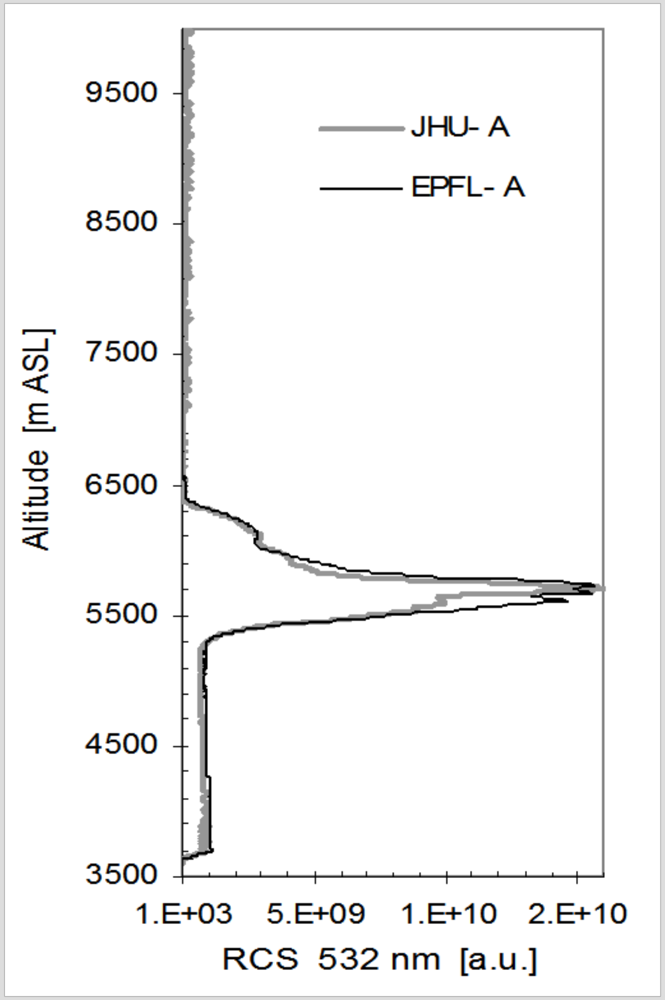
JFJ - LIDAR System :Raw Signals (4000 shots/7.5 m resolution) Examples





JFJ - LIDAR System : JFJ – ON - JHU lidar inter-comparisons



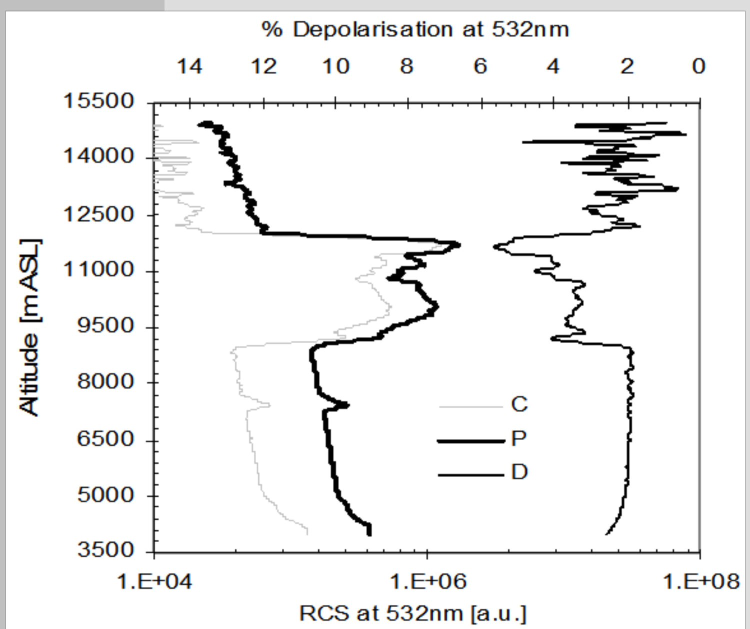


LIDAR Methodology: Depolarization Ratio & Angstrom Coefficients

$$\varphi_{atm}(Z) \sim \frac{S_c(Z)}{S_p(Z)} = C_S(Z)\frac{S_c(Z)}{S_p(Z)}$$

S_c, S_p – perpendicular (cross) and parallel polarization

C_S (Z) is the calibration function

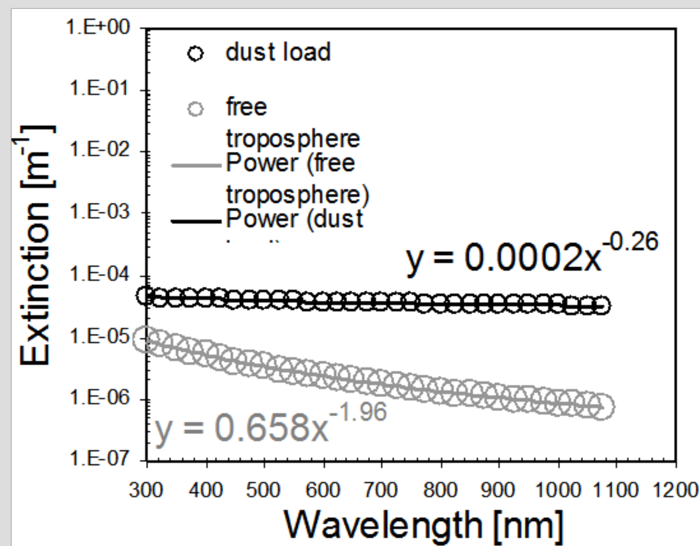


$$\alpha = B\lambda^{-A}$$

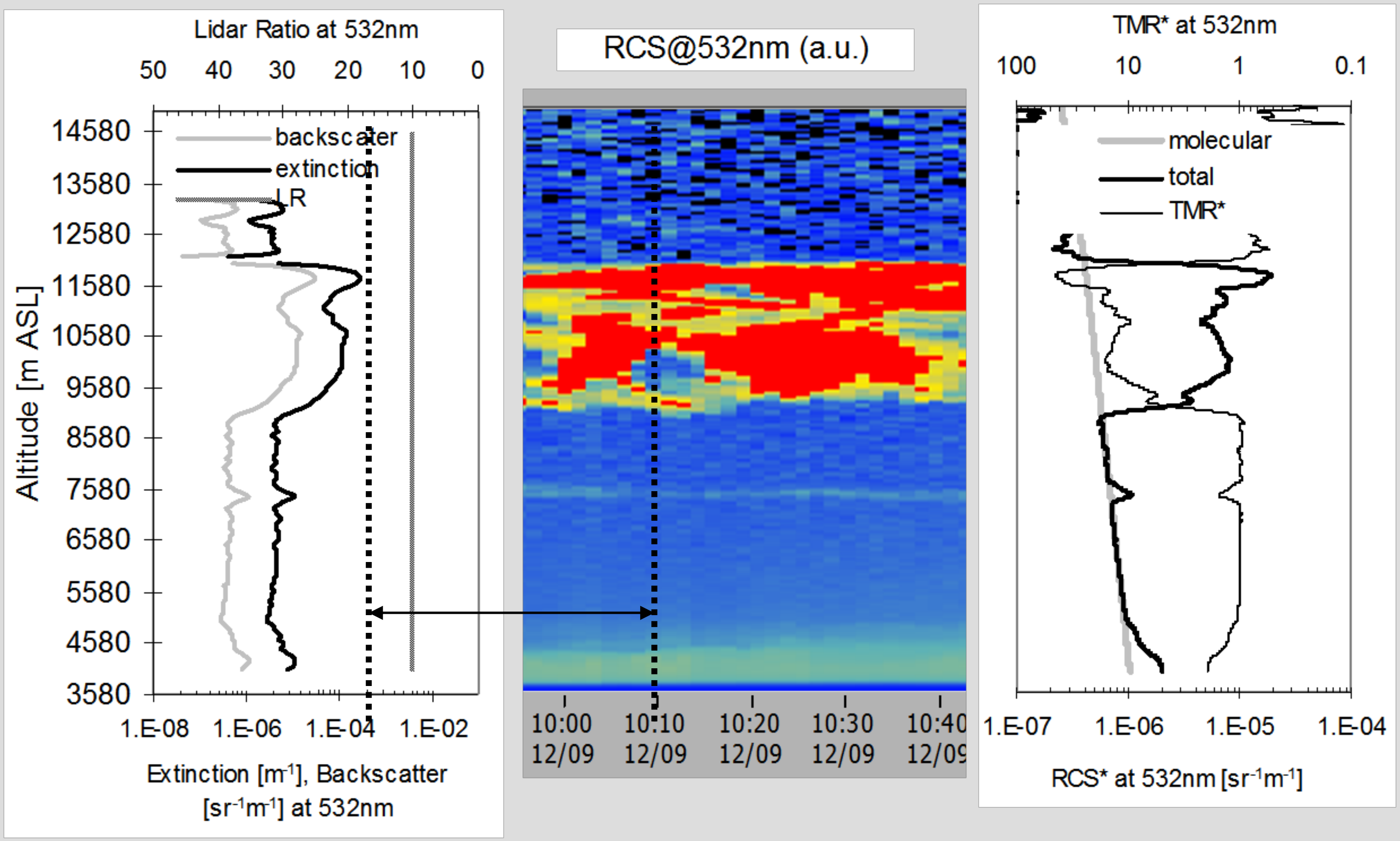
α – is the extinction coefficient

A – Angst. exponent ~ aerosol size (0 – 4)

B - Angst. coefficient ~number density ($10^{-5} \rightarrow 10$)

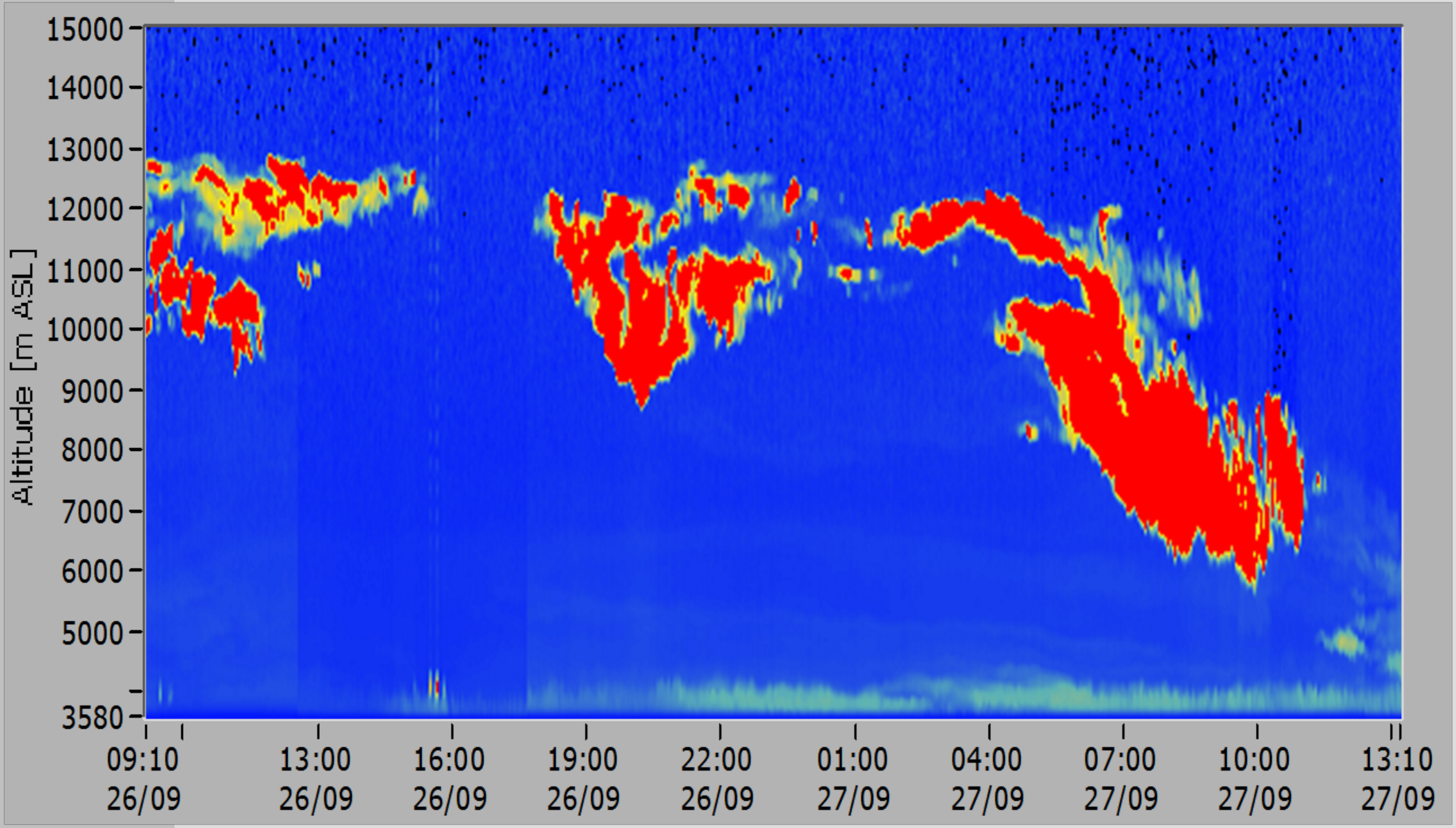


Aerosol-Cirrus-Contrails Optical Properties : Elastic Inversion-Case Example

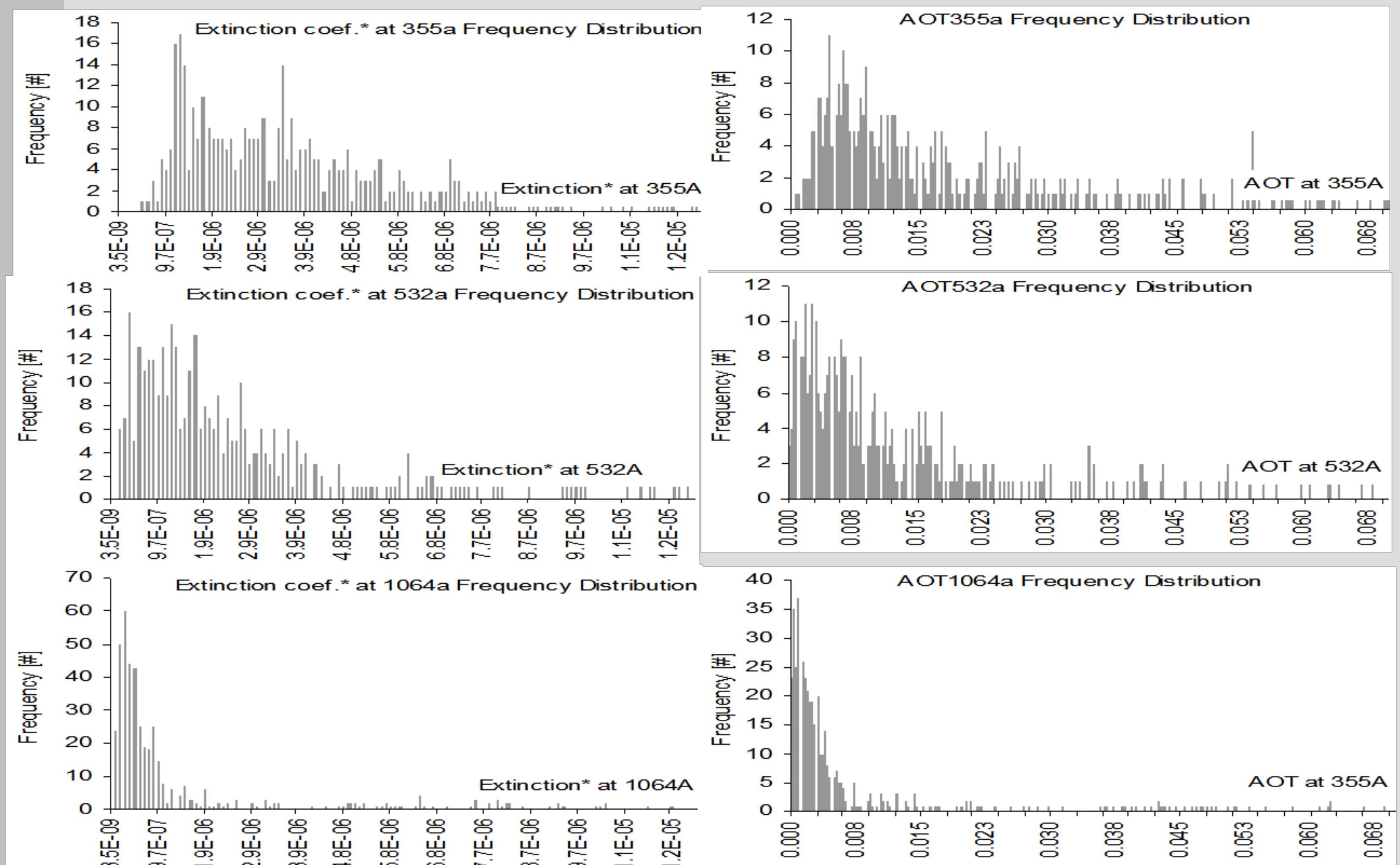


JFJ - LIDAR System: Time Series Example

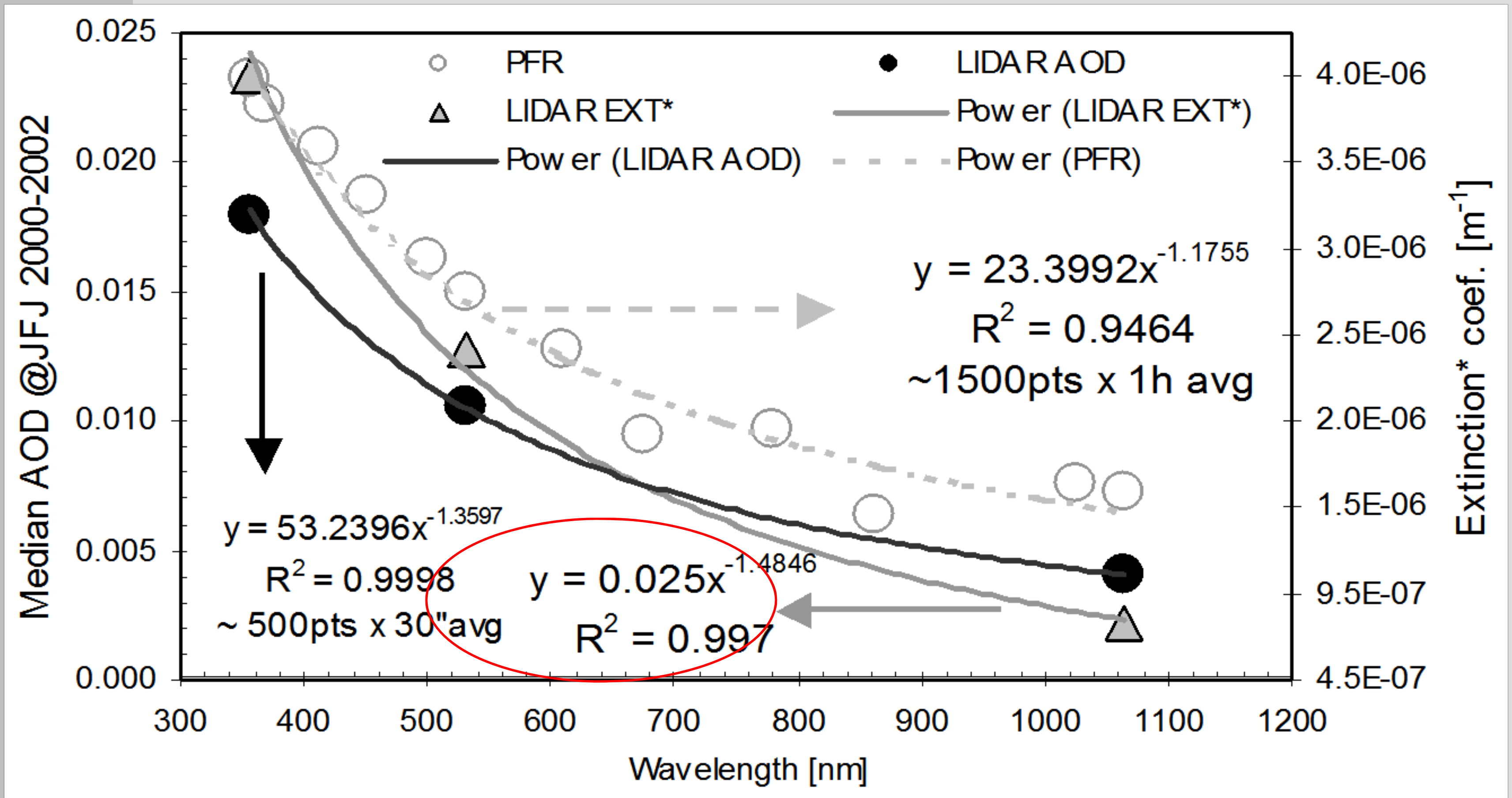
Range Corrected Signal (RCS) Intensity graph at 1064 nm



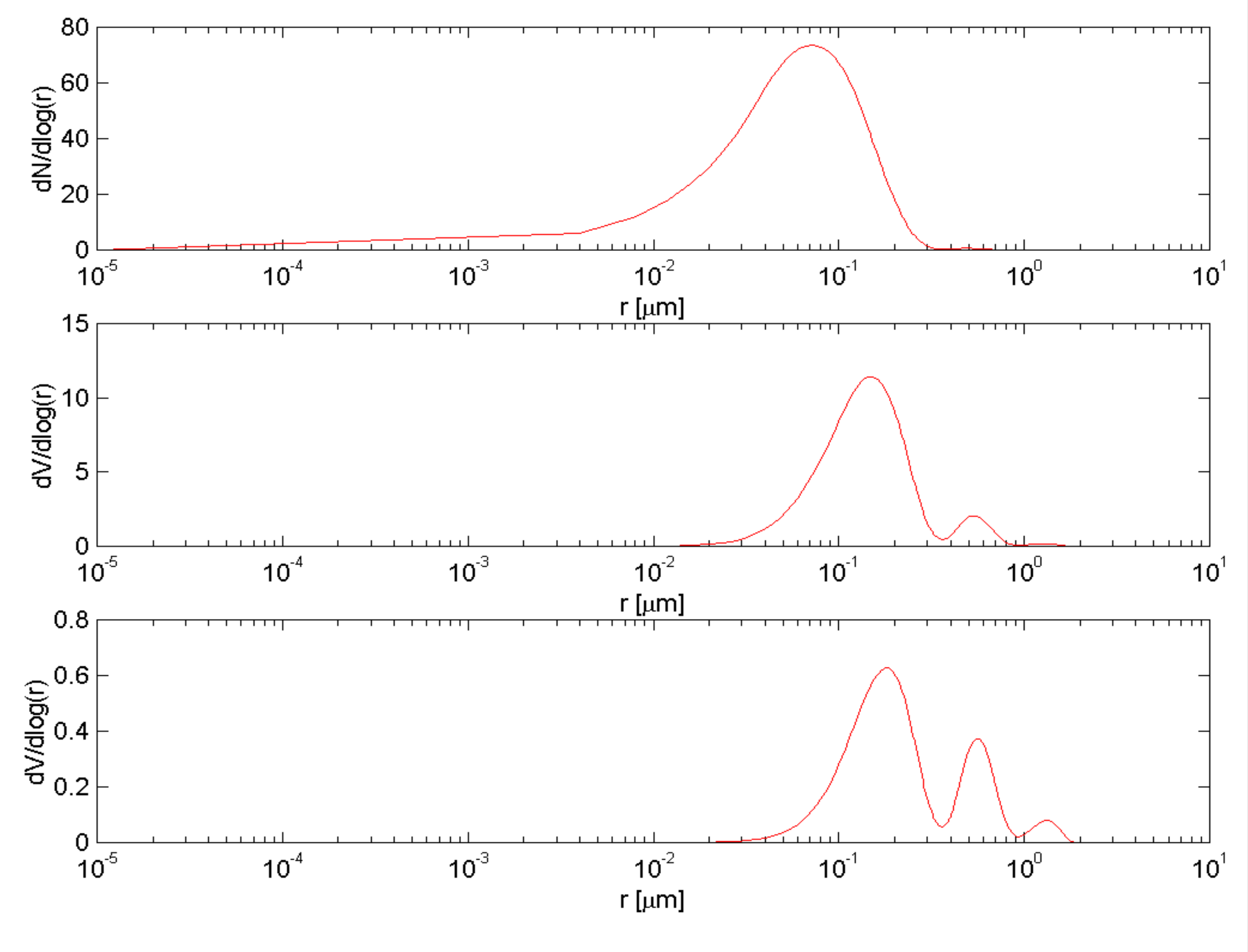
Aerosol-Cirrus-Contrails Optical Properties：Statistic Results – May 2000- May 2002



Aerosol-Cirrus-Contrails Optical Properties : UT Aerosols Extinction



Aerosol-Cirrus-Contrails Optical Properties : UT Aerosols Microphysics



R_{eff} ~0. 173 µm

m = 1.5474 + 0.0005 i

ω_0 = 0.99

n_t ~ 68 cm^{-3}

s_t ~ 6.4 $\mu m^2 cm^{-3}$

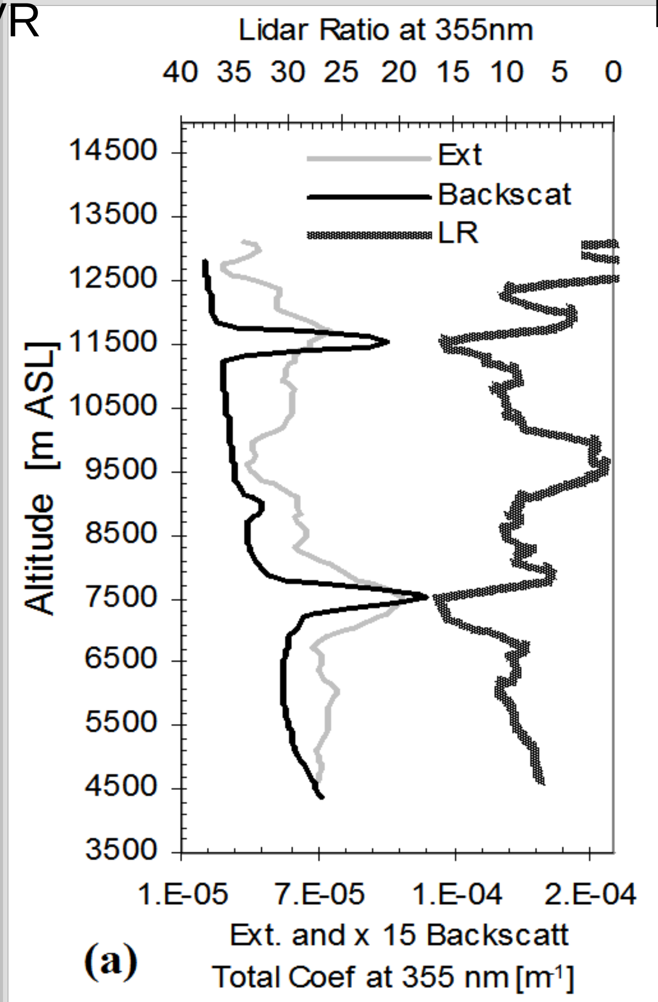
v_t ~ 0.37$\mu m^3 cm^{-3}$

tri-modal distribution

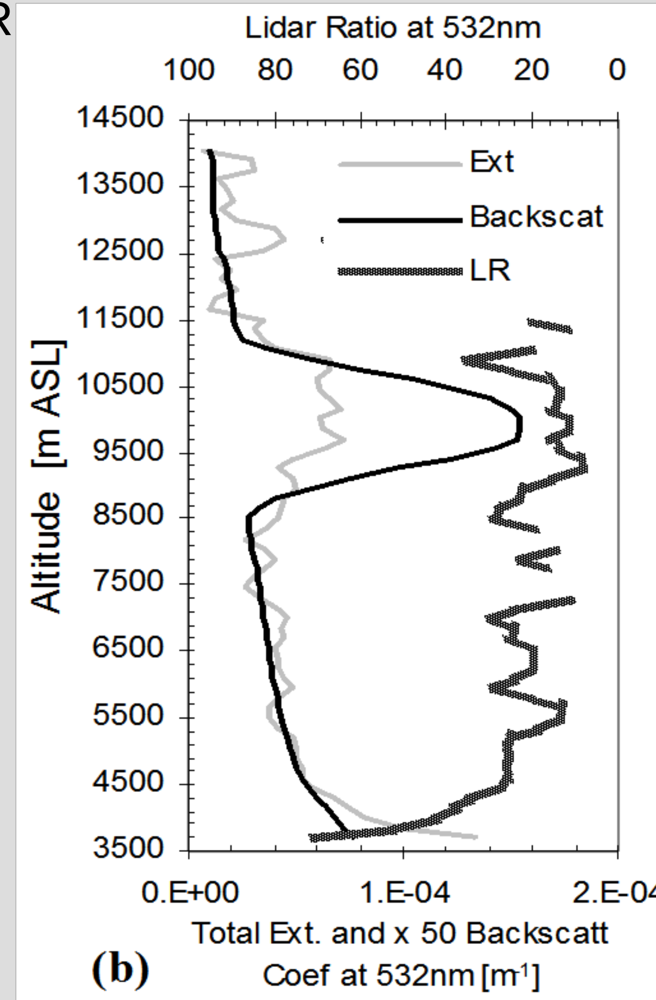
weak absorption

Aerosol-Cirrus-Contrails Optical Properties : Raman retrieval – sample

RVR



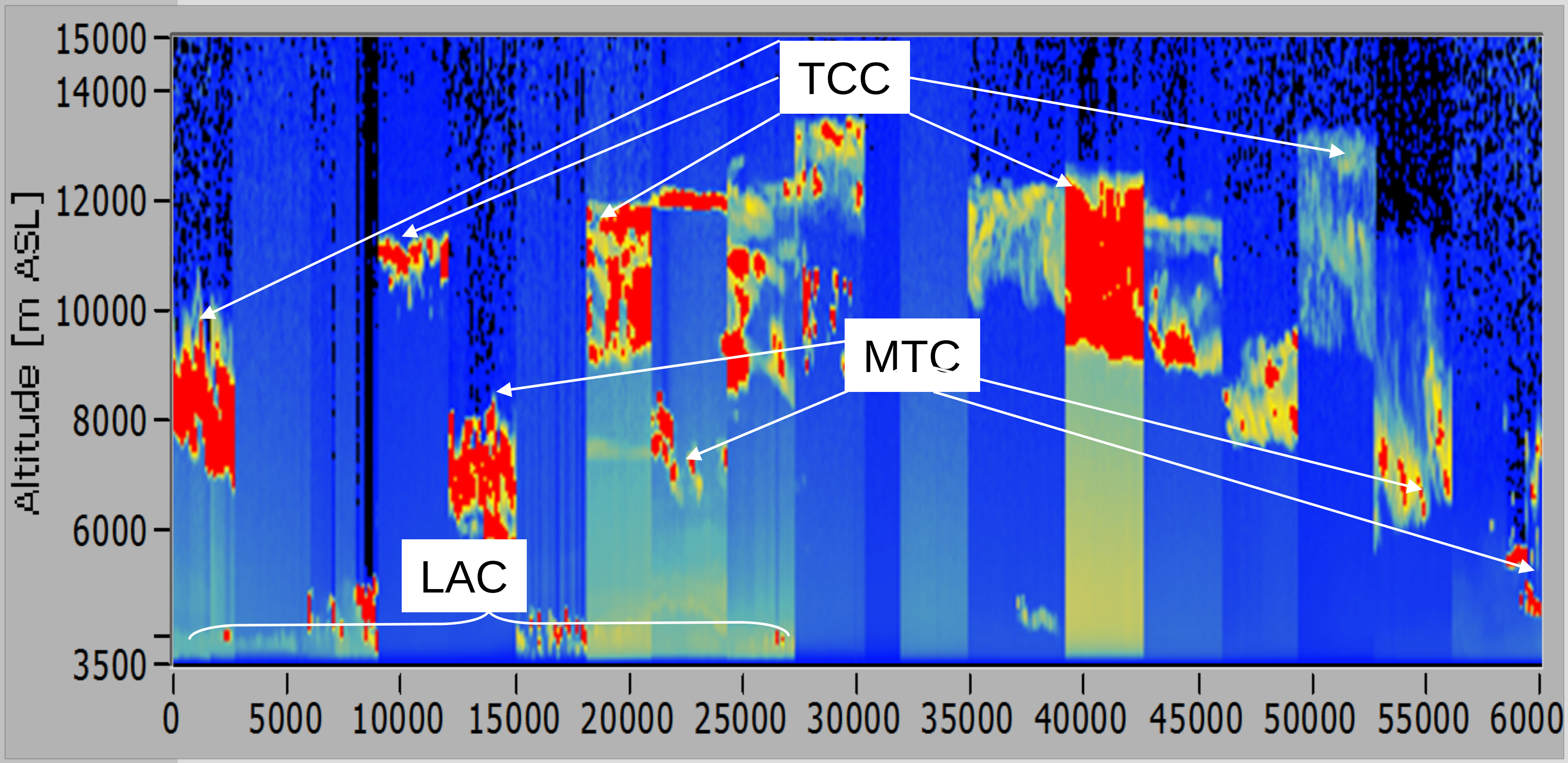
PRR



ESYCH

Aerosol-Cirrus-Contrails Optical Properties : UT clouds: a lidar-based typology

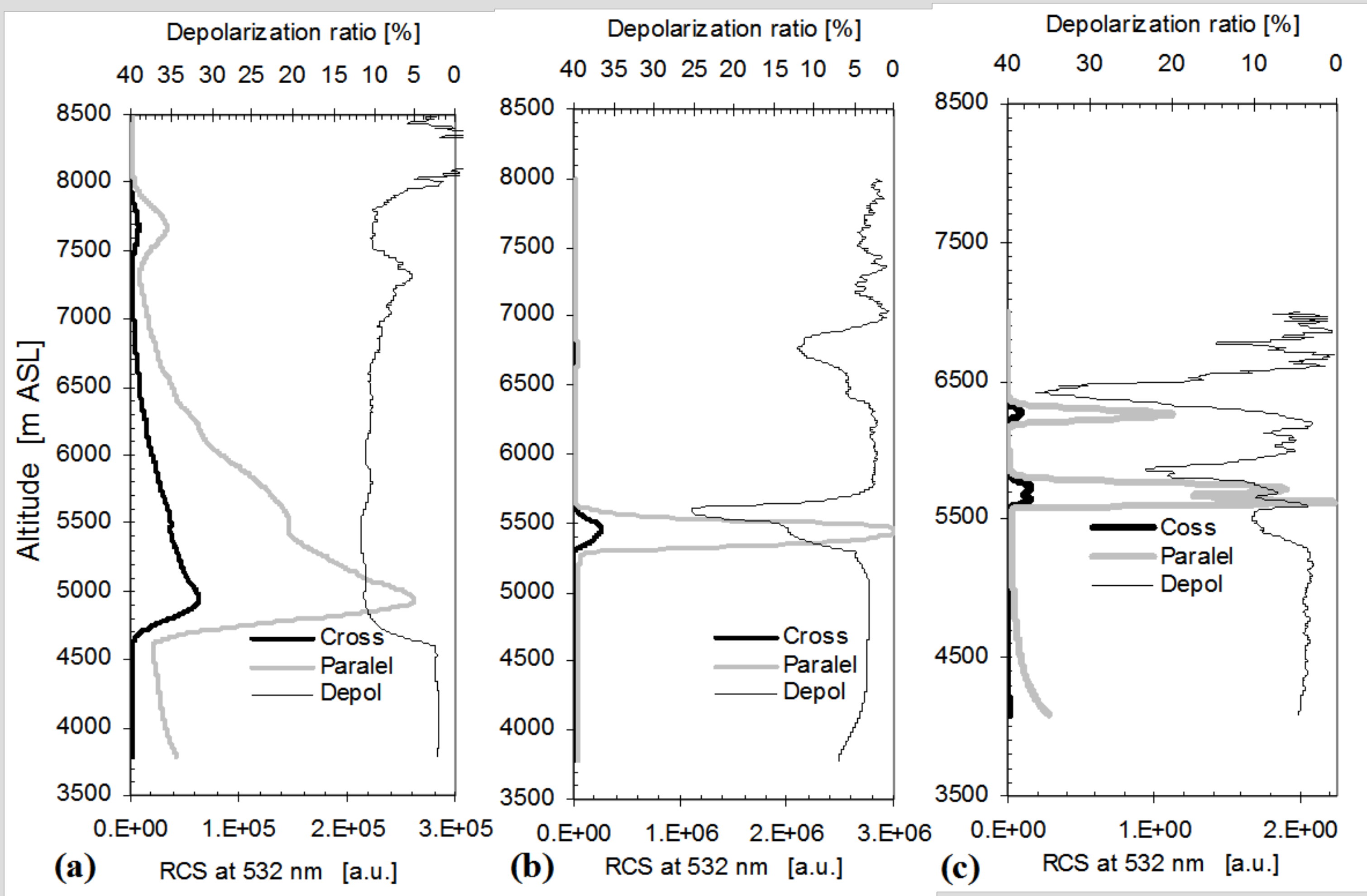
RCS Intensity Graph at 532 nm



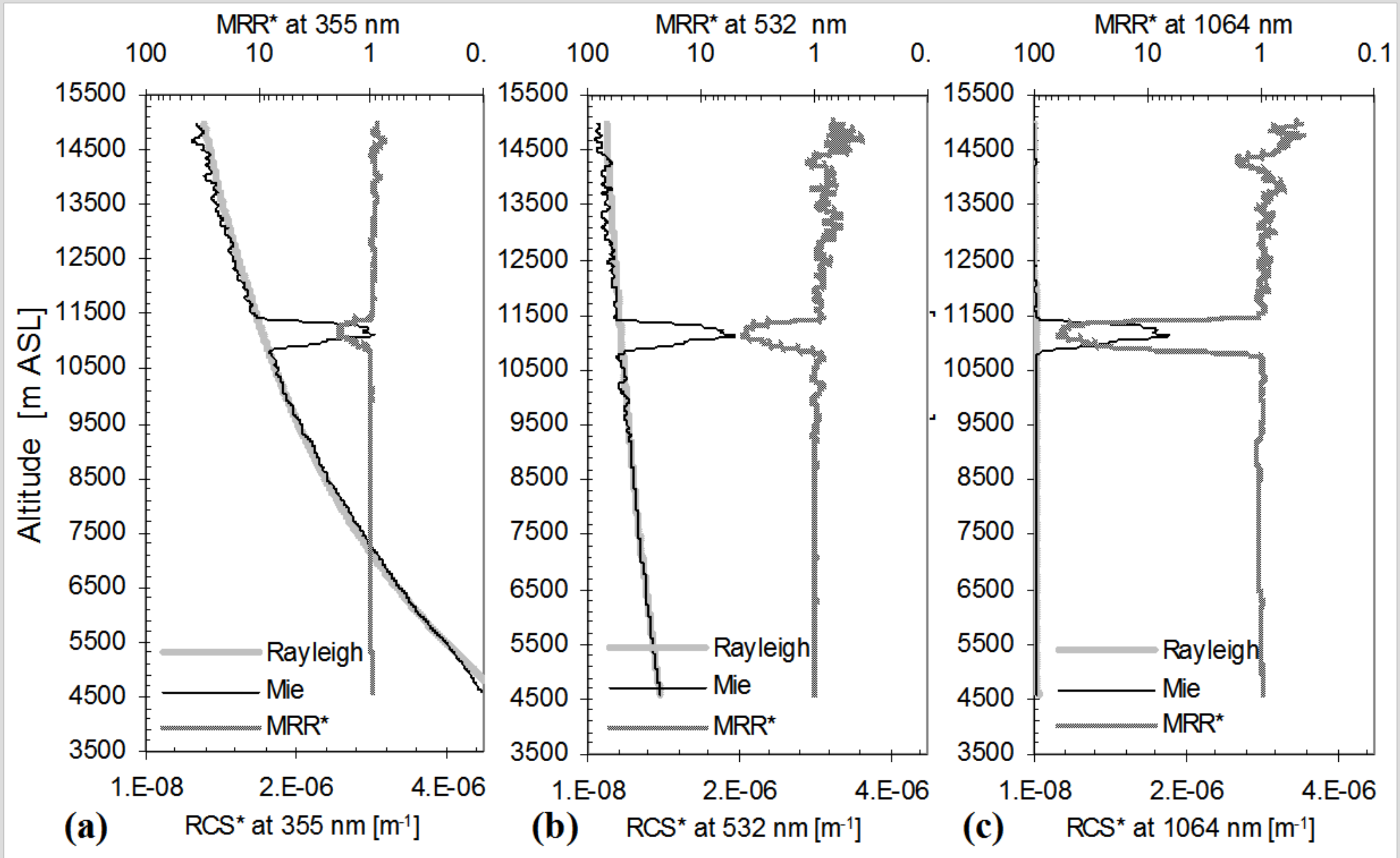
Time [nb.files of 4000 shots~1.5 min]

(selected series between from May 2000 to May 2001)

Aerosol-Cirrus-Contrails Optical Properties : UT Cirrus- Depolarization Ratio



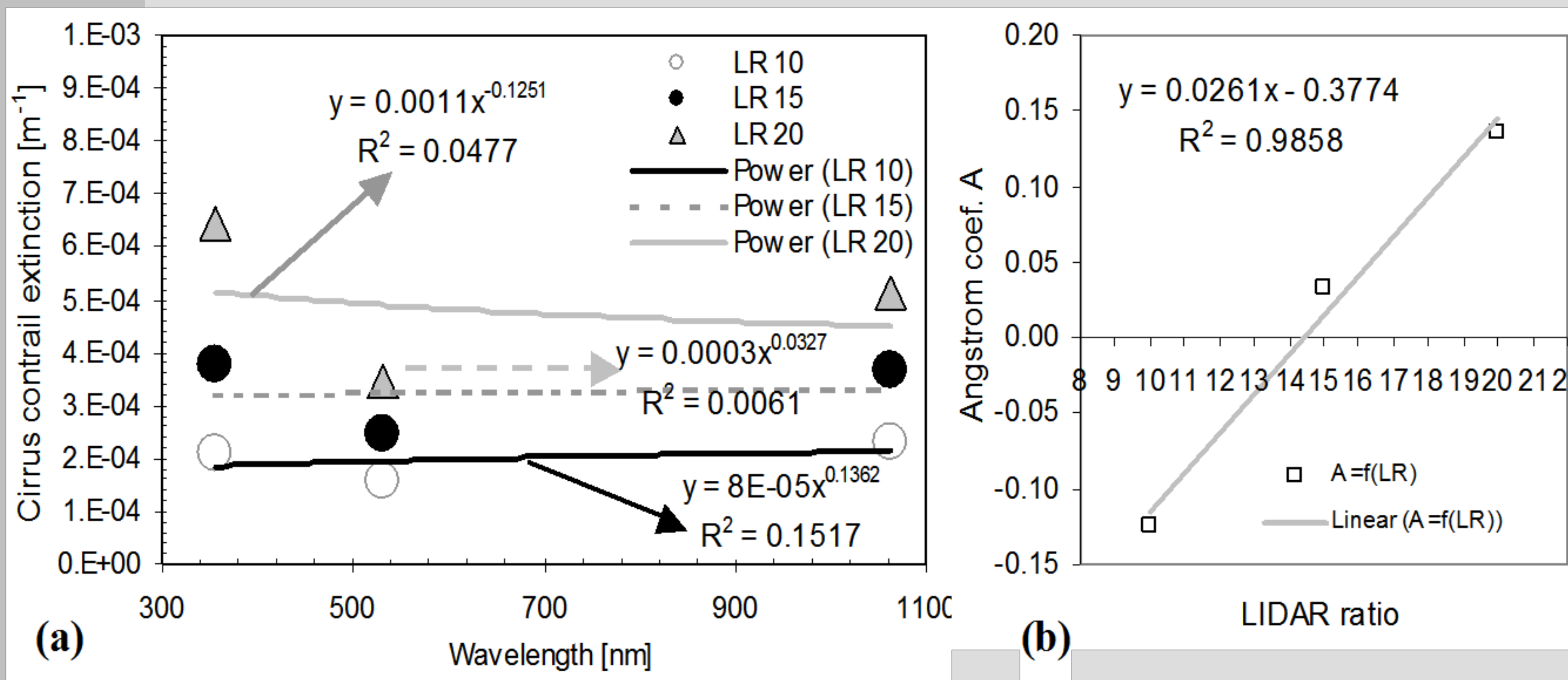
Aerosol-Cirrus-Contrails Optical Properties: Contrail: RCS* & MRR*



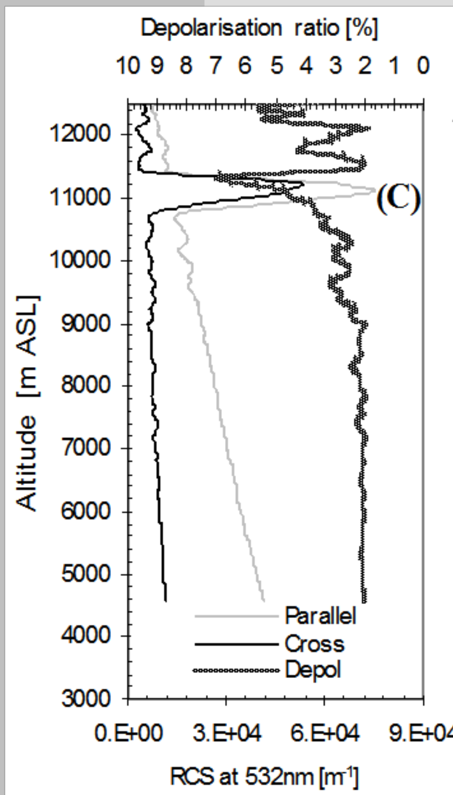
Aerosol-Cirrus-Contrails Optical Properties: Contrail (C) : extinction and lidar ratio

$\alpha_{C\ (avg)} \sim 1\text{-}2 \times 10^{-4}\ [m^{-1}]$

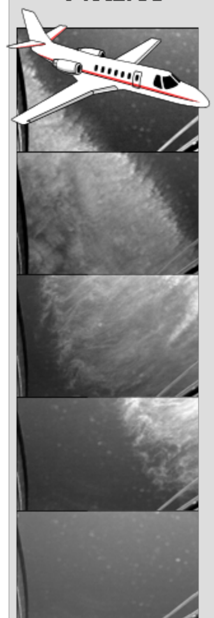
$LR_{C\ (avg)} \sim 14.5\ [sr]$

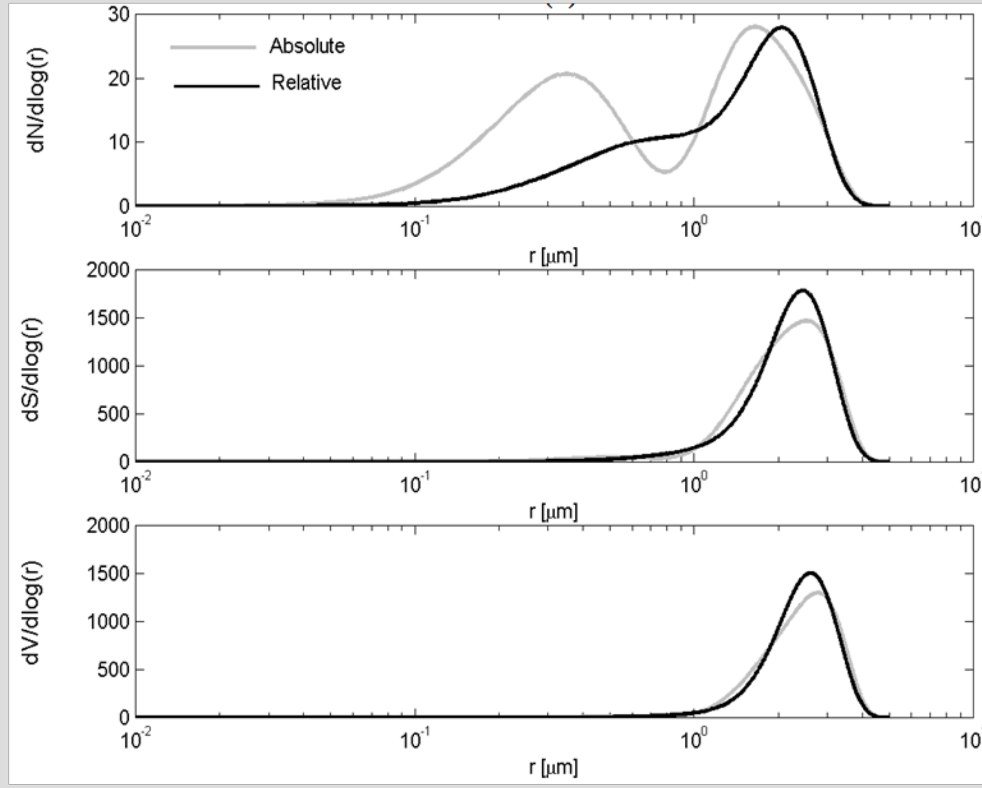


Aerosol-Cirrus-Contrails Optical Properties (Contrail (C): depolarization&microphysics



Contrail Pictures





$\varphi_{C\ (avg)}$ ~ 6 - 7 %

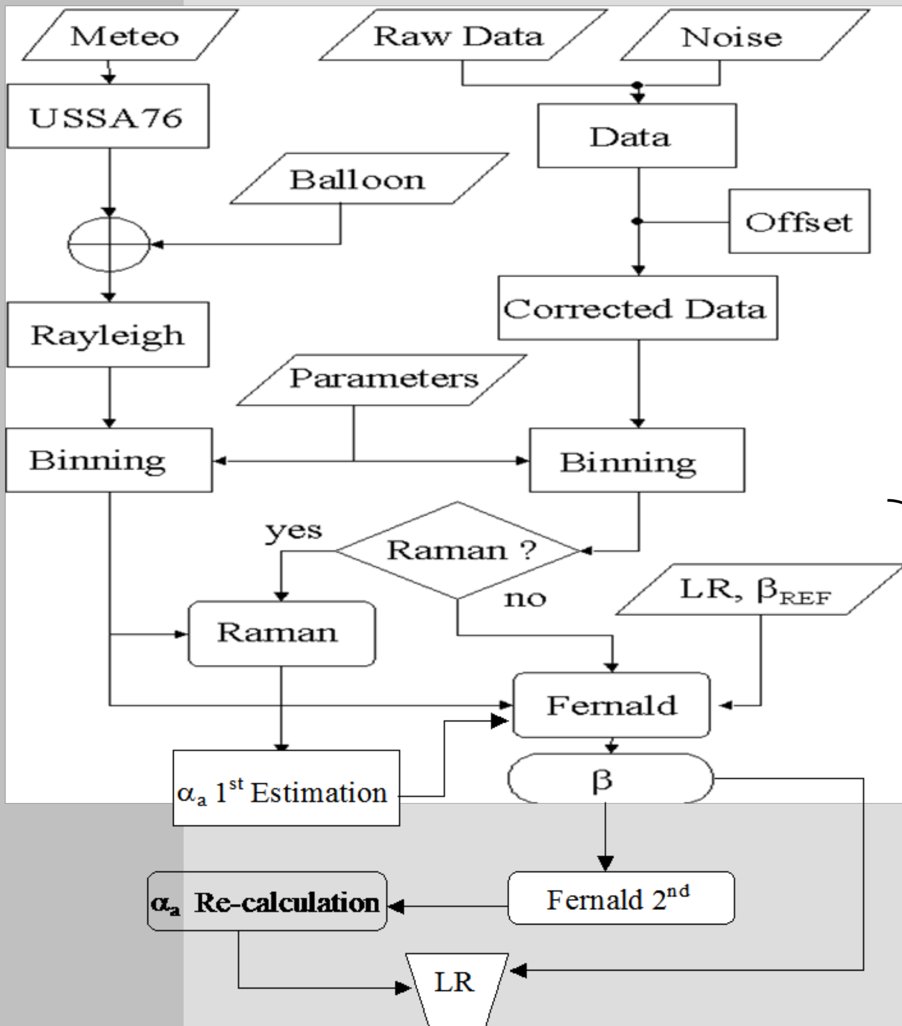
$r_{eff\ C\ (avg)}$ ~ 1.88 – 2 [µm]

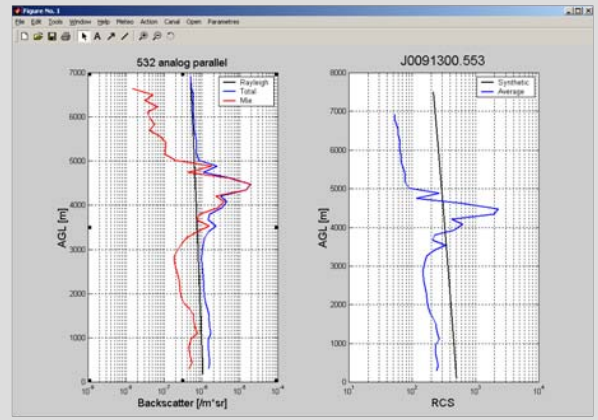
m = 1.4597+0.0000i (abs.$\rightarrow$0)

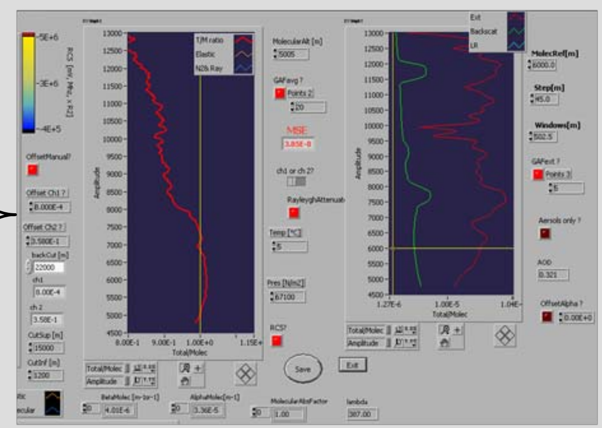
ω_0 ~ 1,

s_t~532 µm^{2}cm^{-3} v_t~ 339 µm^{3}cm^{-3} n_t~88 cm^{-3}

MatLab&LabView implemented algorithms: block diagram







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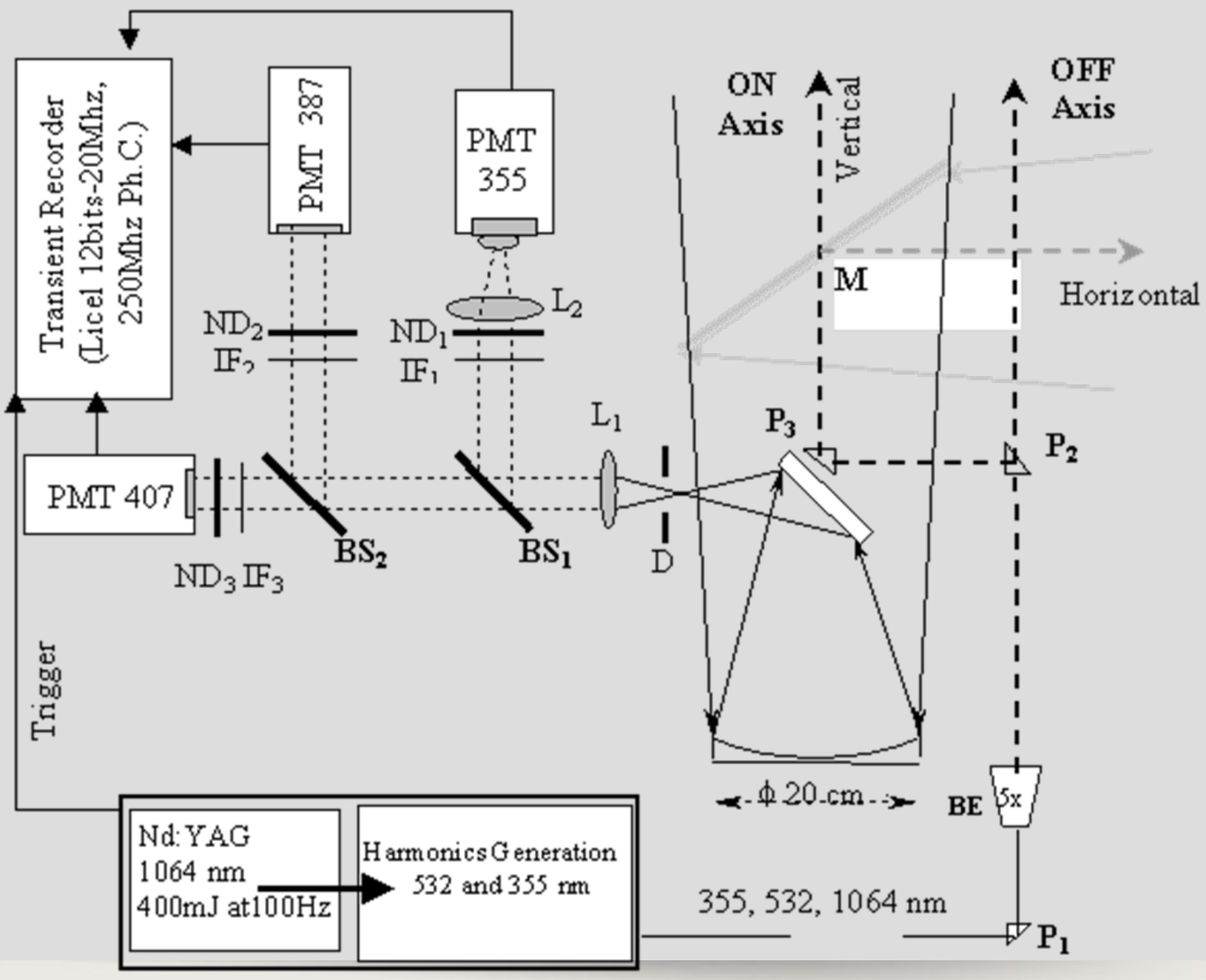
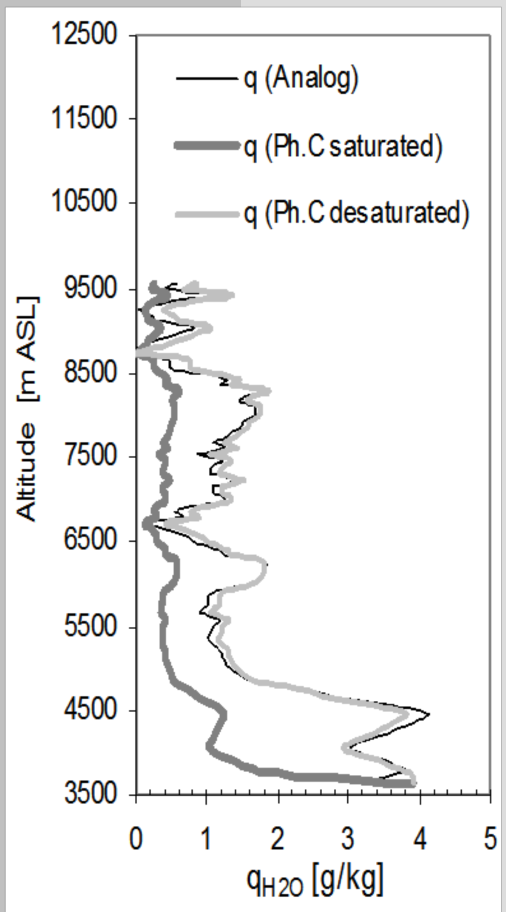
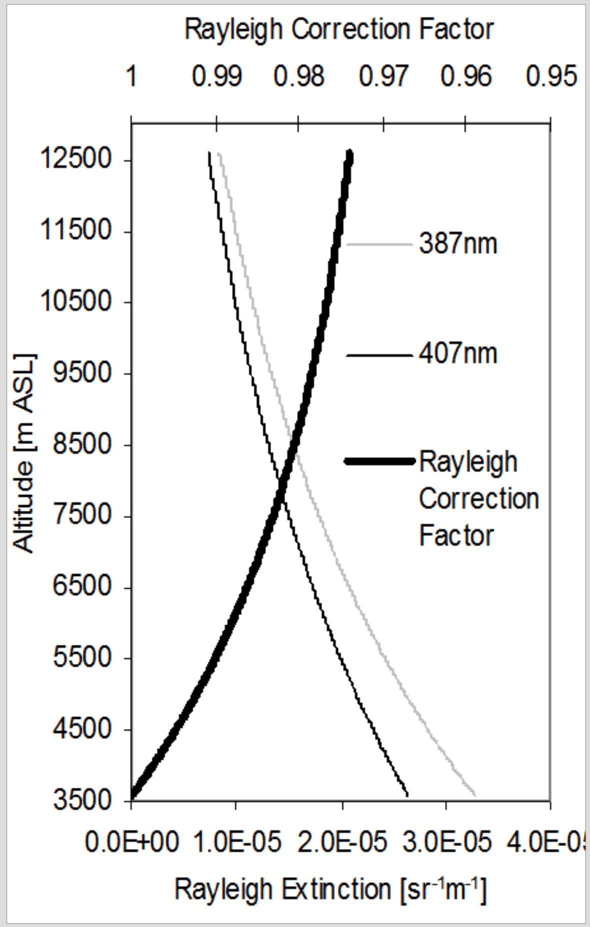
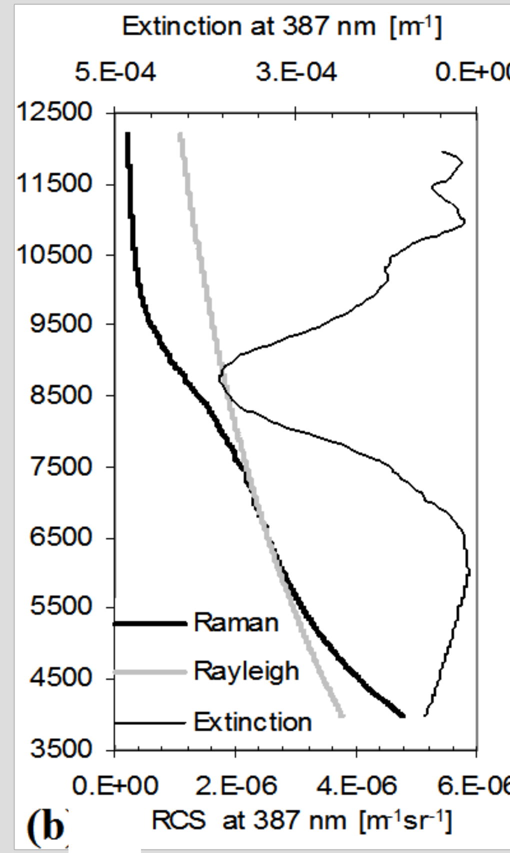
UT water vapor mixing ratio : JFJ LIDAR : RVR H_2O related layout



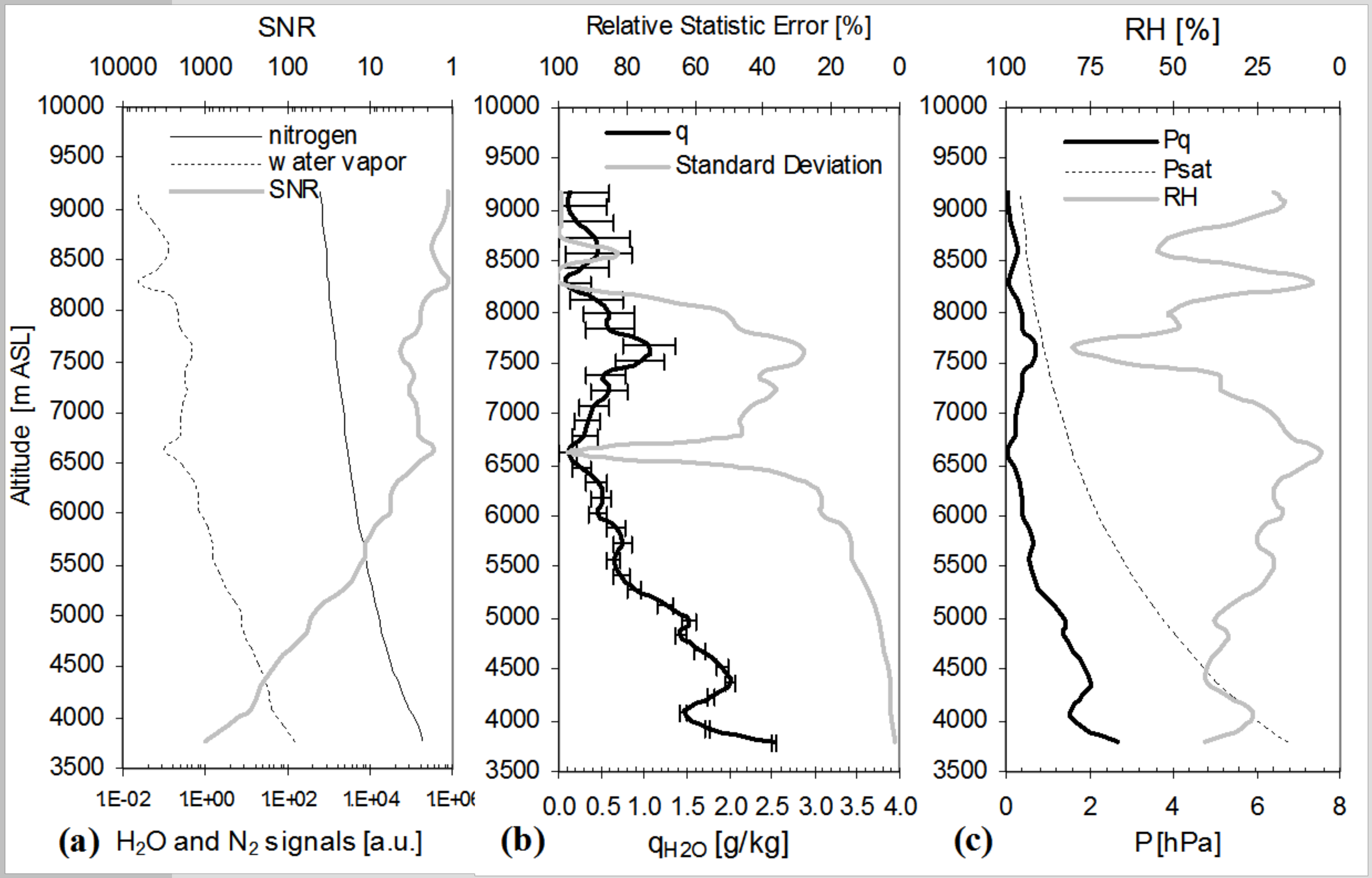
UT water vapor mixing ratio : Corrections exemplification



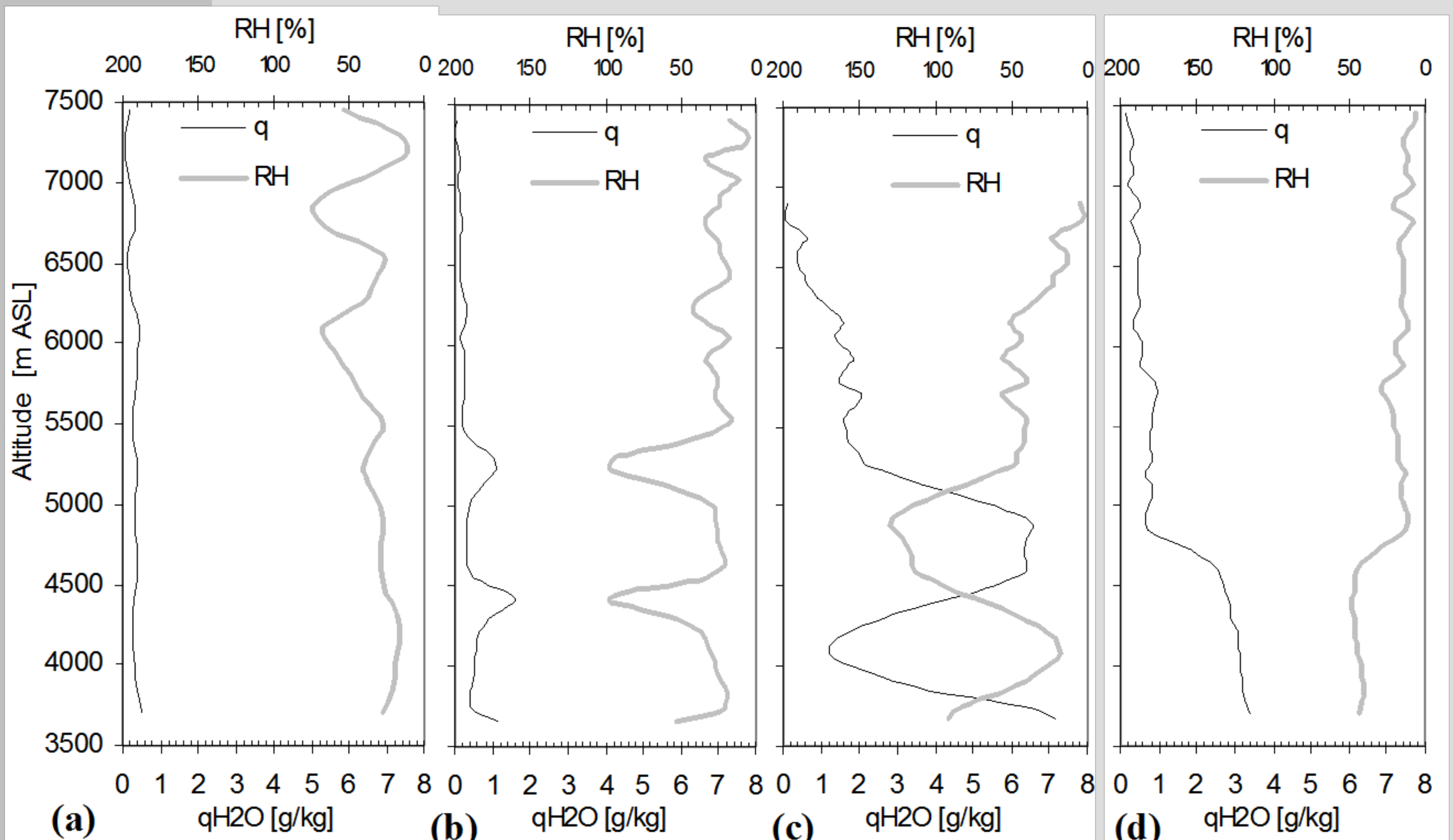




UT water vapor mixing ratio : 1st q_{H2O} profile by RVR Lidar: 01-02.08.2000



UT water vapor mixing ratio : Typical q_{H2O} profiles in UT by RVR Lidar



UT water vapor mixing ratio (8)

UT-IWV column from RVR Lidar

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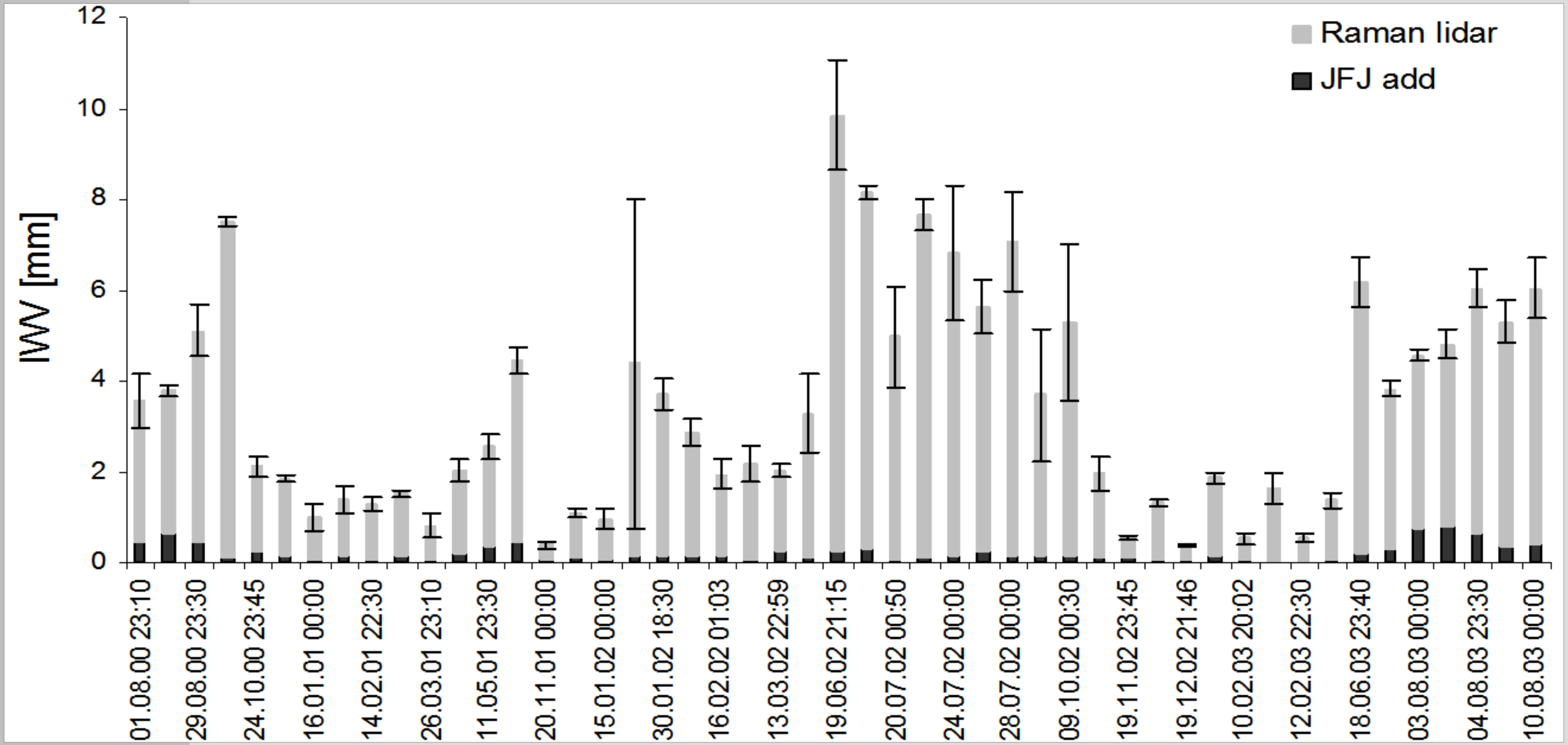
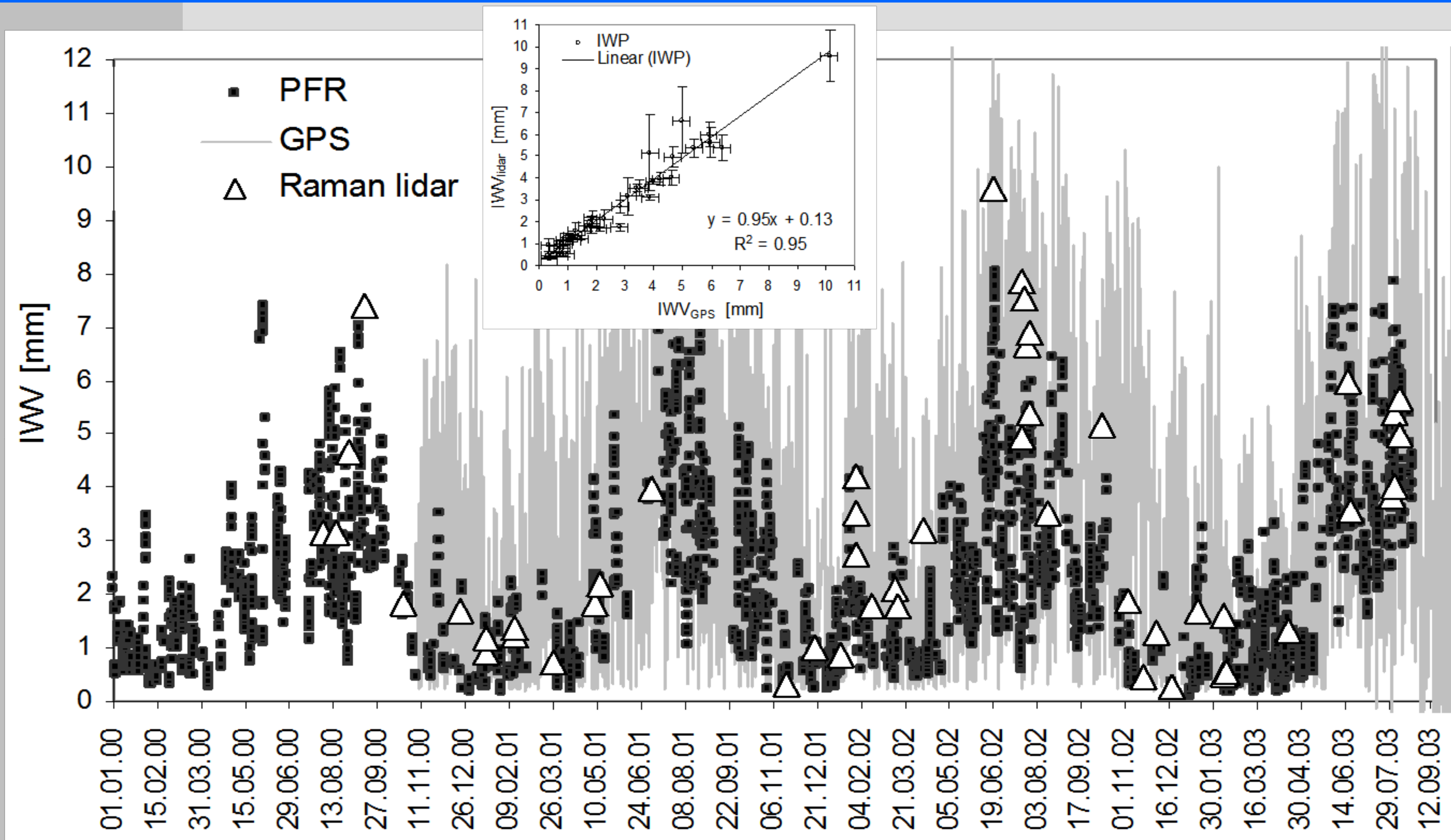
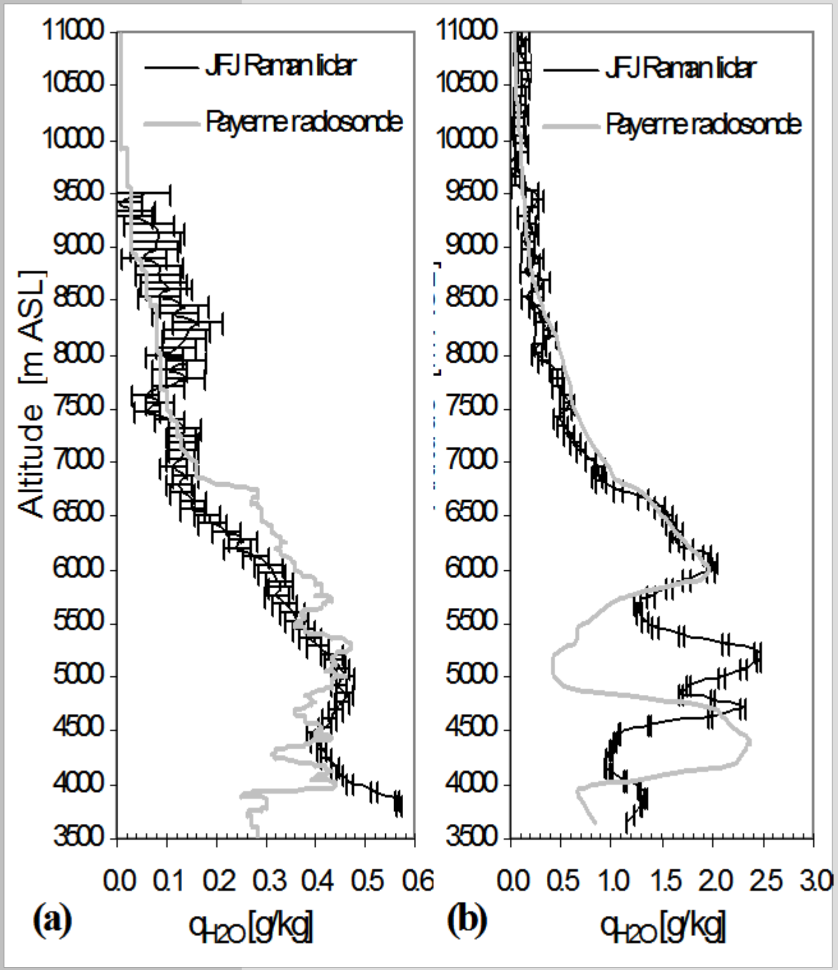
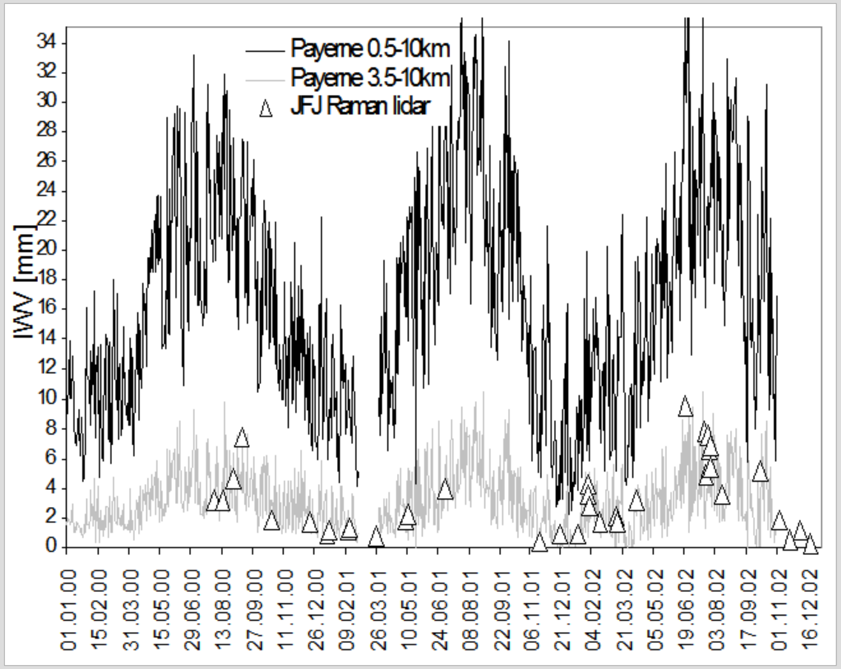


UT water vapor mixing ratio : UT-IWV column: RVR Lidar-PFR-GPS

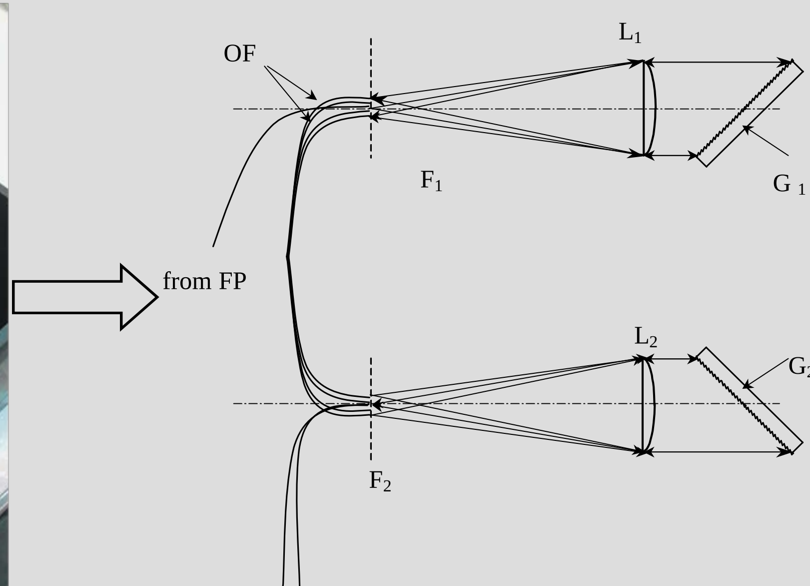


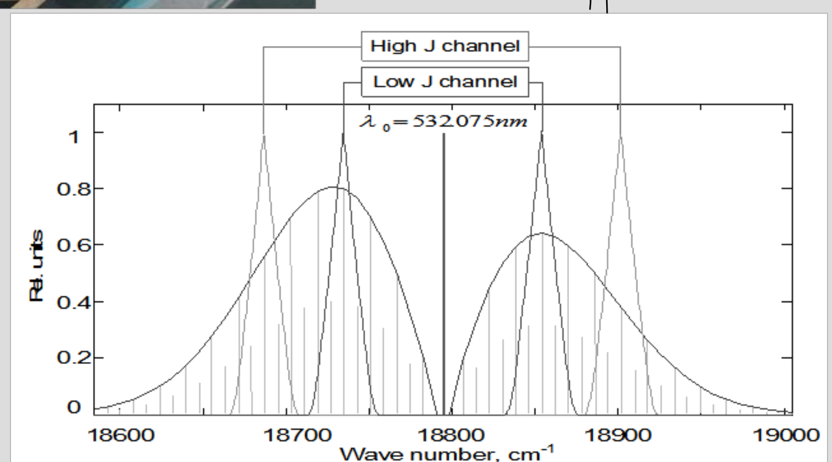
UT water vapor mixing ratio: Payerne radiosounding and JFJ – RVR Lidar



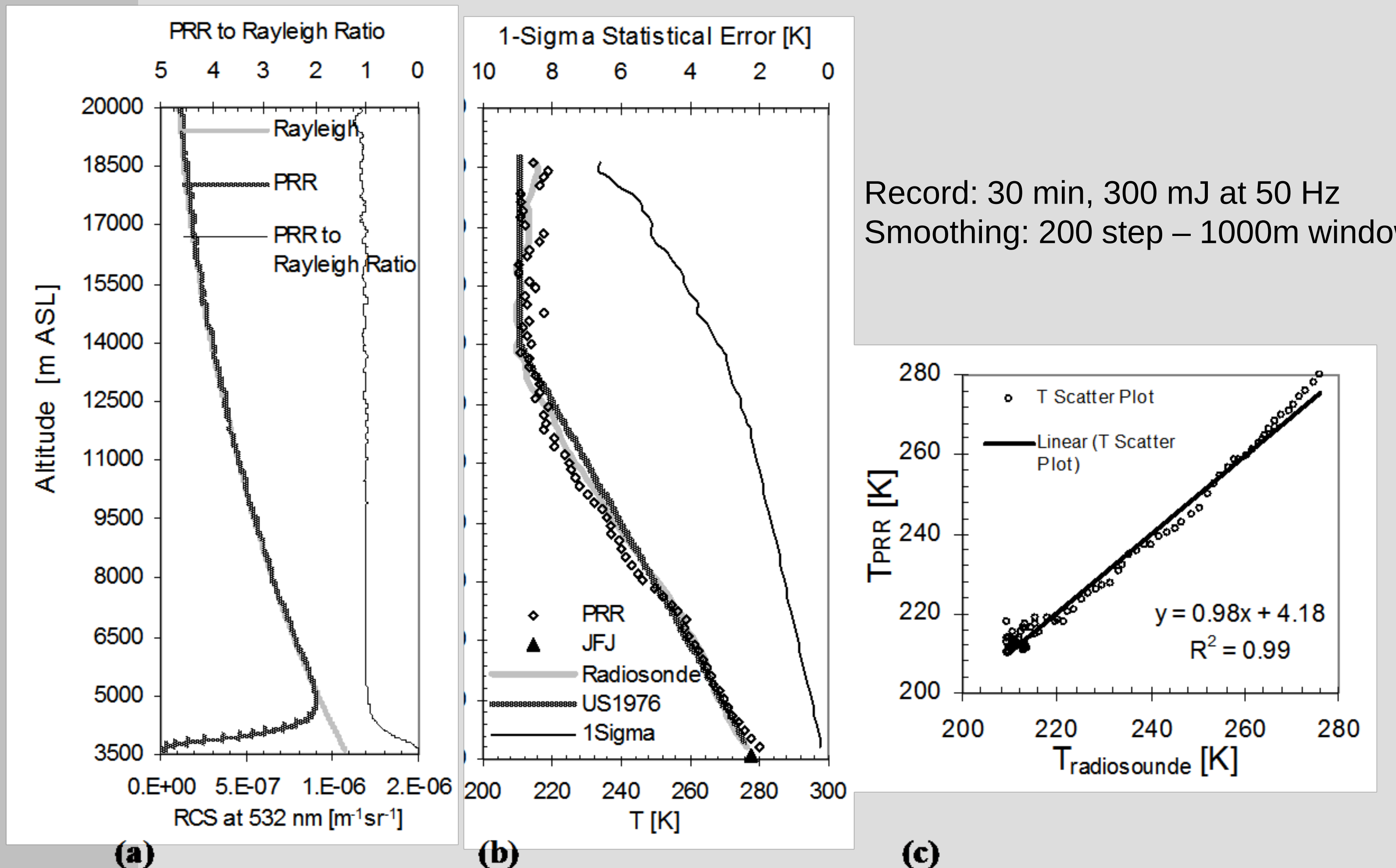


UTLS Temperature from PRR lidar:Double Grating Polychromator (DGP) module



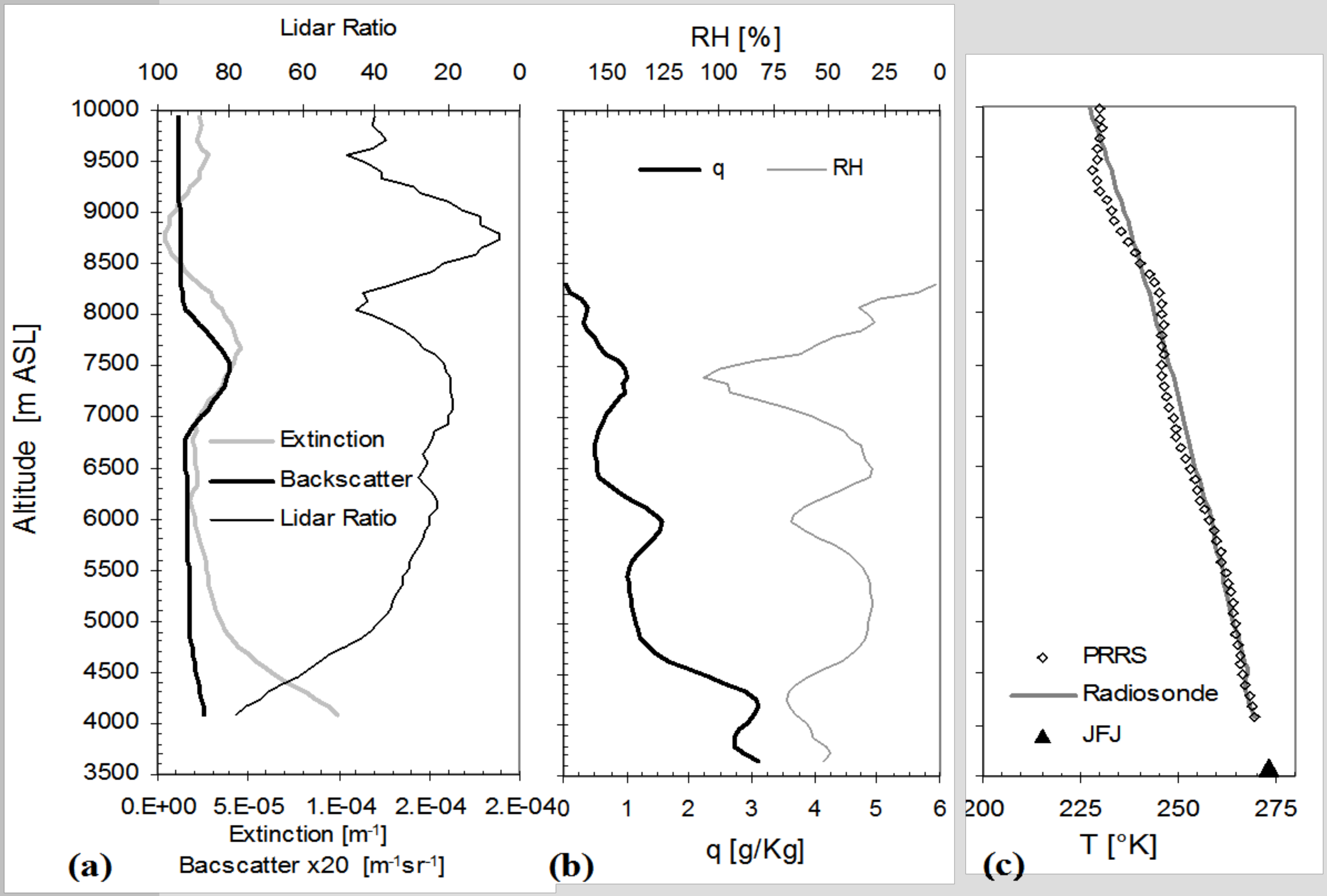


UTLS Temperature from PRR lidar: PRR - RCS and Temperature retrieval

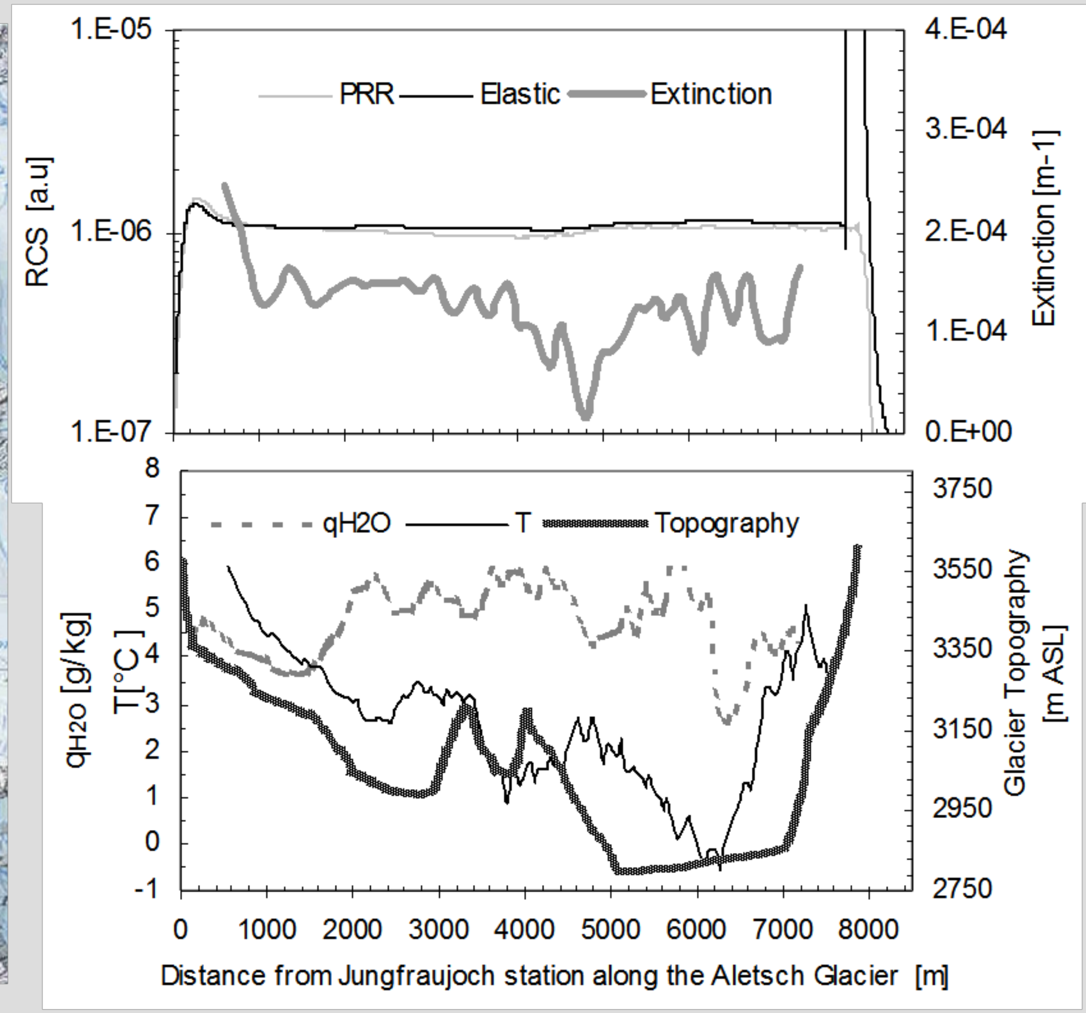


Record: 30 min, 300 mJ at 50 Hz
Smoothing: 200 step – 1000m windows

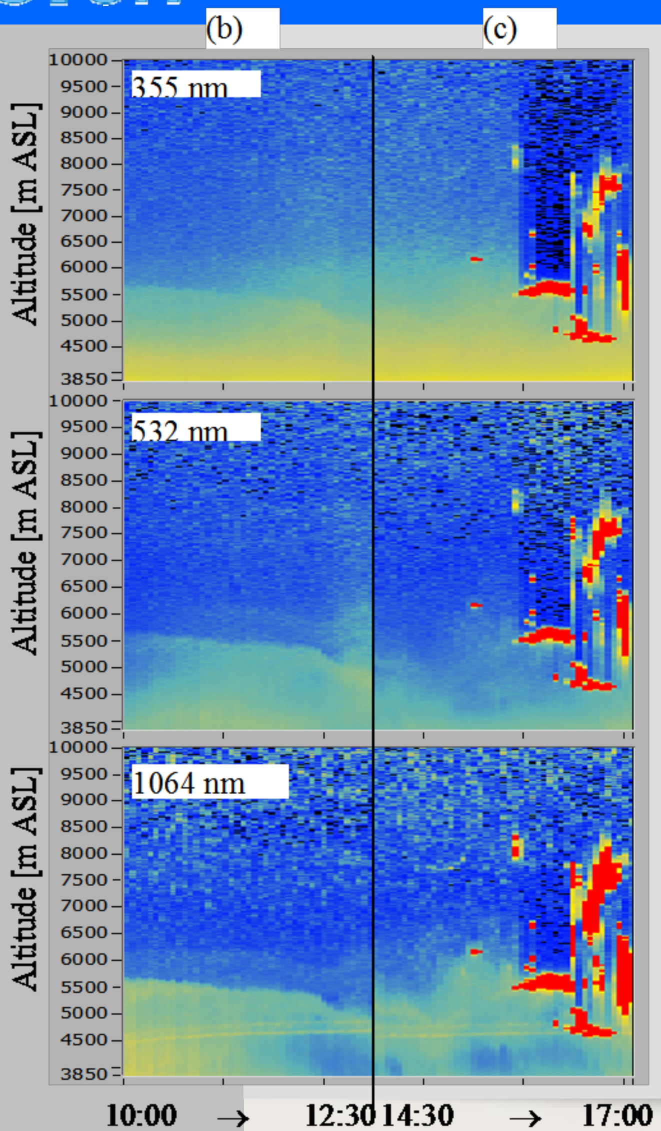
UTLS Temperature from PRR lidar: Aerosol Extinction-Backscatter and Relative Humidity

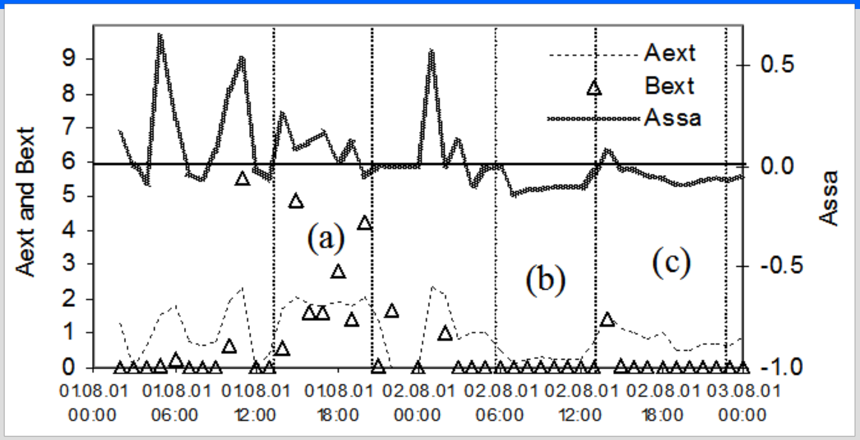


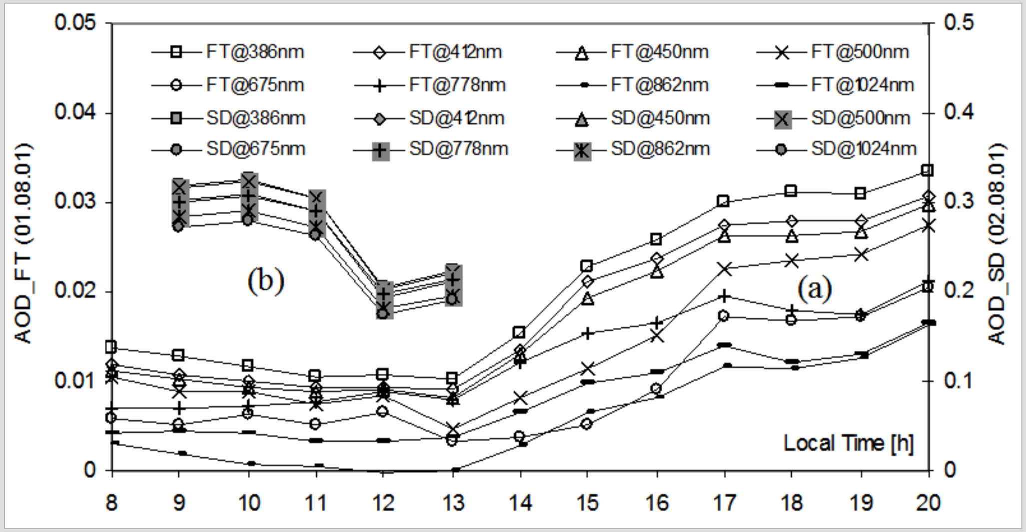
UTLS Temperature from PRR lidar: Horizontal Raman Lidar Observations



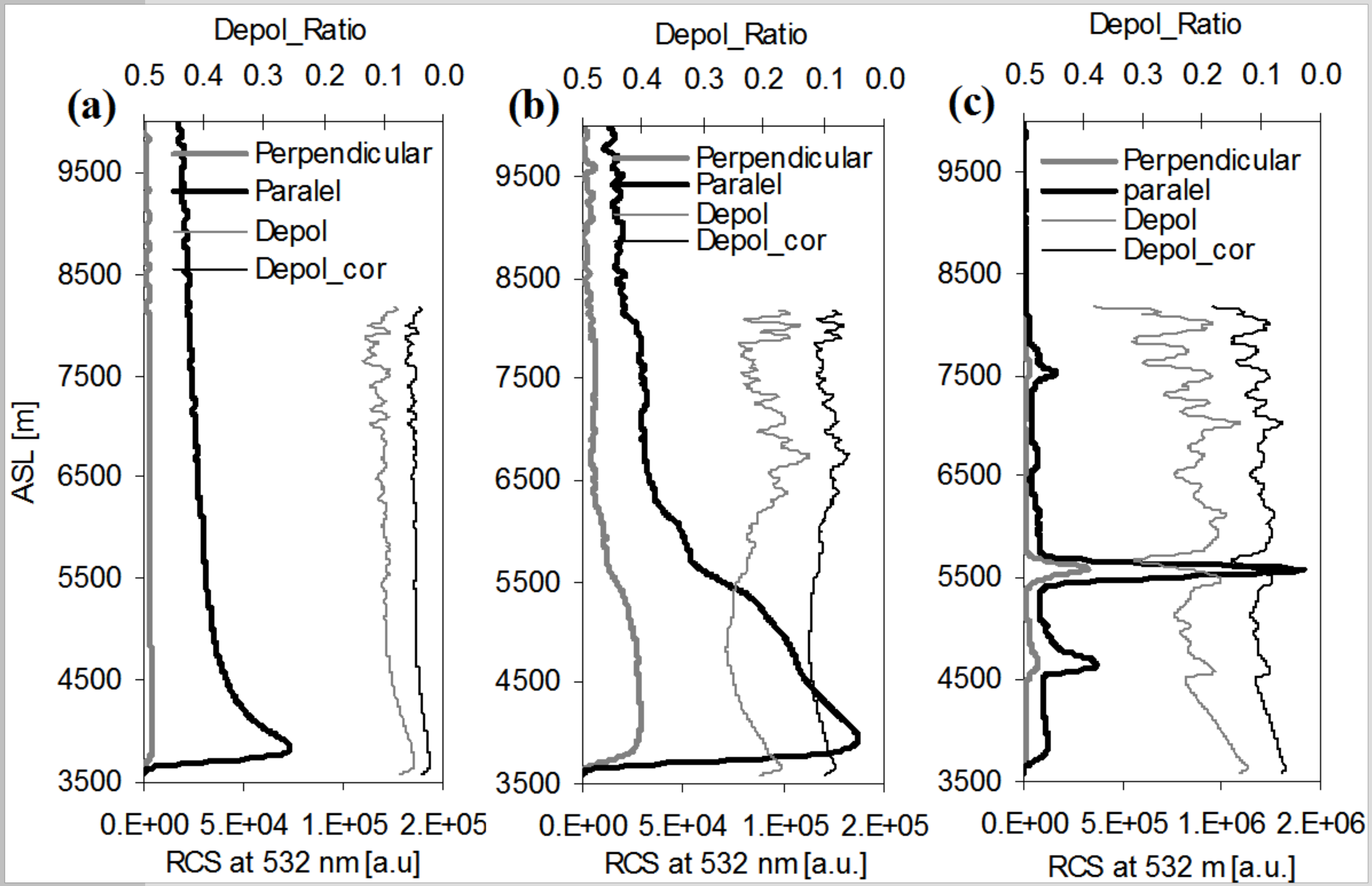
Long range-transported mineral dust study UT Saharan dust occurrence (evidence)on 02.08.2001



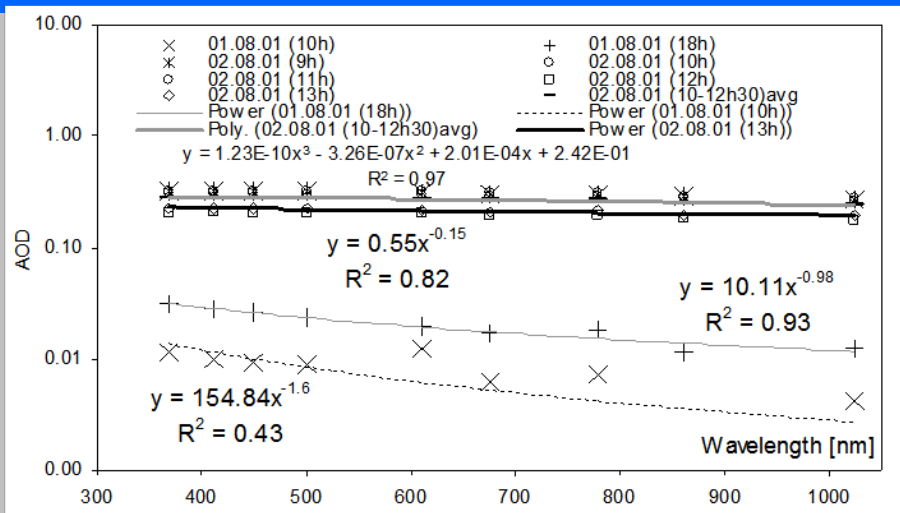


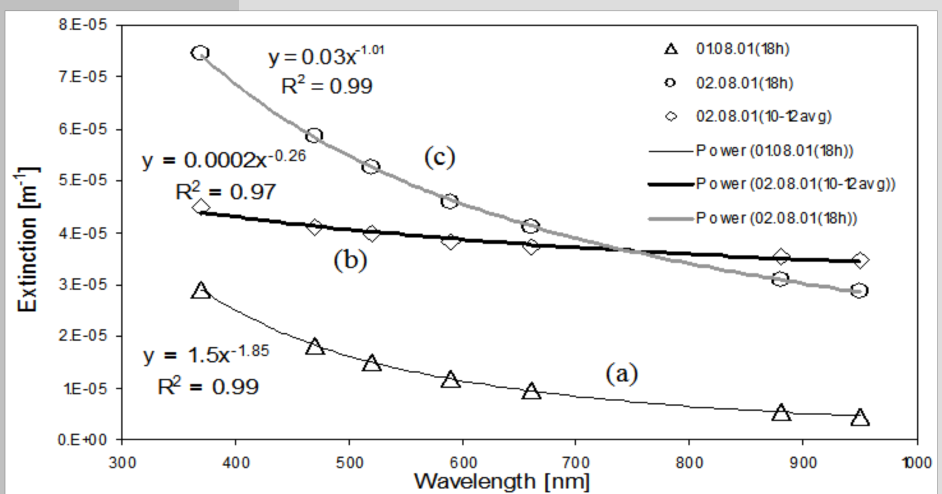


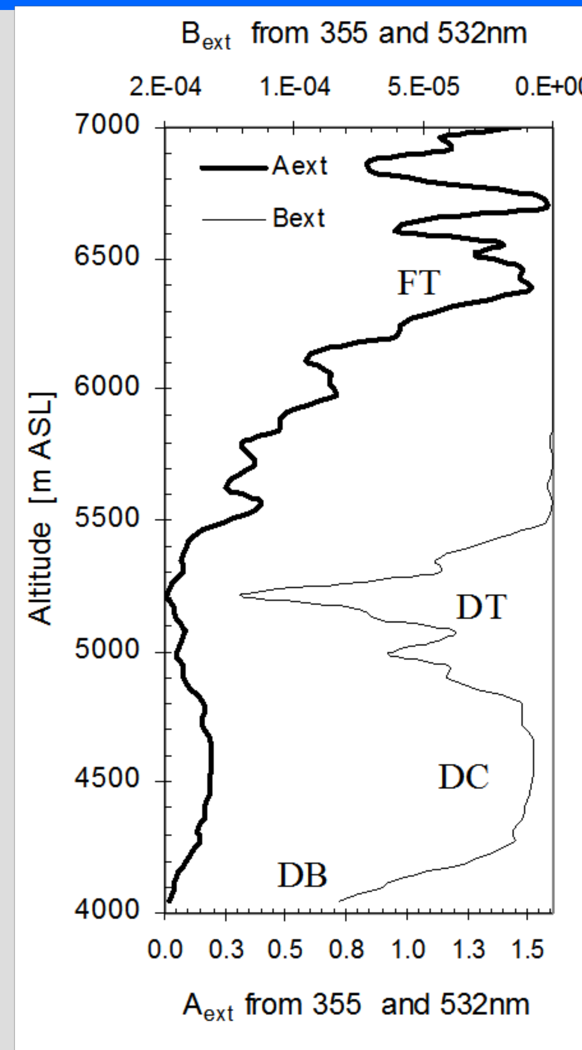
Long range-transported mineral dust study: Depolarization



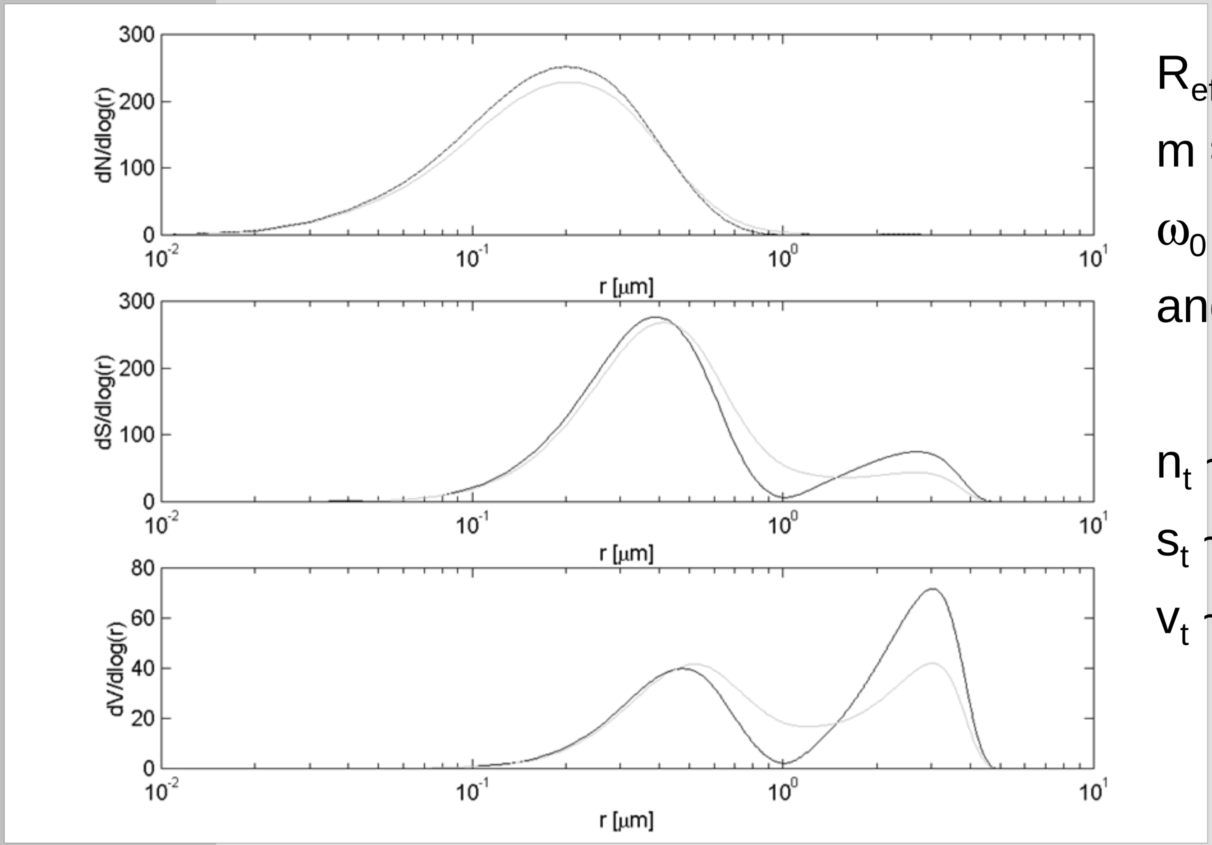
Long range-transported mineral dust study (4)
In situ, PFR and lidar: Angstrom coefficients







Long range-transported mineral dust study : Microphysics



R_{eff} ~1.13 µm

m = 1.5474 + 0.025 i

ω_0 ~ 0.7 (UV),

and ~ 0.75 (VIS-NIR)

n_t ~ 244 cm^{-3}

s_t ~ 175 $\mu m^2 cm^{-3}$

v_t ~ 66 $\mu m^3 cm^{-3}$

PBL high convection (2)

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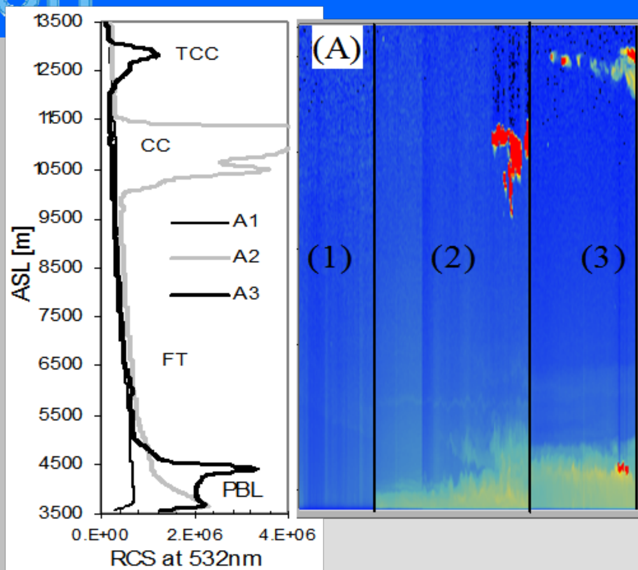
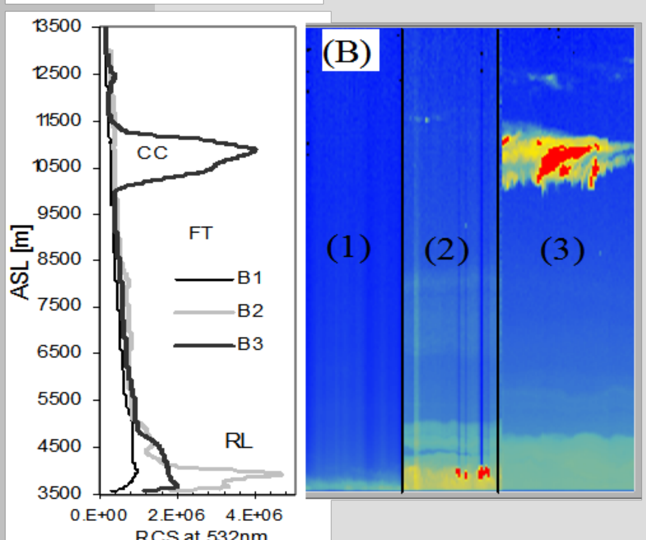
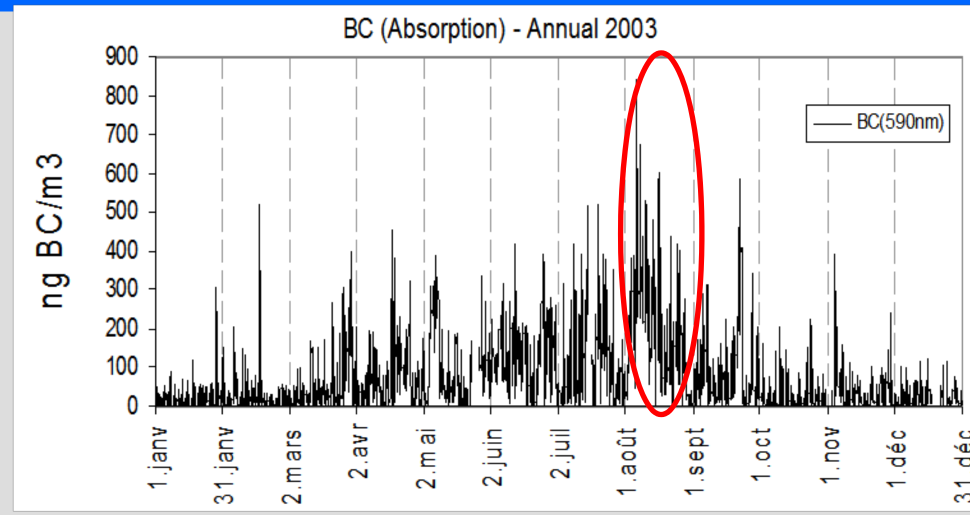
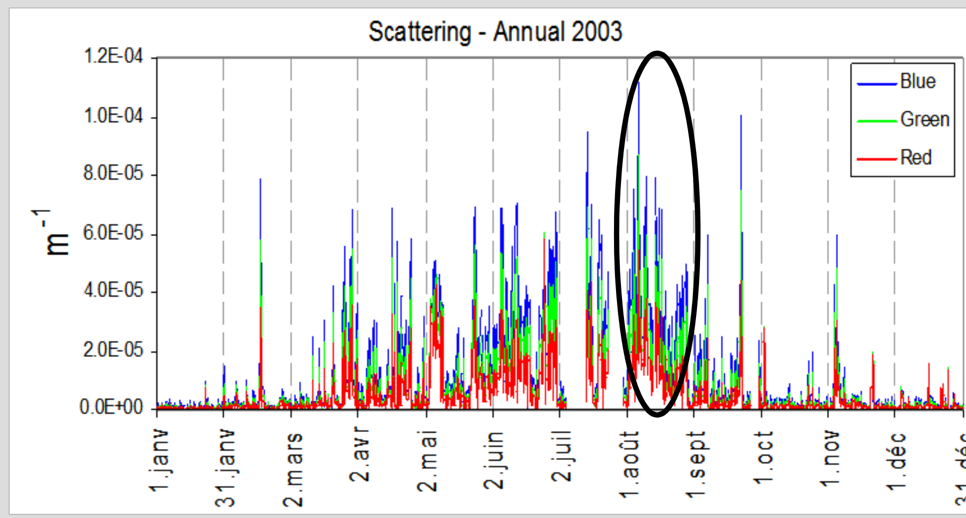
PBL height: aerosol tracing



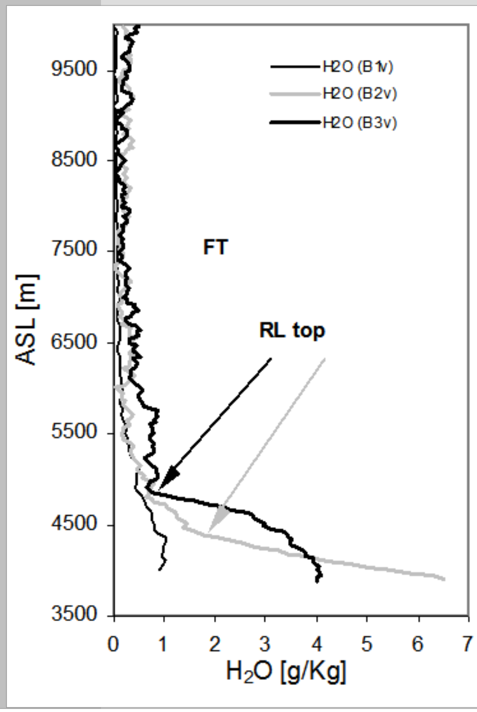


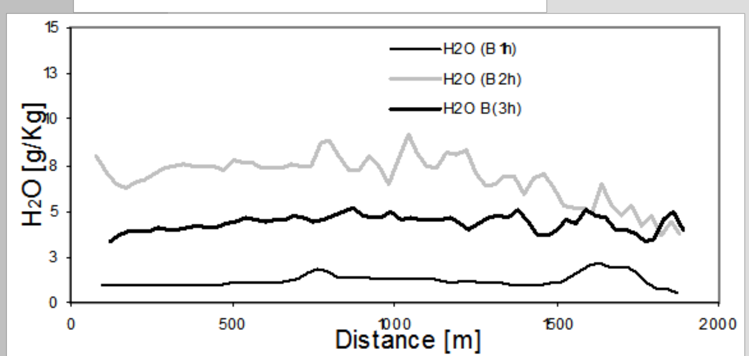


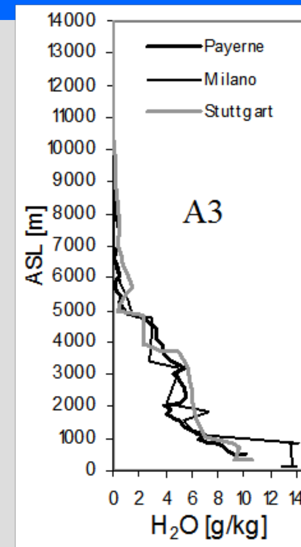


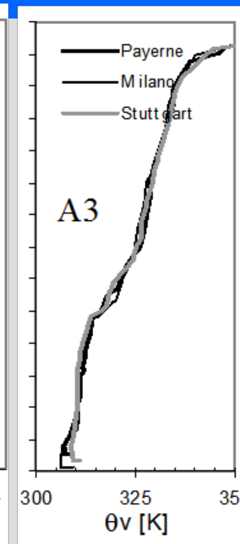
PBL high convection (4)

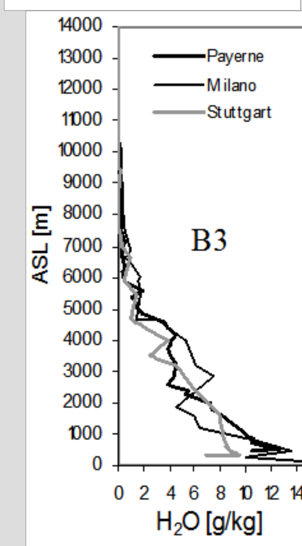
PBL height: water vapor and virtual temperature tracing

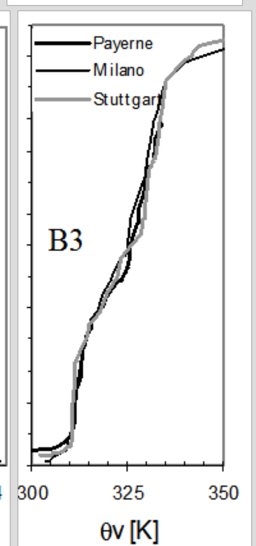




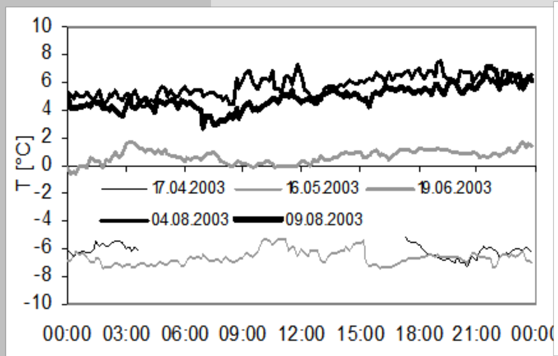


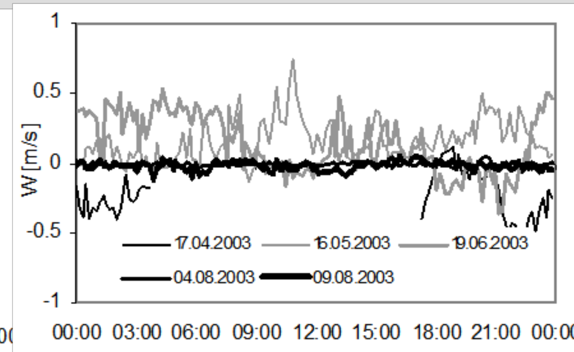


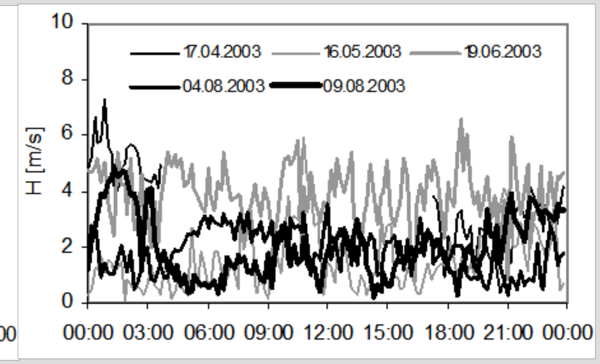


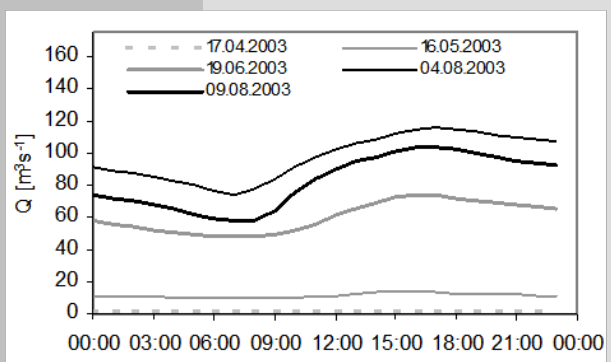


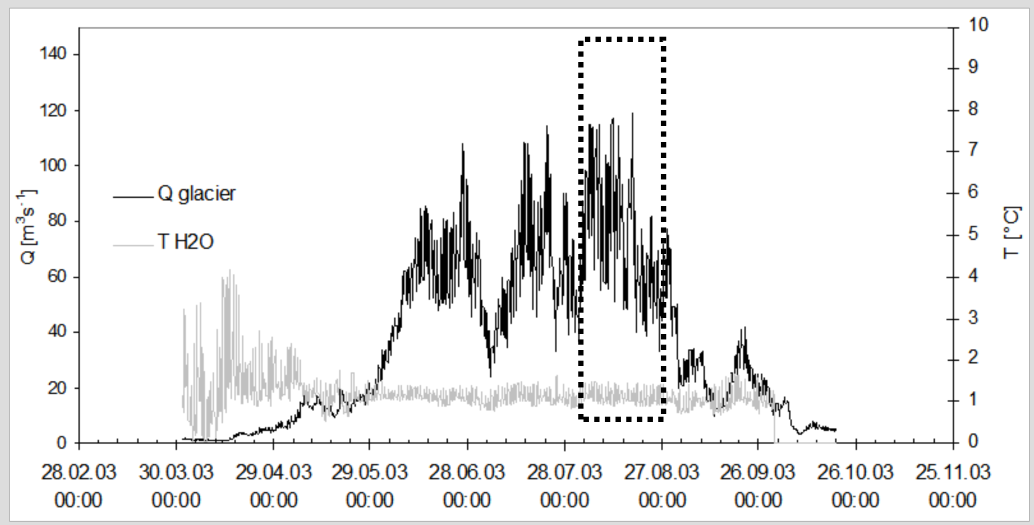
PBL high convection :Turbulence & Glacier Discharge



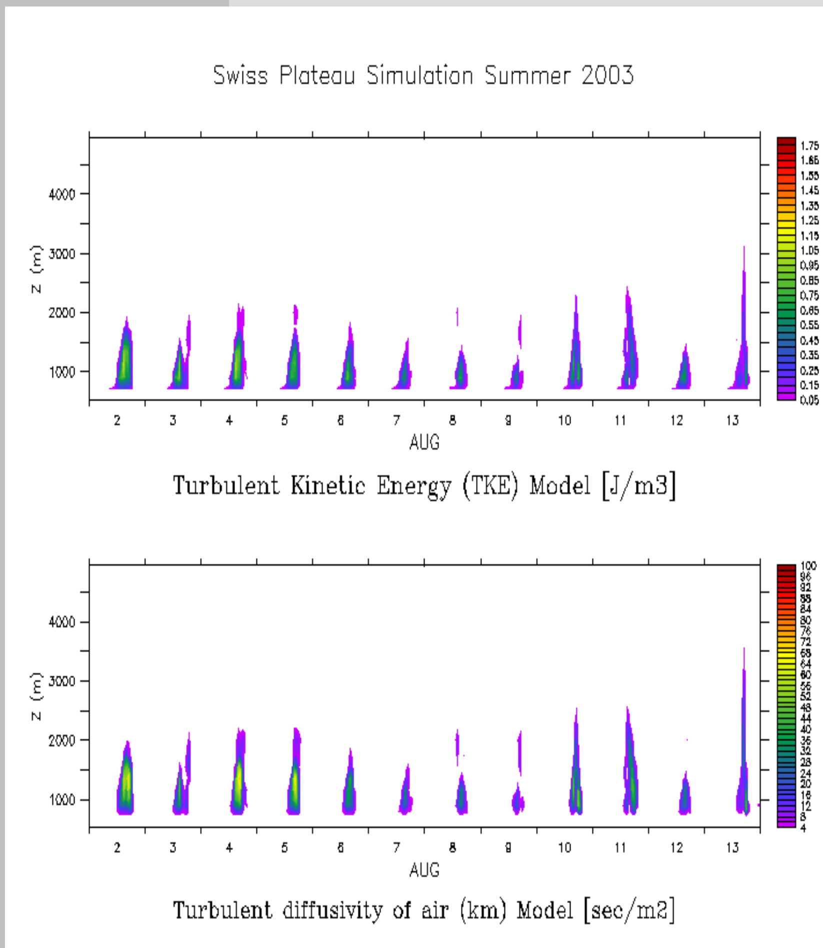


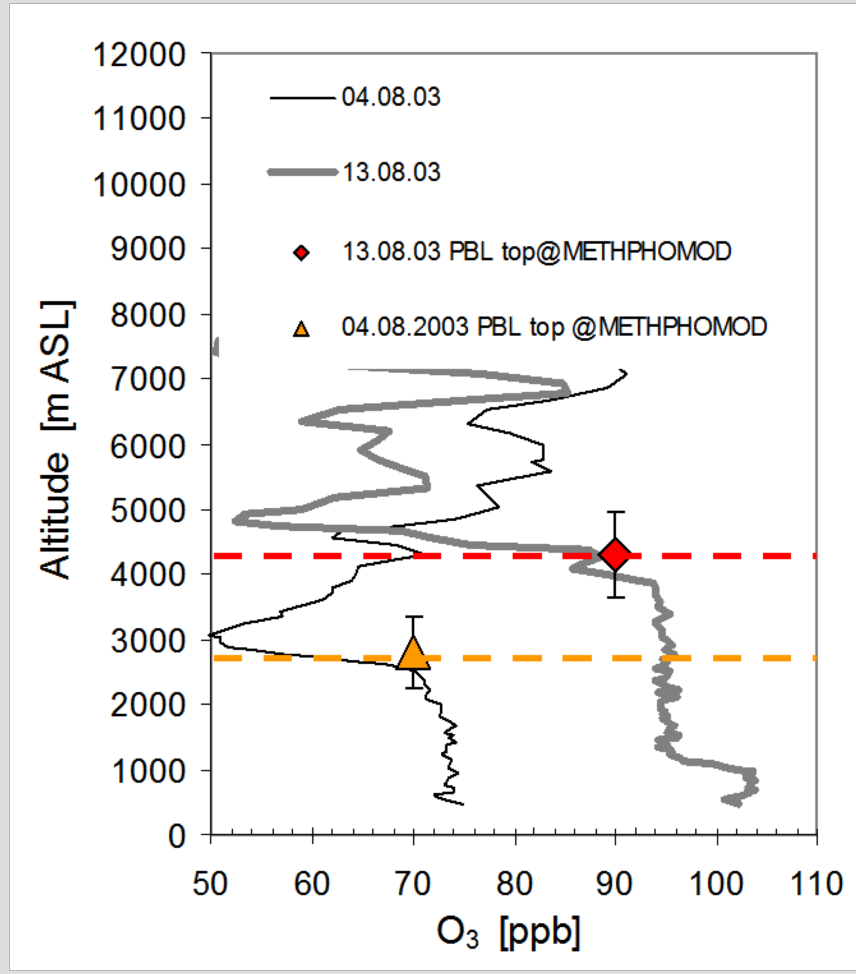






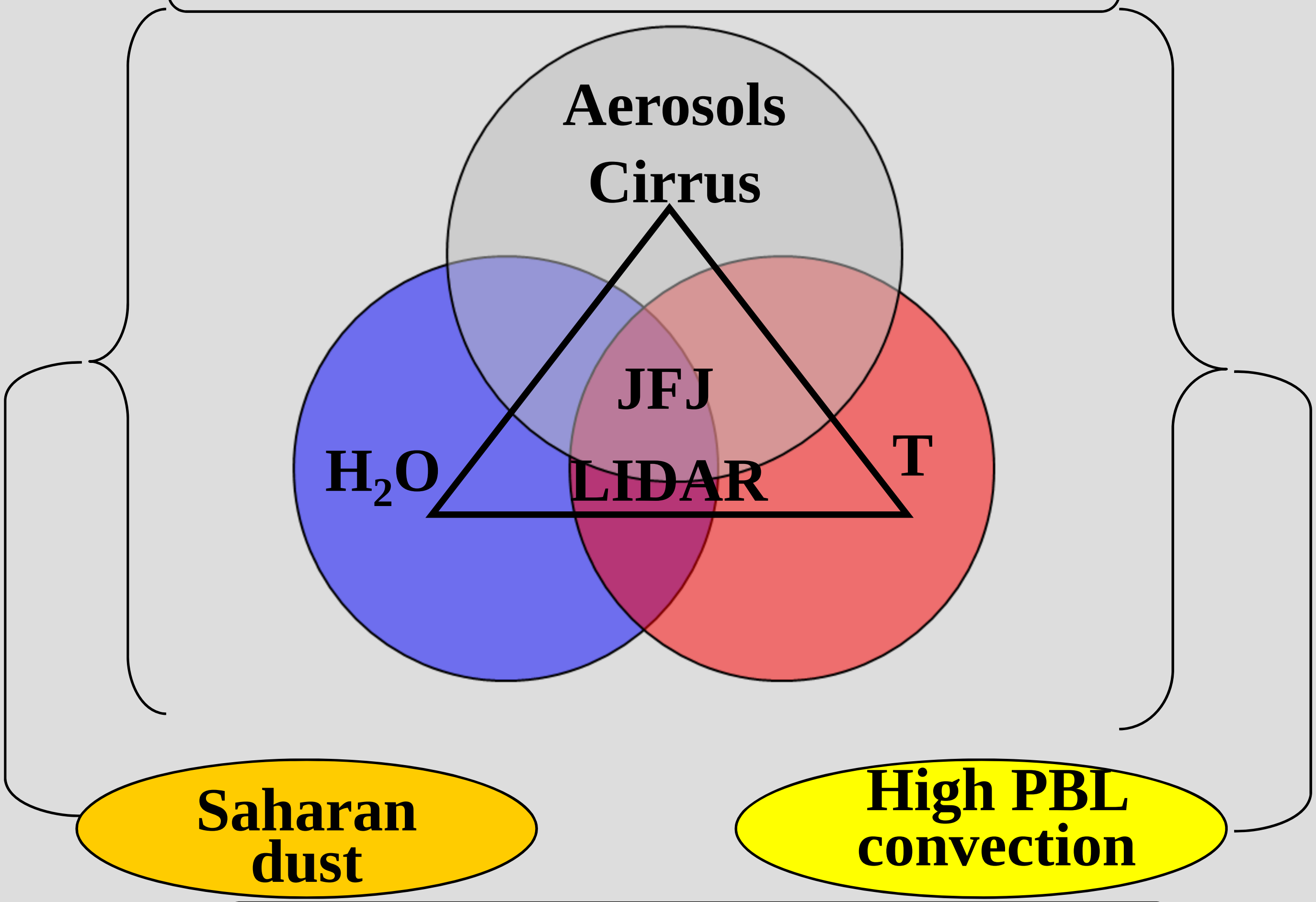
PBL high convection : Other related observations





CONCLUSIONS

Problematic & Objectives




Thanks for your attention
Merci de votre attention
Multam pentru atentie