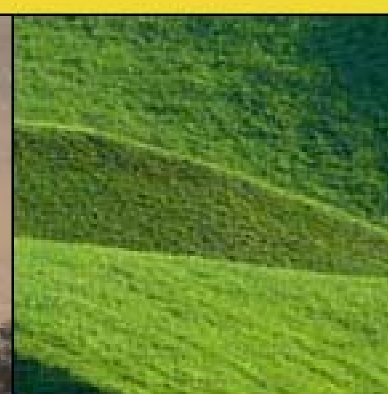
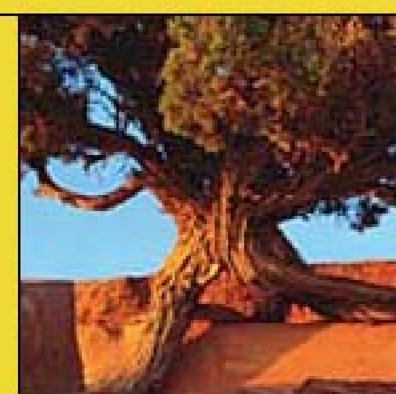
Optimization of aerosol optical properties retrieval by use of low-range and high-range lidars. Comparison with sun photometry





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Outline

- AOD
- Instruments: sunphotometer, lidars
- Our method
- Results
- Conclusions

Aerosol optical depth (AOD)

- a quantitative measure of the extinction of solar radiation by
  - aerosol scattering
  - absorption
- between the point of observation and the top of the atmosphere
- the extinction coefficient integrated on an atmospheric path (generally scaled at the zenith direction)

$$AOD = \int_{Z_0}^{Z} \alpha_a(z)\,dz$$

- used by modellers to assess:
  - the direct radiative forcing of aerosols
  - surface PM (?)
- can be retrieved from observations of atmospheric spectral transmission
- AOD = total optical depth minus modeled estimates of the other components

$$\tau(\lambda)_{aerosol} = \tau(\lambda)_{tot} - \tau(\lambda)_{water} - \tau(\lambda)_{Rayleigh} - \\ - \tau(\lambda)_{O3} - \tau(\lambda)_{NO2} - \tau(\lambda)_{CO2} - \tau(\lambda)_{CH4}$$

Sunphotometer

- CIMEL Electronique 318A spectral radiometer
- 7 wavelengths: 340, 380, 440, 500, 670, 870, and 1020 nm
- Beer-Lambert-Bouguer law
  - *V* =digital voltage at wavelength λ
  - *Vo* =extraterrestrial voltage
  - *d* =ratio of the average to the actual Earth-Sun distance
  - □ τ_{tot} =total optical depth
  - *m* =optical air mass
- uncertainty in AOD (cloud-free conditions)
  - <0.01 for λ>440 nm
  - ≤0.02 for λ<440 nm
- spectral aerosol optical depth → aerosol size distribution
- AOD several wavelengths → Angstrom parameter

$$\alpha = -\frac{d \ln \tau_{aerosol}}{d \ln \lambda}$$

↑

$$V(\lambda) = V_0(\lambda) d^2 \exp[-\tau_{tot}(\lambda) \cdot m]$$

Lidar

- Lidar can detect layers
- Lidar (some of them) can measure extinction profiles → AOD

$$AOD = \int_{Z_0}^{Z} \alpha_a(z)dz$$

- Lidar can measure at several wavelengths → Angstrom parameter →
  - aerosol size
- helpful to assess:
  - if aerosol type is singular
  - if the aerosol is largely confined to the boundary layer
  - the dept of the boundary layer

BUT

- calibration!
  - generally in far range, but not always free of aerosols
- overlap!
  - powerful Raman systems have high overlap (Km) → blind for most of the PBL
- LR
  - elastic channels only → non-determination of lidar equation → large errors for the PBL
  - elastic + Raman channels → not enough SNR to sense the upper troposphere

→ to make sure the assumptions for estimating the surface PM apply!

Our site

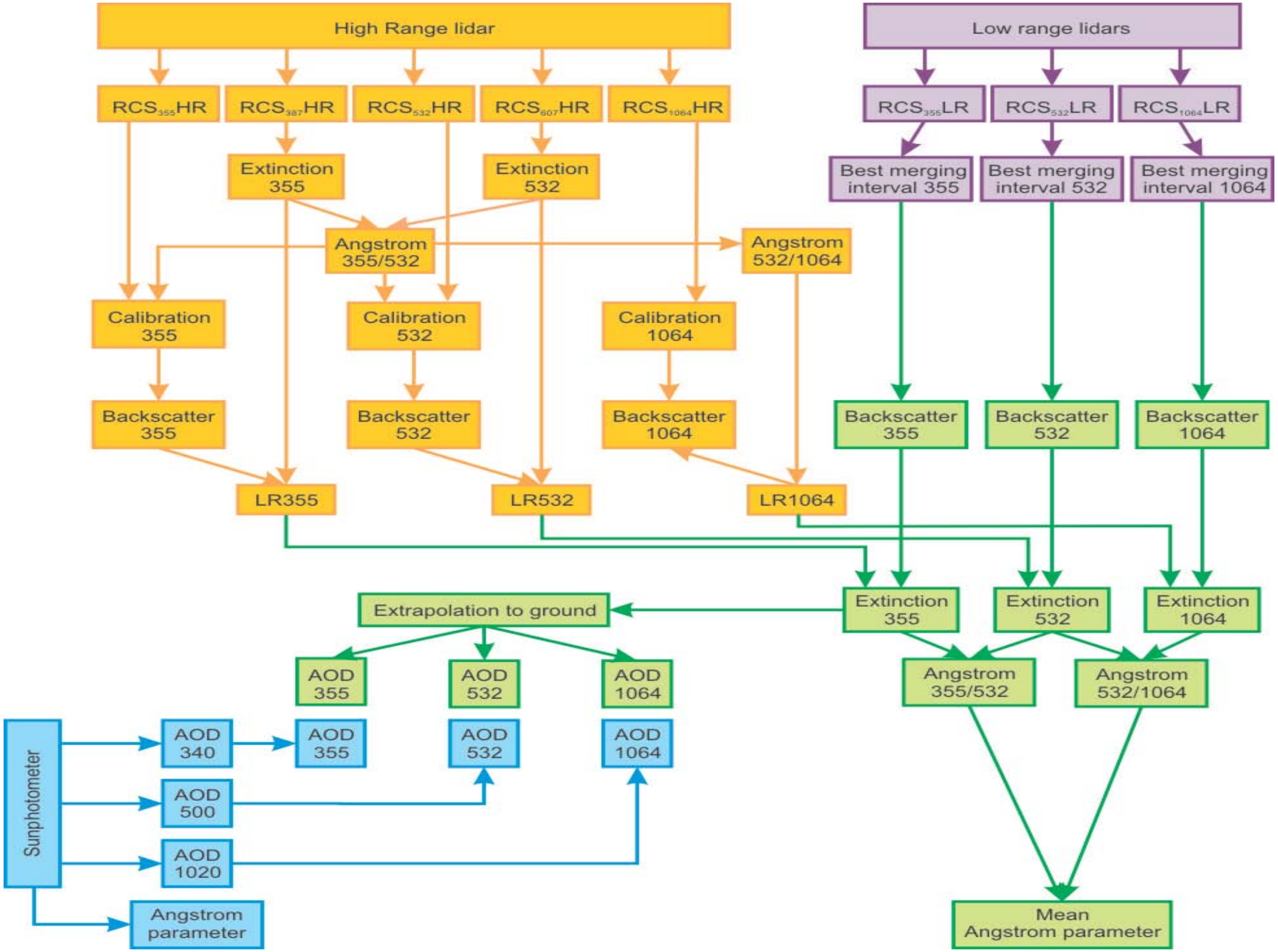
- 7-wavelegths sunphotometer
  - 340, 380, 440, 500, 670, 870, 1020 nm
- 3+2w Raman lidar (RALI)
  - dynamic range: 1-15Km
  - 3 elastic (1064, 532, 355nm)
  - 2 Raman (607, 387nm)
- 2w elastic lidar (LISA)
  - dynamic range: 0.3-6Km
  - 2 elastic (1064, 532nm)
- 1w+dep elastic lidar (MILI)
  - dynamic range: 0.3-6Km
  - 1 elastic (355p, 355s)

Our method

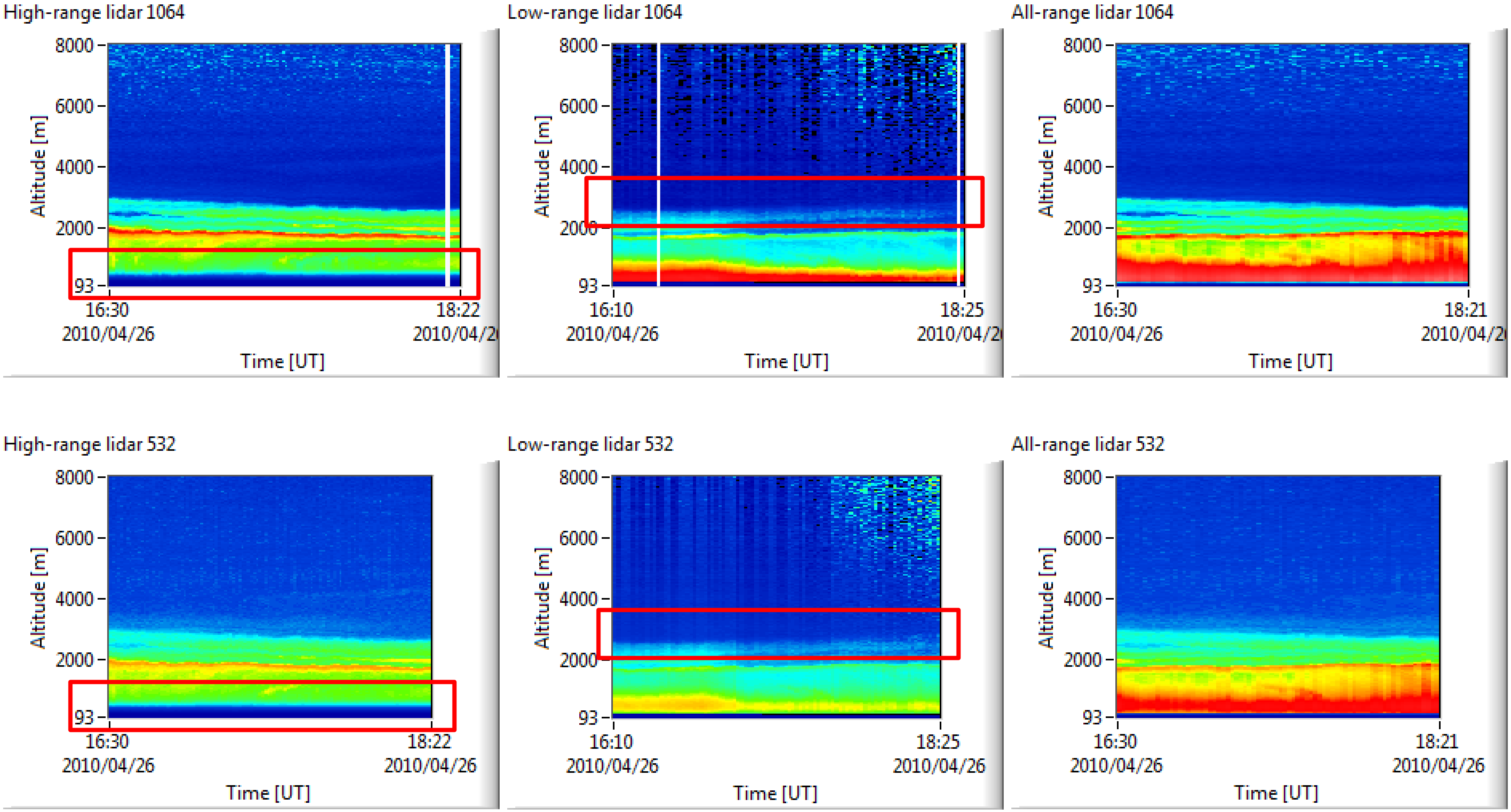
- merge RCS of RALI, LISA and MILI (elastic) → 3 elastic RCS 0.3 – 15Km
  - simultaneous measurements
  - same air column
  - assuming linear behavior of the instrument
  - search for best fit interval (after the full overlap of the HR lidar, bellow the high noise altitude of the LR)
- calculate LR_{532}, LR_{355} profile from RALI
- calibrate backscatter so that linear fit of Angstrom parameter profile has slope≈0
- extrapolate extinction profiles to the ground
- calculate AOD from lidar (532, 355nm)
- use Angstrom parameter to shift AOD from sunphotometer's to lidar's wavelengths
- compare values
- calculate errors (statistical and propagated)

$$\alpha = -\frac{d \ln \tau_{aerosol}}{d \ln \lambda}$$

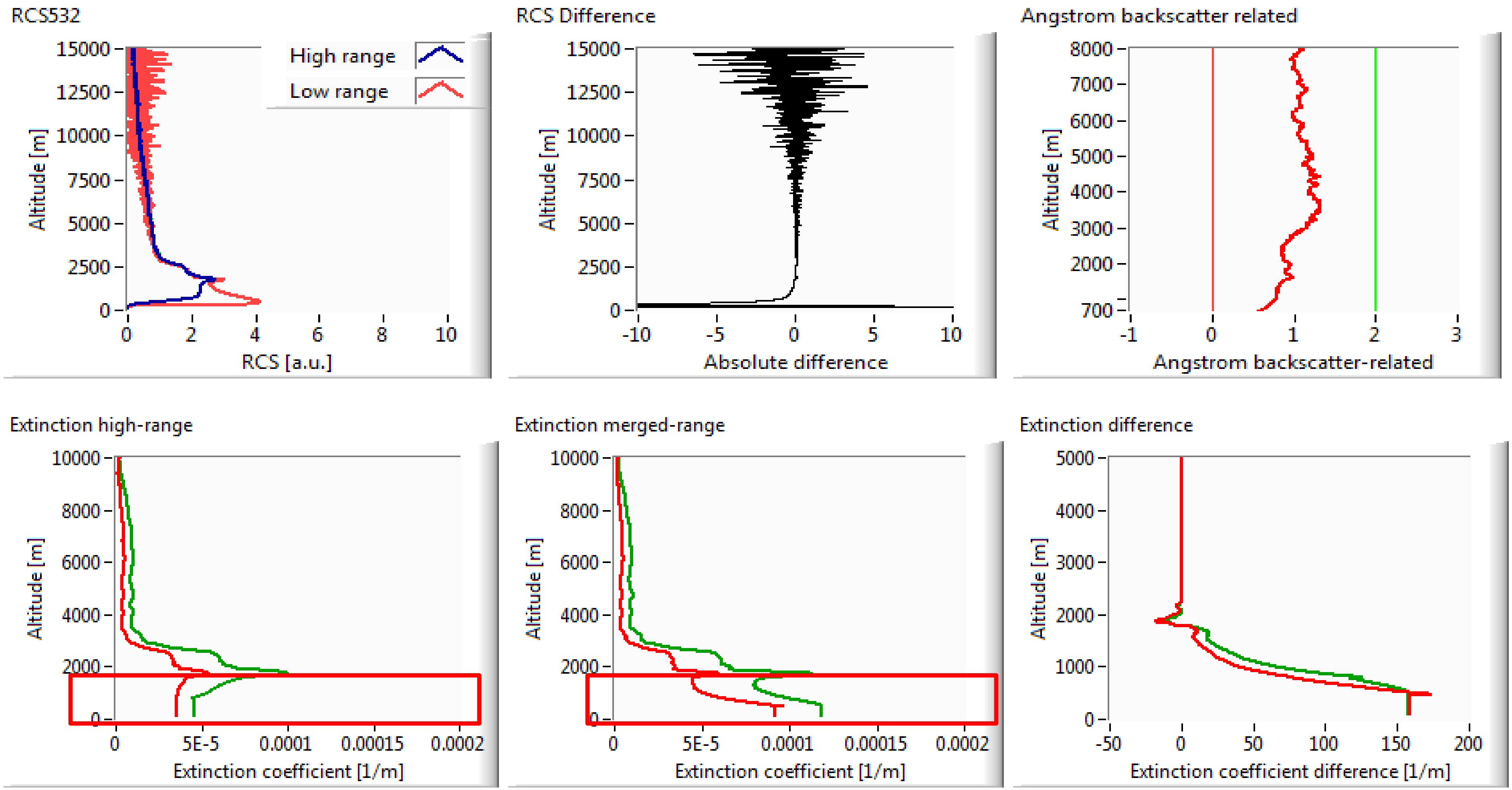
Our method


High Range lidar
Low range lidars
$RCS_{355}HR$
$RCS_{387}HR$
$RCS_{532}HR$
$RCS_{607}HR$
$RCS_{1064}HR$
$RCS_{355}LR$
$RCS_{532}LR$
$RCS_{1064}LR$
Extinction 355
Extinction 532
Best merging interval 355
Best merging interval 532
Best merging interval 1064
Angstrom 355/532
Angstrom 532/1064
Calibration 355
Calibration 532
Calibration 1064
Backscatter 355
Backscatter 532
Backscatter 1064
Backscatter 355
Backscatter 532
Backscatter 1064
LR355
LR532
LR1064
Extrapolation to ground
Extinction 355
Extinction 532
Extinction 1064
AOD 355
AOD 532
AOD 1064
Angstrom 355/532
Angstrom 532/1064
Sunphotometer
AOD 340
AOD 355
AOD 532
AOD 1064
AOD 500
AOD 1020
Angstrom parameter
Mean Angstrom parameter

Results: April 26, 2010

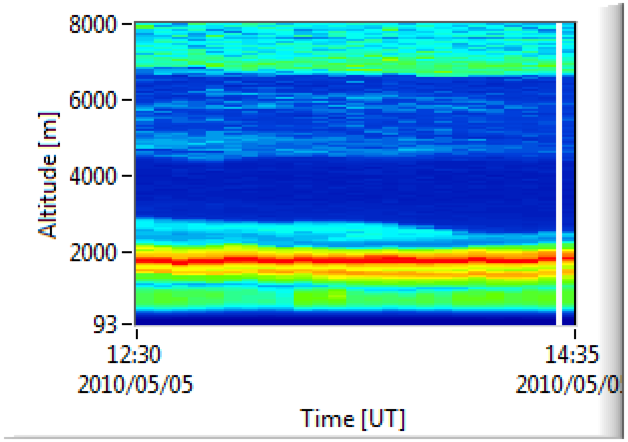


Results: April 26, 2010

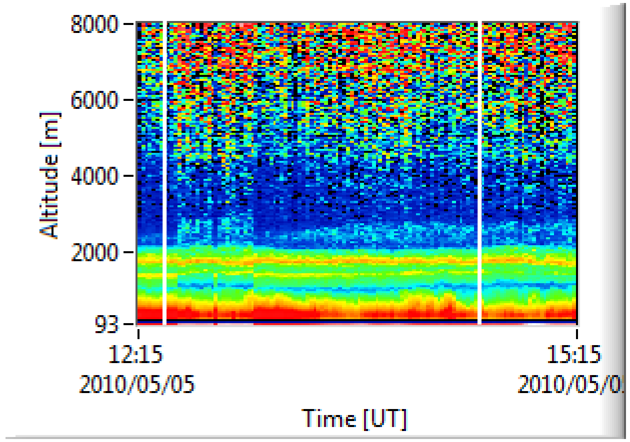


Results: May 05, 2010

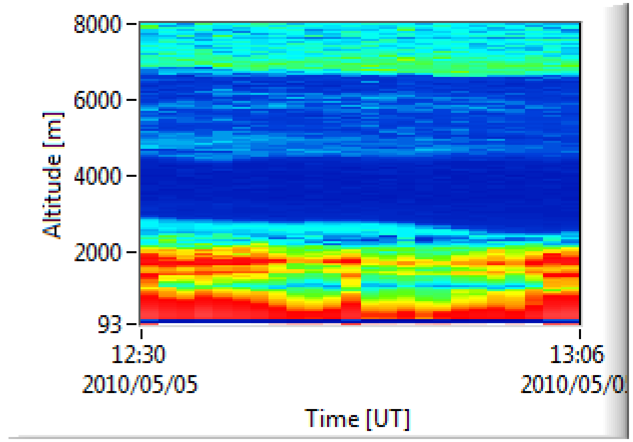
High-range lidar 1064



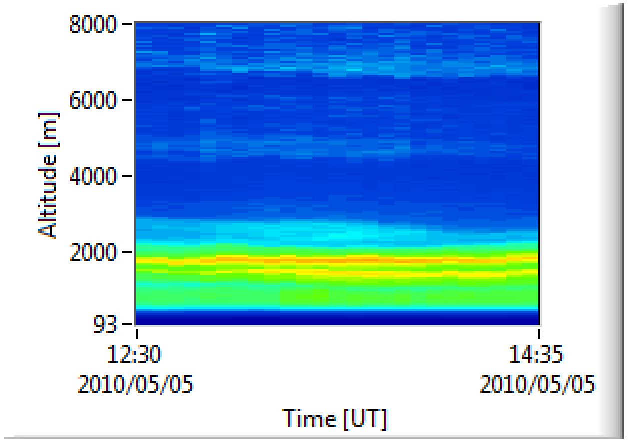
Low-range lidar 1064



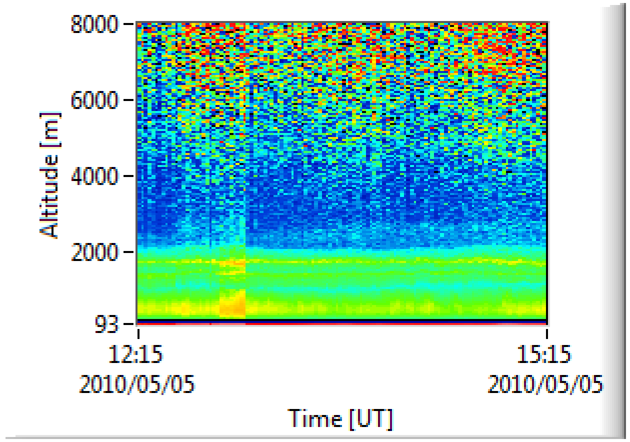
All-range lidar 1064



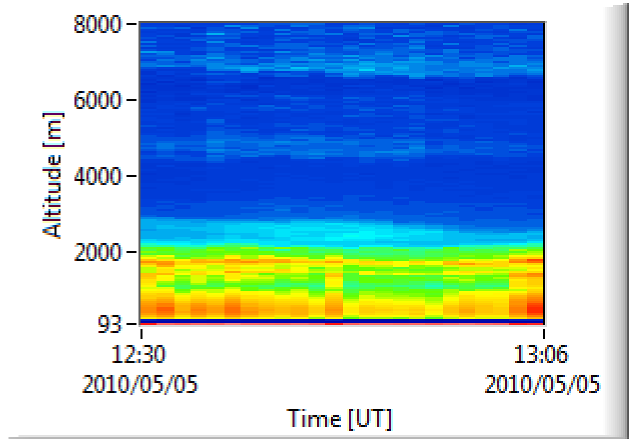
High-range lidar 532



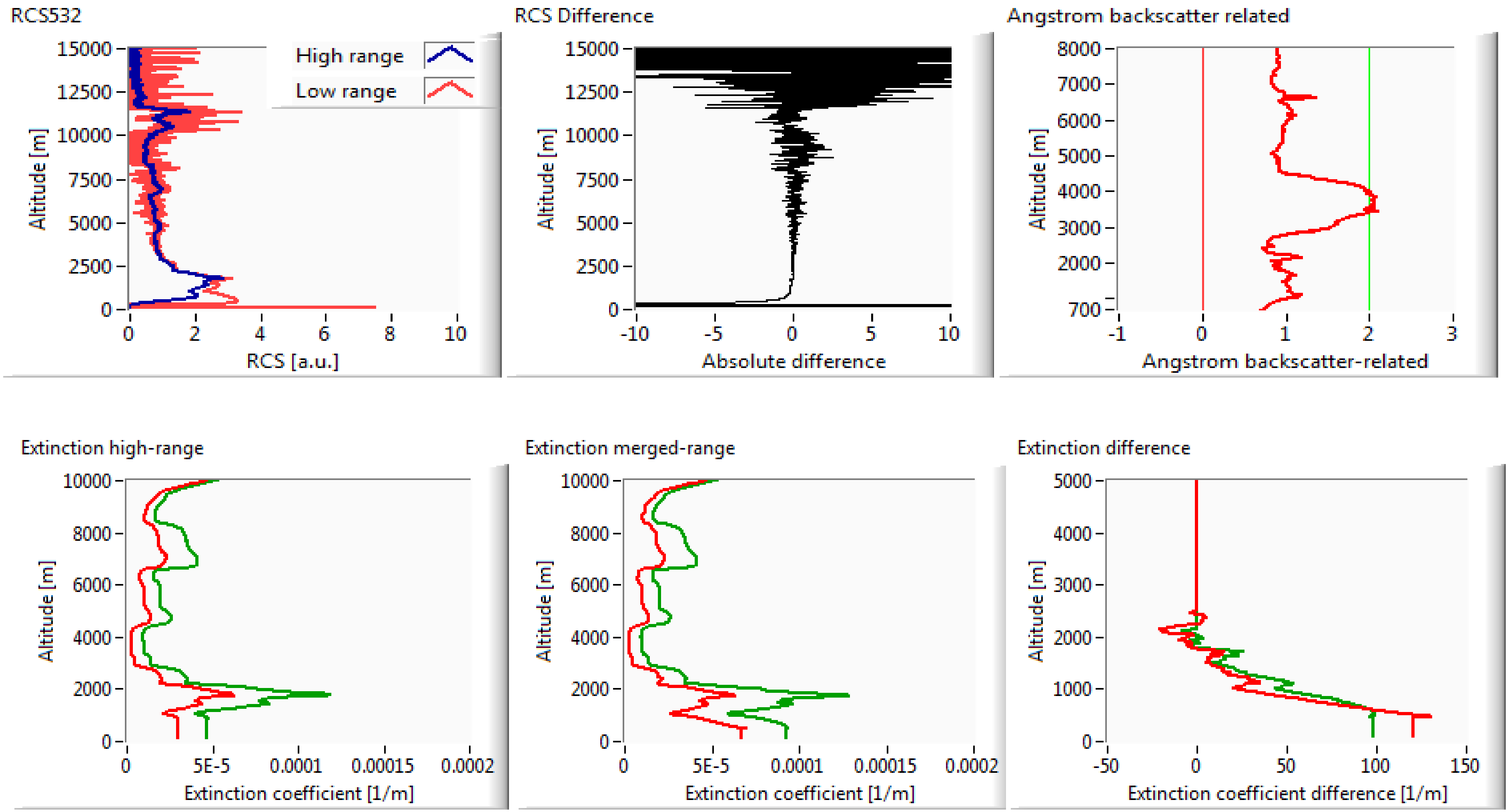
Low-range lidar 532



All-range lidar 532

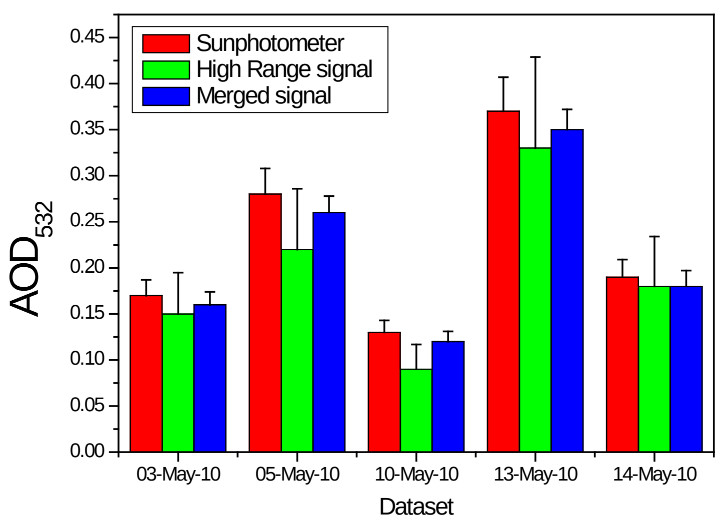


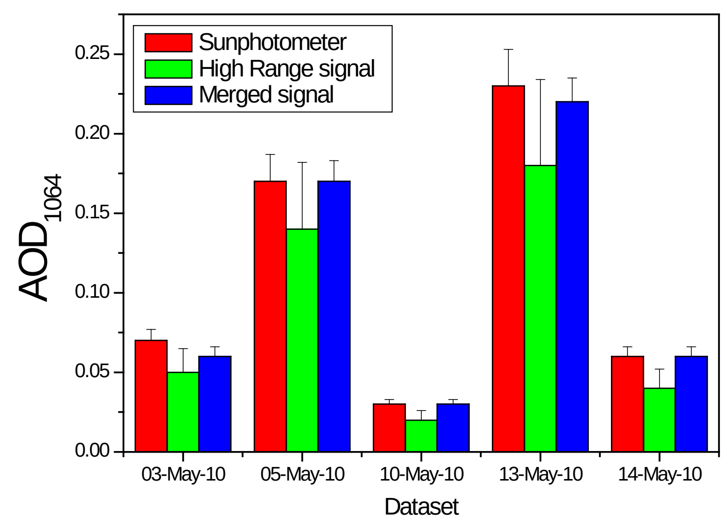
Results: May 05, 2010



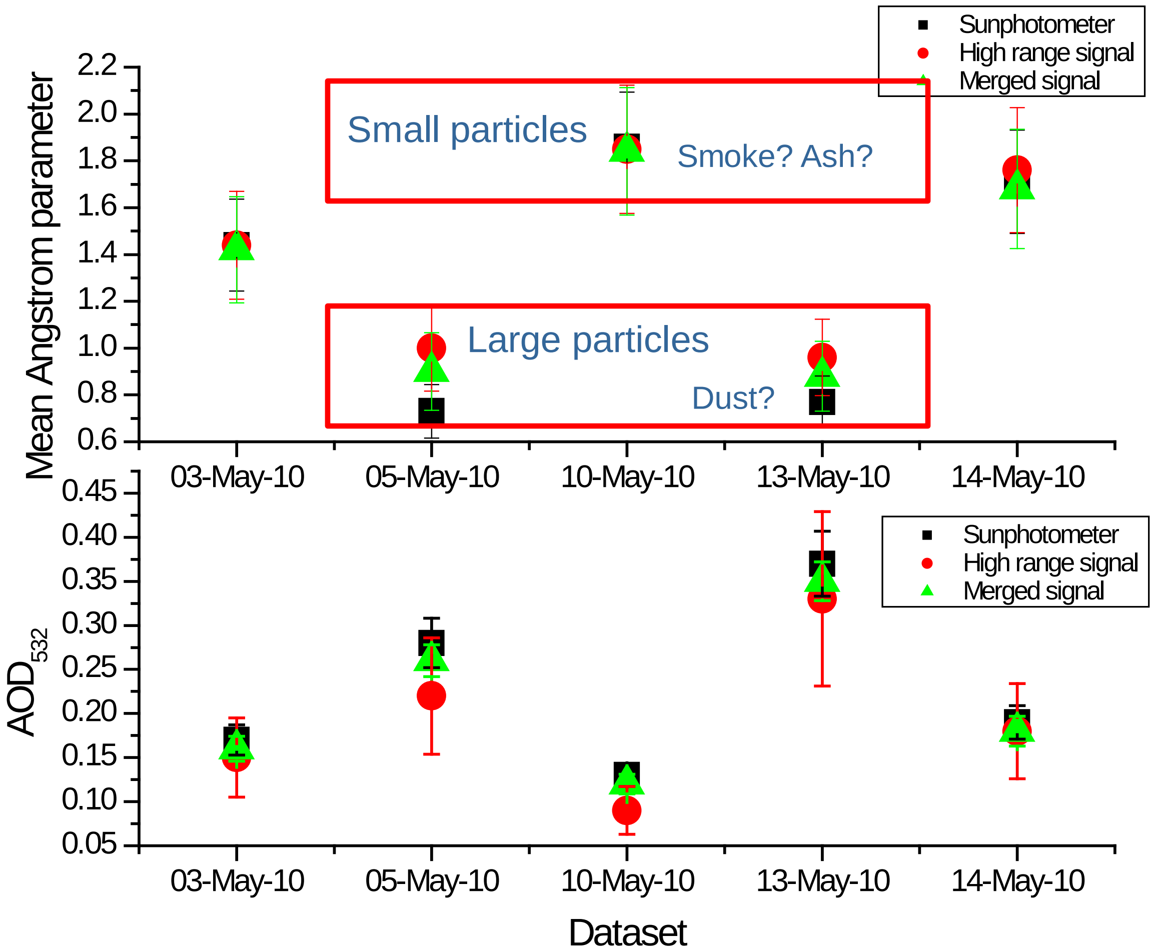
Results

Day	Sunphotometer		HR signal		Merged signal	
	AOD		AOD		AOD	
	532nm	1064nm	532nm	1064nm	532nm	1064nm
03-May-10	0.17+/-0.017	0.07+/-0.007	0.15+/-0.045	0.05+/-0.015	0.16+/-0.014	0.06+/-0.006
05-May-10	0.28+/-0.028	0.17+/-0.017	0.22+/-0.066	0.14+/-0.042	0.26+/-0.018	0.17+/-0.013
10-May-10	0.13+/-0.013	0.03+/-0.003	0.09+/-0.027	0.02+/-0.006	0.12+/-0.011	0.03+/-0.003
13-May-10	0.37+/-0.037	0.23+/-0.023	0.33+/-0.099	0.18+/-0.054	0.35+/-0.022	0.22+/-0.015
14-May-10	0.19+/-0.019	0.06+/-0.006	0.18+/-0.054	0.04+/-0.012	0.18+/-0.017	0.06+/-0.006





Results


Sunphotometer
High range signal
Merged signal
Small particles
Smoke? Ash?
Large particles
Dust?
Mean Angstrom parameter
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
03-May-10
05-May-10
10-May-10
13-May-10
14-May-10
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
AOD532
Sunphotometer
High range signal
Merged signal
03-May-10
05-May-10
10-May-10
13-May-10
14-May-10
Dataset

Conclusions

- The retrieval of aerosol optical parameters from lidar is limited by instrument's capability and inversion algorithm.
  - low-range lidars → calibration in far-range (SNR)
  - far-range lidars → the assumptions for the "blind" region (extrapolation! homogeneous atmosphere!)

→ MERGING

  - to identical products
    - data describing the same atmosphere (measurements are simultaneous and refer to the same air column)
    - free of instrumental dependencies.
  - to time-averaged signal
    - is possible if the 2 lidars have a suitable merging interval (SNR, linearity)
    - the presence of clouds is not important (linearity!)
  - benefits?
    - reduced errors due to calibration (use of HR capabilities)
    - increased dynamic range
    - reduced relative error for AOD
- The combination of sunphotometers and lidars using AOD as common parameter:
  - improved accuracy in the determination of aerosol's optical and microphysical parameters
  - better assumption of the lidar ratio.

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Thank you.

Questions?