Characterization of the aerosol mixture components on a base of multiwavelength lidar measurements

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Motivation

- **Study of characterization of aerosol microphysics on a base of miltiwavelengths lidar measurements started about 20 years ago**

  D. Muller et al., 1999; I. Veselovskii et al., 2002

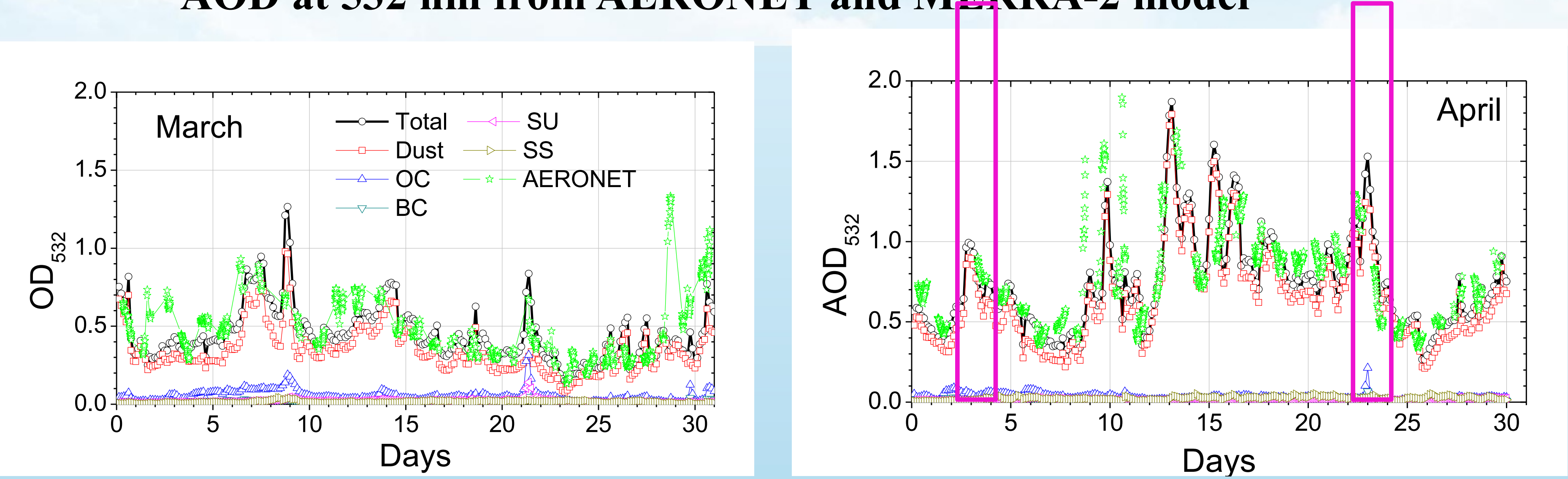
- **The most practical configuration of Raman lidar is based on tripled Nd:YAG laser ($3\beta + 2\alpha + 1\delta$). Typical uncertainties :**

Volume	**~ 20-30%**
Effective radius	**~20-30%**
Real part of refractive index	**± 0.05**
Imaginary part (when Im>0.01)	**~ 50%**

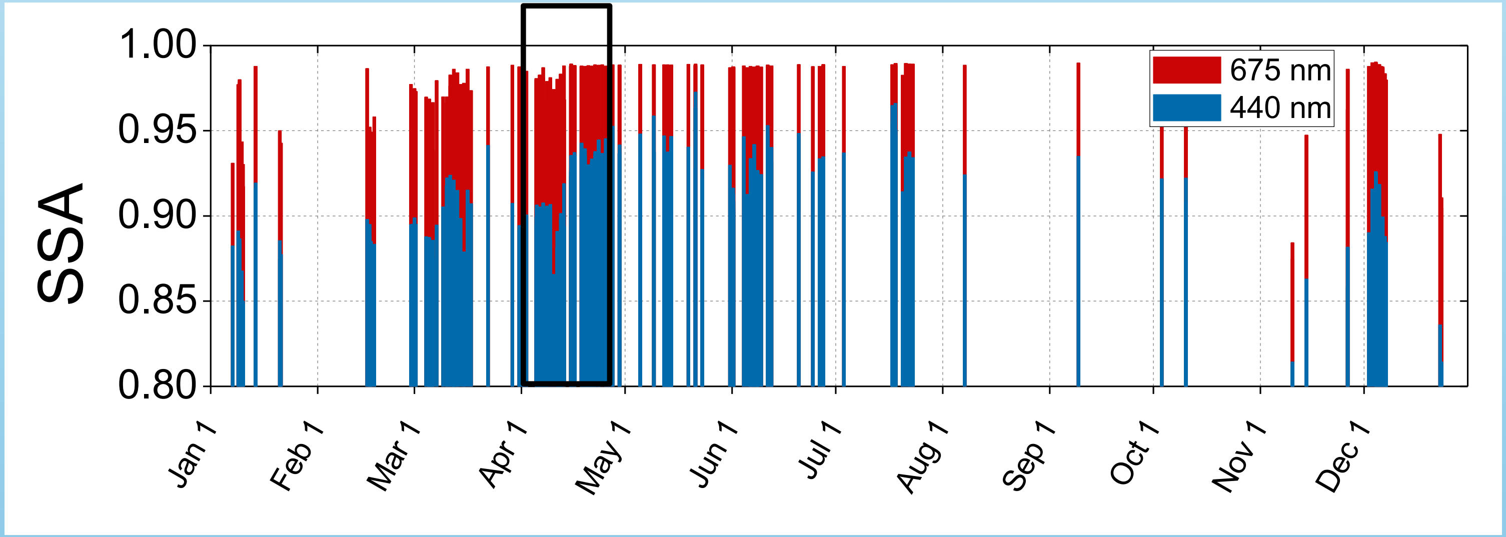
- **However, in many tasks composition of aerosol mixture should be known (organic carbon, black carbon, sulfates, dust, maritime)**
- **There are studies on aerosol classification** *(S. Burton)*, **separation of fine and coarse fractions** *(A. Ansmann)*.
- **To treat corresponding inverse problem we must be confident in properties of the components.**

“Pure” dust properties basing on SHADOW campaign results in Senegal

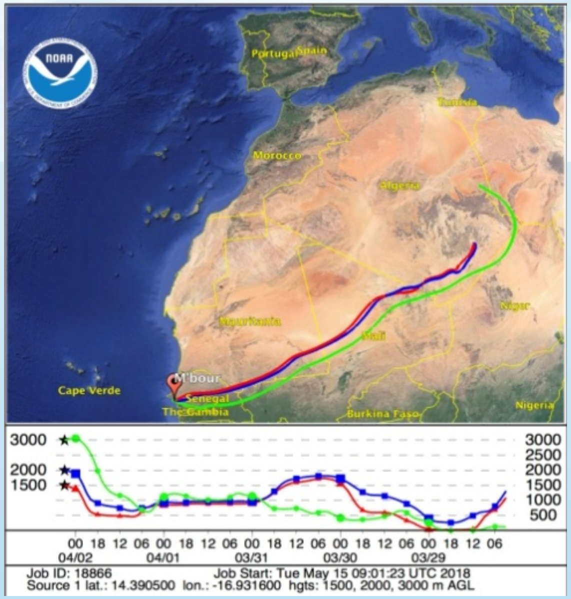
AOD at 532 nm from AERONET and MERRA-2 model



SSA from AERONET at 440 nm and 675 nm in 2015



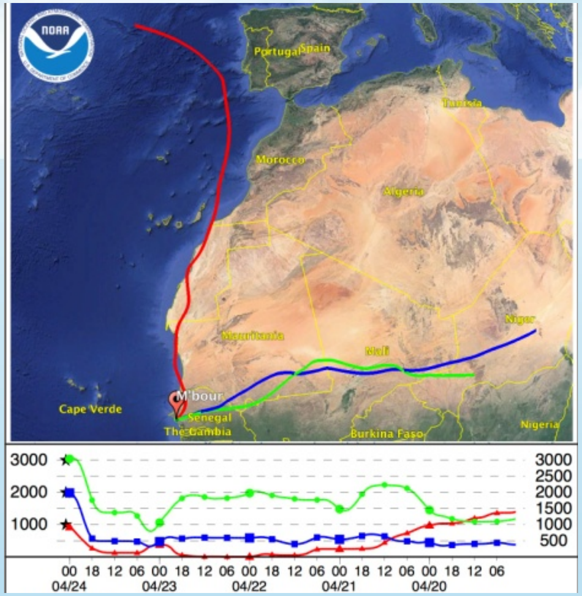
Lidar measurements on 1 and 24 April 2015



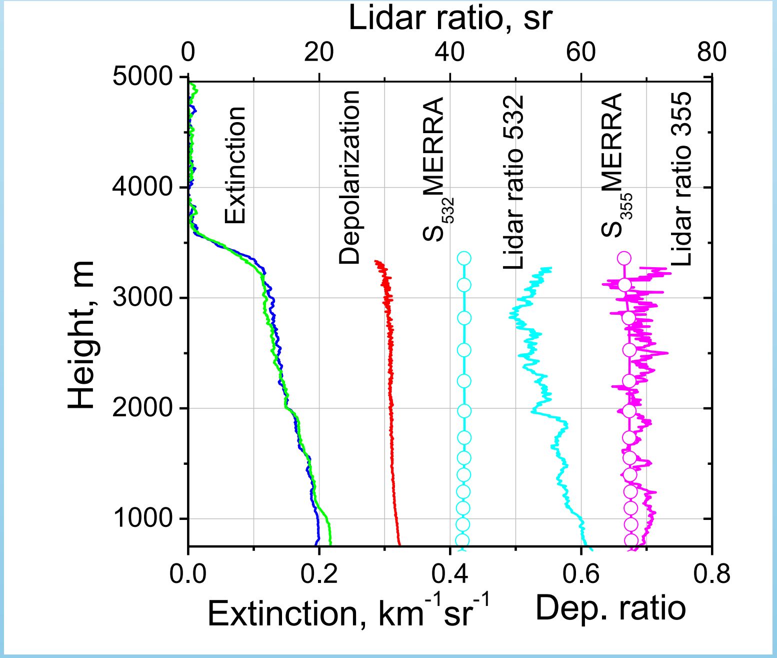
Job ID: 18866 Job Start: Tue May 15 09:01:23 UTC 2018
Source 1 lat.: 14.390500 lon.: -16.931600 hgts: 1500, 2000, 3000 m AGL

1 Apr. $S_{355}>S_{532}$

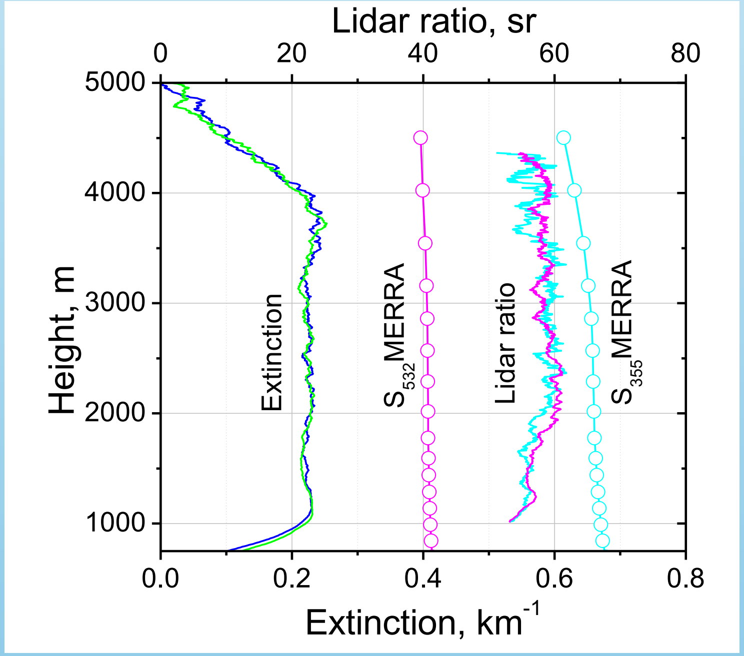
24 Apr. $S_{355}=S_{532}$



1 April

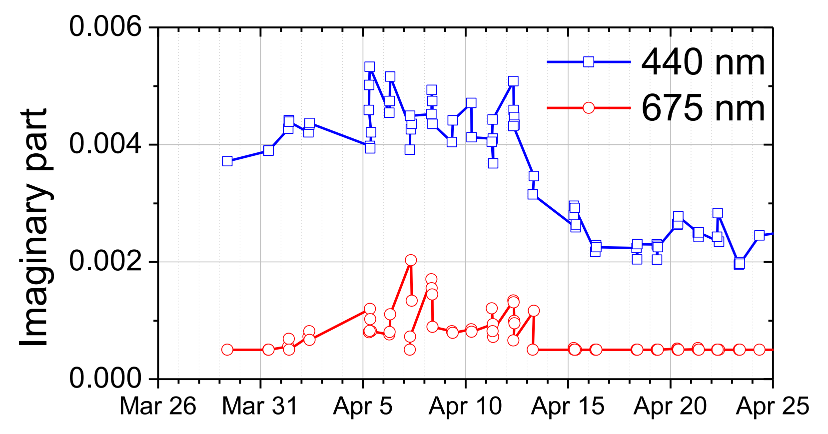


24 April

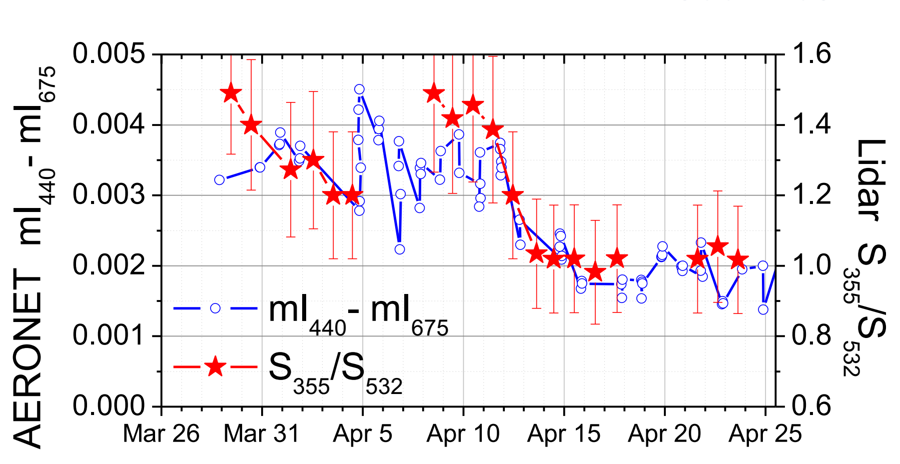


Variation of imaginary part at 675 and 440 nm from AERONET

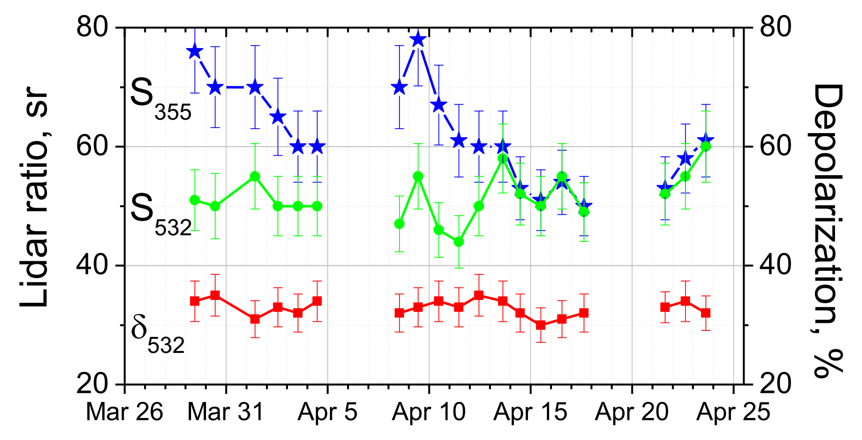
AERONET



Correlation ΔIm and S_{355}/S_{532}



Lidar

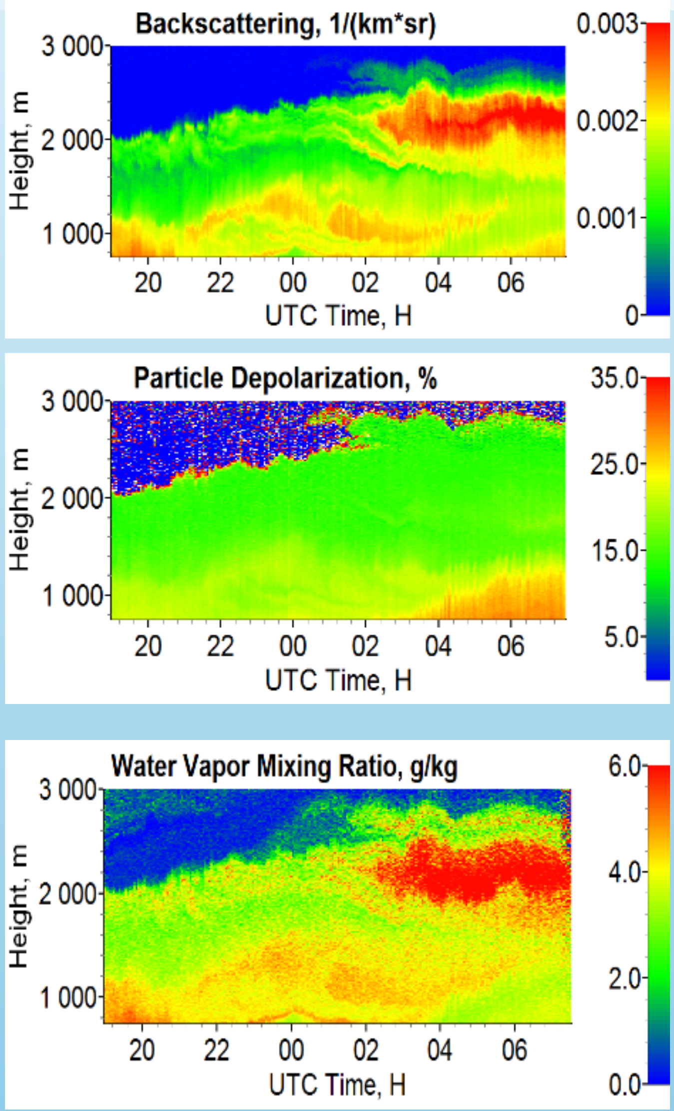


Ratio S_{355}/S_{532} is sensitive to increase of dust absorption in UV

Averaged values of imaginary part in Sahel at 355 and 532 nm are 0.005 and 0.003
(Di Biagio et al., ACPD 2019)

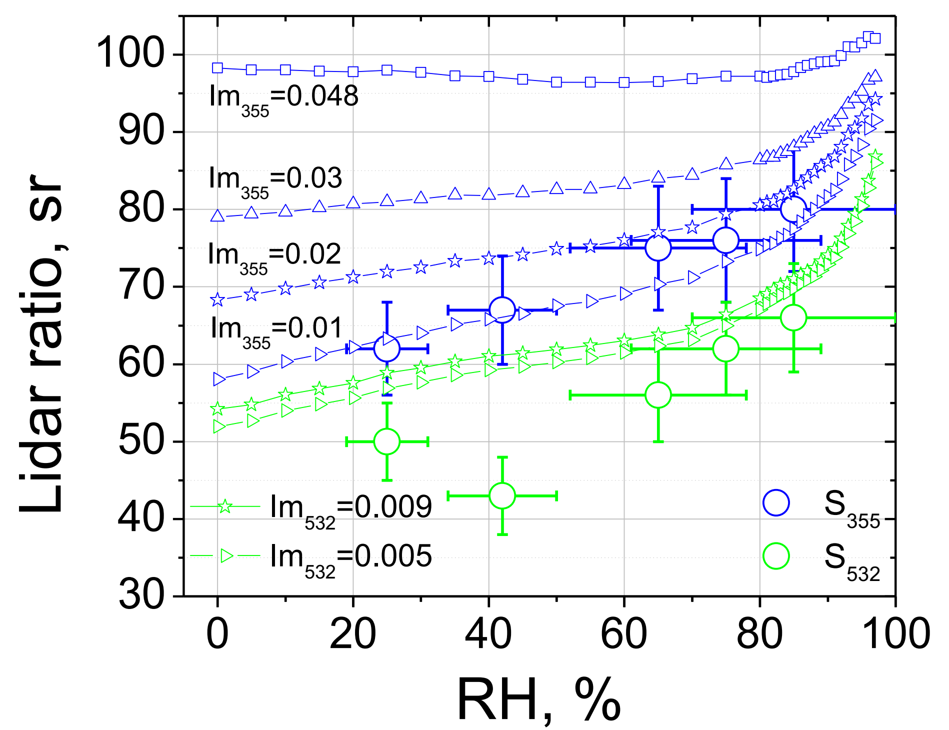
Smoke

Smoke event on 22 Dec.



- **Absorption increases in UV due to BrC**
- **Lidar ratio depends on RH**

MERRA-2 simulation for organic carbon.
Im355 for dry particles: 0.048, 0.03, 0.02, 0.01



Separation of aerosol mixture

We can try to retrieve concentrations of 5 main aerosol components used in models.

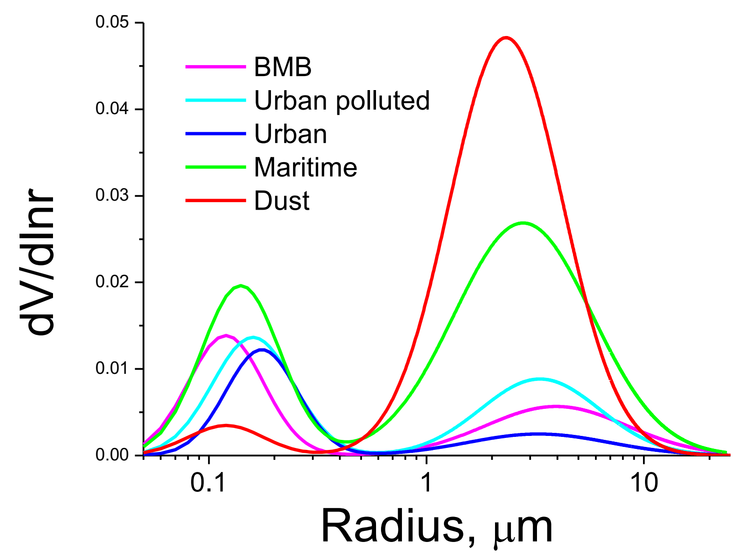
Advantage

- Problem becomes over-determined (6 data and 5 unknowns)
- Spectral dependence of refractive index is accounted

Issues

- Model can not cover all diversity of aerosols

Model based on AERONET observations (from GRASP group)



Biomass burning	1.51-i0.02
Urban	1.4-i0.003
Urban polluted	1.47-i0.15
Dust	1.56-i0.0021(0.0037)
Maritime	1.37-i0.0001

Parameters don't depend on RH

Two approaches for inversion

Direct modeling

Brute force approach

$$g_i = \sum_{j=1}^{5} A_{ij} C_j$$

All possible mixtures are considered for which

$$\alpha \approx \sum_{j=1}^{5} \alpha_j$$

Discrepancy is minimized

$$\sum_{i=1}^{6} \left(\frac{g_i - g_i^{\exp}}{g_i^{\exp}} \right)^2$$

No negative solutions!

Least square inversion

$$\mathbf{g} = \mathbf{AC}$$

$$\mathbf{C} = (\mathbf{A}^T \mathbf{A})^{-1} \mathbf{A}^T \mathbf{g}$$

Nonnegative constraints

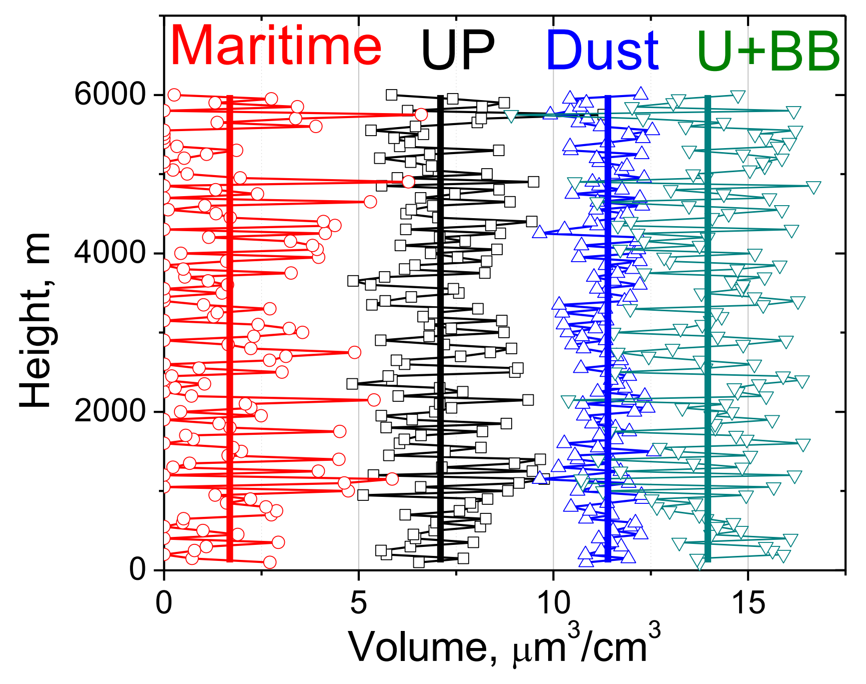
GRASP inversion

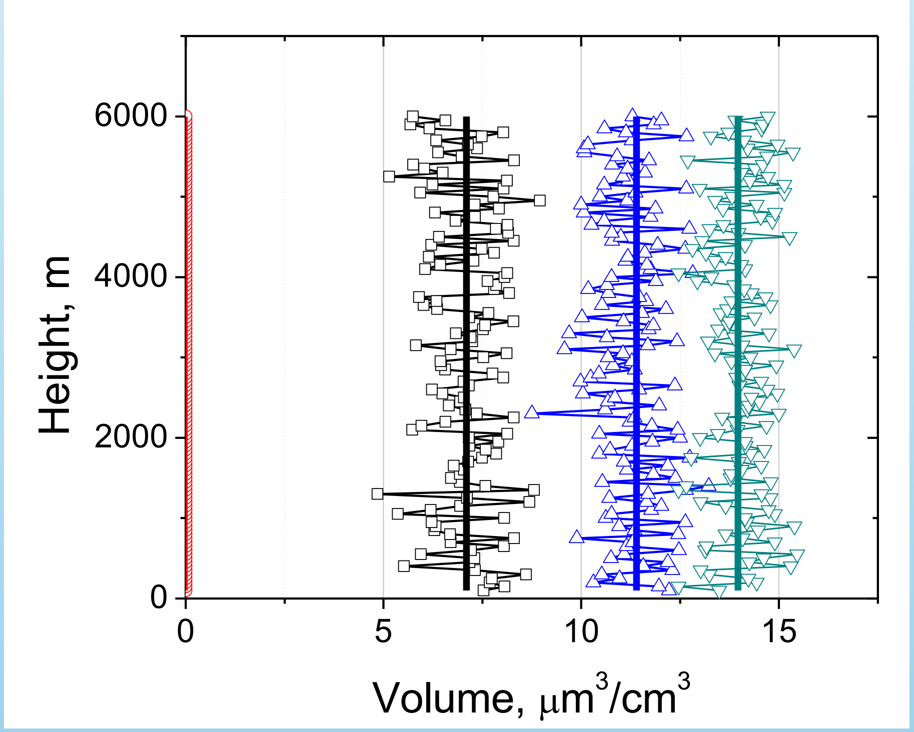
Simulation

Evaluation of algorithm stability for 10% errors

5 components

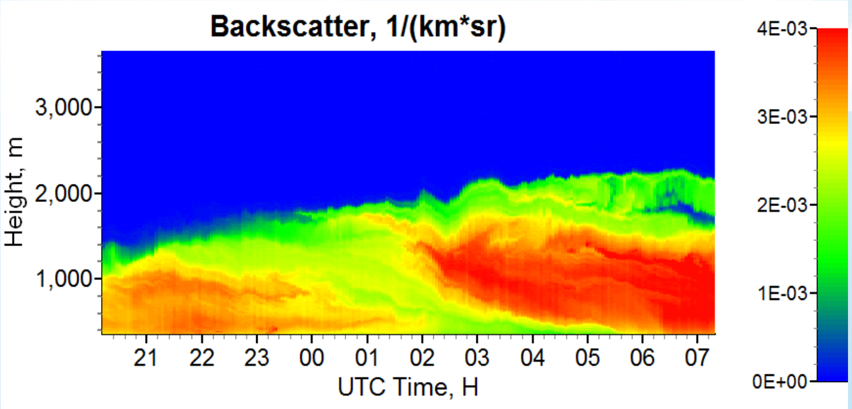
4 components (Maritime is excluded)

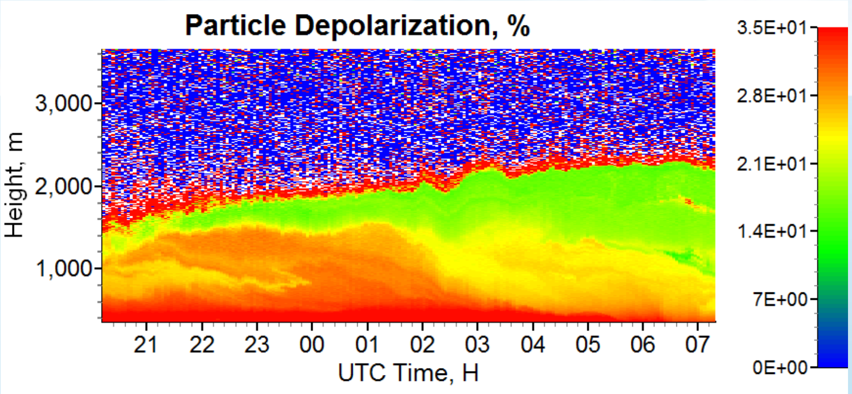




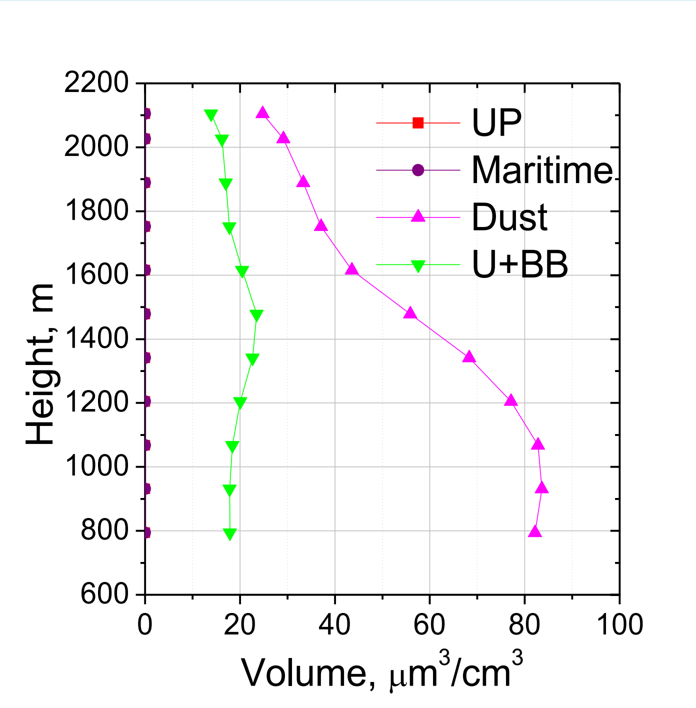
- Algorithm is stable for input noise
- Biomass Burning and Urban are difficult to separate

Components separation on 14 December 2015 in Senegal

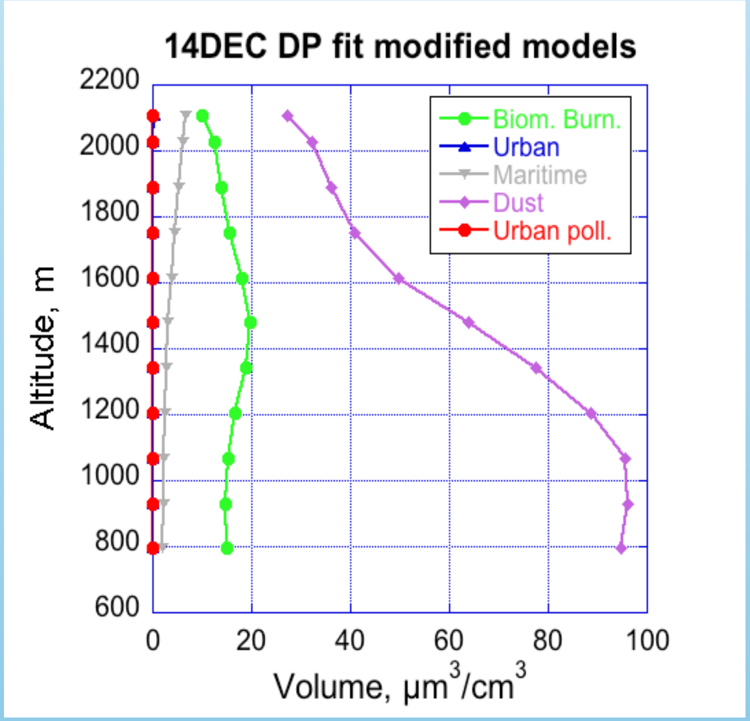




LSM inversion

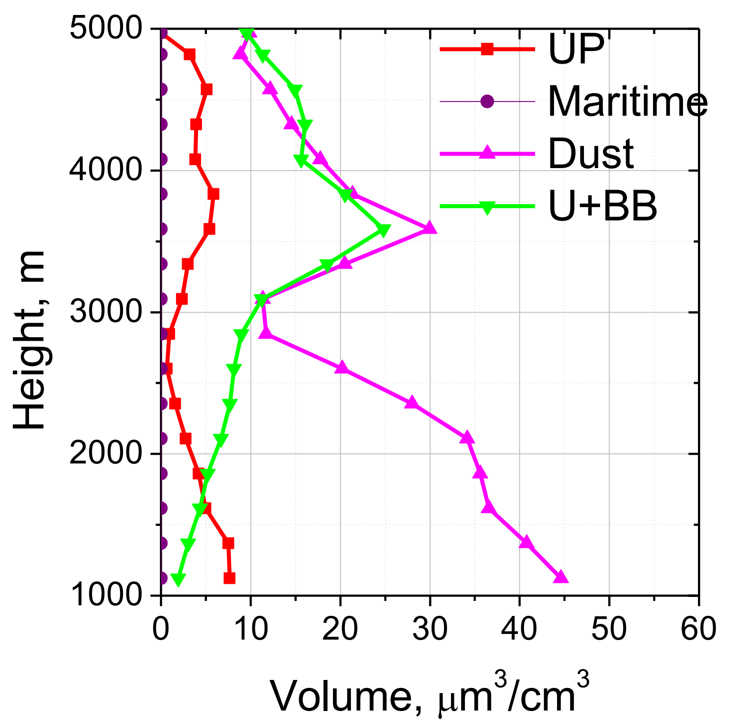


GRASP

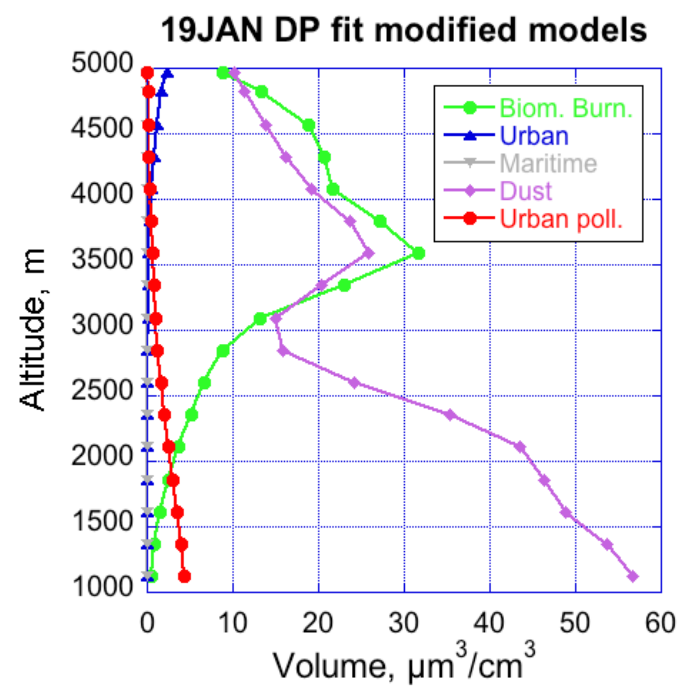


Separation of aerosol components. 19 Jan. 2016, Senegal

LSM inversion



GRASP inversion



Absorbing “Urban Polluted” fraction is separated

Conclusion

Separation of aerosol components on a base of multiwavelength lidar measurements is possible. Account for RH is the next step.