Aerosol typing

D. Müller

- Various ways of aerosol typing
- Tools
- Examples

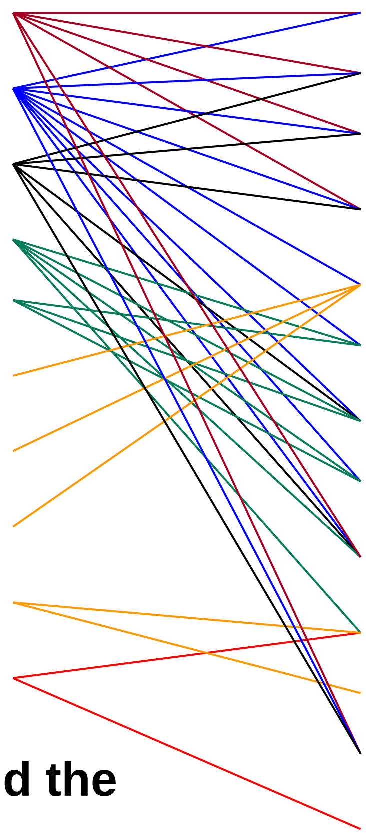
Different approaches to aerosol typing

1. OPAC (Database on Optical Properties of Aerosols and Clouds, Hess et al. 1998)

from — **Mixing rules** — **to**

Aerosol components

Insoluble
Water-soluble
Soot
Sea-salt: accumulation mode
coarse mode
Mineral: nucleation mode
accumulation mode
coarse mode
transported
Sulfate droplets



Aerosol types

Continental: clean
average
polluted
Urban
Desert
Maritime: clean
polluted
tropical
Arctic
Antarctic
Mineral transported
Free troposphere
Stratosphere

Aerosol components, types, and the modelling of it: N. Sugimoto

Different approaches to aerosol typing
2. CALIPSO aerosol typing scheme
(with lidar ratio estimates at 532 and 1064 nm)

dust
40 sr / 30 sr (v2)
→ 55 sr (v3)

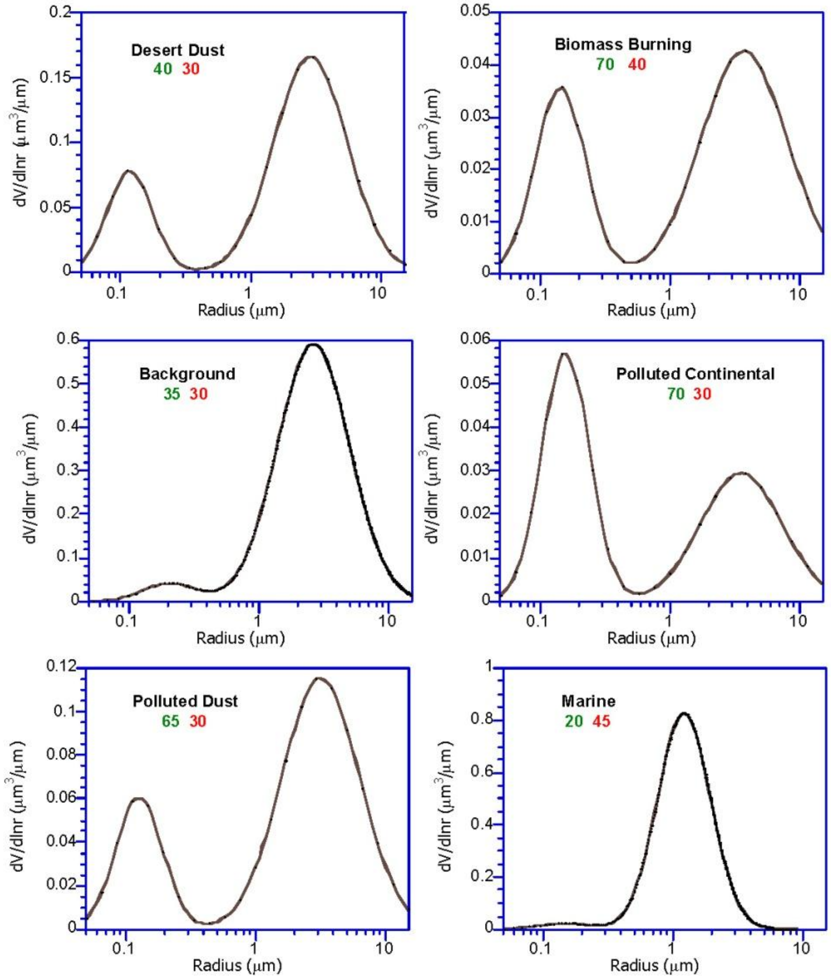
r_{eff} = 0.41 µm

clean continental
35 sr / 30 sr

r_{eff} = 1.4 µm

polluted dust
55 sr / 48 sr

r_{eff} = 0.42 µm



smoke
70 sr / 40 sr

r_{eff} = 0.36 µm

polluted continental
70 sr / 30 sr

r_{eff} = 0.26 µm

clean marine
20 sr / 45 sr

r_{eff} = 0.92 µm

Different approaches to aerosol typing

3. Aerosol typing from real-world lidar observations

Aerosol Type and Source Region (Campaign)	Layer	S335, sr	S532, sr	$\mathring{A}_{\beta}(z)$ (355/532)	$\mathring{A}_{\alpha}(z)$ (532/1064)	δ_{par} (532,710)
Marine						
North Atlantic (ACE 2)	PBL		23 ± 3	0.3 ± 0.1		
Tropical Indian Ocean (INDOEX)	PBL		23 ± 5			
Tropical Indian Ocean (INDOEX)	FT	29 ± 10	29 ± 8	0.1 ± 0.3	0.1 ± 0.2	
Desert dust						
Sahara (SAMUM)	PBL	55 ± 6	55 ± 5	0.2 ± 0.2	0.2 ± 0.2	30% – 35%
Sahara (EARLINET)	FT	65 ± 15	59 ± 11	0.5 ± 0.5	0.5 ± 0.5	10% – 25%
Gobi (Beijing)	PBL		35 ± 5			
Saudi Arabia (INDOEX)	FT	38 ± 5	38 ± 5	0.6 ± 0.3	1.1 ± 0.4	
Urban haze						
Central Europe (EARLINET)	PBL	58 ± 12	53 ± 11	1.4 ± 0.5	1.3 ± 0.5	<5%
Southwest Europe (ACE 2)	FT		45 ± 9	1.4 ± 0.2	1.4 ± 0.3	<5%
North America (EARLINET)	FT	53 ± 10	39 ± 10	1.7 ± 0.5	1 ± 0.5	<5%
Arctic haze						
North polar region (EARLINET)	FT	60 ± 12	60 ± 12	1.9 ± 0.3	1.2 ± 0.3	<5%
Forest fire smoke Siberia/Canada (EARLINET)	FT	46 ± 13	53 ± 11	1.0 ± 0.5	1.0 ± 0.4	<5%
SEt Asian aerosol						
North India (INDOEX)	FT	70 ± 20	65 ± 16	1.2 ± 0.2	1.1 ± 0.3	<5%
South India (INDOEX)	FT	40 ± 10	37 ± 10	0.9 ± 0.1	1.4 ± 0.3	<5%
Southeast Asia (INDOEX)	FT	55 ± 20	51 ± 20	1.5±0.3	1.1 ± 0.3	<5%
South China (PRD)	PBL		47 ± 6	1.0 ± 0.2	1.2 ± 0.2	
North China (Beijing)	PBL		38 ± 7	1.1 ± 0.2	1.3 ± 0.2	

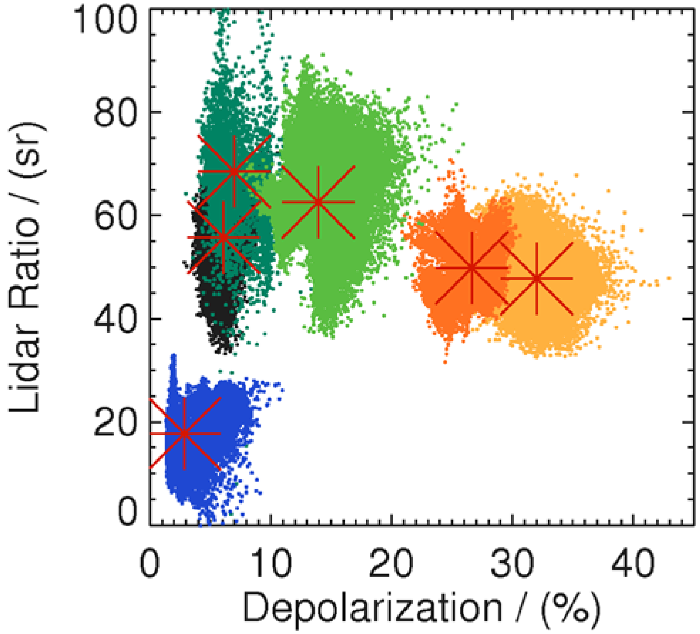
Müller et al., 2007

+

ESA - ICAROHS

aerosol type classification

icarohs
support to science element



Pure Saharan Dust

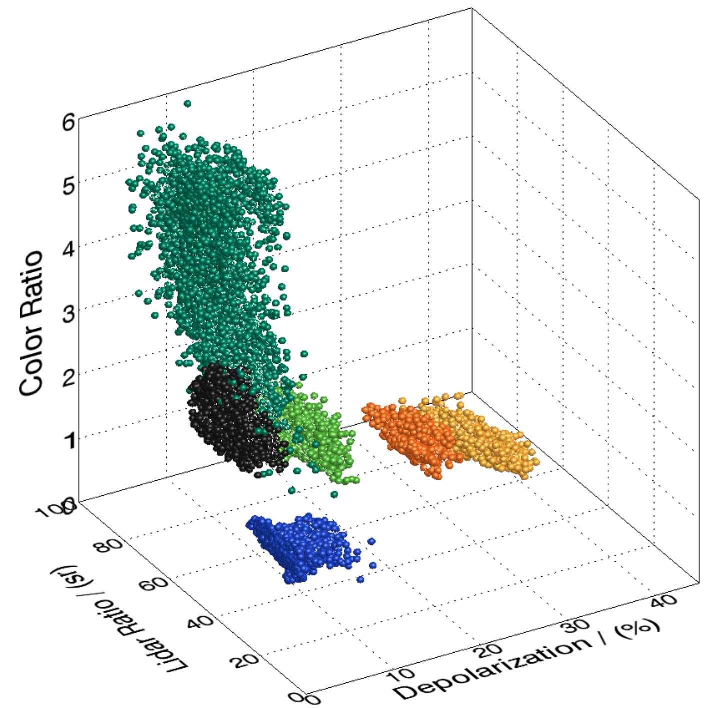
Aged Saharan Dust

Biomass Burning Aerosol + Mineral Dust

Canadian Biomass

Industrial Pollution

Marine Aerosol

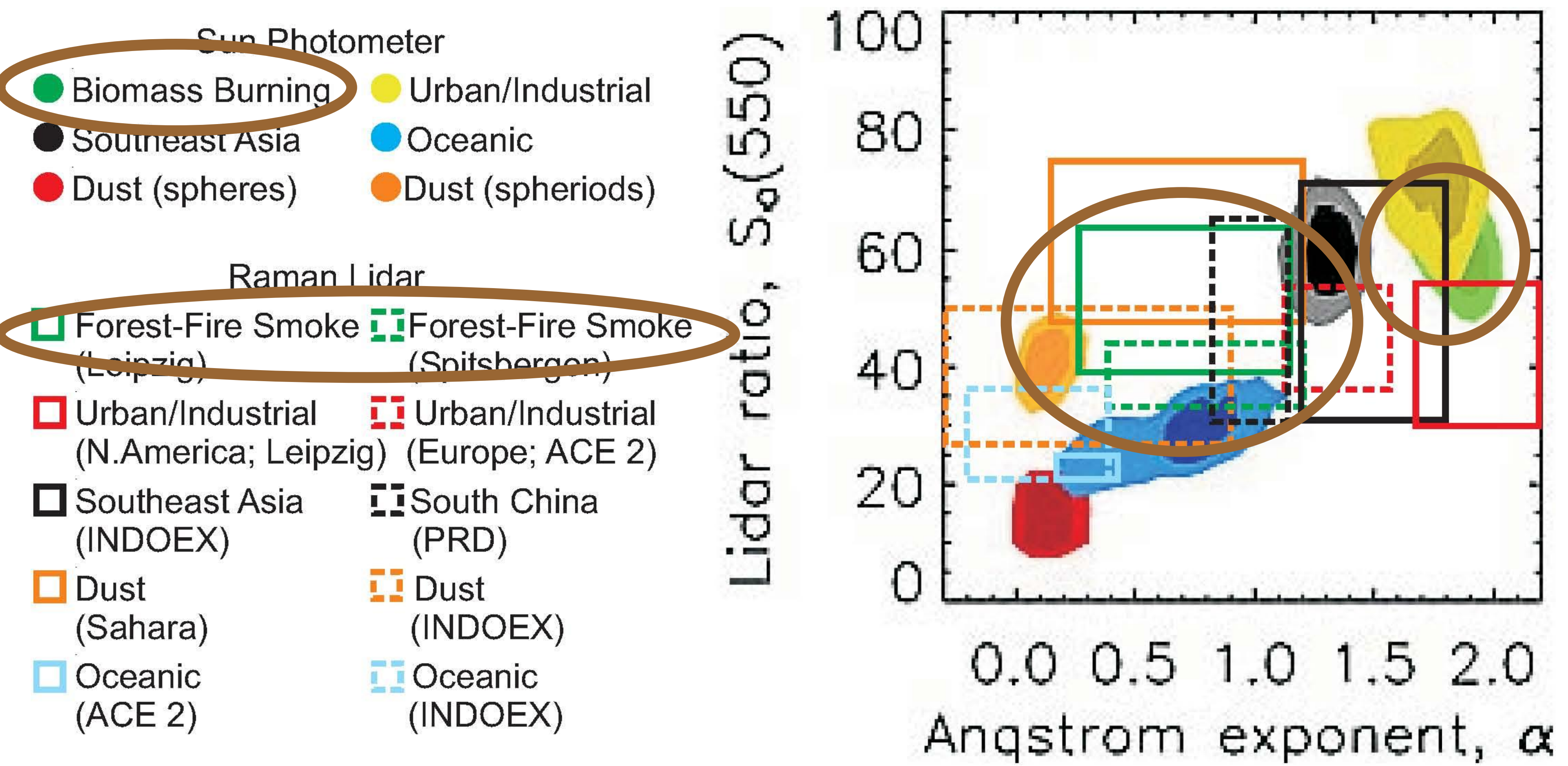


- different aerosol types cluster and can be distinguished
- spread of the clusters is limited by natural variations in the end

DLR

Petzold et al. ESA -ICAROHS, 2009
Esselborn et al., Appl. Opt., in preparation

AERONET aerosol typing: column values



Airborne High Spectral Resolution Lidar Aerosol Measurements and Classification

Richard A. Ferrare, Sharon P. Burton, Chris A. Hostetler, John W. Hair,

Raymond R. Rogers, Mike Obland, Anthony L. Cook, David B. Harper,

Mike Wusk, Amy Jo Swanson

Sponsors

NASA Langley Research Center

NASA CALIPSO Project

NASA HQ Science
Mission Directorate
Radiation Sciences Program

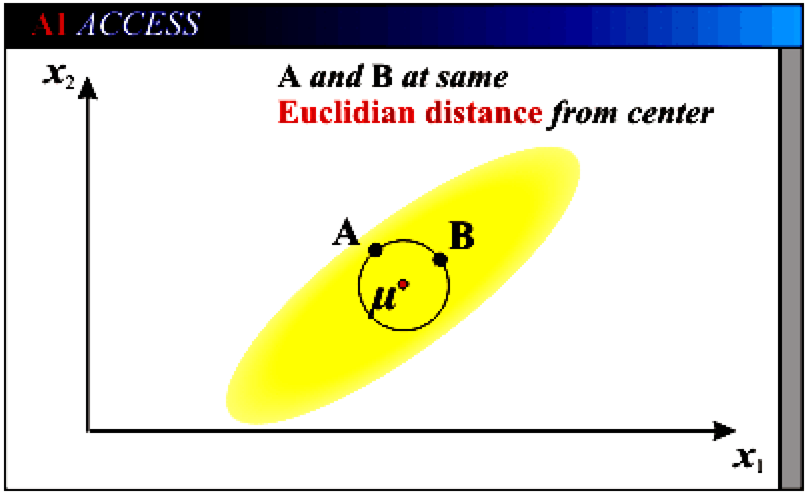
Department of Energy
Atmospheric System Research

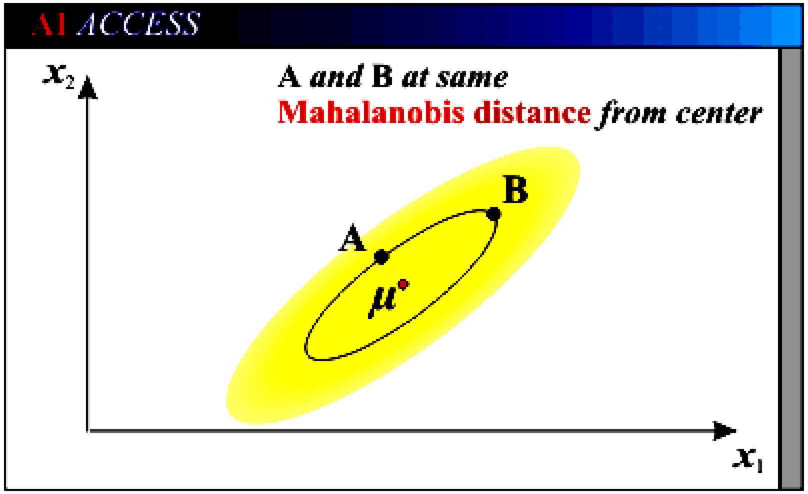
NASA Langley Airborne HSRL Aerosol Classification Method

•4 intensive parameters that do not depend on aerosol amount

• Mahalanobis distance, instead of Euclidean distance, to sort points into classes

•Estimate 4-d normal distributions of classes from labeled data, and calculate Mahalanobis distance from each point to each class





What information do we have?

Intensive aerosol parameters:

- particle depolarization ratio (at 355/532...1064 nm)
- particle lidar ratio (at 355/532 nm)
- Ångström exponent or color ratio (backscatter and/or extinction)

} per layer

Extensive aerosol parameters:

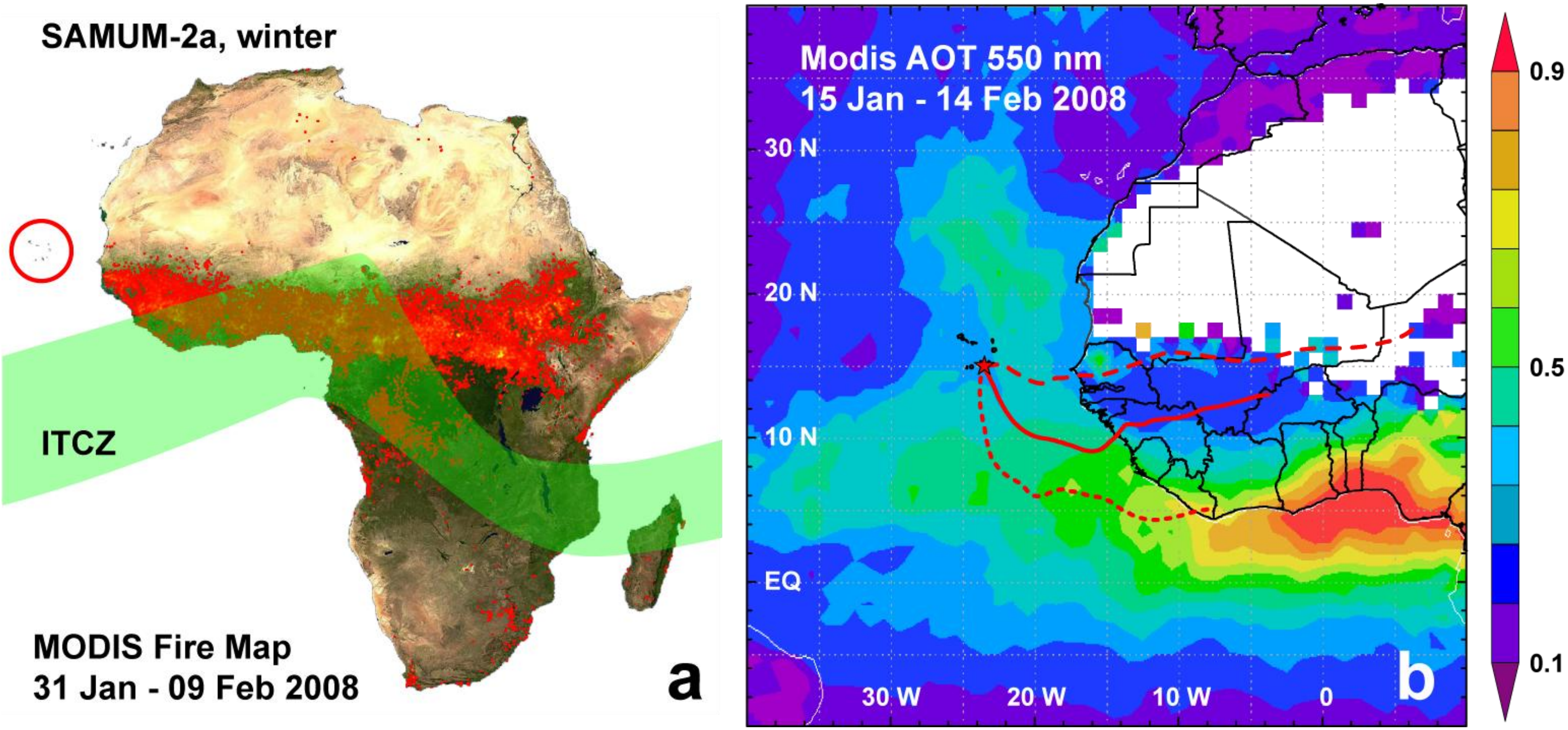
- extinction and backscatter coefficients (thresholds)

Auxiliary information:

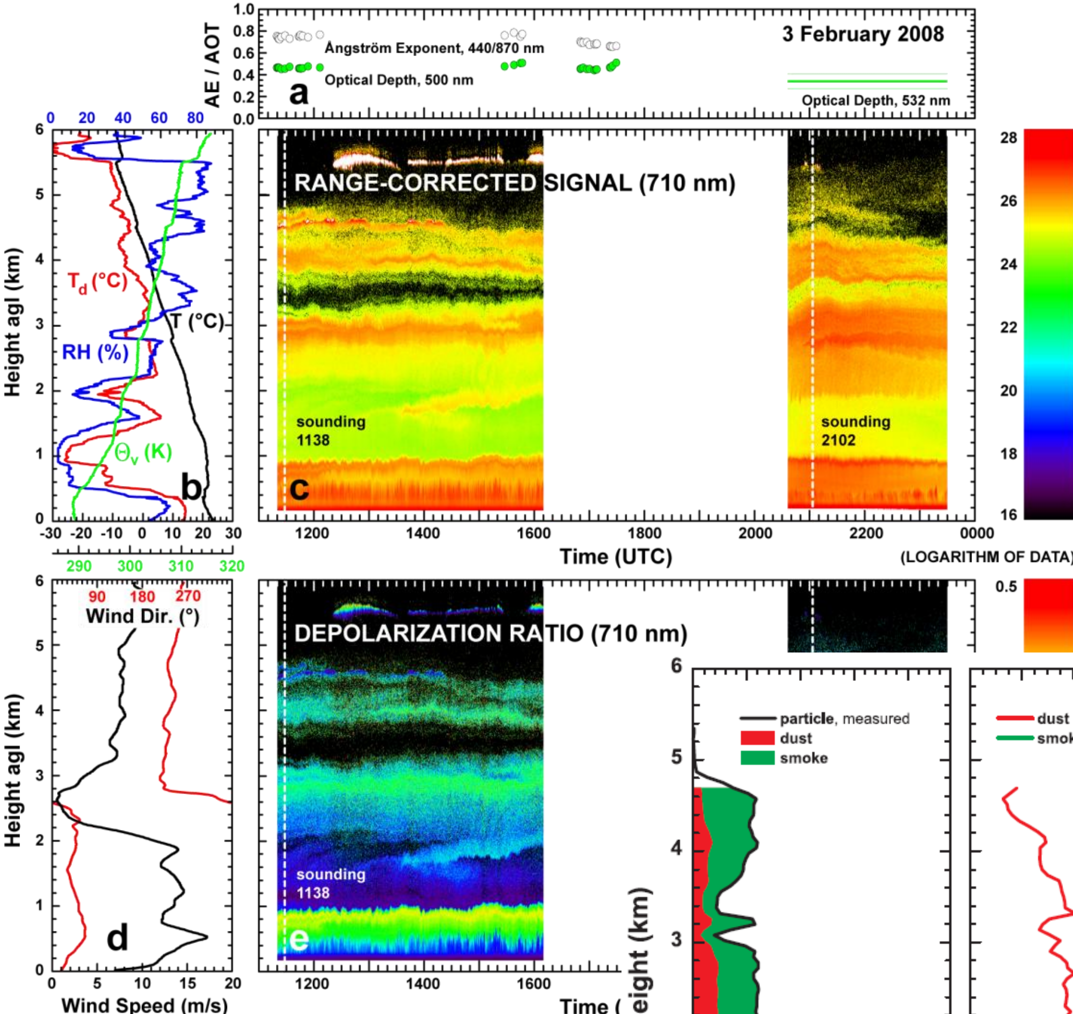
- height range (e.g., PBL, stratosphere)
- temperature
- geographical location/surface (arctic, ocean, desert)
- source information + transport modeling

Mixing of aerosol types

SAMUM-2 Winter Campaign (January-February 2008)

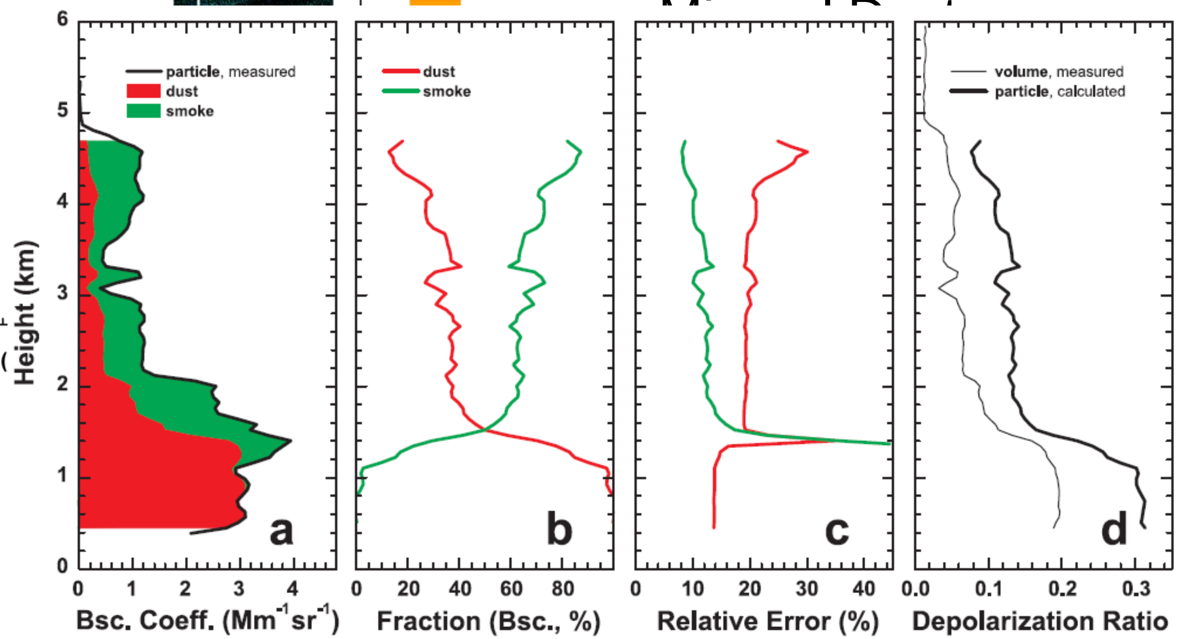


Layering: marine + dust + smoke (SAMUM-2)

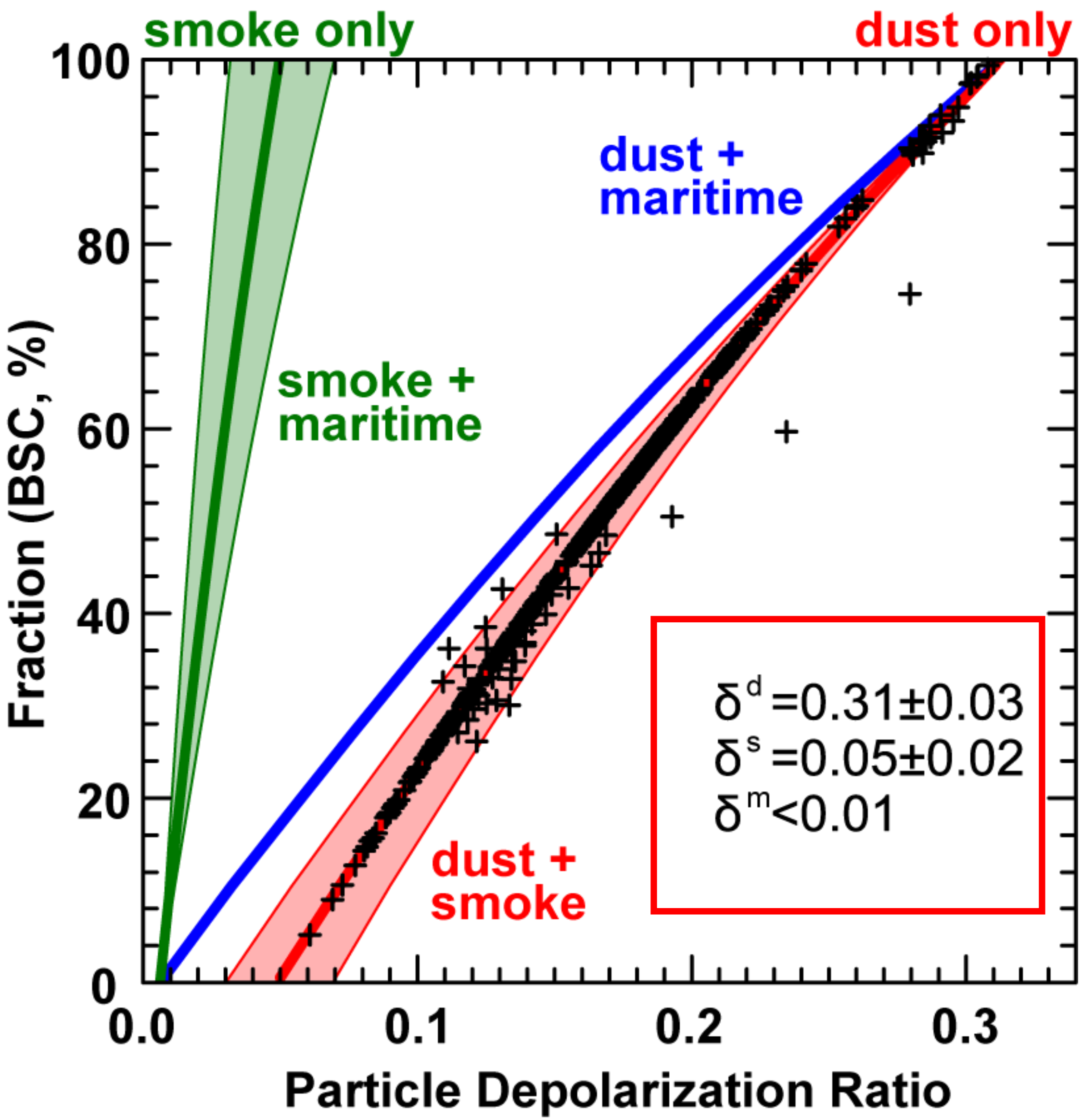


Tesche et al.,

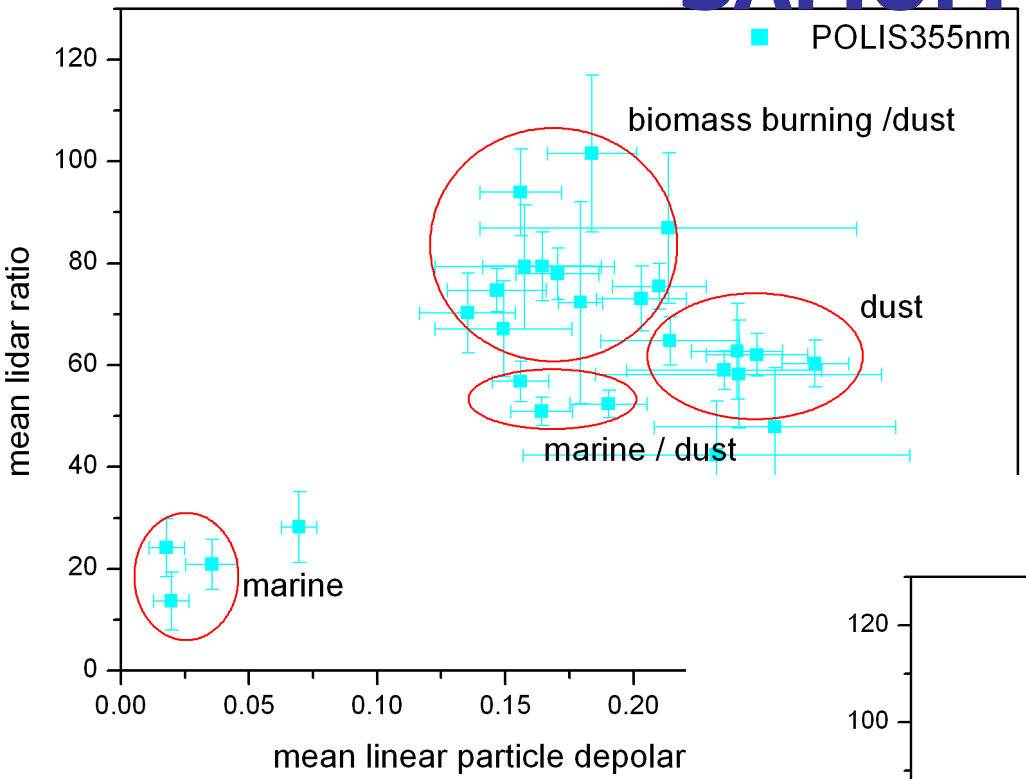
Vertically resolved separation of dust and smoke over Cape Verde using multiwavelength Raman and polarization lidars during Saharan

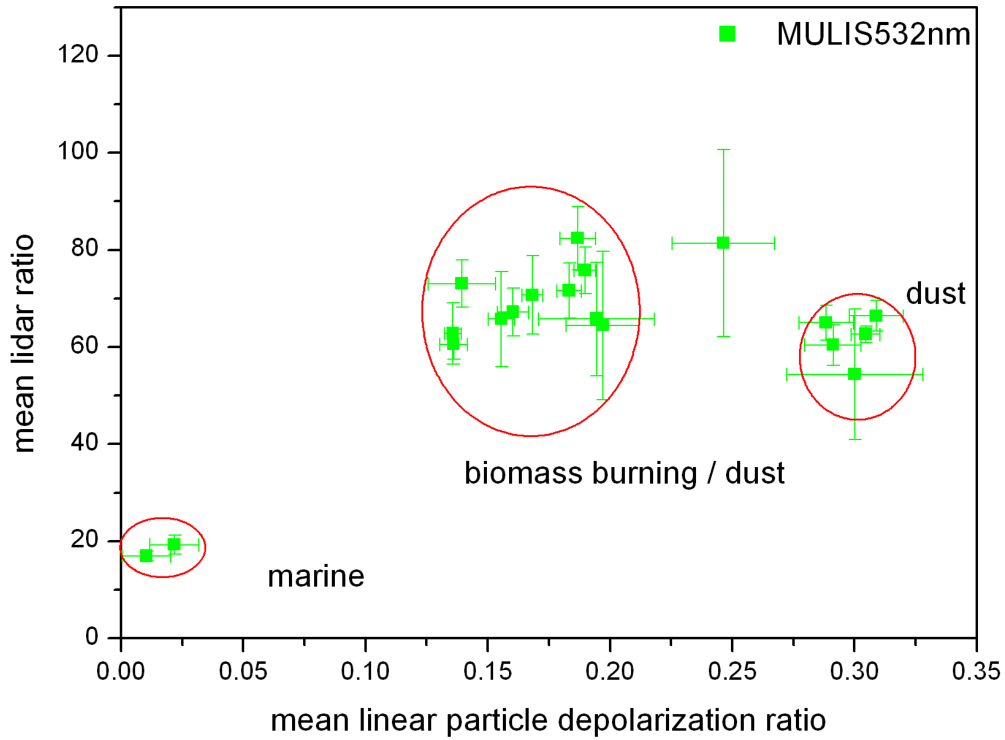


General scheme for aerosol-type separation based on measurements of the particle depolarization ratio



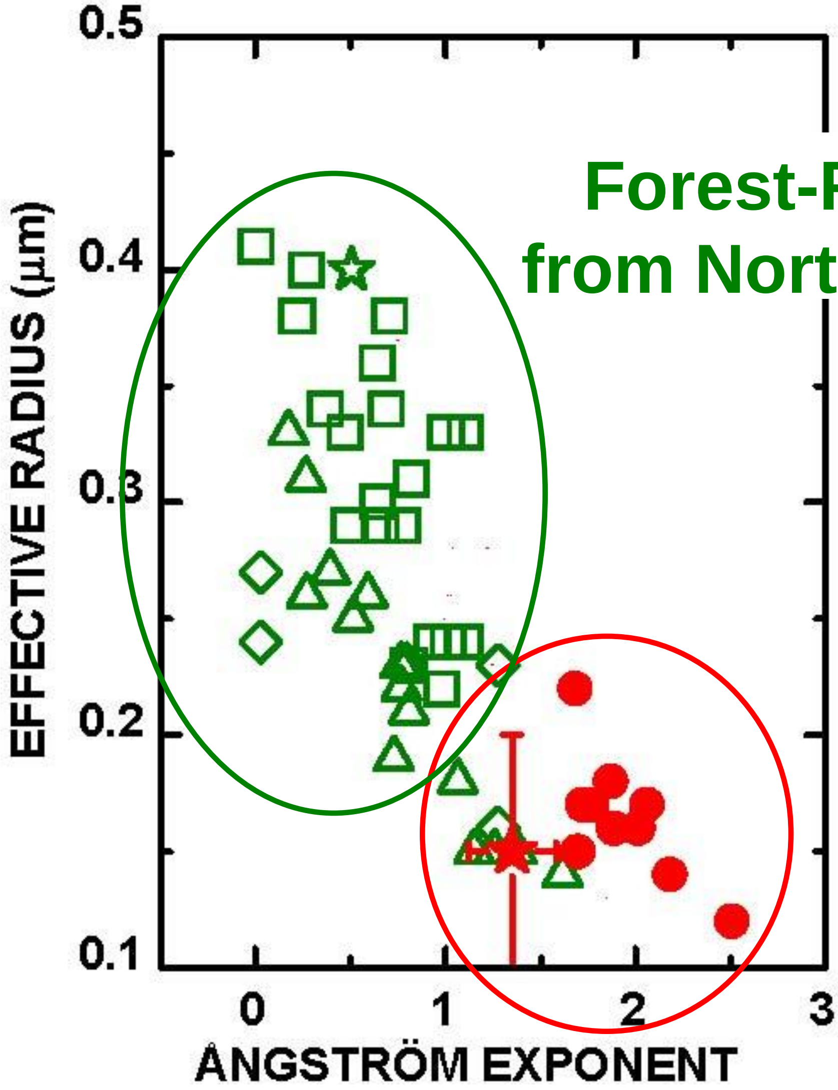
SAMUM 2





Silke Groß,
Meteorological Institute
Munich

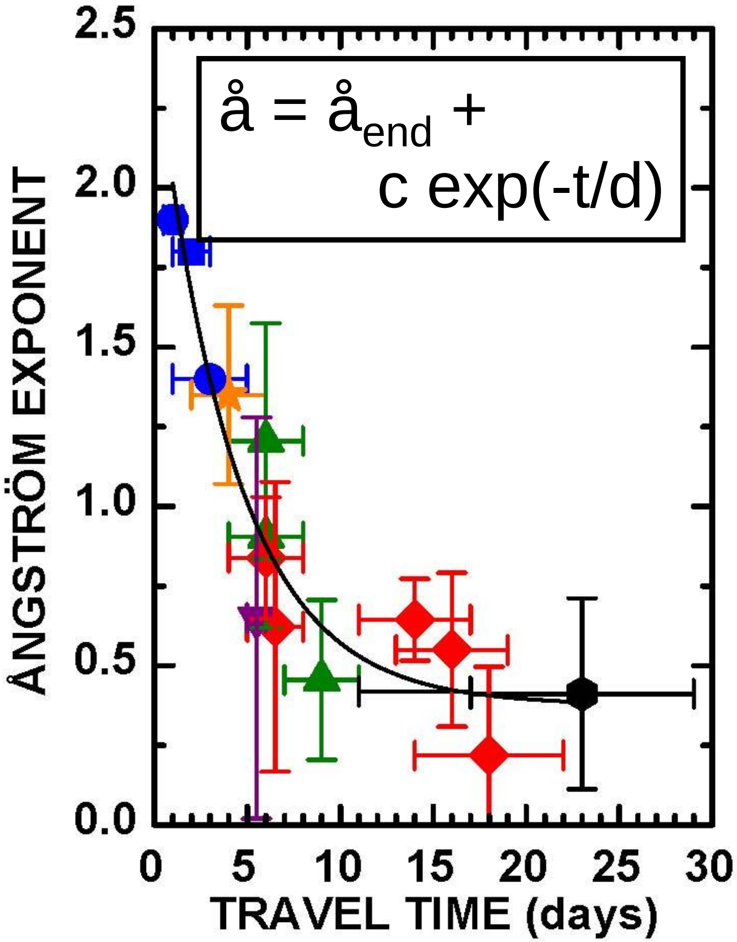
Change of aerosol type properties with transport

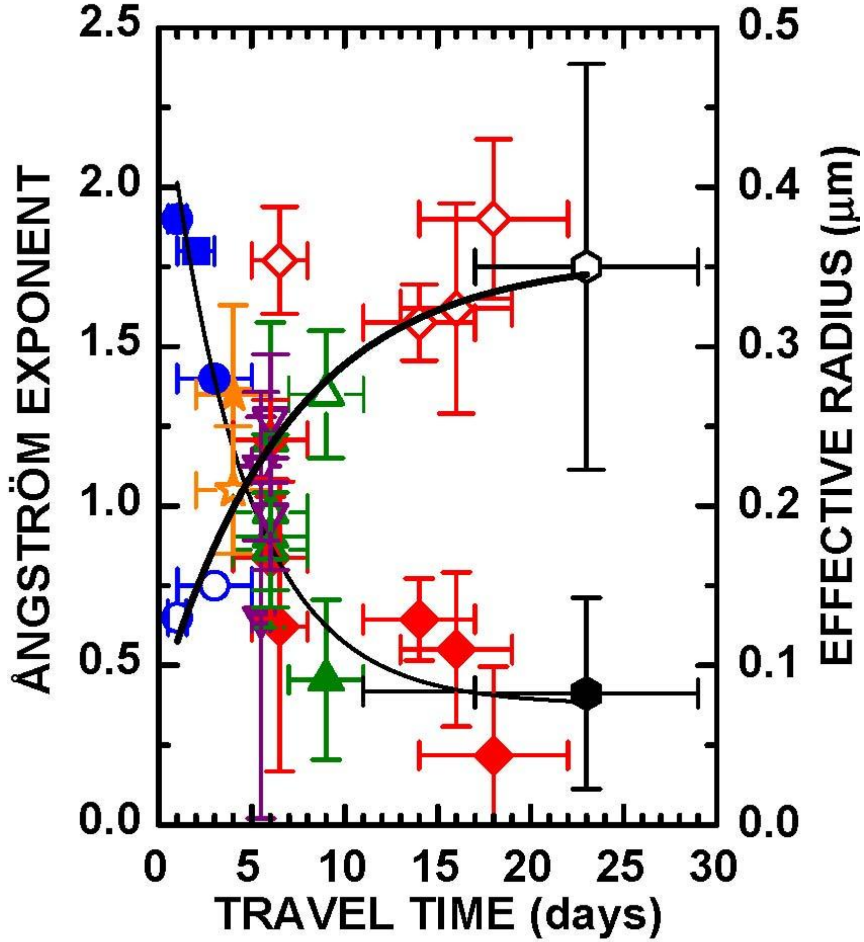


Forest-Fire Smoke Particles from North America and Siberia

Anthropogenic Pollution from North America and Europe (ACE2)

Forest-Fire Smoke – Northern Latitudes Long-Range Transport





Correlation Coefficient = 0.89

Müller et al., GRL, 2007

Approach for the exploitation of observational data

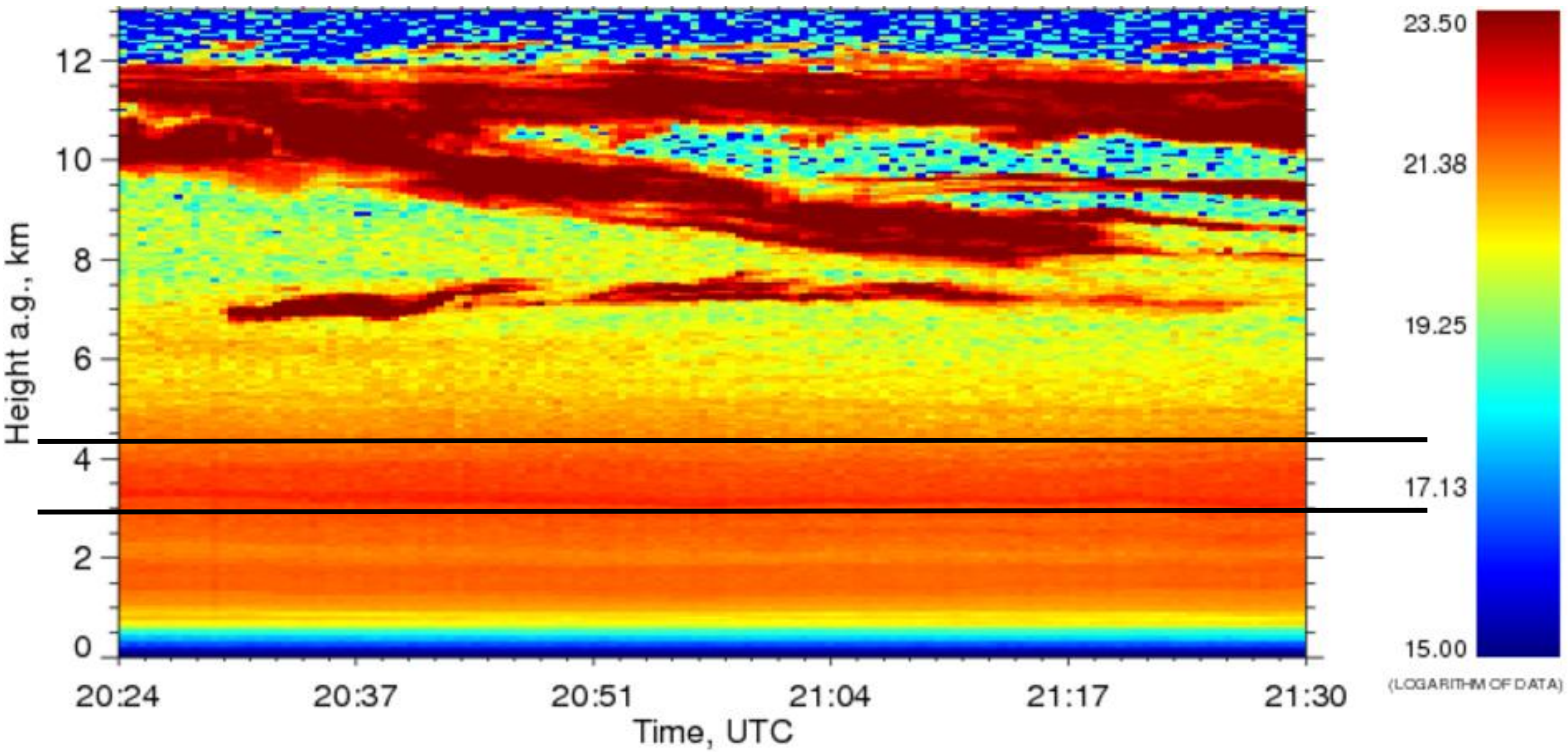
Aerosol layer products

1) Feature finding

2) Feature classification

Example: Aerosol layer products

1) Feature finding coherent structures in time series plots (= quicklooks)

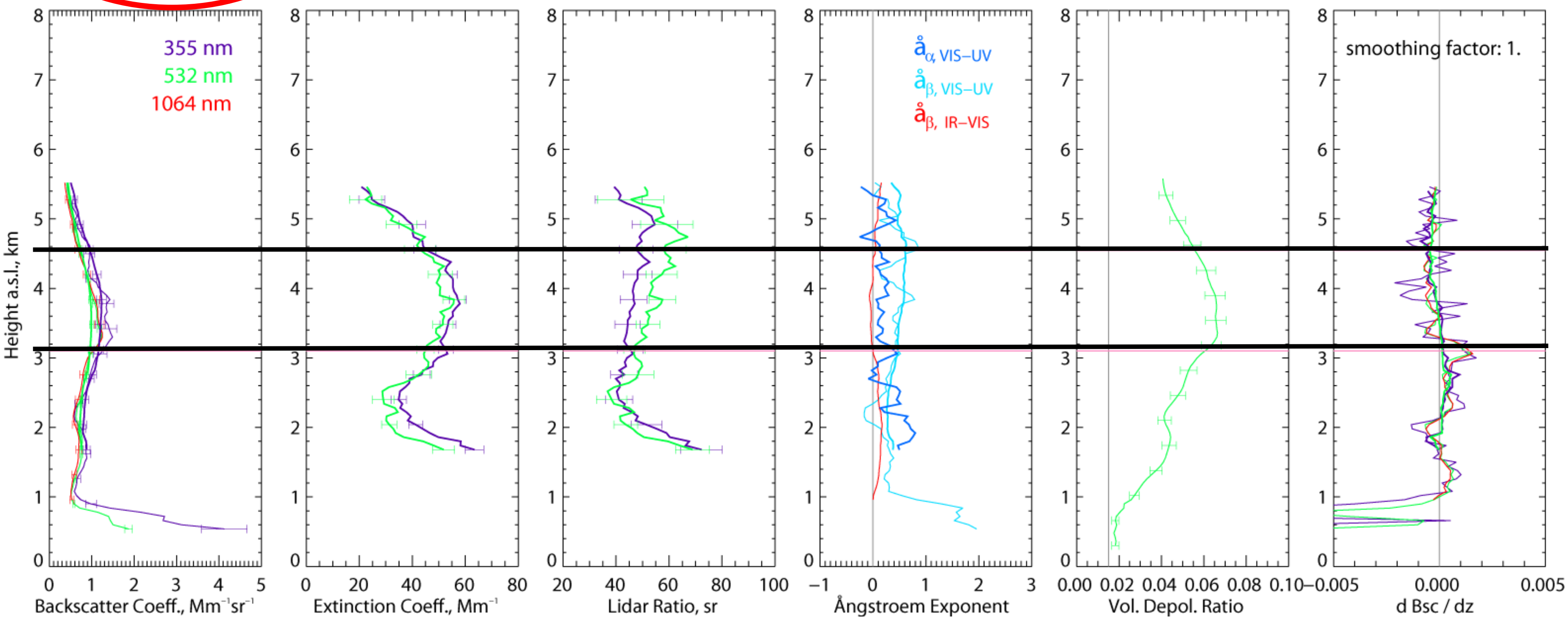


1064 nm range corrected signal, Leipzig, 27 May 2008, 20:24 – 21:30 UT

Optical properties Leipzig, 27 May 2008, 20:24 – 21:30 UT

backscatter significantly larger than 0

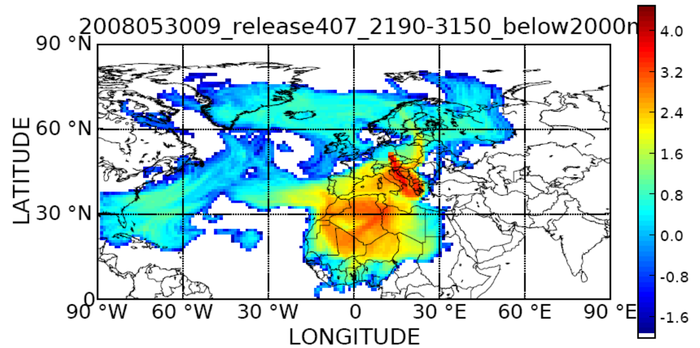
derivative method: d Bsc / dz

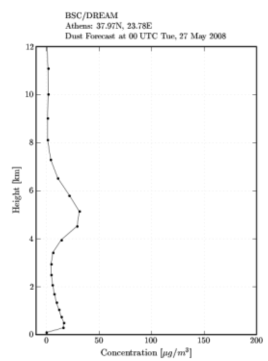


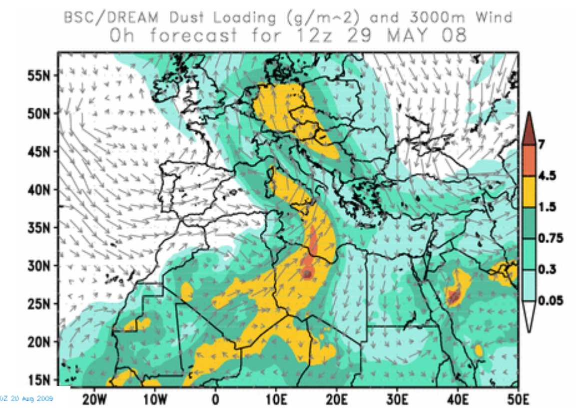
→ feature boundaries

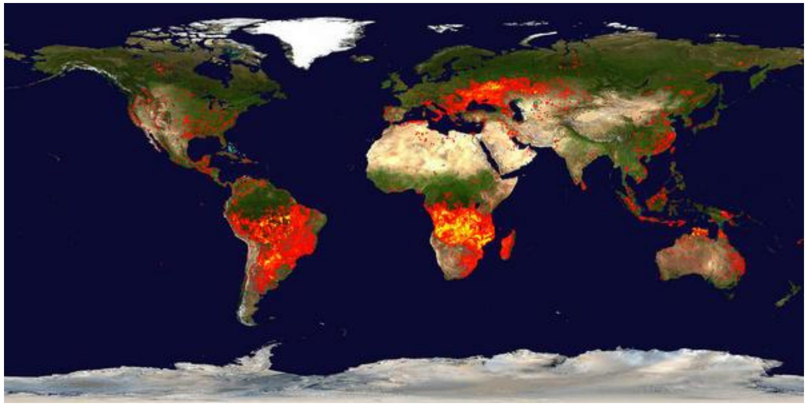
Identification of source, type and age of aerosol

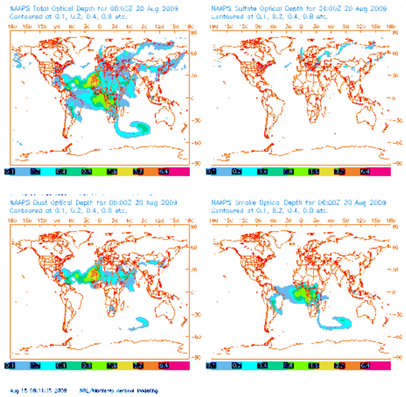
- different trajectory and transport models (FLEXPART, DREAM, HYSPLIT,…)
- MODIS fire maps
- NAAPS (Navy Aerosol Analysis and Prediction System)
- AERONET data
- …

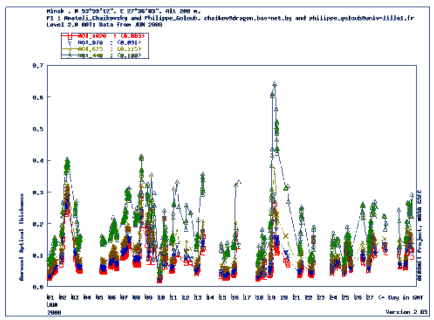












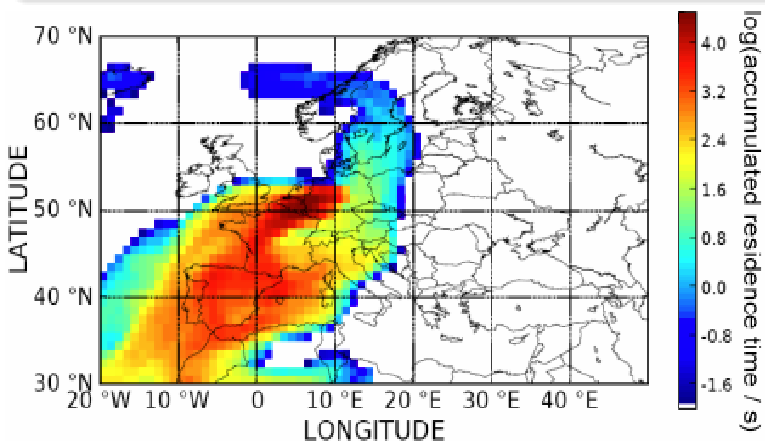
Classification of aerosol with respect to source region: FLEXPART transport simulations

Input

GFS wind fields for 00, 06, 12 and 18 UTC

FLEXPART

- Lagrangian particle dispersion model
- 10 days backward in time



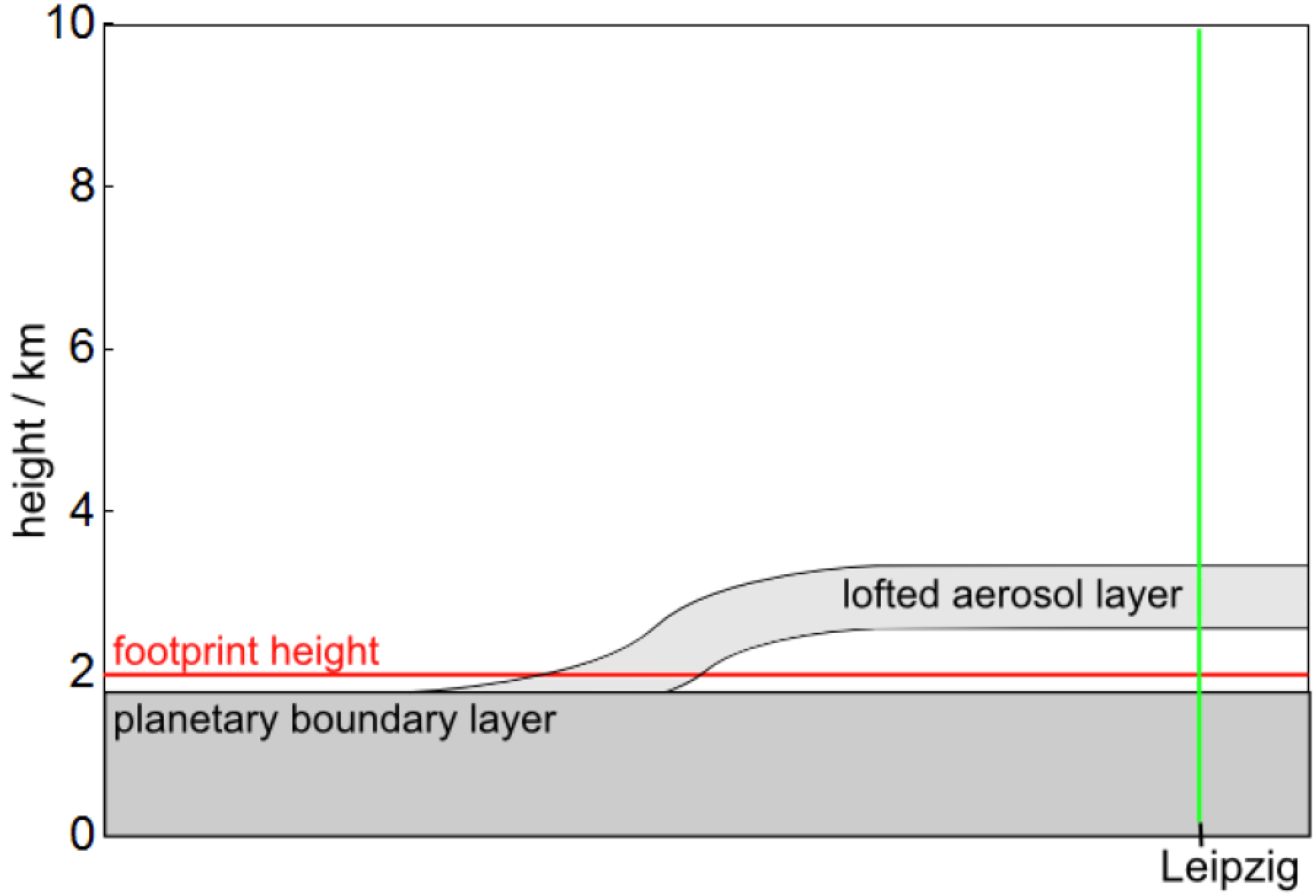
Output

residence time of the particles accumulated over the simulation time period plotted as

- time series
- 'footprints'

Classification of aerosol with respect to source region: FLEXPART transport simulations

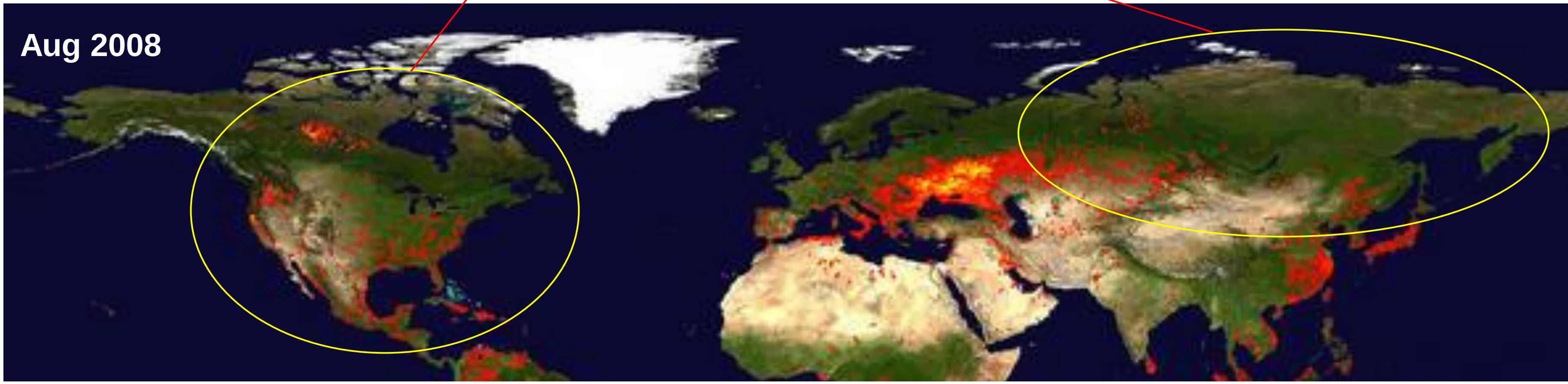
Footprints



Example: biomass-burning aerosol (smoke)
Identification of Fire Source Region
more on smoke by D. Balis/A. Chaikovsky

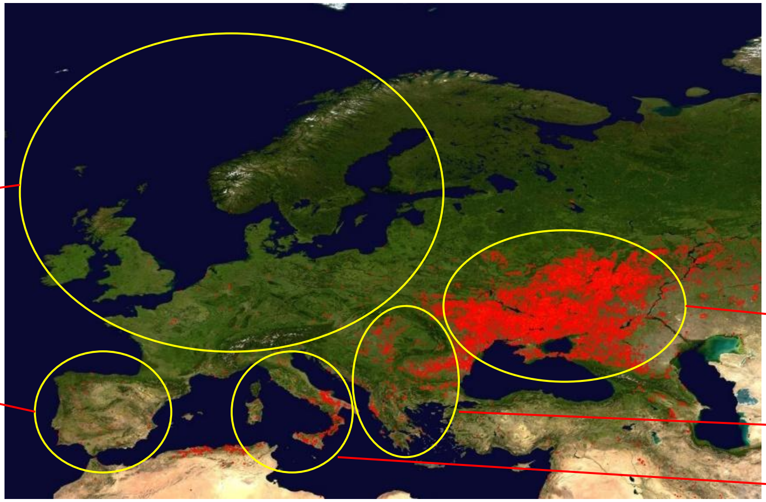
Extra-European:

- Siberia
- North America



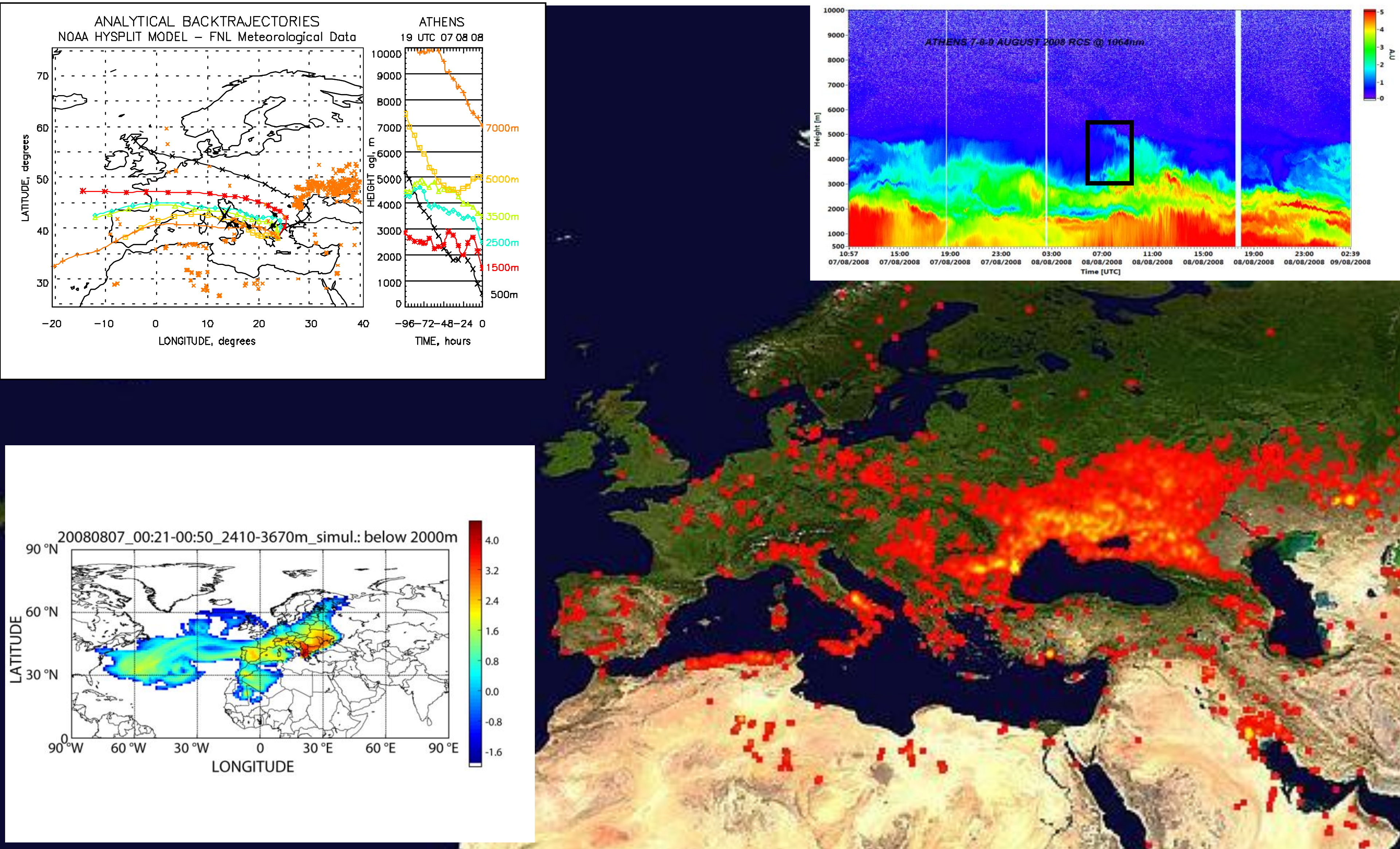
European:

- central and northern Europe
- southwestern Europe

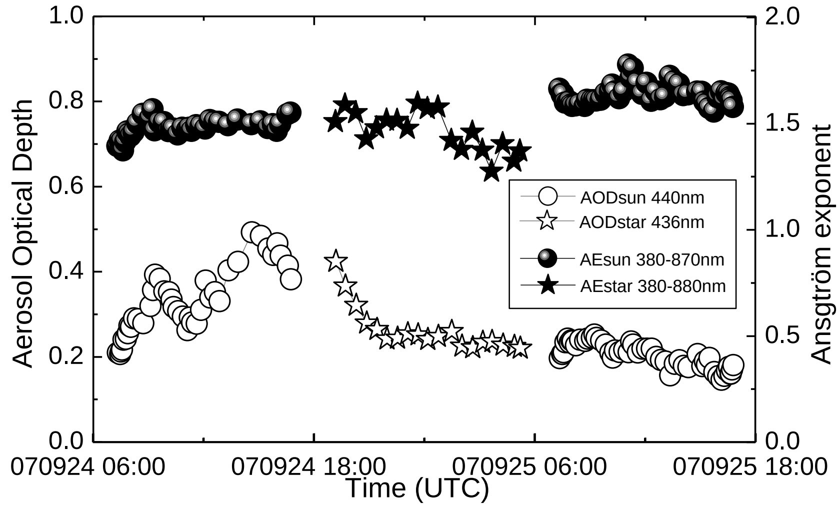


- Ukraine and surrounding areas
- southeastern Europ
- southern Europe

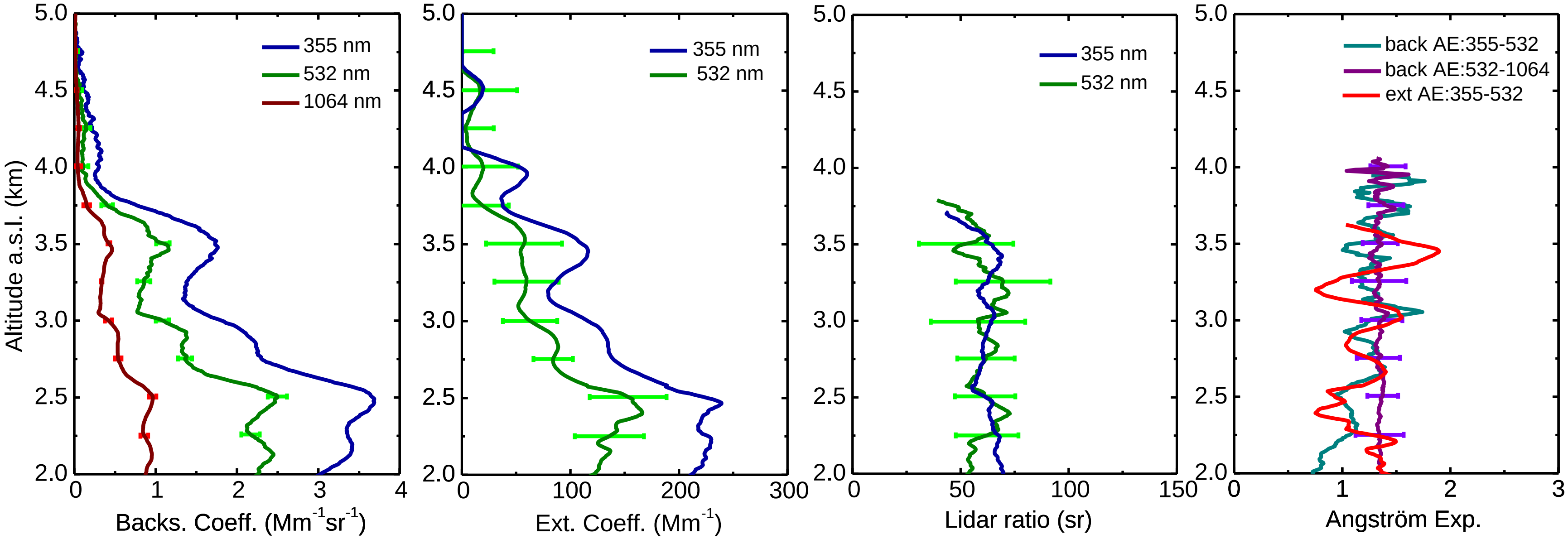
MODIS Fire Map 29 Jul - 7 August 2008 and HYSPLIT backward trajectories and FLEXPART



Fresh Biomass-Burning Smoke: Granada



More on Biomass Burning: D. Balis

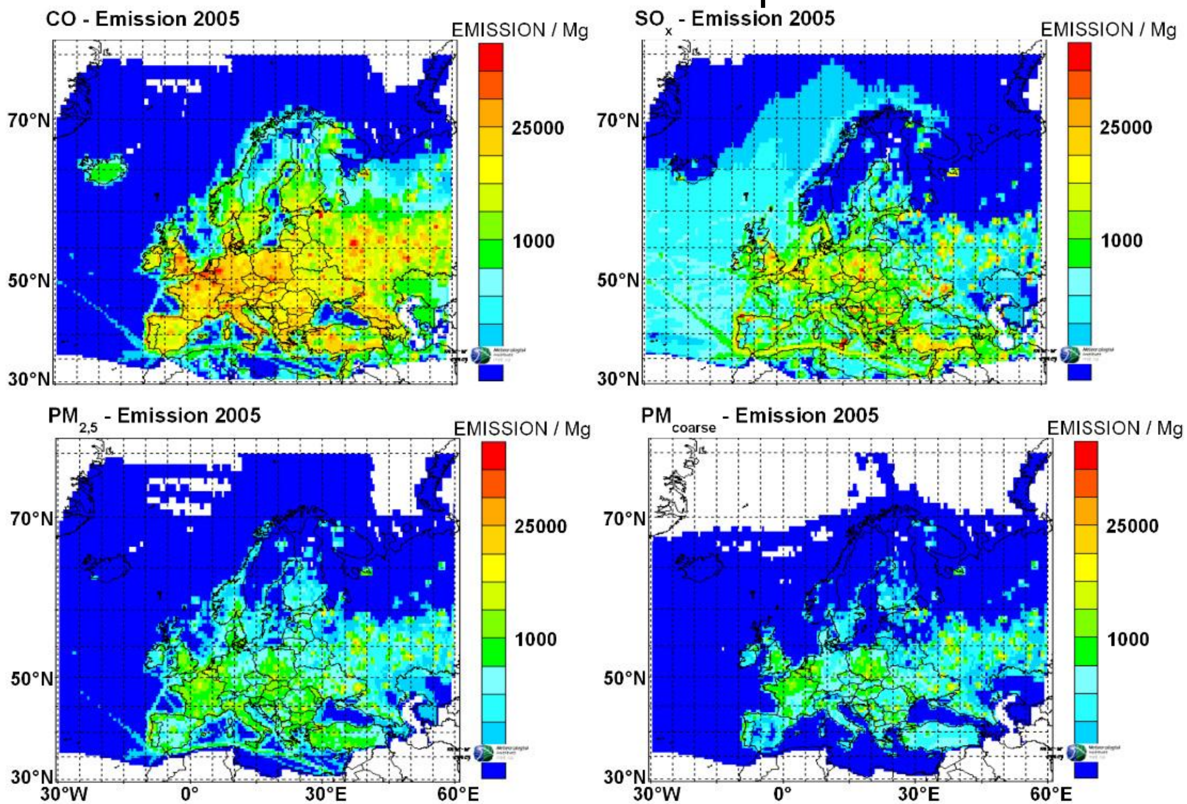


L. Alados-Arboledas et al., GRL, submitted

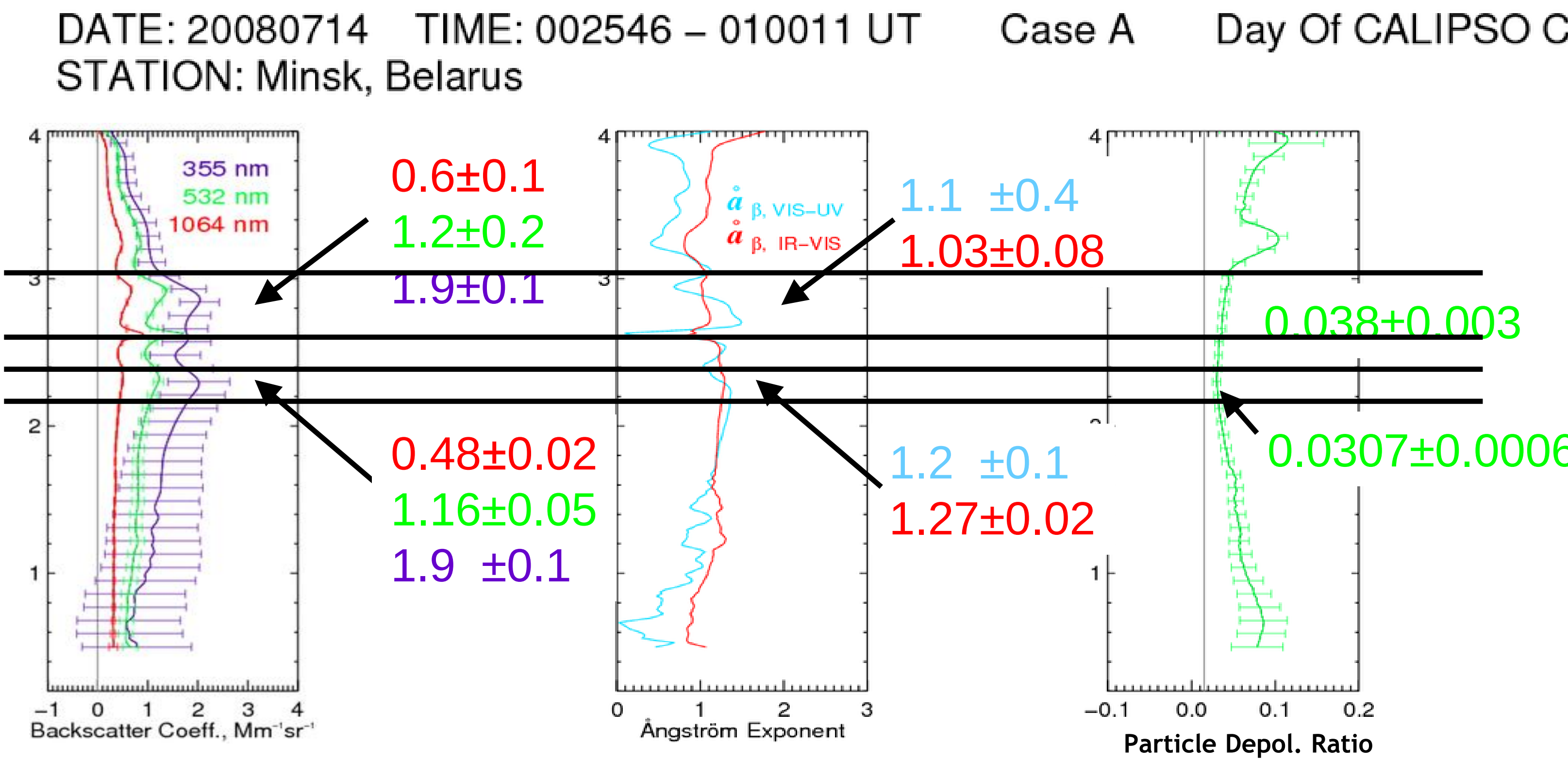
Example: Definition of Source Region of Polluted Continental Aerosol

EMEP emission inventory

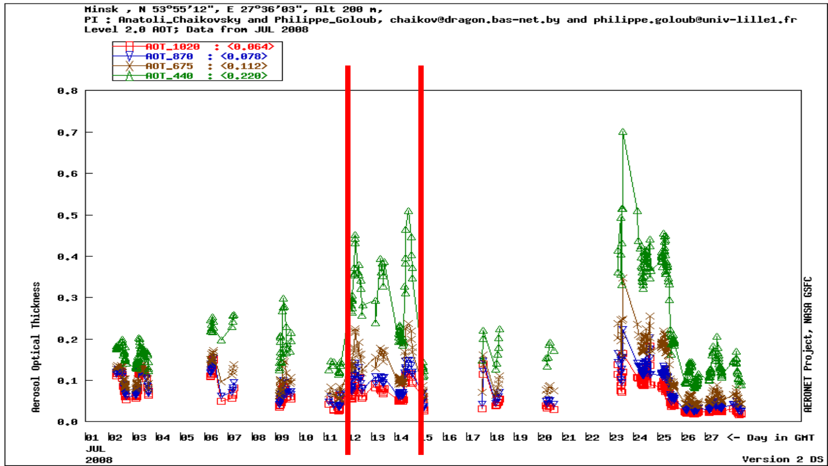
Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe



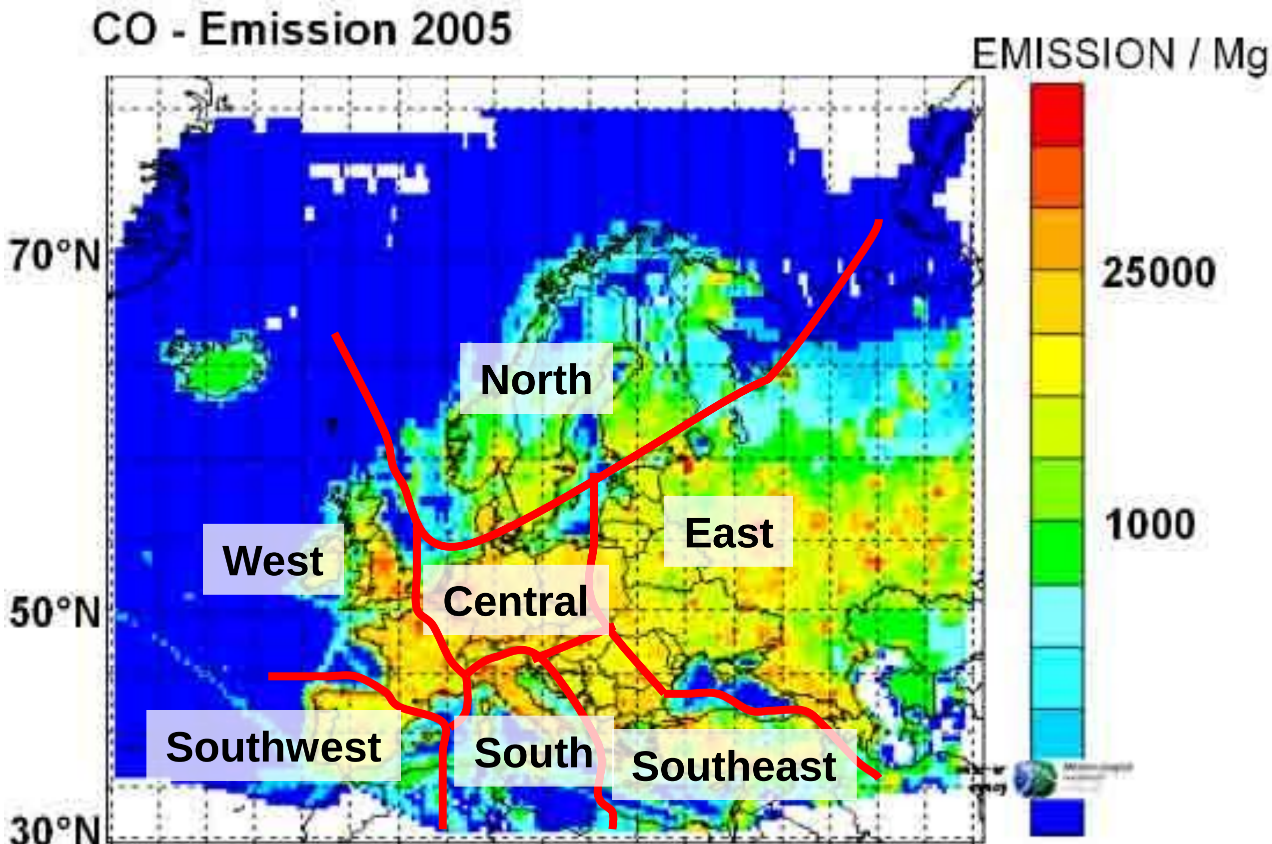
Optical properties, Minsk, 14 July 2008, 00:25 – 01:00 UT



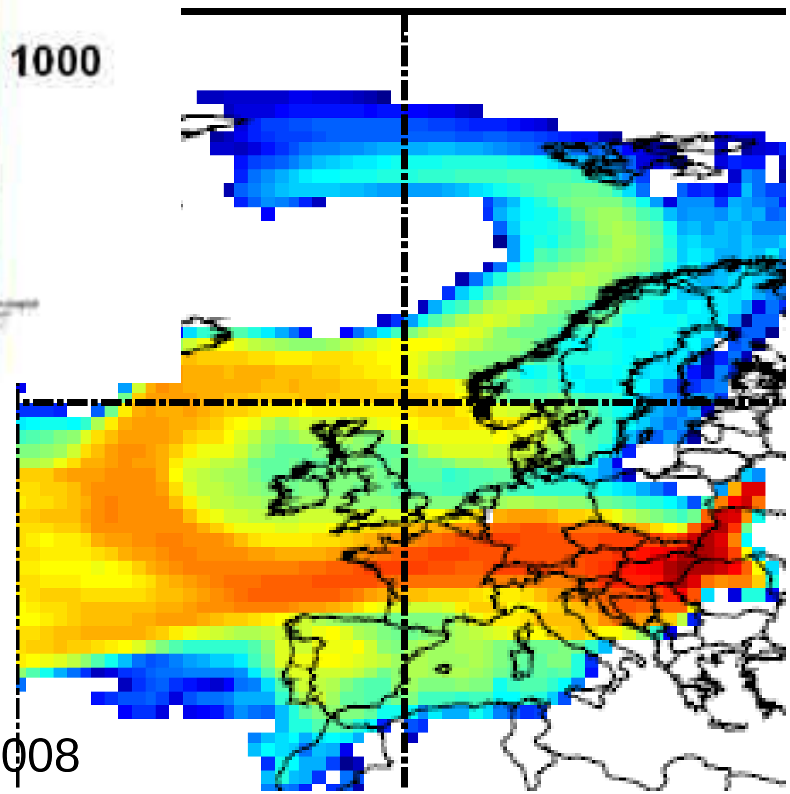
AERONET Aerosol Optical Depth, Minsk, July 2008



Definition of European source regions for polluted continental aerosol



Polluted continental aerosol from Eastern Europe

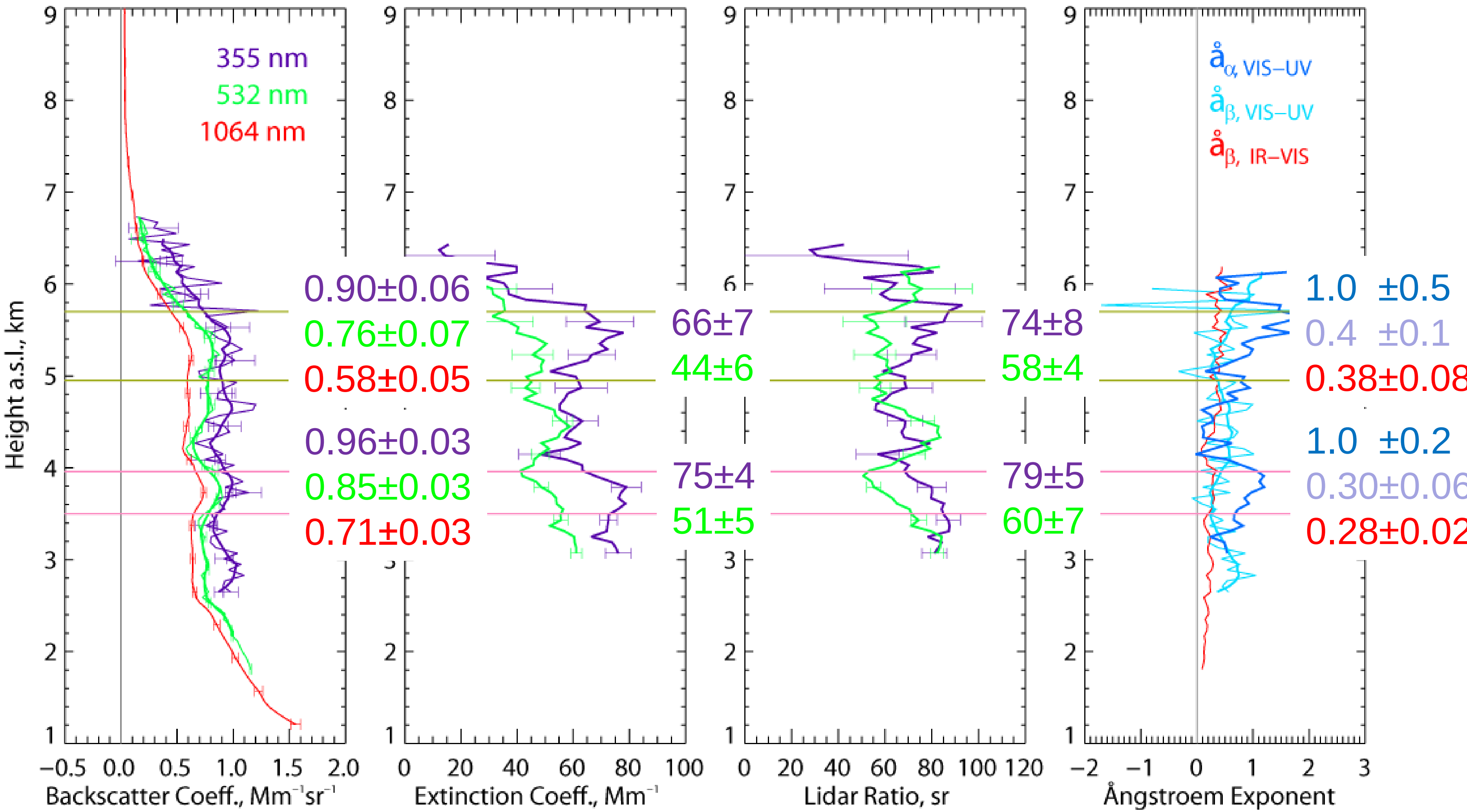


feature: 2.2 – 2.42 km

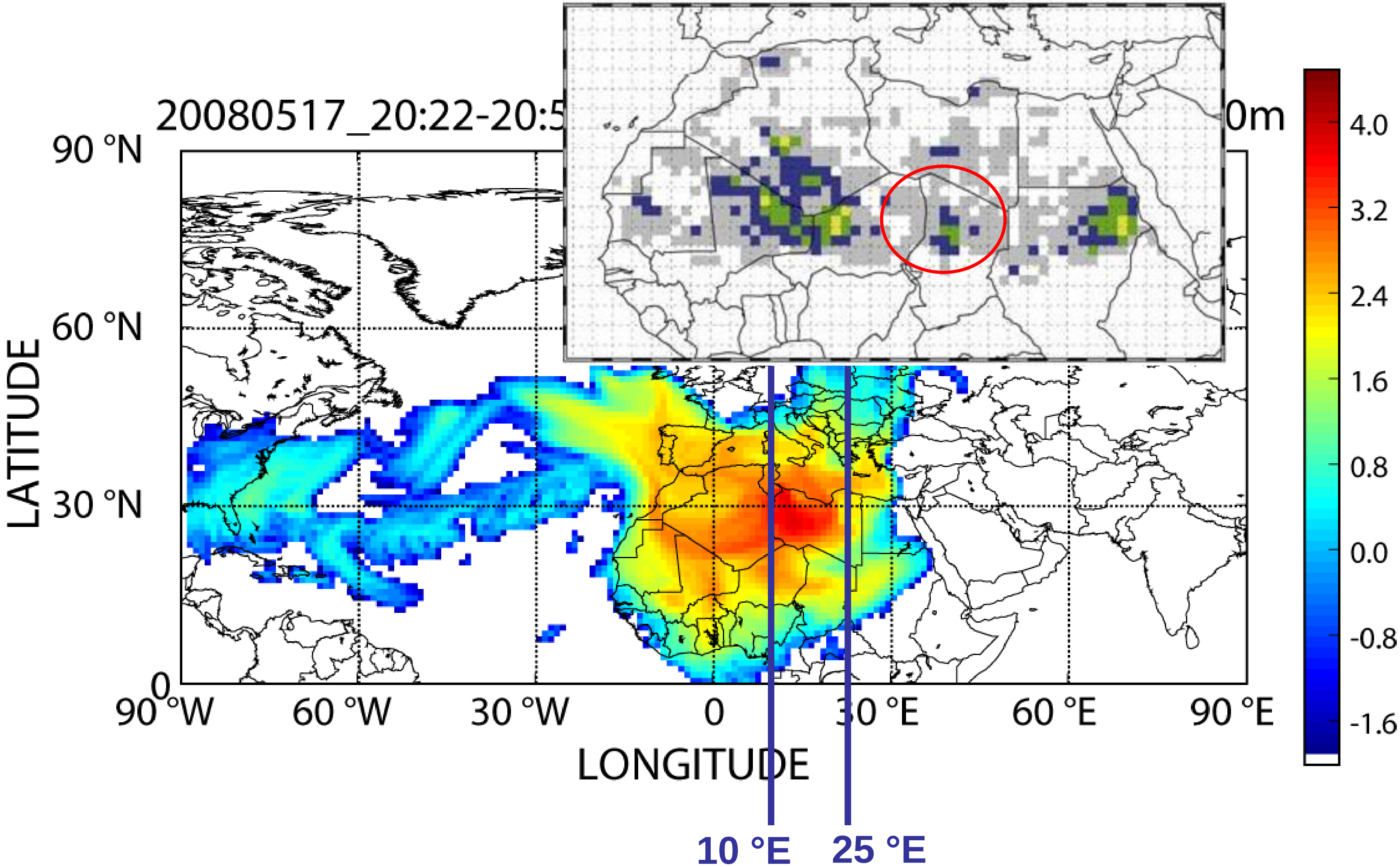
FLEXPART footprint (2000 m) Minsk, 14 July 2008

Example: Mineral dust aerosol
more on mineral dust by A. Papayannis

Optical properties, Potenza, 17 May 2008, 20:22 – 20:52 UT

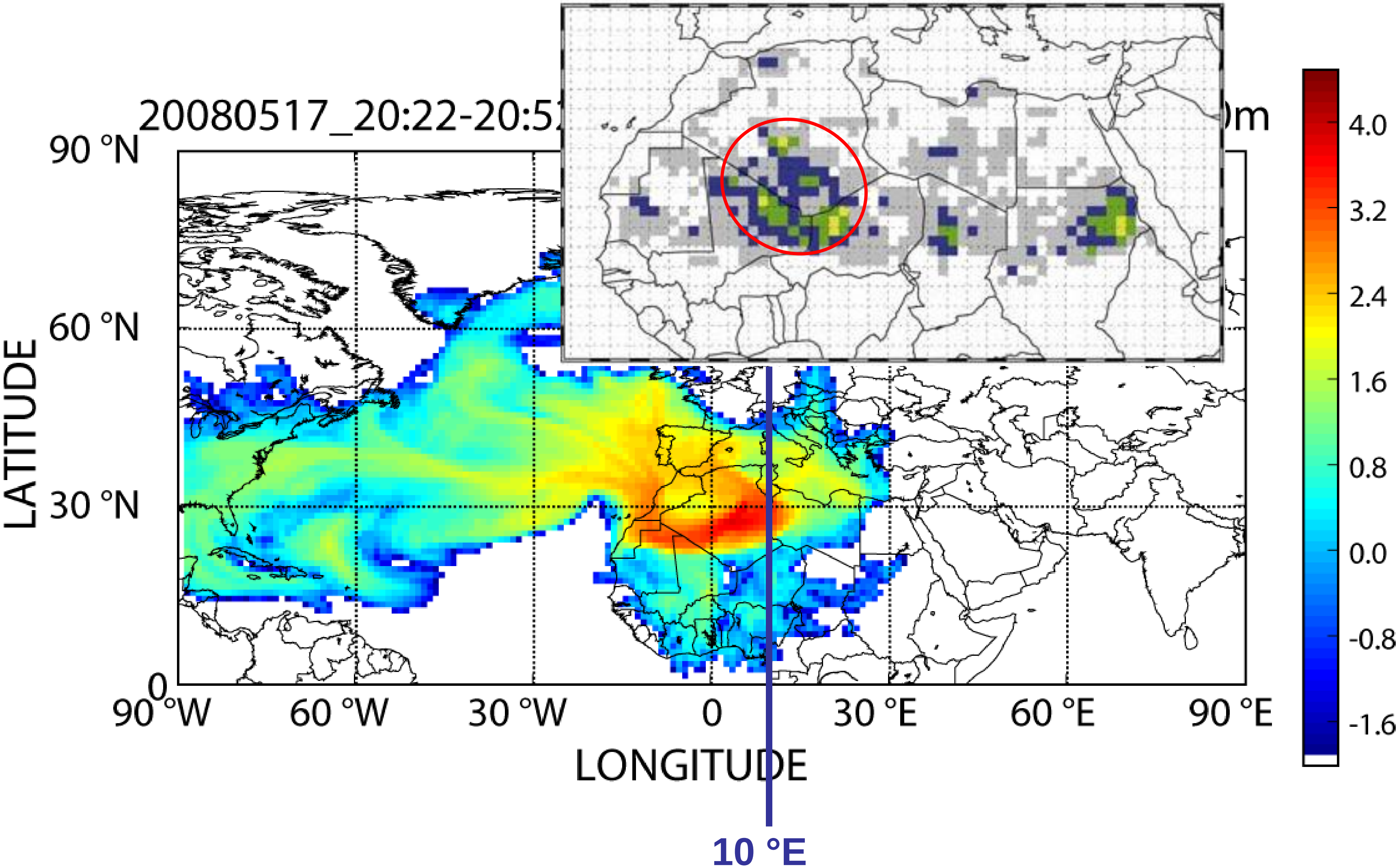


Classification of aerosol with respect to source region



FLEXPART footprint (2000 m) Potenza, 17 May 2008

Classification of aerosol with respect to source region



FLEXPART footprint (2000 m) Potenza, 17 May 2008

Optical Properties of Different Dust Mixtures

Dust mixed with marine aerosol (sea-salt particles):

large and non-absorbing particles

Dust mixed with smoke or anthropogenic pollution:

relatively small particles which show a considerable absorption

results: quite different optical properties compared to pure dust

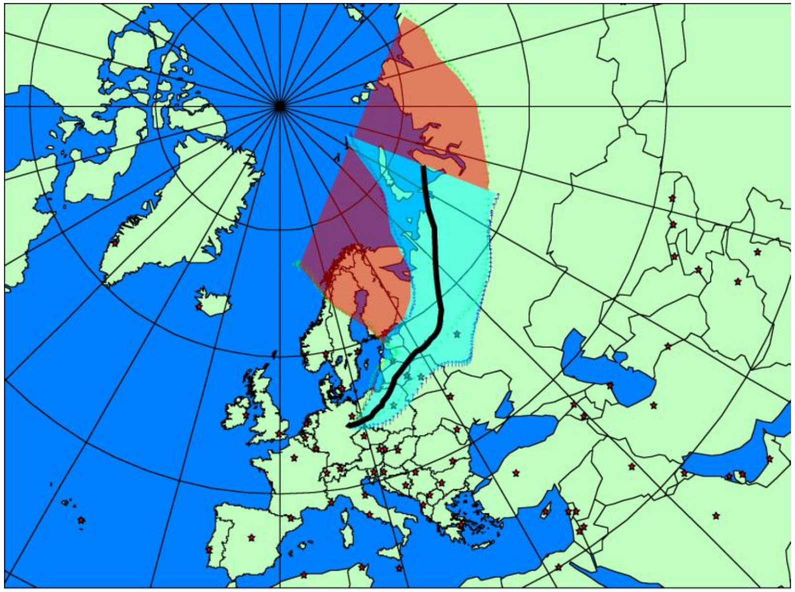
→ lower lidar ratio

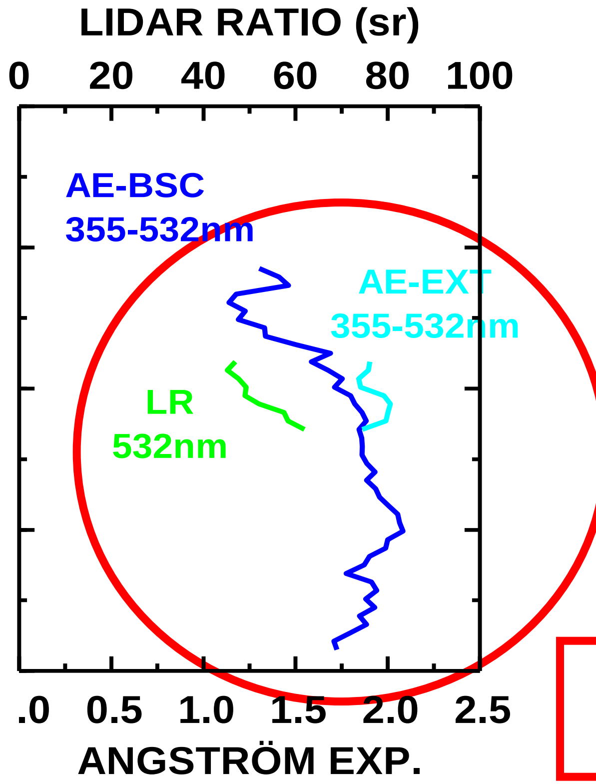
→ higher lidar ratio

→therefore, we introduce term MIXED DUST, when considering influence of marine aerosol, in order to indicate the difference to the CALIPSO definition of polluted dust!

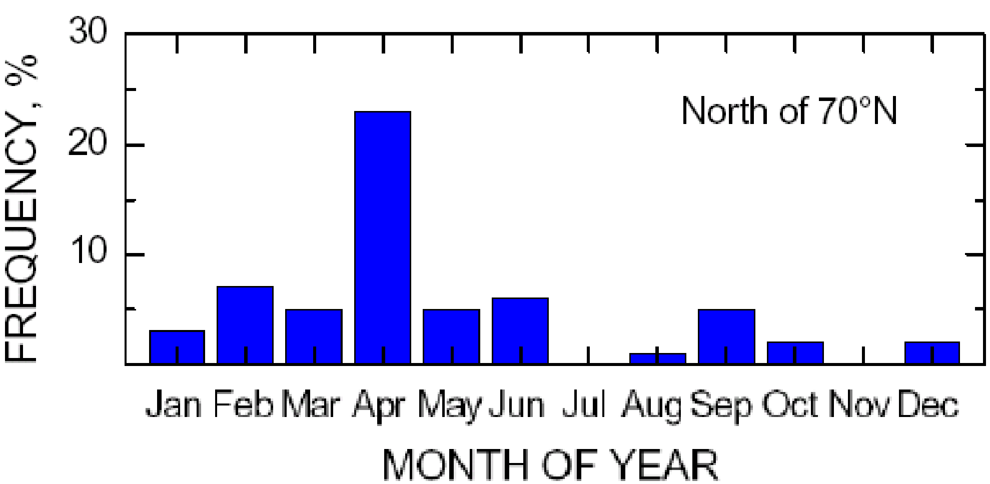
More on CALIPSO related issues by U. Wandinger

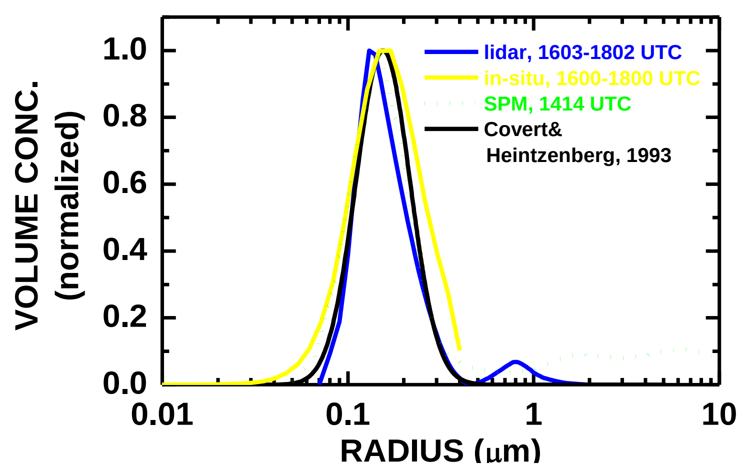
ARCTIC HAZE: Season as an indicator





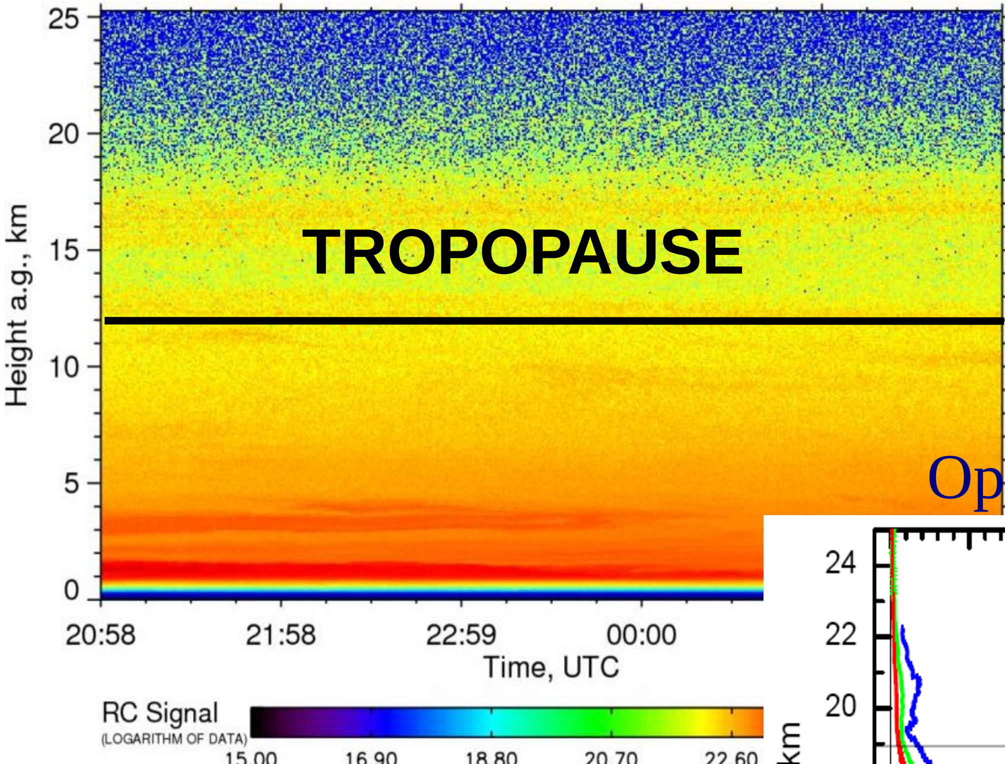
å ≈ 2





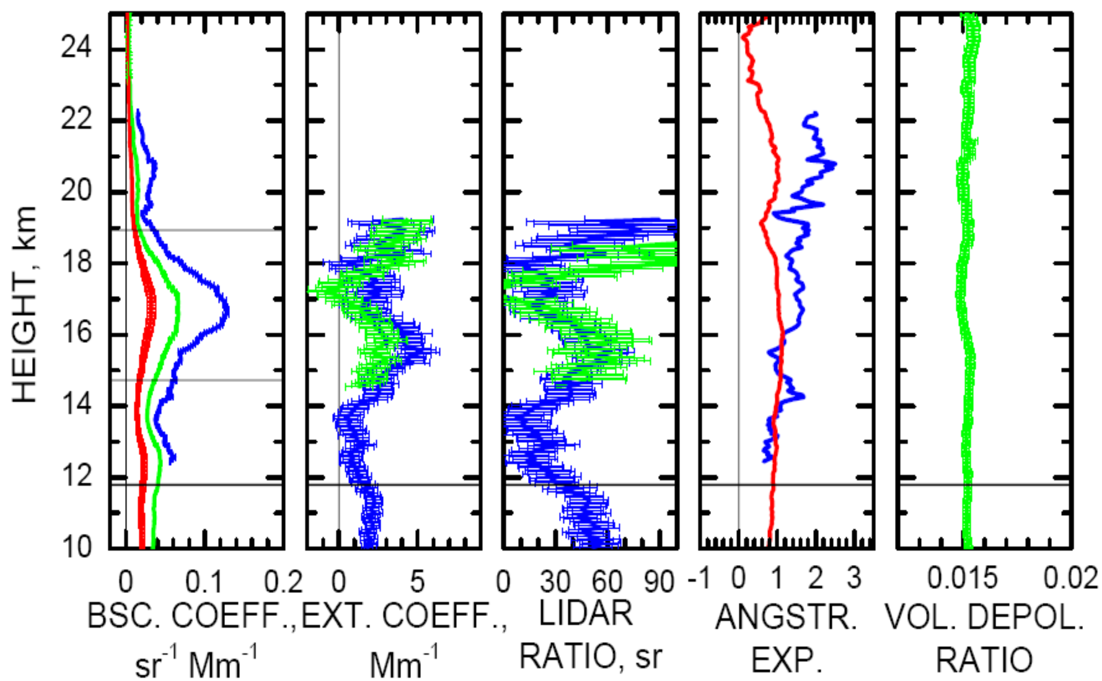
Volcanic Aerosols from Volcanic Eruptions

Height as Information Source



More on Volcanic Aerosols: I. Mattis

Optical depth at 532 nm: 0.015



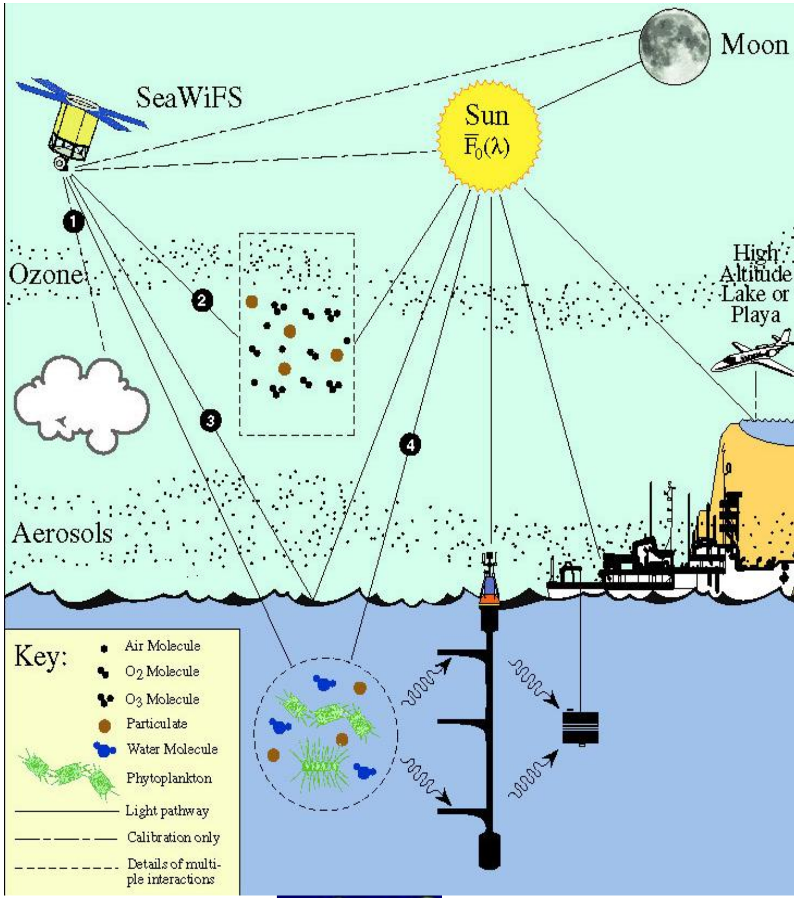
VRAME:

Vertically Resolved Aerosol Model for Europe from a Synergy of EARLINET and AERONET data

More on VRAME: E. Giannakaki

Ocean Color Retrieval

- Requires atmospheric correction
- New: include lidar data



Challenge

introduce new concepts on aerosol typing into established ocean color retrieval algortihms

Conclusions

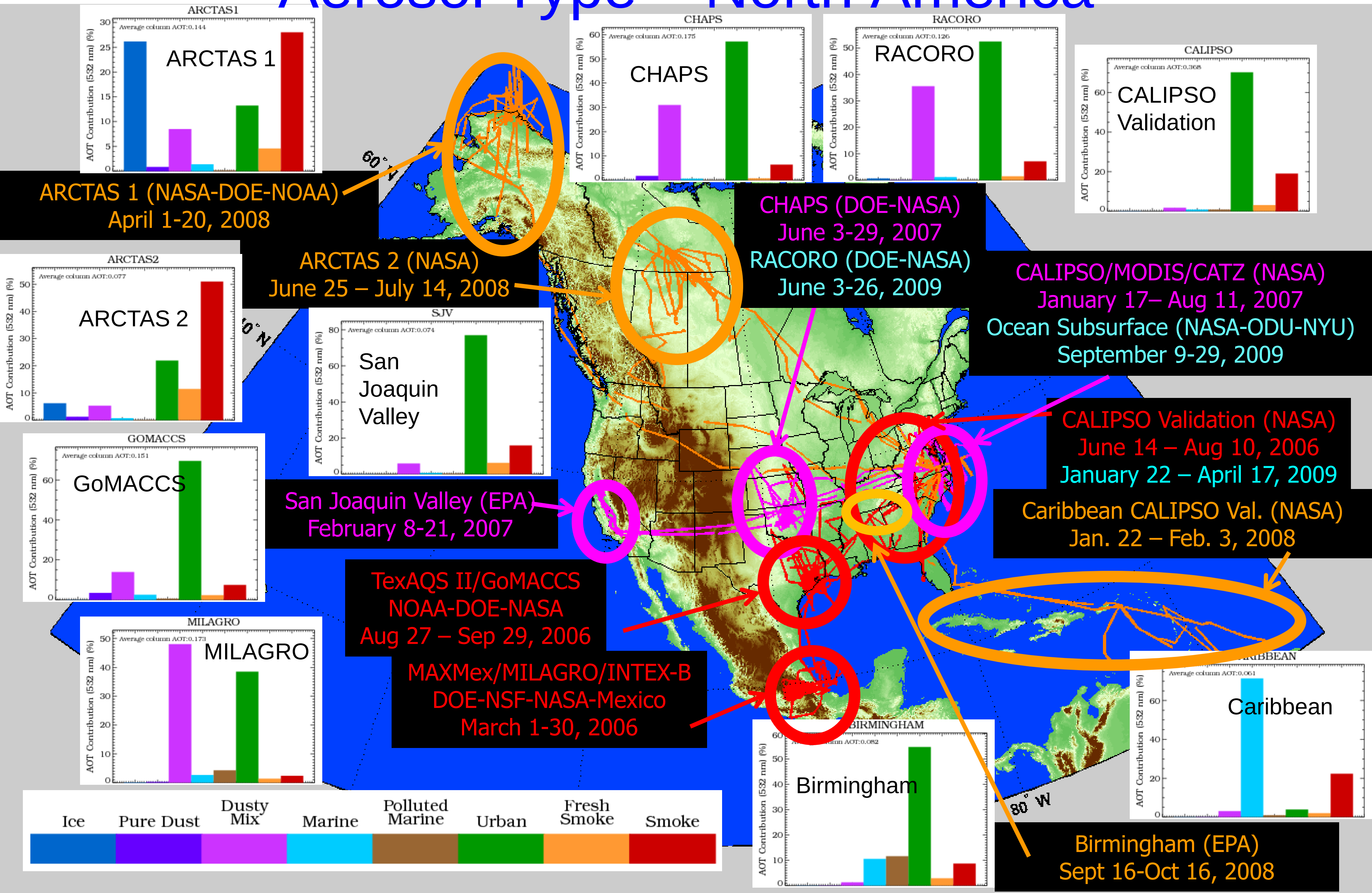
- Various Approaches to Aerosol Typing
- The Problem of „Defining“ Aerosol Types?
  - Source, Season, Region, Height, Age, Mixing State, Spread of Parameters
- Synergy of lidar and additional techniques:
  - satellite images, sunphotometer, backward trajectories/modelling(HYSPLIT, FLEXTRA/FLEXPART, DREAM, NAAPS ...), emission inventories (EMEP, ...), ...

Aerosol Typing

Europe - EARLINET

Global:
(U. Wandinger will come back to some issues tomorrow)
North Africa
North America
South America
South Asia
East Asia

Apportionment of Aerosol Optical Thickness by Aerosol Type – North America



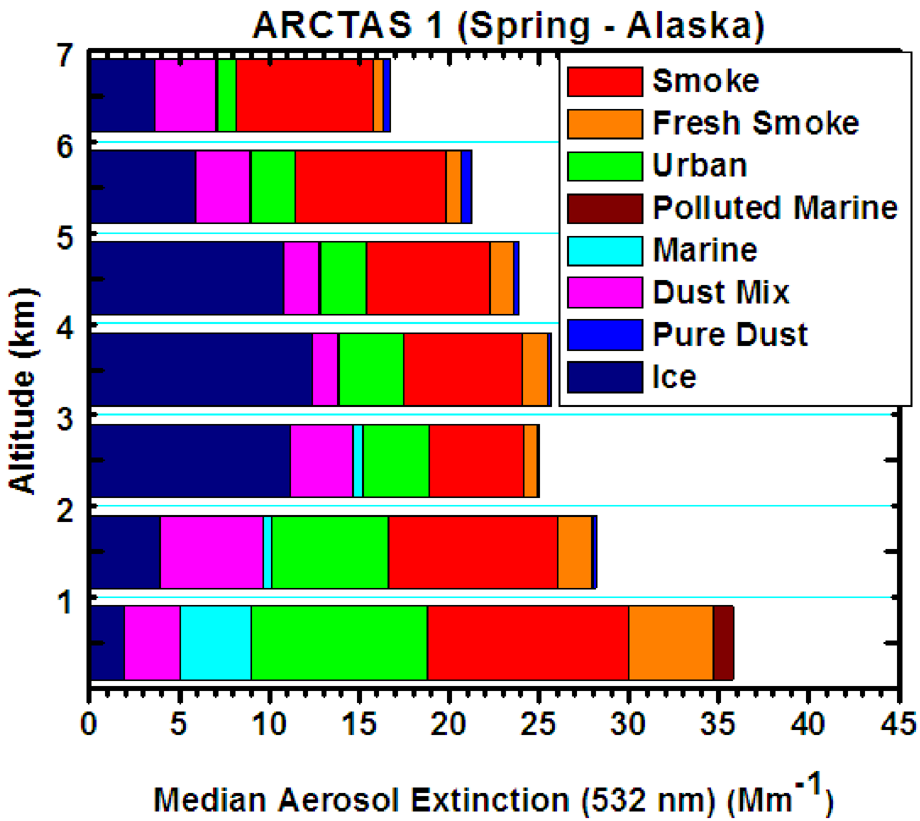
Variation of Aerosol Extinction and Aerosol Type with Altitude

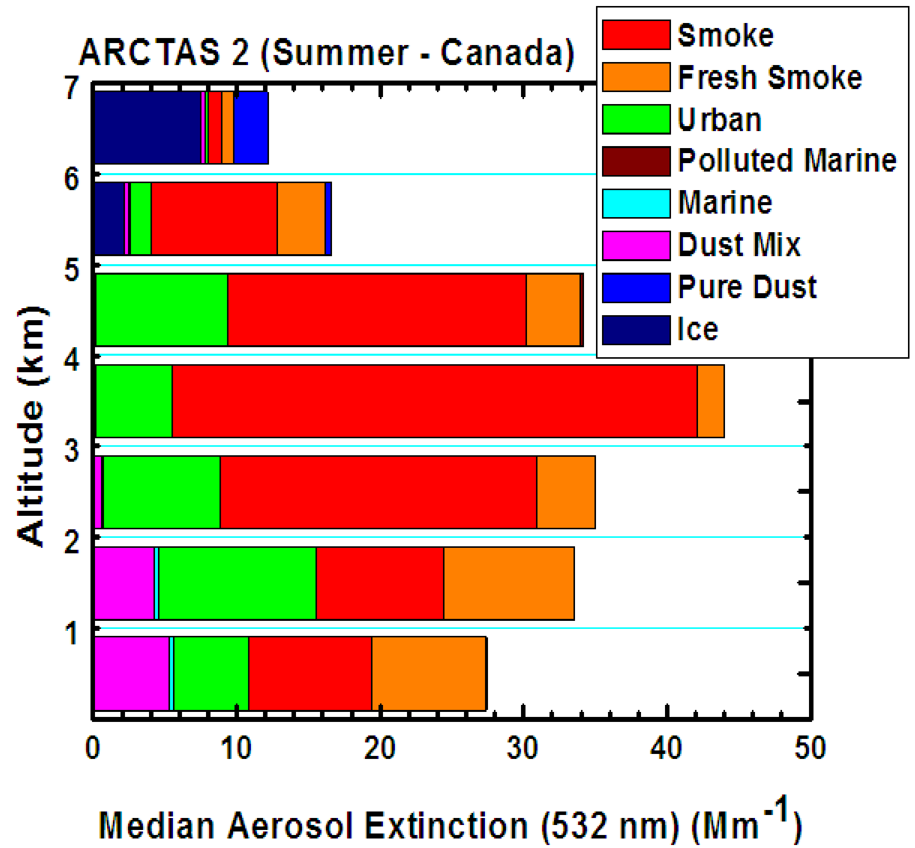
ARCTAS 1 (Spring – Alaska)

- Ice was pronounced from 2-5 km
- Dust fraction increased with altitude
- Lowest levels had variety of aerosol types
- Urban type was most prominent at lowest levels

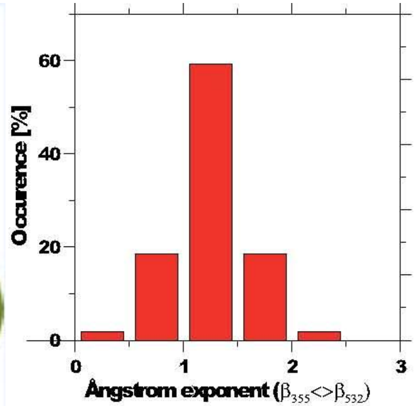
ARCTAS 2 (Summer – Canada)

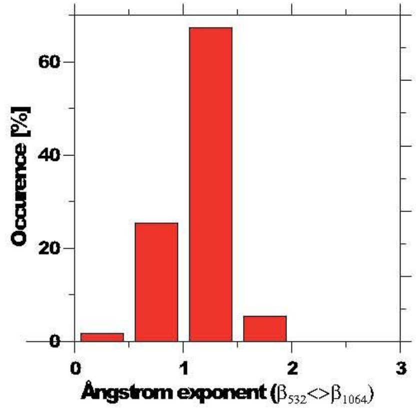
- Ice found only at high altitude
- Lowest levels (< 2 km) had more fresh smoke
- Biomass burning (smoke) was dominant type 2-6 km
- Some dust found below 2 km

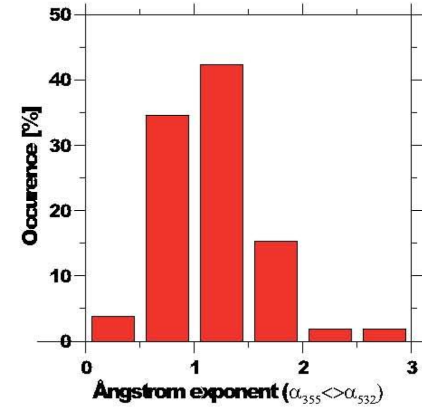




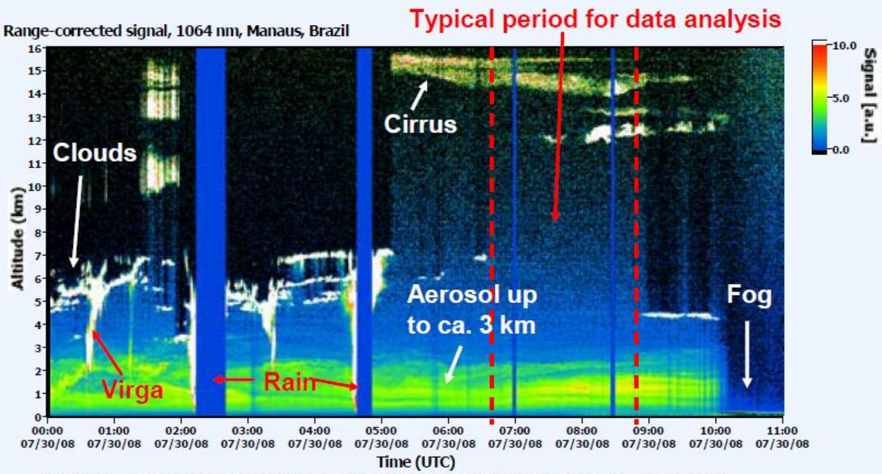
South America – Biomass Burning



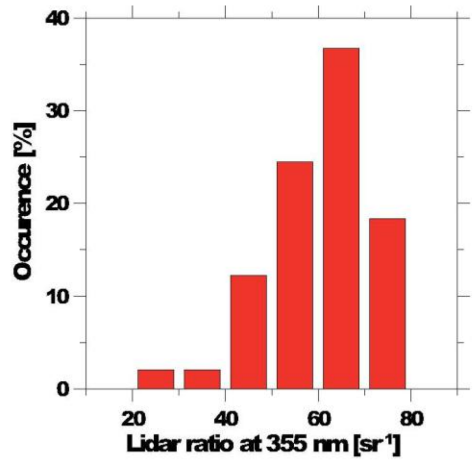


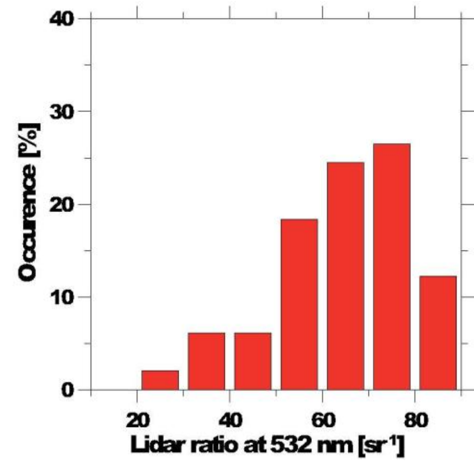


Typical measurement: 30 July 2008



Temporal development of the range-corrected signal at 1064 nm observed with Polly^{XT} near Manaus, Brazil, on 30 July 2008. Local time = UTC – 4h.



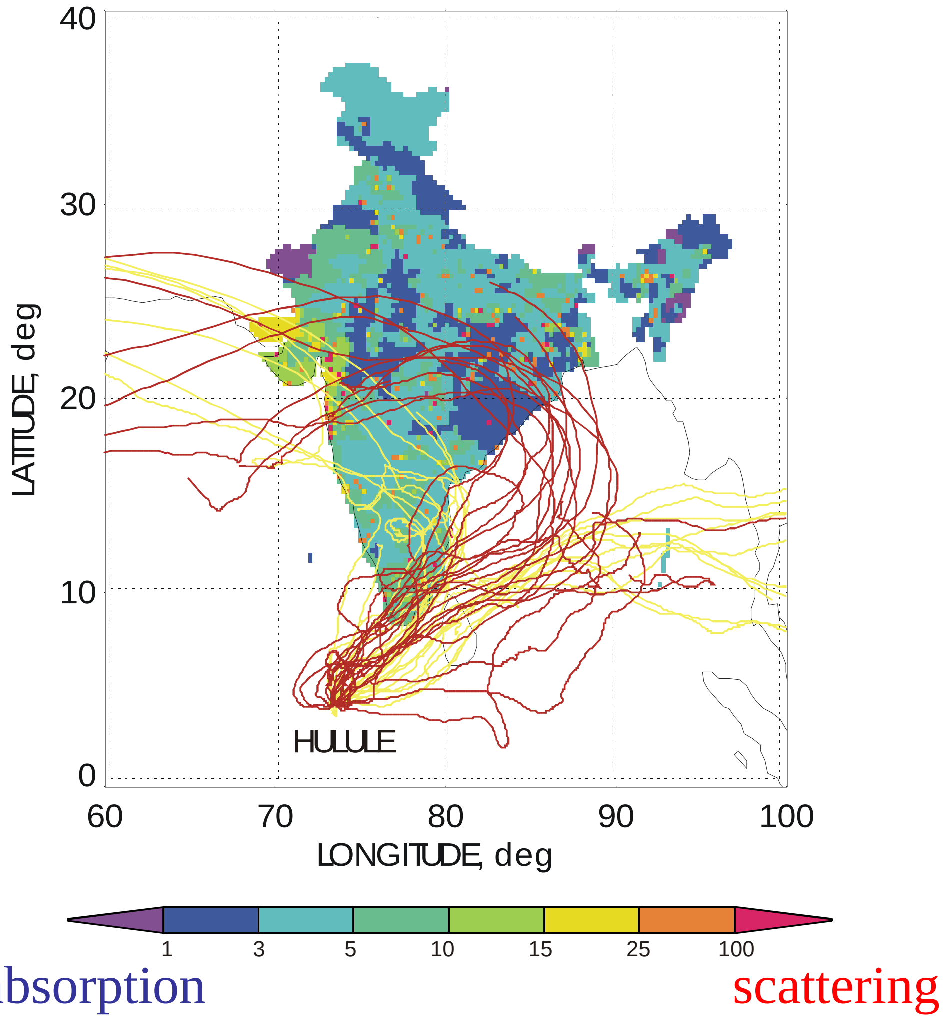


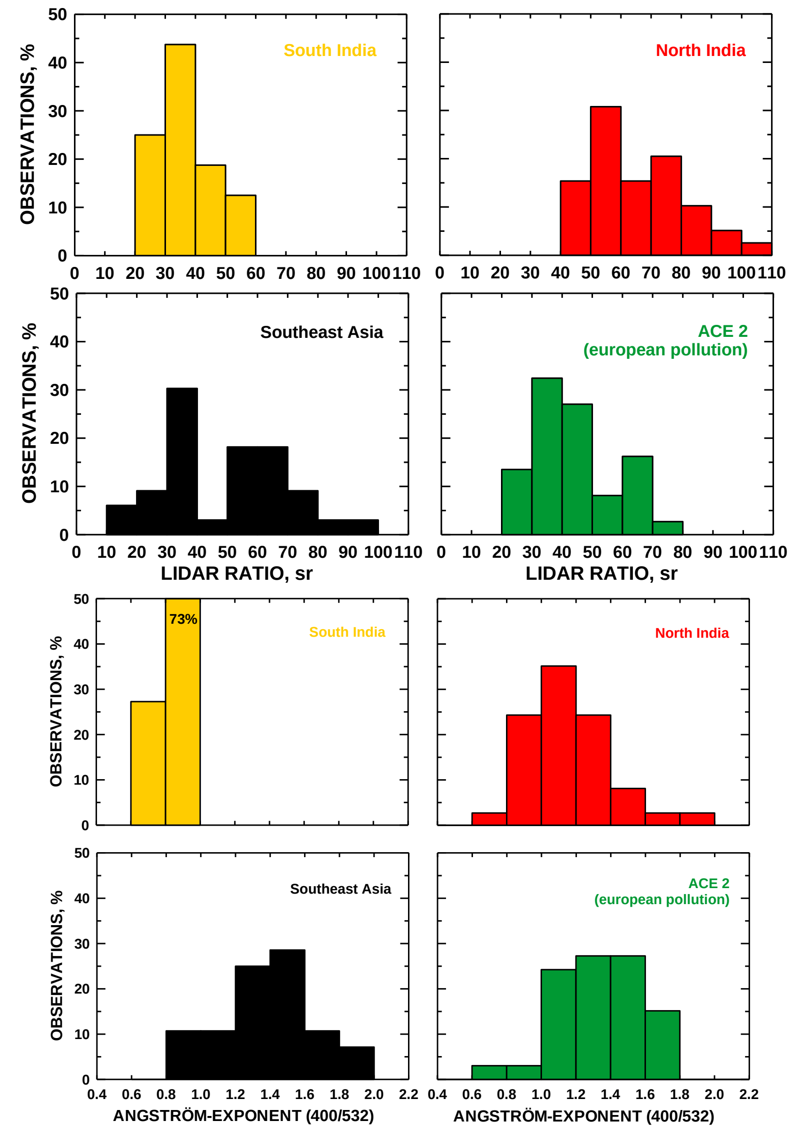
EUCAARI - IfT, H. Baars, D. Atlhausen, R. Engelmann et al.

South Asia – Indian Ocean Long-Range Transport

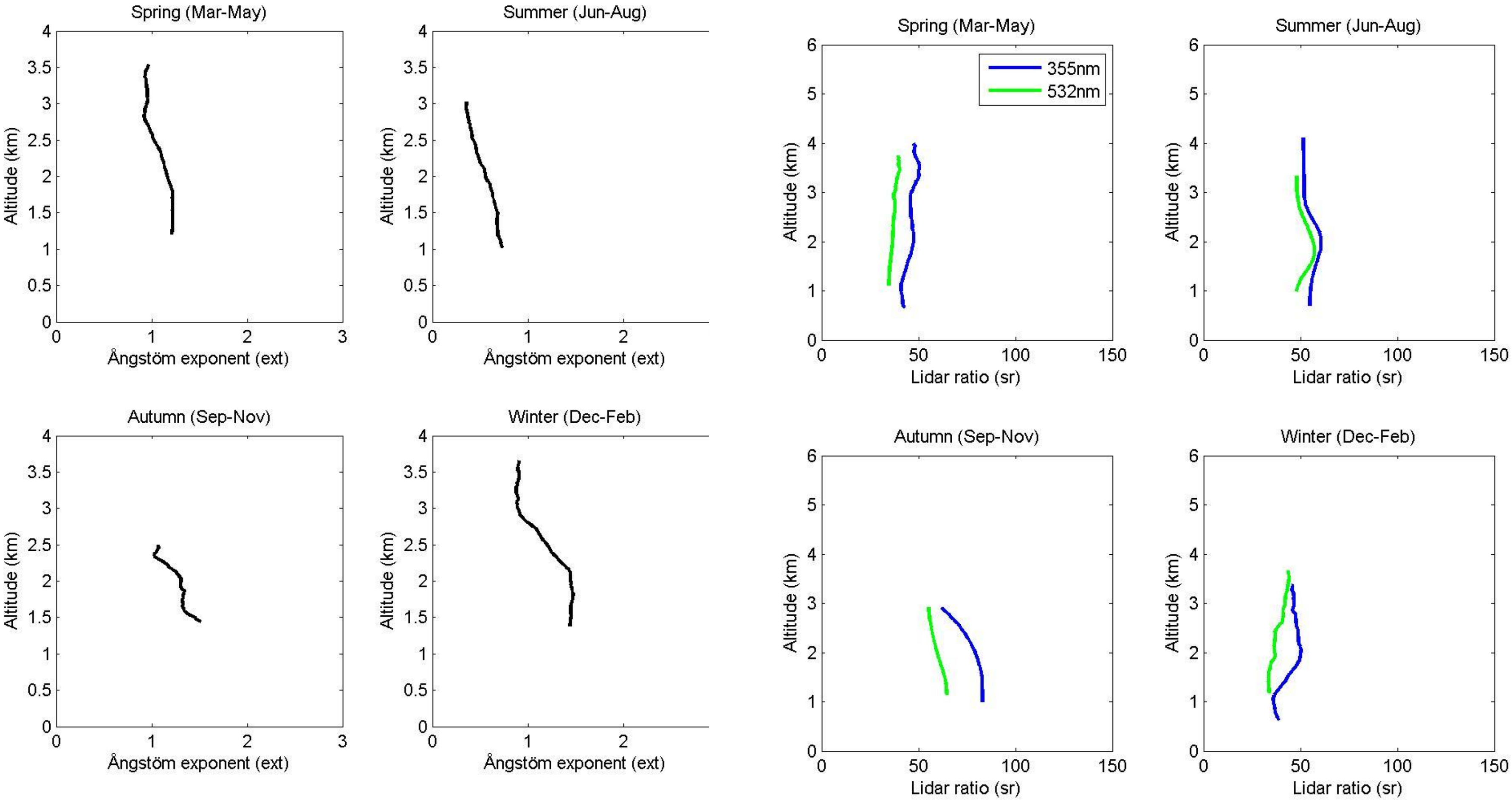
INDOEX 1999/2000

Airmass-Related Characterization





South Asia - North India: Source Region

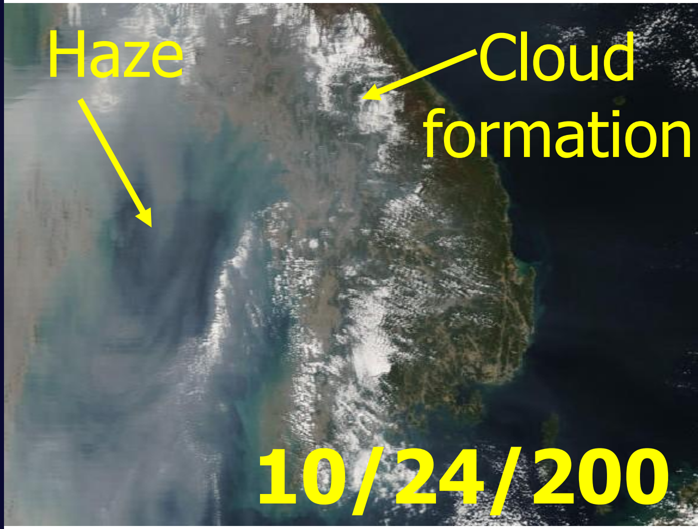


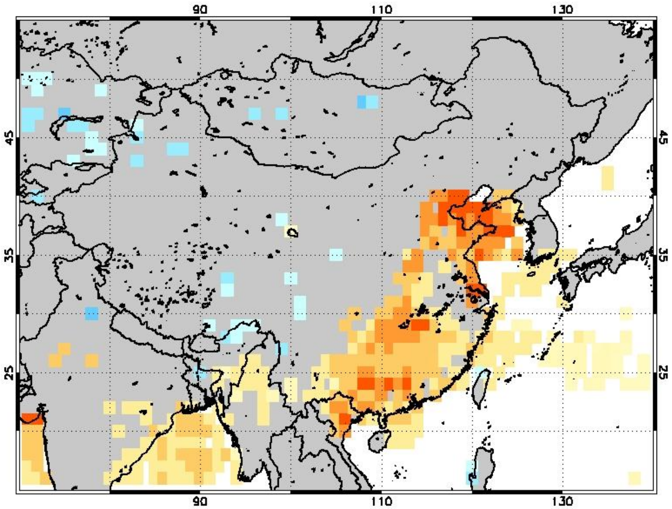
EUCAARI – FMI/IfT

Finnish Meteorological Institute: M. Komppula et al.,

IfT: D. Atlhausen, R. Engelmann et al.

East Asia – "Medium" Long-Range Transport



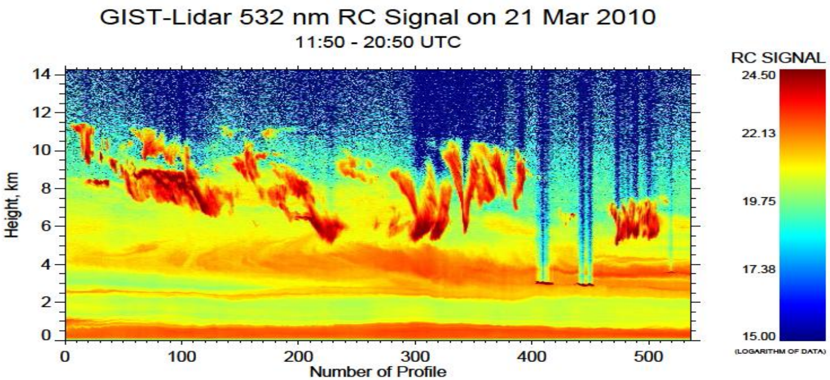


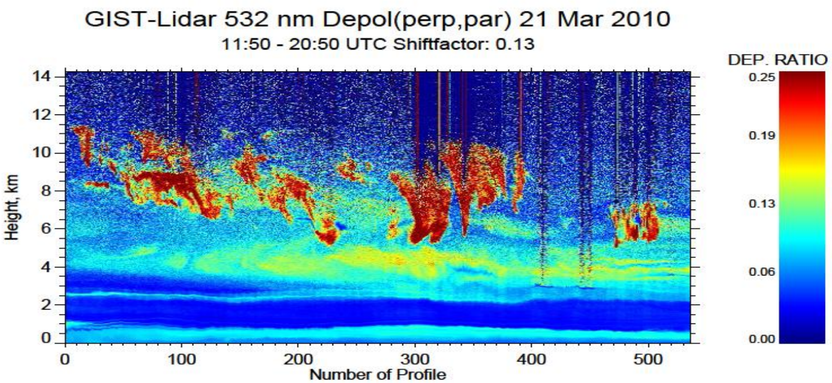
MODIS Annual increasing rate of AOT (1999 - 2008)

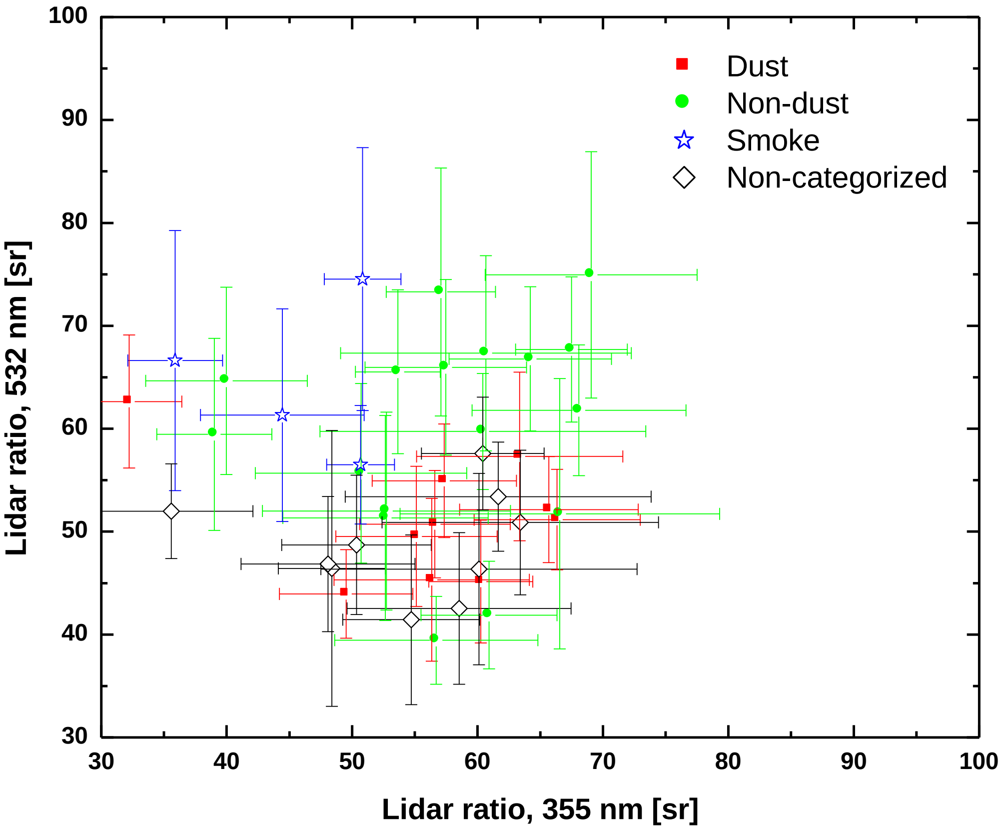
$$\frac{\Delta AOT}{Year} : 0.01 - 0.03$$

[Lee et al., 2008]

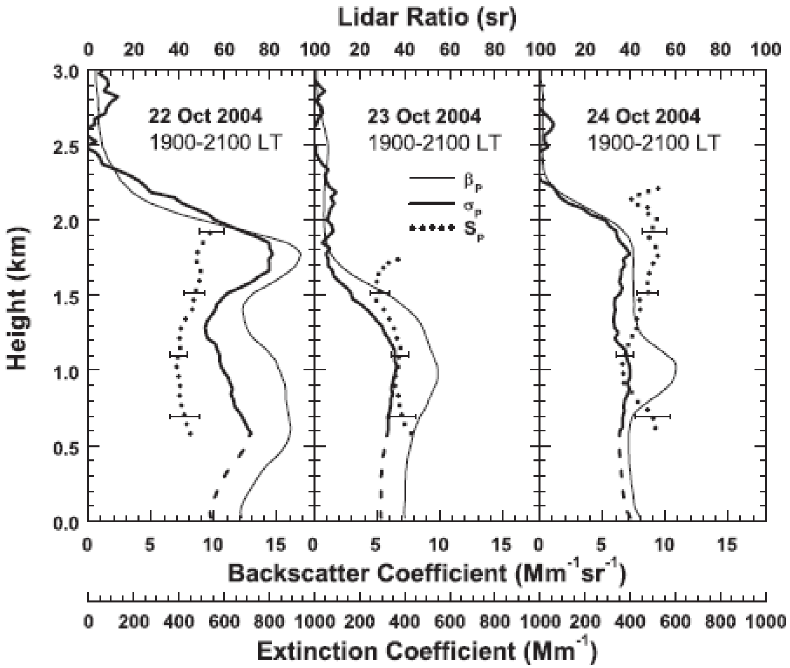
Spectral Signature of Lidar Ratio

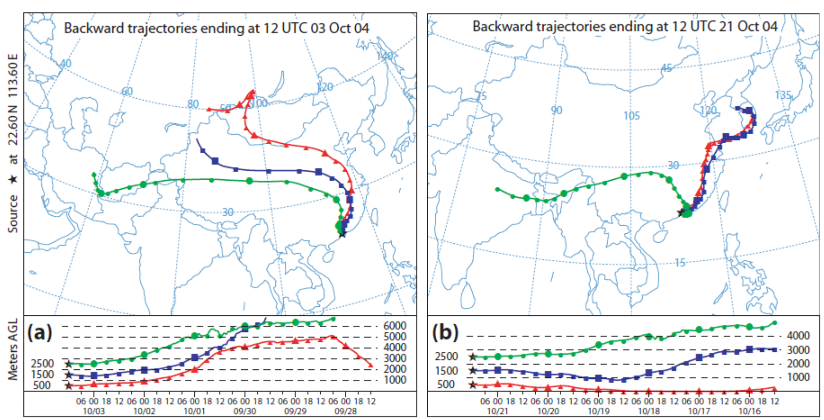




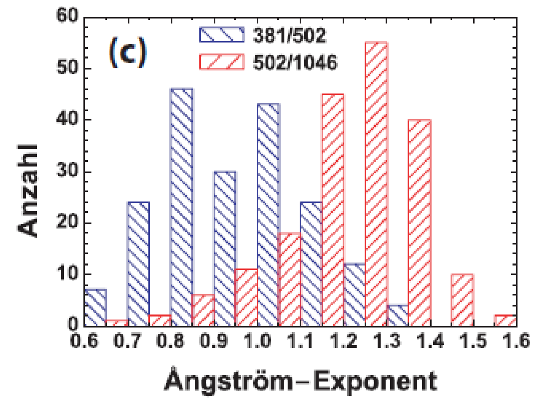


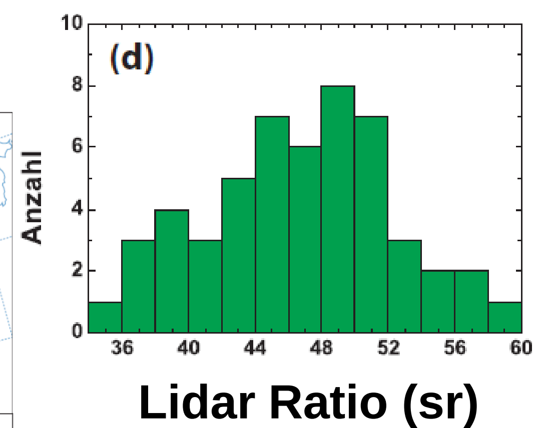
East Asia: China - „In Source Region“



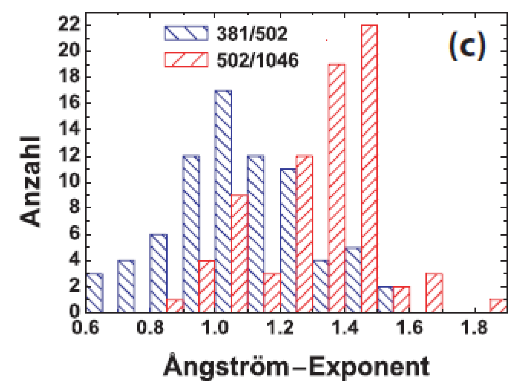


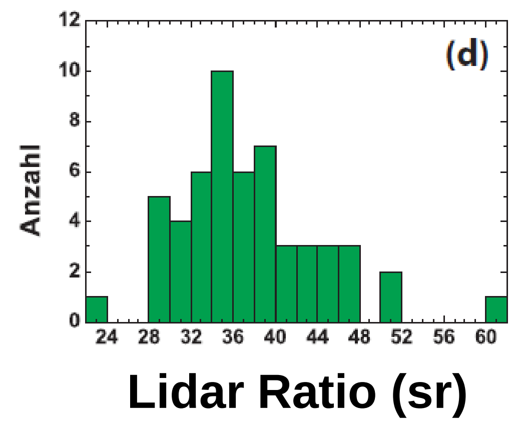
South China





North China

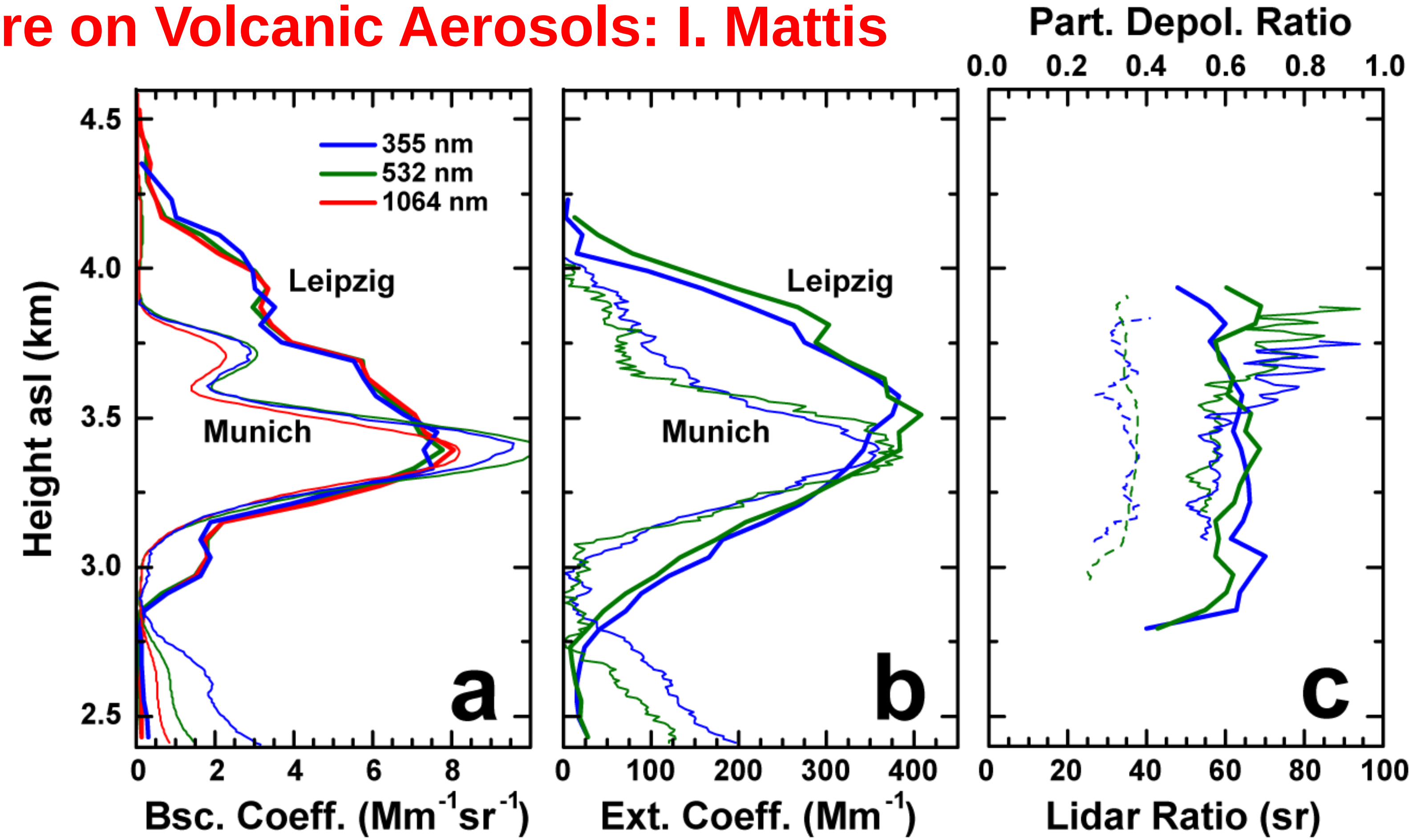




ICELAND: Fresh volcanic ash (younger than 2 days)

Depolarization Ratio as Information Source

More on Volcanic Aerosols: I. Mattis



Matthias Tesche, Albert Ansmann (IfT), Silke Groß, Volker Freudenthaler (MIM)