

# Determination of the extinction-to-backscatter ratio from airborne HSRL and ground-based Raman lidar measurements

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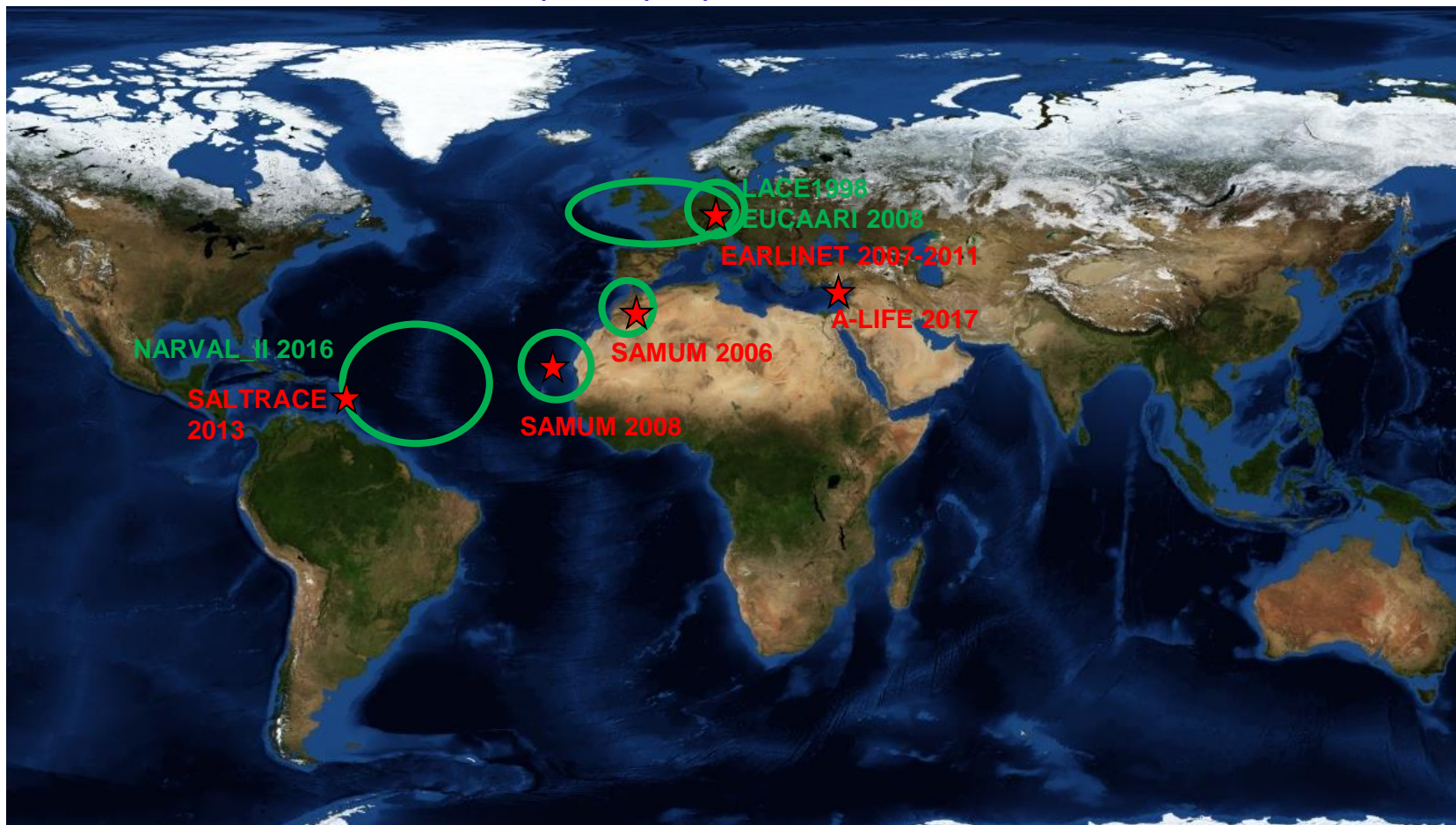
Knowledge for Tomorrow





# Airborne and ground-based lidar measurements

Measurements of aerosol optical properties



→ Ground-based Raman lidar measurement (POLIS/MULIS/POLIS-6 – LMU)

→ Airborne HSRL measurements (WALES – DLR)





# WALES Lidar System

Airborne water vapor DIAL and HSLR, developed and build at DLR-IPA

## Aerosol

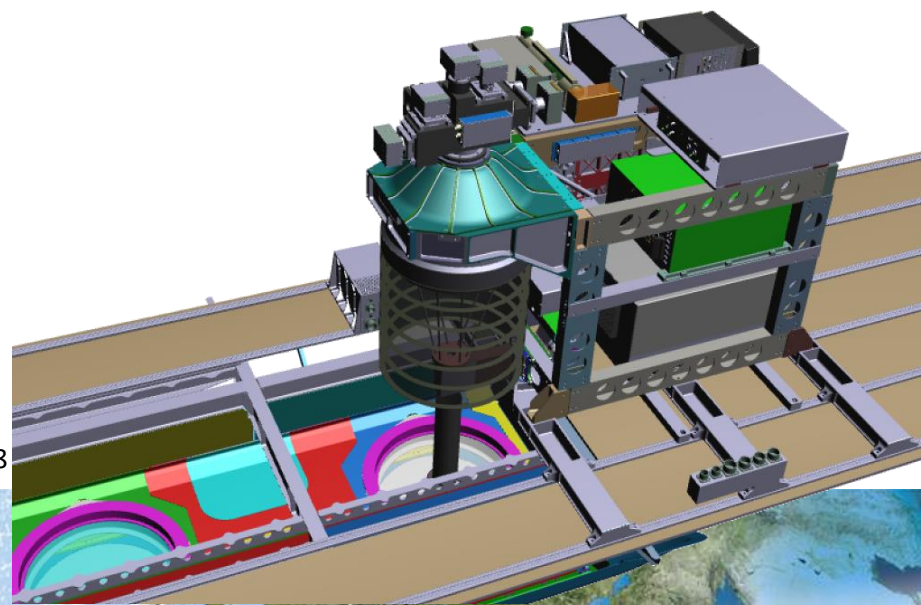
- Backscatter coefficient (532 nm, 1064 nm)
- Color ratio (532 nm/1064 nm)
- Aerosol **depolarization** (532 nm, 1064 nm)
- Aerosol extinction (**532 nm – HSRL**)
- Resolution: range ~15 m, time = 0.2-1s

→ Possibility of aerosol classification

→ In-cloud and outside cloud distribution  
of relative humidity and water vapor

## Water Vapor

- H<sub>2</sub>O mixing ratio  
(4 wavelengths ~935 nm)
- Resolution: range ~ 290m, time = 25s
- Relative humidity (in combination with  
external temperature data)



Wirth et al., 2009; Esselborn et al., 2008



# Small portable 6-channel lidar system POLIS

2006-2013 measurements: combination of POLIS355 and MULIS532



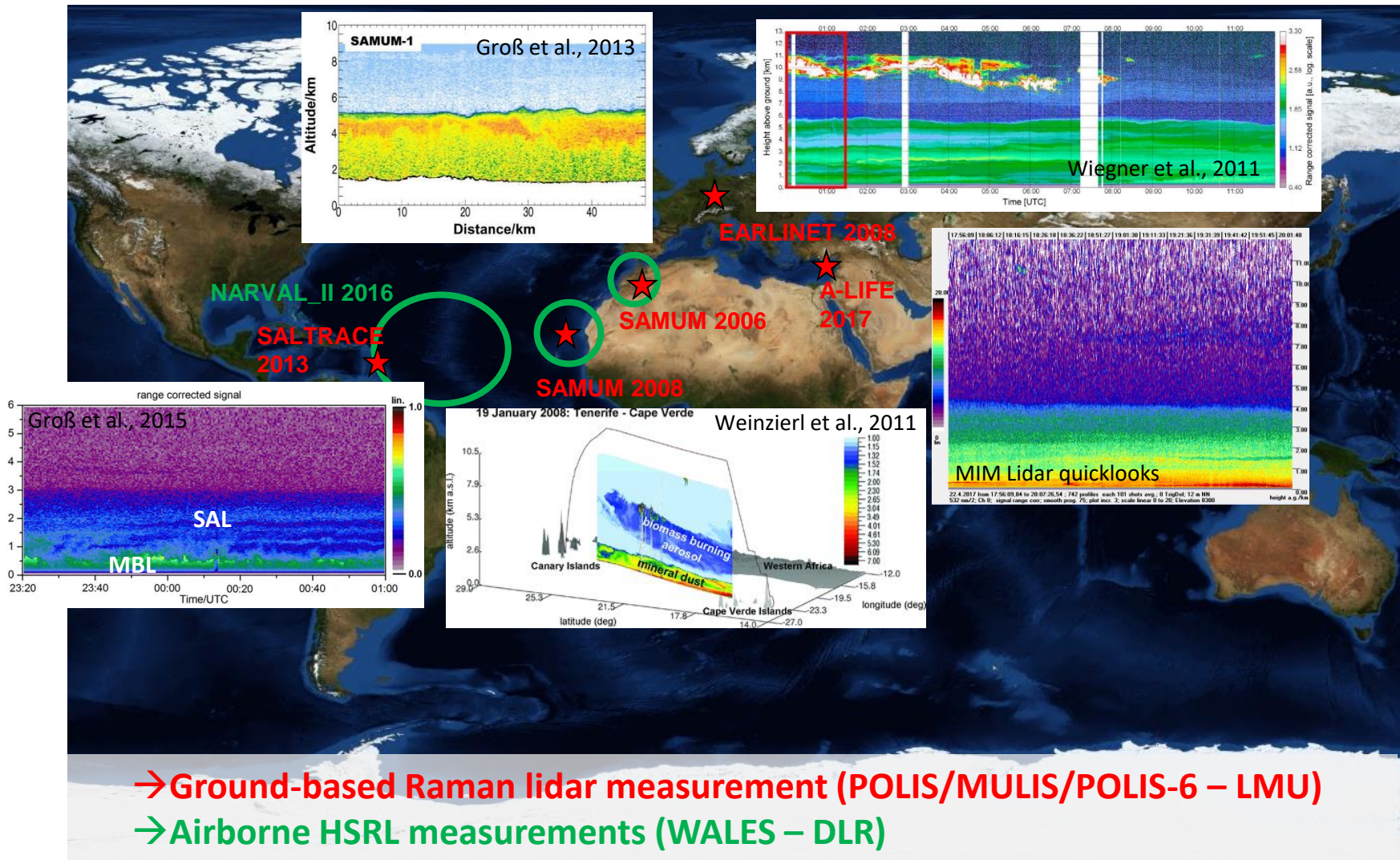
## Instrument Features:

- Developed and constructed at LMU-MIM
- Raman and depolarization measurements (355 nm, 532 nm)
- Aerosol characterization:
  - Profiles of **backscatter coefficient** (355 nm, 532 nm)
  - Profiles of **extinction coefficient** (355 nm, 532 nm)
  - Profiles of **linear depolarization ratio** (355 nm, 532 nm)
  - Angström Exponent and Color Ratio (355nm/532nm)
- Possibility for **aerosol classification**





# Characterization of Saharan mineral dust Measurements of fresh and long-range transported dust



→ Ground-based Raman lidar measurement (POLIS/MULIS/POLIS-6 – LMU)  
 → Airborne HSRL measurements (WALES – DLR)



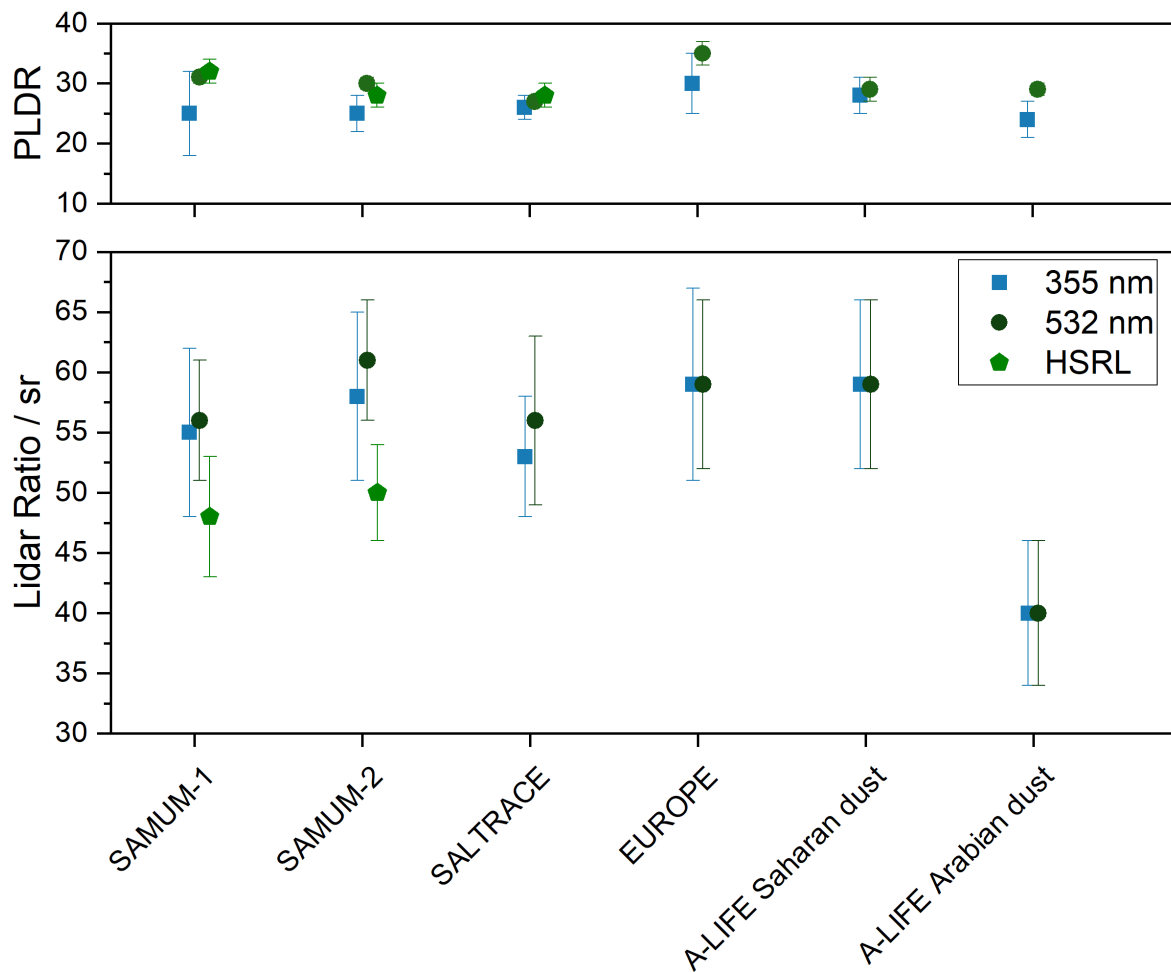
Figure: NASA Visible Earth





# Characterization of Saharan mineral dust

## Measurements of fresh and long-range transported dust



### Lidar ratio Saharan dust:

- Wavelength independent
- between **50 – 60 sr**
- **no changes due to aging / transport**

### Lidar ratio Arabian dust:

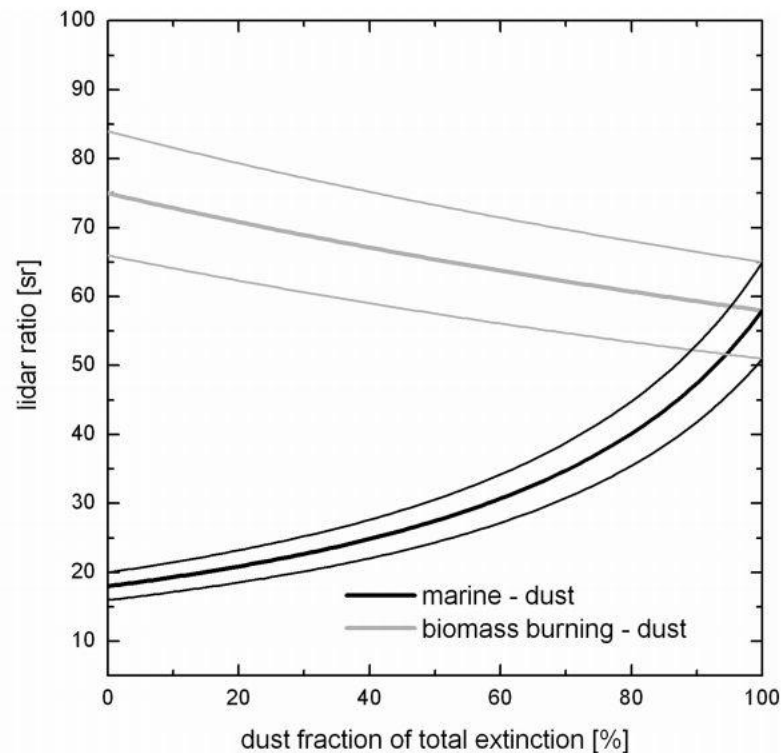
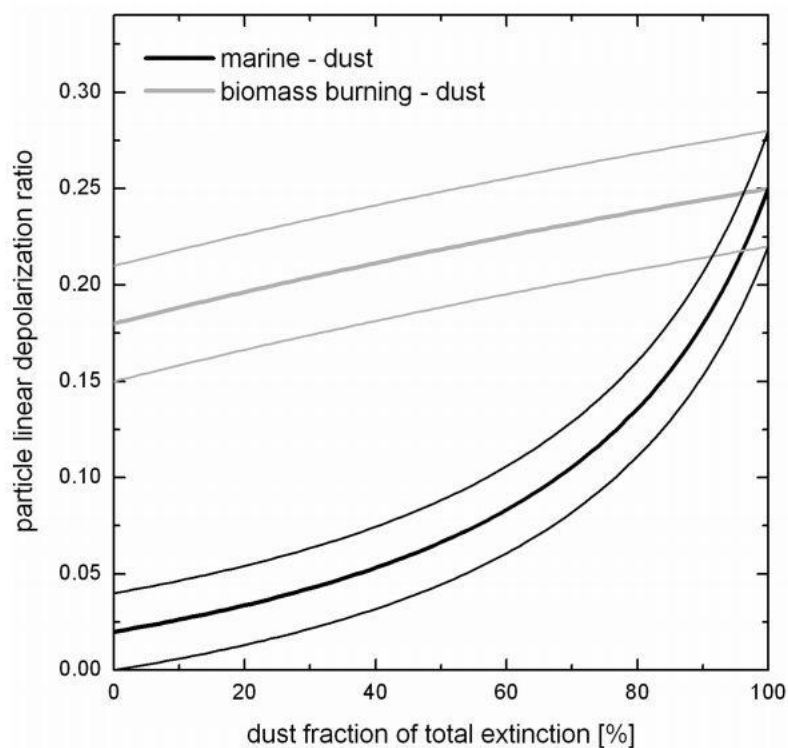
- about **40 sr**
- Smaller than for Saharan dust





# Optical properties in Saharan dust mixtures

Determination of intensive optical properties depending on mixing state



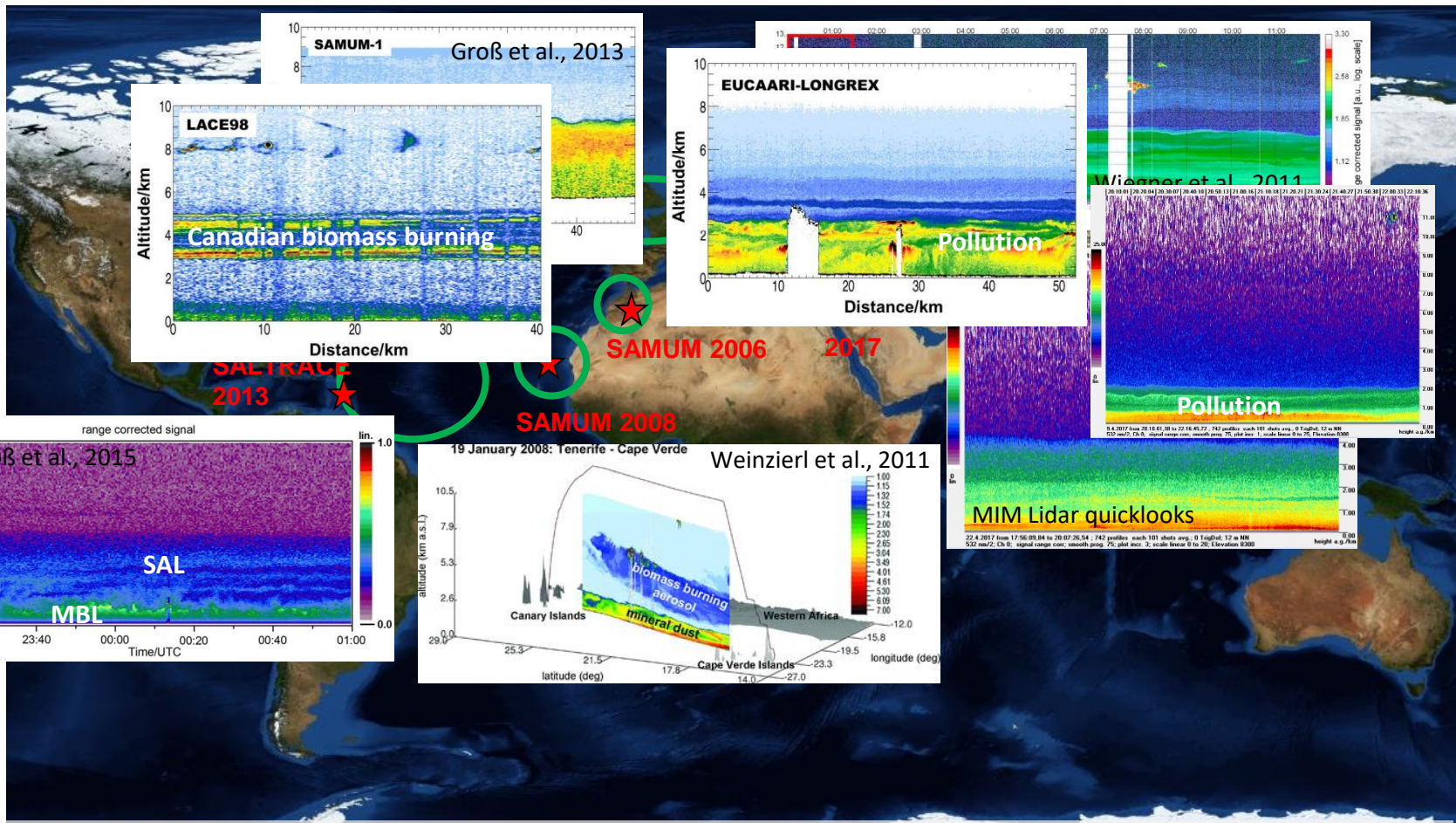
- Intensive optical properties depend on mixing ratio of dust and other aerosols
- Mixing ratio can be calculated from lidar derived optical properties





# Characterization of major atmospheric aerosol types

## Measurements of aerosol optical properties



- Ground-based Raman lidar measurement (POLIS/MULIS/POLIS-6 – LMU)
- Airborne HSRL measurements (WALES – DLR)



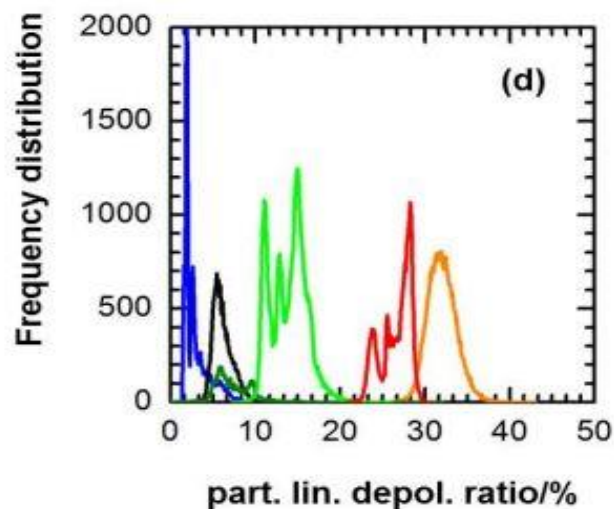
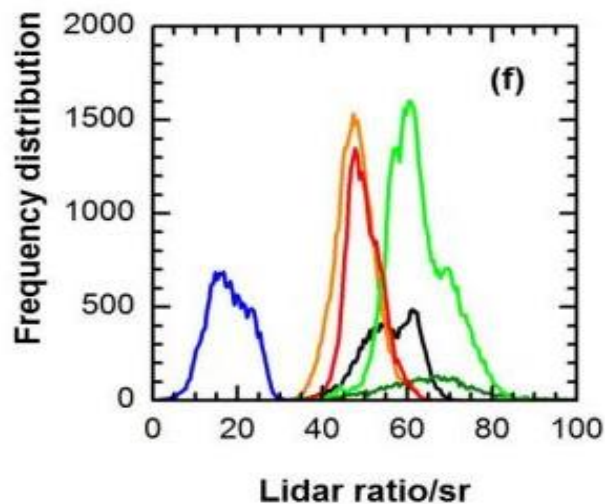
Figure: NASA Visible Earth



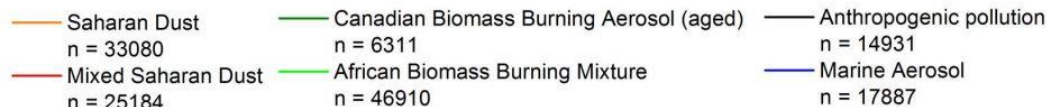


# Aerosol characterization with airborne HSRL

## Intensive optical properties of different aerosol types



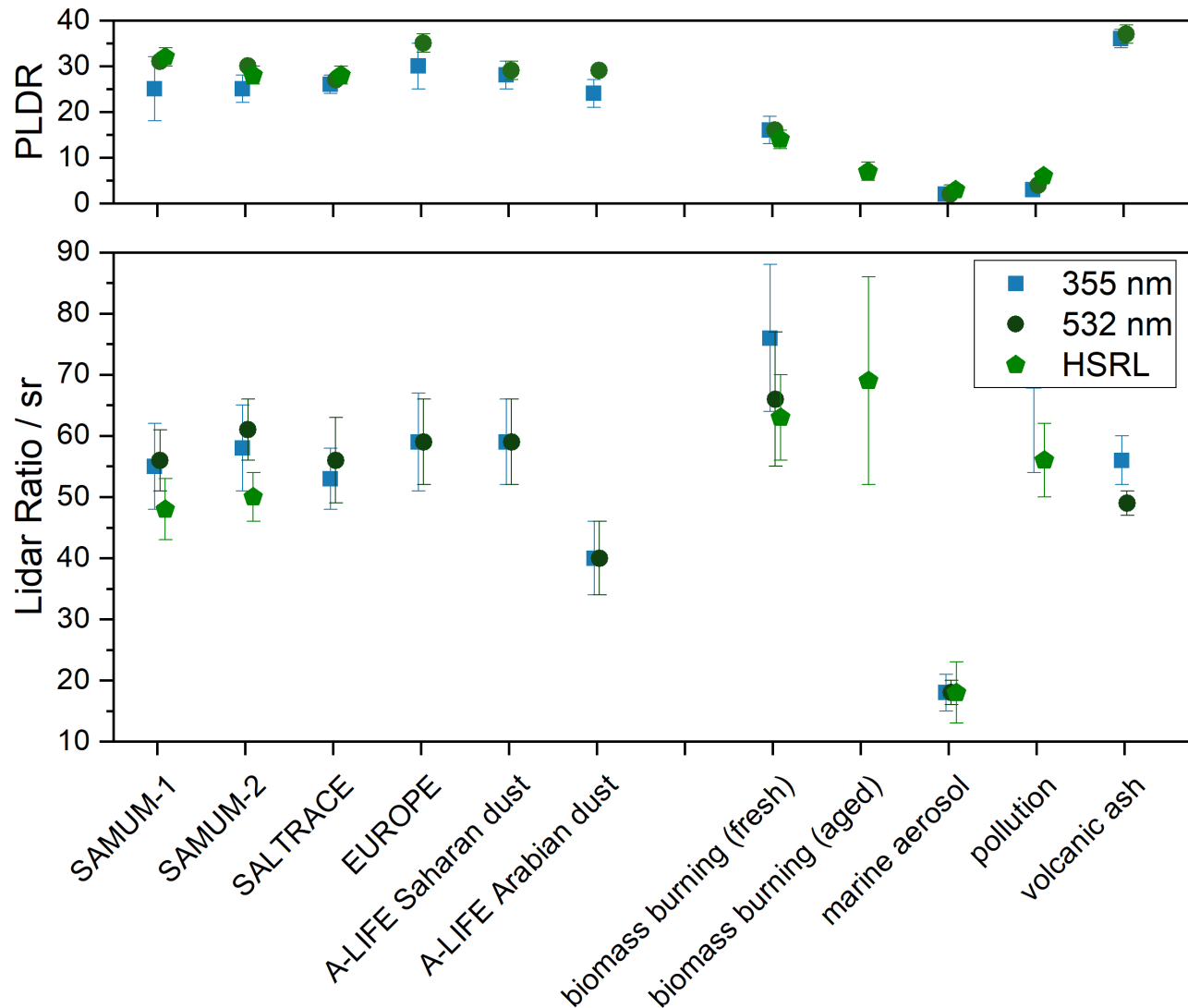
Aerosol Type	mean $\pm$ stdv	value of maximum frequency
aerosol lidar ratio [sr] at 532 nm		
Saharan dust	$48 \pm 5$	47 (1538)
mixed Saharan dust	$50 \pm 4$	48 (1348)
biomass burning mixture (Africa)	$63 \pm 7$	60 (1601)
biomass burning aerosol (Canada)	$69 \pm 17$	61 (485)
marine aerosol (North Atlantic)	$18 \pm 5$	18 (687)
anthropogenic pollution aerosol (Europe)	$56 \pm 6$	61 (485)
particle linear depolarization ratio [%] at 532 nm		
Saharan dust	$32 \pm 2$	32 (806)
mixed Saharan dust	$27 \pm 2$	28 (1034)
biomass burning mixture (Africa)	$14 \pm 2$	15 (1245)
biomass burning aerosol (Canada)	$7 \pm 2$	6 (188)
marine aerosol (North Atlantic)	$3 \pm 1$	2 (2596)
anthropogenic pollution aerosol (Europe)	$6 \pm 1$	6 (686)





# Intensive optical properties of different aerosol types

Combining airborne and ground-based measurements

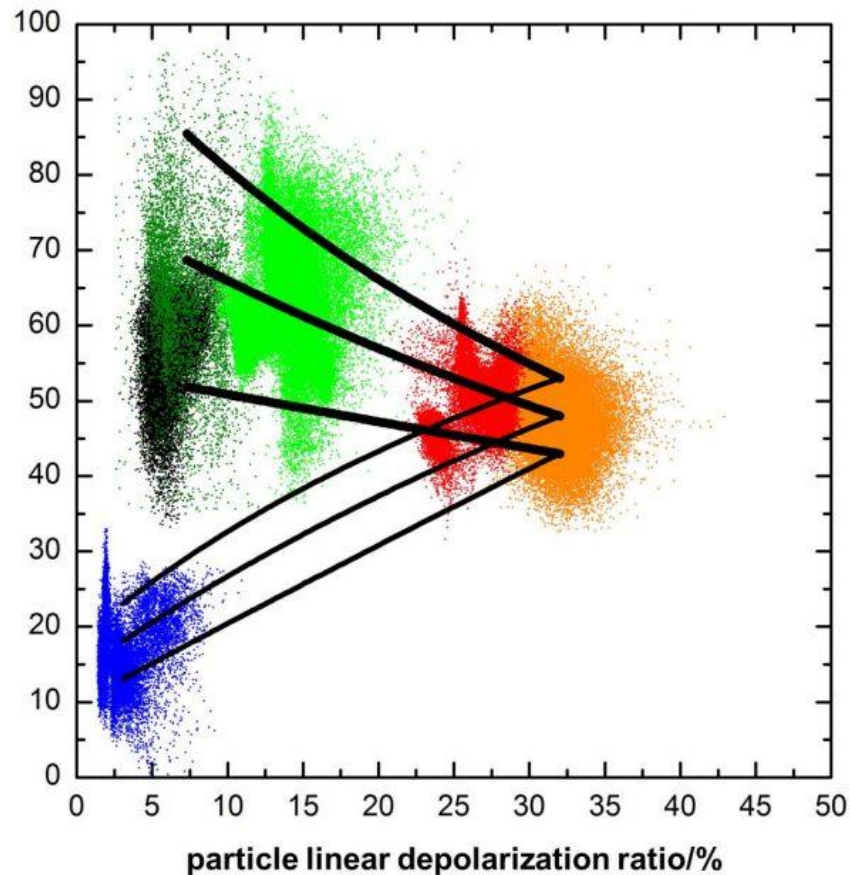
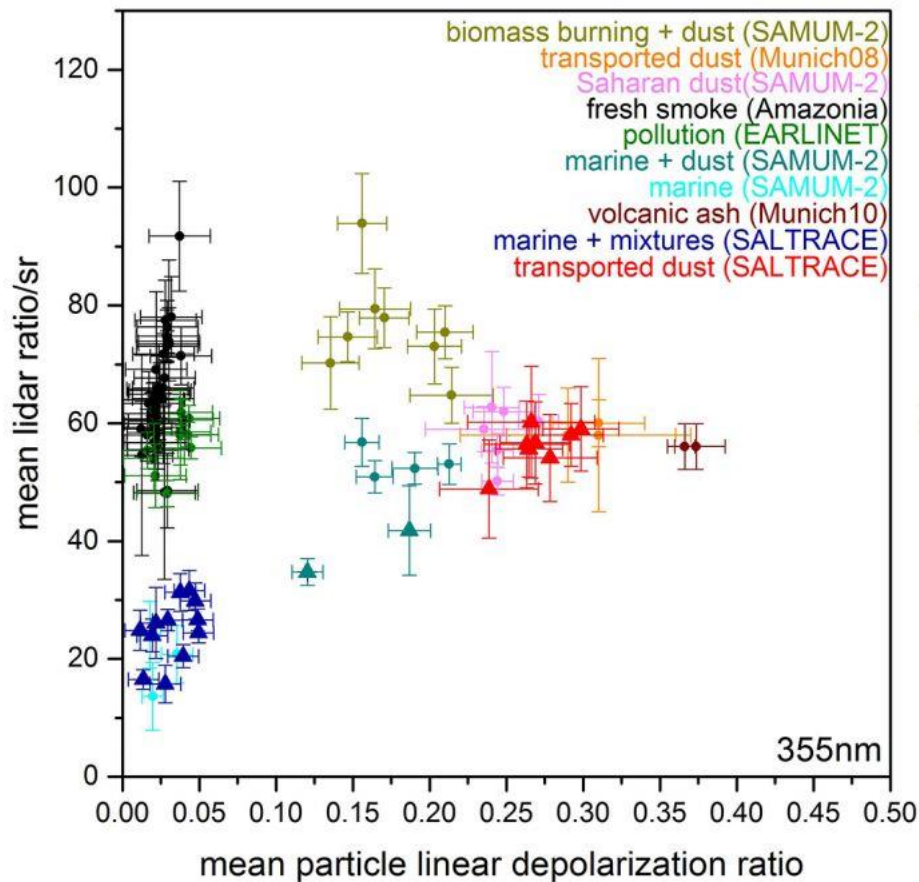


Freudenthaler et al., 2009; Groß et al., 2011; Wiegner et al., 2011; Groß et al., 2013; Groß et al., 2015



# Classification of different aerosol types and mixtures

Combination of intensive aerosol properties



- Saharan dust
- Canadian Biomass Burning (aged)
- Anthropogenic pollution
- mixed Saharan dust
- African Biomass Burning mixture
- Marine Aerosol





## Summary

- **Ground-based Raman lidar** and **airborne HSRL** measurements have been performed to **characterize optical properties of different aerosol types**
- **Mineral dust** was studied at **different stages of long-range transport** and under different mixing conditions
  - Long-range transport does **not show a significant impact on intensive optical properties**
  - **Lidar ratio of Arabian dust lower than lidar ratio of Saharan dust**
- Intensive optical properties **different for different aerosol types**
  - Possibility for **aerosol type classification**

