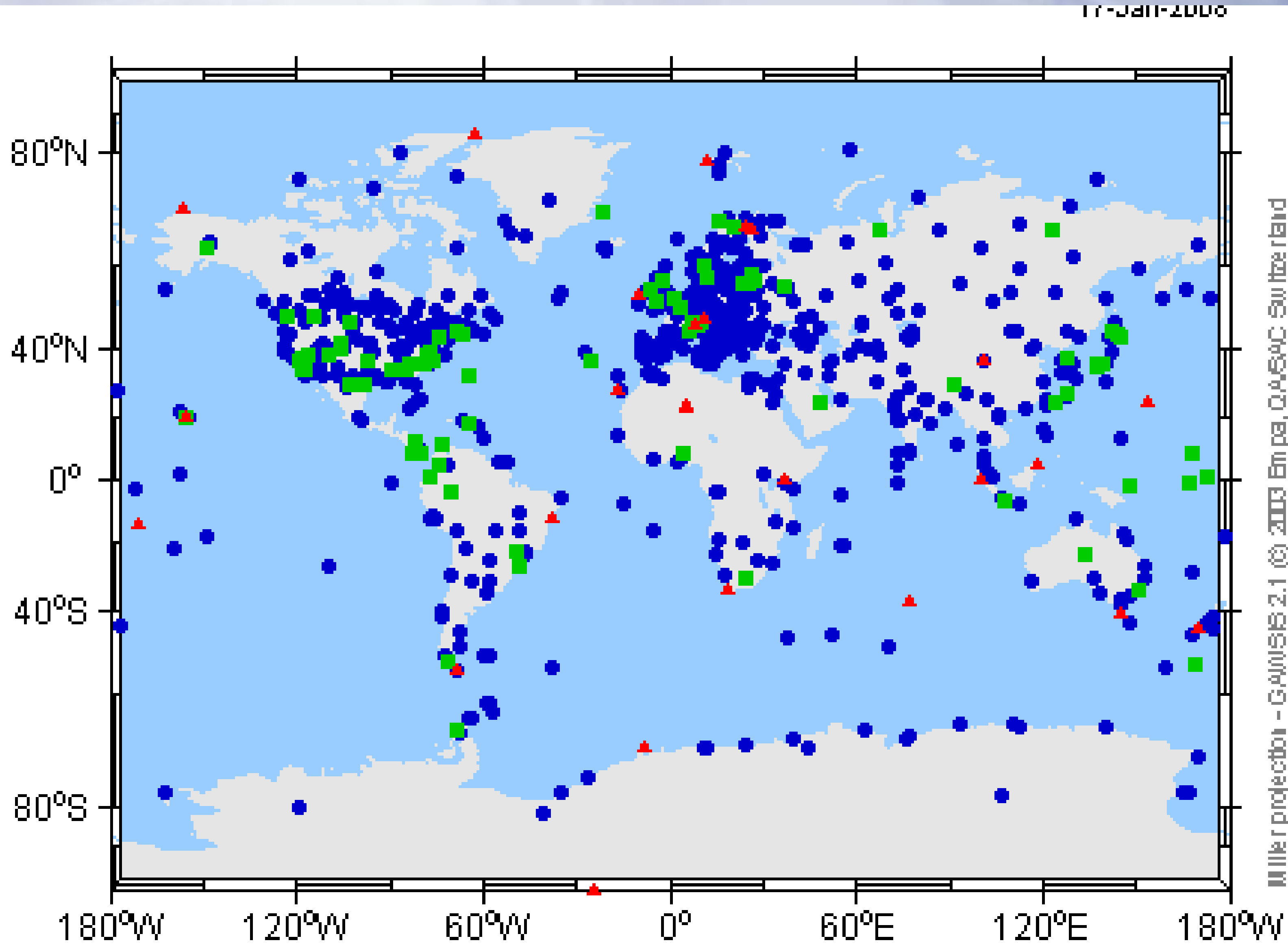
Optical Properties: The Global Atmosphere Watch (GAW) Aerosol Lidar Observation Network (GALION): Issues Involved with Obtaining Precise Optical Extinction Profiles for Climate Records

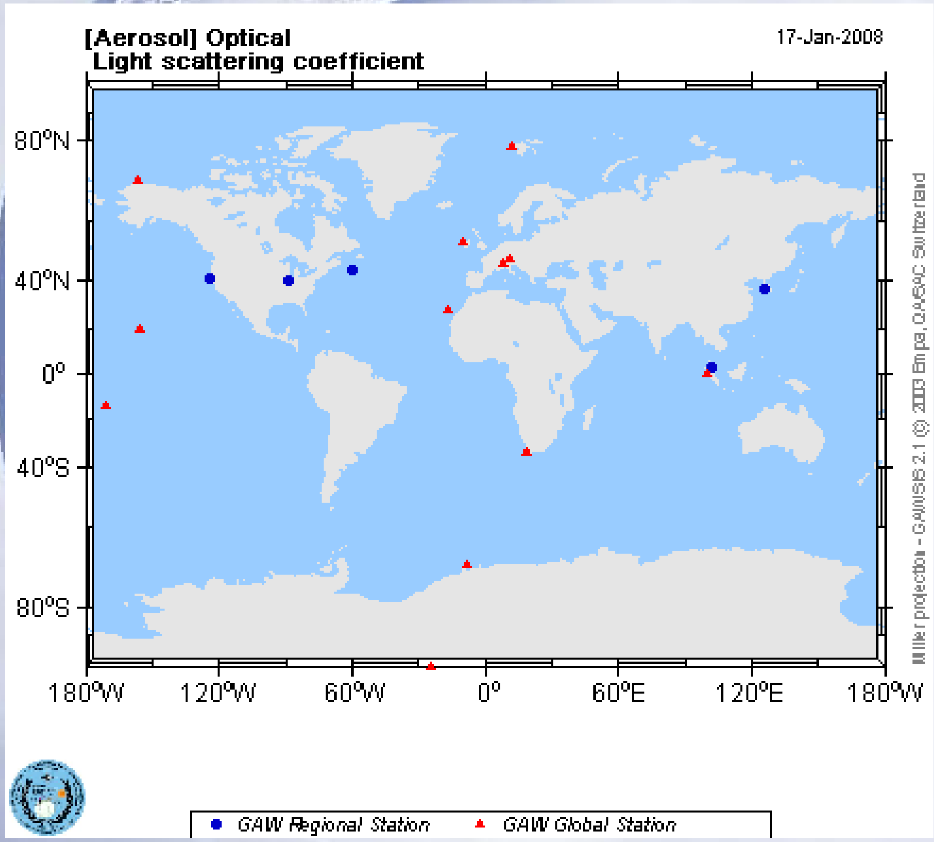
Raymond Hoff

Gelsomina Pappalardo

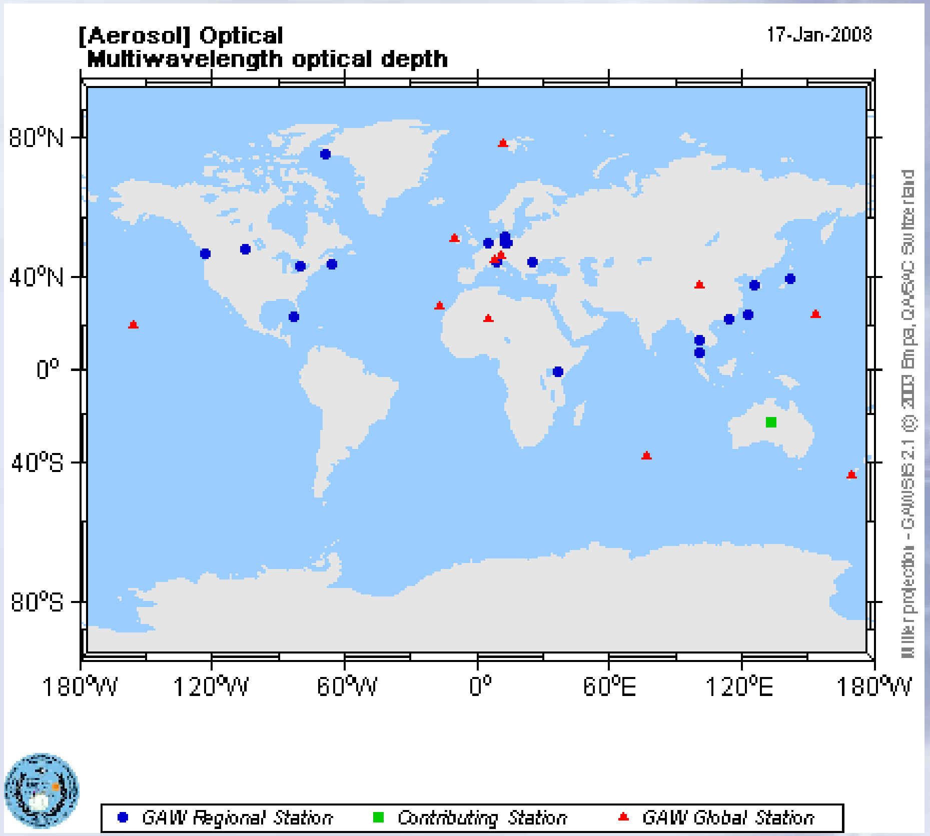


GAW Regional Station · Contributing Station · GAW Global Station

AEROSOL:
Light scattering coefficient



AEROSOL:
AOD



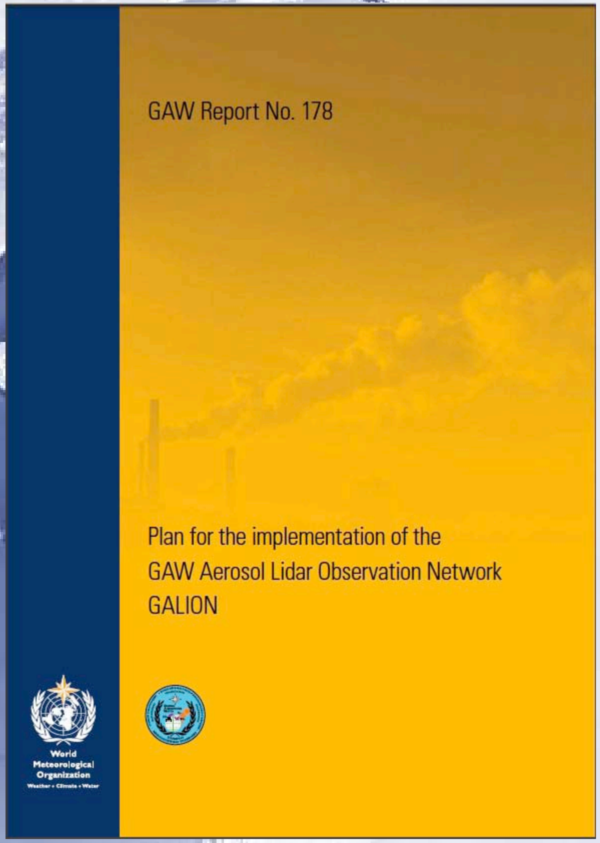
Early GAW conclusions

- GAW was bound to the surface
- Global climatologies are difficult without involving satellite measurements
- Correspondence with satellite measurements require understanding of the column and require precision AOD
- AOD measurements are difficult to understand without the aerosol profile

Objectives for GALION Supports Task 7.84 of GAW IP

- *1.* Detection of long-term man-made trends in the concentration of greenhouse gases and aerosols
- *2.* Better environmental assessments
- *3.* Better quantification of pollution sources and their atmospheric pathways
- *4.* Reliable global concentration fields
- *5.* Better prediction of UV intensities
- *6.* Direct observation of plumes from major events
- *7.* Improved regional forecasts of both weather and air quality

GAW Aerosol Lidar Observation Network (GALION)

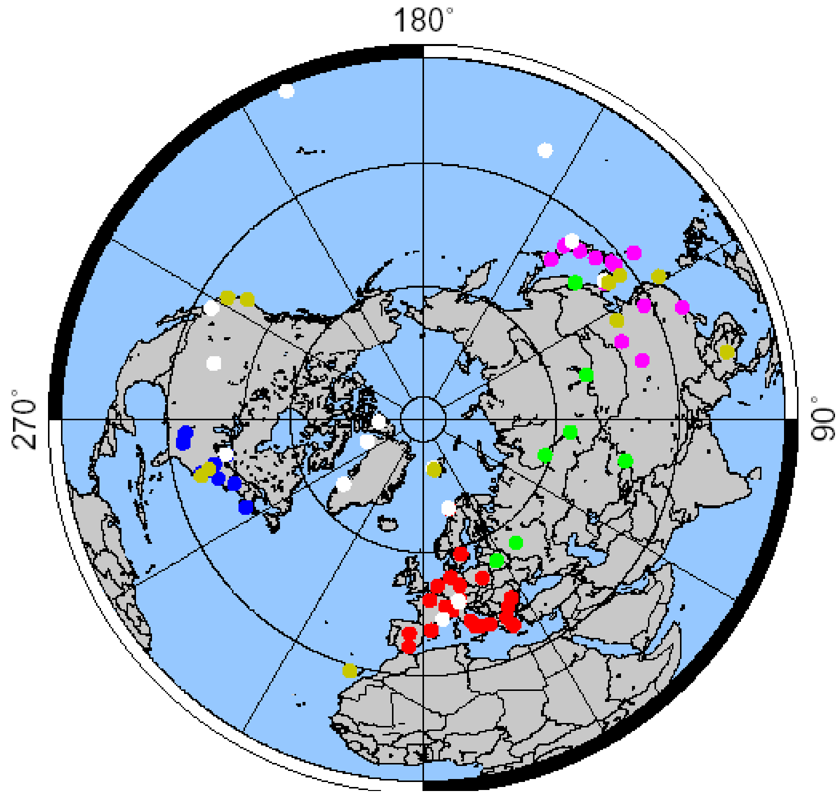


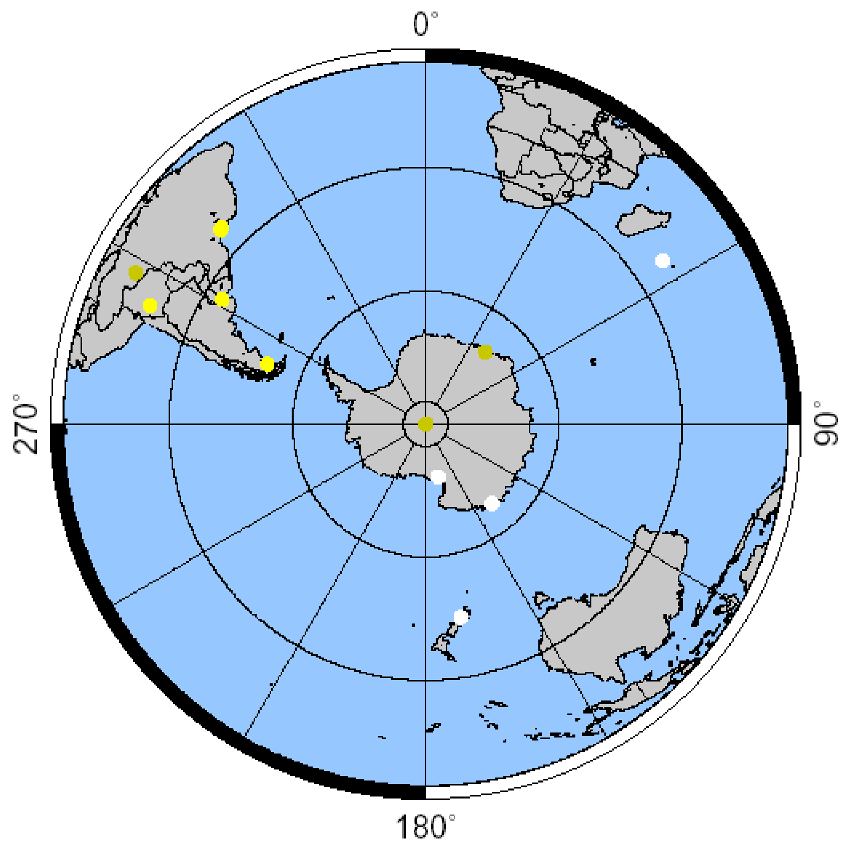
2010
Geneva

ftp://ftp.wmo.int/Documents/PublicWeb/arep/gaw/gaw178-galion-27-Oct.pdf

http://www.wmo.int/gaw/galion/

Distribution of stations





- ALINE, Latin America
- AD-Net, East Asia
- CIS-LINET, Commonwealth of Independent States
- EARLINET, Europe
- NDACC, Global Stratosphere
- CLN, Eastern North America
- MPLNET, Global, Micropulse Lidar

Conceptually GALION fits GEOSS since it is a Network of Networks and GAW is GEOSS

AEROSOL PROPERTIES

Table 3.1-2: Aerosol properties that can be derived from lidar observations. Only the simpliest lidar type that is needed to provide the product is listed. Depolarization channels (DEPOL) are required to identify desert dust.

Parameter (product)	**Basic lidar type**
Range corrected signal (color plots of aerosol and cloud distributions)	BL
Attenuated backscatter coefficient (calibrated range-corrected signal)	BL
PBL depth	BL
Aerosol backscatter coefficient	BL
Aerosol type discrimination (dust, anthropogenic)	BL+DL
Aerosol extinction coefficient (estimate), optical depth, column lidar ratio	BL+SPM
Aerosol extinction coefficient, optical depth, lidar ratio	RL or HSRL
Ångström exponent (backscatter-related)	MBL
Ångström exponent (extinction-related)	MRL
Aerosol type determination (dust, maritime, fire smoke, urban haze)	MRL+DL
Aerosol microphysical properties (volume and surface conc., refractive index)	MRL
Single scattering albedo (aerosol)	MRL

MEASUREMENTS POSSIBLE

Observational configuration	Bsc. cf.	Ext cf.	Lidar ratio	Opt. depth	Ang. exp.	Microphys
1-λ standard backscatter lidar	β(z)					
1-λ standard backscatter lidar + Sun photometer	β(z),	σ(z) estimate	LR(col)	δ(λ,col)	$Å_δ$(col)	MPP(col)
m-λ standard backscatter lidar	β(λ,z)				$Å_β$(z)	
m-λ standard backscatter lidar + Sun photometer	β(λ,z)	σ(λ,z) estimate	LR(λ,col)	δ(λ,col),	$Å_β$(z), $Å_δ$(col)	MPP(col)
1-λ Raman lidar/HSRL	β(z)	σ(z)	LR(z)	δ(z)		
1-λ Raman lidar/HSRL + Sun photometer	β(z),	σ(z)	LR(z)	δ(z), δ(λ,col),	$Å_δ$(col)	MPP(col)
m-λ Raman lidar	β(λ,z)	σ(λ,z)	LR(λ,z)	δ(λ,z)	$Å_β$(z), $Å_σ$(z)	MPP(z)
m-λ Raman lidar + Sun photometer	β(λ,z)	σ(λ,z)	LR(λ,z)	δ(λ,z), δ(λ,col)	$Å_β$(z), $Å_σ$(z), $Å_δ$(col)	MPP(z), MPP(col)

Which type of lidar is necessary and sufficient to obtain the most important aerosol parameters is described in Table 3.2-2, ordered according to increasing instrument and retrieval complexity. Tables 3.2-1 and 3.2-2 form the basis for the decisions to be made for the selection of instruments for the different purposes of the network operation.

Elastic lidar (eg. MPLNET)

$$P(r) = P_o \frac{C}{r^2} \cdot O(r) \cdot \beta_\pi(r) \cdot e^{-2\cdot\int_0^r \alpha(r')dr'} + P_b$$

Backscatter crosssection (m^{-1} sr^{-1})

Extinction crosssection (m^{-1})

S (sr)

$$\tau = \int_0^\infty \alpha(r')dr$$

Colocated Sunphotometer

(Multi λ) Raman Lidar

$$\alpha_a^{v_L}(r) = \frac{\dfrac{d}{dr}\ln\dfrac{N(r)}{(P\cdot r^2)} - \alpha_m^{v_L}(r)\left\{1+\left(\dfrac{\lambda_L}{\lambda_R}\right)^{-4}\right\}}{1+\left(\dfrac{\lambda_L}{\lambda_R}\right)^{-\mathring{A}}}$$

All the required parameters can be measured with a N_2 Raman lidar
(with a small assumption for the 355-387 nm Angstrom coefficient

High Spectral Resolution Lidar (HSRL) Technique (Iodine Vapor Filter Implementation)

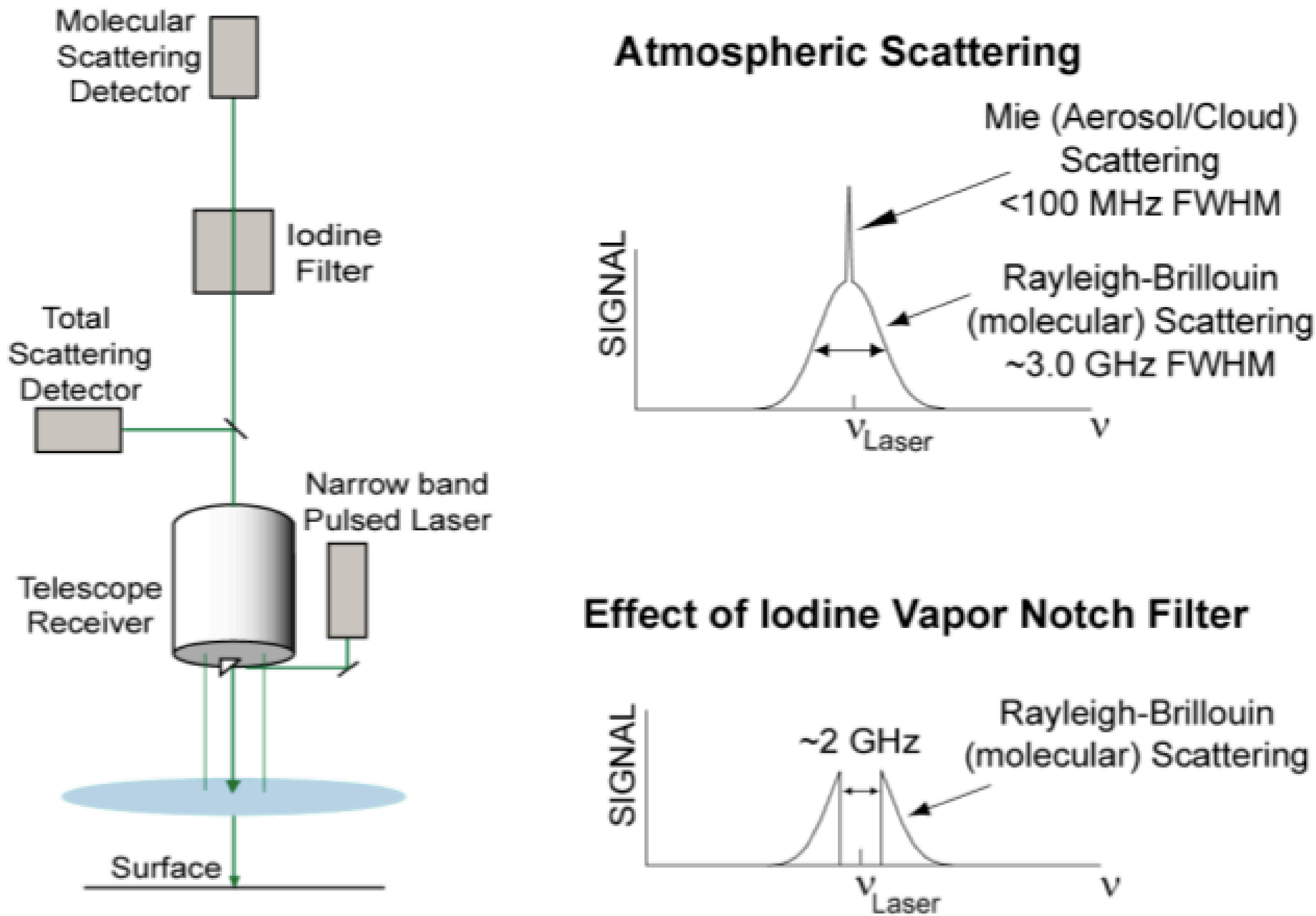


Figure courtesy Aerosols-Clouds-Ecosystems Mission (ACE)

High Spectral Resolution Lidar

$$P^m(r) = P_o \frac{C}{r^2} \cdot \beta_\pi^m(r) \cdot e^{-2\cdot\int_0^r \alpha(r')\,dr'}$$

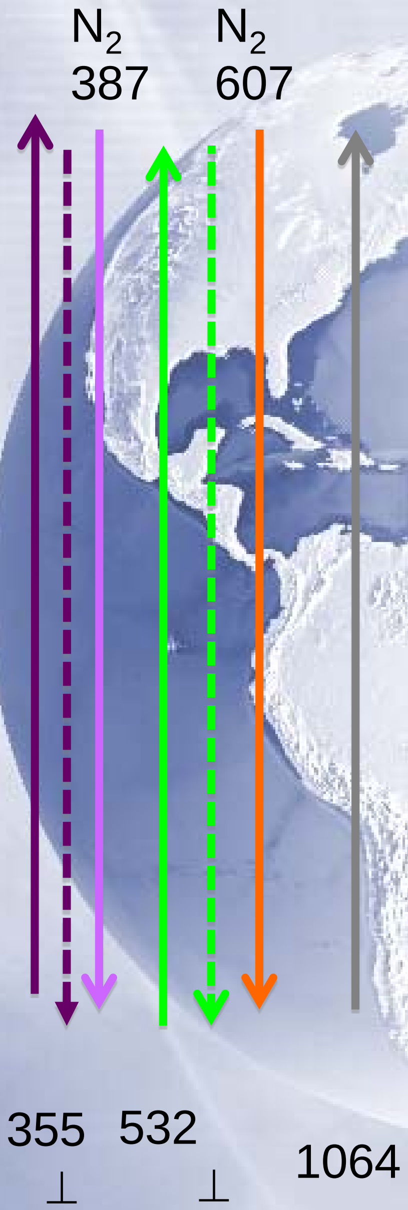
$$P^a(r) = P_o \frac{C'}{r^2} \cdot \beta_\pi^a(r) \cdot e^{-2\cdot\int_0^r \alpha(r')\,dr'}$$

$$S_m = \frac{P_m(r) r^2}{P_o}$$

$$\tau(r) - \tau(r_o) = \frac{1}{2}\ln\left(\frac{\rho(r)}{\rho(r_o)}\right) - \frac{1}{2}\ln\left(\frac{S_m(r)}{S_m(r_o)}\right) = \overline{\alpha}\cdot(r - r_o)$$

State of the art in lidar aerosol metrology

3β+2α+2δ (to come HSRL)



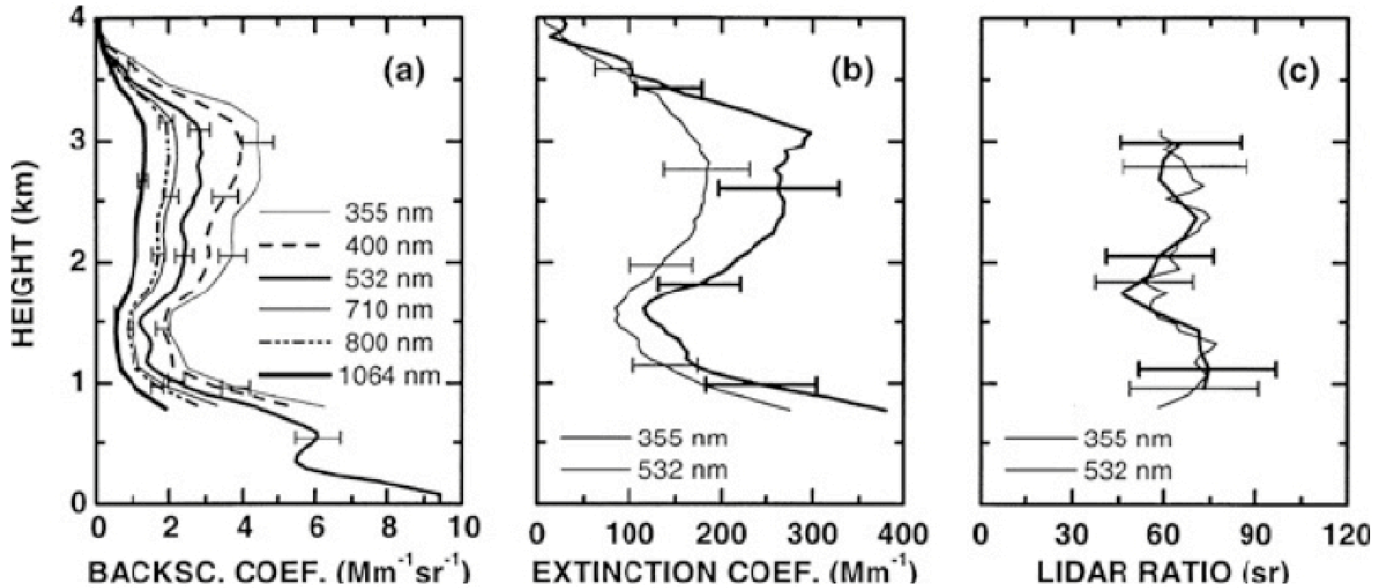


Fig. 4.2. Profiles of (a) backscatter and (b) extinction coefficient, and (c) lidar ratio measured on March 25, 1999 [105]. Error bars denote standard deviations caused by signal noise and systematic errors resulting from the estimates of input parameters. Because of large uncertainties introduced by the overlap effect and detector problems at 355 nm only the 532-nm backscatter profile is trustworthy down to the ground.

From Ansmann and Müller in Weitkamp (2005)

Aerosol microphysics

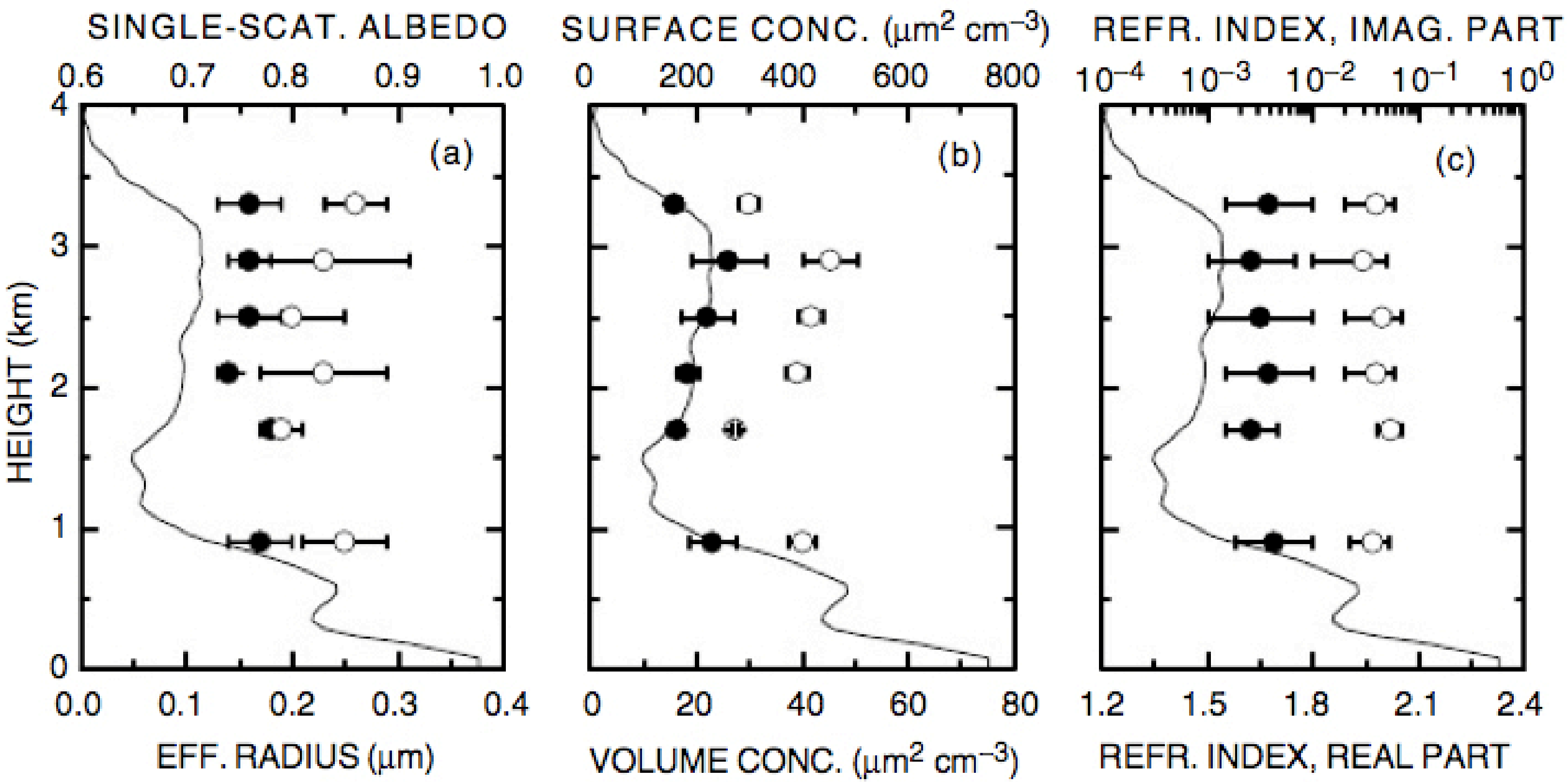
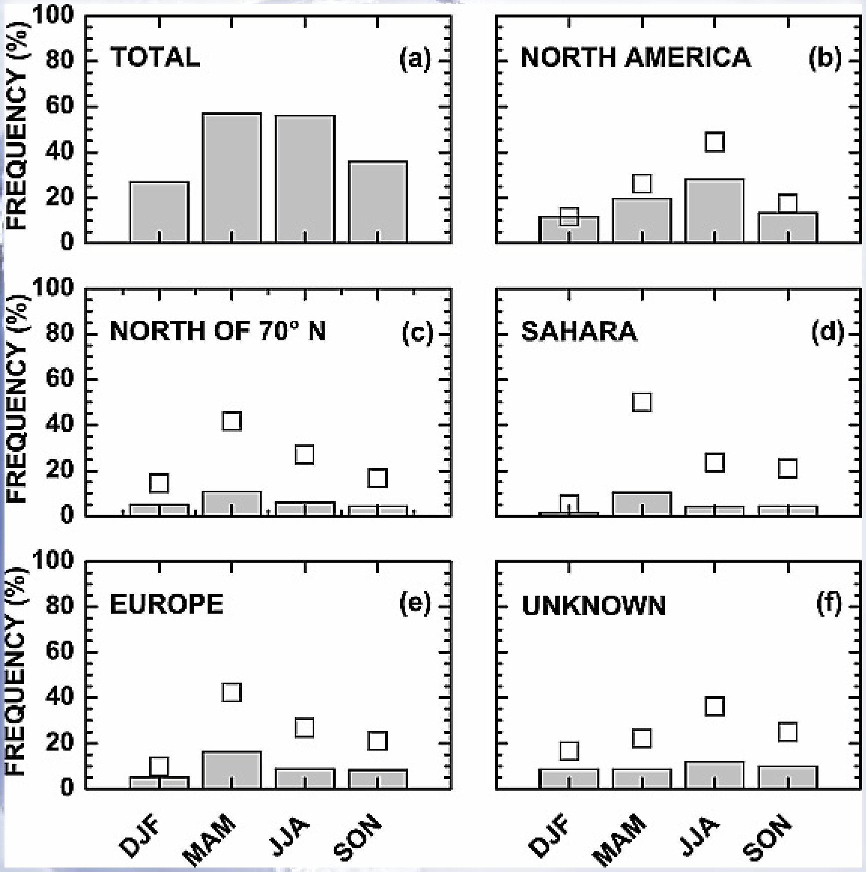


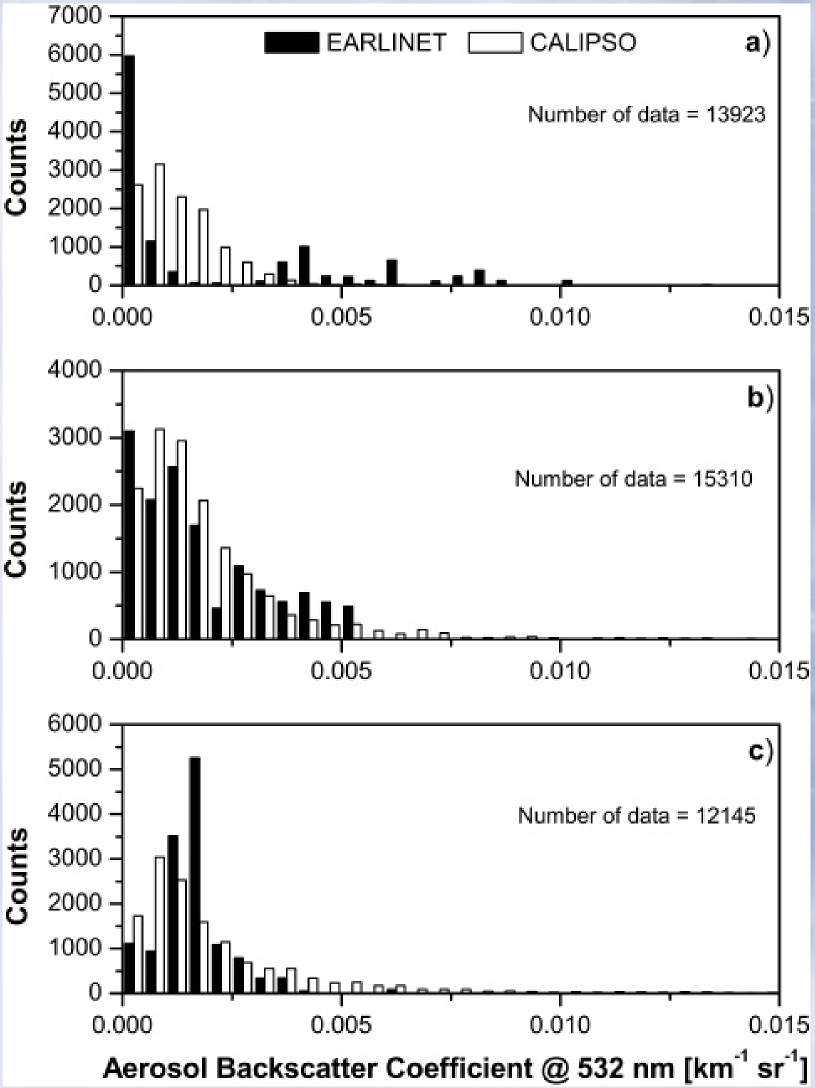
Fig. 4.3. Profiles of (a) effective radius (●) and single-scattering albedo (○), (b) volume concentration (●) and surface-area concentration (○), and (c) mean values of the real (●) and imaginary part (○) of the complex refractive index [106, 107]. The error bars for the particle size parameters indicate the standard deviation. For the inversion the profiles were averaged across layers of 400 m thickness. The solid curve in each of the

Climatologies

Free tropospheric layers over Europe

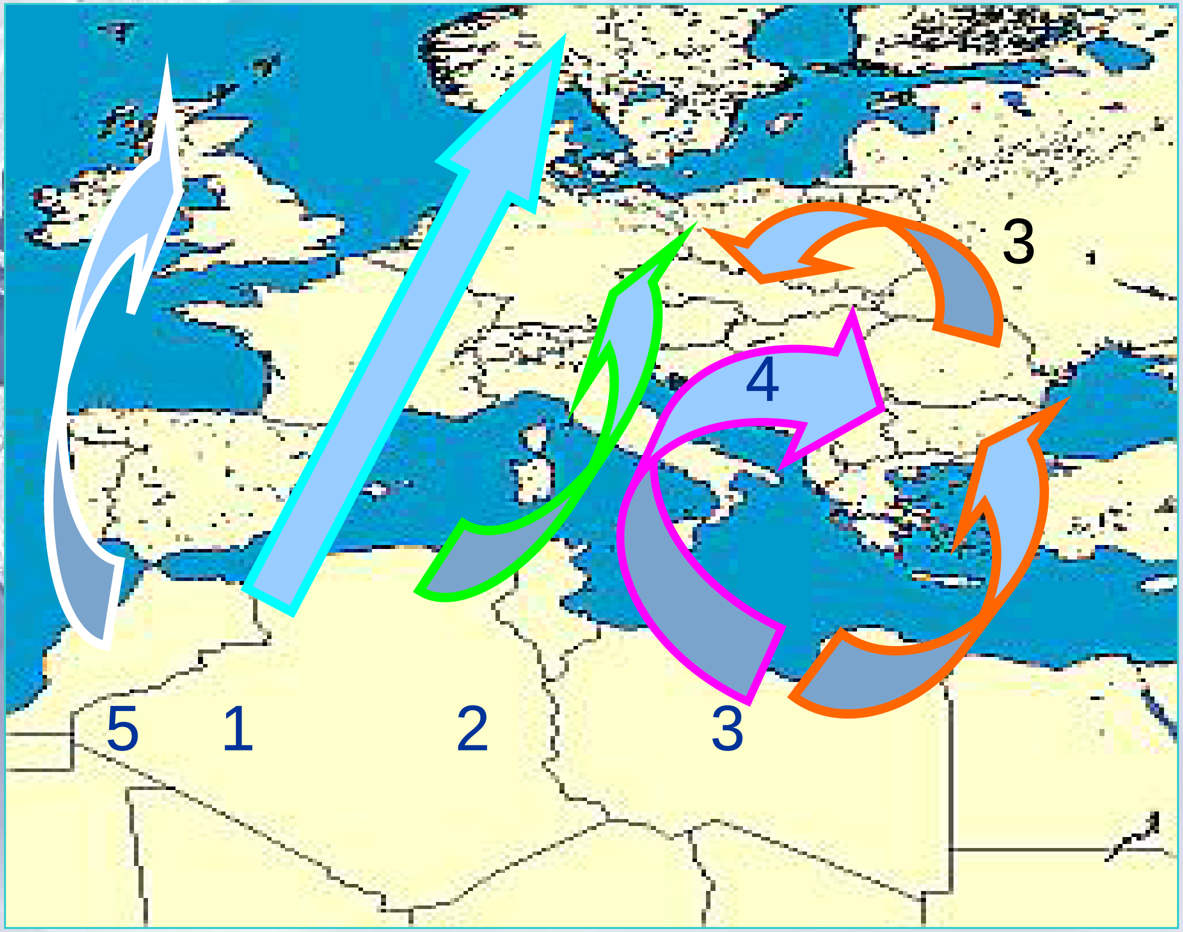


Mattis et al, 2008



Pappalardo et al, 2010

DUST: Earlinet Assessment of Possible Pathways of Saharan Dust Transport over Europe (see A. Pappayanis, L. Mona papers in GALION Workshop)



1: ~20 %

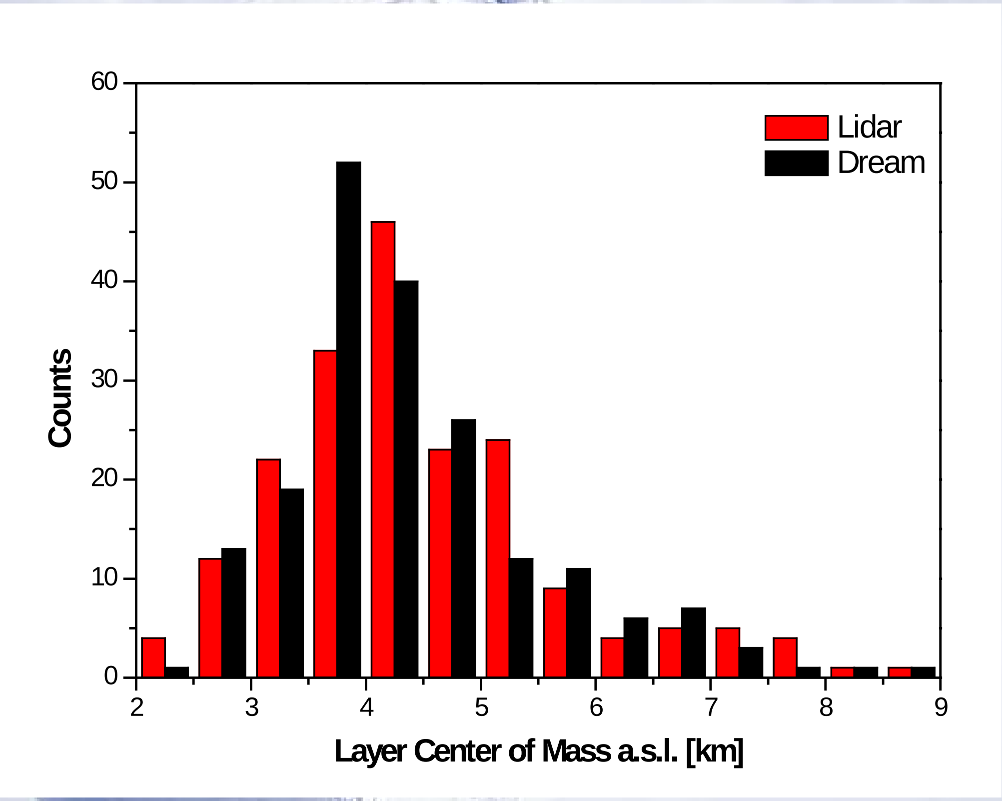
2: ~ 35 %

3: ~ 30 %

4: ~ 5 %

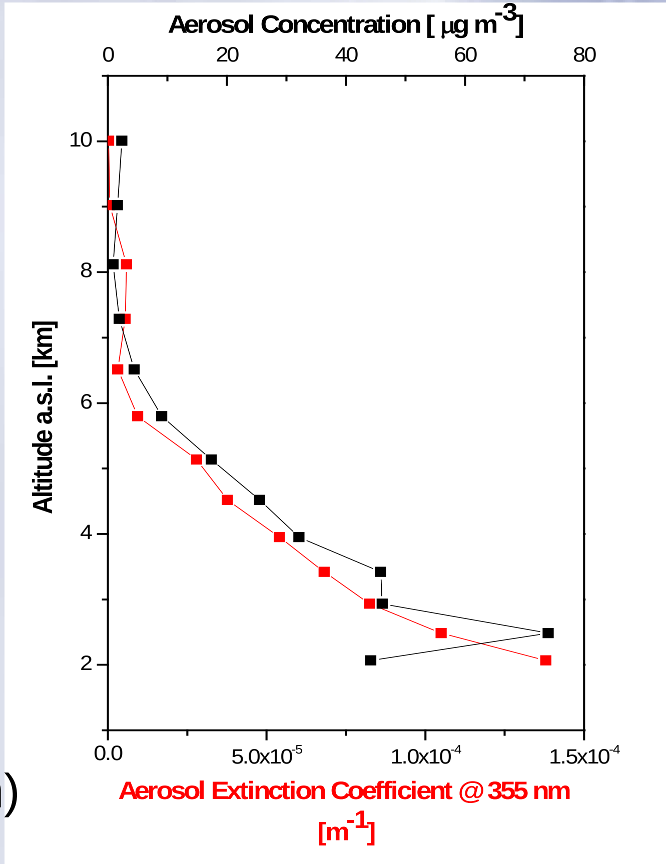
5: ~ 10 %

DREAM Model (May 2000-April 2005) – Potenza station

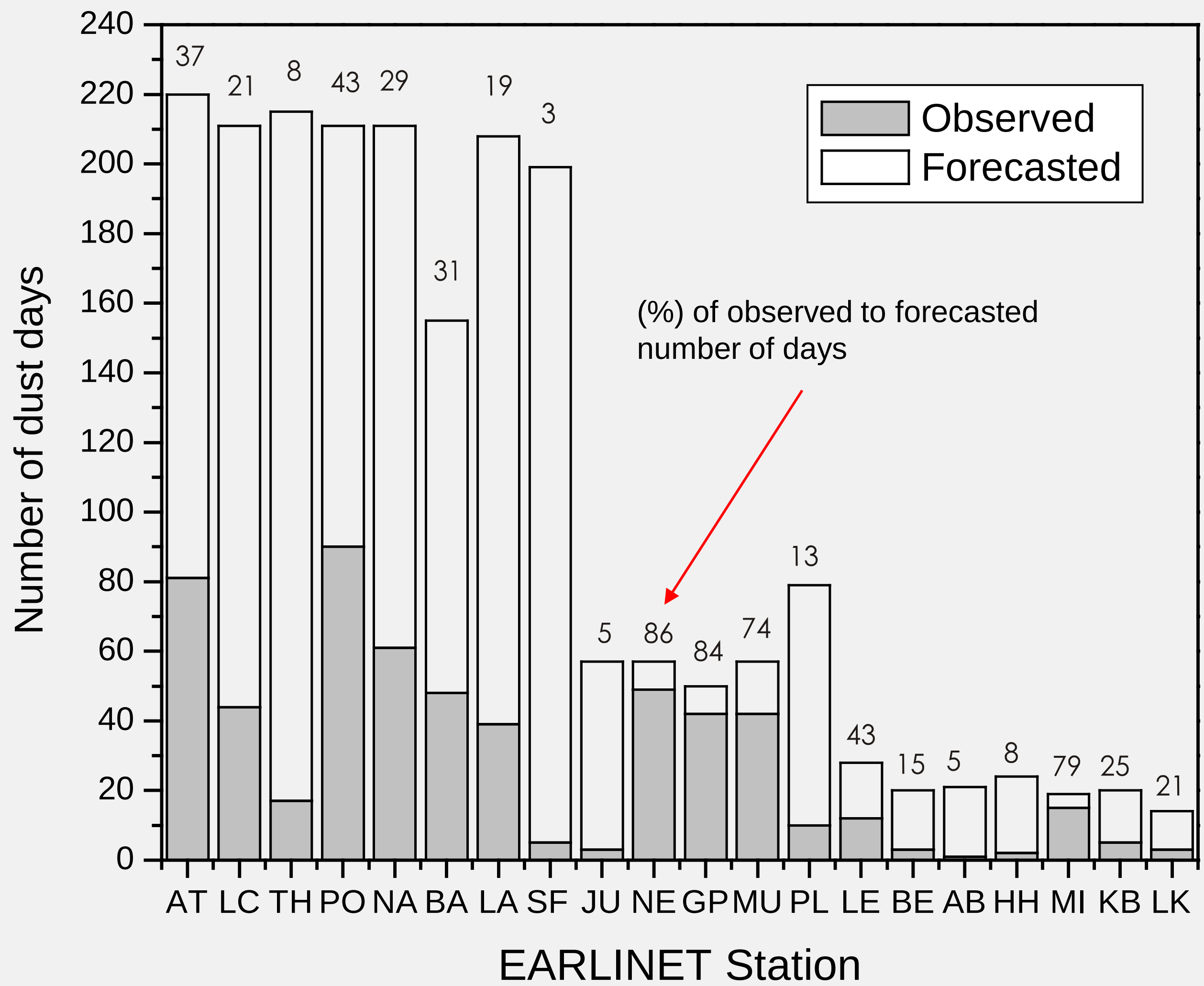


Center of Mass (CoM)

$CoM_{Lidar} = (4.5 \pm 1.2)$ km
$CoM_{Dream} = (4.4 \pm 1.1)$ km



Aerosol concentration-Aerosol extinction (355 nm)



Papayannis et al., *J. Geophys. Res.*, 113, D10204, doi:10.1029/2007JD009028, 2008

ARM Raman Lidar (CARL)

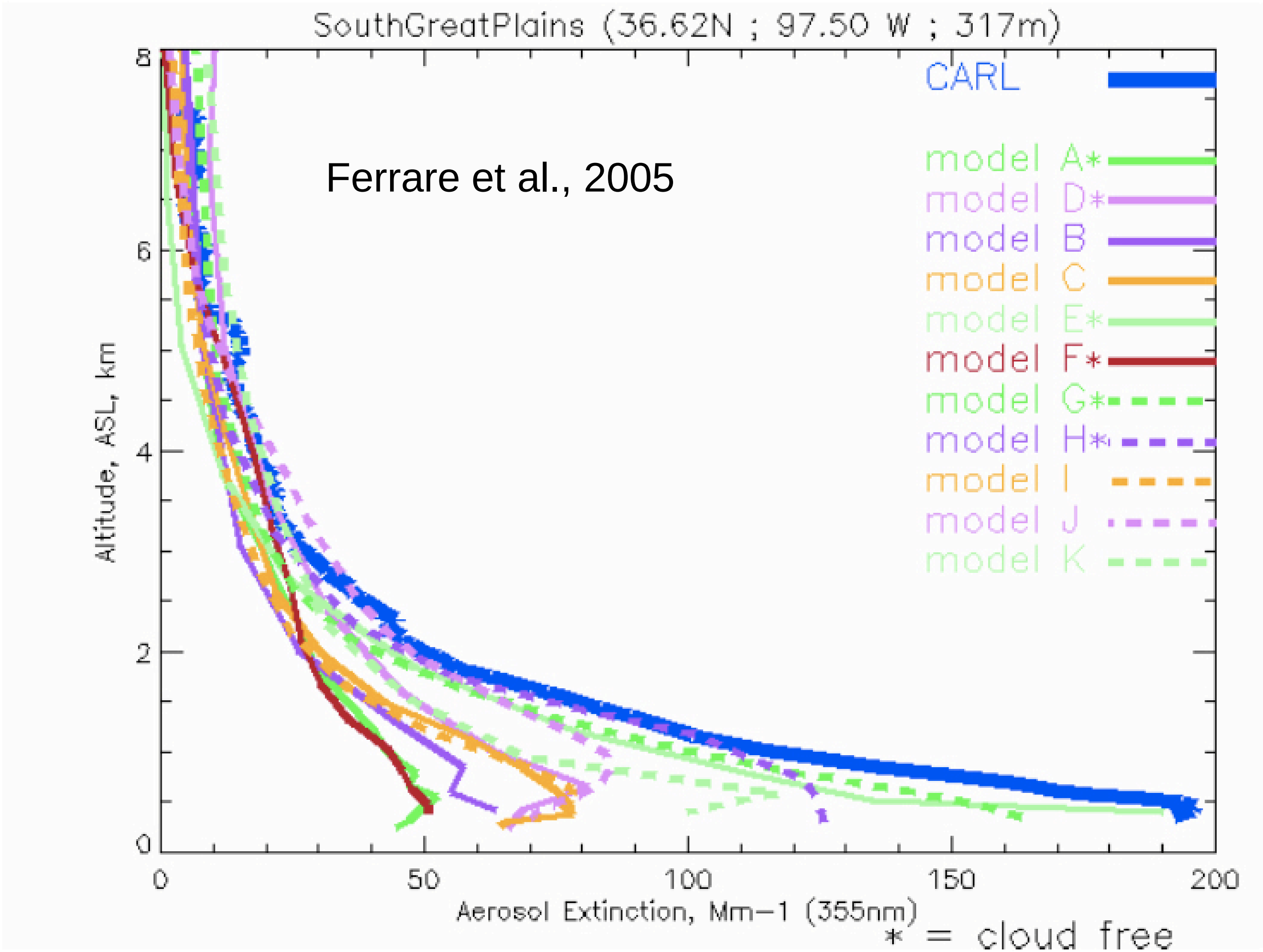


Figure 3. Average annual extinction profile from the various models and from the Climate Research

Unanswered GALION questions

- Exactly how precise are the extinction profiles?
  - Still struggling with error assessment
- Can an extinction climatology be derived and made into a climate record?
  - Hasn't happened for ARM yet
  - Hasn't happened for all of EARLINET yet
- How do we validate the retrieved microphysical values, n_r, n_i, N(r)?

Issues that could involve NIST

- New technology (sources/detectors/filters, especially 1.55 µm eyesafe lasers and APDs, notch filters)
- Sources and detector characterization
- Calibration on polarimetry channels
- Validation of the inverse methods in
  $3\beta+2\alpha+2\delta$
- Calibration of nighttime $\tau$for fixed magnitude STARS experiment

Acknowledgements

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- Contributors to the GAW report
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