Statistics of Aerosol Optical Parameters

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Contents

1. Introduction

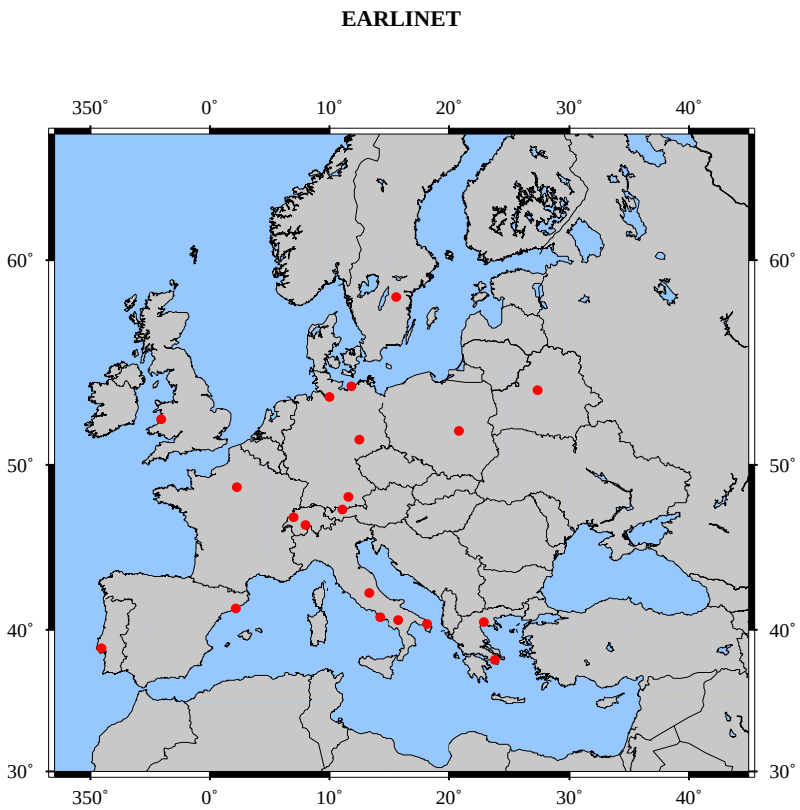
EARLINET is a joint project of 22 lidar groups from different European countries

One of the main goals is to

establish a quantitative, statistically relevant data base of the vertical aerosol distribution on a continental scale.

Quantitative measurements: aerosol extinction profiles from Raman lidar

Statistically relevant: significant number of regular measurements on a fixed time scale



2. Aerosol extinction measurements

Raman lidar for aerosol extinction:

$$\alpha_{aer}(\lambda_0) = \frac{1}{1+(\frac{\lambda_R}{\lambda_0})^a}\left(\frac{d}{dz}\ln\left(\frac{N(z)}{P_R(z)z^2}\right) - \alpha_{mol}(\lambda_0, \lambda_R, z)\right)$$

Raman lidar for aerosol backscatter:

$$\beta_{aer}(\lambda_0, z) = -\beta_{mol}(\lambda_0, z) + (\beta_{aer}(\lambda_0, z_0) + \beta_{mol}(\lambda_0, z_0)\times$$

$$\frac{P(\lambda_0, z)P(\lambda_R, z_0)N_R(z)}{P(\lambda_0, z_0)P(\lambda_R, z)N_R(z_0)}\exp\left(\int_z^{z_0}(\Delta\alpha_{aer}(\zeta) + \Delta\alpha_{mol}(\zeta))d\zeta\right)$$

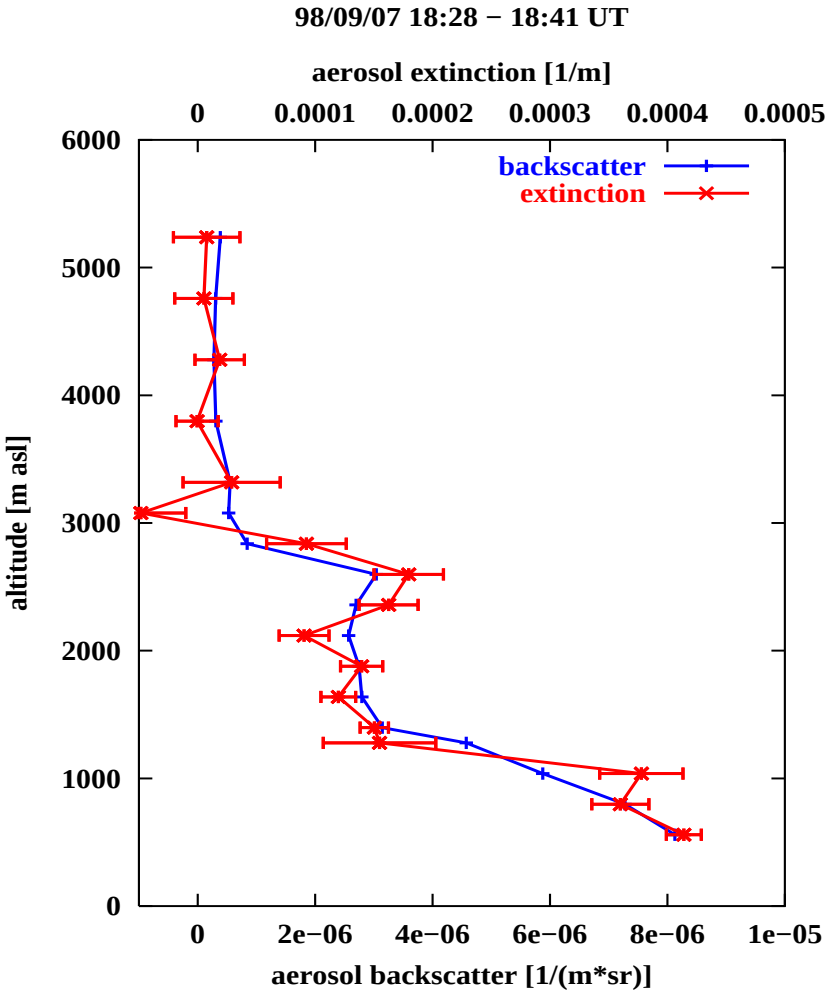
This equation for the aerosol backscatter is also valid in regions of incomplete overlap.

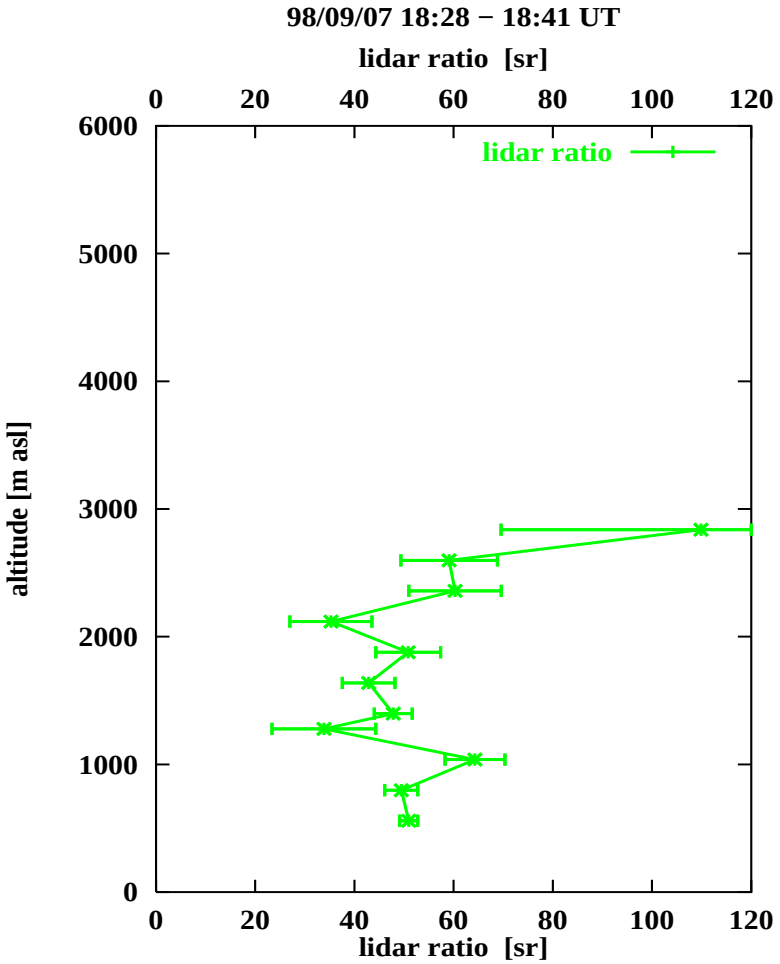
EARLINET Raman Lidar Systems

Group	Country	elastic ch.			Raman ch.
		355 nm	532 nm	1064 nm	355 nm
MPI Hamburg	D	x	x	x	x
U Aberystwyth	GB	x			x
NTU Athens	GR	x	x		x
EPF Lausanne	CH	x	x	x	x
IAP Kühlungsborn	D	x	x	x	x
U L'Aquila	I	x[(1)]			x
INFM Lecce	I	x[(1)]			x
IFT Leipzig	D	x	x	x	x
INFM Napoli	I	x[(1)]			x
IMAA Potenza	I	x	x		x
AU Thessaloniki	GR	x	x		x

(1): emitted wavelength is 351 nm

Aerosol Profiles





3. Statistical Methods

1. Take from the data base:

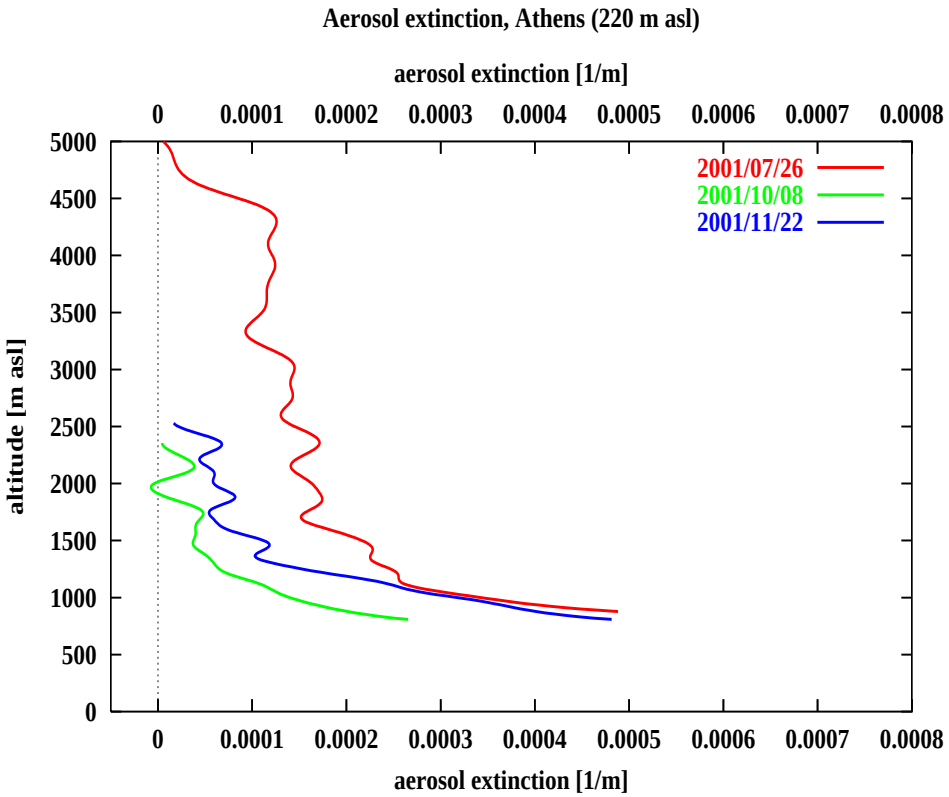
- aerosol extinction profiles
- dust layer height / planetary boundary layer height for that profile

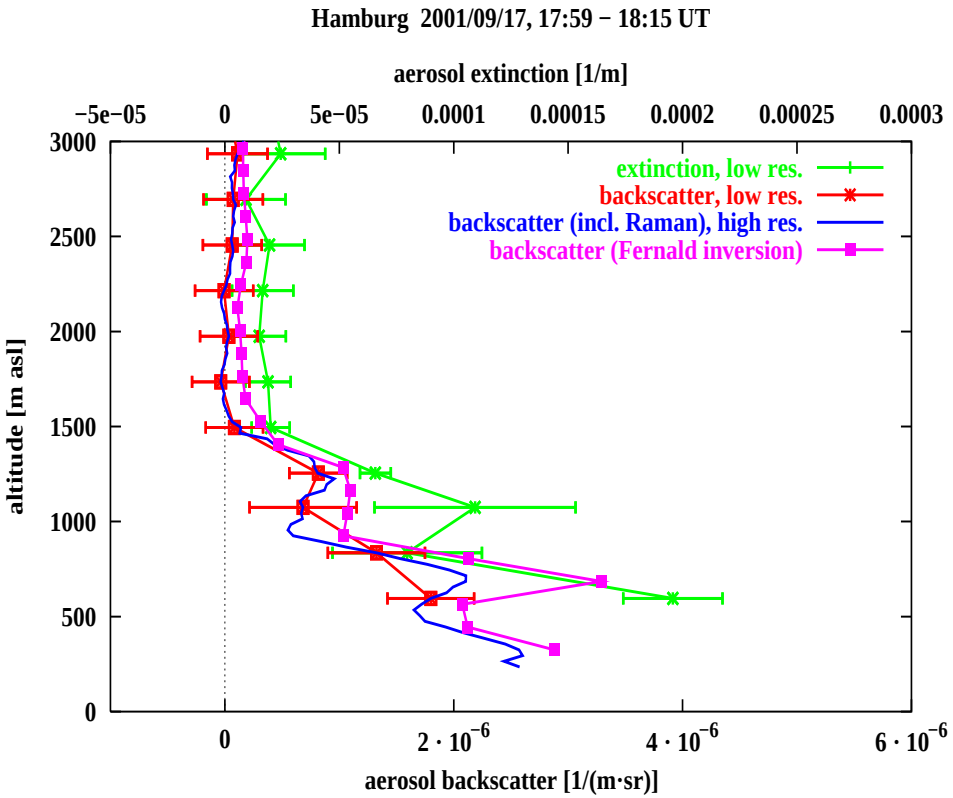
2. Calculate

- aerosol optical depth (AOD) in the planetary boundary layer (PBL)
- mean, stand. dev. and skewness of AOD in PBL
- mean, stand. dev. and skewness of PBL-height
- cumulative frequency distributions of AOD in PBL and PBL-height

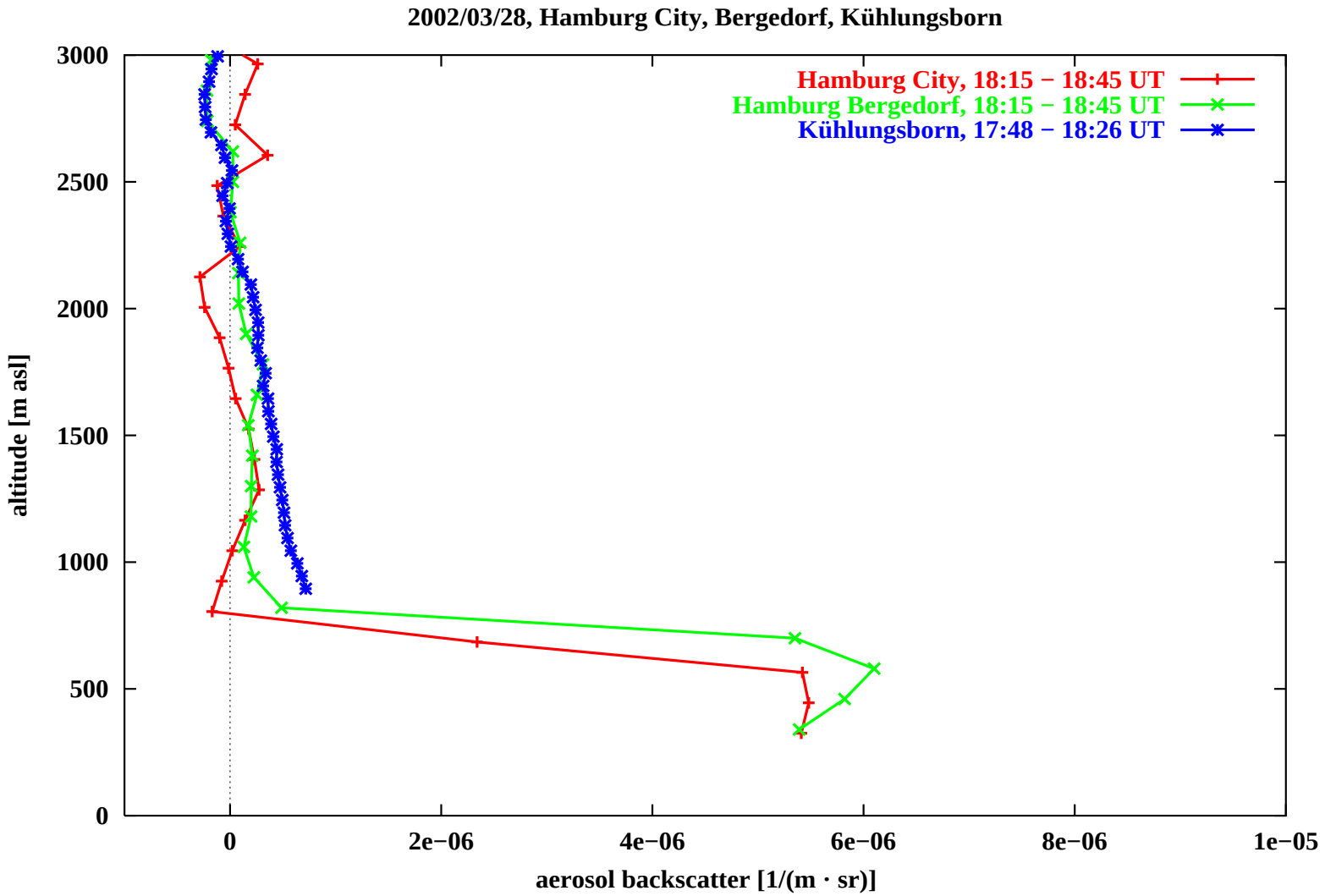
Statistical methods: requirements on the data

- high quality of the data (e.g. no cloud contamination)
- dust layer height accurately determined and given in the files
- lowest data point represents the aerosol extinction down to ground
- measurements cover all seasons

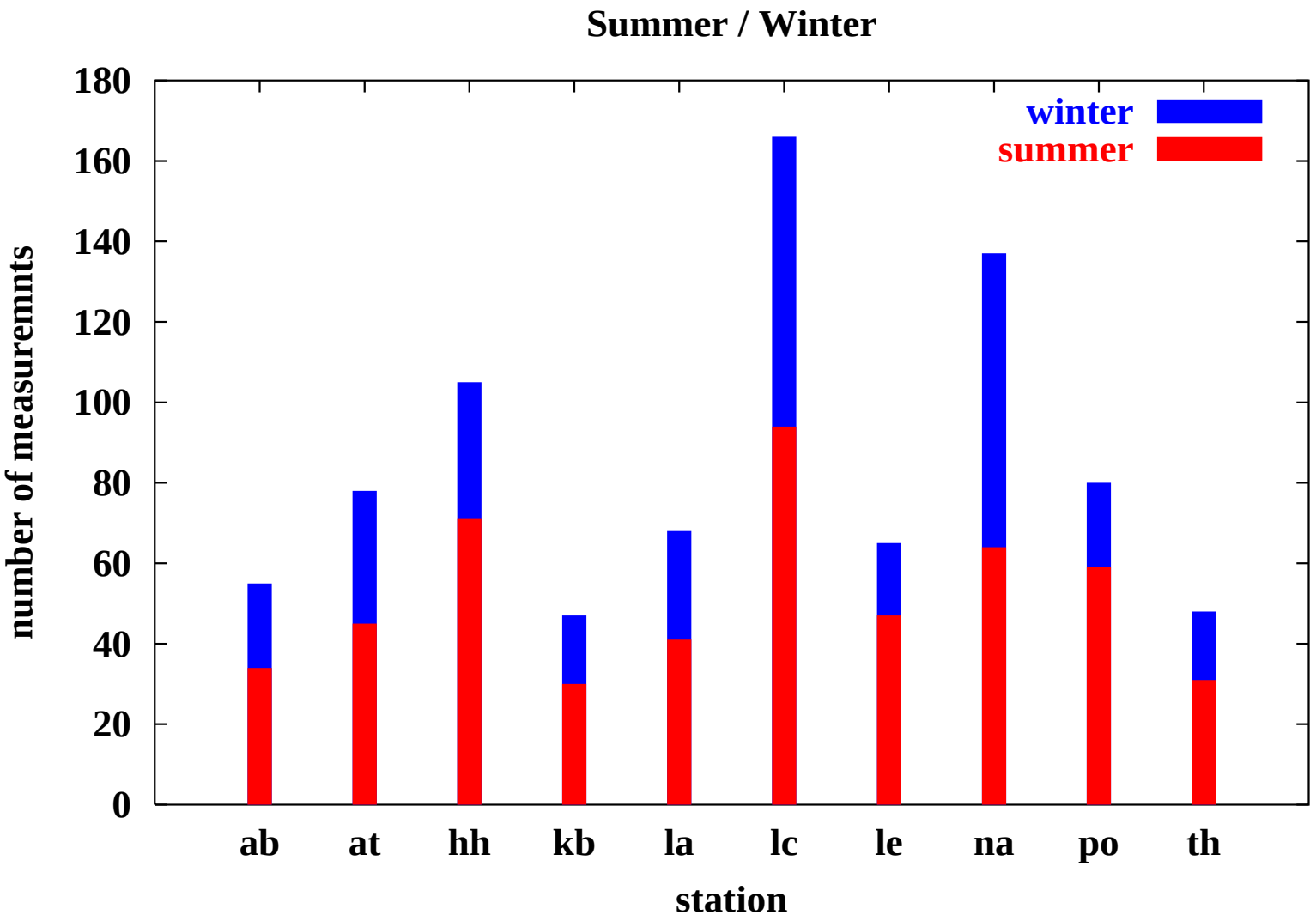




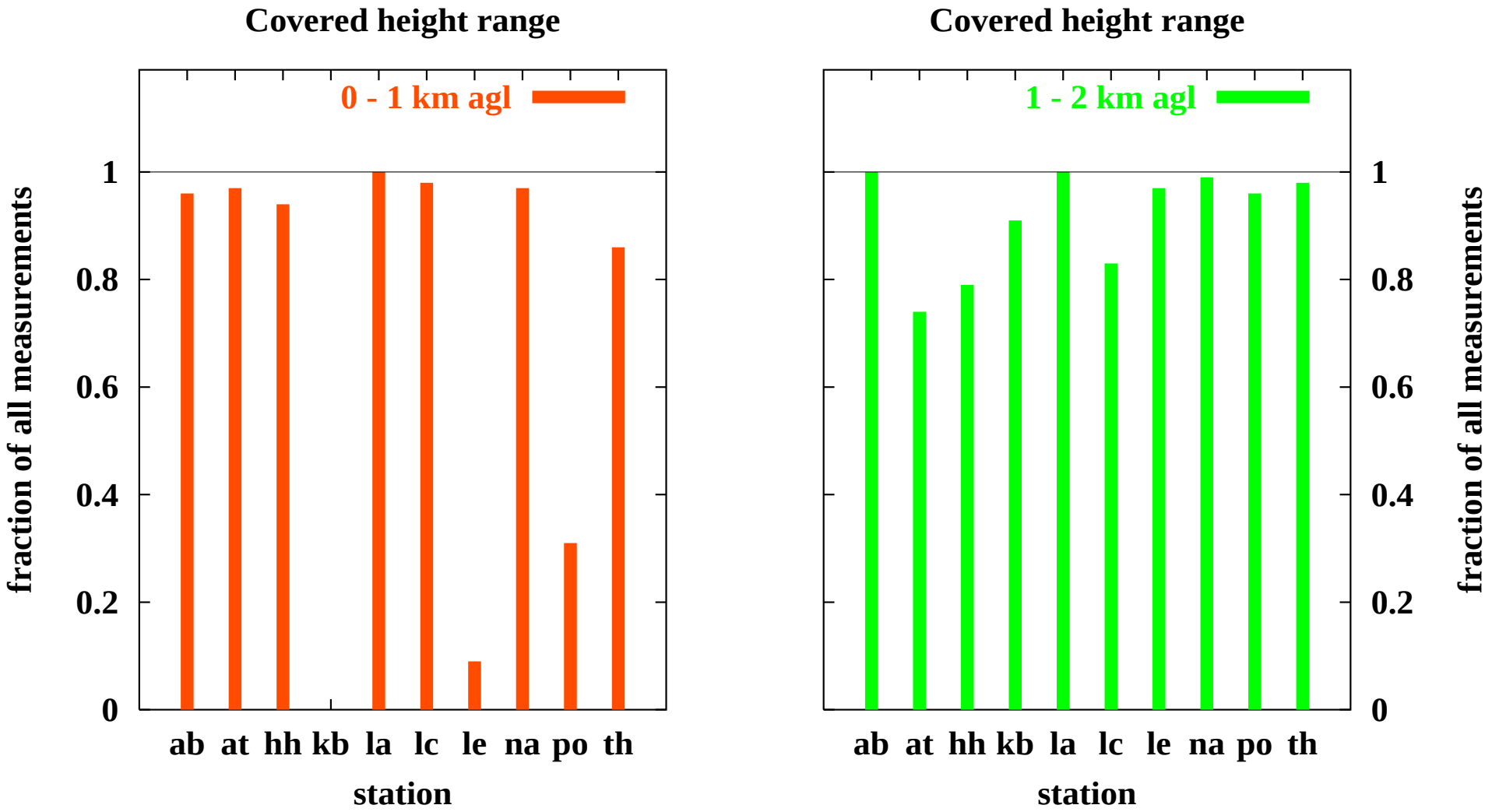
Comparibility of aerosol profiles



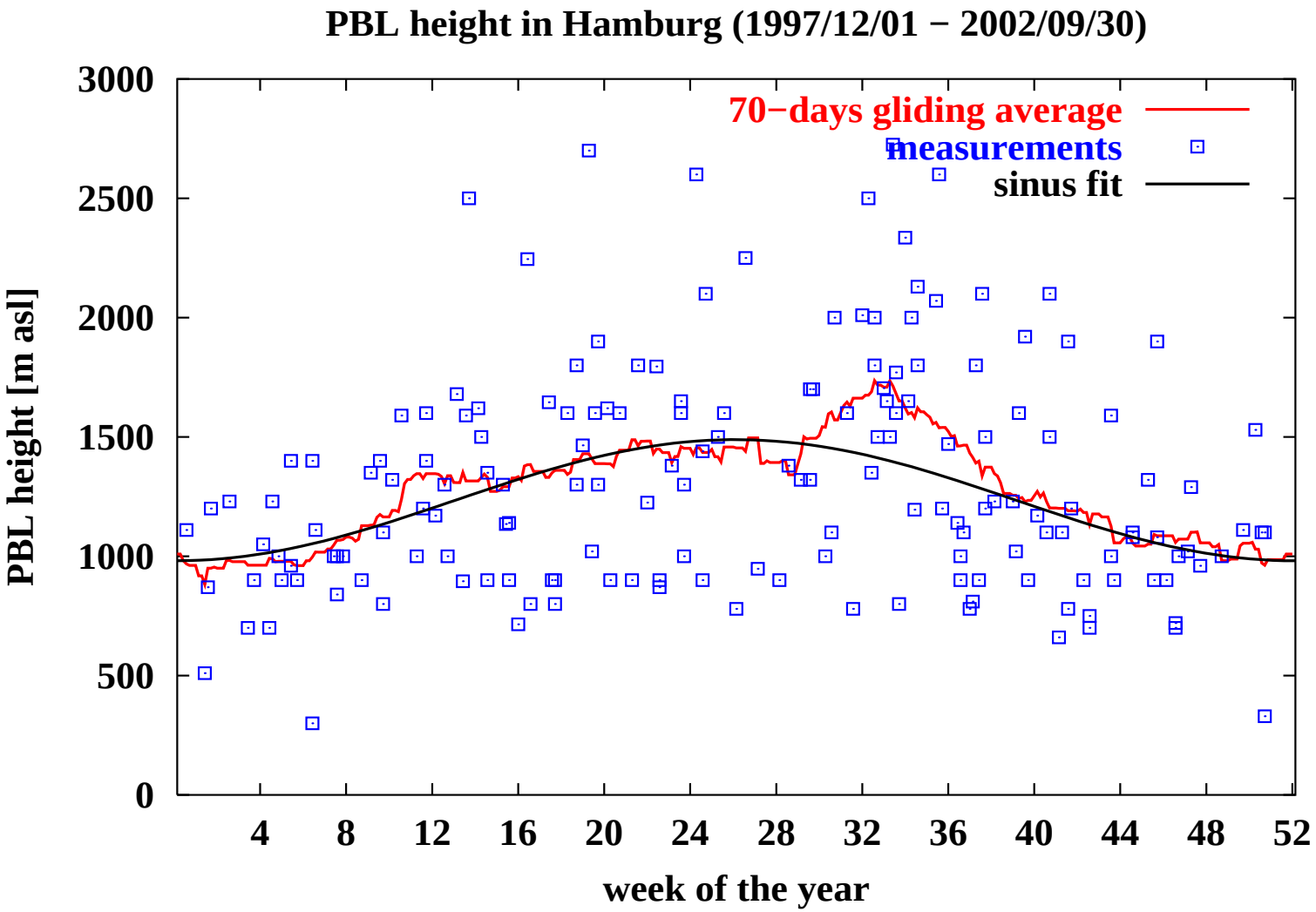
Seasonal coverage of measurements



Height coverage of measurements

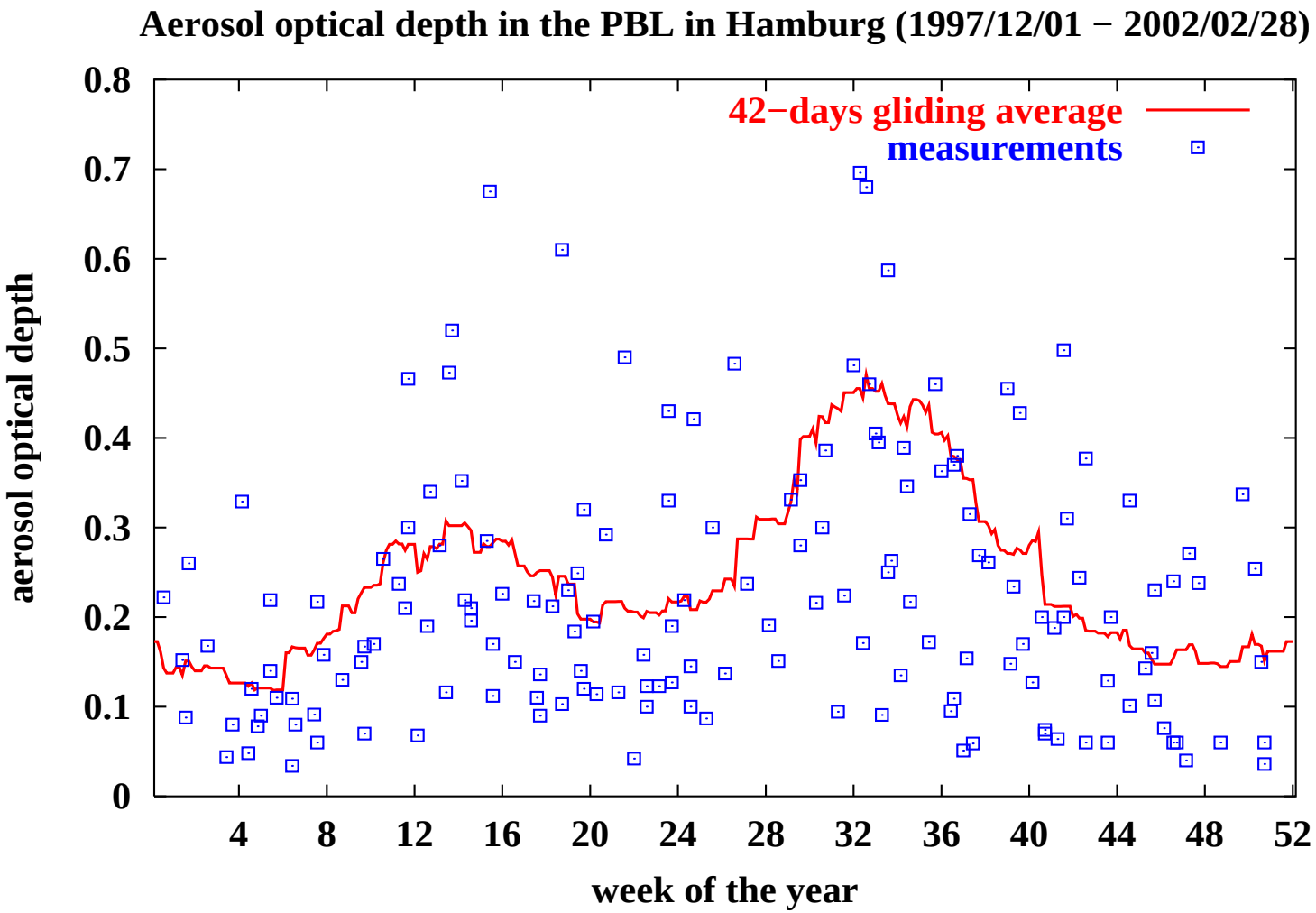


4. Results: PBL-height in Hamburg

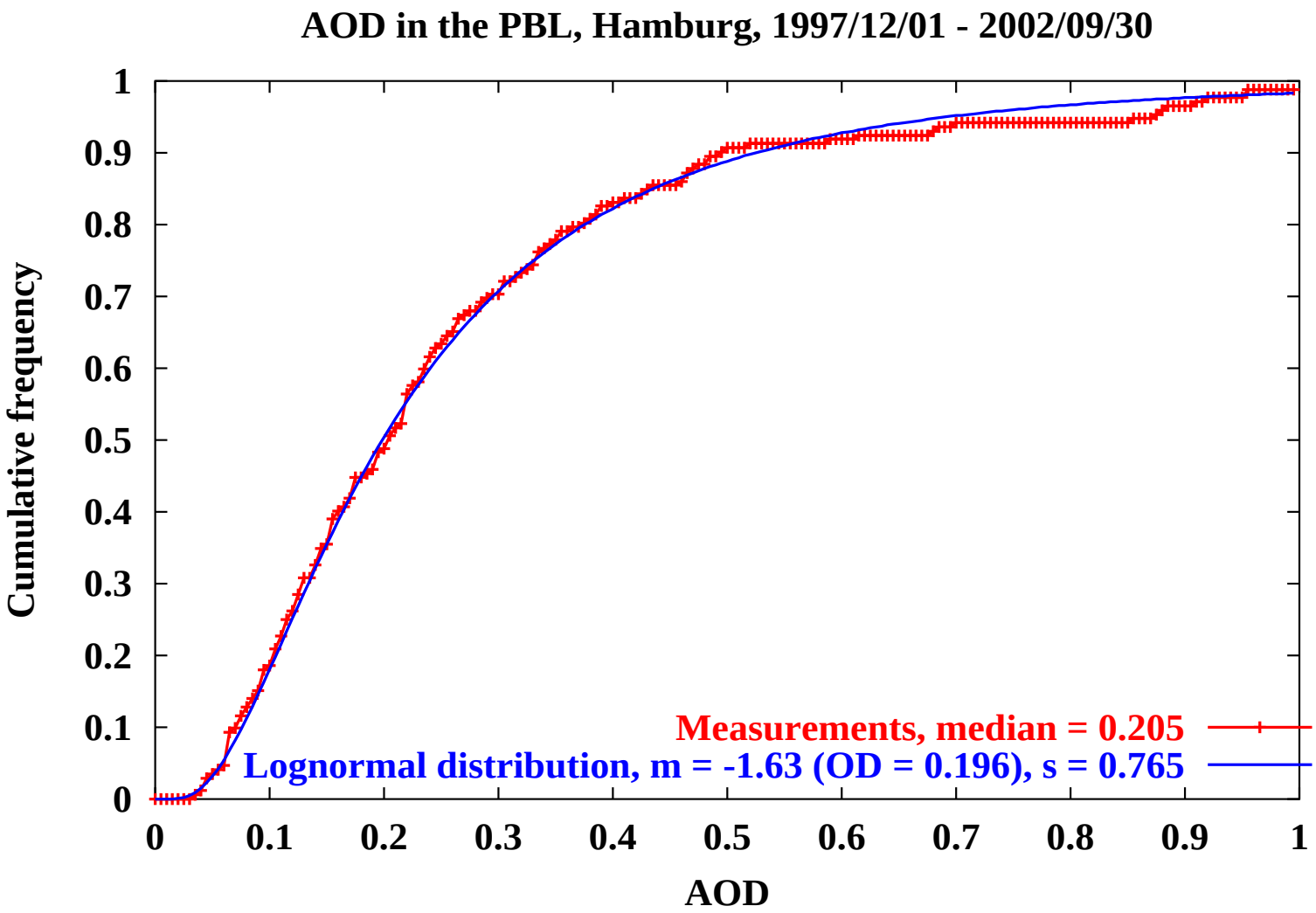


Aerosol optical depth in PBL in Hamburg

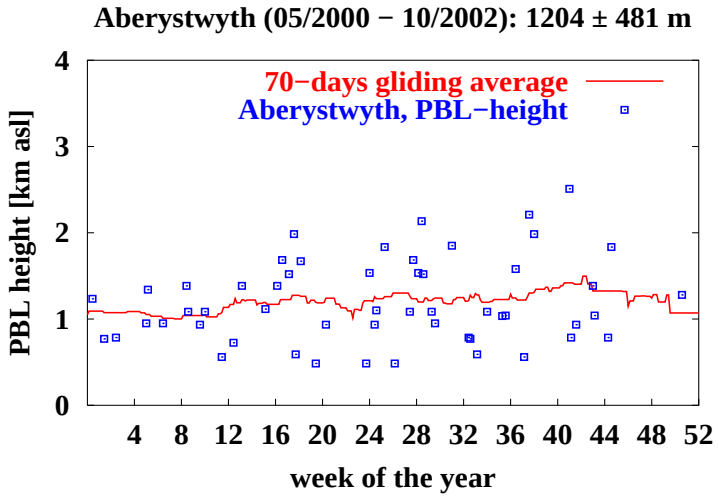
mean AOD 0.26 $\pm$ 0.22 (355 nm), skewness 1.84

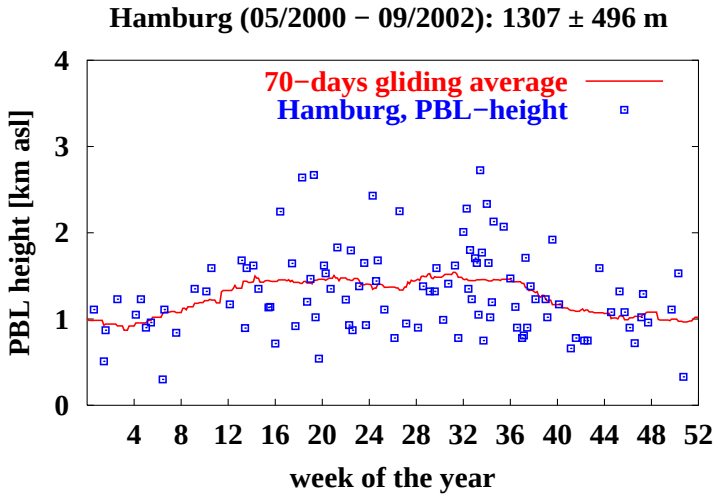


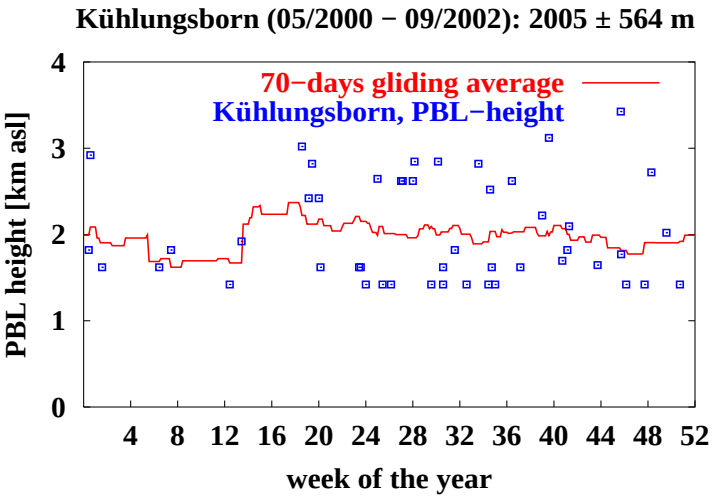
Cumulative frequency distribution of the AOD in the PBL in Hamburg

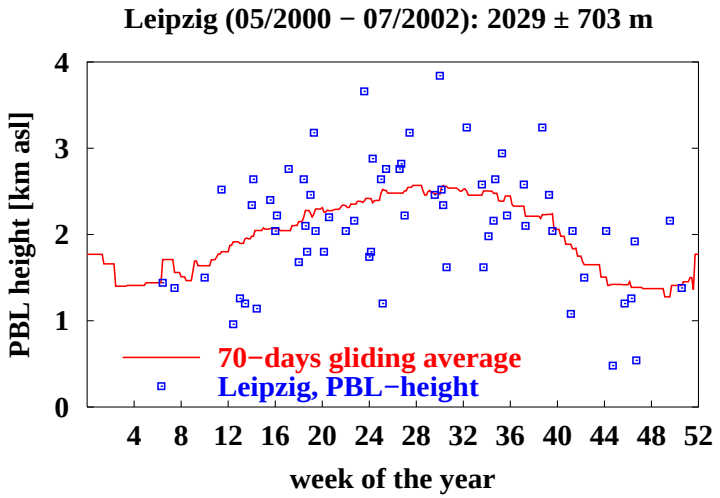


Comparison of the annual cycle of the PBL-height (1)



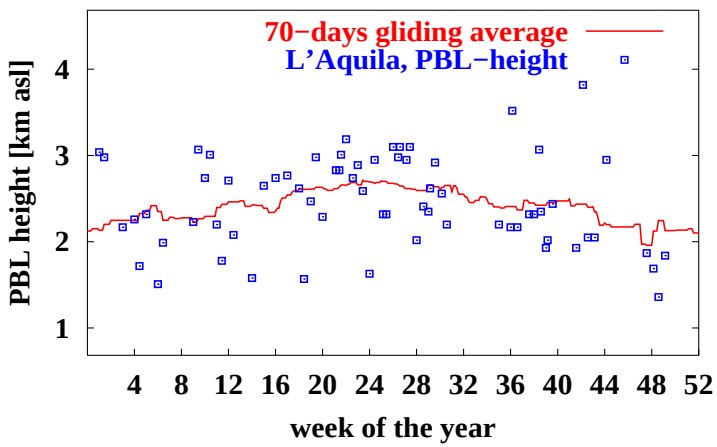




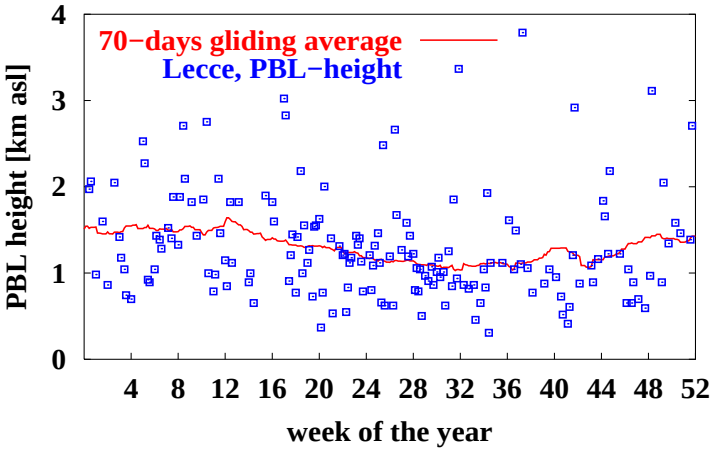


Comparison of the annual cycle of the PBL-height (2)

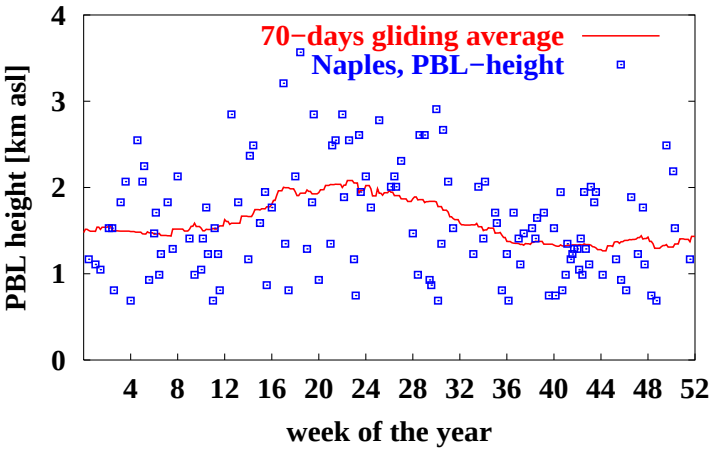
L'Aquila (05/2000 − 09/2002): 1773 ± 521 m



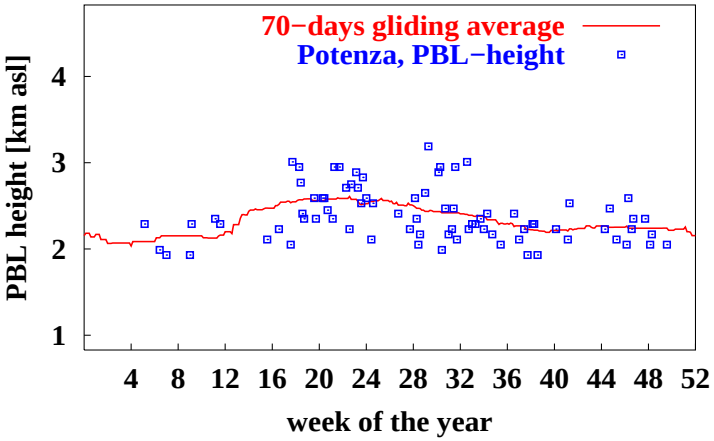
Lecce (05/2000 − 08/2002): 1290 ± 599 m



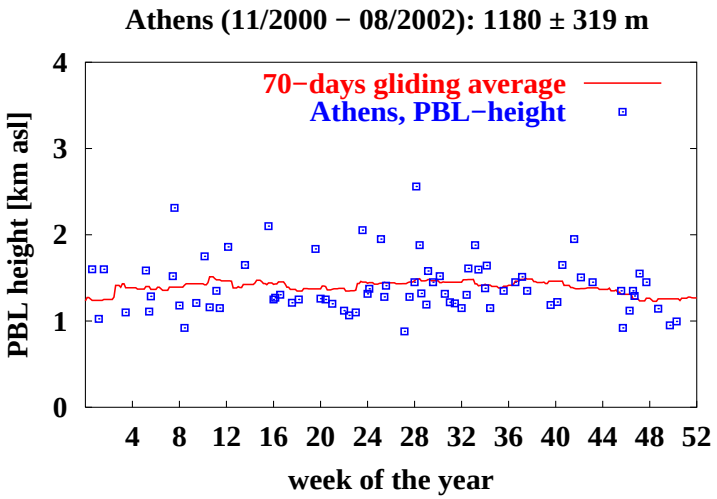
Naples (10/2000 − 10/2002): 1469 ± 628 m

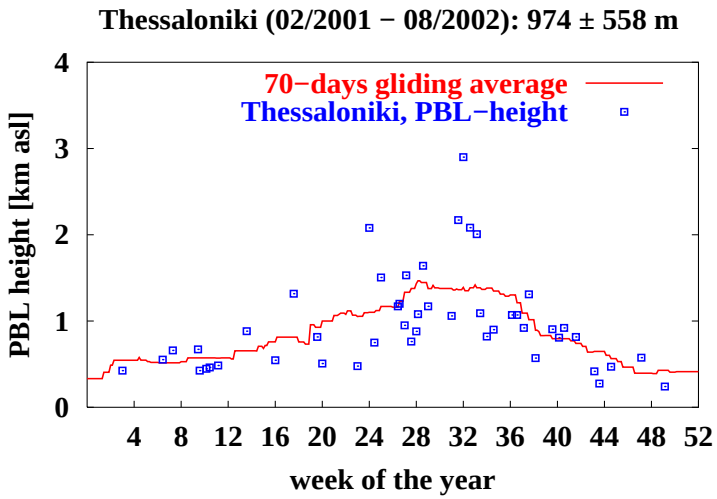


Potenza (05/2000 − 09/2002): 1561 ± 306 m



Comparison of the annual cycle of the PBL-height (3)

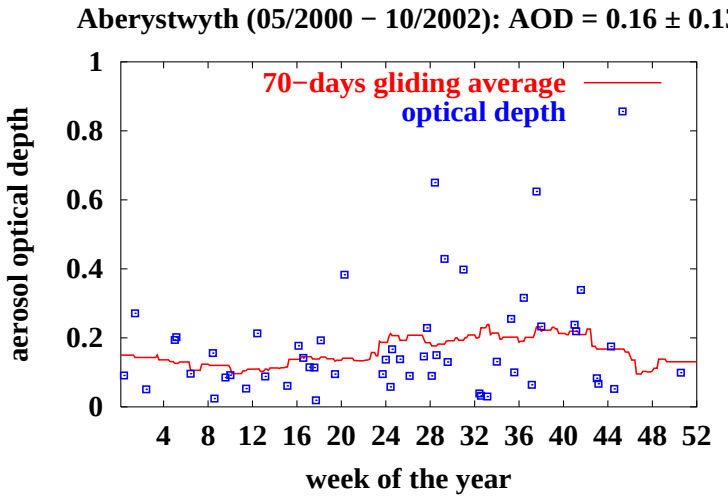


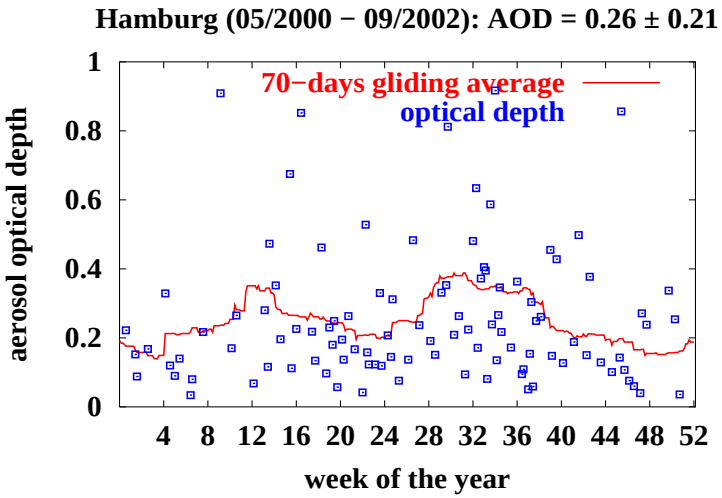


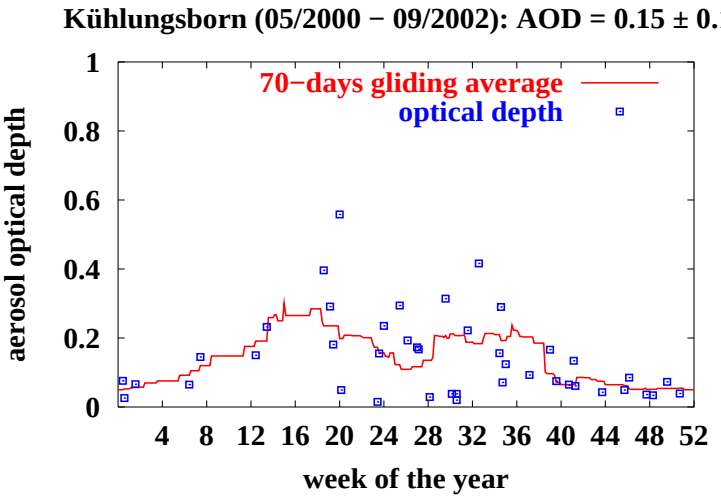
PBL-height statistics

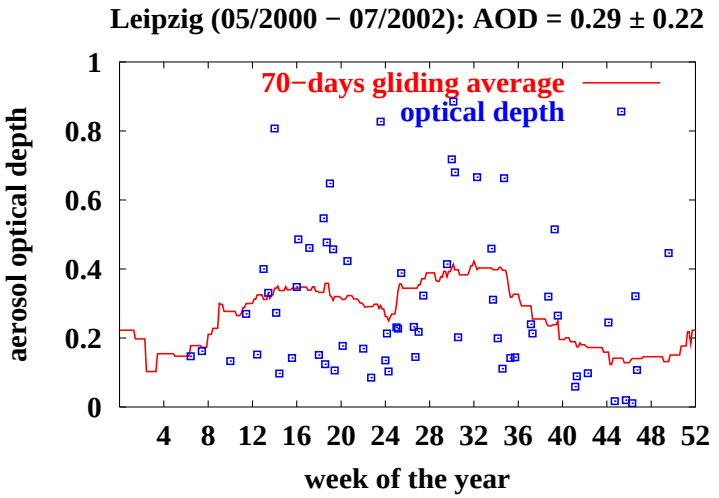
Station	PBL-height / m	Std. Dev / m	Rel. Std. Dev	Skewness
Aberystwyth	1204	481	0.40	0.57
Hamburg	1308	497	0.38	0.74
Kühlungsborn	2005	564	0.28	0.52
Leipzig	2029	703	0.35	-0.02
L'Aquila	1773	521	0.29	0.05
Lecce	1290	599	0.46	1.29
Napoli	1587	628	0.40	0.65
Potenza	1561	306	0.20	0.64
Athens	1180	319	0.27	1.16
Thessaloniki	975	558	0.57	1.35

Comparison of the annual cycle of the AOD in the PBL (1)

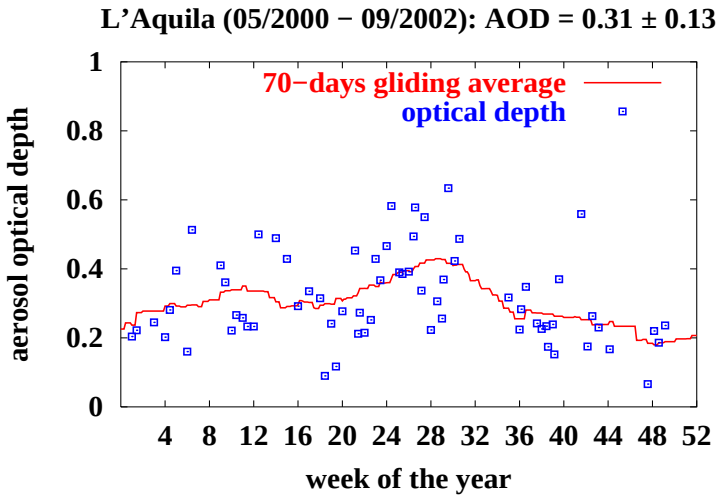


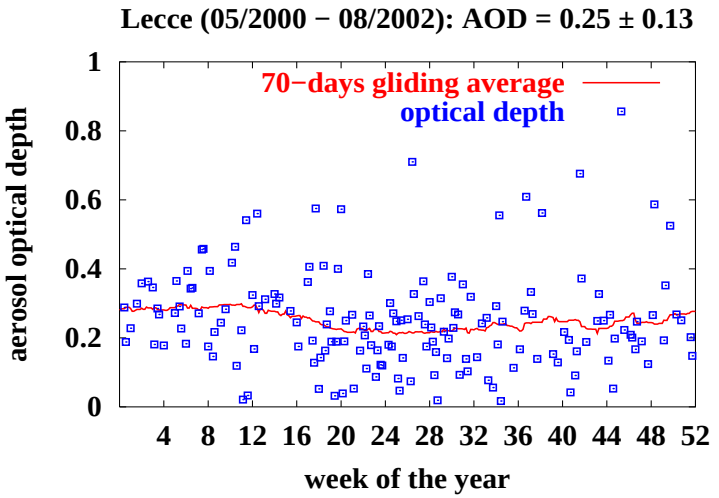


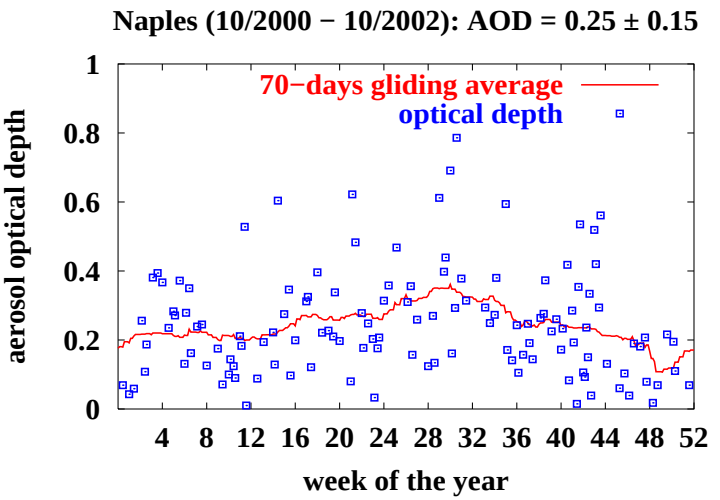


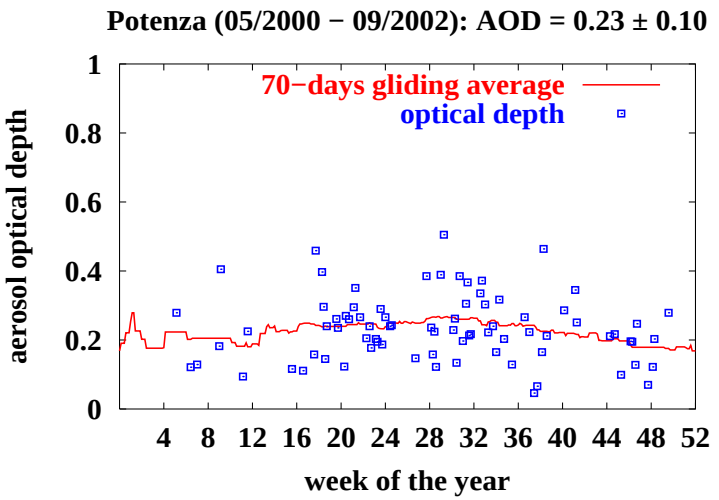


Comparison of the annual cycle of the AOD in the PBL (2)

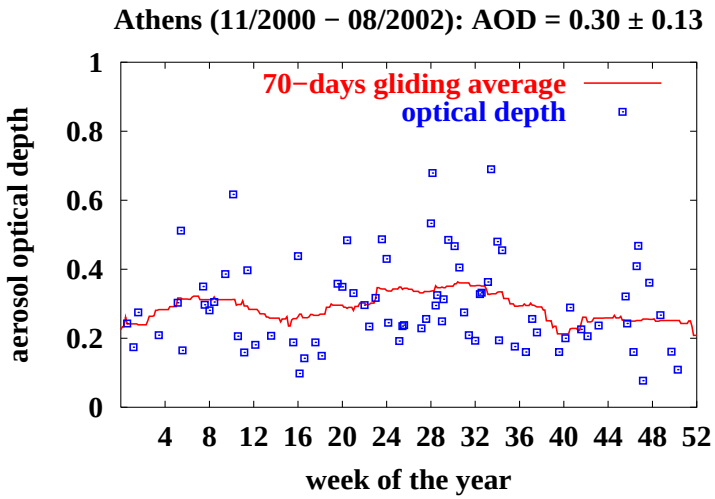


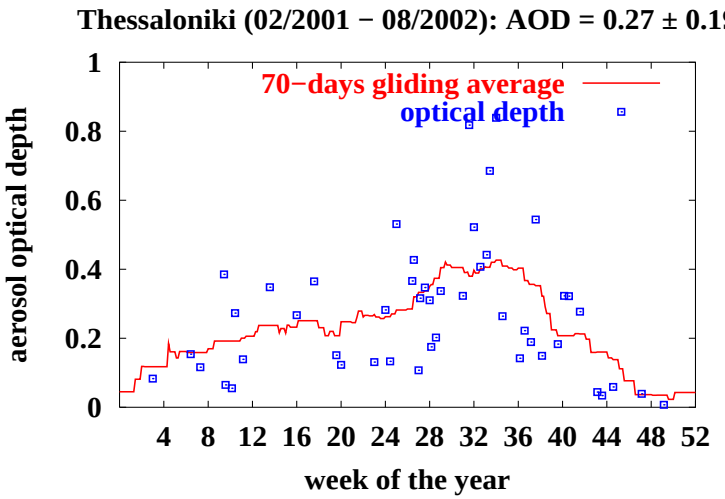






Comparison of the annual cycle of the AOD in the PBL (3)

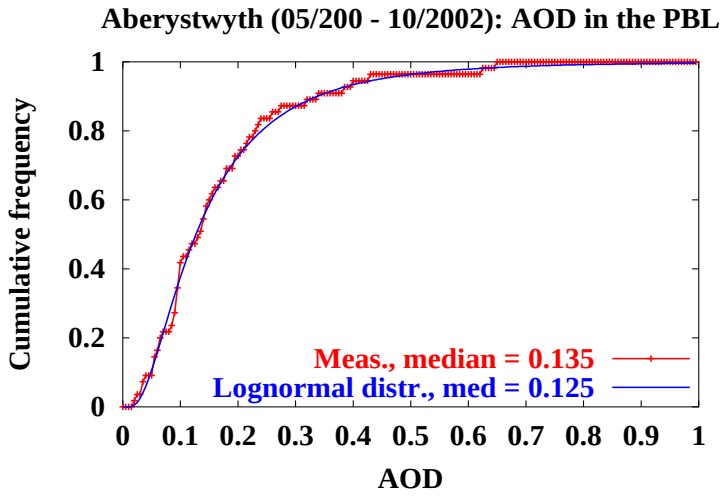


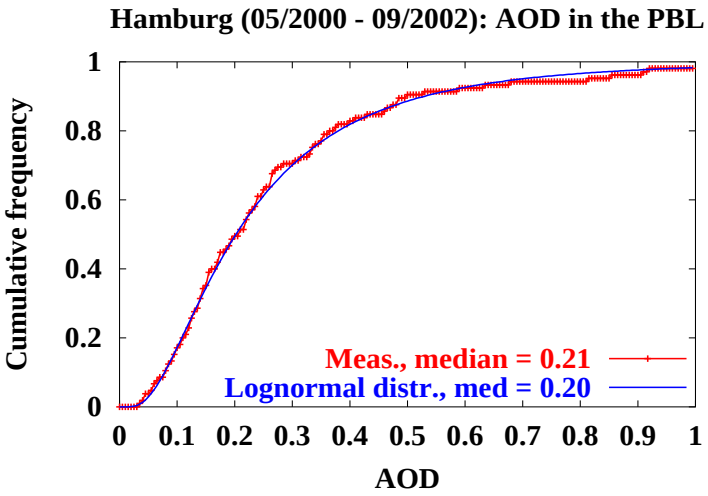


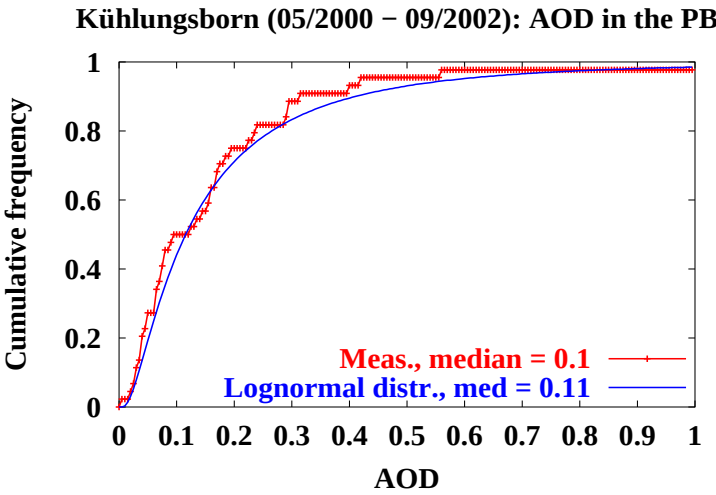
AOD statistics

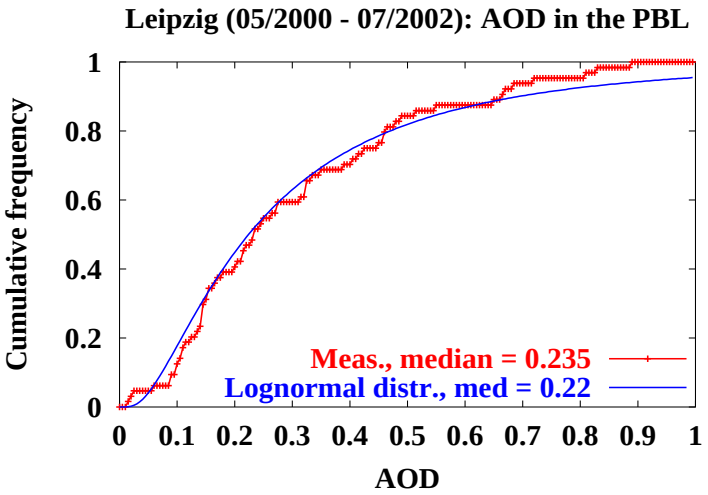
Station	Mean AOD	Std. Dev	Rel. Std. Dev	Skewness
Aberystwyth	0.16	0.13	0.81	1.86
Hamburg	0.26	0.22	0.82	1.91
Kühlungsborn	0.15	0.19	1.30	2.81
Leipzig	0.29	0.22	0.73	0.96
L'Aquila	0.31	0.13	0.41	0.56
Lecce	0.25	0.13	0.54	0.92
Napoli	0.24	0.15	0.62	1.00
Potenza	0.23	0.10	0.67	0.53
Athens	0.30	0.13	0.44	0.94
Thessaloniki	0.27	0.19	0.71	1.09

Comp. of the cumulative frequency distribution of the AOD (1)

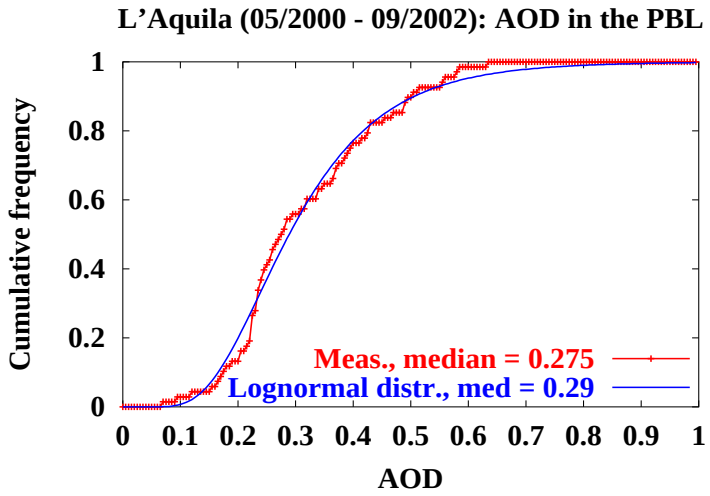


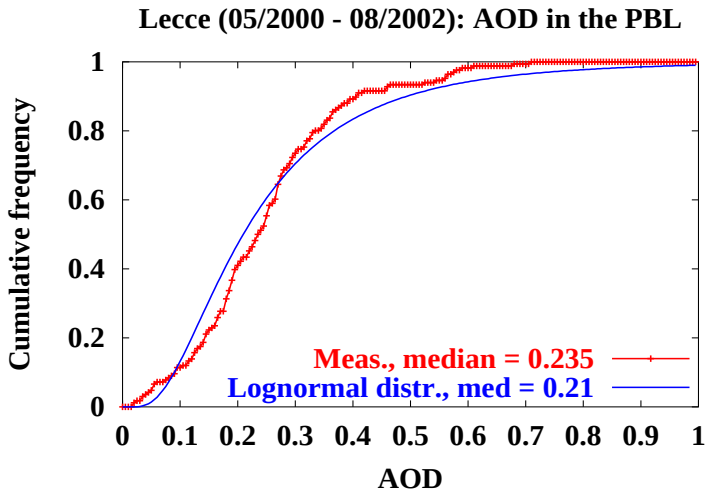


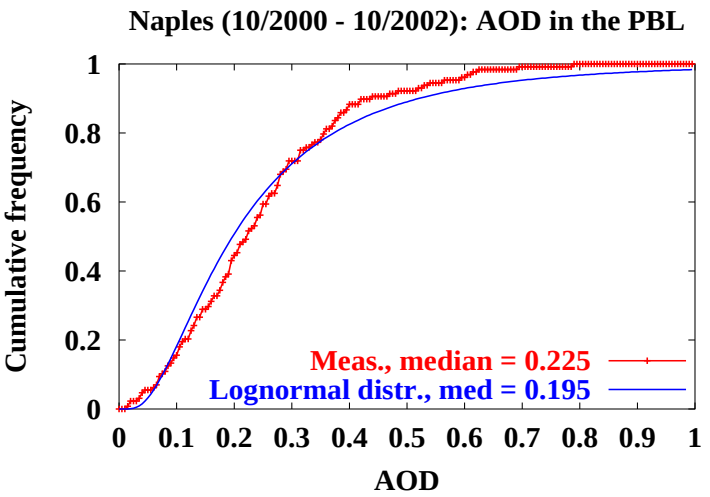


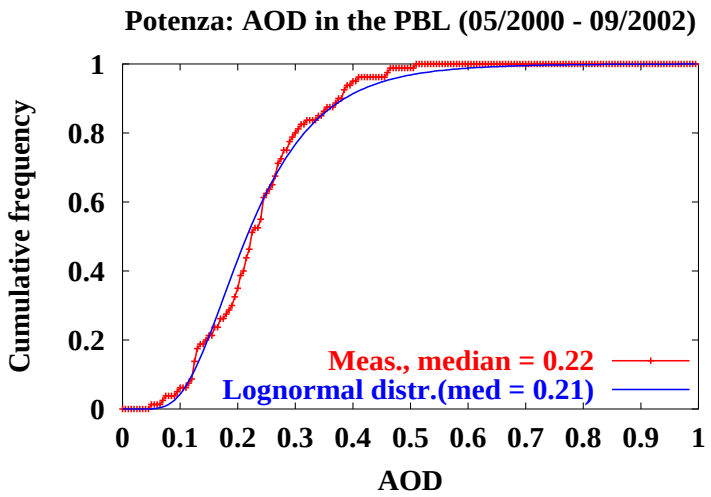


Comp. of the cumulative frequency distribution of the AOD (2)

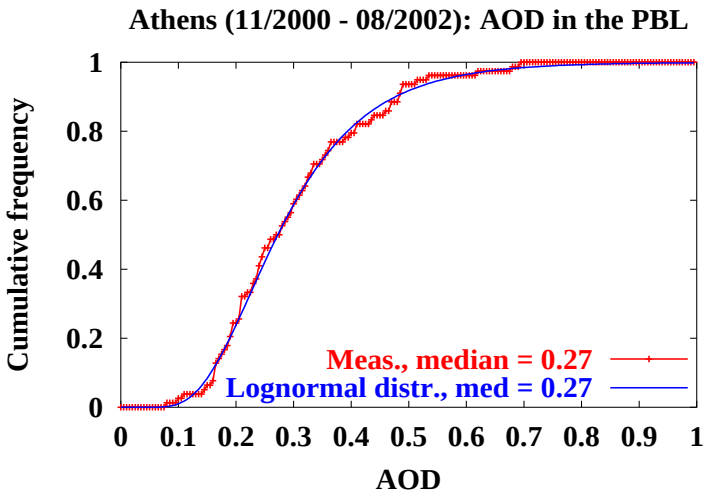


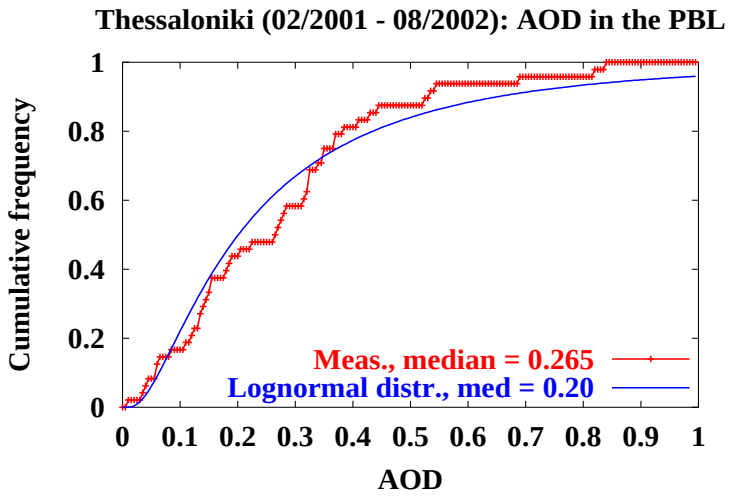






Comp. of the cumulative frequency distribution of the AOD (3)



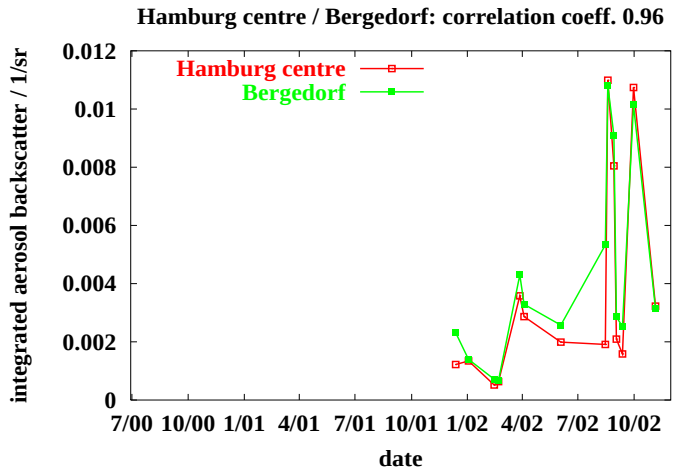


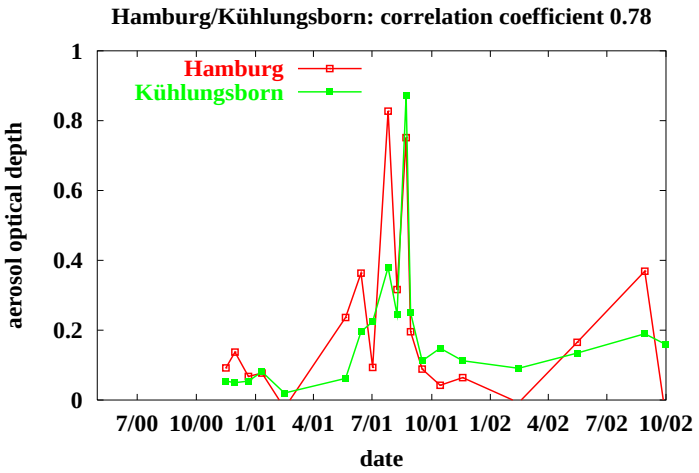
AOD log-normal statistics

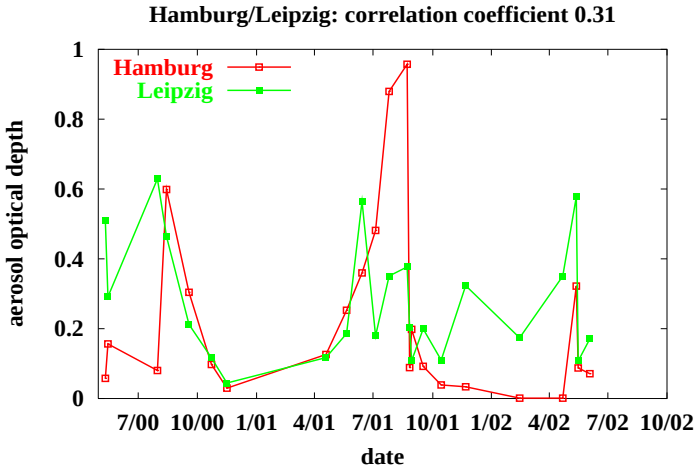
Station	Median of AOD (meas.)	Median of AOD (fitted)	Std. Dev (in log scale)	1-σ-interval
Aberystwyth	0.135	0.125	0.77	0.06 - 0.27
Hamburg	0.21	0.20	0.76	0.10 - 0.43
Kühlungsborn	0.10	0.11	1.00	0.04 - 0.30
Leipzig	0.235	0.22	0.89	0.09 - 0.54
L'Aquila	0.275	0.29	0.44	0.18 - 0.44
Lecce	0.235	0.21	0.67	0.11 - 0.41
Napoli	0.225	0.195	0.76	0.09 - 0.41
Potenza	0.22	0.21	0.46	0.13 - 0.34
Athens	0.27	0.27	0.44	0.17 - 0.42
Thessaloniki	0.265	0.20	0.92	0.08 - 0.50

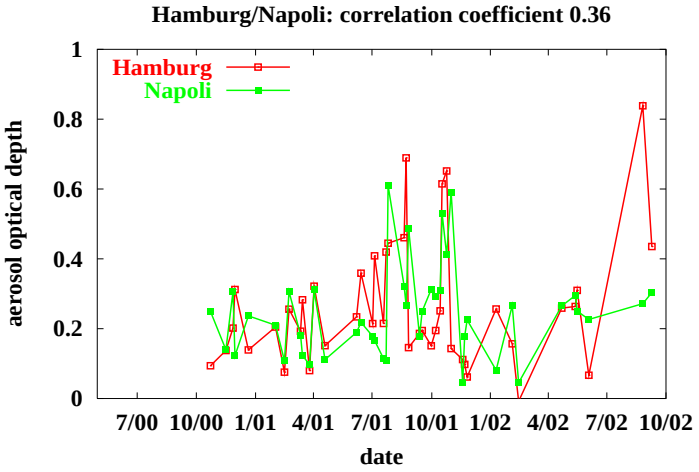
Correlation of AOD at different sites

Assumptions: Only common days and common height ranges have been taken

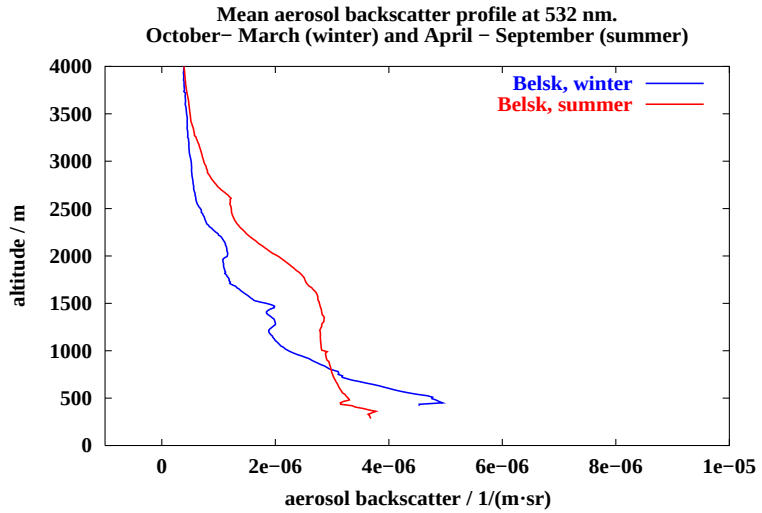


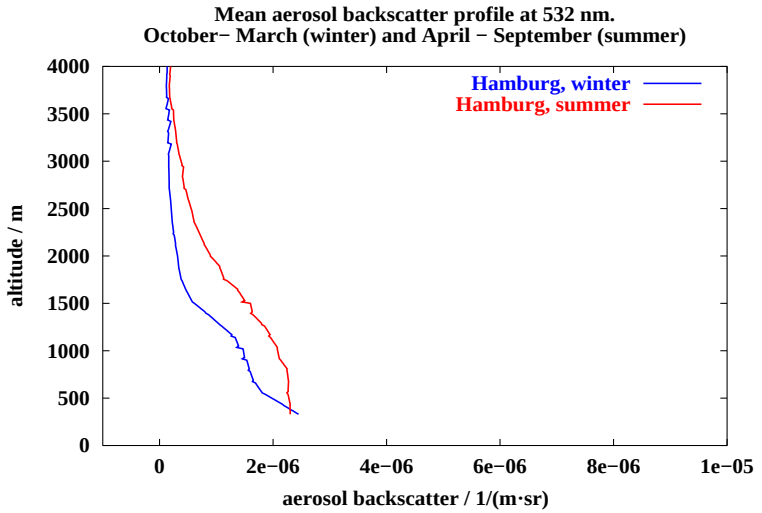


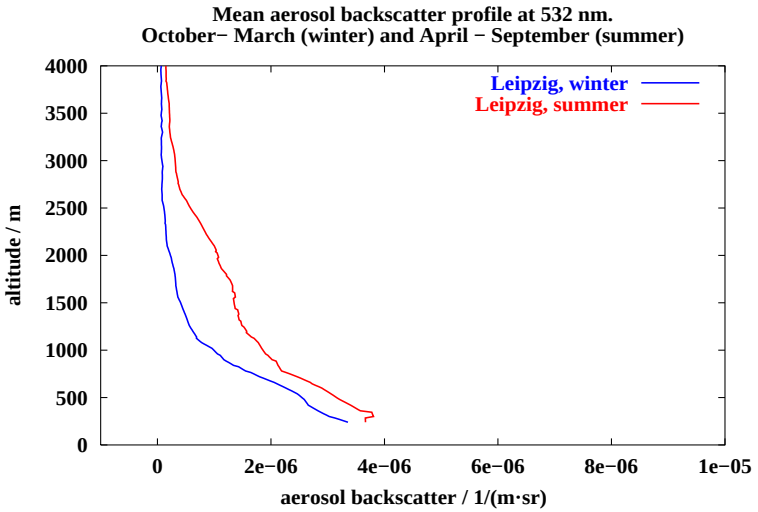


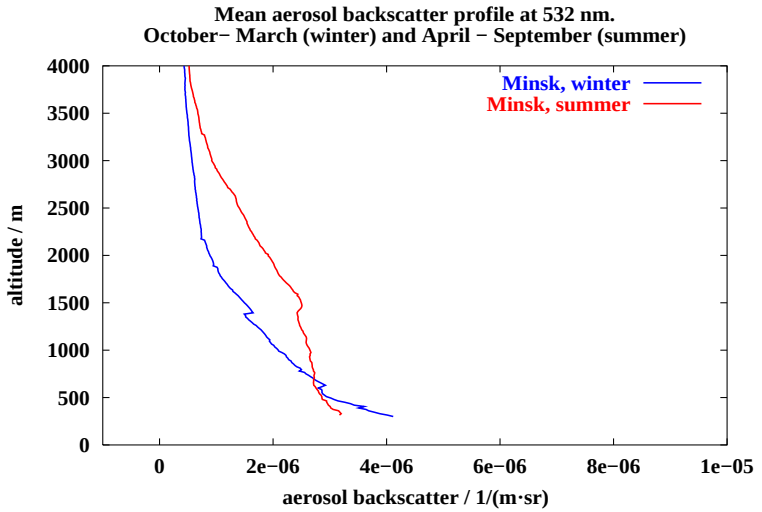


Comparison of aerosol backscatter profiles (532 nm) (Seasonal averages)

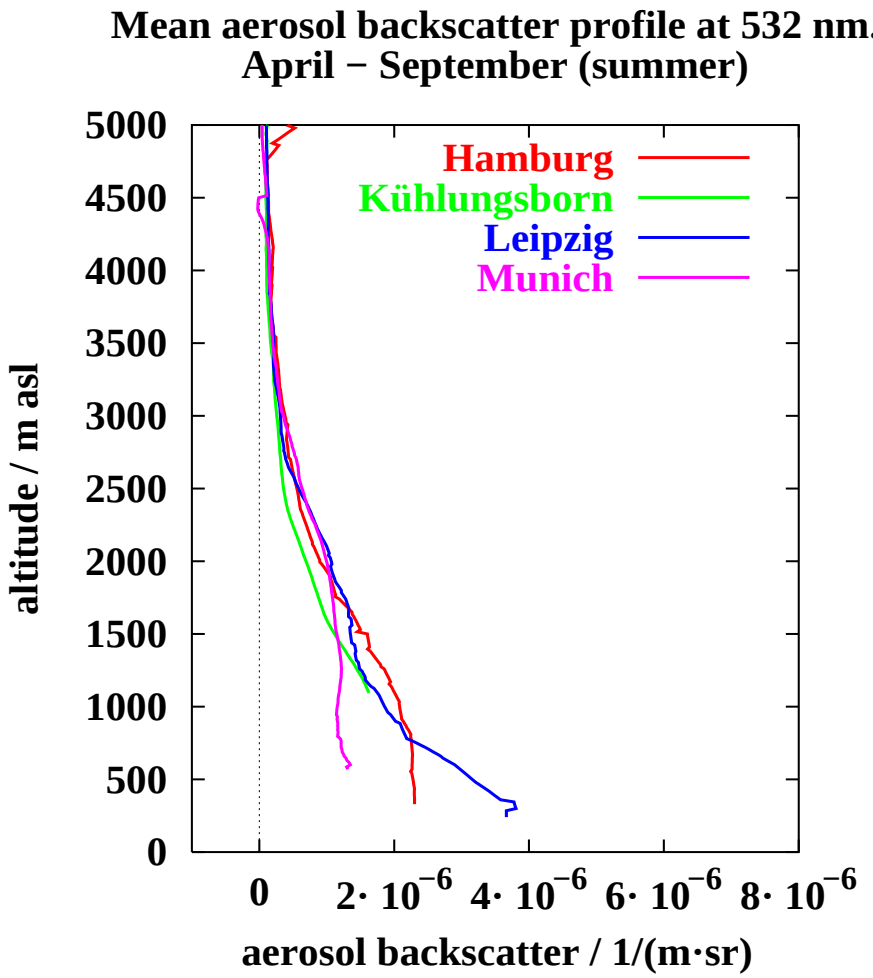


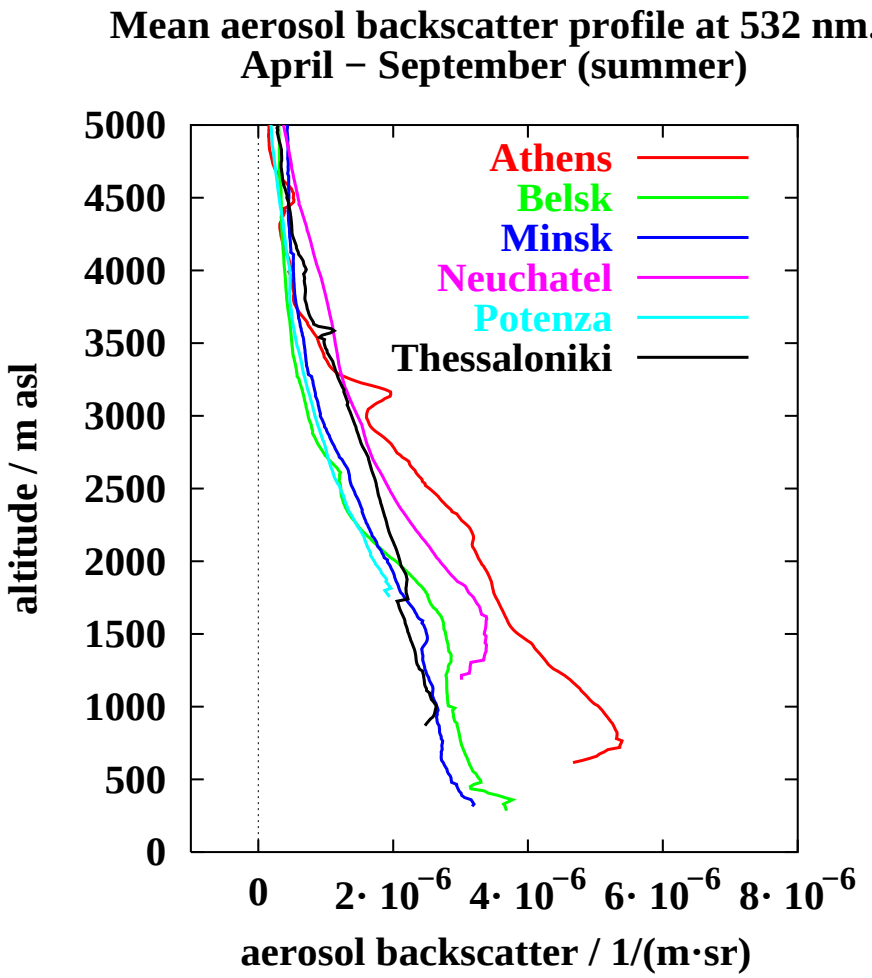




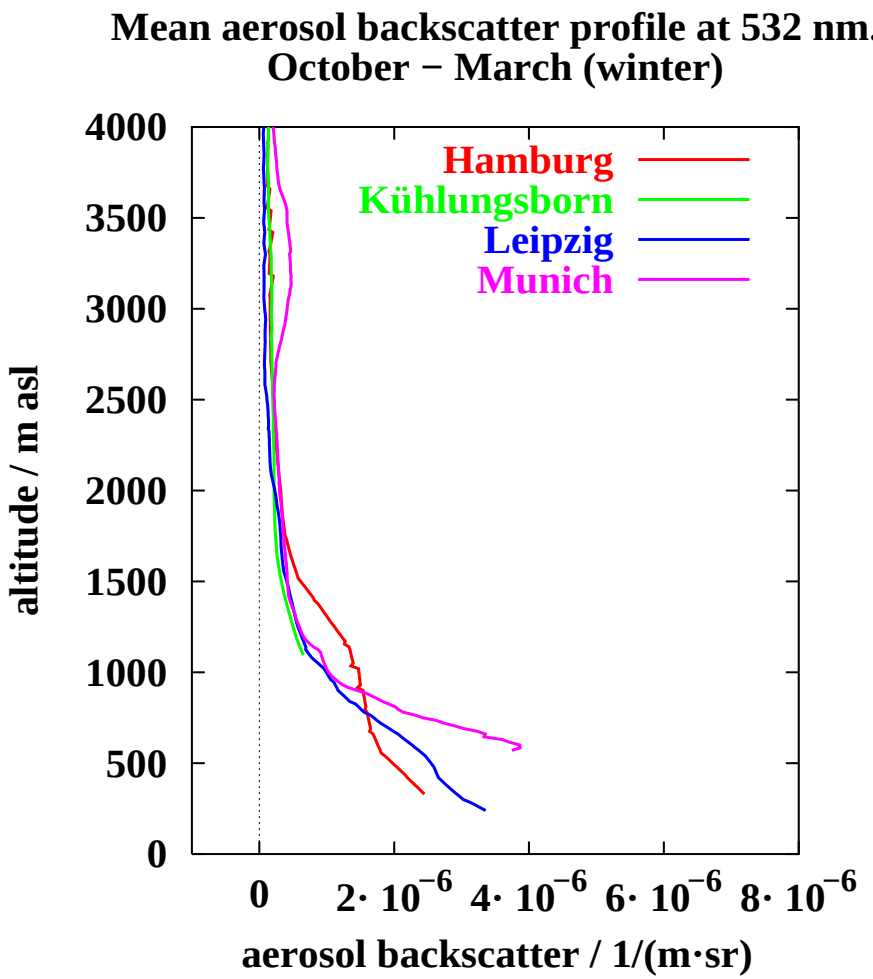


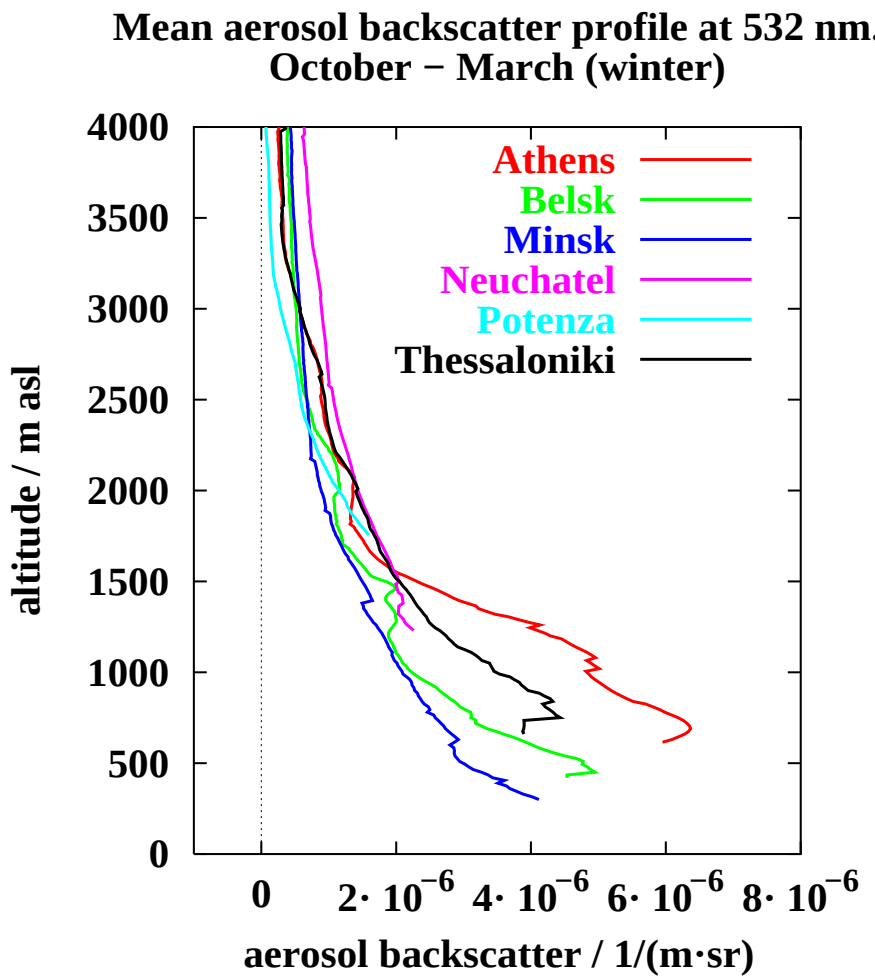
Aerosol backscatter profiles (532 nm): summer





Aerosol backscatter profiles (532 nm): winter





Summary and outlook (1)

- Statistical evaluations and correlation studies have been started with the EARLINET data base
- First results show:
  - PBL-height and AOD show large variability at all stations
  - AOD in the PBL follows a lognormal distribution for almost all chosen stations
  - German (Central European?) stations show spring and late summer maxima of the AOD
  - Aerosol profiles represent the vertical aerosol distribution on a horizontal scale of at least a few tens of kilometers
- Comparisons between different stations have to take the different vertical coverage into account
- Related problems can be solved using additional backscatter profiles from combined elastic/Raman measurements

Summary and Outlook (2)

- Vertical aerosol distribution shows:
  - significant aerosol backscatter up to 3000 m in summer months
  - large part of the aerosol is located in the lowest 1000 m in winter

Acknowledgements

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