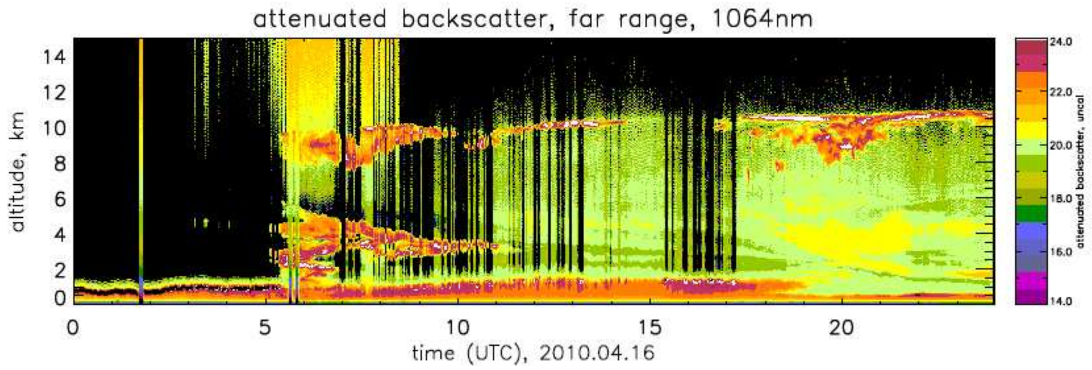
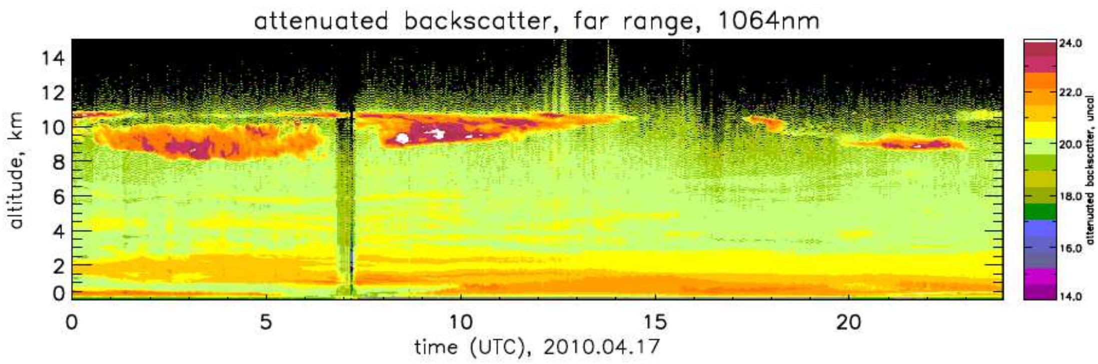
Aerosol measurements at MPI for Meteorology in Hamburg (9.97E, 53.57N) after the Eyjafjallajökull volcano eruption (during the morning of April 14) on Iceland

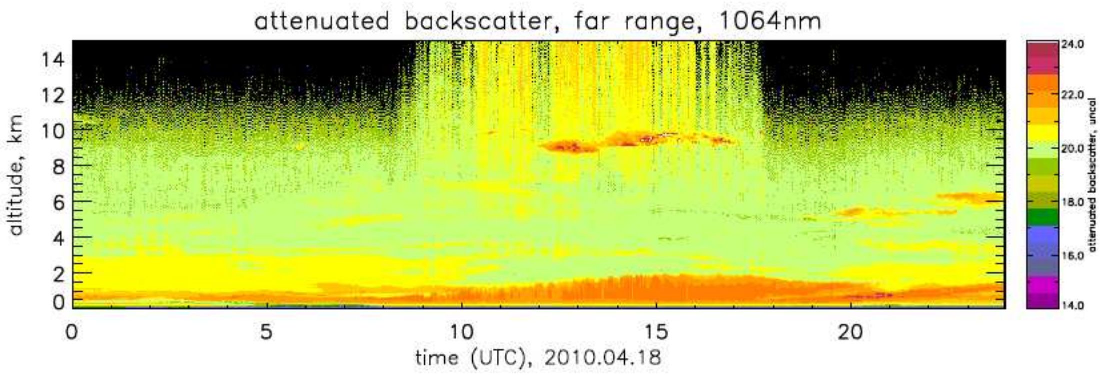
The Max Planck Institute for Meteorology conducts regular aerosol measurements via

- a sun-photometer as part of the AERONET network (passive remote sensing) and
- a multi-wavelength RAMAN lidar as part of the EARLINET network (active remote sensing)

The time series below shows the attenuated far-range lidar backscatter as function of altitude in the near-infrared region of the solar spectrum (at 1064nm) from April 16 to 18, 2010. An intense ash plume reached Hamburg during the morning hours of April 16 and was easily detected by the lidar after a dense low-level cloud cover broke after sunrise. (time series for the near-range and for green light, at 532nm, are given in Appendix A).







Parallel to the ash cloud also high altitude cirrus was observed. The cirrus may have been a direct result of the Iceland eruption (occurring in the morning hours of April 14), because the initial eruption also transported - aside from ash - significant amounts of water vapor into the tropopause region. Back-trajectory data (see Appendix C) indicate that the cirrus on April 16 was at least contaminated by volcanic ash.

After the initial plume had passed the lower tropospheric aerosol load recovered almost to background conditions during the afternoon of April 16, when also low level clouds appeared. Then starting that evening the ash enhancement below 3 km started to pick up again and a small enhancement of the aerosol continued April 17 all day well into the evening hours of April 18. The small enhancement was refined to a small layer which slowly descended in altitude based on (aerosol to air molecule) scattering ratios (see Appendix B) especially at night, when the planetary boundary layer is refined close to the surface. At the beginning of April 17 the ash plume enhanced near 1.8 km, whereas 24 hours later the ash enhancement had dropped to near 0.8 km in altitude.

A useful complement to the lidar data and the trajectory simulations are sun-photometer data. Sun-photometers sample during sunlight hours and cloud-free conditions the incoming direct solar insolation at the surface in different spectral band of the solar spectrum (e. g. separately the red, the green and the blue light). Sun-photometers provide (column) data on aerosol load (via the aerosol optical depth or AOD) and data on aerosol size (via the AOD spectral dependence). In other words if the red AOD matches the blue AOD then the aerosol particles are several micrometer in size, whereas if the blue AOD significantly exceeds the red AOD, then aerosol size are smaller on the order of a few tens of a micrometer. Matching time series between lidar backscattering at 1064nm and column AOD values at 1064nm, as well as at 6 shorter solar wavelengths are presented for the four ash days from April 16 to April 19 in the plots below.

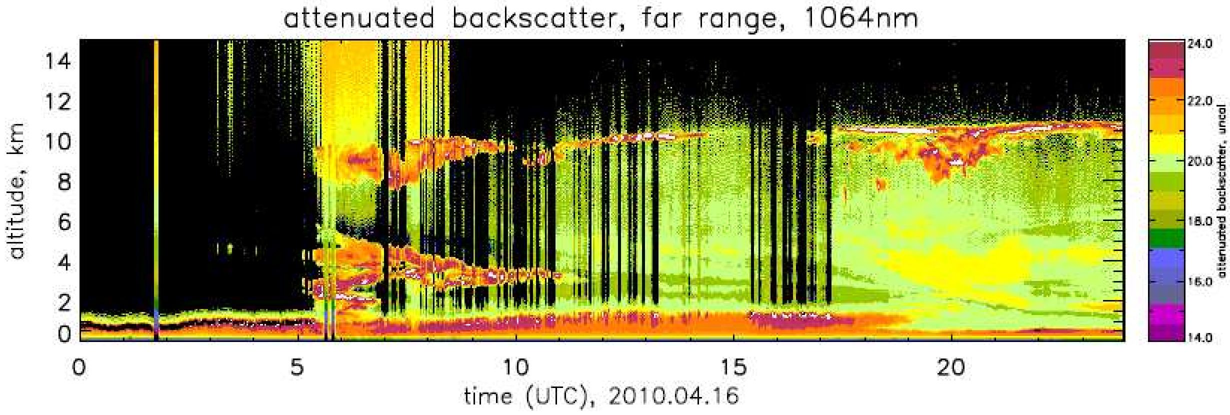
On April 16 contaminating clouds only permitted two measurements of the major plume. Aerosol optical depths mainly between 1.5 and 3.5 km in altitude had a relatively AOD high value of about 1.3. Similar high values were confirmed at Helgoland Island about 70 miles NW of Hamburg in the North Sea. Compare this to seasonal values of 0.2 to 0.3 in the mid-visible and even lower values of about 0.15 to 0.20 at 1064nm. The lack of a spectral dependence for AOD, also confirmed by Helgoland measurements, indicates relatively large aerosol particles. Later at 5 pm local time AOD values had dropped to background levels.

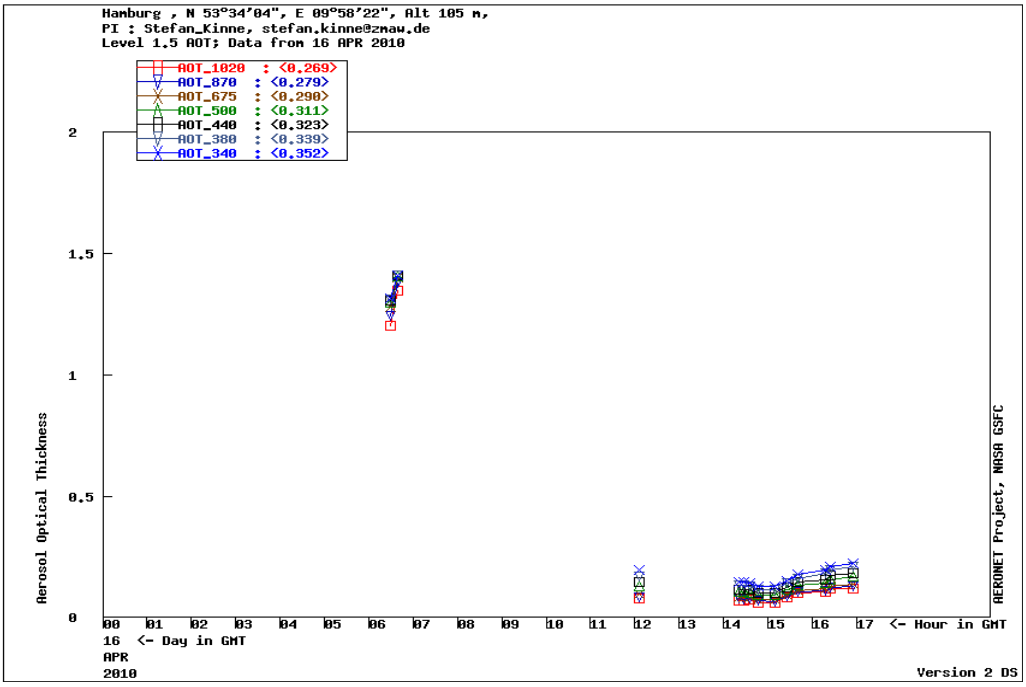
On April 17 layers at around 2 km but also thin layers reaching up to 6 km in altitude slowly faded with time. It remains unclear if the high-altitude lidar signal with a thin separated layer above at 12km may have been cirrus, ash or a mixture of both. Even though a potential presence of ice crystals may lead to an AOD underestimate, even then the overall AOD is small. Actually large ice crystals are unlikely since the AOD displays a strong spectral dependence suggesting tenth-micrometer aerosol sizes.

On April 18 the AOD slowly increased towards the evening hours, mainly as the planetary boundary layer developed during the day. The AOD increase also contributed from 0.03 optical depth attributed to the arrival of large particles (constant spectral behaviors), probably thin cirrus at 9 km in altitude.

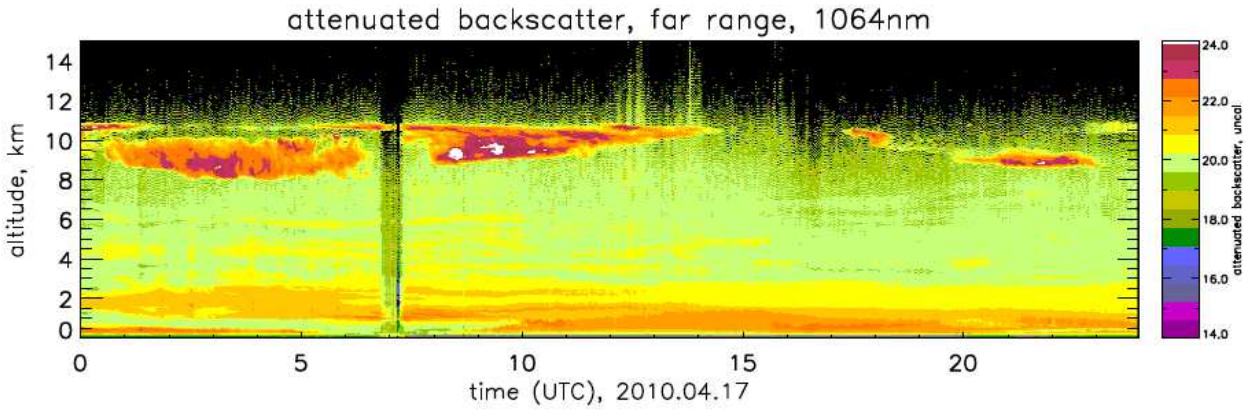
On April 19 the AOD remained at relatively low levels and there seemed a small 0.02 increase in optical depth between 8 and 10 local time, due to slightly enhanced signals near 4 km altitude.

April 16

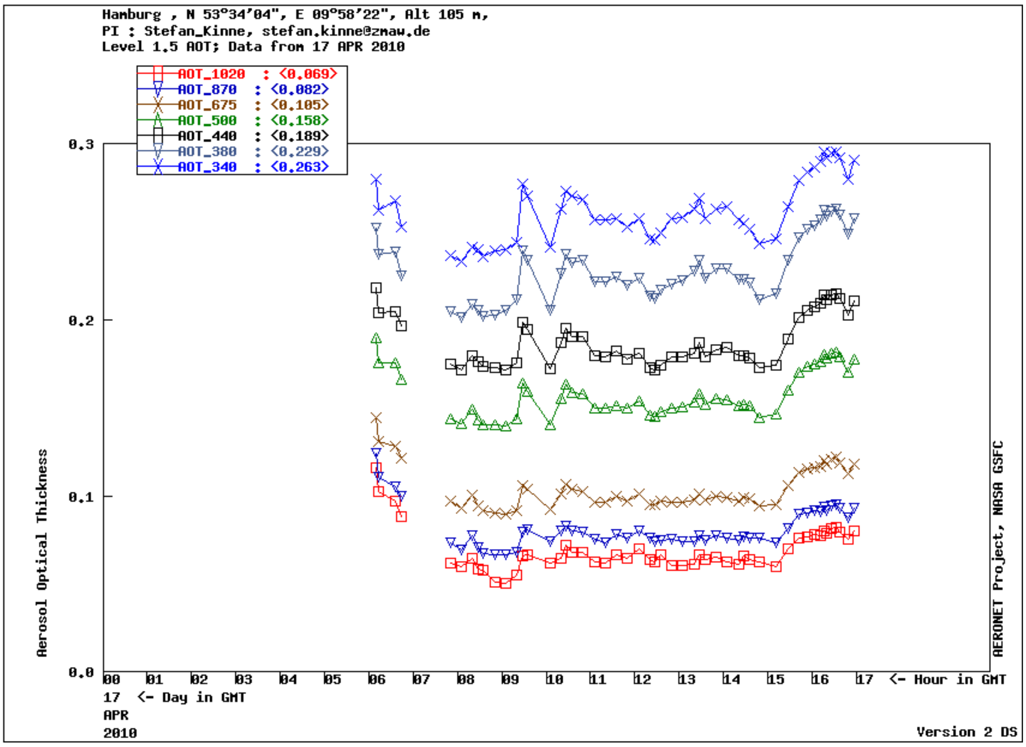




April 17

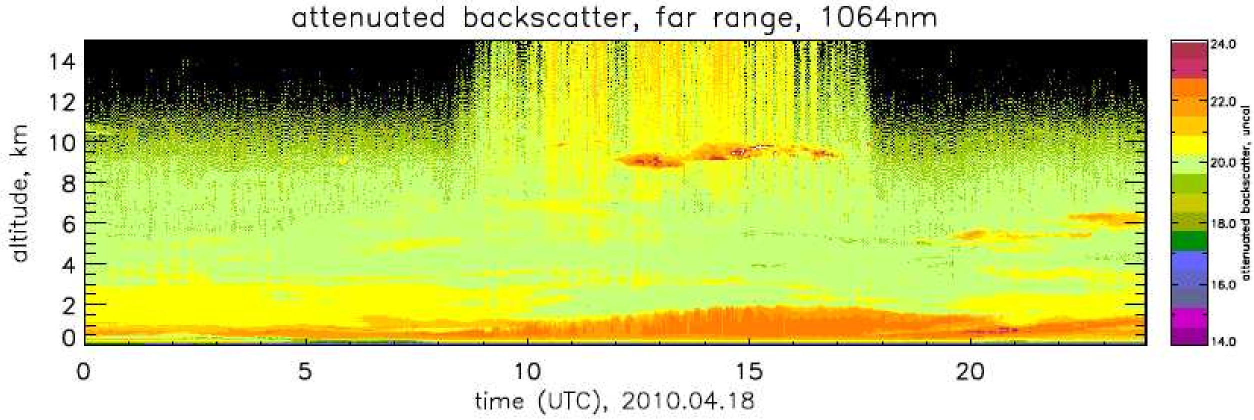


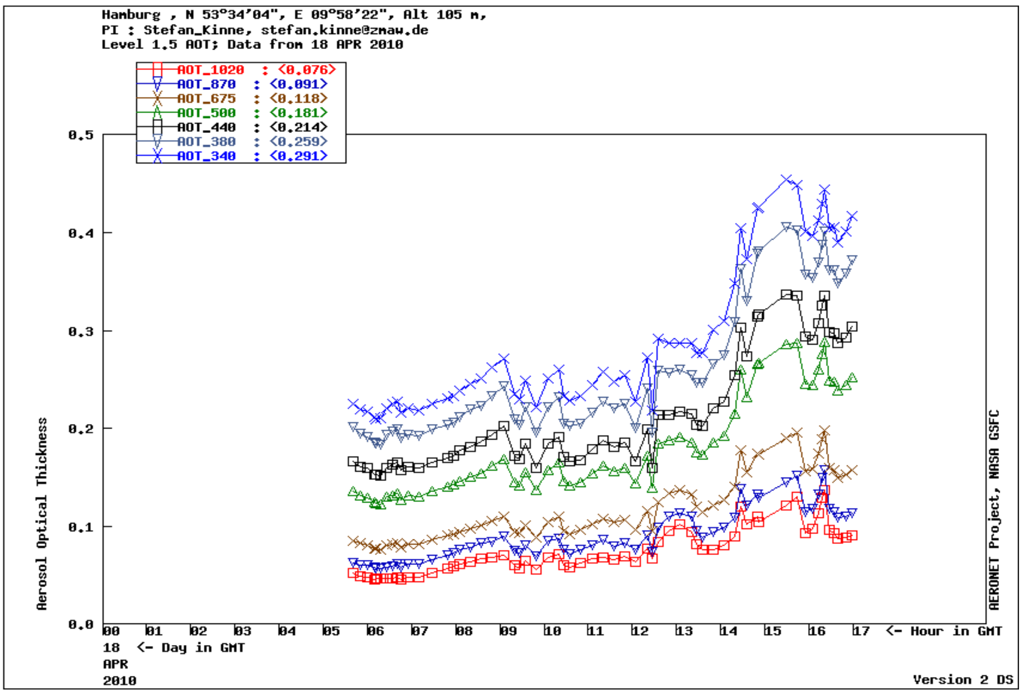
attenuated backscatter, far range, 1064nm
altitude, km
time (UTC), 2010.04.17
attenuated backscatter, uncal



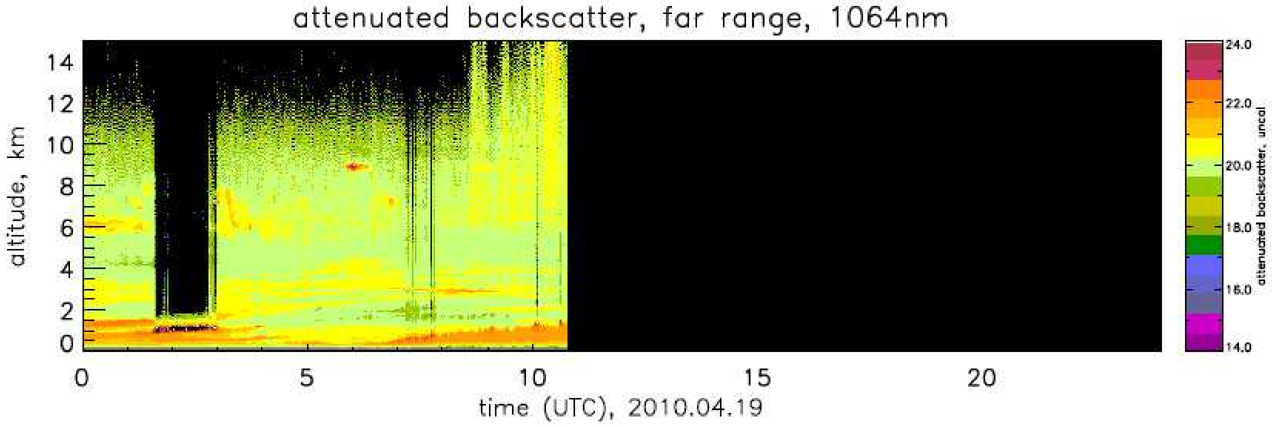
Hamburg , N 53°34'04", E 09°58'22", Alt 105 m,
PI : Stefan_Kinne, stefan.kinne@zmaw.de
Level 1.5 AOT; Data from 17 APR 2010
AOT_1020 : (0.069)
AOT_870 : (0.082)
AOT_675 : (0.105)
AOT_500 : (0.158)
AOT_440 : (0.189)
AOT_380 : (0.229)
AOT_340 : (0.263)
Aerosol Optical Thickness
<- Hour in GMT
17 <- Day in GMT
APR
2010
AERONET Project, NASA GSFC
Version 2 DS

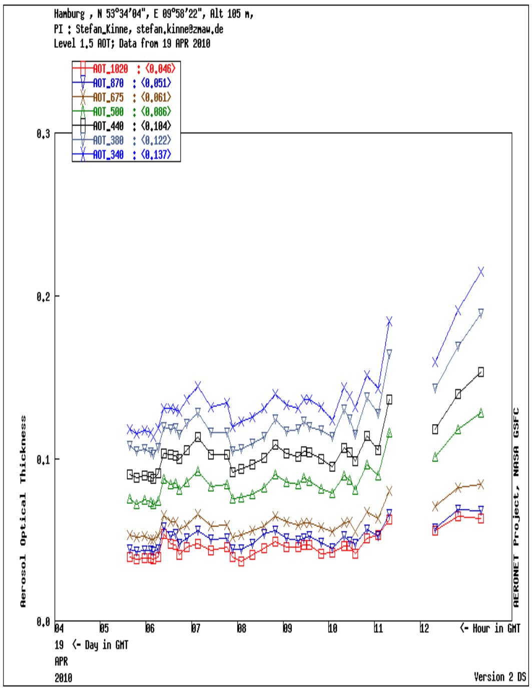
April 18


attenuated backscatter, far range, 1064nm
altitude, km
time (UTC), 2010.04.18
attenuated backscatter, uncal


Hamburg , N 53°34'04", E 09°58'22", Alt 105 m,
PI : Stefan_Kinne, stefan.kinne@zmaw.de
Level 1.5 AOT; Data from 18 APR 2010
AOT_1020 : (0.076)
AOT_870 : (0.091)
AOT_675 : (0.118)
AOT_500 : (0.181)
AOT_440 : (0.214)
AOT_380 : (0.259)
AOT_340 : (0.291)
Aerosol Optical Thickness
<- Hour in GMT
18 <- Day in GMT
APR
2010
AERONET Project, NASA GSFC
Version 2 DS

April 19



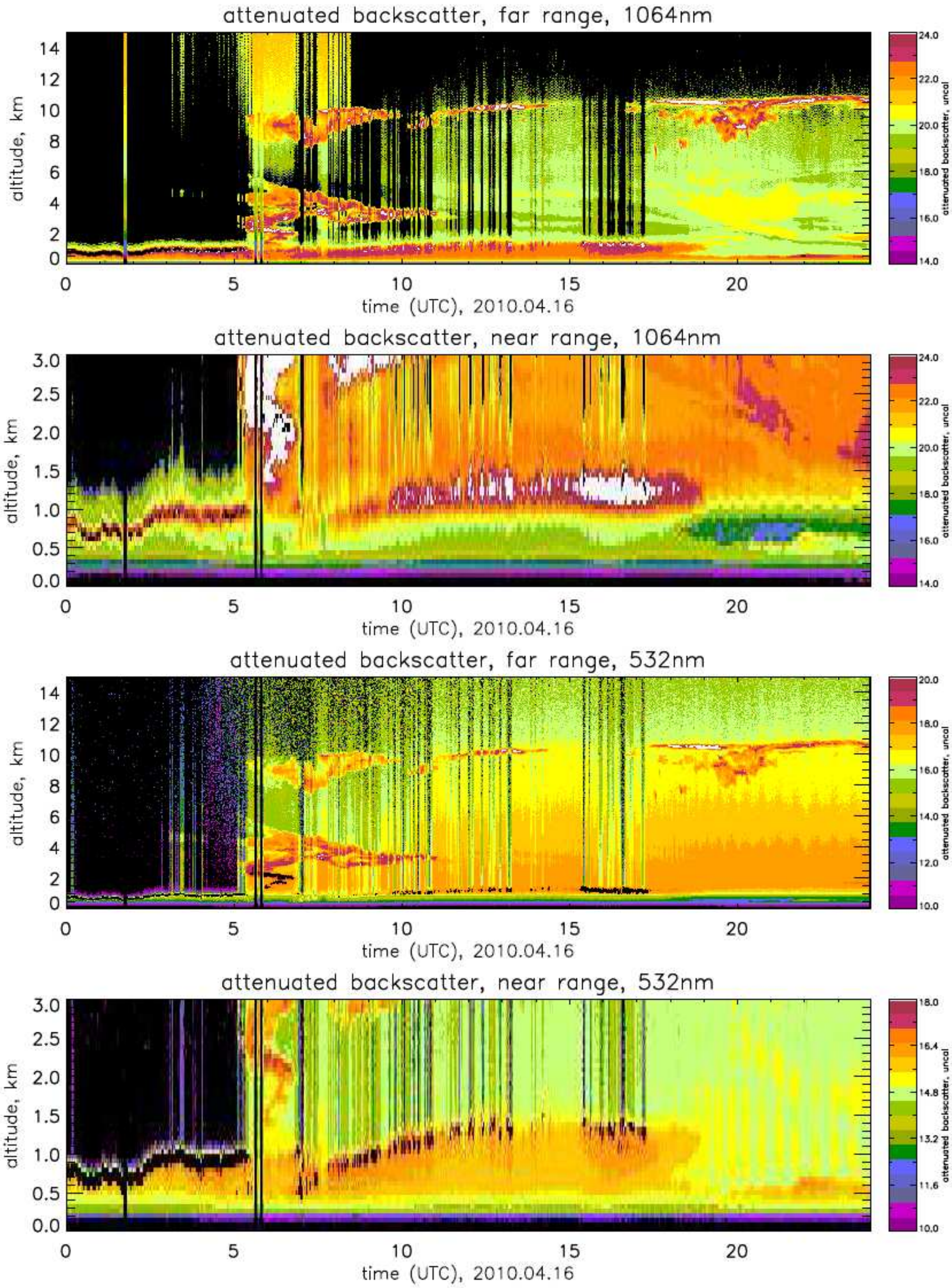


Contact:

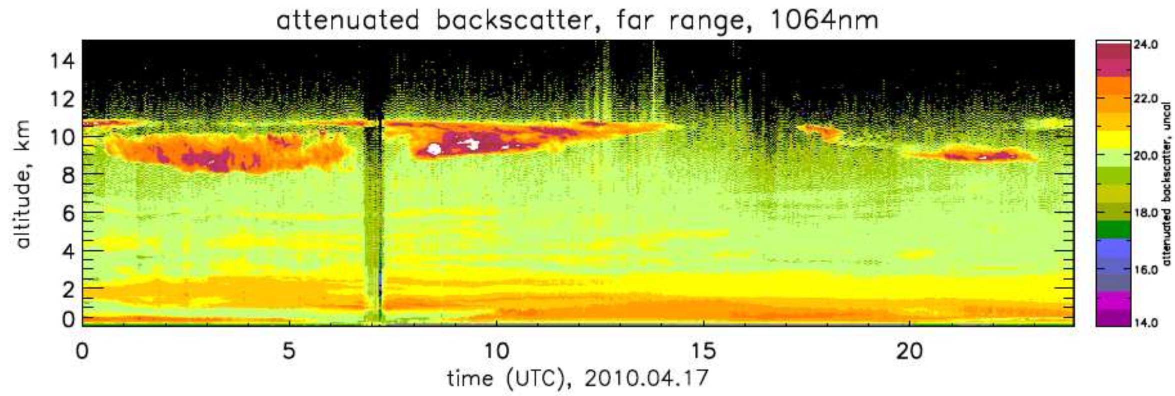
Dr. Stefan Kinne
Max Planck Institute for Meteorology
Phone: +49 40 41173 383
Email: stefan.kinne@zmaw.de

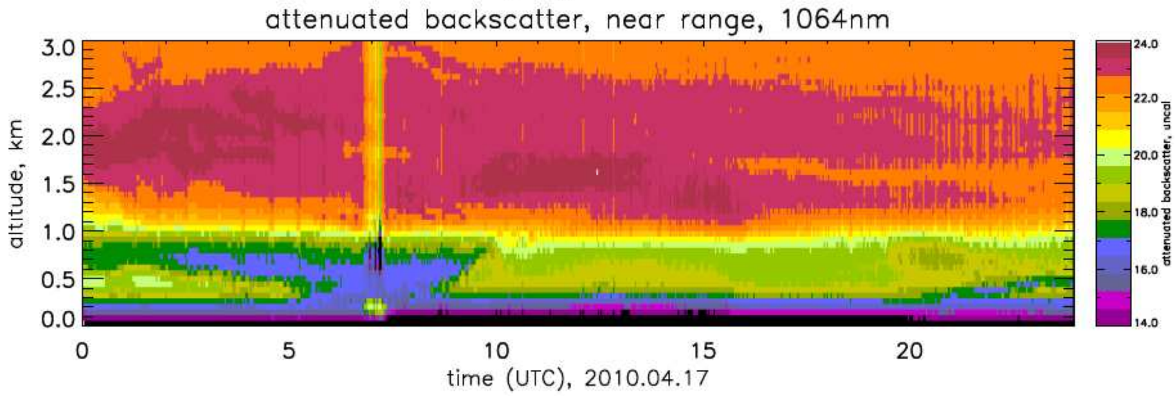
Appendix A: Hamburg lidar back-scatter data

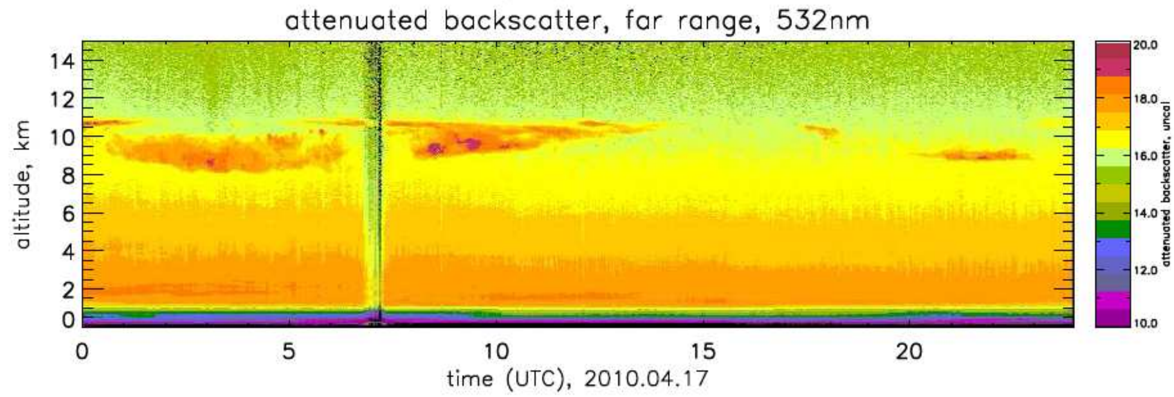
April 16

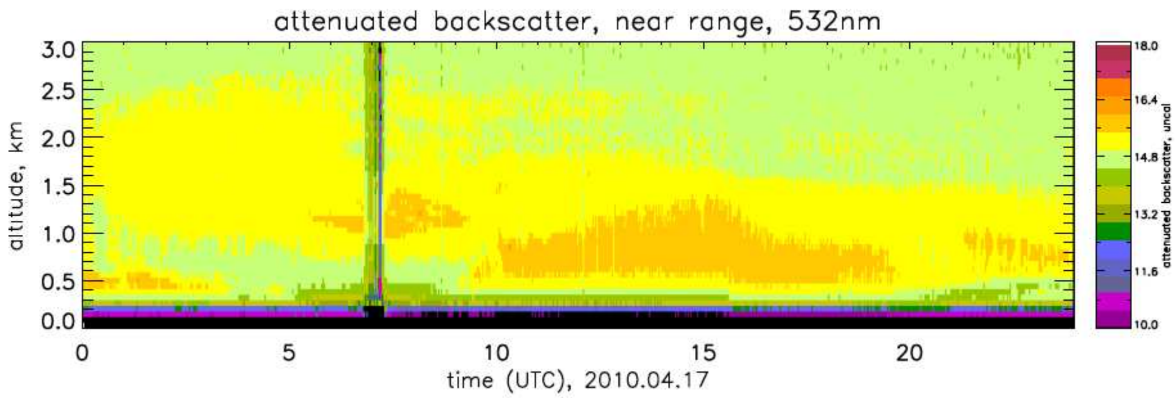


April 17

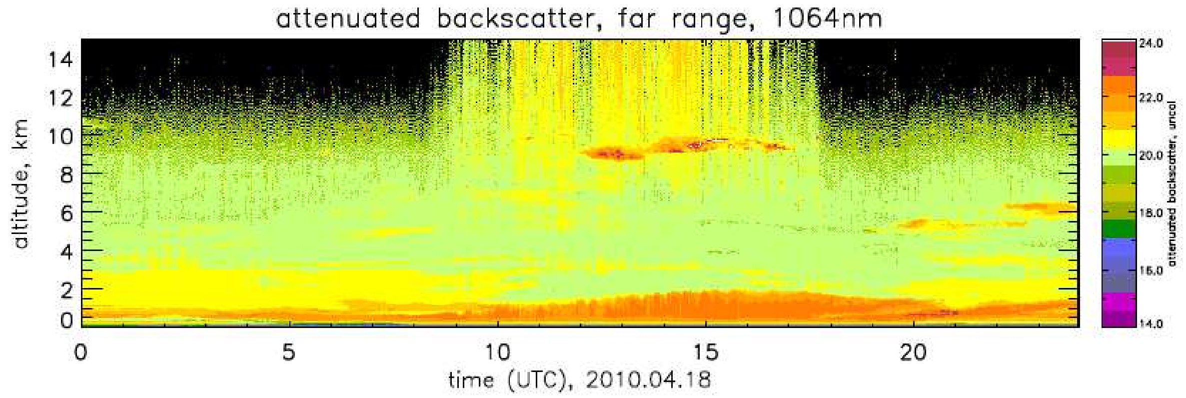

attenuated backscatter, far range, 1064nm
altitude, km
14
12
10
8
6
4
2
0
0
5
10
15
20
time (UTC), 2010.04.17
24.0
22.0
20.0
18.0
16.0
14.0
attenuated backscatter, uncal

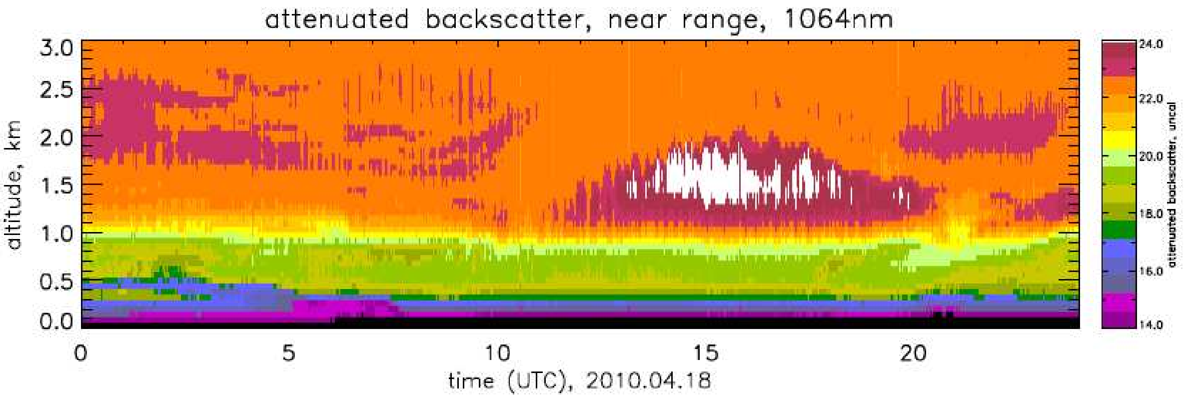

attenuated backscatter, near range, 1064nm
altitude, km
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
5
10
15
20
time (UTC), 2010.04.17
24.0
22.0
20.0
18.0
16.0
14.0
attenuated backscatter, uncal


attenuated backscatter, far range, 532nm
altitude, km
14
12
10
8
6
4
2
0
0
5
10
15
20
time (UTC), 2010.04.17
20.0
18.0
16.0
14.0
12.0
10.0
attenuated backscatter, uncal


attenuated backscatter, near range, 532nm
altitude, km
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
5
10
15
20
time (UTC), 2010.04.17
18.0
16.4
14.8
13.2
11.6
10.0
attenuated backscatter, uncal

April 18


attenuated backscatter, far range, 1064nm
altitude, km
14
12
10
8
6
4
2
0
0
5
10
15
20
time (UTC), 2010.04.18
24.0
22.0
20.0
18.0
16.0
14.0
attenuated backscatter, uncal


attenuated backscatter, near range, 1064nm
altitude, km
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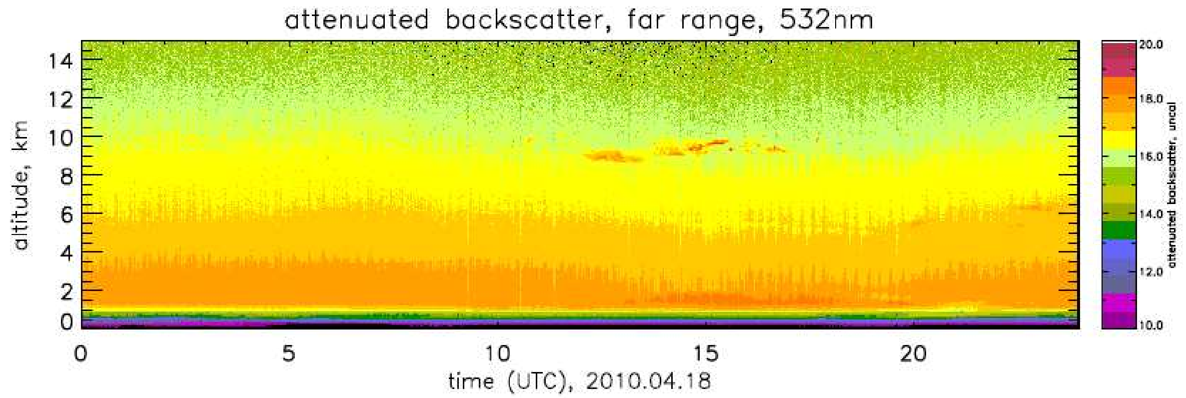
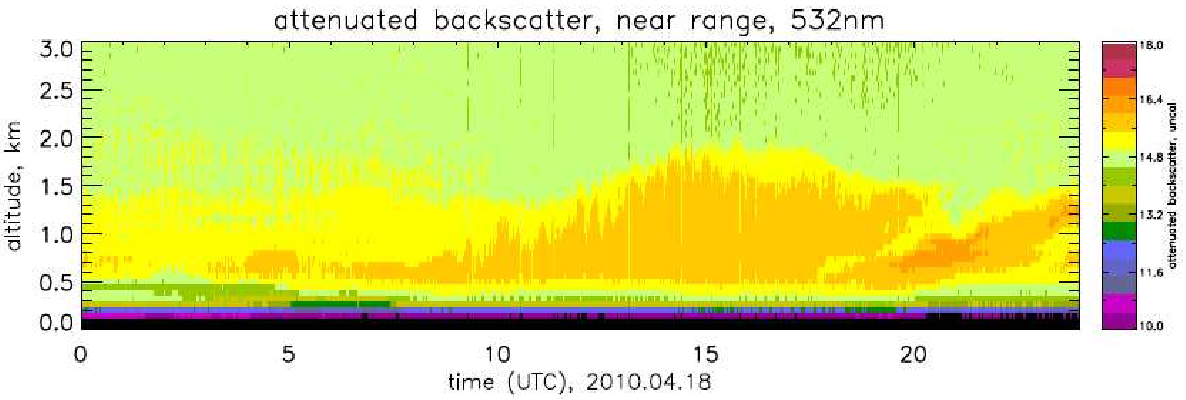
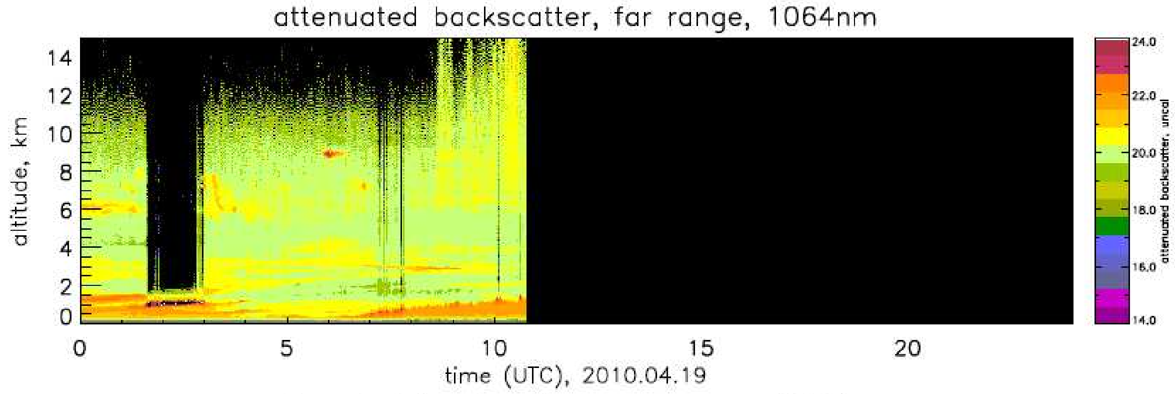
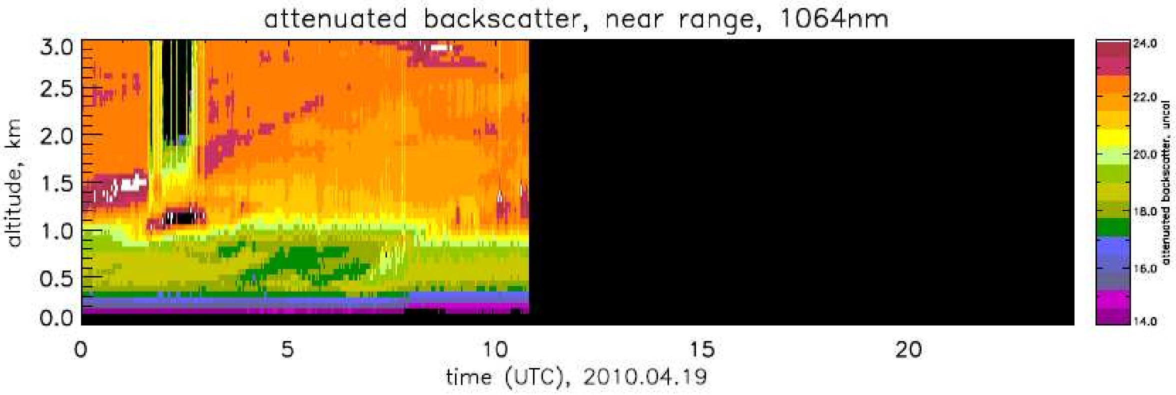
2.5
2.0
1.5
1.0
0.5
0.0
0
5
10
15
20
time (UTC), 2010.04.18
24.0
22.0
20.0
18.0
16.0
14.0
attenuated backscatter, uncal


attenuated backscatter, far range, 532nm
altitude, km
14
12
10
8
6
4
2
0
0
5
10
15
20
time (UTC), 2010.04.18
20.0
18.0
16.0
14.0
12.0
10.0
attenuated backscatter, uncal


attenuated backscatter, near range, 532nm
altitude, km
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
5
10
15
20
time (UTC), 2010.04.18
18.0
16.4
14.8
13.2
11.6
10.0
attenuated backscatter, uncal

April 19


attenuated backscatter, far range, 1064nm
altitude, km
time (UTC), 2010.04.19
attenuated backscatter, uncal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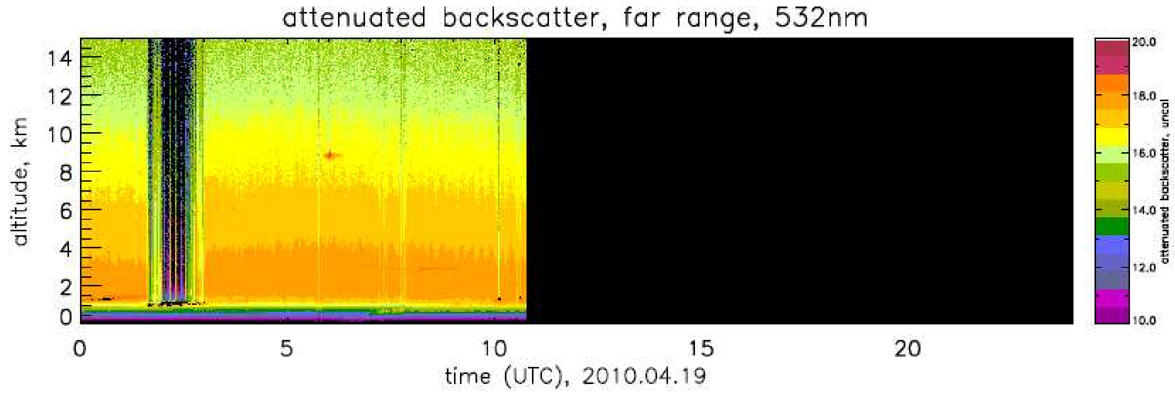
altitude, km
time (UTC), 2010.04.19
attenuated backscatter, uncal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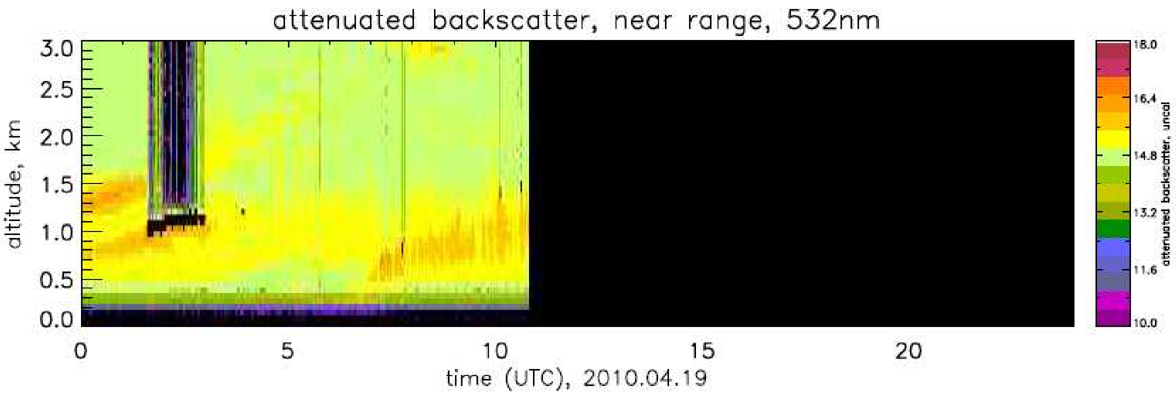
altitude, km
time (UTC), 2010.04.19
attenuated backscatter, uncal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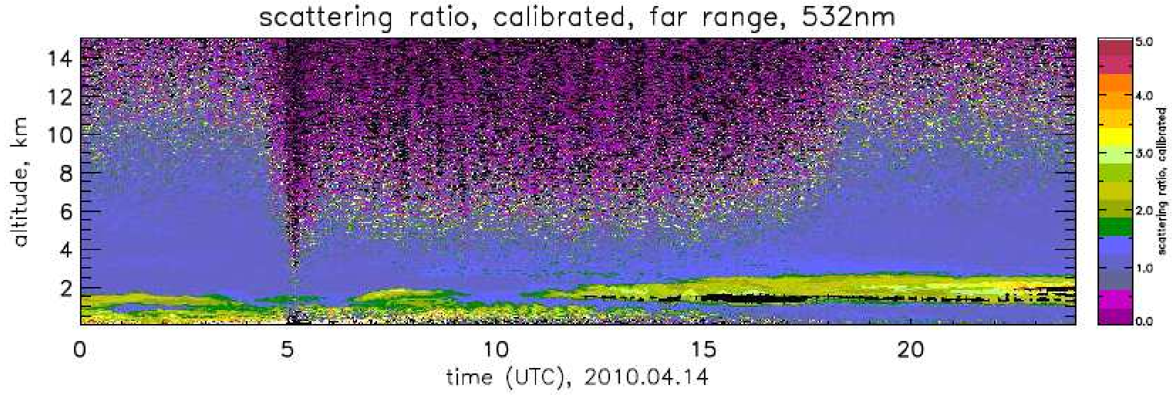
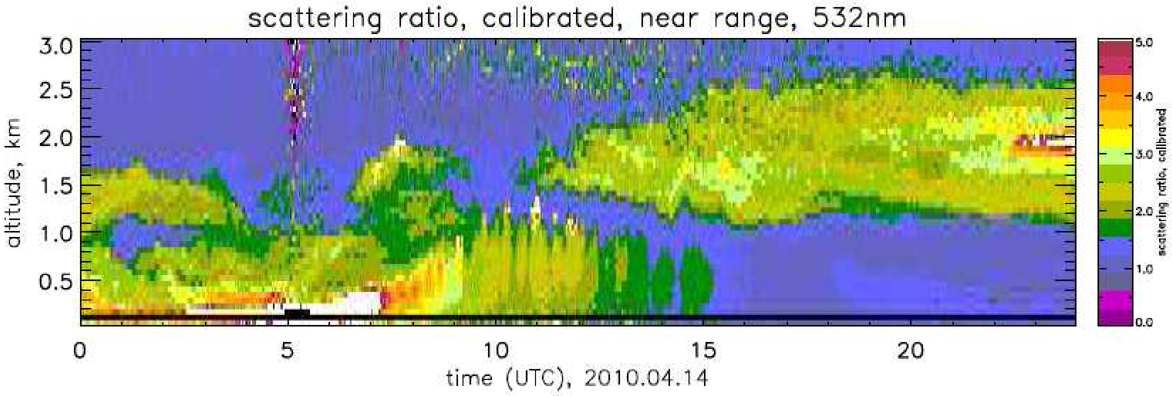
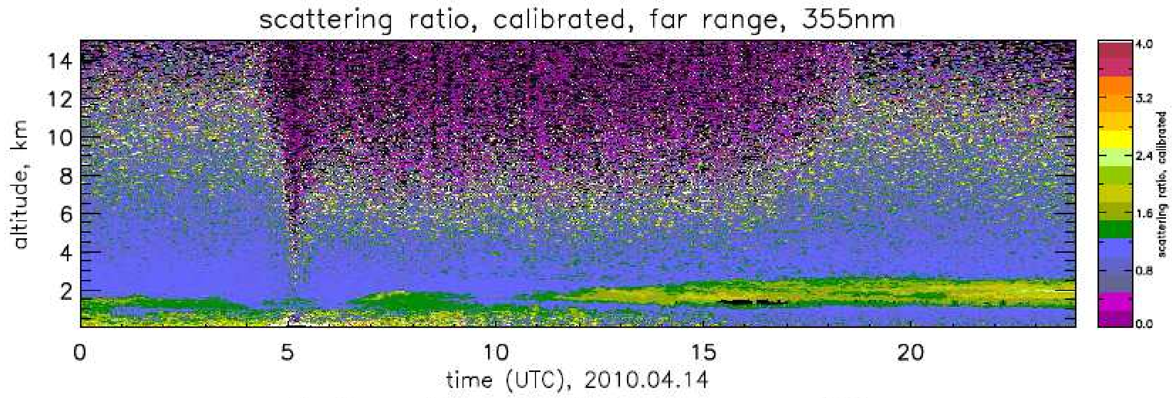
altitude, km
time (UTC), 2010.04.19
attenuated backscatter, uncal

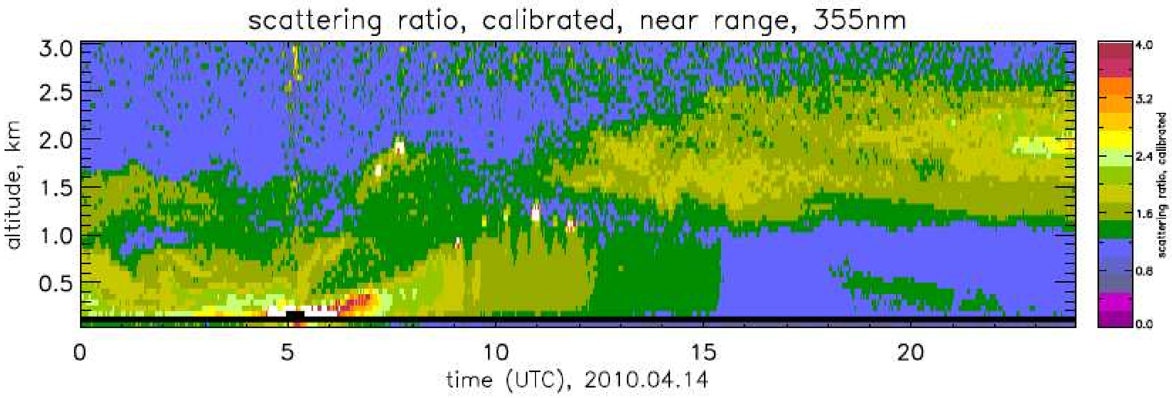
Appendix B: Hamburg aerosol / molecular scatter ratios

April 14

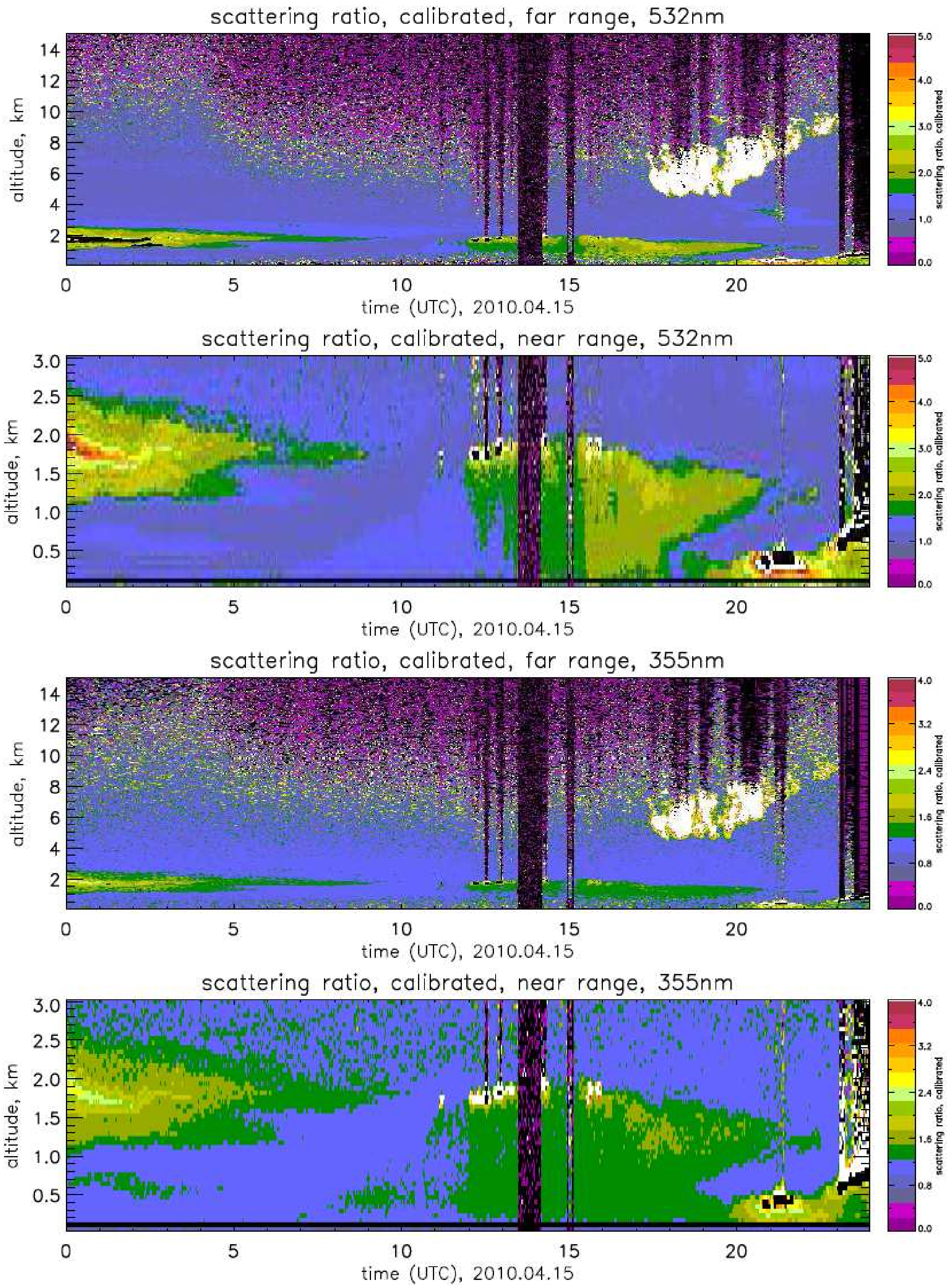






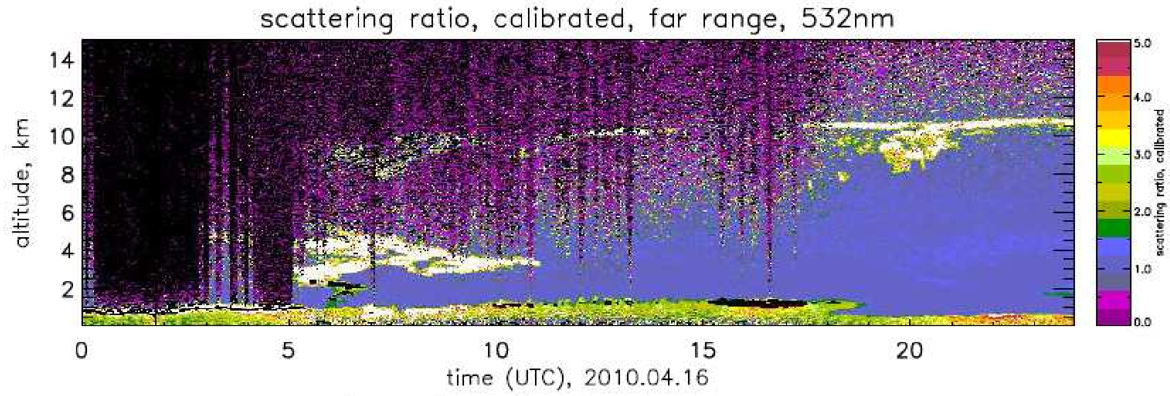


April 15



scattering ratio, calibrated, far range, 532nm
altitude, km
time (UTC), 2010.04.15
scattering ratio, calibrated, near range, 532nm
altitude, km
time (UTC), 2010.04.15
scattering ratio, calibrated, far range, 355nm
altitude, km
time (UTC), 2010.04.15
scattering ratio, calibrated, near range, 355nm
altitude, km
time (UTC), 2010.04.15
scattering ratio, calibrated

April 16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altitude, km
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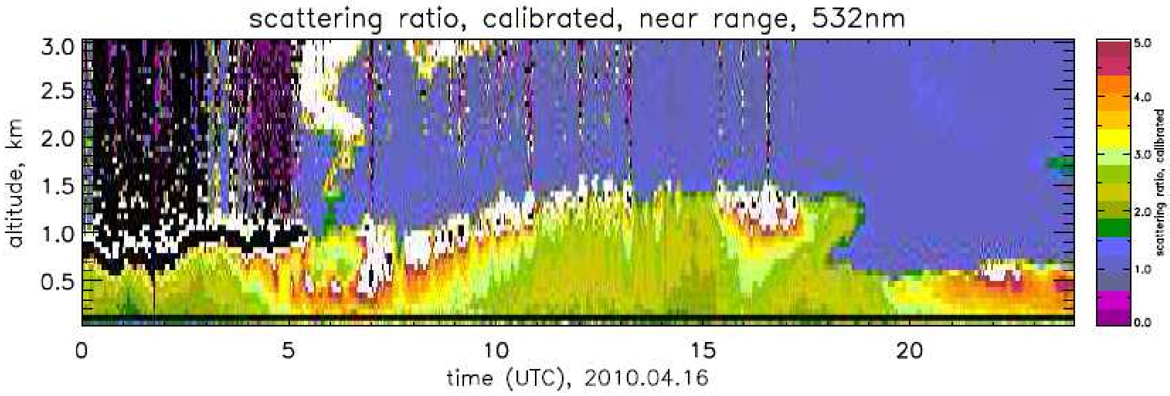
scattering ratio, calibrated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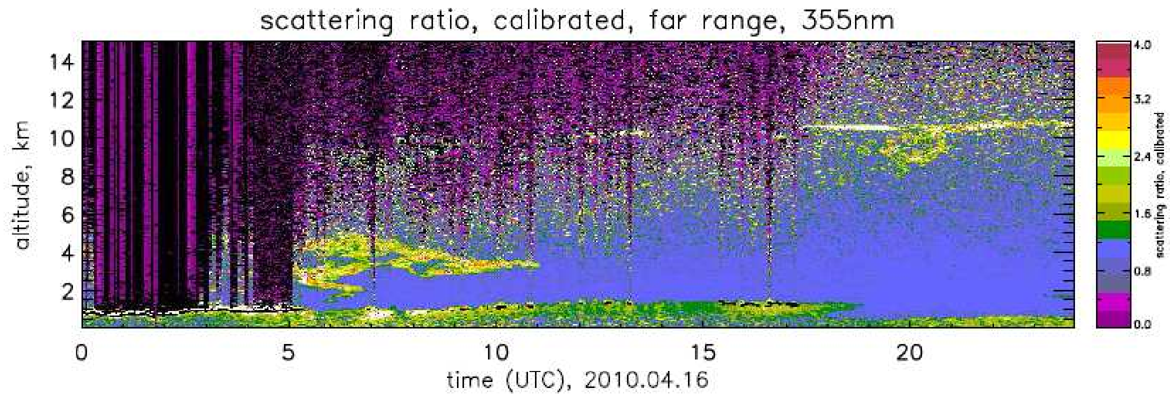
altitude, km
time (UTC), 2010.04.16
scattering ratio, calibrated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altitude, km
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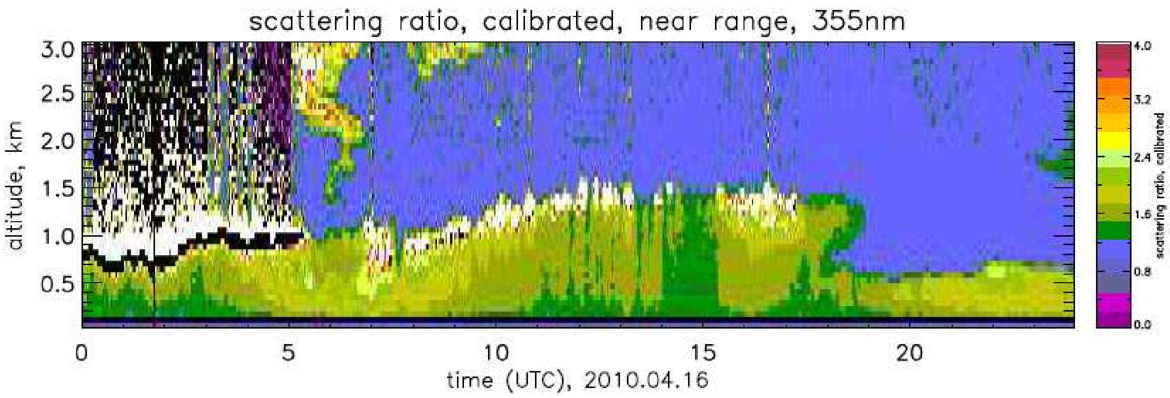
scattering ratio, calibrated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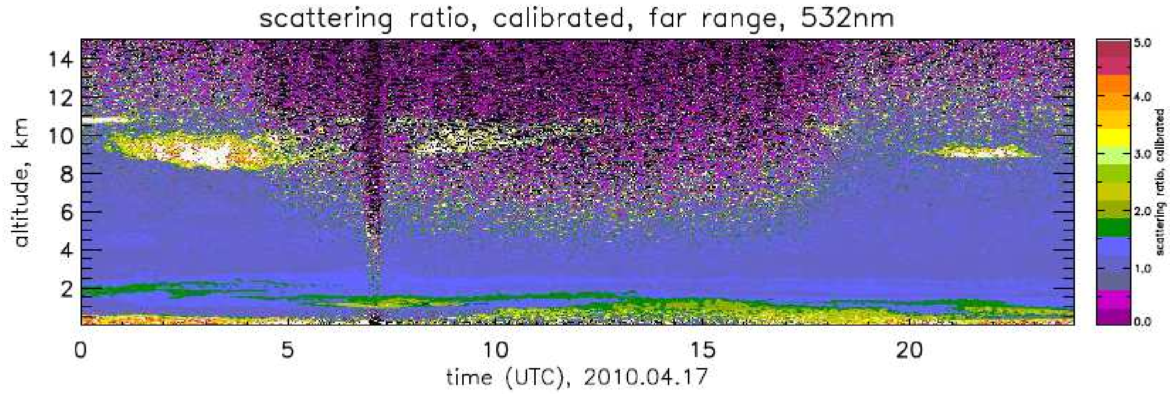
altitude, km
time (UTC), 2010.04.16
scattering ratio, calibrated

April 17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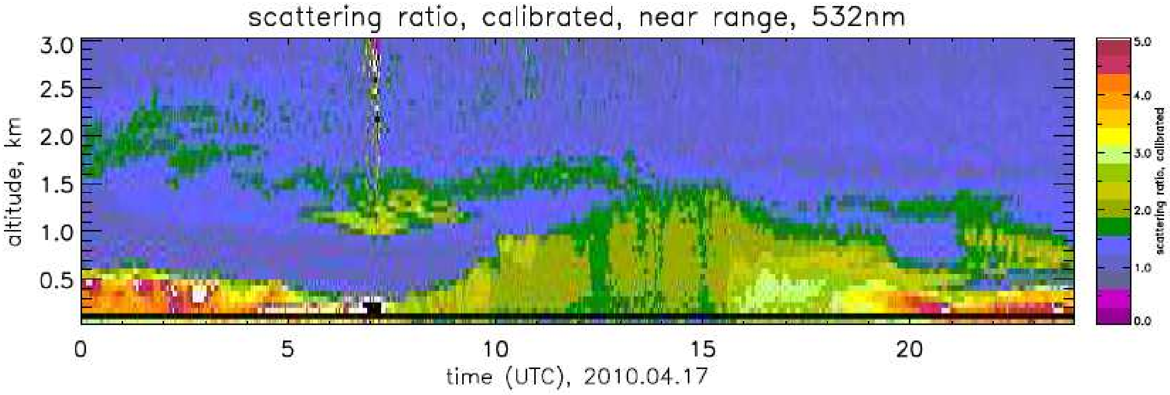
altitude, km
time (UTC), 2010.04.17
scattering ratio, calibrated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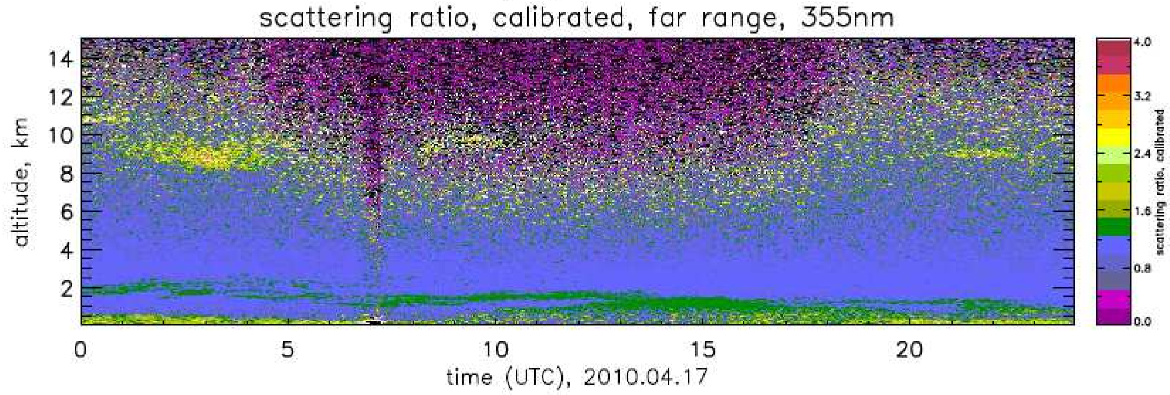
altitude, km
time (UTC), 2010.04.17
scattering ratio, calibrated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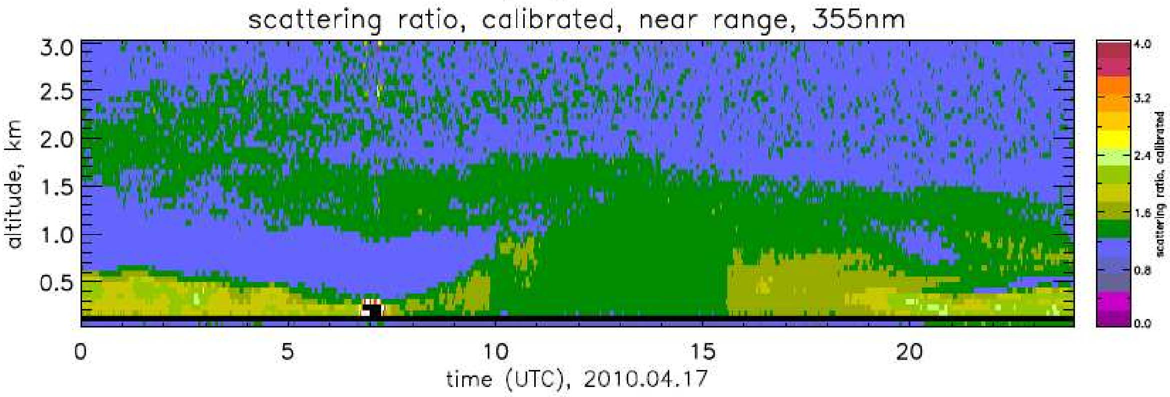
altitude, km
time (UTC), 2010.04.17
scattering ratio, calibrated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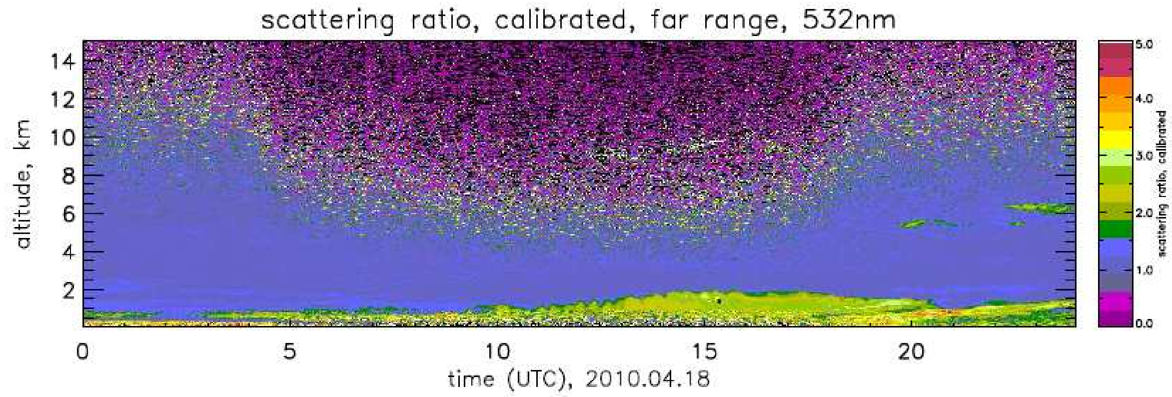
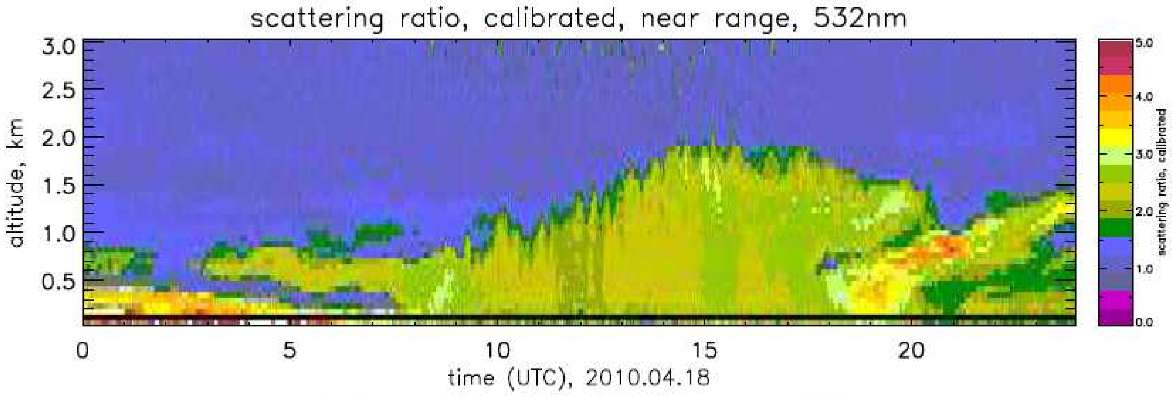
altitude, km
time (UTC), 2010.04.17
scattering ratio, calibrated

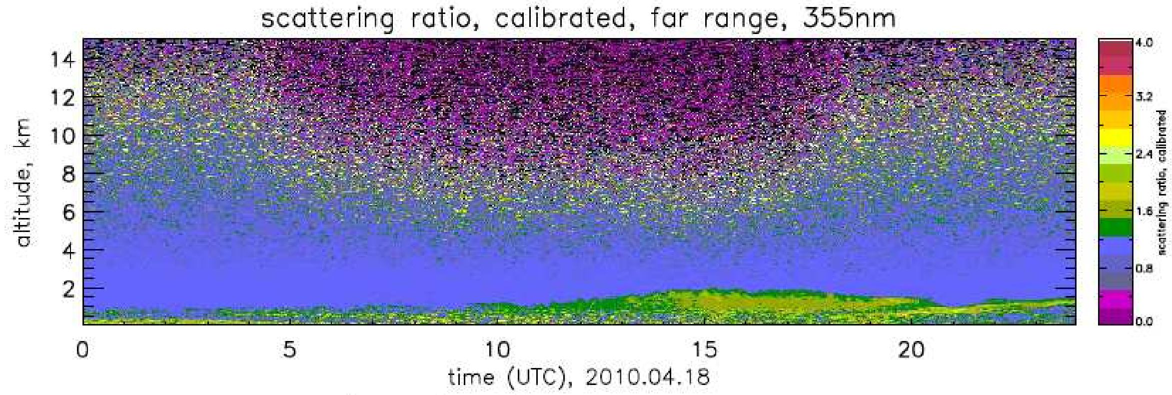
April 18



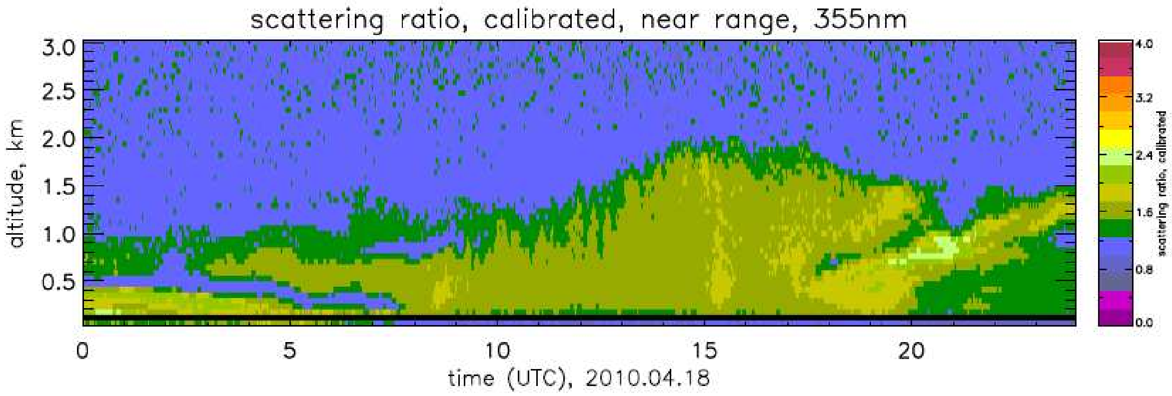
scattering ratio, calibrated, far range, 532nm
altitude, km
14
12
10
8
6
4
2
0
5
10
15
20
time (UTC), 2010.04.18
5.0
4.0
3.0
2.0
1.0
0.0
scattering ratio, calibrated



scattering ratio, calibrated, near range, 532nm
altitude, km
3.0
2.5
2.0
1.5
1.0
0.5
0
5
10
15
20
time (UTC), 2010.04.18
5.0
4.0
3.0
2.0
1.0
0.0
scattering ratio, calibrated

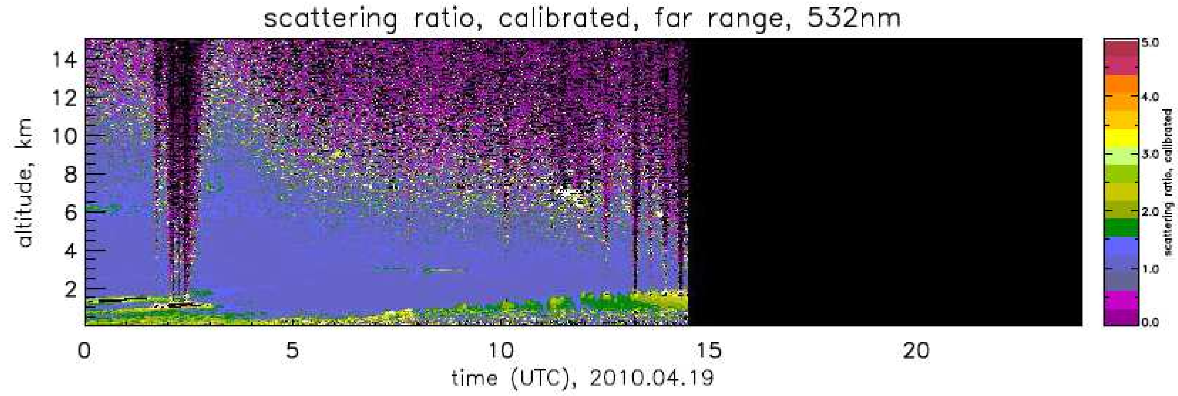


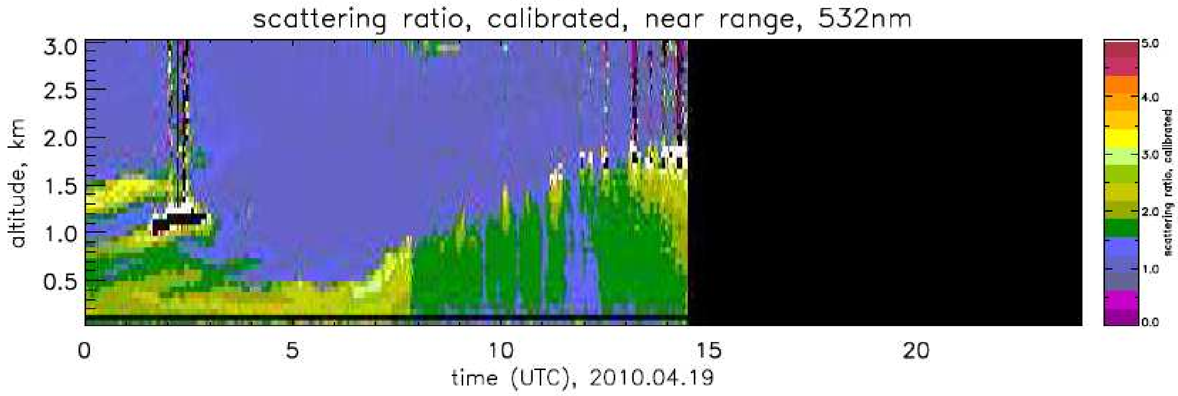
scattering ratio, calibrated, far range, 355nm
altitude, km
14
12
10
8
6
4
2
0
5
10
15
20
time (UTC), 2010.04.18
4.0
3.2
2.4
1.6
0.8
0.0
scattering ratio, calibrated

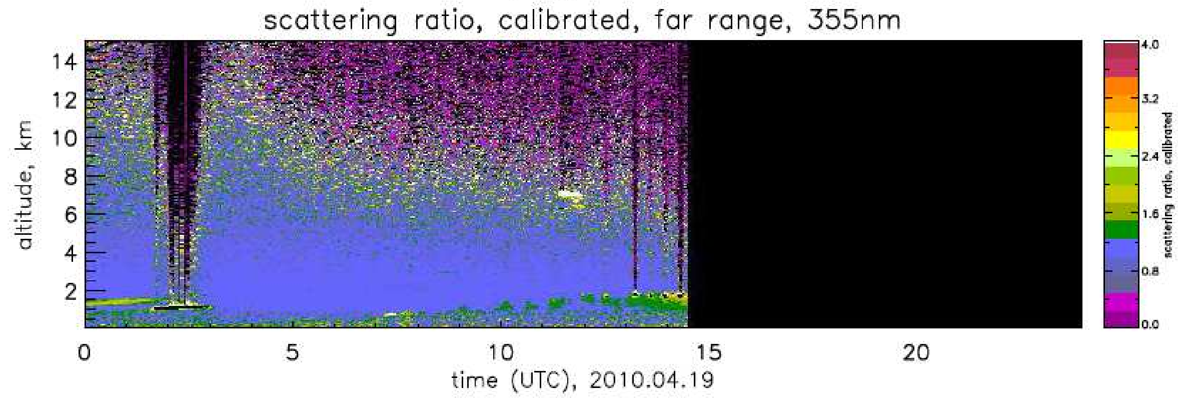


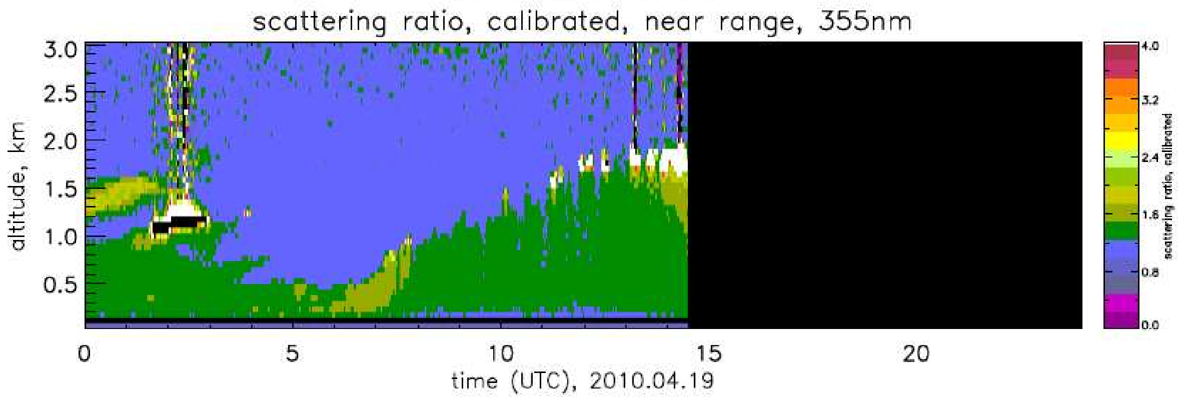
scattering ratio, calibrated, near range, 355nm
altitude, km
3.0
2.5
2.0
1.5
1.0
0.5
0
5
10
15
20
time (UTC), 2010.04.18
4.0
3.2
2.4
1.6
0.8
0.0
scattering ratio, calibrated

April 19


scattering ratio, calibrated, far range, 532nm
altitude, km
14
12
10
8
6
4
2
0
5
10
15
20
time (UTC), 2010.04.19
5.0
4.0
3.0
2.0
1.0
0.0
scattering ratio, calibrated

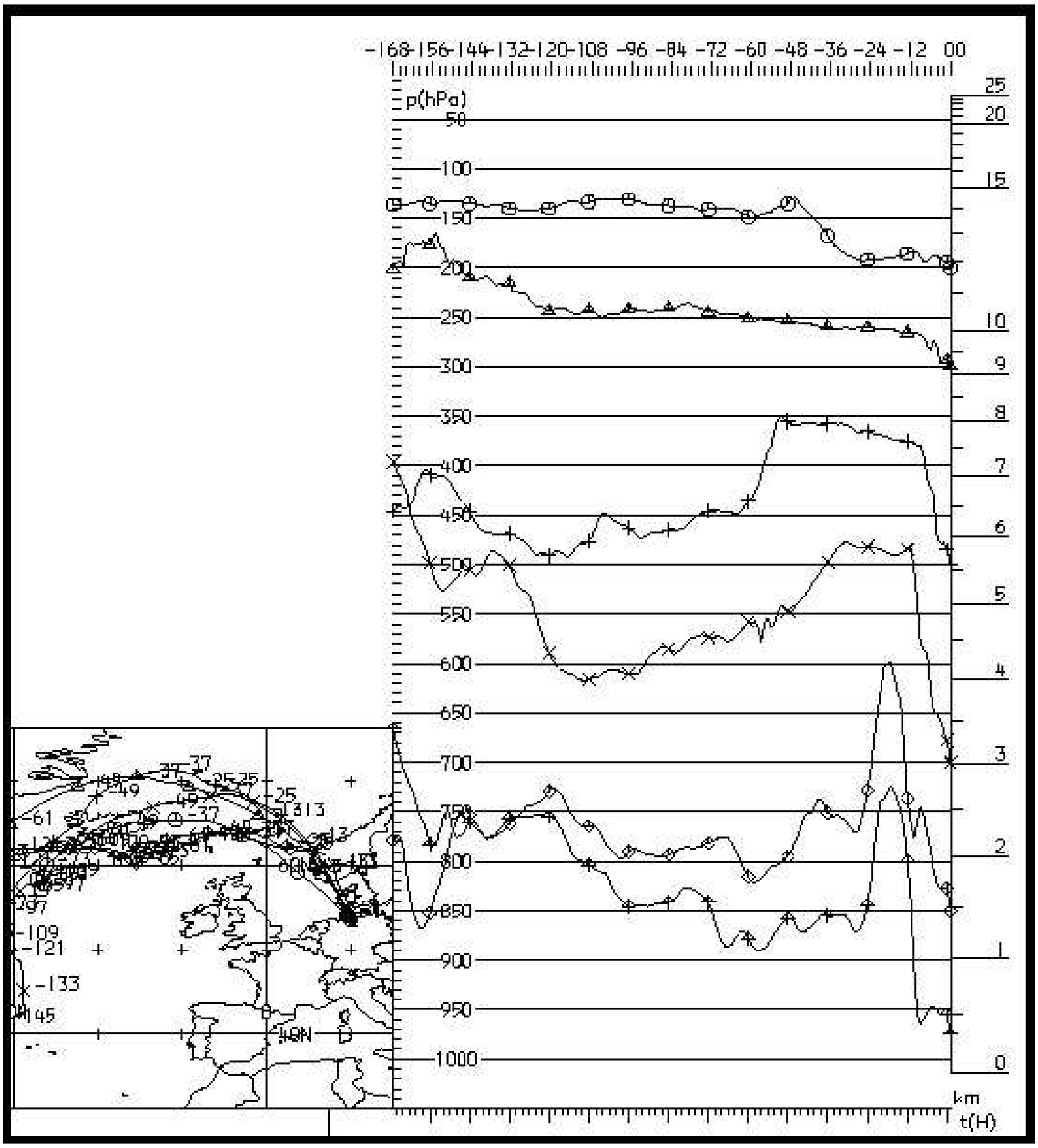

scattering ratio, calibrated, near range, 532nm
altitude, km
3.0
2.5
2.0
1.5
1.0
0.5
0
5
10
15
20
time (UTC), 2010.04.19
5.0
4.0
3.0
2.0
1.0
0.0
scattering ratio, calibrated


scattering ratio, calibrated, far range, 355nm
altitude, km
14
12
10
8
6
4
2
0
5
10
15
20
time (UTC), 2010.04.19
4.0
3.2
2.4
1.6
0.8
0.0
scattering ratio, calibrated


scattering ratio, calibrated, near range, 355nm
altitude, km
3.0
2.5
2.0
1.5
1.0
0.5
0
5
10
15
20
time (UTC), 2010.04.19
4.0
3.2
2.4
1.8
0.8
0.0
scattering ratio, calibrated

Appendix C: DWD back-trajectories

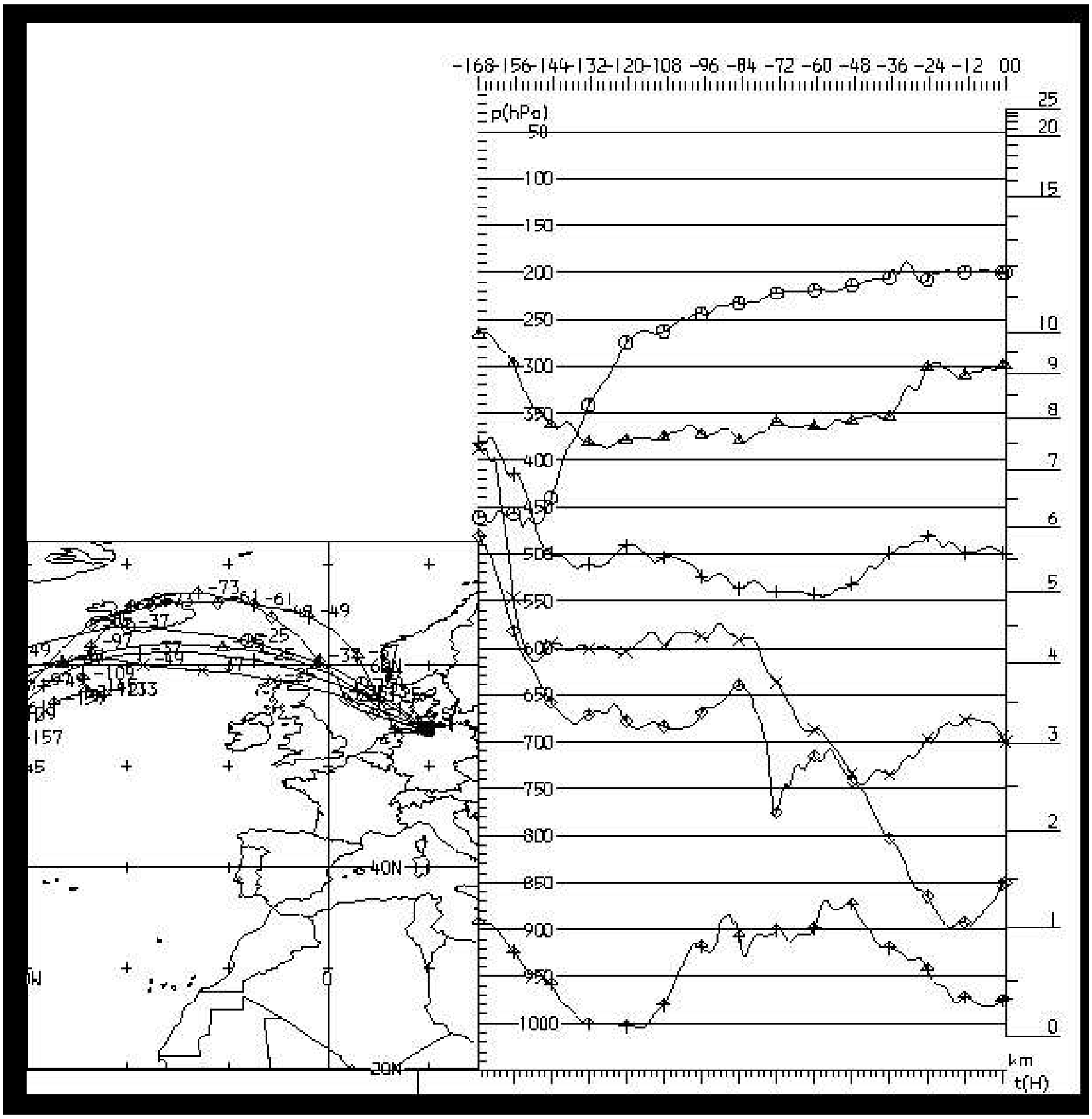
April 16, 13 utc



Five of the six selected trajectories arriving at 12.0, 5.5, 3.2, 1.7 and 0.4 km altitude at Hamburg passed near the Iceland volcano ca. 52 hours earlier. This strongly suggests that during the early afternoon (3 pm) local time on April 16 the entire atmosphere below 6 km altitude contained ash enhancements of the Iceland eruption. A further indication is that all five air-masses experienced an altitude increase after passing the volcano area.

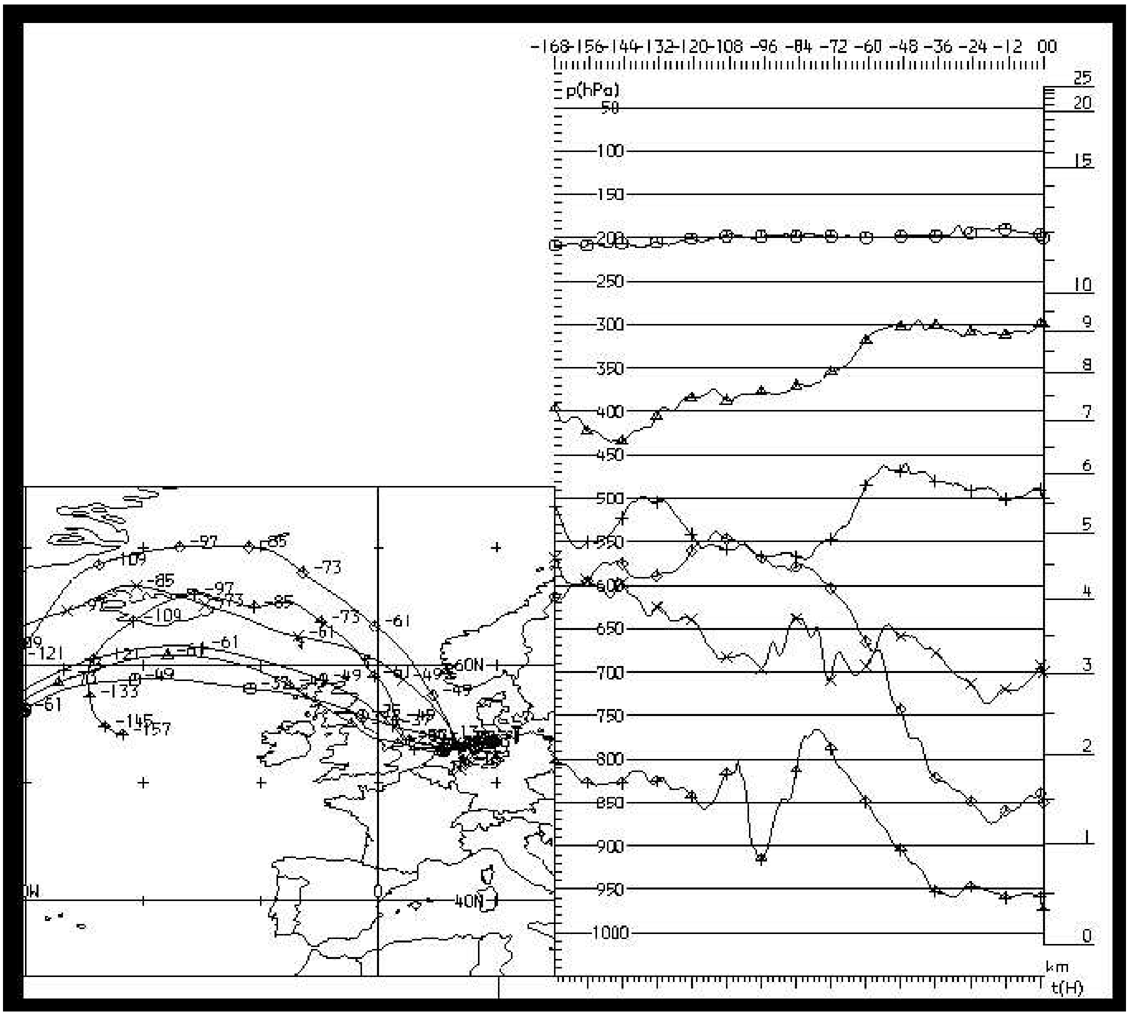
The high altitude trajectory indicates that if ash reached altitudes of 12 km, then this high altitude ash should have been also expected over Hamburg on April 16. Extra aerosol particles and extra water near the tropopause also is expected to have enhanced cirrus cloud frequency and enhanced their lifecycle.

April 17, 13 utc



Of the six selected trajectories, only those two arriving at 1.5 and 0.3 km at Hamburg at 3 pm local time passed near the Iceland volcano ca. 76 hours earlier - at then significantly higher altitudes of 2.8 and 1.3 km. Both trajectories experienced an altitude increase after passing the volcano area but weaker than lower altitude air-masses arriving at Hamburg the day before. Thus, volcano related enhanced ash (and aerosol) contributions on April 17 over Hamburg are only expected below 2.5 km altitude.

April 18, 13 utc



Of the six selected trajectories, only the single one arriving at the lowest altitude of 0.5 km passed near the Iceland volcano ca. 100 hours earlier. However, also the trajectory arriving at 1.5 km altitude may have contained ash, as it passed north of the volcano, the dominant direction of volcano exhaust at lower altitudes the days before. Thus, as for the day before, on April 18 aerosol and ash contributions over Hamburg are expected below 2.5 km altitude.