Role of MPL in ALIVE

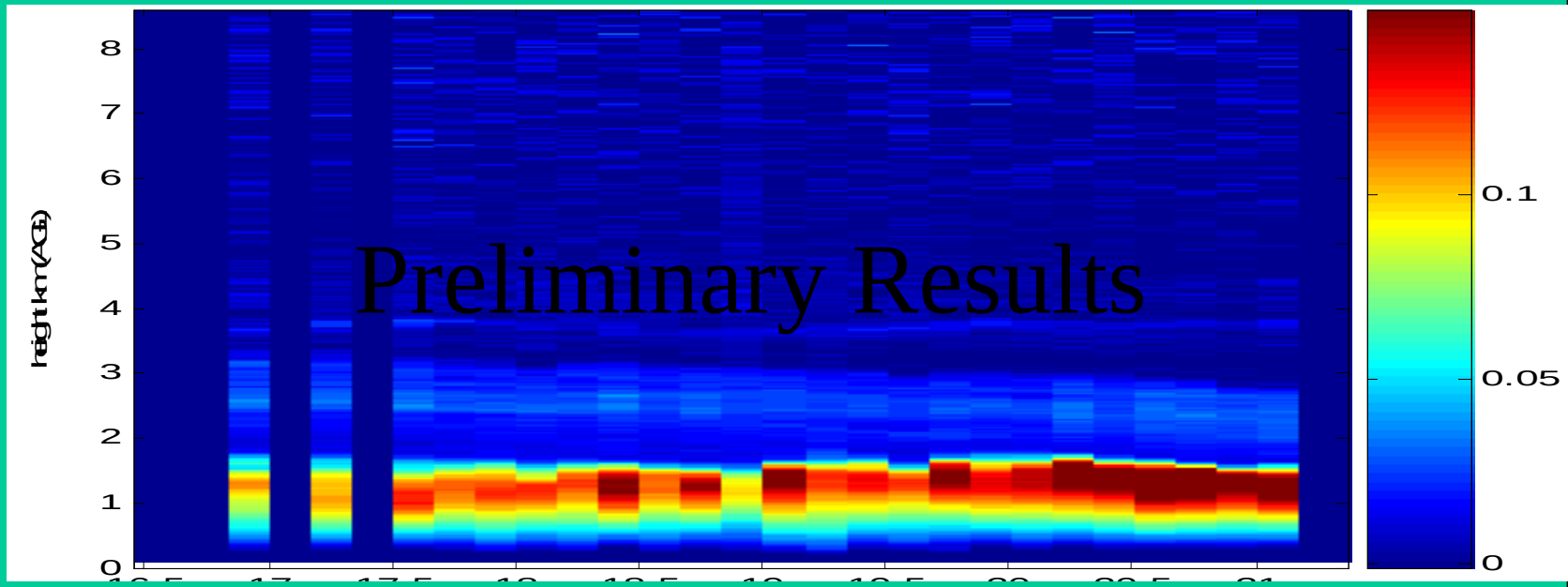
ARM
Atmospheric Radiation Measurement

- Part of the purpose of ALIVE was to document the improved capability of the RL and to permit comparison/validation of MPL ext. retrievals versus RL and AATS.

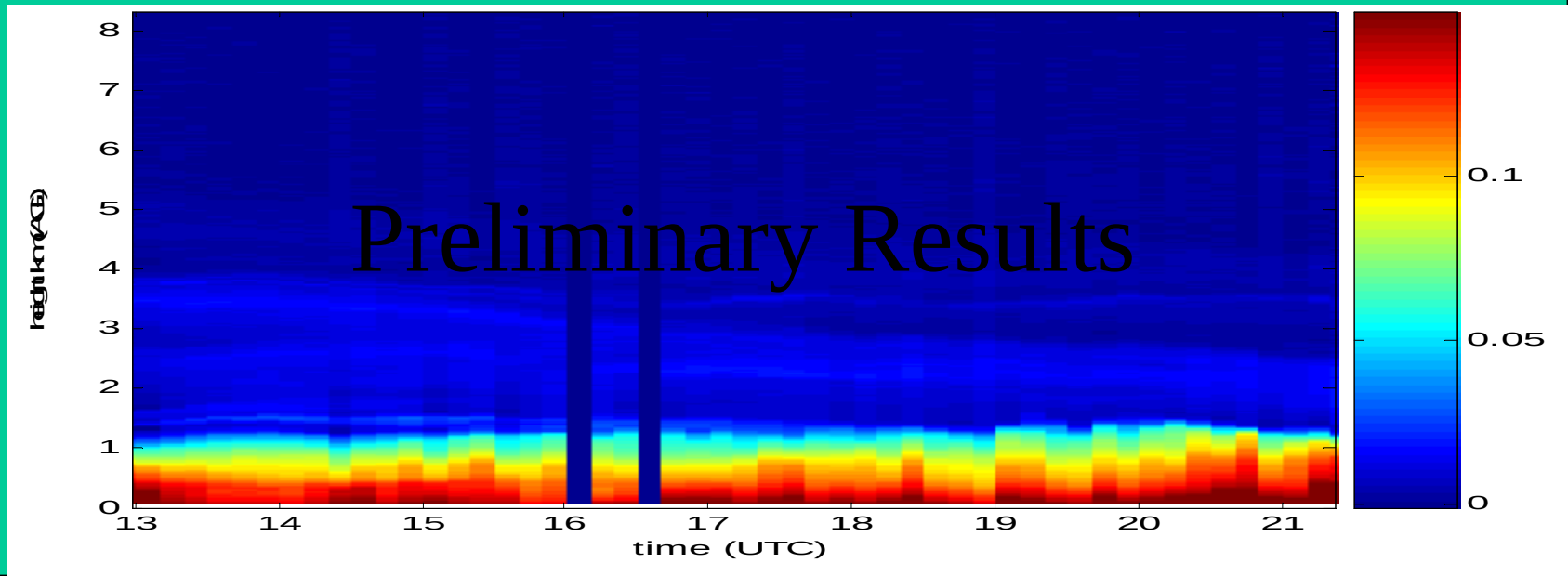
- Additionally, ARM had purchased new MPL systems with unexpected problems. Comparison of collocated instruments is a powerful means of evaluating instrument issues.

MPL Attenuated Backscatter 21-Sept-2005

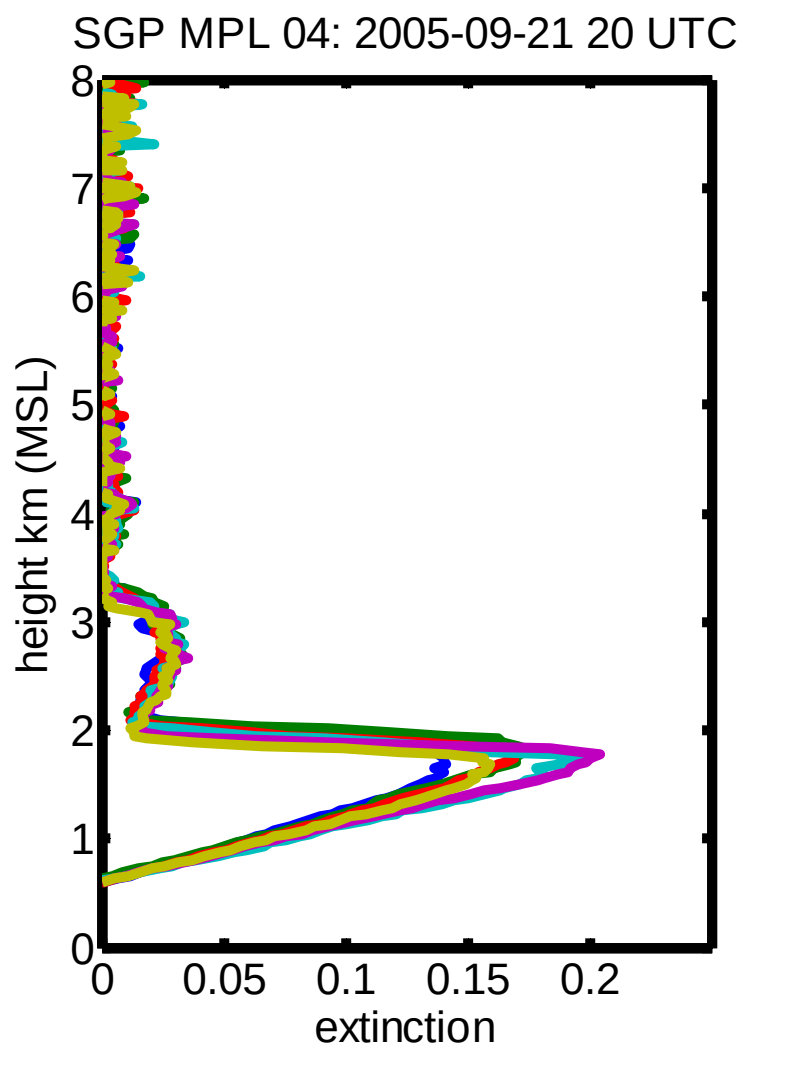
MPL 04

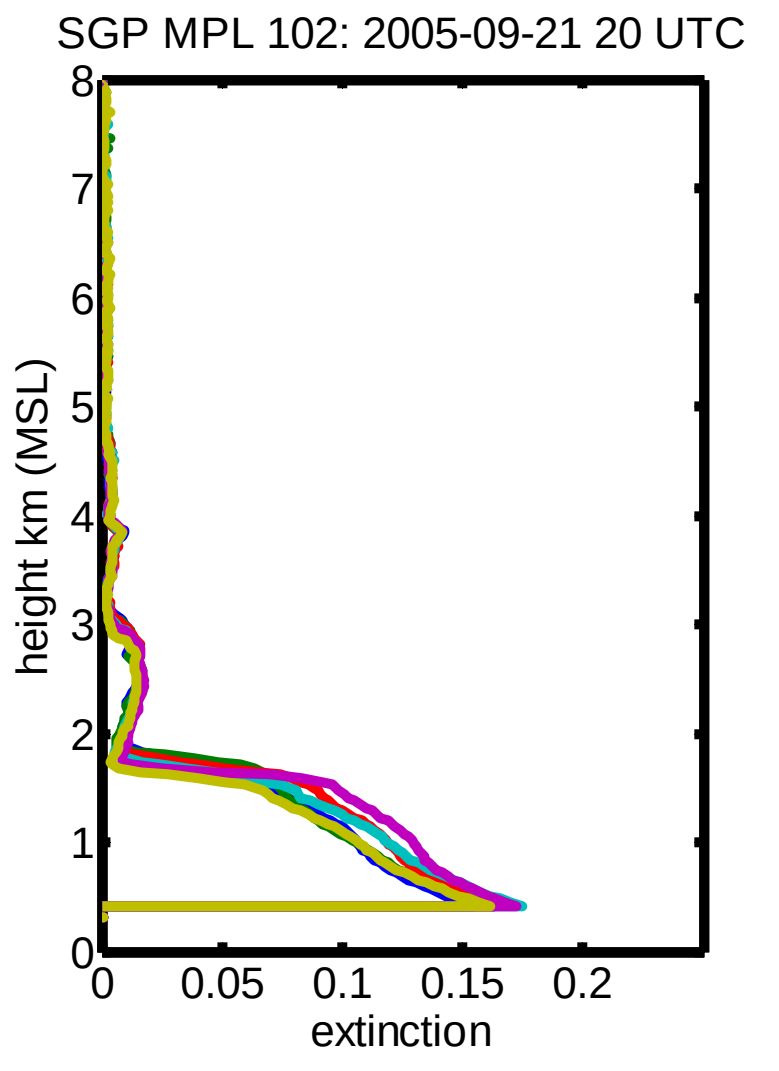


MPL 102



Discrepancies evident





Problems with MPL004

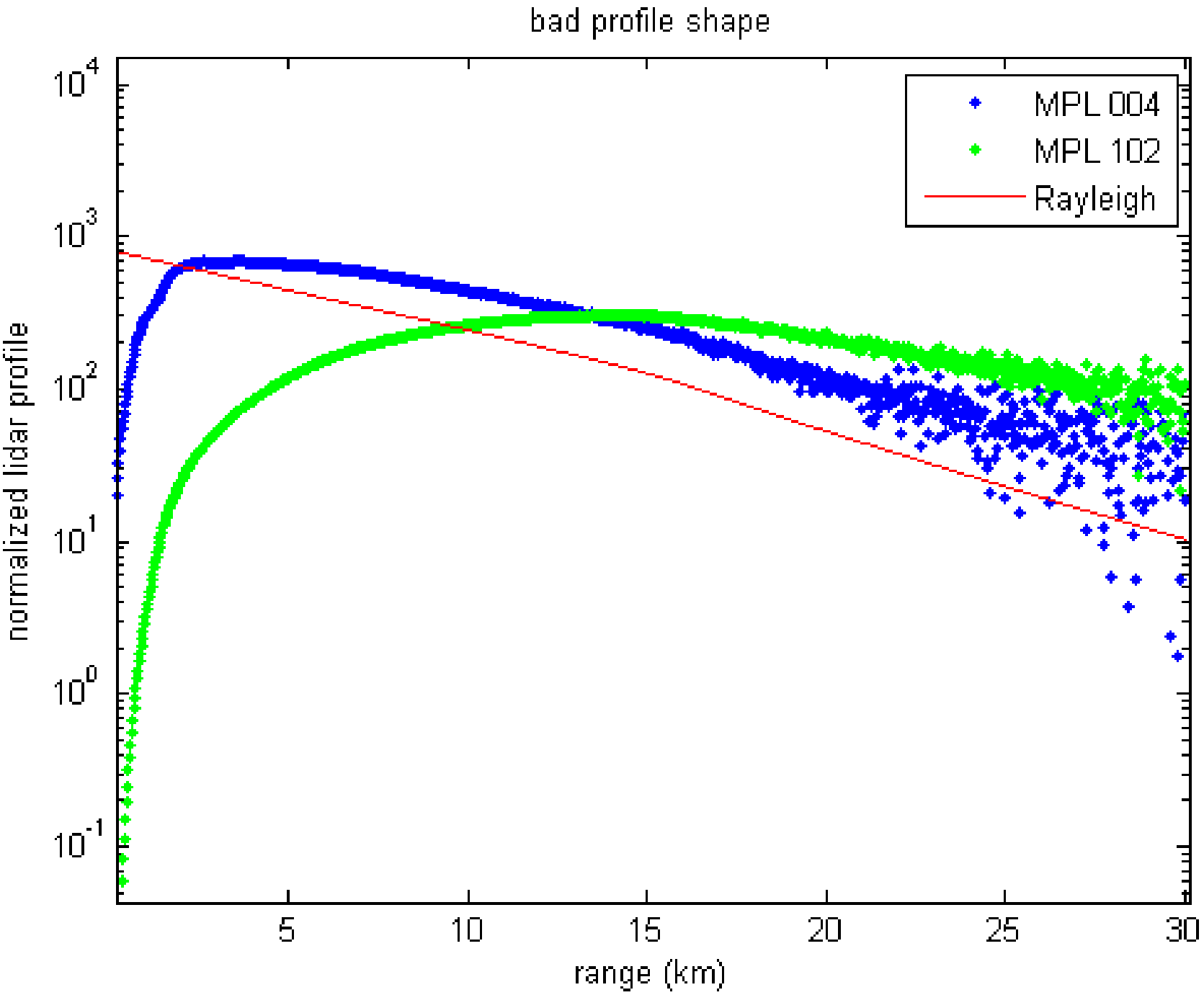
ARM
Atmospheric Radiation Measurement

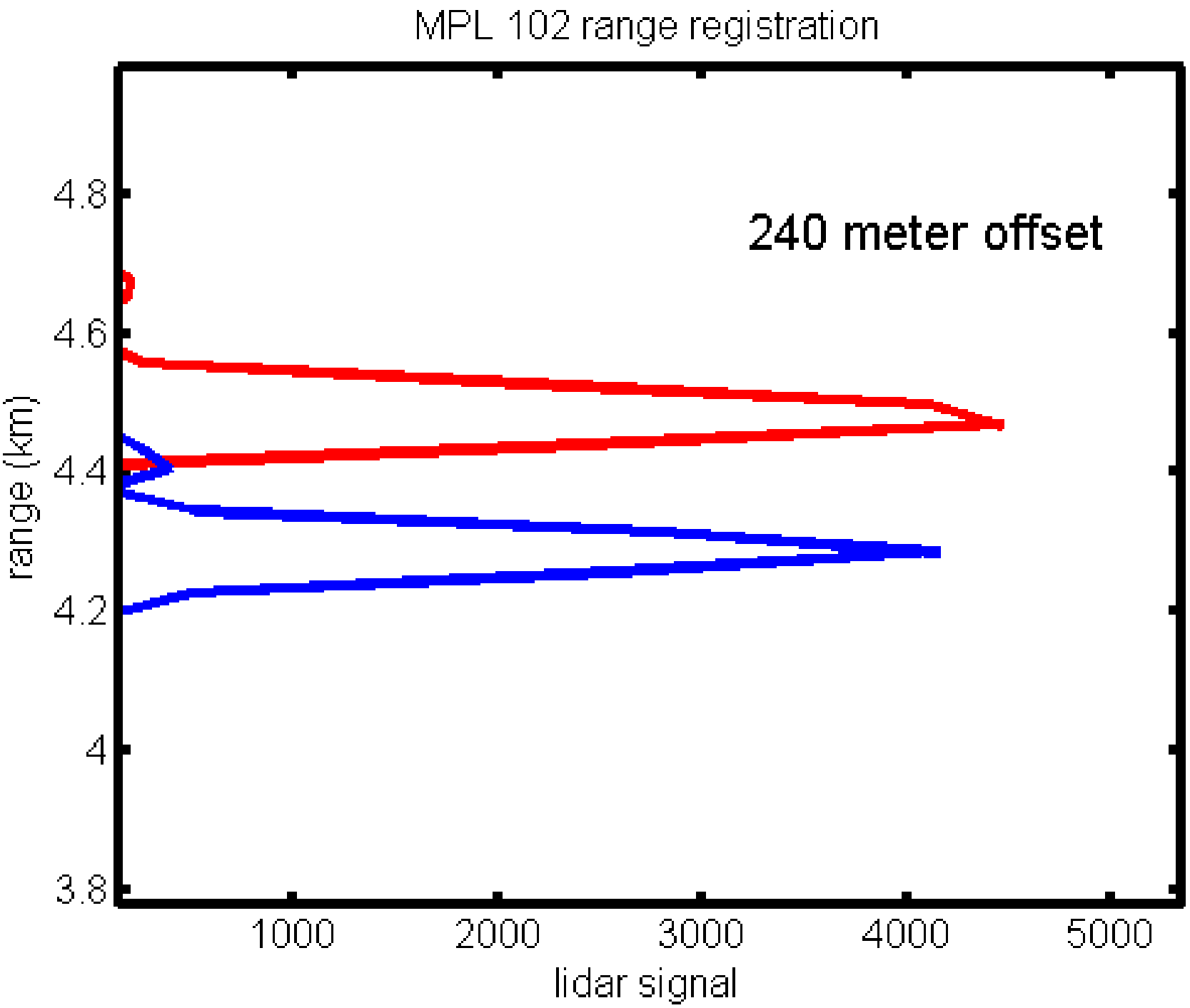
- Laser double pulse
- Temperature sensitivity
- Nearly useless energy monitor
- Nearly useless temperature
- Collimation problem

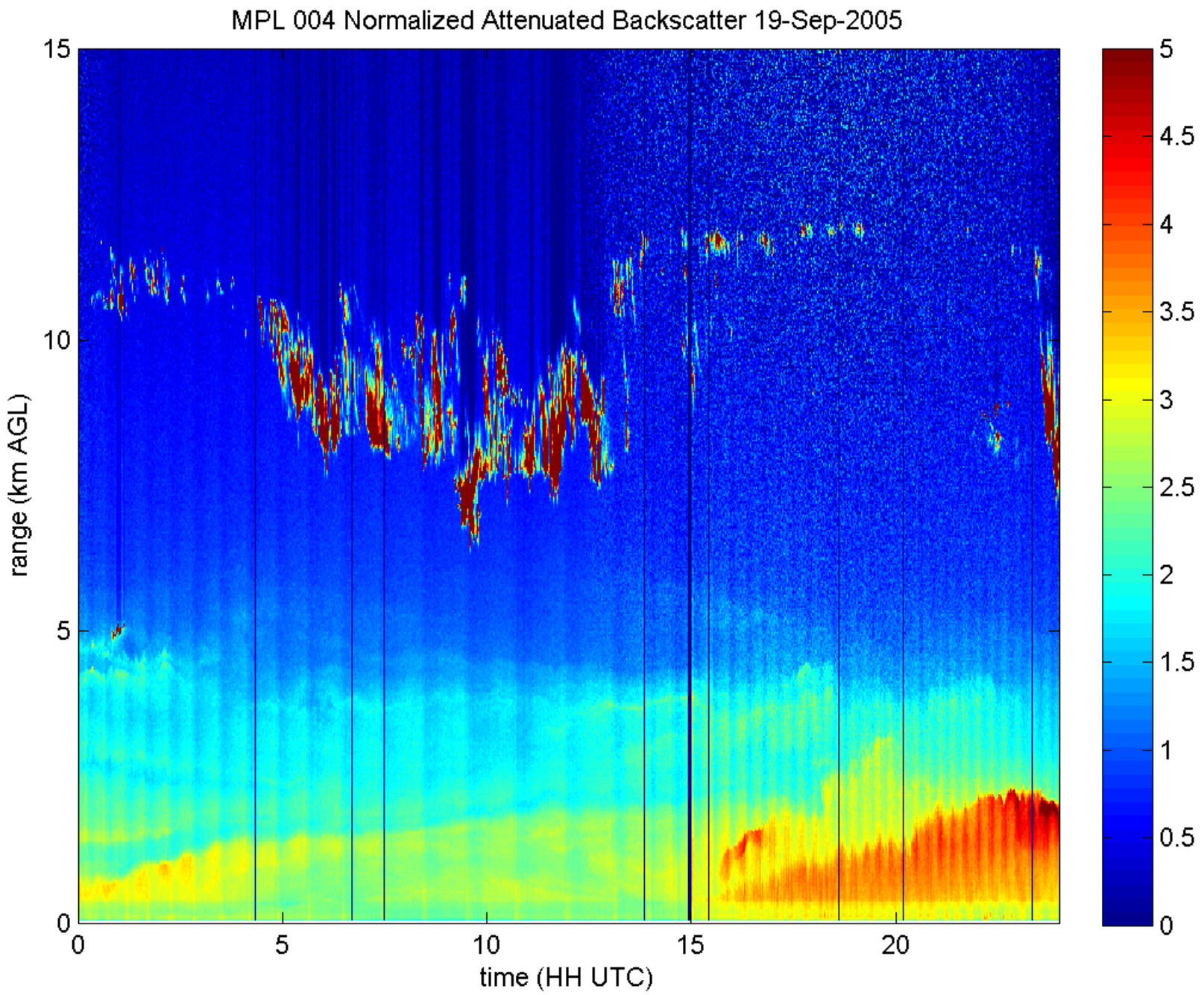
Problems with MPL102

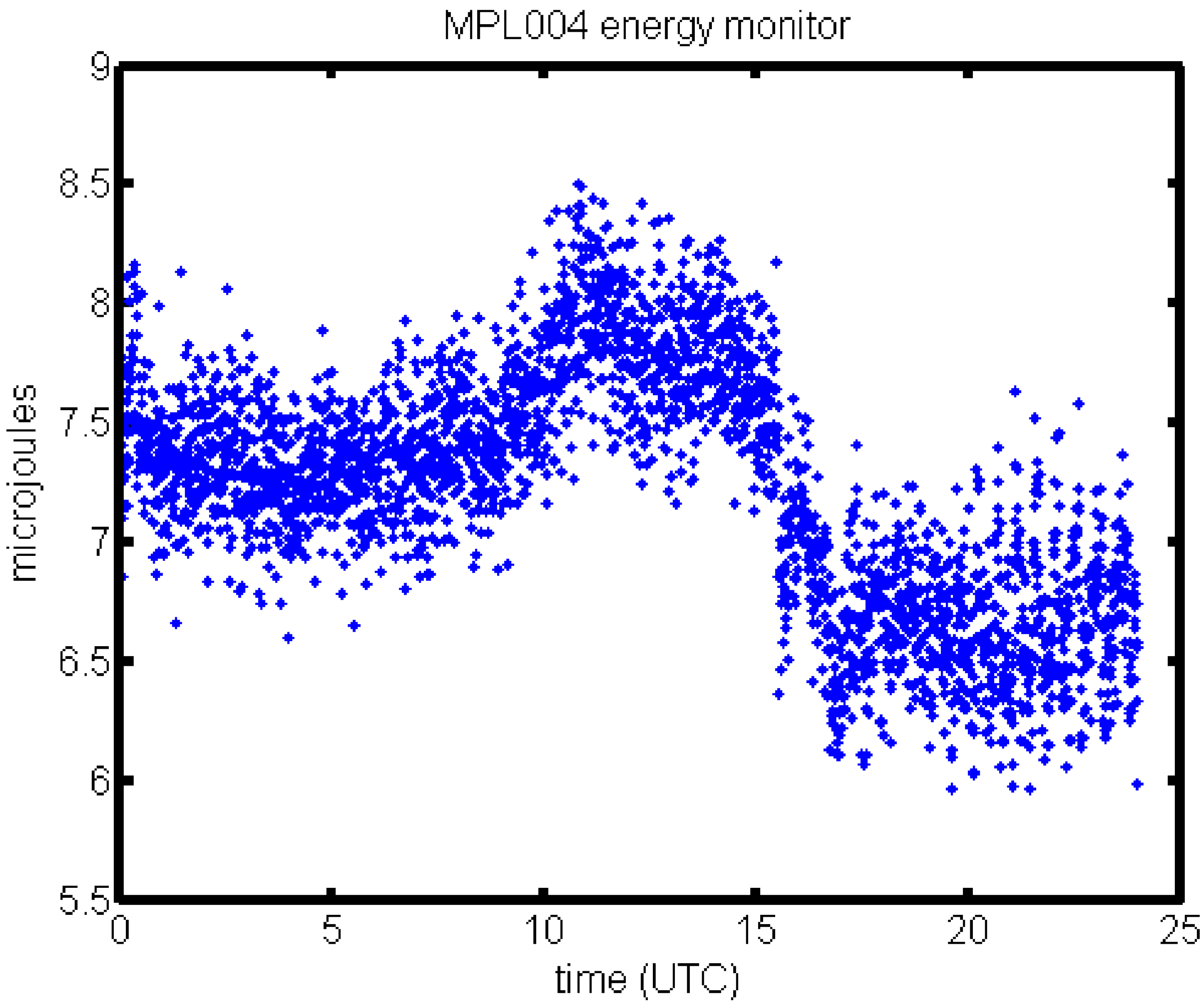
ARM
Atmospheric Radiation Measurement

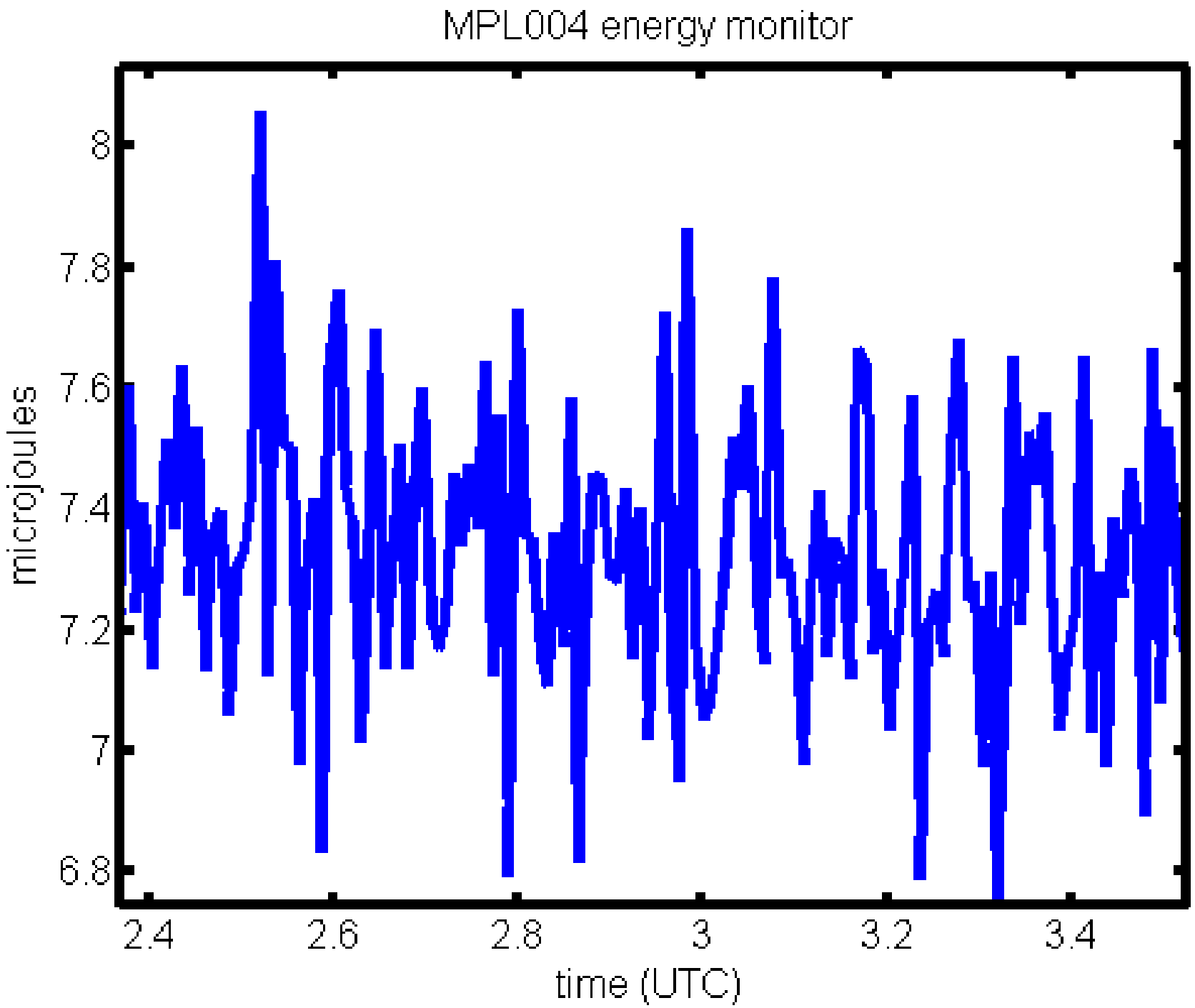
- Detector saturation/afterpulsing
- Improper range registration
- No working energy monitor
- Similar sensitivities to temperature

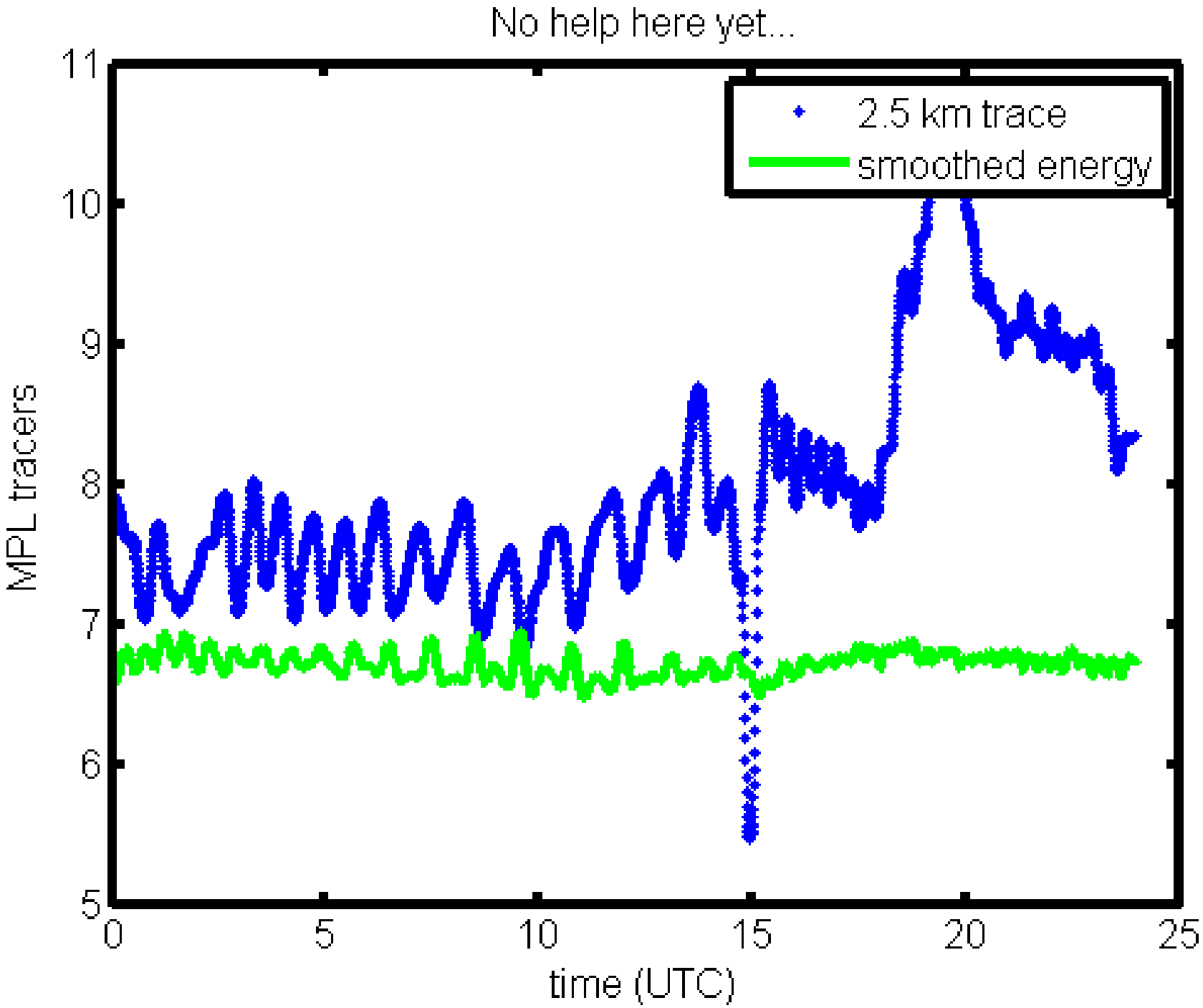

bad profile shape
MPL 004
MPL 102
Rayleigh
normalized lidar profile
range (km)
10^4
10^3
10^2
10^1
10^0
10^{-1}
5
10
15
20
25
30

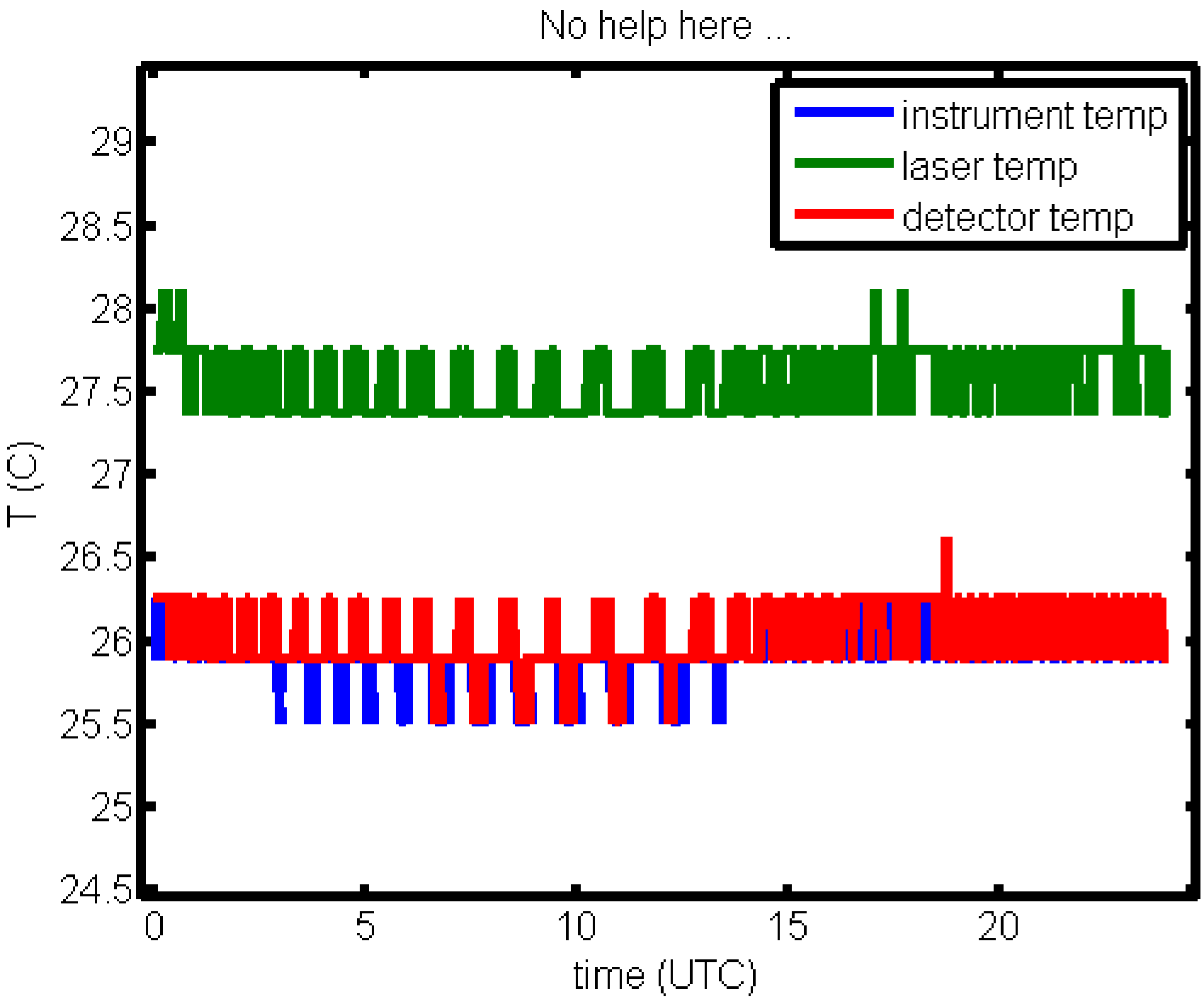

MPL 102 range registration
240 meter offset
range (km)
4.8
4.6
4.4
4.2
4
3.8
1000
2000
3000
4000
5000
lidar signal


MPL 004 Normalized Attenuated Backscatter 19-Sep-2005
range (km AGL)
time (HH UTC)
0
5
10
15
20
0
5
10
15
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


MPL004 energy monitor
microjoules
time (UTC)
9
8.5
8
7.5
7
6.5
6
5.5
0
5
10
15
20
25


MPL004 energy monitor
microjoules
8
7.8
7.6
7.4
7.2
7
6.8
2.4
2.6
2.8
3
3.2
3.4
time (UTC)

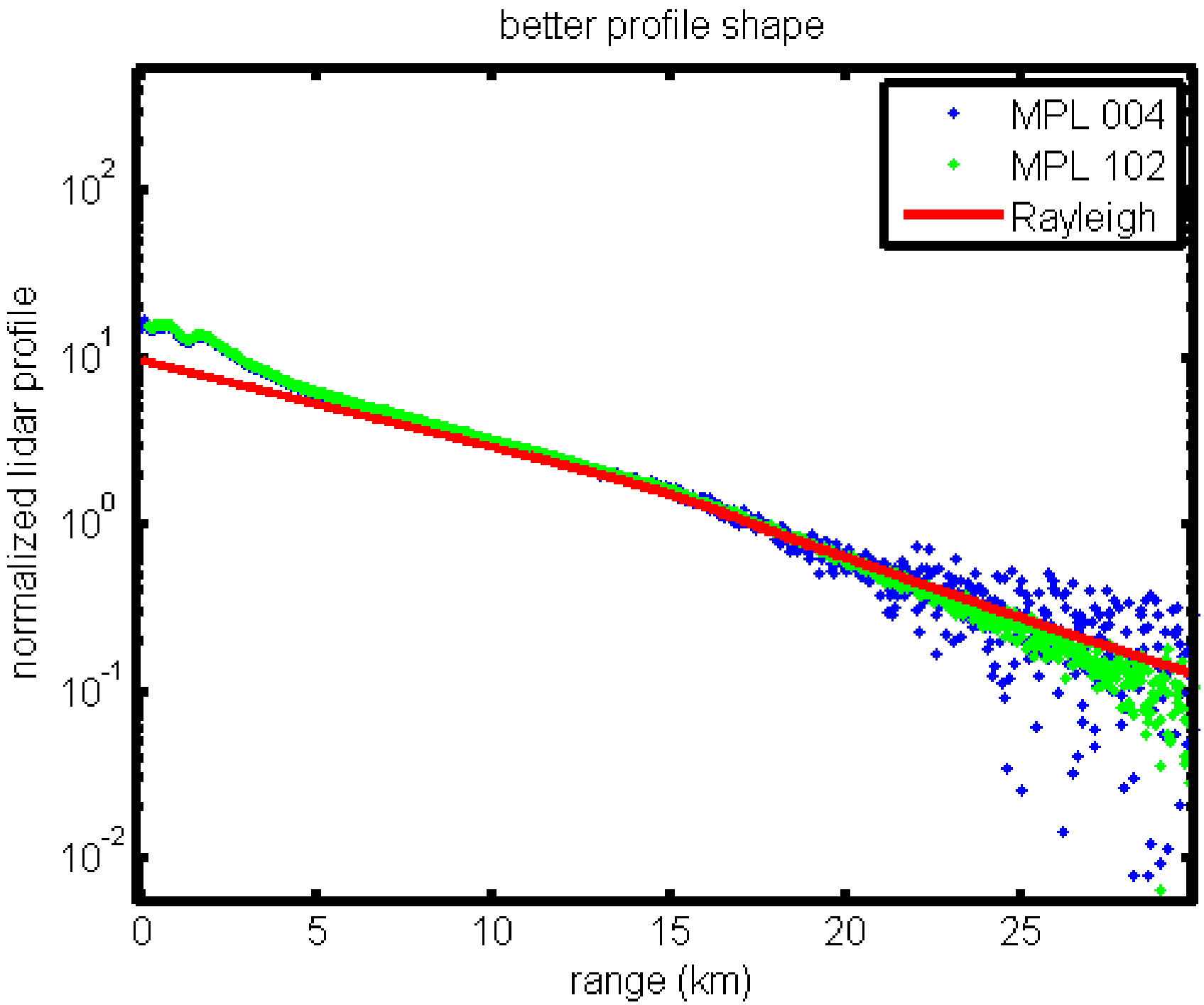

No help here yet...
2.5 km trace
smoothed energy
MPL tracers
time (UTC)
11
10
9
8
7
6
5
0
5
10
15
20
25

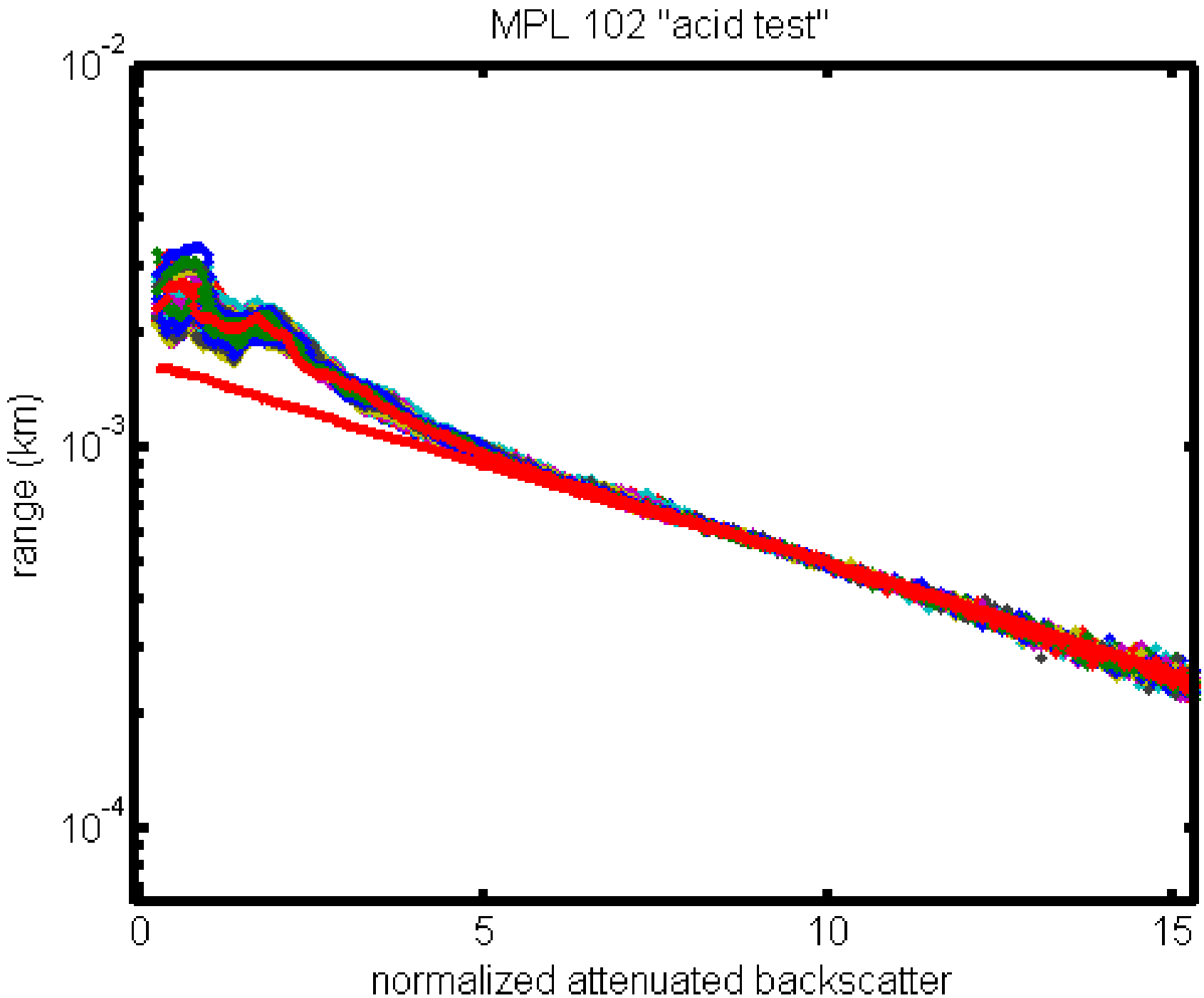

No help here ...
instrument temp
laser temp
detector temp
T (C)
29
28.5
28
27.5
27
26.5
26
25.5
25
24.5
0
5
10
15
20
time (UTC)

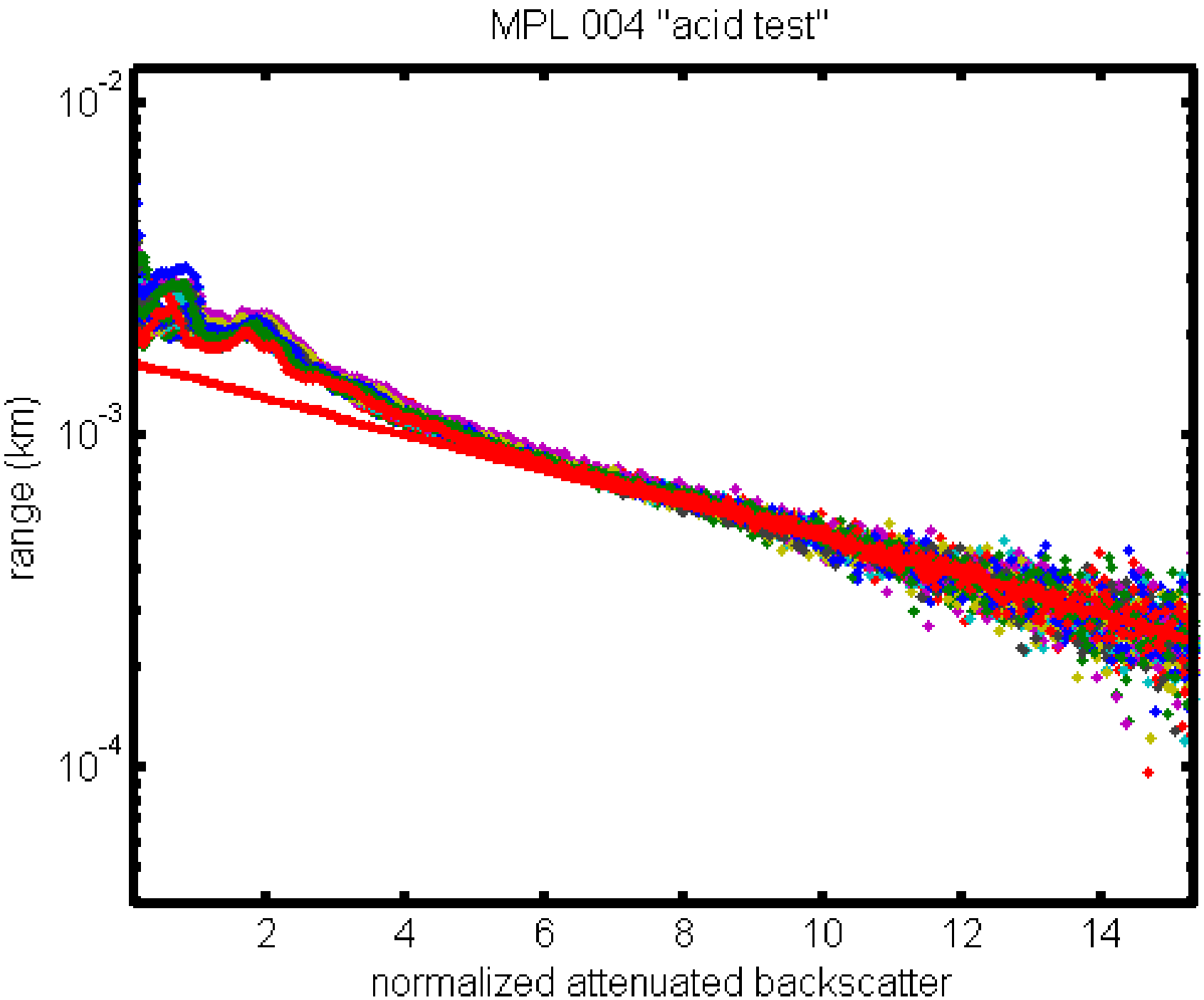
Hard work pays off though

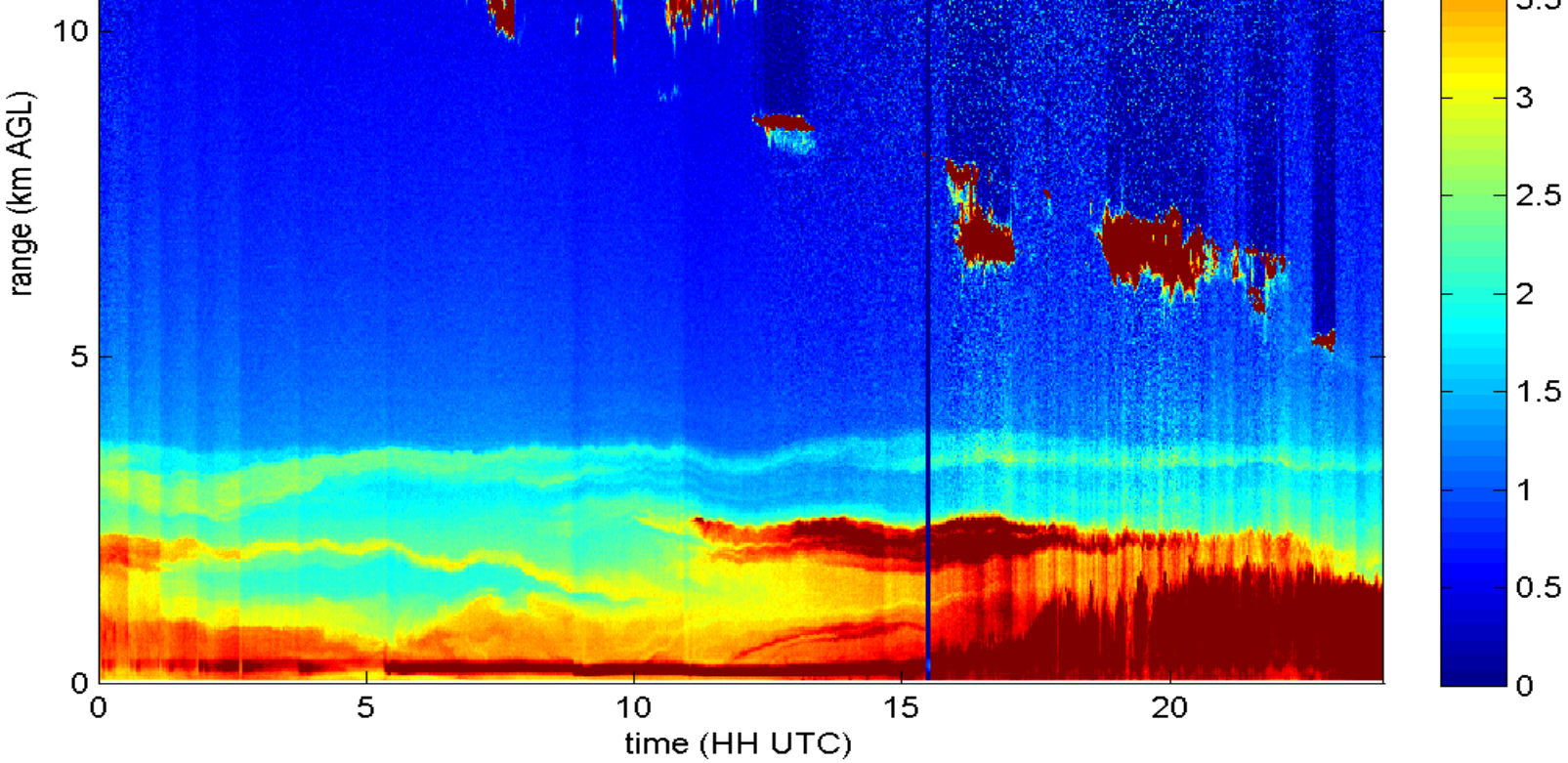
ARM
Atmospheric Radiation Measurement

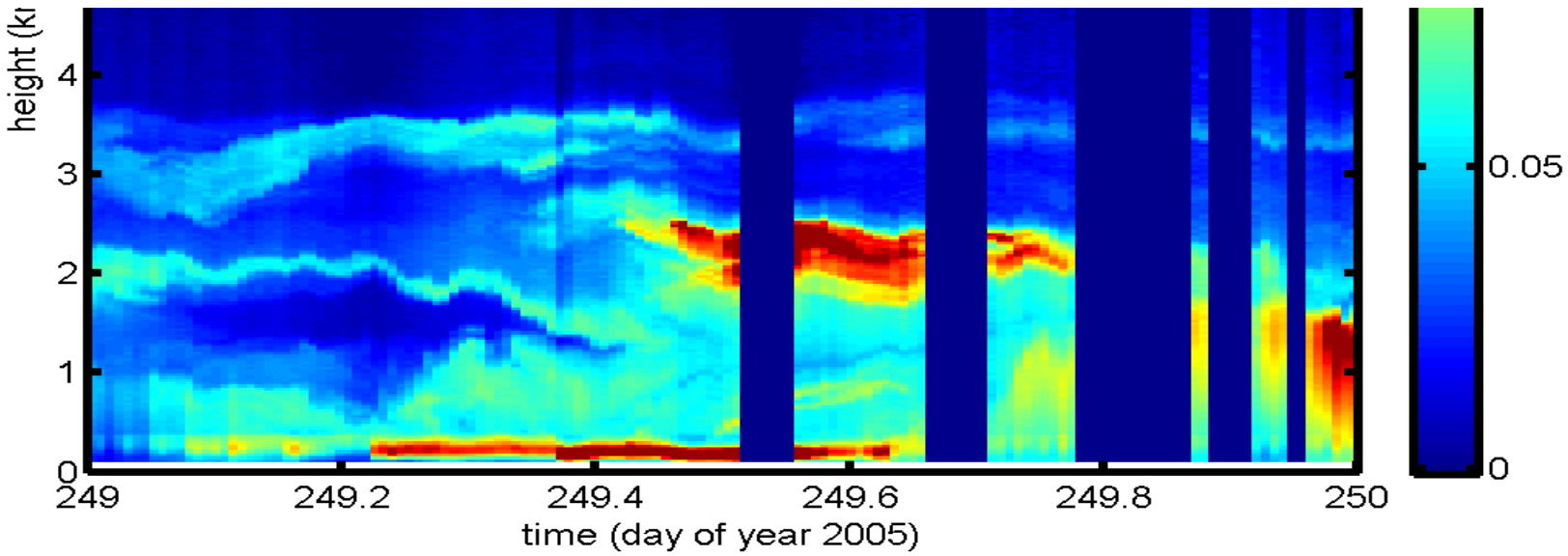
- Fixed range registration problem in MPL102 through comparison with MPL004
- Fixed collimation of MPL004 using MPL102 and sondes.
- Improved near-field overlap corrections of both instruments
- Partially reduced impact of temperature sensitivity

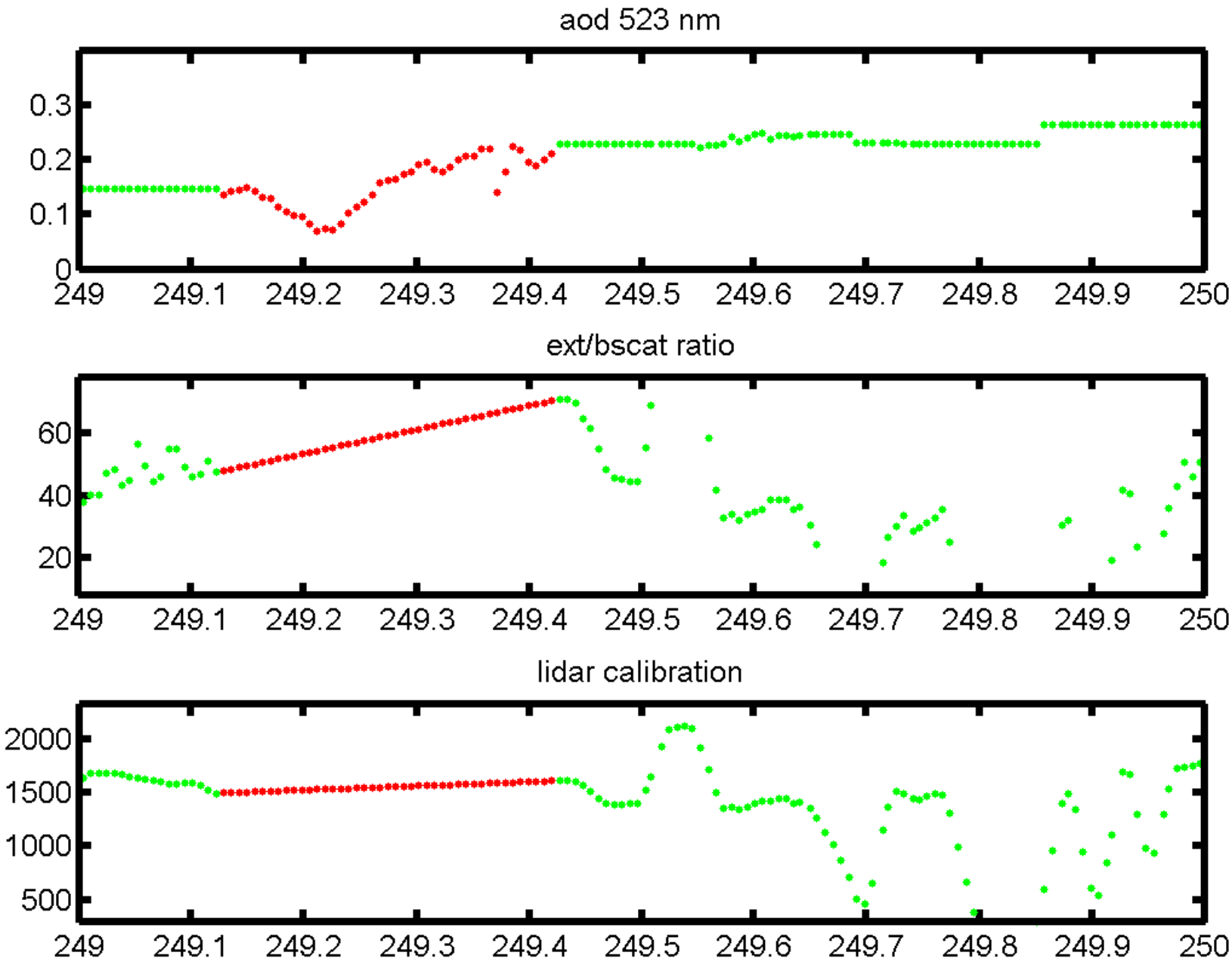

better profile shape
MPL 004
MPL 102
Rayleigh
normalized lidar profile
range (km)
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
0
5
10
15
20
25

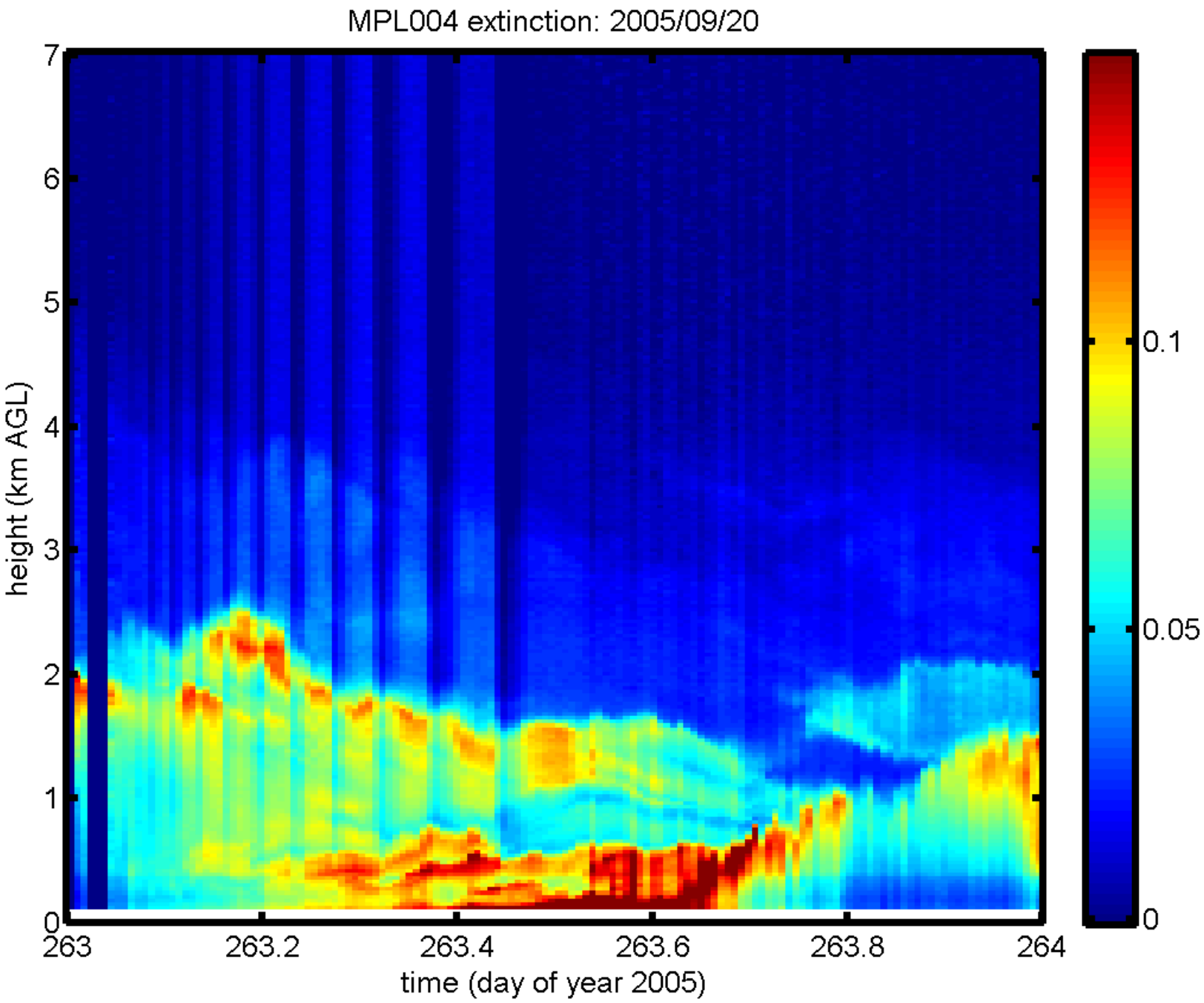

MPL 102 "acid test"
10^{-2}
10^{-3}
10^{-4}
range (km)
0
5
10
15
normalized attenuated backscatter

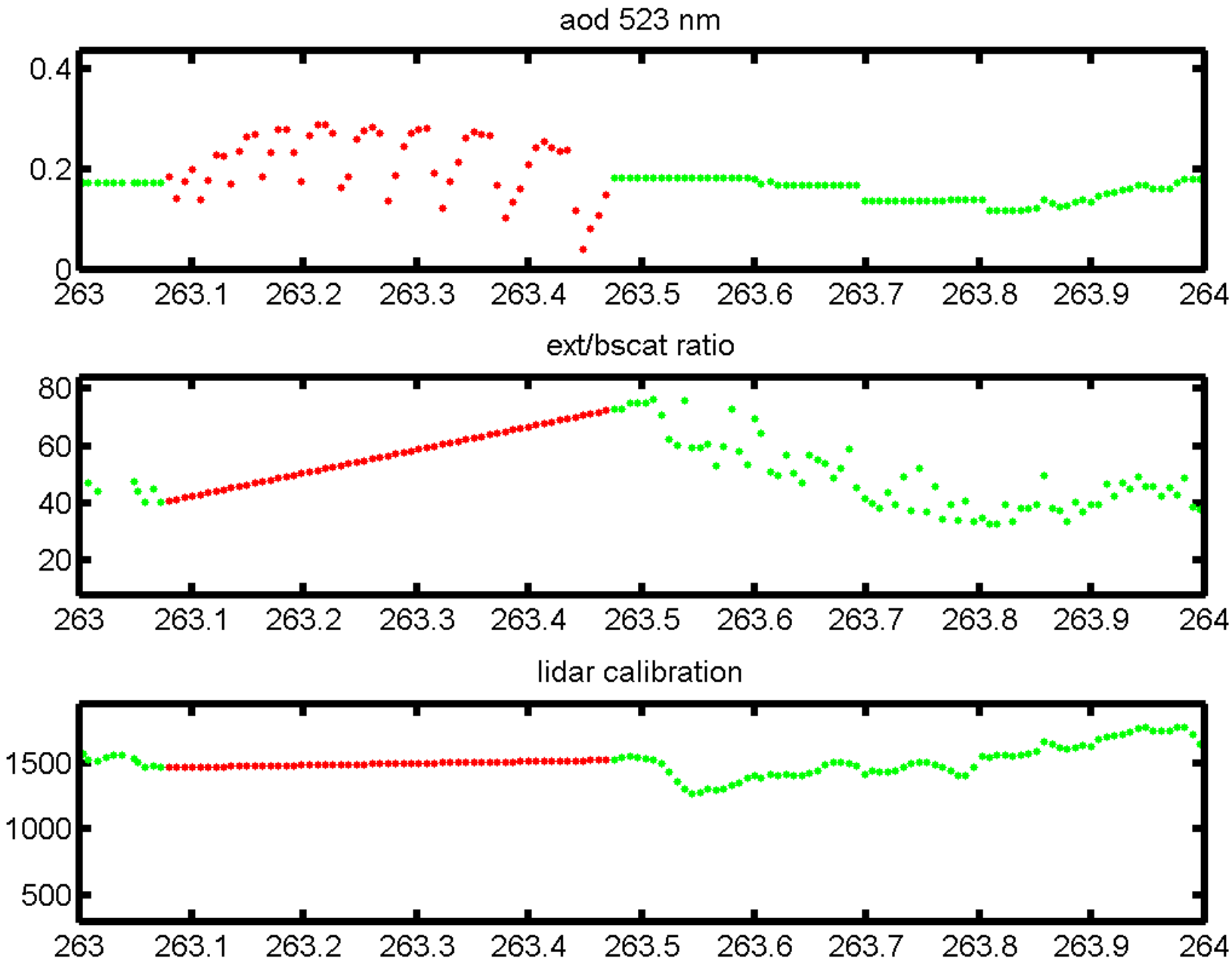

MPL 004 "acid test"
range (km)
10^{-2}
10^{-3}
10^{-4}
2
4
6
8
10
12
14
normalized attenuated backscatter

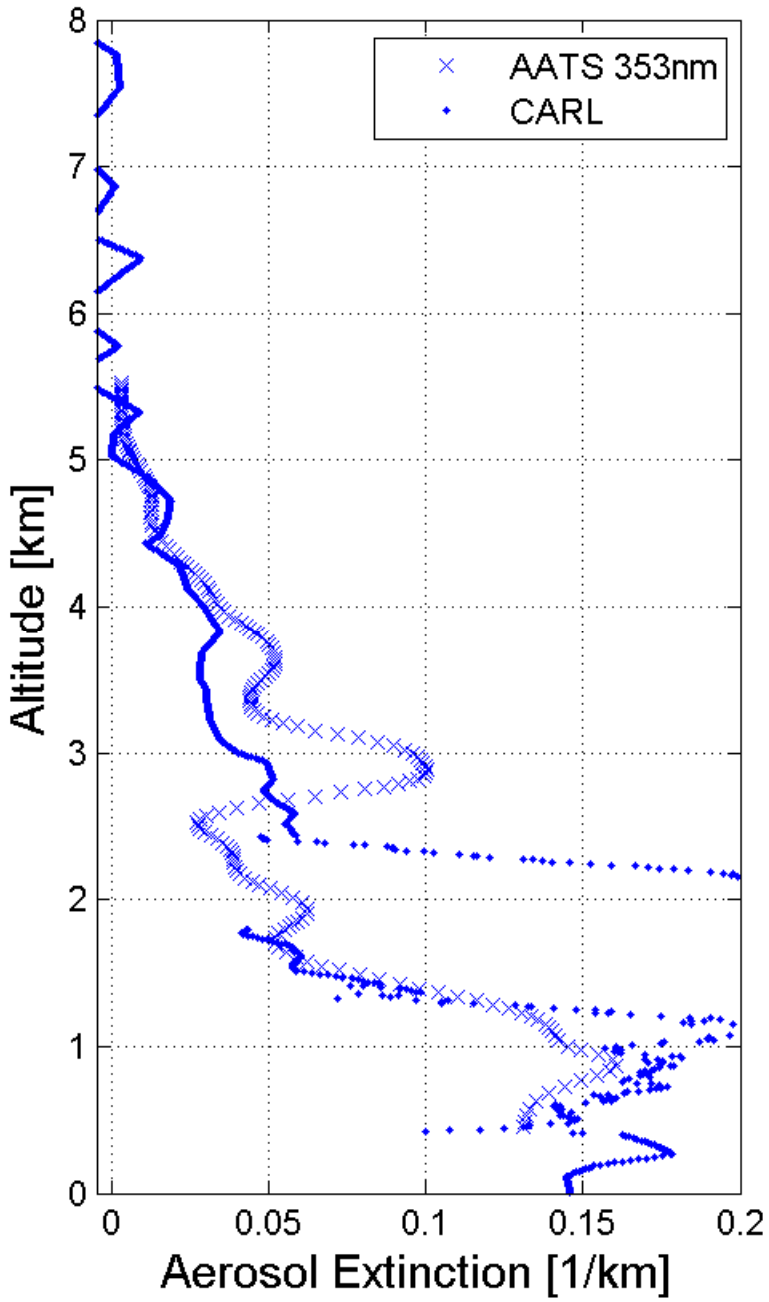

range (km AGL)
0
5
10
0
5
10
15
20
time (HH UTC)
0
0.5
1
1.5
2
2.5
3
3.5

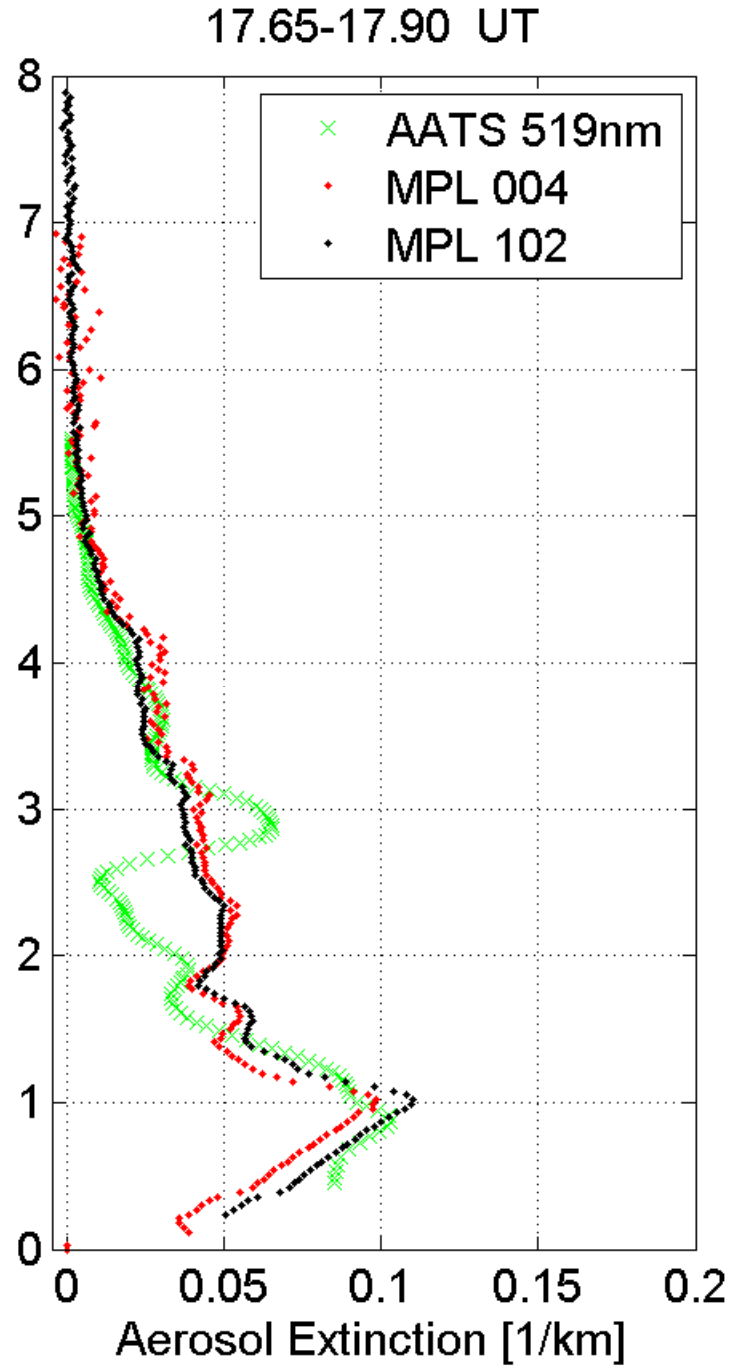

height (k
0
1
2
3
4
249
249.2
249.4
249.6
249.8
250
time (day of year 2005)
0
0.05

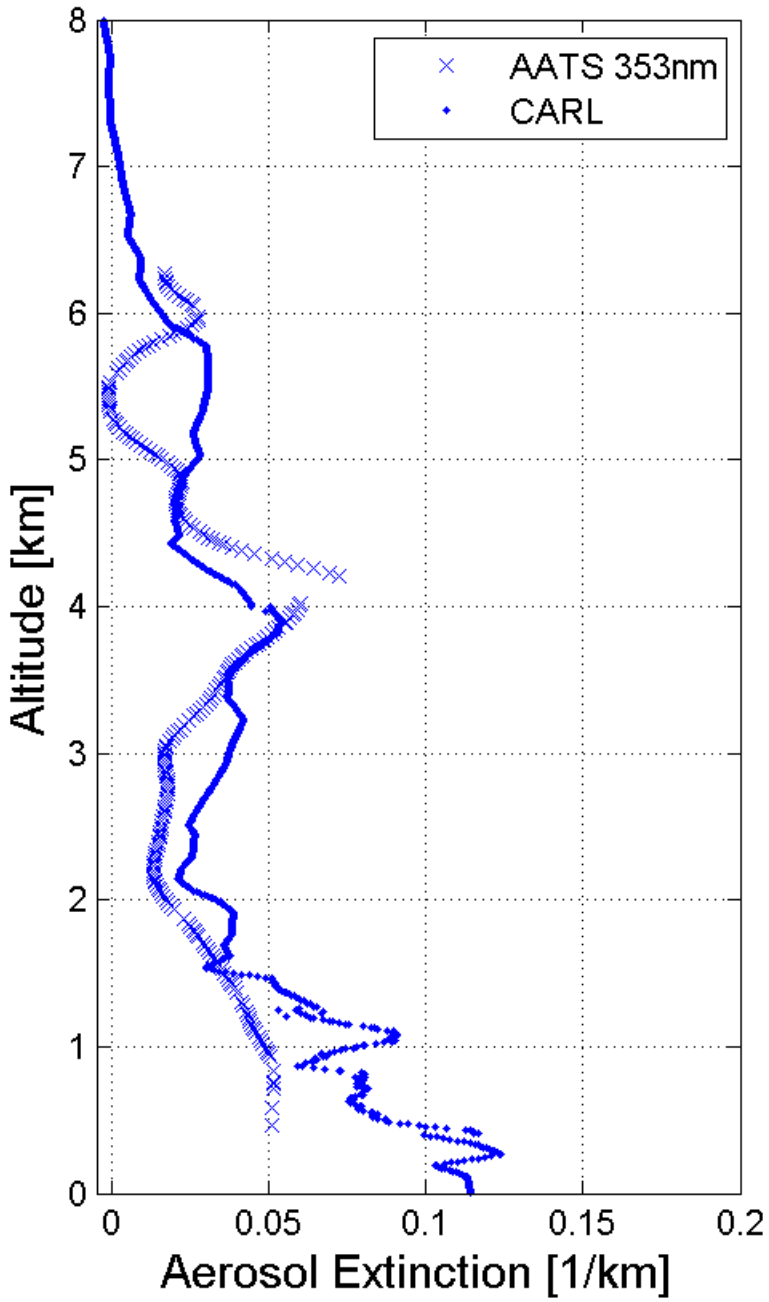

aod 523 nm
0.3
0.2
0.1
0
249
249.1
249.2
249.3
249.4
249.5
249.6
249.7
249.8
249.9
250
ext/bscat ratio
60
40
20
249
249.1
249.2
249.3
249.4
249.5
249.6
249.7
249.8
249.9
250
lidar calibration
2000
1500
1000
500
249
249.1
249.2
249.3
249.4
249.5
249.6
249.7
249.8
249.9
250

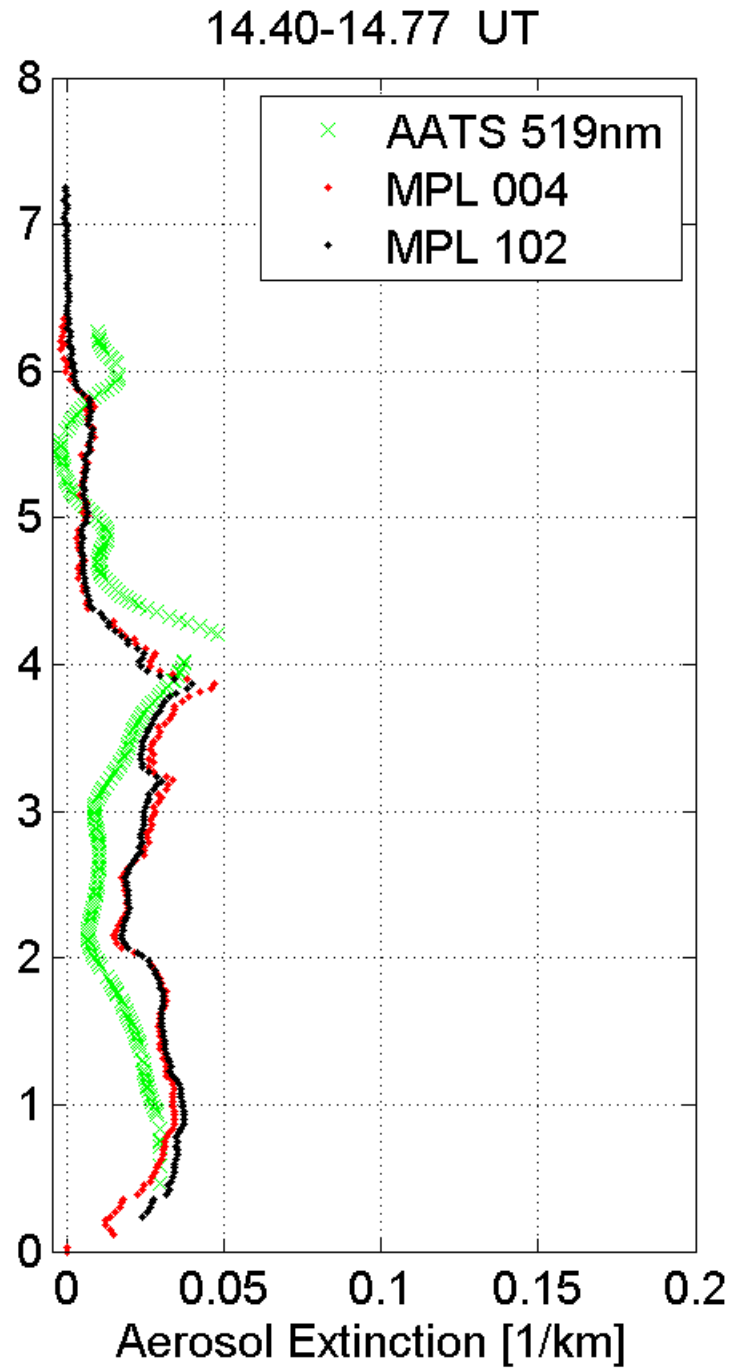

MPL004 extinction: 2005/09/20
height (km AGL)
0
1
2
3
4
5
6
7
263
263.2
263.4
263.6
263.8
264
time (day of year 2005)
0
0.05
0.1

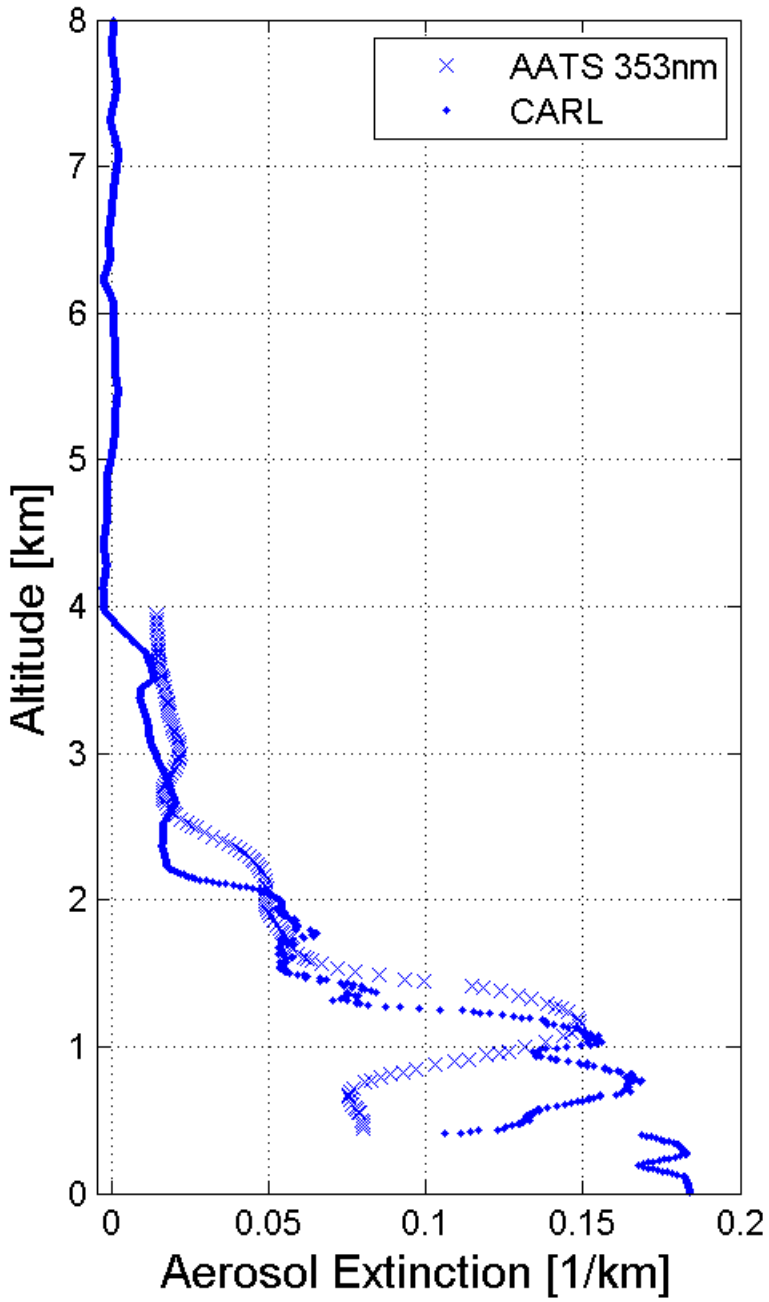

aod 523 nm
0.4
0.2
0
263
263.1
263.2
263.3
263.4
263.5
263.6
263.7
263.8
263.9
264
ext/bscat ratio
80
60
40
20
263
263.1
263.2
263.3
263.4
263.5
263.6
263.7
263.8
263.9
264
lidar calibration
1500
1000
500
263
263.1
263.2
263.3
263.4
263.5
263.6
263.7
263.8
263.9
264

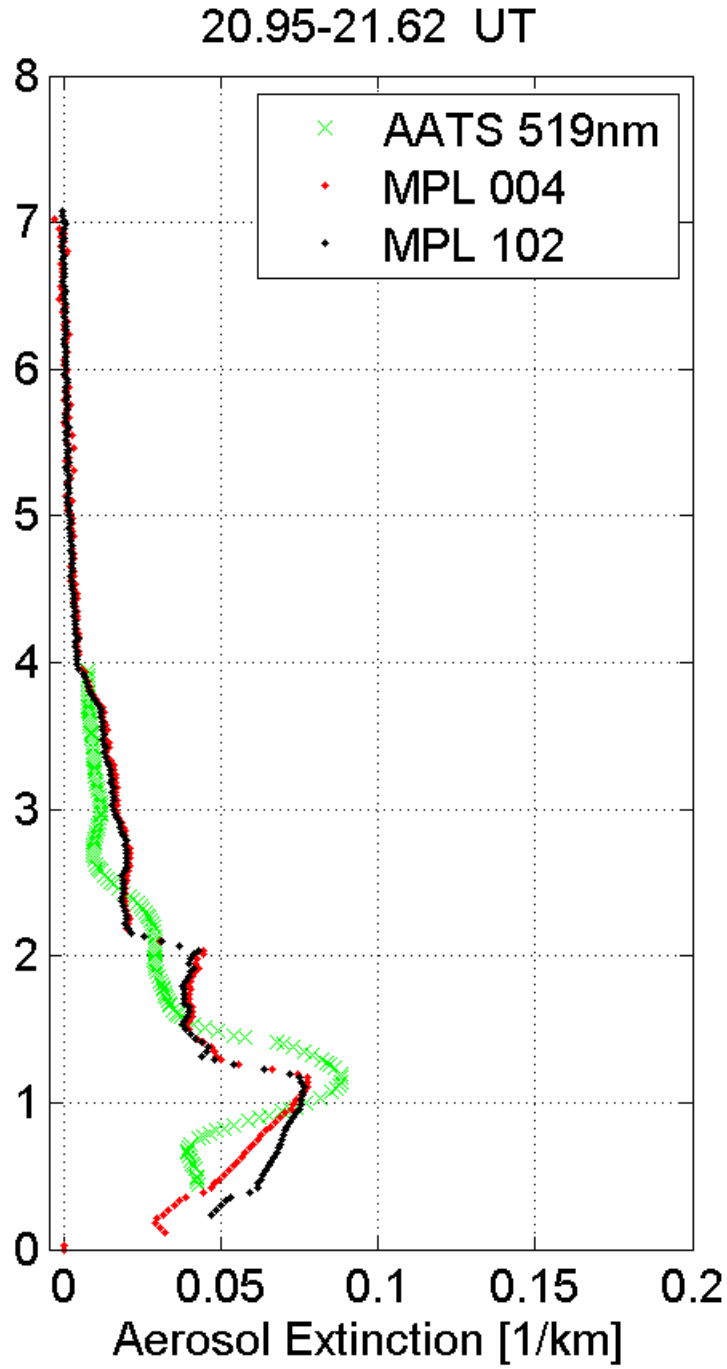

AATS 353nm
CARL
Altitude [km]
Aerosol Extinction [1/km]
0
0.05
0.1
0.15
0.2
1
2
3
4
5
6
7
8


17.65-17.90 UT
AATS 519nm
MPL 004
MPL 102
Aerosol Extinction [1/km]
0
0.05
0.1
0.15
0.2
1
2
3
4
5
6
7
8


AATS 353nm
CARL
Altitude [km]
Aerosol Extinction [1/km]
0
0.05
0.1
0.15
0.2
1
2
3
4
5
6
7
8


14.40-14.77 UT
AATS 519nm
MPL 004
MPL 102
Aerosol Extinction [1/km]
0
0.05
0.1
0.15
0.2
1
2
3
4
5
6
7
8


AATS 353nm
CARL
Altitude [km]
Aerosol Extinction [1/km]
0
0.05
0.1
0.15
0.2
1
2
3
4
5
6
7
8


20.95-21.62 UT
AATS 519nm
MPL 004
MPL 102
Aerosol Extinction [1/km]
0
0.05
0.1
0.15
0.2
1
2
3
4
5
6
7
8

The "Lidar Equation" continued…

ARM
Atmospheric Radiation Measurement

$$\beta'(r) = \beta(r)T^2(r)$$
$$= \beta(r)\exp\{-2\tau\}$$
$$= \beta(r)\exp\left\{-2\int_0^r \sigma(r')dr'\right\}$$

$$\text{with}\ \beta(r) = \beta_m(r) + \beta_c(r) + \beta_a(r)$$
$$\text{and}\ \sigma(r) = \sigma_m(r) + \sigma_c(r) + \sigma_a(r)$$

Measured quantity versus the "Lidar Equation"

ARM
Atmospheric Radiation Measurement

$$\left[\left(D(r) * dtf\right) - P_{bg} - P_{ap}(r)\right] \times \left(\frac{r^2}{CE_0 O(r)}\right) = \beta(r) T^2(r)$$

$$\beta'(r) = \beta(r) T^2(r)$$

Fernald Solution to the Lidar Equation

The forward form: $r_c < r$, $\beta(r) =$

$$\frac{\beta'(r)\exp\left\{-2(S_a - S_m)\int_{r_c}^{r}\beta_m(r')dr'\right\}}{\frac{\beta'(r_c)}{\beta(r_c)} - 2S_a\int_{r_c}^{r}\beta'(r')\exp\left\{-2(S_a - S_m)\int_{r_c}^{r}\beta_m(r'')dr''\right\}dr'}$$

Klett Backward Solution

The backward or top-down form: $r_c > r$

$\beta(r) =$

$$\frac{\beta'(r)\exp\left\{2(S_a - S_m)\int_{r_c}^{r}\beta_m(r')dr'\right\}}{CT^2(r) + 2S_a\int_{r_c}^{r}\beta'(r')\exp\left\{2(S_a - S_m)\int_{r_c}^{r}\beta_m(r'')dr''\right\}dr'}$$

Applicability of Forward and Backward Solutions

Forward: Unless the lidar calibration constant is accurately known (~1%) and the functional form relating $\alpha(r)$ and $\beta(r)$ is also appropriate, the solution can be unstable.

- Backward: If the boundary is chosen above cloud base the solution is much more stable. However, the extinction coefficient $\alpha(r)$ may be difficult to determine due to attenuation. Thus, the backward solution is more stable but unavailable in presence of opaque clouds.