

Supplement of

Validation of ceilometer aerosol profile retrievals using sun–sky photometer and balloon-borne in situ measurements

Muñiz et al.

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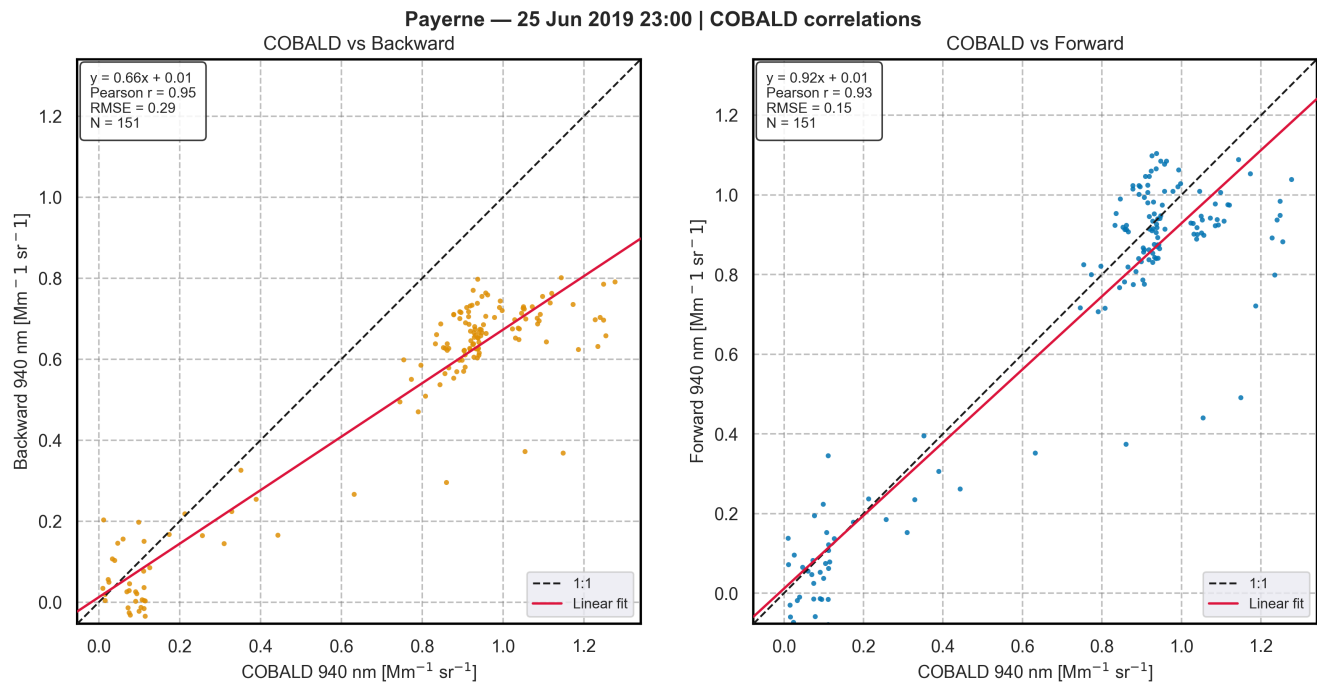


Figure 1. COBALD Balloon Sounding vs. Ceilometer Klett Retrievals — Payerne, 25 June 2019

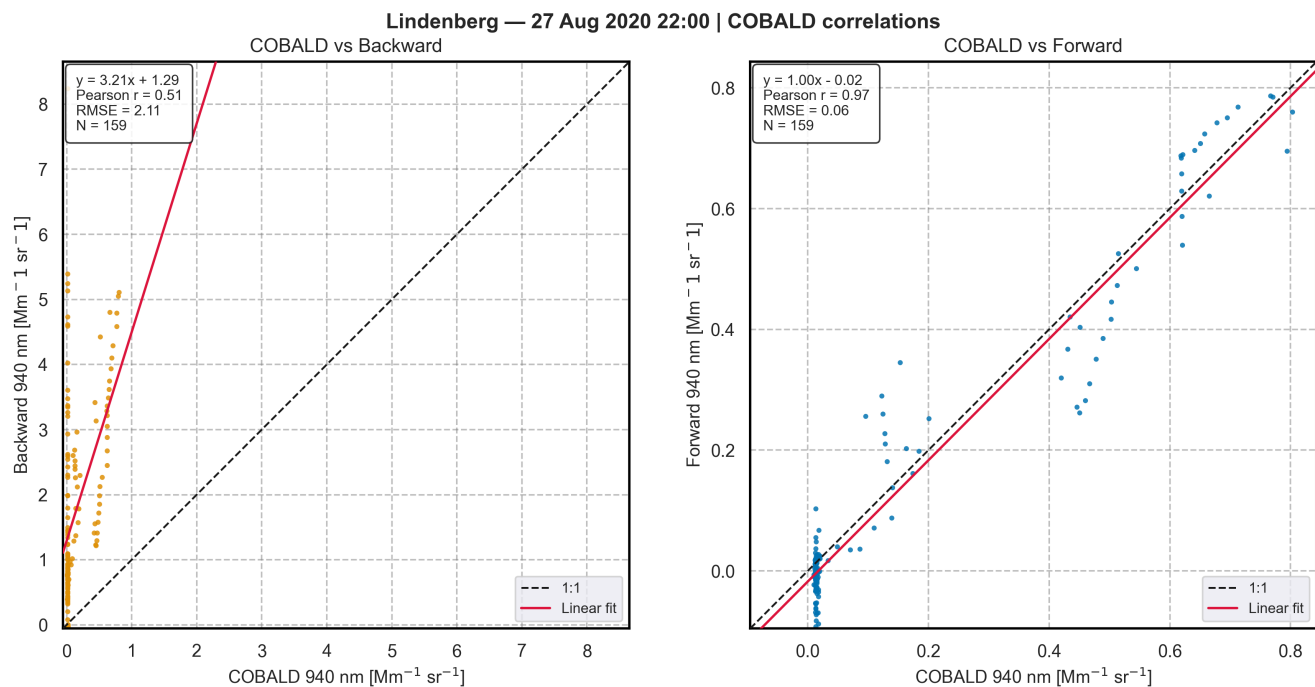


Figure 2. COBALD Balloon Sounding vs. Ceilometer Klett Retrievals — Lindenberg, 27 August 2020

Klett Backward vs GRASP — backscatter coefficient

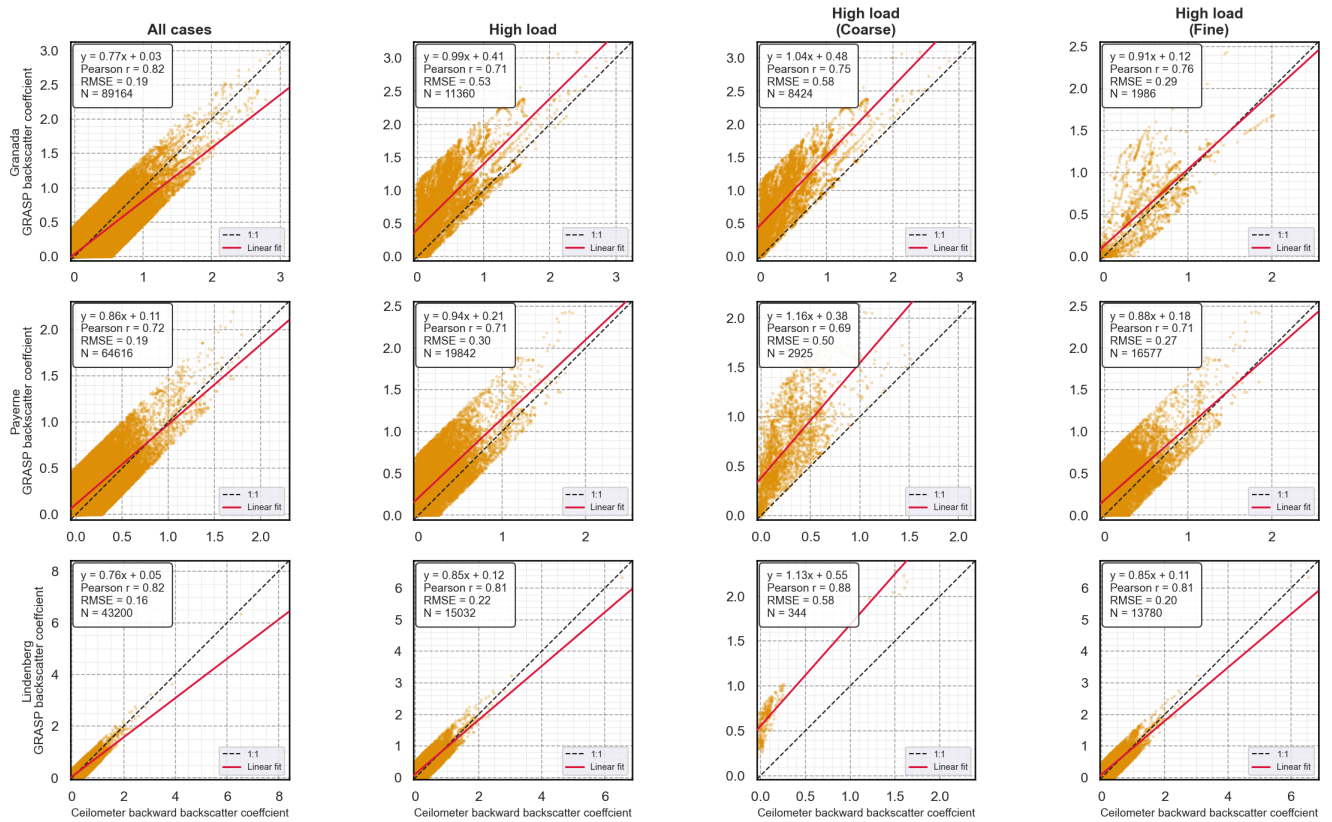


Figure 3. Ceilometer Backscatter Coefficient (Klett Backward) vs. GRASP. For this scatter analysis same filtering criteria of profile comparison using Percentiles 10-90 was applied.

Klett Forward vs GRASP — backscatter coefficient

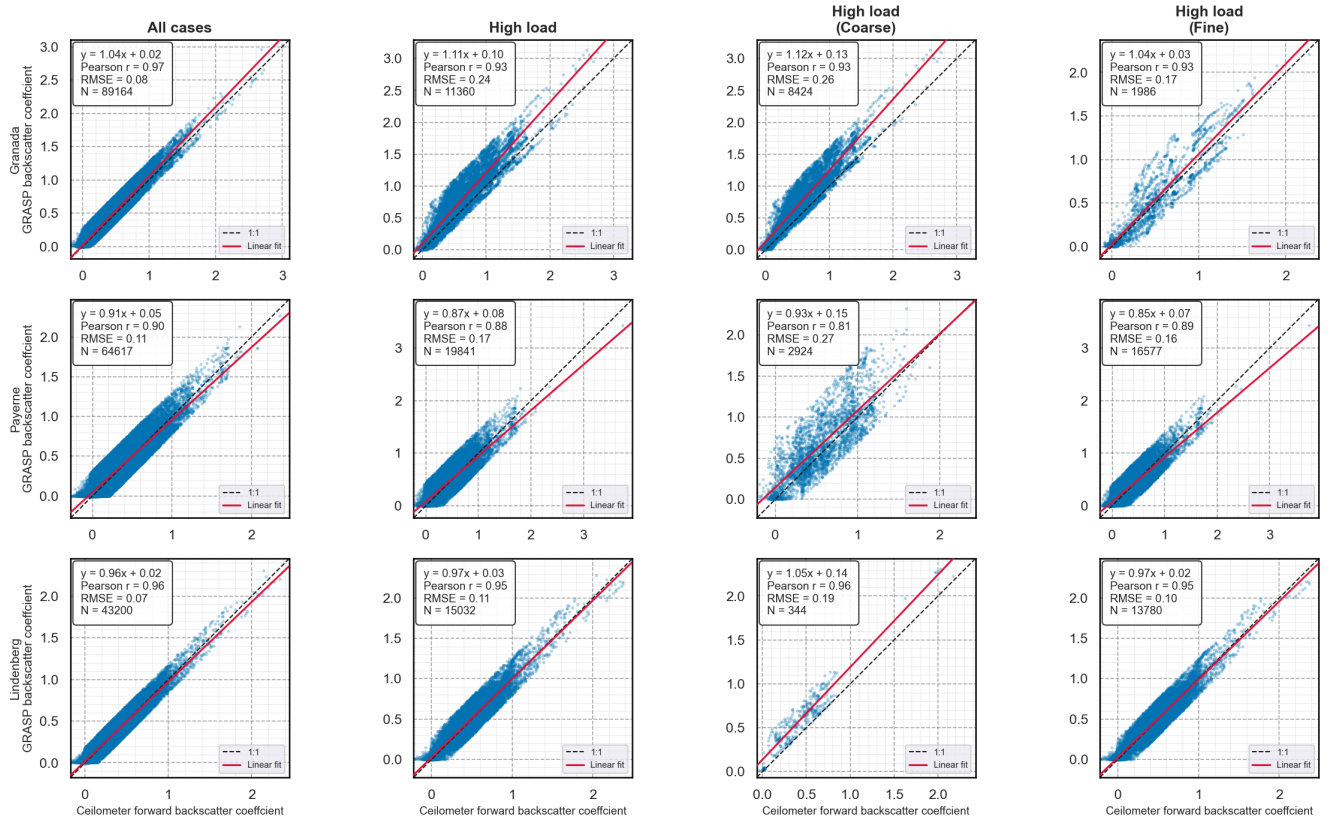


Figure 4. Ceilometer Backscatter Coefficient (Klett Forward) vs. GRASP. For this scatter analysis same filtering criteria of profile comparison using Percentiles 10-90 was applied.

Klett Backward vs GRASP — extinction

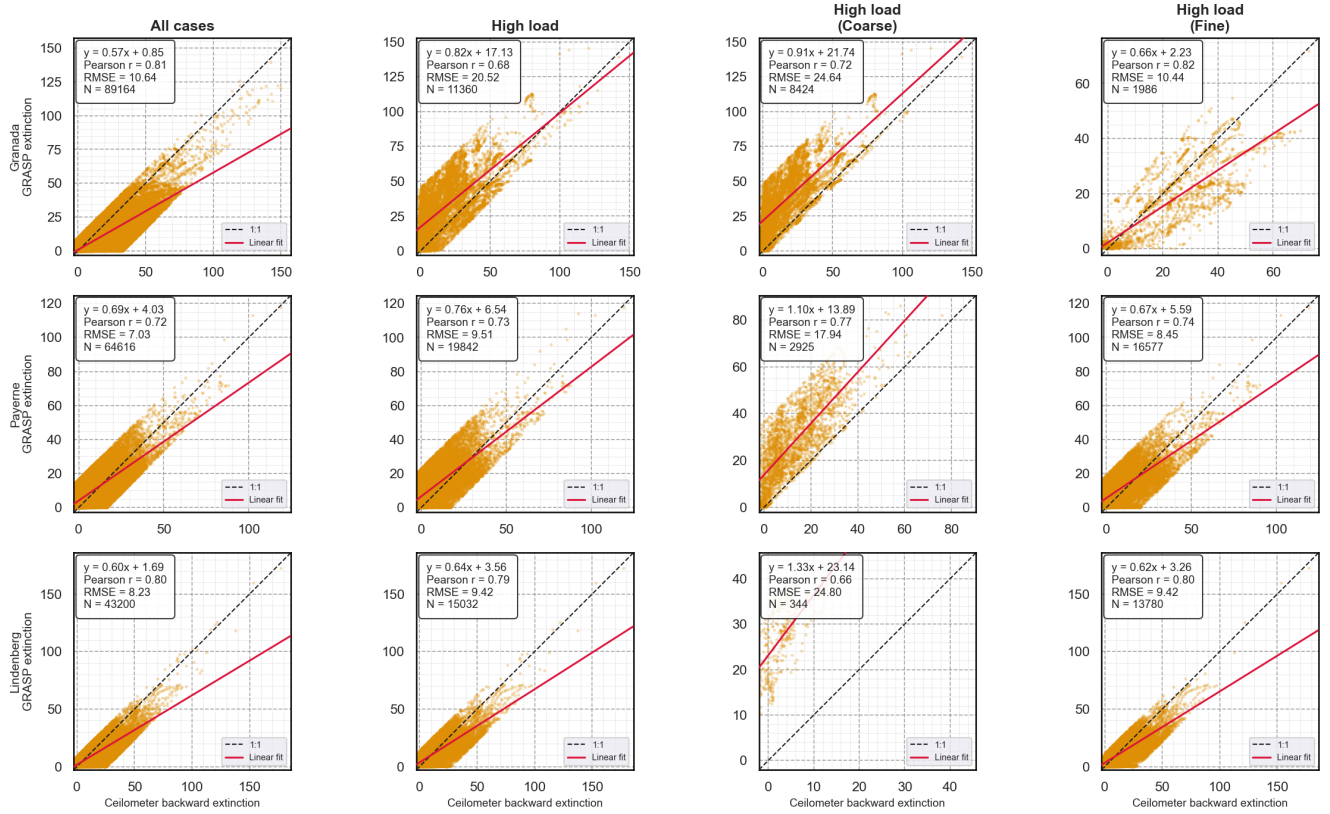


Figure 5. Ceilometer Extinction Coefficient (Klett Backward) vs. GRASP. For this scatter analysis same filtering criteria of profile comparison using Percentiles 10-90 was applied.

Klett Forward vs GRASP — extinction

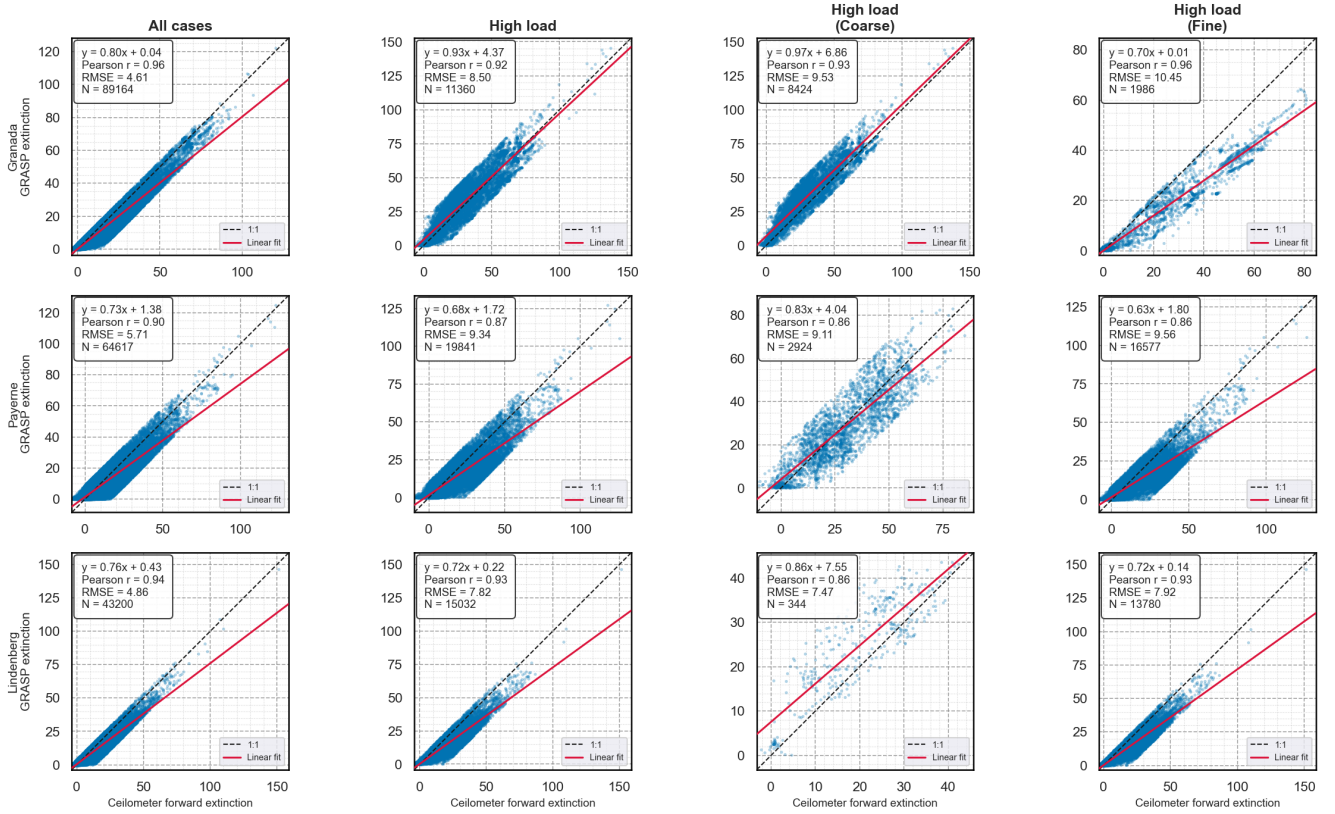


Figure 6. Ceilometer Extinction Coefficient (Klett Forward) vs. GRASP. For this scatter analysis same filtering criteria of profile comparison using Percentiles 10-90 was applied

Ceilometer AOD₁₀₆₄ vs AERONET AOD₁₀₆₄ — Backward

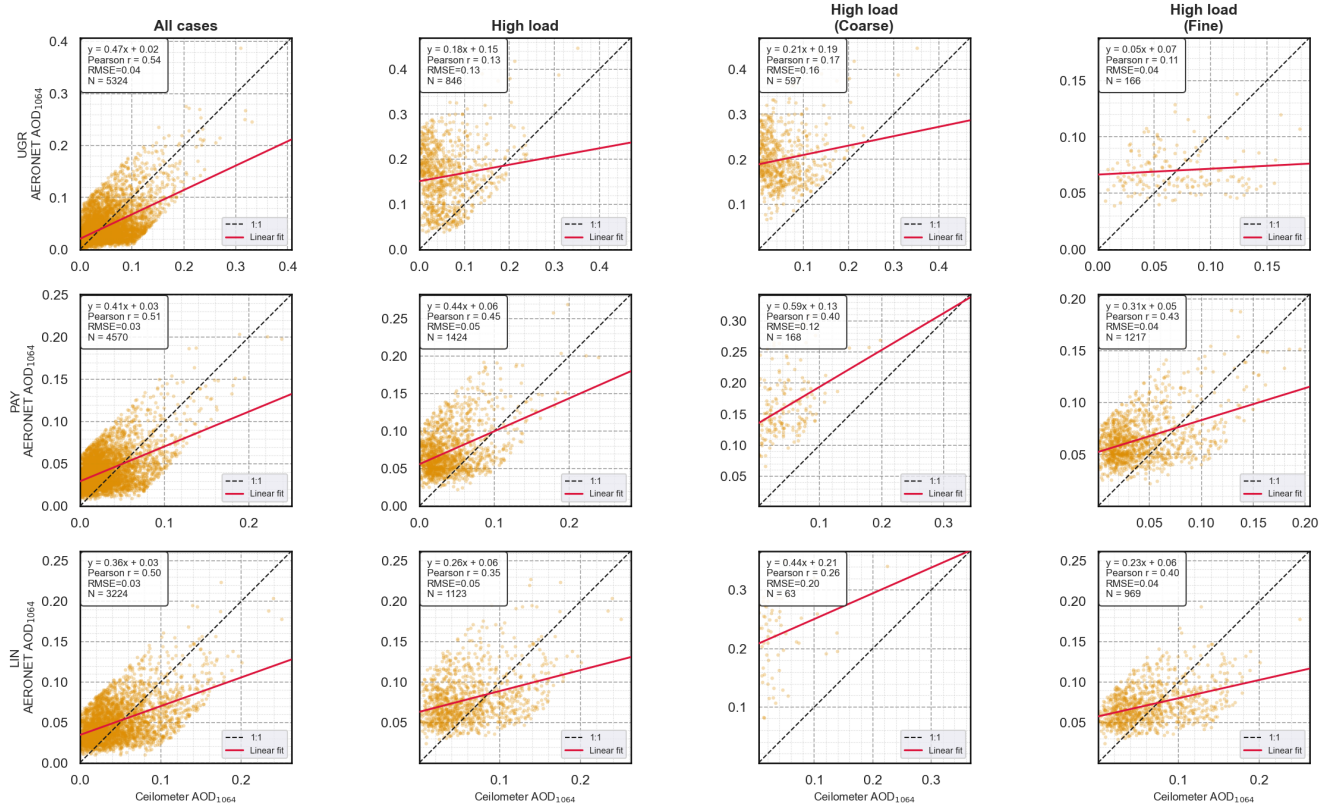


Figure 7. Ceilometer-derived AOD at 1064 nm (Klett Backward) vs. AERONET AOD. For this scatter analysis same filtering criteria of profile comparison using Percentiles 10-90 was applied.

Ceilometer AOD₁₀₆₄ vs AERONET AOD₁₀₆₄ — Forward

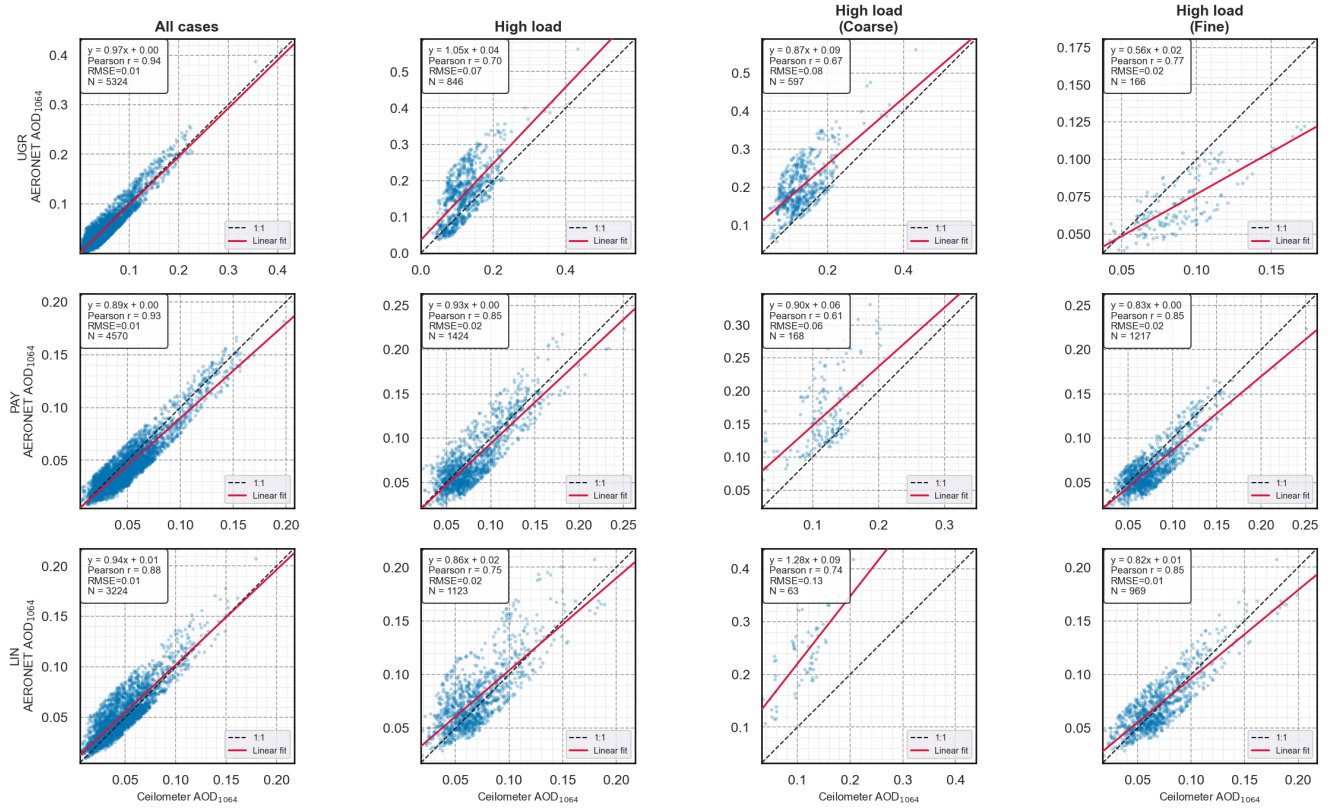


Figure 8. Ceilometer-derived AOD at 1064 nm (Klett Forward) vs. AERONET AOD. For this scatter analysis same filtering criteria of profile comparison using Percentiles 10-90 was applied.

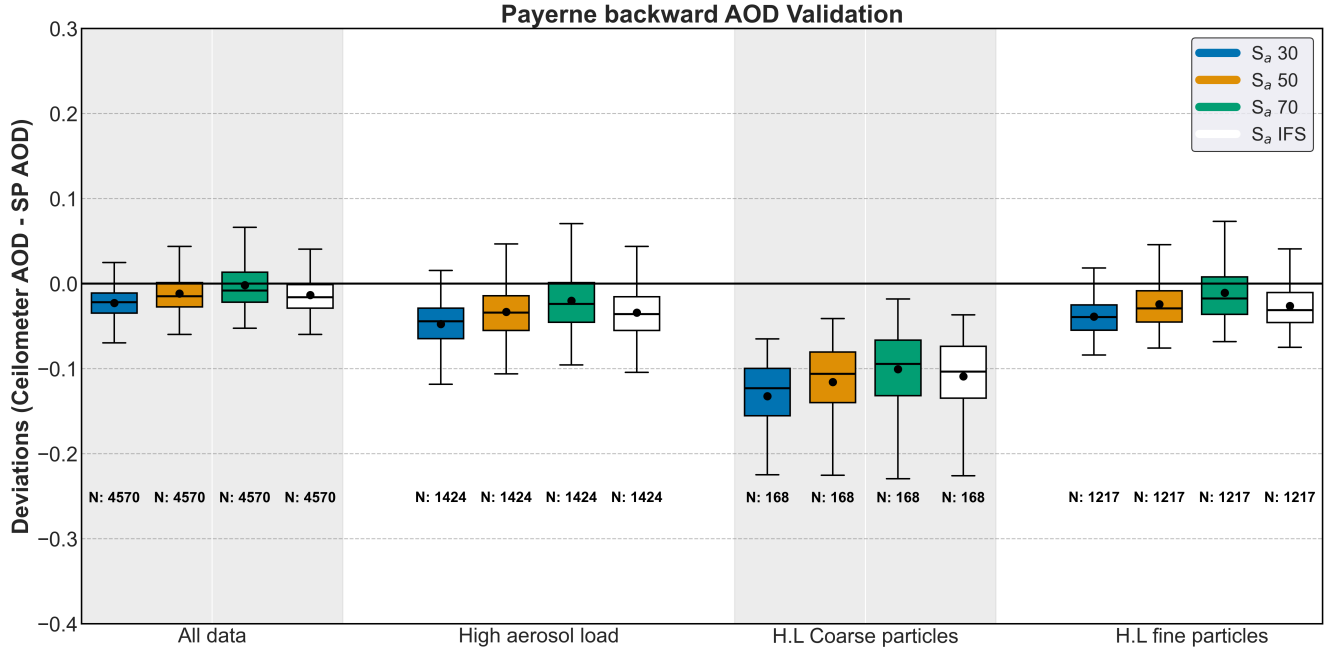


Figure 9. Deviations between ceilometer-derived AOD and AERONET sun-sky photometer AOD at Payerne for the backward (Klett–Fernald) retrieval, evaluated under four lidar ratio configurations: fixed values of 30, 50 and 70 sr and the daily variable IFS–CAMS estimate (LR IFS). From left to right: all cases, high aerosol load, high-load coarse particles and high-load fine particles. The whiskers of each box show the interquartile range, the dot and black line inside the boxes represent the mean and median respectively, and N shows the number of integrated profiles used

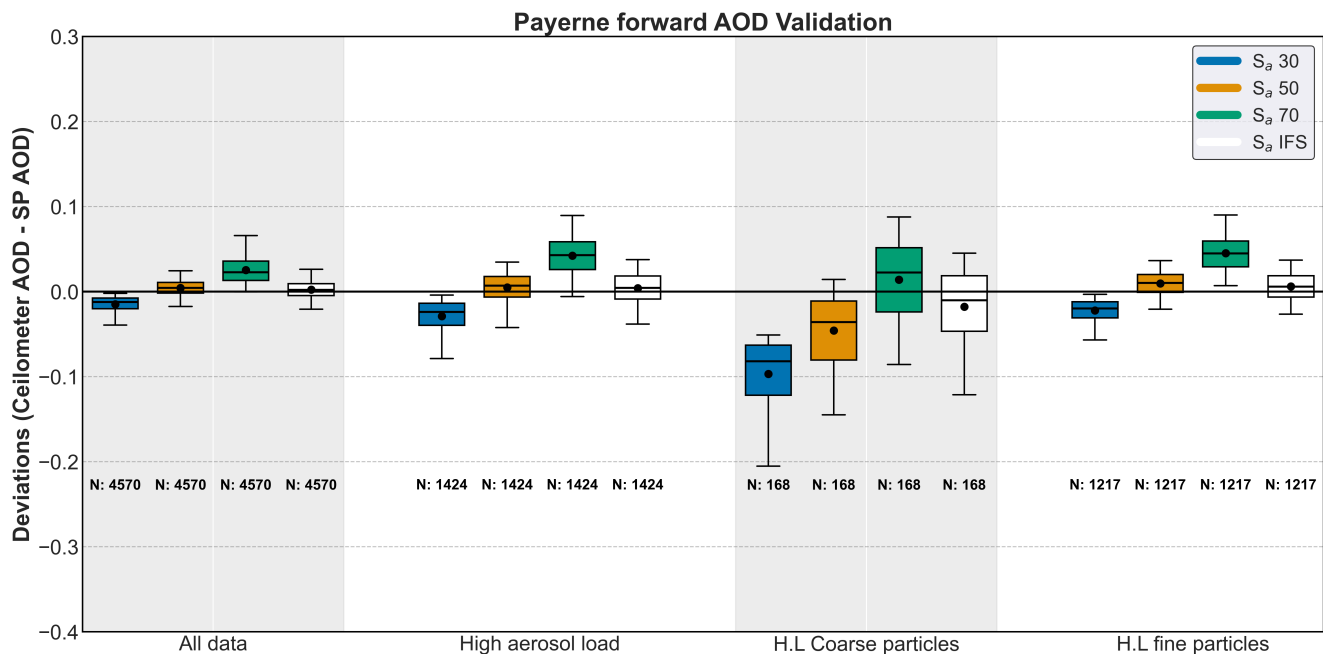


Figure 10. As in Fig. 9, but for the forward iterative retrieval at Payerne

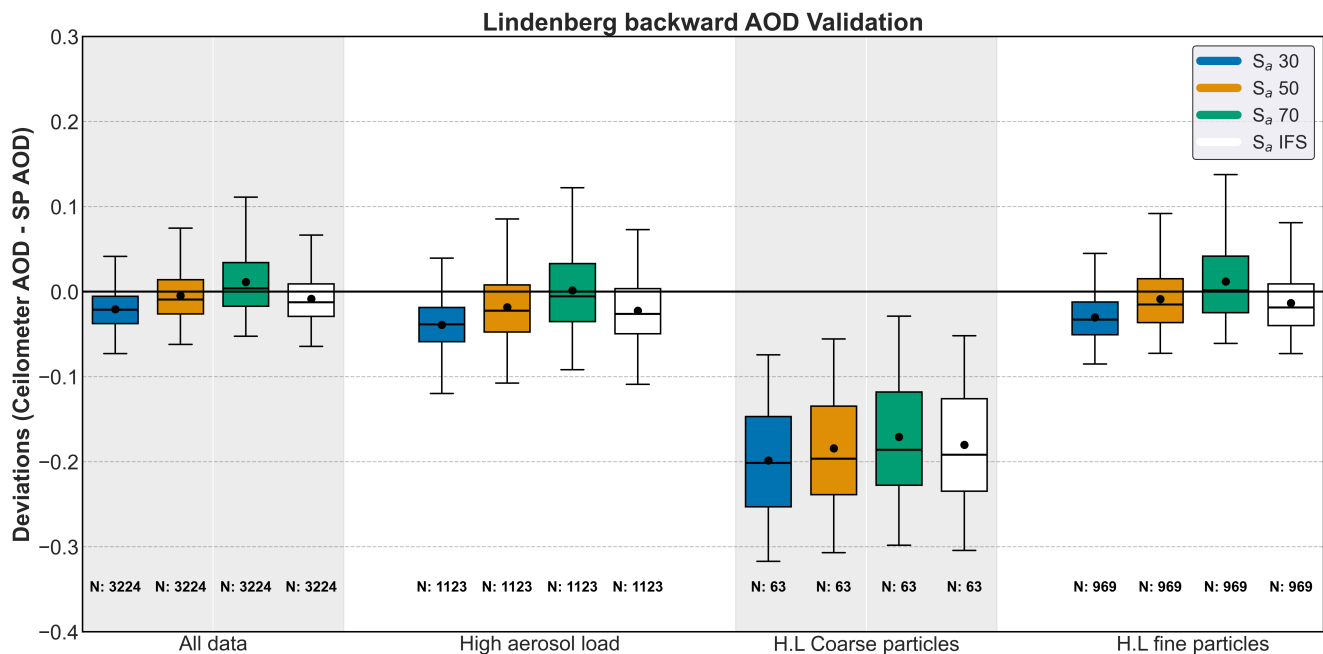


Figure 11. As in Fig. 9, but for the backward iterative retrieval at Lindenberg

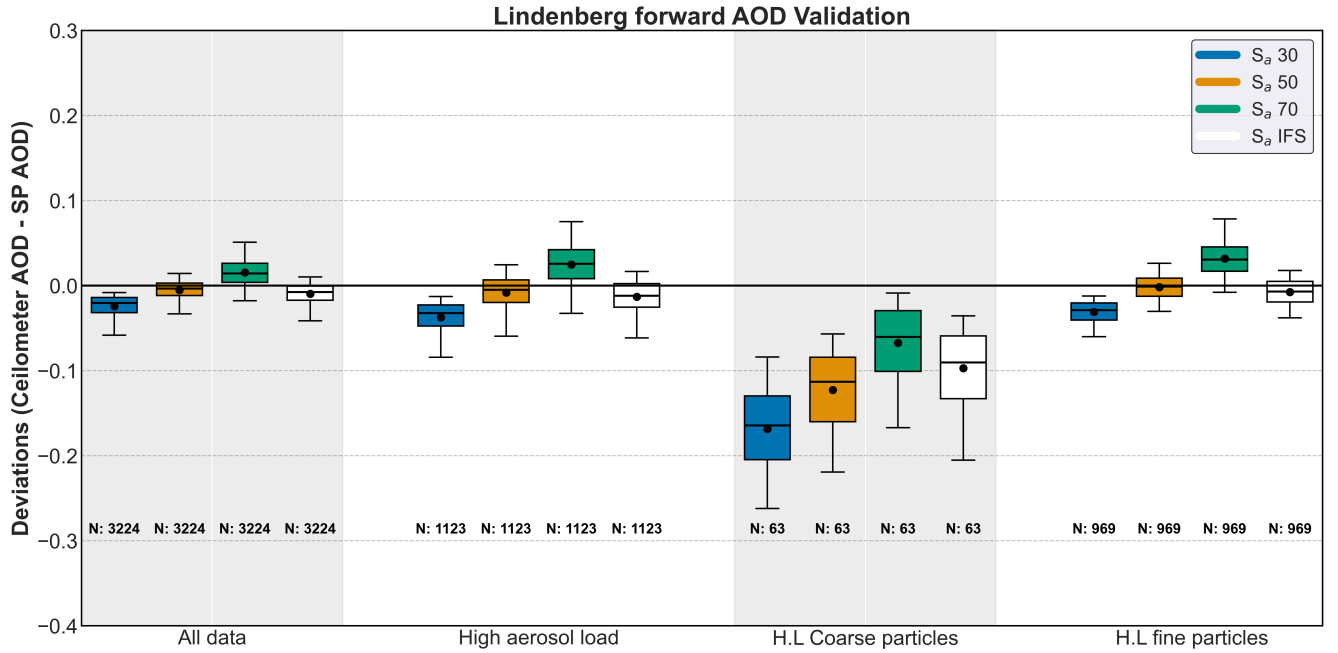


Figure 12. As in Fig. 9, but for the forward iterative retrieval at Lindenberg

Table 1. Lidar Ratio Comparison - Granada - Backward Method

Lidar Ratio	Mean (%)	STD (%)	RMSE
<i>All data</i>			
LR 30	-0.012 (-13.7%)	0.029 (64.0%)	0.031
LR 50	0.006 (34.0%)	0.035 (95.0%)	0.035
LR 70	0.021 (76.9%)	0.041 (121.1%)	0.047
LR IFS	0.003 (21.6%)	0.033 (85.3%)	0.033
<i>High aerosol load</i>			
LR 30	-0.123 (-71.5%)	0.069 (23.8%)	0.141
LR 50	-0.103 (-56.5%)	0.076 (34.9%)	0.128
LR 70	-0.086 (-43.3%)	0.083 (44.1%)	0.119
LR IFS	-0.093 (-50.3%)	0.077 (37.6%)	0.120
<i>H.L Coarse particles</i>			
LR 30	-0.165 (-81.1%)	0.060 (15.5%)	0.175
LR 50	-0.147 (-71.1%)	0.067 (22.5%)	0.161
LR 70	-0.131 (-62.3%)	0.074 (28.4%)	0.150
LR IFS	-0.132 (-63.3%)	0.073 (27.6%)	0.151
<i>H.L Fine particles</i>			
LR 30	-0.026 (-32.9%)	0.030 (41.8%)	0.040
LR 50	-0.002 (3.8%)	0.041 (61.6%)	0.041
LR 70	0.020 (36.4%)	0.049 (77.8%)	0.053
LR IFS	-0.005 (-1.7%)	0.040 (58.8%)	0.040

Table 2. Lidar Ratio Comparison - Granada - Forward Method

Lidar Ratio	Mean (%)	STD (%)	RMSE
<i>All data</i>			
LR 30	−0.018 (−38.2%)	0.016 (17.6%)	0.024
LR 50	0.001 (5.8%)	0.012 (29.1%)	0.012
LR 70	0.021 (54.1%)	0.019 (44.4%)	0.029
LR IFS	0.001 (0.6%)	0.013 (31.6%)	0.013
<i>High aerosol load</i>			
LR 30	−0.094 (−53.2%)	0.052 (14.9%)	0.108
LR 50	−0.043 (−18.9%)	0.050 (26.6%)	0.066
LR 70	0.023 (25.4%)	0.053 (40.7%)	0.058
LR IFS	0.000 (5.7%)	0.043 (27.1%)	0.043
<i>H.L Coarse particles</i>			
LR 30	−0.126 (−61.2%)	0.046 (9.8%)	0.134
LR 50	−0.070 (−32.8%)	0.047 (17.8%)	0.085
LR 70	0.003 (5.3%)	0.057 (28.6%)	0.057
LR IFS	−0.006 (0.5%)	0.053 (25.9%)	0.053
<i>H.L Fine particles</i>			
LR 30	−0.020 (−26.9%)	0.011 (12.9%)	0.022
LR 50	0.018 (25.9%)	0.017 (23.2%)	0.024
LR 70	0.060 (88.2%)	0.027 (35.7%)	0.066
LR IFS	0.012 (18.7%)	0.017 (25.3%)	0.021

Table 3. Lidar Ratio Comparison - Payerne - Backward Method

Lidar Ratio	Mean (%)	STD (%)	RMSE
<i>All data</i>			
LR 30	−0.023 (−51.4%)	0.019 (38.6%)	0.030
LR 50	−0.012 (−23.5%)	0.024 (57.8%)	0.027
LR 70	−0.002 (1.8%)	0.029 (73.9%)	0.029
LR IFS	−0.013 (−27.8%)	0.023 (55.2%)	0.027
<i>High aerosol load</i>			
LR 30	−0.047 (−62.6%)	0.029 (26.8%)	0.055
LR 50	−0.033 (−41.6%)	0.033 (39.6%)	0.047
LR 70	−0.020 (−22.2%)	0.038 (50.5%)	0.043
LR IFS	−0.034 (−43.8%)	0.032 (37.9%)	0.046
<i>H.L Coarse particles</i>			
LR 30	−0.132 (−81.8%)	0.045 (11.3%)	0.140
LR 50	−0.116 (−71.3%)	0.047 (17.2%)	0.125
LR 70	−0.101 (−61.7%)	0.050 (22.5%)	0.112
LR IFS	−0.109 (−67.4%)	0.048 (19.3%)	0.119
<i>H.L Fine particles</i>			
LR 30	−0.039 (−58.4%)	0.023 (29.2%)	0.045
LR 50	−0.024 (−35.1%)	0.029 (42.9%)	0.038
LR 70	−0.011 (−13.6%)	0.036 (54.6%)	0.037
LR IFS	−0.026 (−38.4%)	0.028 (41.1%)	0.038

Table 4. Lidar Ratio Comparison - Payerne - Forward Method

Lidar Ratio	Mean (%)	STD (%)	RMSE
<i>All data</i>			
LR 30	−0.015 (−33.8%)	0.010 (13.2%)	0.018
LR 50	0.004 (13.2%)	0.009 (22.9%)	0.010
LR 70	0.026 (63.9%)	0.016 (33.3%)	0.030
LR IFS	0.002 (6.8%)	0.010 (24.5%)	0.011
<i>High aerosol load</i>			
LR 30	−0.029 (−35.7%)	0.019 (14.2%)	0.034
LR 50	0.005 (11.3%)	0.018 (24.9%)	0.018
LR 70	0.042 (64.2%)	0.022 (36.5%)	0.048
LR IFS	0.004 (7.6%)	0.018 (24.1%)	0.018
<i>H.L Coarse particles</i>			
LR 30	−0.097 (−57.3%)	0.042 (10.9%)	0.105
LR 50	−0.046 (−24.7%)	0.042 (19.4%)	0.062
LR 70	0.014 (13.3%)	0.046 (29.2%)	0.048
LR IFS	−0.018 (−7.4%)	0.045 (25.5%)	0.048
<i>H.L Fine particles</i>			
LR 30	−0.022 (−31.9%)	0.013 (13.2%)	0.026
LR 50	0.010 (17.6%)	0.014 (23.3%)	0.017
LR 70	0.045 (73.1%)	0.020 (34.5%)	0.049
LR IFS	0.006 (10.8%)	0.016 (23.9%)	0.017

Table 5. Lidar Ratio Comparison - Lindenberg - Backward Method

Lidar Ratio	Mean (%)	STD (%)	RMSE
<i>All data</i>			
LR 30	−0.021 (−37.1%)	0.024 (43.7%)	0.032
LR 50	−0.005 (−3.0%)	0.031 (64.1%)	0.032
LR 70	0.011 (30.3%)	0.039 (82.6%)	0.040
LR IFS	−0.008 (−11.5%)	0.030 (59.4%)	0.031
<i>High aerosol load</i>			
LR 30	−0.039 (−47.1%)	0.033 (35.3%)	0.051
LR 50	−0.018 (−18.8%)	0.041 (51.5%)	0.045
LR 70	0.002 (8.0%)	0.050 (65.5%)	0.050
LR IFS	−0.022 (−24.7%)	0.039 (47.5%)	0.045
<i>H.L Coarse particles</i>			
LR 30	−0.199 (−88.2%)	0.064 (9.9%)	0.209
LR 50	−0.184 (−81.8%)	0.068 (14.6%)	0.196
LR 70	−0.171 (−75.2%)	0.071 (18.8%)	0.185
LR IFS	−0.180 (−80.2%)	0.066 (13.7%)	0.192
<i>H.L Fine particles</i>			
LR 30	−0.030 (−41.0%)	0.028 (37.1%)	0.042
LR 50	−0.009 (−9.7%)	0.038 (53.6%)	0.039
LR 70	0.012 (20.0%)	0.047 (67.7%)	0.049
LR IFS	−0.013 (−16.8%)	0.036 (49.5%)	0.038

Table 6. Lidar Ratio Comparison - Lindenberg - Forward Method

Lidar Ratio	Mean (%)	STD (%)	RMSE
<i>All data</i>			
LR 30	−0.024 (−45.8%)	0.013 (12.1%)	0.027
LR 50	−0.005 (−8.9%)	0.011 (20.7%)	0.013
LR 70	0.016 (34.1%)	0.016 (30.7%)	0.022
LR IFS	−0.010 (−18.0%)	0.012 (20.0%)	0.015
<i>High aerosol load</i>			
LR 30	−0.037 (−45.8%)	0.019 (13.0%)	0.042
LR 50	−0.008 (−7.4%)	0.020 (22.6%)	0.021
LR 70	0.025 (37.4%)	0.024 (33.8%)	0.035
LR IFS	−0.013 (−14.5%)	0.018 (21.2%)	0.023
<i>H.L Coarse particles</i>			
LR 30	−0.168 (−73.2%)	0.049 (5.9%)	0.175
LR 50	−0.123 (−53.8%)	0.045 (10.5%)	0.131
LR 70	−0.067 (−29.7%)	0.043 (16.5%)	0.080
LR IFS	−0.097 (−44.6%)	0.045 (15.8%)	0.107
<i>H.L Fine particles</i>			
LR 30	−0.031 (−42.1%)	0.013 (11.3%)	0.033
LR 50	−0.002 (−1.0%)	0.014 (19.8%)	0.014
LR 70	0.032 (46.8%)	0.021 (30.0%)	0.038
LR IFS	−0.008 (−10.0%)	0.015 (20.5%)	0.016