Response to David Winker

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MS type: Research article
Title: Aerosol Optical Properties Measurement using the Orbiting High Spectral Resolution Lidar onboard DQ-1 Satellite: Retrieval and Validation
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Dear David Winker:
We would like to extend our deepest appreciation to you for investing your precious time in thoroughly reviewing our manuscript and providing us with constructive feedback and suggestions. The invaluable insights shared have played a crucial role in elevating the overall quality of our work. We have taken each comment into careful consideration, resulting in significant revisions to our manuscript. Our heartfelt gratitude also goes to both the Editor and the referee for their invaluable suggestions, which have greatly contributed to refining the previous version of our manuscript. We sincerely hope the revised manuscript will be considered for publication in Atmospheric Measurement Techniques.

General comments

This paper reports important results from the high spectral resolution lidar flying on the DQ-1 satellite. These are the first HSRL aerosol retrievals from space, so the paper is quite significant. The paper presents initial retrieval results and comparisons with other observations but requires additional details and explanation before it is publishable. To better understand the retrieval algorithm and the nature of the data products, more detailed description of the instrument and the signal processing steps applied are necessary. Several figures require more explanation. Since the paper has a focus on validation, methods use to calibrate the instrument and calibration accuracy should be explained, as well as the expected retrieval accuracy. Expressing ratios in dB is confusing. While common in the radar community, in the lidar community ratios are nearly always expressed as linear ratios rather than in dB. I strongly recommend that linear ratios be used rather than dB. When validating instrument retrievals, one would like to compare with data which is more accurate, or equally accurate. This is a problem for DQ-1 because there may not be any suitable profile data available for comparisons. Discussion of comparisons with MPLnet and CALIPSO in Section 3 should acknowledge that aerosol extinction retrievals from the MPLnet and CALIPSO elastic backscatter lidars have significant uncertainties, which may be larger than the uncertainties of the DQ-1 retrievals. Thus the discrepancies between MPLnet and DQ1 could be entirely due to uncertainties in the MPLnet retrieval and it could be difficult to say what the accuracy of the DQ1 retrieval is. Comparisons of column AOD from AERONET, on the other hand, represent a true validation as AERONET AOD is quite accurate.

Responses to general comments: We are very thankful to you for your kind words and positive feedback about our article. We have followed your suggestions carefully and revised the manuscript accordingly, including instrument calibration and calibration accuracy. The comparison with CALIPSO and MPLNET is qualitative and has been explained in the revised manuscript.

Detailed comments

Section 1. Introduction

Point 1: Lines 49-51: What instrument was used to conduct the "observational experiments"? Was this the "airborne scaling system for ACDL" mentioned later? Please clarify. Does "multi-source data" refer to ground-based instruments? What type of instruments provided data?
Response 1: We apologize for our wording and mistakes here. The ACDL airborne scaling system conducted this experiment, we have made corresponding modifications to the wording here. The multi-source data includes CALIPSO, ground-based micro pulse lidar, and sun photometer. The corresponding modifications were made to the manuscript at:

Line 49-51: The Shanghai Institute of Optics and Fine Mechanics (SIOM) of the Chinese Academy of Sciences, in collaboration with Nanjing University of Information Science and Technology (NUIST), Zhejiang University (ZJU), and other institutions, has conducted observational experiments on airborne HSRL system at two distinct geographical locations, Dunhuang and Shanhaiguan. This airborne system is a scaled system of the DQ-1 HSRL. The aerosol optical parameters in these two regions obtained by the HSRL system were validated using CALIPSO, ground-based Micro Pulse Lidar (MPL), and sun photometer.

Point 2: Line 65: CALIPSO was "retired" in fall 2023 but not because of fuel consumption. CALIPSO science operations were terminated in August 2023 because the satellite's solar arrays could no longer generate enough electrical power to operate the CALIOP lidar.
Response 2: Thank you for bringing this matter to our attention. According to the information provided on the NASA LARC website (*https://www-calipso.larc.nasa.gov/, last access: Jan 2nd.*), Calipso's fuel reserves are exhausted, and in its decaying orbit the satellite can no longer generate sufficient power to operate the science instruments. Considering your comment, we believe that the insufficient energy is the real reason for its retirement. Corresponding modifications are made to the manuscript at:

Line 65: Due to insufficient energy (Langley Research Center, 2024), the CALIPSO science mission ended in August 2023, a well-established and developed new-generation spaceborne Lidar is needed to replace CALIPSO for global aerosol observation.

Point 3: Lines 72-74: Plans for AOS no longer include an HSRL instrument. AOS information on the vertical motion of clouds will come from Doppler radar.
Response 3: We apologize for our negligence, According to the literature cited in this sentence (Cornut et al., 2023), the AOS program has studied the scientific value of spaceborne HSRL systems. We have modified the manuscript at:

Line 73: Furthermore, under the leadership of NASA, the Atmosphere Observing System (AOS) international program analyzes the additional value provided by the spaceborne HSRL system. This research has shown that the results of spaceborne HSRL systems are more accurate than the results of traditional elastic backscatter lidar in three different cases (Cornut et al., 2023).

Point 4: Line 79: EarthCARE is anticipated to be launched in spring 2024.

Response 4: Thank you for pointing out this issue. We have modified the manuscript at:

Line 38: This satellite is anticipated to be launched in the spring of 2024.

Point 5: Line 85: Is the "airborne scaling system for ACDL" an airborne simulator of the DQ-1 HSRL?

Response 5: Yes, like the DQ-1, the airborne ACDL system also includes the HSRL system, the main purpose of the airborne experiment is to verify the reliability and accuracy of the spaceborne system.

Point 6: Line 95: "to ensure the accuracy" – HSRL retrievals should be more accurate than elastic backscatter lidars such as CALIOP and MPLNET. Intercomparisons are useful but elastic backscatter lidars have significant retrieval errors and are not suited to validate HSRL accuracy. The comparison of DQ-1 AOD with AERONET is more helpful.

Response 6: Thank you for pointing out this issue. We apologize for our negligence in the manuscript. The word "accuracy" is not appropriate here. The comparison between DQ-1 and CALIOP, MPLNET belongs to qualitative comparison. Corresponding modifications are made to the manuscript at:

Line 95: The attenuated backscatter coefficient is first compared with the CALIPSO dataset to ensure the accuracy of instrument calibration. The retrieval results were then compared with the corresponding data products of CALIPSO and NASA MPLNET qualitatively. To ensure accuracy, the retrieved aerosol optical depth was against the corresponding data products of AERONET, where the errors were analyzed.

Section 2. Instrumentation and Method

Point 7: Line 118: Is the suppression of the aerosol signal only 25 dB? Using an iodine filter, the suppression of the aerosol signal can be much greater than 25 dB. Can the authors discuss?

Response 7: Thank you for raising this important issue. For an iodine filter at the spaceborne HSRL system, a higher suppression ratio will reduce signal energy and increase the proportion of system noise, resulting in retrieval errors. Based on the previous simulation, the most suitable iodine filter temperature and pressure were selected as well as the length of the filter, resulting in a suppression ratio of 25 dB (Dong et al., 2018). This suppression ratio is sufficient to filter out the Mie scattering for subsequent retrieval. To illustrate this, we have selected a representative profile to analyze its filtering effect. Figure 2 showcases an attenuated backscatter profile. The red line represents the unfiltered signal, the green line represents the filtered signal, and the blue line represents the molecular backscatter signal. The unfiltered signal displays the echo signal of the cirrus at an altitude of 13-15 km. The signals of cirrus contain strong Mie scattering signals, the filtered signal only contains molecular backscatter, without the Mie scattering signal. Similarly, clouds at 5-6 km are only observed in the unfiltered signal. At an altitude of 3 km, the signal cannot penetrate thick cumulus clouds, resulting in signal attenuation below this altitude. The filtered signal is more in line with the molecular scattering, the signals from clouds and aerosols have been filtered out.

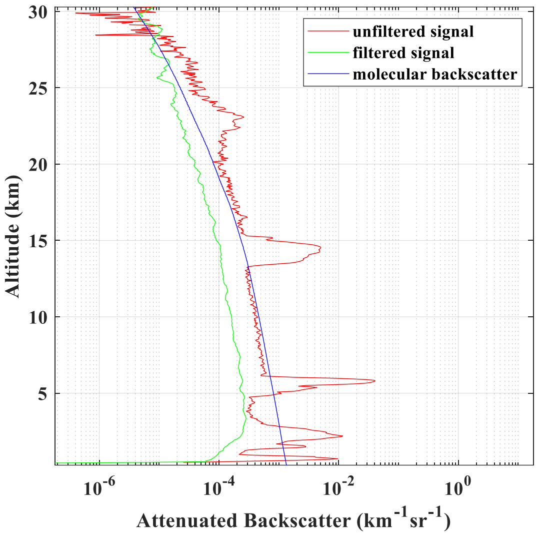


Figure 2 Attenuated backscatter profile

The corresponding modifications and figures were made or added to the manuscript at:

Line 118: Based on the previous simulation, the most suitable iodine filter temperature, pressure and length were selected, resulting in a suppression ratio of 25 dB (Dong et al., 2018), this suppression ratio is sufficient to filter out the Mie scattering for subsequent retrieval. Figure 1 shows the comparison of signals before and after filtering, the filtered signal consists of no aerosol Mie scattering, presenting a residual portion of molecular Rayleigh scattering.

Line 535: Figure 1:

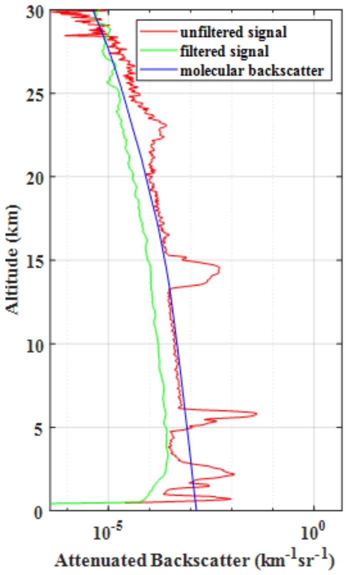


Figure 1: The transmittance spectra of the filter and comparison of signals before and after filtering. (a) The actual measured transmittance spectra of the onboard iodine vapor filter of the DQ-1 satellite, the subfigure in the lower right corner display the transmittance spectrum in the 1110 line. The red solid line delineates the spectral of the echo signal prior to the filter (parallel channel), and the blue solid line delineates the spectral of the echo signal after the filter (high spectral channel). (b) Comparison of signals before and after filtering, the red line represents the unfiltered signal, the green line represents the filtered signal, and the blue line represents the molecular backscatter signal.

Point 8: Lines 121-122: Some discussion of the pre-processing steps is required. What is meant by "signal to noise ratio control" and what type of moving average and pulse averaging is applied? Line 131: Explain what kind of signal smoothing was applied to the pre-processed data. How is this different from the averaging applied as a pre-processing step?

Response 8: We are sorry for our wording and negligence here. To ensure signal quality, we have deducted signals with a low SNR and used a low-pass filtering algorithm for moving averages of signal profiles before retrieval. Due to the horizontal resolution of 20 km designed for the DQ-1 HSRL system, considering the satellite orbital velocity, the pulse averaging process mainly involves normalizing the profiles within a 20 km horizontal range before averaging them. Corresponding modifications were made to the manuscript at:

Lines 121-122: Prior to L2A data retrieval, some pre-processing steps are taken, including SNR control, moving average, and pulse averaging. SNR control refers to removing the backscatter signal with insufficient SNR, this includes removing the heavy cloud-covered signal and removing erroneous echoes under the surface and signals with poor SNRs, this is achieved by setting an SNR threshold. After this, the low-pass filtering algorithm is used to perform moving average on the profile. To achieve the design's horizontal resolution of 20 km, the profiles within a 20 km horizontal range are normalized and averaged.

Point 9: Table 1 gives laser energy as "> 150 mJ" but the manuscript says laser pulses A and B have different energies. What is the energy of each pulse, A and B, and how they are averaged together? What is the time delay between these two 532 nm pulses? What does it mean they can be "categorized and adjusted during the retrieval process" (Line 110) The operations described in lines 125-127 are not clear. What is meant by "48 sets".

Response 9: We apologize for our negligence and wording here. It is inaccurate to consider that the pulse energy in Table 1 is greater than 150 mj. The energy of both pulses is greater than 120mj. In orbit, the pulse energy of the two pulses is monitored for calibration, Figure 3 shows the changes in pulse energy. After normalization, the pulses within a horizontal spatial distance of 20km were averaged together.

16.1 μs is the time delay of pulses A and B. The 48 sets mean within a horizontal distance of 20 km, DQ-1 emitted 48 times pulses A and B.

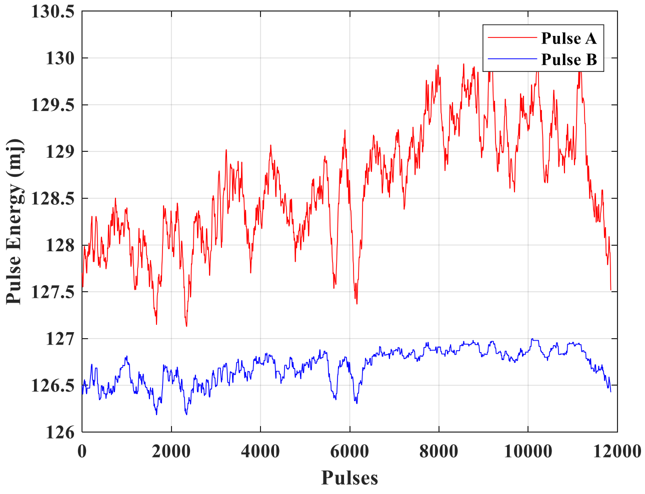


Figure 3 Pulse energy of the two pulses

The corresponding modifications are made to the manuscript at:

Line 110: There is an energy difference between laser pulses A and B, where the L2A data have been calibrated during the production, and the time delay of pulses A and B is 16.1 μs. To improve the SNR of the original data, the two pulses have been normalized and averaged.

Line 605: Table 1. Main parameters of the DQ-1 HSRL system

Parameter	Value
Laser Wavelength	532.245nm
Laser Energy	≥120mj for pulses A and B
Laser Frequency Stability	1MHz@10000s
Laser repetition frequency	40 Hz
Telescope aperture	1000 mm
Field of view	0.2 mrad
Broadband bandpass filter	0.45 nm
Narrowband FP filter	30 pm
HSRL filters	iodine vapor filter, 1110 line aerosol signal suppression ratio ≥ 25 dB
Overall optical efficiency (excluding iodine filter)	0.16 at parallel polarized channel 0.561 at perpendicular polarized channel 0.375 at high spectral resolution channel
Quantum efficiency of the detector	40%
Error of retrieval result	15% uncertainty with 20km horizontal resolution

Point 10: How is "measurement accuracy" in Table 1 defined? Is this the random error of the parallel channel signal or does it include calibration errors? Measurement accuracy depends on many factors, including background lighting, altitude, and averaging. Under what conditions is the measurement accuracy of 15% achieved? Is this before or after noise reduction is applied?

Response 10: We are sorry for our wording here. What we want to express here is that the relative error between the retrieved aerosol optical parameters and the true values is less than 15%. The corresponding modifications are made to the Table 1 at:

Table 1. Main parameters of the DQ-1 HSRL system (Dong et al., 2018; Weibiao et al., 2023).

Parameter	Value
Laser Wavelength	532.245nm
Laser Energy	≥120mj for pulses A and B
Laser Frequency Stability	1MHz@10000s
Laser repetition frequency	40 Hz
Telescope aperture	1000 mm
Field of view	0.2 mrad
Broadband bandpass filter	0.45 nm
Narrowband FP filter	30 pm
HSRL filters	iodine vapor filter, 1110 line

	aerosol signal suppression ratio ≥ 25 dB
Overall optical efficiency (excluding iodine filter)	0.16 at parallel polarized channel 0.561 at perpendicular polarized channel 0.375 at high spectral resolution channel
Quantum efficiency of the detector	40%
Error of retrieval result	15% uncertainty with 20km horizontal resolution

Point 11: Important parameters are missing from Table 1. Lidar sensitivity depends on more than laser pulse energy. To gain more understanding of data quality and to better interpret intercomparisons, parameters such as receiver field of view, laser linewidth, bandwidth of the Fabry-Perot etalon, detector type (PMT, APD?, other?), detection scheme (analog or photon counting), and dynamic range of the detection system should be given. What is the view angle of the lidar - pointed at nadir or off-nadir?

Response 11: We are sorry for our negligence here, the corresponding parameters were added to Table 1 and the manuscript at:

Table 1:

Parameter	Value
Laser Wavelength	532.245nm
Laser Energy	≥120mj for pulses A and B
Laser Frequency Stability	1MHz@10000s
Laser repetition frequency	40 Hz
Telescope aperture	1000 mm
Field of view	0.2 mrad
Broadband bandpass filter	0.45 nm
Narrowband FP filter	30 pm
HSRL filters	iodine vapor filter, 1110 line aerosol signal suppression ratio ≥ 25 dB
Overall optical efficiency (excluding iodine filter)	0.16 at parallel polarized channel 0.561 at perpendicular polarized channel 0.375 at high spectral resolution channel
Quantum efficiency of the PMT detector	40% in analog scheme
Error of retrieval result	15% uncertainty with 20km horizontal resolution

Line 110: The laser is with two distinct pulses, pulse A and pulse B, to observe the atmosphere practically, the laser beam is off-zenith pointing at a specific angle.

Point 12: Line 124 says "L2A data have been calibrated during production". How is calibration of the three signals accomplished? What is the accuracy of this calibration? What is the accuracy of the ratio of the parallel channel to molecular channel and of the volume depolarization ratio.
Line 127: The DQ-1 L2A dataset is an input to the algorithm. Explain what the L2A dataset is

and what processing steps are used to produce the L2A.

Response 12: The correction includes energy normalization, distance squared correction, and channel efficiency correction, this will be added in section 2.1.2 of the manuscript. Figure 4 illustrates the result of the calibration, which is the attenuated backscatter coefficient. Due to the absence of aerosol distribution at high altitudes, molecular echo signals can also detect the accuracy of results. The attenuation backscatter coefficients of DQ-1 and CALIPSO are consistent with molecular scattering signals at high altitudes, verifying the accuracy of the calibration.

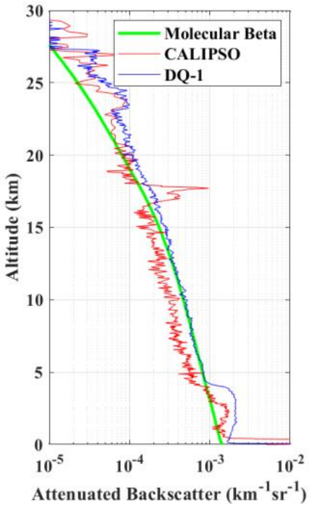


Figure 4 Attenuated backscatter coefficient of DQ-1 and CALIPSO with molecular backscatter (the same as the revised Figure 4e in the manuscript)

There has been research on the polarization properties of atmospheric molecules. Retrieving the depolarization ratio of atmospheric molecules at high altitudes can verify the accuracy of the ratio of the parallel channel to the perpendicular channel. We have chosen a profile illustrating a high-altitude depolarization ratio result, as depicted in Figure 5. The results show that DQ-1 retrieved the molecular depolarization ratio of 1%, which is consistent with the literature (Young, 1982; Rowell et al., 1971), so we believe that the depolarization ratio is accurately retrieved.

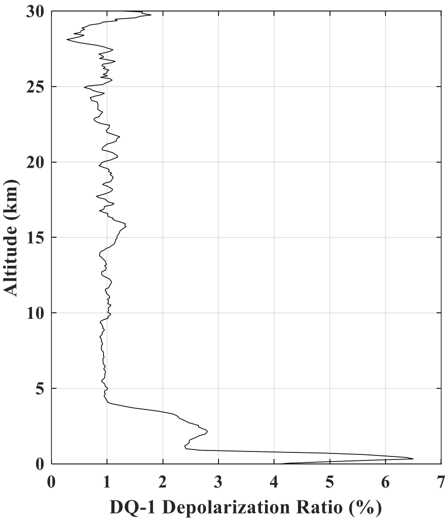


Figure 5 Profile of DQ-1 depolarization ratio at high altitude.

As shown in the previous Figure 2, it also demonstrates the accuracy of parallel channels and molecular channels. After calibration, the echo signals of both channels match the molecular signals, while the high spectral channel experiences signal attenuation due to passing through the iodine filter.

The DQ-1 L2A dataset includes the attenuation backscatter coefficients of parallel channels, perpendicular channels, and high spectral channels. The parameters and steps used to generate L2A have been added to the manuscript:

Line 139:

$$B^{\perp}(r) = \frac{P(r)r^2}{P_0\eta^{\perp}AL}[\beta_m^{\perp}(r) + \beta_a^{\perp}(r)] \times exp\left\{-2\int_0^r [\alpha_m(r) + \alpha_a(r)]\,dr\right\} \tag{2.1}$$

$$B_C^{\parallel}(r) = \frac{P(r)r^2}{P_0\eta_C^{\parallel}AL}[\beta_m^{\parallel}(r) + \beta_a^{\parallel}(r)] \times exp\left\{-2\int_0^r [\alpha_m(r) + \alpha_a(r)]\,dr\right\} \tag{2.2}$$

$$B_H^{\parallel}(r) = \frac{P(r)r^2}{P_0\eta_H^{\parallel}AL}[T_m(r)\beta_m^{\parallel}(r) + T_a(r)\beta_a^{\parallel}(r)] \times exp\left\{-2\int_0^r [\alpha_m(r) + \alpha_a(r)]\,dr\right\} \tag{2.3}$$

Line 144: $P(r)$ represents the power of the laser echo signal at distance r. P_0 represents the emitting power of the laser, η represents the optical efficiency of the corresponding receiving channel, A represents the aperture of the telescope, and L stands for the half of the pulse spatial transfer length, where L is calculated as $L = c\Delta t/2$, with c representing the speed of light and Δt denoting the pulse duration.

Point 13: Line 131: Explain how SNR is used to control data quality.

Response 13: We are sorry about our wording here. The data quality control of SNR refers to setting a threshold to filter out signals with an SNR lower than the threshold, which filters out pseudo signals below the surface and signals below thick clouds. Corresponding modifications are made to the manuscript at:

Lines 121-122: SNR control refers to removing the backscatter signal with insufficient SNR, this includes removing the heavy cloud-covered signal, and removing erroneous echoes under the surface and signals with poor SNRs, this is achieved by setting a SNR threshold.

Point 14: The authors should discuss the magnitude of Tm and Ta in equation 2.3 and refer to Fig 1. From Fig 1 it looks like Ta is about 0.002 and Tm is perhaps 40-50%. Since this is a validation paper, the authors should address how Tm and Ta vary on-orbit and whether this variation is a source of retrieval uncertainty.

Response 14: Thank you for raising this important question. On orbit, the changes in Tm and Ta are related to two factors, one is the absorption spectrum of the iodine filter, and the other is the temperature and pressure of the atmosphere. The temperature and pressure of iodine in the DQ-1 filter are strictly controlled, ensuring the stability of the absorption spectrum and thus ensuring the accuracy of the retrieval algorithm. We used ERA5, an authoritative dataset, to ensure the accuracy of the atmospheric temperature and pressure brought into the algorithm. The corresponding discussions were added to the manuscript at:

Line 145:

$T_m(T,p)$ and $T_a(T,p)$ respectively represents the transmittance of the echo signal of molecular and aerosol while passing the iodine filter, they can be expressed as:

$$T_m(T,p) = \int F(v) \int R_m(v',T,p) l(v-v') dv' dv \tag{2.4}$$

$$T_a(T,p) = \int F(v) \int R_a(v',T,p) l(v-v') dv' dv \tag{2.5}$$

Where $l(v-v')$ represents the spectrum distribution of the laser beam, $F(v)$ represents the normalized transmission spectrum of the iodine filter. $R_m(v',T,p)$ represents the normalized molecular scattering spectrum related to temperature and pressure. $R_a(v',T,p)$ represents the normalized aerosol particles scattering spectrum (Dong et al., 2018). To ensure the stability of the absorption spectrum, the temperature and pressure of iodine in the filter are strictly controlled on the orbit.

Point 15: Line 159: Is the extinction profile really computed from a simple derivative as described in Eq 2.9? This method is extremely sensitive to signal noise.

Response 15: The extinction coefficient results in this manuscript were calculated through derivative calculations. The signal SNR of DQ-1 is high, which can meet the requirements of this calculation method. Moreover, since we have already done the signal smoothing and quality control mentioned above, it can meet the requirements of derivative calculations

Point 16: Line 169-171: These two sentences are not correct. In the last few years, the CALIOP laser was producing an increasing number of laser pulses with near zero energy. As explained above, science operations were terminated in August 2023 because the orbit had precessed to the east and the satellite's solar arrays could no longer generate enough electrical power to operate the lidar.

Response 16: We are sorry for our mistake here. The corresponding modifications were made to the manuscript at:

Line 169: Due to insufficient power supply, the CALIPSO science mission has ended, demanding the deployment of a new satellite platform to continue global observations of clouds and aerosols.

Section 3. Validation

Point 17: Additional detail is needed on how CALIPSO data is used in the intercomparison with DQ-1. "Energy attenuation of the CALIPSO laser" is mentioned a number of times and pointed to as the source of various discrepancies. It is not clear what is meant by "laser energy attenuation". This term needs to be explained. The manuscript mentions "energy differences" between CALIOP and DQ-1 several times but does not explain what the difference is.

Response 17: Thank you for pointing out this issue and we are sorry for our negligence. Due to CALIPSO's prolonged in-orbit operation, laser energy attenuation causes a diminished SNR, leading to more noise signals within the echo signal and consequently, increased measurement inaccuracies. As depicted in Figure 6, the SNR profile of DQ-1 is shown within a spatial region identical to that of CALIPSO. Within the latitude range of 40°N to 10°N, the SNR of DQ-1 measures 60, while CALIPSO measures a lower value of 20. The noise signal of CALIPSO affects the retrieval results, resulting in the depolarization ratio results exceeding the credible range.

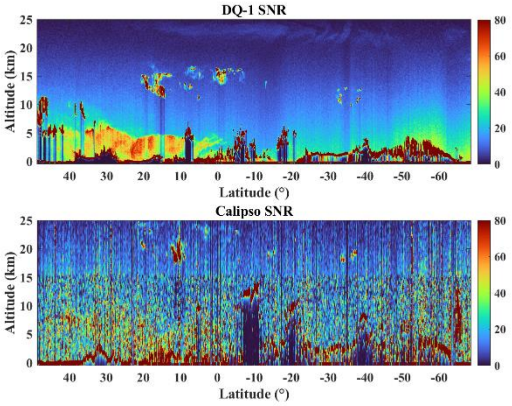


Figure 6 SNR of DQ-1 and CALIPSO total attenuated backscatter

Corresponding explanations about energy attenuation were added in the manuscript:

Line 225: Due to CALIPSO's prolonged in-orbit operation, laser energy attenuation causes a diminished SNR, leading to more noise signals within the echo signal and consequently, increased measurement inaccuracies.

Point 18: l. 83: Line 207: There are no stratocumulus clouds at 15 km altitude. There are clouds at 15 km at about 15N which attenuate the lidar signal and look like dense cirrus.

Response 18: We are sorry for our mistake here. The lidar ratio of these clouds shows the characteristics of ice crystals, which are cirrus. The correct sentences are made to the manuscript at:

Line 207: At an altitude of 15 km, the distribution of dense cirrus was observed, with the satellite's emitted laser failing to penetrate certain portions of the cloud cover.

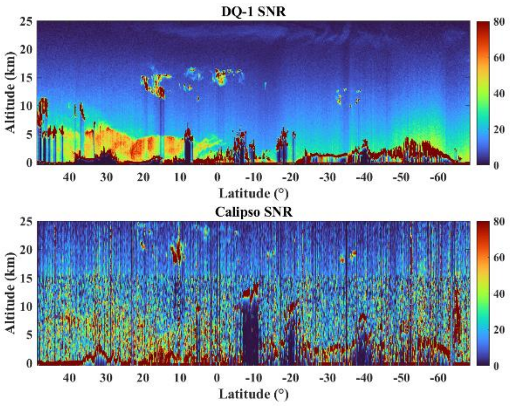
Point 19: Line 218: The method used to estimate SNR needs to be described in more detail. Variability of the signal due to noise must be separated from variability of the atmosphere. Expressing ratios in dB is confusing. While common in the radar community, in the lidar community ratios are nearly always expressed as linear ratios rather than in dB. I strongly recommend that linear ratios be used rather than dB.

Response 19: We are sorry for our negligence here. There is less variation in the high-altitude atmosphere, and the variation of echo signals at high altitudes is caused by noise. To separate the noise in the signal, we selected the high-altitude echo signal as the noise for SNR calculation. To represent SNR more intuitively, the use of dB to represent SNR has been eliminated, and the SNR is directly represented by the ratio of noise to echo signal. Corresponding modifications are made to the manuscript at:

Line 218: The local variations in the high-altitude atmosphere are relatively small, making system noise more easily distinguishable. Using high-altitude echo signals as noise and utilizing the ratio of the noise to echo signals as SNR (SNR). To compare both the signal quality, the SNR of the total attenuated backscattered signals was analyzed, as illustrated in Figures 4c and 4d.

Line 220: While the value of CALIPSO's aerosol signal SNR varied from 10 to 40, the SNR of DQ-1's aerosol signal exceeded 40. Additionally, DQ-1 has maintained a high-altitude molecular scattering SNR above 20, whereas CALIPSO's high-altitude molecular scattering signal SNR has a value of less than 20.

Line 550 Figure 4 (c), (d):



Point 20: Line 221: What is the "aerosol signal SNR" and how is it computed? For a backscatter lidar, the SNR of the component of the return signal due only to aerosol scattering doesn't make much sense.

Response 20: We are sorry for our wording here. What we want to express is the SNR of echo signals in areas with aerosol distribution, rather than the SNR of aerosol signals. Corresponding modification is made to the manuscript at:

Line 221: In areas with aerosol distribution, the value of CALIPSO's signal SNR varied from 10 to 40, and the SNR of DQ-1's signal exceeded 40.

Point 21: Line 243-244: Please explain why the difference in depolarization is attributed to CALIPSO and not to DQ-1? What is meant by "the depolarization ratio retrieved by the laser energy attenuation in CALIPSO."

Response 21: Due to CALIPSO's prolonged in-orbit operation, laser energy attenuation causes diminished SNR, leading to more noise signals within the echo signal and consequently, increased measurement inaccuracies. The noise signal of CALIPSO affects the retrieval results, resulting in the depolarization ratio results exceeding the credible range. The corresponding discussion is added to the manuscript at:

Line 225: Due to CALIPSO's prolonged in-orbit operation, laser energy attenuation causes a diminished SNR, leading to more noise signals within the echo signal and consequently, increased measurement inaccuracies.

Point 22: Line 245: CALIPSO lidar ratios are estimated, not retrieved, so they do not themselves provide validation of lidar ratios retrieved from DQ-1.

Response 22: We apologize for our negligence. We have acknowledged this issue in the relevant section of the manuscript. Due to the relatively new onboard HSRL system of DQ-1 and the lack of accurate lidar ratio results, we chose to compare it with CALIPSO. The lidar ratio of DQ-1 was only qualitatively compared with CALIPSO. The corresponding modifications were made to the manuscript at:

Line 244: The advantage of the DQ-1 HSRL system is that it can retrieve the lidar ratio without assumptions, which is significantly different from CALIPSO. DQ-1 indicates that the lidar ratio of aerosol particles is around 40 sr, describing the characteristics of dust aerosols, consistent with CALIPSO's aerosol type.

Point 23: Line 253: Comparisons with MPLnet set a bound on the accuracy of DQ-1 retrievals but do not “ensure the accuracy of aerosol optical property retrieval using DQ-1" because DQ-1 retrievals should be more accurate than those from MPLnet.

Response 23: Thank you for raising the question and we apologize for our negligence. Due to the use of traditional Fernald methods for retrieval in ground lidars such as MPLNET, which may cause errors due to assumptions, it should not be stated here that the observation results are accurate. We only make qualitative comparisons with MPLNET. The corresponding modifications are made to the manuscript at:

Line 253: We qualitatively compared the aerosol optical parameter data products from the NASA MPLNET ground station with the retrieval results of DQ-1.

Point 24: Line 333: Please describe how the data was ‘corrected for energy variations’. If the attenuated backscatter profiles are properly calibrated, further correction for energy variations should not be necessary.

Response 24: We are sorry about our wording here. The correction we made refers to the correction based on molecular scattering at the reference height, and it is inappropriate to refer to it as energy correction. The corresponding modification has been made to the manuscript at:

Line 331: As DQ-1 data is available from June to December 2022, we substituted data from February to June 2022 with CALIPSO data. Figure 10 presents the observed attenuated backscatter coefficient from January to December 2022 within the stratosphere over the South Atlantic Ocean, using both CALIPSO and DQ-1.

Point 25: Line 353 states that DQ-1 yields more reliable depolarization ratios than CALIOP. This statement needs more discussion and needs to be supported by analysis. How was it established that DQ-1 is “more reliable”, does this mean more accurate?

Response 25: We apologize for our wording here. The reliability of DQ-1's depolarization ratio depends on the analysis of system errors. The expressions "more reliable" or "more accurate" are not appropriate to use here. The corresponding modification has been made to the manuscript at:

Line 353: The aerosol optical parameters obtained from DQ-1 have been validated against the product of CALIPSO and molecular backscatter coefficients. The results indicated that DQ-1 exhibited a higher SNR and conforms to the results of trends in molecular scattering.

Comments on figures

Point 26: There is a problem in the way the CALIOP profile has been plotted in Fig 4e. Does “raw

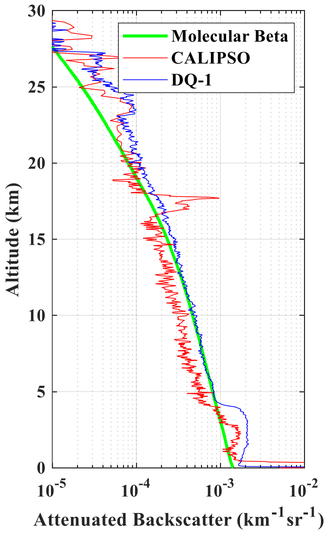
signal" refer to the Level 1 attenuated backscatter profiles? Inspection of CALIOP browse images shows the mean 532 nm attenuated backscatter at 20 km is roughly 1E-4 /km/sr whereas Fig 4e indicates the attenuated backscatter is already below 1E-4 /km/sr at 10 km altitude. Please explain how the CALIOP profile in Fig 4e was computed.

Response 26: We apologize for the mistake. After a comprehensive inspection and full double-check of the figure in the manuscript, the height axis of Figure 4e is incorrect. The figure has been modified correctly, and the corresponding descriptions and analysis in the manuscript have been modified at:

Line 215: The raw signals of the DQ-1 and the CALIPSO align with the molecular scattering profile.

Line 223: In conclusion, the two satellites give consistent raw data results in close orbits, DQ-1 operating at a higher resolution, achieving a better SNR.

Line 550 Figure 4e:



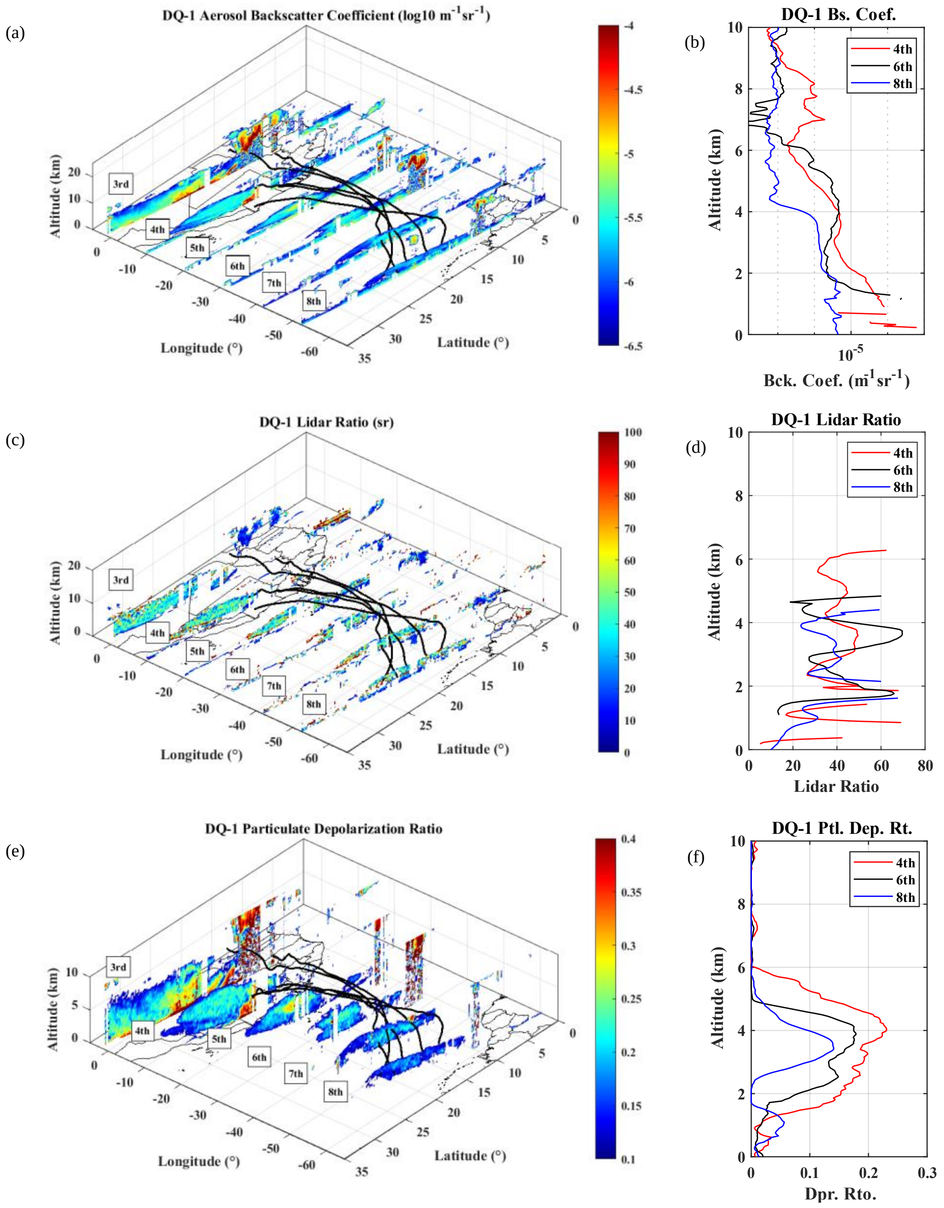
Point 27: Figure 8 shows a significant high bias in many of the AOD retrievals from DQ-1. The authors attribute this high bias to cloud contamination. Have the authors demonstrated this? Improved removal of clouds should improve the agreement or might reveal other sources of bias.

Response 27: The results in Figure 8 have already utilized the improved cloud removal algorithm. Before improving the cloud removal algorithm, a smaller correlation coefficient was obtained. The current cloud removal algorithm is based on the backscatter ratio (Ke et al., 2022). but its drawback is that it does not have a good removal effect on the edges of the cloud layer, so this comparison is still partially affected by the cloud layer.

Point 28: In Section 4.1 it is stated that the backscatter coefficient and volume depolarization of Sahara dust decreased during transport across the Atlantic, while the dust lidar ratio remained constant. This is difficult to tell from Figure 9. It would be helpful to add additional plots which show these trends (or lack of trend) more clearly.

Response 28: Thanks for raising the issue here. We have enlarged the figures and added the figures of mean profile to better show the trends. Corresponding modifications were made to the figures at:

Figure 9:



Point 29: What do the data curtains in Figure 10 represent? Is each curtain a single orbit (at what longitude?) on the first day of the month, or the average of several orbits (over what range of longitudes) averaged over a month of data?

Response 29: We apologize for our negligence, the corresponding information has been added to the title at:

Line 599:

Figure 10 Observed volcanic aerosol attenuated backscatter profile in the stratosphere over the South Atlantic in 2022. The left axis displays date, while the bottom axis displays latitude, with an altitude range of 18 to 26 km, displaying the observation results of a single orbit passing through the central South Pacific (10 ° to 30 ° W) on the first day of each month. The results from January 1st to May 1st are derived from CALIPSO, while the results from June 1st to December 1st are derived from DQ-1.

Minor issues and technical corrections

Point 30: Line 56: “This global information values …” should be “This global information is valuable …”.

Response 30: We are sorry for our wording here. The corresponding modification was made to the manuscript at:

Line 56: This global information is valuable for tracking aerosol particle dispersion pathways and compensates for the limitations of ground-based and airborne observations.

Point 31: Line 64: Does Chiang et al. 2011 describe a retrieval algorithm? It looks like a validation paper.

Response 31: We are sorry for our mistake here. The correct citation position of this literature has been modified to:

Line 61: The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO), developed by NASA, is the most representative spaceborne lidar satellite. Since its launch in 2006, it has been fully verified by comparing its dataset with other multi-source datasets (Bibi et al., 2015; Wang et al., 2016; Mcgill et al., 2007; Chiang et al., 2011).

Point 32: Line 67: I don’t understand what “has filtered the Mie scattering at different echoes” means. Please clarify. Line 68: “avoids” would be better than “exempts”

Response 32: We are sorry for our wording here. The corresponding modification was made to the manuscript at:

Line 66: As a new-generation lidar, high spectral resolution lidar filters out the Mie scattering in the return signals through a filter. This method avoids the assumptions made by traditional lidar during retrieval, resulting in more precise results.

Point 33: Line 75: the reference for Cornut et al. 2023 is missing.

Response 33: The reference for Cornut et al. 2023 is on line 407 of the manuscript.

Point 34: Equations 2.6 and 2.8 appear to be the same

Response 34: We are sorry for our mistake here. The duplicate formula has been deleted and other formulas have been rechecked.

The above is the complete response to your comments. We look forward to hearing from you regarding our responses. We would be glad to respond to any further questions and comments you may have.

Reference

Cornut, F., Amraoui, L., Cuesta, J., and Blanc, J.: Added Value of Aerosol Observations of a Future AOS High Spectral Resolution Lidar with Respect to Classic Backscatter Spaceborne Lidar Measurements, Remote Sensing, 15, 506, 10.3390/rs15020506, 2023.

Dong, J., Liu, J., Bi, D., Ma, X., Zhu, X., Zhu, X., and Chen, W.: Optimal iodine absorption line applied for spaceborne high spectral resolution lidar, Appl. Opt., 57, 5413-5419, 10.1364/AO.57.005413, 2018.

Rowell, R. L., Aval, G. M., and Barrett, J. J.: Rayleigh–Raman Depolarization of Laser Light Scattered by Gases, The Journal of Chemical Physics, 54, 1960-1964, 10.1063/1.1675125, 1971.

Weibiao, C., Jiqiao, L., Xia, H., Huaguo, Z., Xiuhua, M., Yuan, W., and Xiaopeng, Z.: Lidar Technology for Atmosphere Environment Monitoring Satellite, Aerospace Shanghai (Chinese & English), 40, 13-20, 10.19328/j.cnki.2096-8655.2023.03.002, 2023.

Young, A. T.: Rayleigh scattering, Physics Today, 35, 42-48, 10.1063/1.2890003, 1982.