A Second Review of "Incorporating EarthCARE observations into a multi-lidar cloud climate record: the ATLID Cloud Climate Product" by A. G. Feofilov, H. Chepfer, V. Noël, and F. Szczap

Reviewed by Mark Vaughan (mark.a.vaughan@nasa.gov)

The authors' revision does an excellent job of addressing my many and highly detailed comments on their original manuscript. The newly added paragraph beginning on line 113 nicely summarizes the goals of the study while at the same time clearly explaining the rationale some self-imposed limits (e.g., their choice to deemphasize contributions from the perpendicular channel signal). Throughout the manuscript, assumptions underlying various choices in the analysis are now clearly identified. And the depth of discussion and detail added in section 3 is genuinely impressive. The added insights on noise generation in the simulations and the minimum detectable backscatter comparisons were both hugely helpful, and I fully expect future readers will agree with this assessment. Overall, I very much appreciate the extra clarity their thorough and thoughtful revisions have added to the manuscript.

I have only one serious quibble with this latest effort. On lines 425–427 the authors say, "However, using this value in synthetic noise calculations leads to an overestimation of the daytime noise, for the calculations below we took a more conservative value NSF=3.16, which better represents real CALIOP nighttime and daytime noises in the aerosol-free stratosphere". In their responses to my comments, the authors raise some interesting points about the formulation of the noise scale factor and its application to CALIOP data. However, a brief email discussion of their ideas with Zhaoyan Liu (i.e., the lead author of Liu et al., 2006) highlighted some very real differences of opinion about the correct approach. So, rather than obliquely raising their issues with the original NSF formulation in this manuscript, the authors should instead surface their concerns in a published comment in Applied Optics (i.e., the journal that published Liu et al., 2006). The ensuing response from Liu et al. would ensure that the authors' NSF criticisms are properly resolved in a totally public and transparent way that would be readily available for review and comment by the entire lidar community. With regards to the current manuscript, the authors need to delete the adjective clause (i.e., the text in red). While NSF = 3.16 value may be the best choice for the synthetic data they have generated, suggesting that it is also the correct choice for "real CALIOP" is a bold and controversial statement that is not supported by any development given in the manuscript. As demonstrated in the document appended below (which is publicly available via the CALIPSO web site), the NSF values reported in the CALIPSO level 1 data files correctly characterize noise throughout CALIOP's full vertical profile. The correlations between adjacent bins due to the electronic bandwidth of the CALIOP receiver are explained further in Appendix A of Vaillant de Guélis et al., 2021.

Computing Uncertainties for Attenuated Backscatter Products

Updated on November 7, 2012

Uncertainties for the attenuated backscatter, β', are not explicitly reported in the CALIOP Level 1 (L1) data products to save data volume, which would otherwise approximately double the L1 data volume. If needed, users can compute random errors for the attenuated backscatter products using

$$\Delta\beta'(k,r_i) = \left[\frac{r_i^2 \cdot NSF^2(k)\cdot \beta'(k,r_i)}{E\cdot C(k)} + \left(\frac{r_i^2 \cdot RMS(k)}{E\cdot G_A \cdot C(k)} \right)^2 \right]^{0.5} \frac{f_{correct}[N_{bin}(r_i), N_{shift}]}{\sqrt{N_{bin}(r_i), N_{shot}}}. \qquad (1)$$

In this equation, r_i is the range from the CALIPSO satellite to the ith range bin, *NSF* the noise scale factor, *E* the laser energy, *C* the calibration coefficient, G_A the gain of the amplifier, *RMS* the random noise of the background signal including detector dark current, background radiation, etc. N_{bin} and N_{shot} are, respectively, the number of range bins and laser shots averaged for the different altitude ranges as shown in Table 1. $f_{correct}$ is a correction factor used to account for the partial correlation among neighboring samples in a raw Level 0 (L0) profile [Liu et al., 2006], and additional correlation due to data redistribution in the altitude registration of L0 data samples during the L1 processing. The integral time of the amplifier of the lidar receiver is slightly longer than 0.02 ms (30 meter in distance) and is larger than the onboard sampling interval (15 m), causing the down linked data (averaged over different numbers of 15-m samples for different altitude ranges as listed in Table 1) to be partially correlated. In addition, there may be an offset in the altitude registration of a profile due to the variation of the nadir viewing angle of the lidar system. In the L1 processing, each 30-m bin in the -0.5 km – 8.2 km altitude range (altitude indices of 288 – 577) is registered to the nearest bin of the altitude array. For the other altitude ranges, because the bin size is larger than 30 meters (60 to 300 meters), the shift is accomplished by regridding then reaveraging the L0 data, thus redistributing the magnitudes of neighboring data samples, and thereby introducing additional correlation in the L1 data. N_{shift} is the number of 15-m bins shifted. $f_{correct}$ can then be computed using

$$f_{correct}(N_{bin}, N_{shift}) = \left\{ \left[\left(\frac{N_{bin}-N_{shift}}{N_{bin}} \right)^2 + \left(\frac{N_{shift}}{N_{bin}} \right)^2 \right] f^2(N_{bin}) + 2\left(\frac{N_{bin}-N_{shift}}{N_{bin}} \frac{N_{shift}}{N_{bin}} \right) \left(\sum_{m=1}^{N_{bin}} \frac{m}{N_{bin}} R(m) + \sum_{m=1}^{N_{bin}-1} \frac{N_{bin}-m}{N_{bin}} R(N_{bin}+m) \right) \right\}^{0.5} \qquad (2)$$

where $f(N_{bin}) = \left[1 + 2\sum_{m=1}^{N_{bin}-1} \left(\frac{N_{bin}-m}{N_{bin}} \right) R(m) \right]^{1/2}$ and *R* represents the autocorrelation coefficients [Liu et al., 2006]. The computed $f_{correct}$ values are given Table 2, using the R values determined based on the prelaunch lab experiment data.

Liu, Z., et al., 2006: Estimating Random Errors Due to Shot Noise in Backscatter Lidar Observations, *Appl. Opt.*, **45**, 4437-4447.

Table 1 numbers of 15-m range bins and laser shots averaged for different altitude ranges in L1B data products

Altitude range (km)	Altitude index range	532 nm		1064 nm	
		N_{bin}	N_{shot}	N_{bin}	N_{shot}
39.9 – 30.3	0-32	20	15	N/A	N/A
30.0 – 20.3	33-87	12	5	12	5
20.2 – 8.3	88-287	4	3	4	3
8.2 – -0.5	288-577	2	1	4	1
-0.6 – -1.8	578-582	20	1	20	1

Table 2 $f_{correct}$ for different altitude range and number of 30 meter bins shifted

Bin index	N_{shift}											Remark
	0	1	2	3	4	5	6	7	8	9	10	
0-32	1.598	1.450	1.324	1.226	1.163	1.141	1.163	1.226	1.324	1.450	1.598	Cycle of 10
33-87	1.578	1.350	1.192	1.134	1.192	1.350	1.578	1.578	1.350	1.192	1.134	Cycle of 6
88-287	1.489	1.105	1.489	1.105	1.489	1.105	1.489	1.489	1.105	1.489	1.105	Cycle of 2
288-577	1.386 1.489	1.386 1.489	1.386 1.489	1.386 1.489	1.386 1.489	1.386 1.489	1.386 1.489	1.386 1.489	1.386 1.489	1.386 1.489	1.386 1.489	532 nm 1064 nm
578-582	1.598	1.450	1.324	1.226	1.163	1.141	1.163	1.226	1.324	1.450	1.598	Cycle of 10

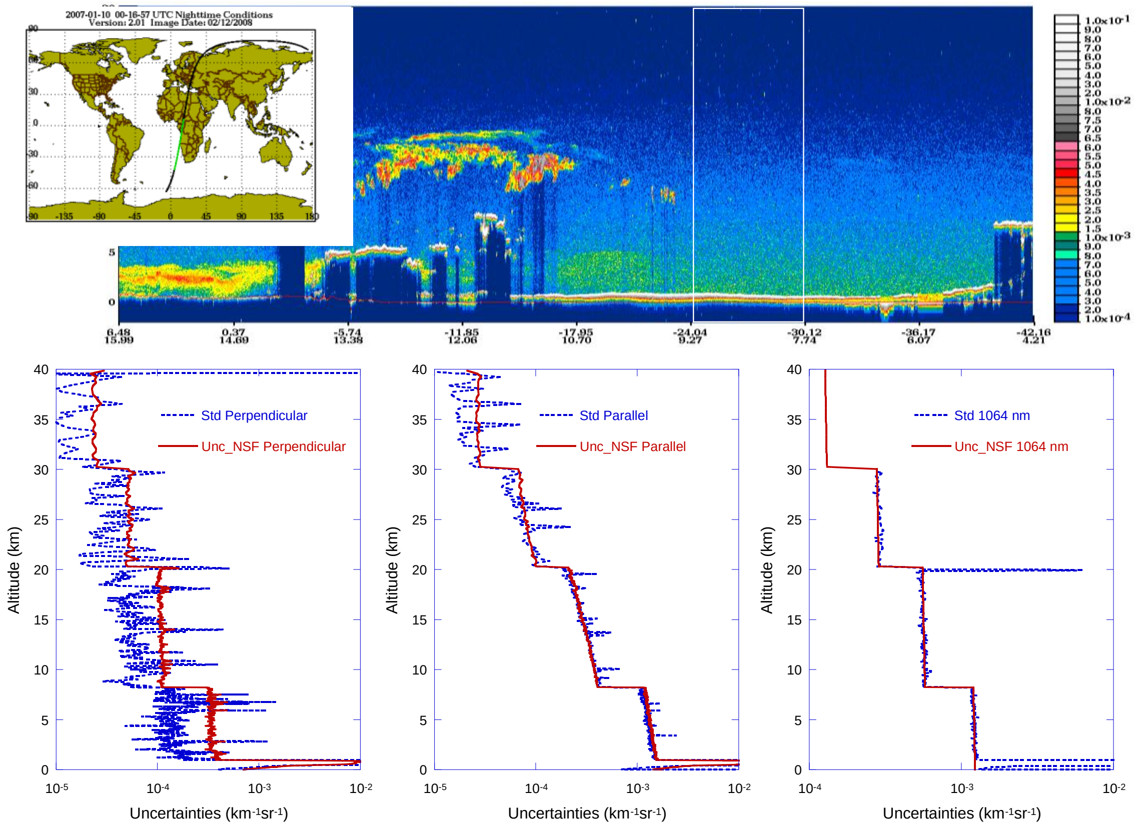

Figure 1: Random uncertainties computed using equation (1) for a nighttime CALIOP data segment acquired while passing over the southern Atlantic Ocean, as indicated by the white box in the upper browse image. The lower row of images shows uncertainty estimates for the 532 nm perpendicular (left panel in the lower row) and parallel (middle panel) channels and 1064 nm channels. The red lines represent the mean of uncertainties calculated using equation (1), and the blue lines show the standard deviation of the single-shot profiles. Good agreement is seen in the NSF-estimated uncertainties and standard deviations, except in the 532-nm perpendicular signal and the upper part of the 532-nm parallel signal where the return signal is very weak.

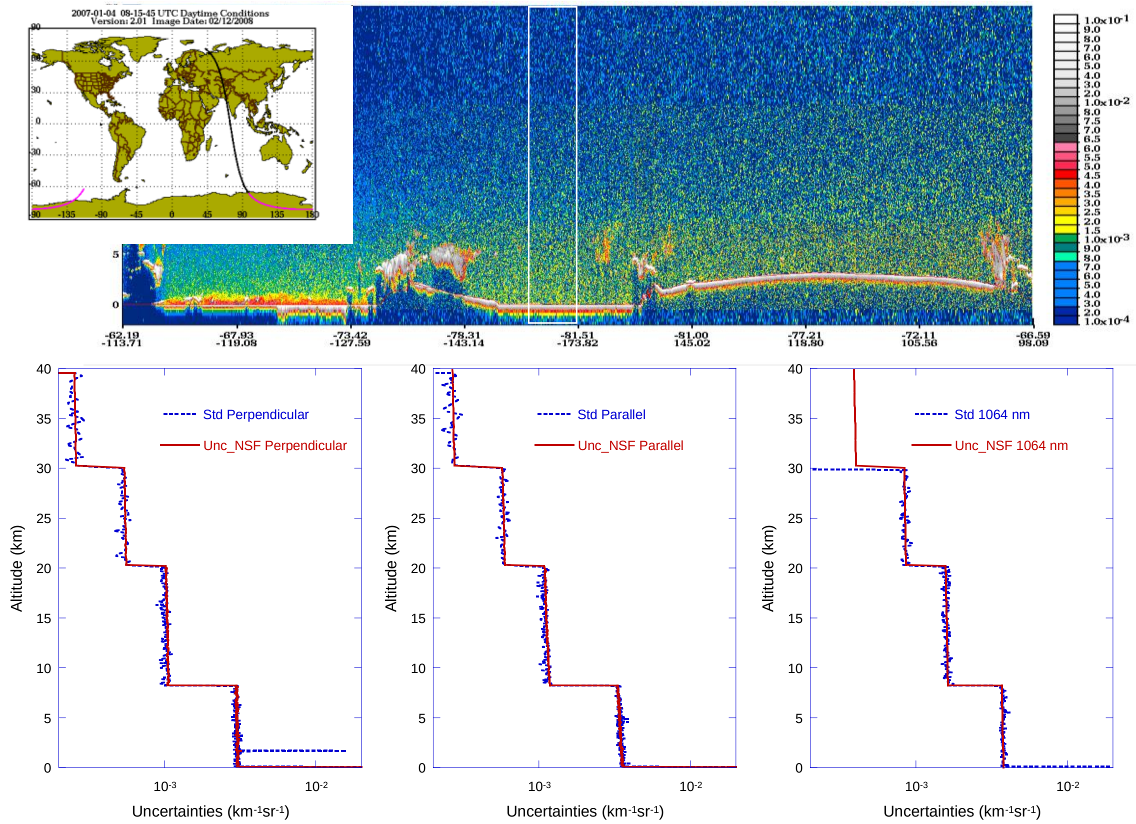

Figure 2 Same as Figure 1, but for a data segment acquired during daytime.