Overview and Assessment of the CALIOP 1064 nm Calibration Algorithm

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Calibration Algorithm

Procedure

(a) identify all clouds located between 17-km and 8.2-km with attenuated scattering ratios that exceed 50 for three or more vertically adjacent range bins

(b) compute the calibration scale factor for each cloud

(c) compute the mean calibration scale factor for all clouds detected during the orbit segment

(d) use the mean value of the calibration scale factor to derive C_{1064} for all profiles in the orbit segment

1064 nm calibration coefficient

Particulate backscatter color ratio: $\chi_P = \beta_{P,1064} / \beta_{P,532}$

Assumption: $\chi_{cirrus} = 1 \pm 0.04$

$$C_{1064} = C_{532}\,\chi_{cirrus}^{-1}\left(\frac{X_{1064}}{X_{532}}\right)$$

Calibration Scale Factor

532 nm calibration coefficient

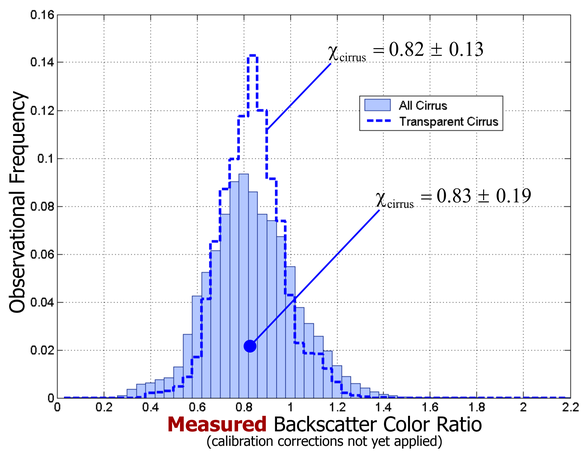
Integrated uncalibrated backscatter

$$X_\lambda = \sum_{k=top}^{base} \frac{r_k^2\, P_\lambda(r_k)}{G_\lambda\, E_\lambda\, T_{m,\lambda}^2(r_k)\, T_{O_3,\lambda}^2(r_k)}$$

Validating the Assumption that $\chi_{cirrus} = 1$

Cloud Physics Lidar Measurements

The histogram to the right shows backscatter color ratios retrieved from Cloud Physics Lidar (CPL) measurements of transparent cirrus (13,332 samples) and semi-opaque and opaque cirrus (153,959 samples) acquired in the northern hemisphere between November 2002 and August 2007. For the strongly scattering cirrus clouds typically used for CALIPSO calibrations, **the uncorrected CPL-derived backscatter color ratio is 0.83 ± 0.19. The deviation from an expected mean value of 1 arises from assumptions made in the CPL calibration process.** Both CPL channels are calibrated using the traditional molecular normalization technique, most often in the altitude range between 17-km and 15-km, where the CPL algorithm assumes a pristine atmosphere entirely free of aerosols. They therefore normalize both channels to an expected scattering ratio of $R = \beta_{total}/\beta_{molecular} = 1$.



CPL Calibration Corrections

Due to the differences in the molecular scattering cross-sections at 532 nm and 1064 nm, and the fact that the aerosol color ratio is not unity, any errors in the R = 1 assumption will propagate nonlinearly into the cirrus cloud color ratio retrieval. These errors are quantified by a multiplicative bias term, given below, that **rescales the measured color ratios retrieved from data calibrated using R=1 to their correct values** for a 532 nm scattering ratio of $R_{true} > 1$ in the CPL calibration region.

$$\chi_{corrected} = \Delta\chi_{bias} \cdot \chi_{measured}$$

assumed backscatter color ratio for background aerosols = 0.4

$$\Delta\chi_{bias} = \left(\frac{1}{R_{532,true}}\right)\left(1 + \left(\frac{\chi_{a,bkg}}{\chi_m}\right)\left(R_{532,true} - 1\right)\right)$$

correct 532 nm scattering ratio in the CPL calibration region; Rtrue ≥ 1

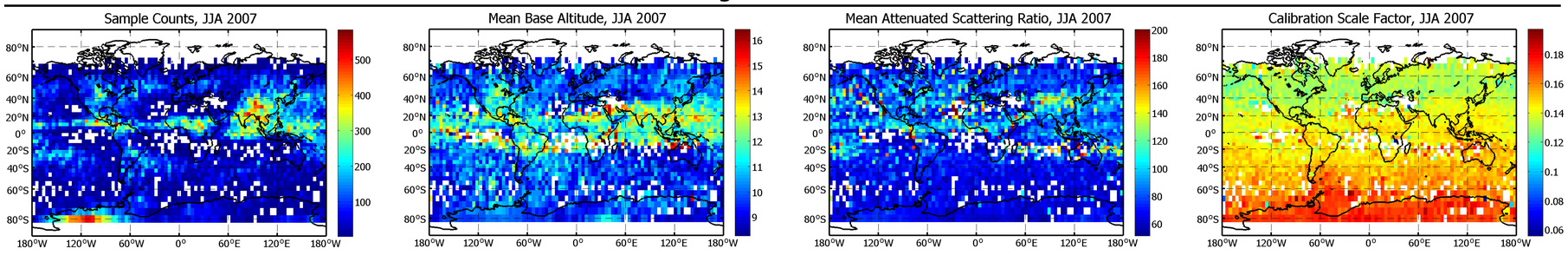
molecular backscatter color ratio = $2^{-4.05}$

The table below shows rescaled estimates of the measured CPL color ratio, $\chi = 0.83 \pm 0.19$, for $1 \le R_{true} \le 1.08$. Based on an extensive review of the spatial and temporal variability of stratospheric and upper tropospheric aerosols reported by the Stratospheric Processes and their Role in Climate (SPARC) project, we have concluded that the appropriate value for the 532 nm CPL calibration is R_{true} is ~1.04 (Vaughan et al., ACPD 2009, submitted). As seen above, **the corrected CPL cirrus color ratio estimate is 1.01 ± 0.23**.

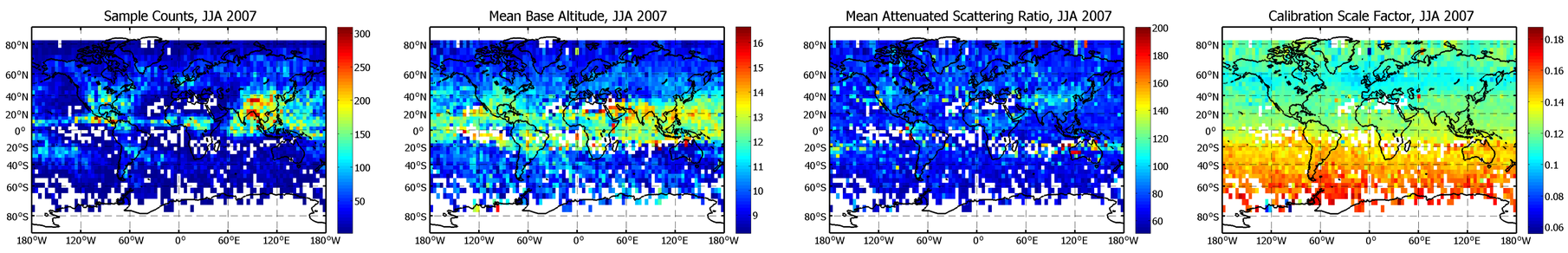
$R_{532,true}$	R_{1064}	$\Delta\chi_{bias}$	$\chi_{corrected}$
1.00	1.00	1.00	0.83 ± 0.19
1.01	1.07	1.06	0.88 ± 0.20
1.02	1.13	1.11	0.92 ± 0.21
1.03	1.20	1.16	0.97 ± 0.22
1.04	1.27	1.22	1.01 ± 0.23
1.05	1.33	1.27	1.05 ± 0.24
1.06	1.40	1.32	1.09 ± 0.25
1.07	1.46	1.37	1.14 ± 0.26
1.08	1.53	1.42	1.18 ± 0.27

Characterizing the CALIOP Calibration Measurements

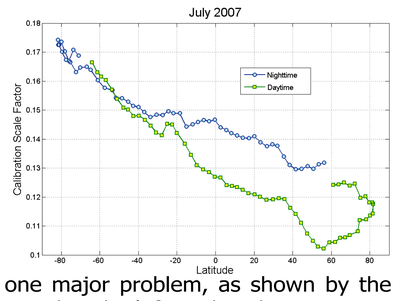
Nighttime Data



Where are the clouds? How high are the clouds? How strong are the clouds? What is the mean scale factor?



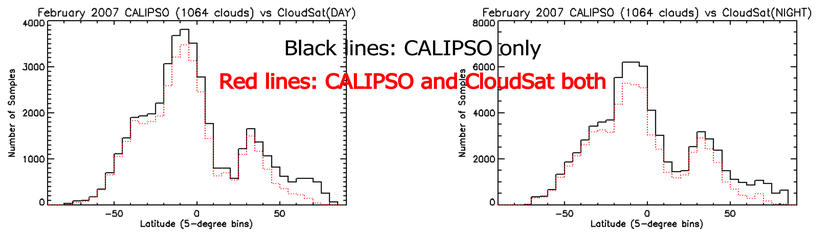
In general, the CALIOP cirrus cloud calibration scheme appears to be working as designed. There are, however, a few tweaks that can be applied in future version (i.e., post release 3); e.g., steps can be taken to ensure that stratospheric features are never used.



The one major problem, as shown by the plots above and to the left, is that there appears to be a pronounced latitudinal structure to the calibration scale factor. This is believed to be an instrument artifact similar in nature to the thermally induced beam steering problem that effects the daytime 532 nm measurements and calibration. Additional research into the causes and cures of this effect will be a major focus of the CALIOP team's efforts over the next several months.

Daytime Data

Large Particle Assumption: how frequently does CloudSat detect CALIOP calibration targets?



Calibration Cloud Phase

high confidence, water or oriented ice crystals