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Atmospheric Chemistry and Physics Discussions

ACPD

7, S6875–S6886, 2007

Interactive Comment

Interactive comment on "Validation of aerosol and cloud layer structures from the space-borne lidar CALIOP using Seoul National University ground-based lidar" *by* S.-W. Kim et al.

S.-W. Kim et al.

Received and published: 14 November 2007

We would like to thank the reviewer for their detailed and helpful comments. We are fully aware that taking time to provide in-depth reviews is a sacrifice and we greatly appreciate it. Below we have reply to the comments of the reviewer and revised text and figures have been provided. We have made additional significant changes by including corrections for molecular attenuation as well as calculations of aerosol extinction profiles from CALIOP backscatter data. We have updated the figures and text to reflect these changes. We apologize to the reviewer that such significant changes were made. Again, we really appreciate the valuable comments and suggestions given by the reviewer and thank him/her for his/her interest in our paper. Responses to the comments of the referee are embedded below.

Reply to specific comments -a-

We appreciate for good comments and providing several references.
The SNU have two lidar systems: one is a micro-pulse lidar (MPL; 523.5 nm; SES Inc., USA), and the other is 2-wavelength polarization lidar system used in this study. The 1st lidar, MPL, was operated from 1997 to 2004 at SNU campus as part of the Asian dust network (AD-Net; as described in Murayama et al., 2001). It moved to the Gosan (33.29N, 126.16E), Korea, a super site of Atmospheric Brown Cloud (ABC)- East Asia Regional Experiment (EAREX, http://abc-gosan.snu.ac.kr) project, in the spring of 2005, and have permanently operated as part of the NASA Micro Pulse Lidar Network (MPL-NET; http://mplnet.gsfc.nasa.gov). The 2nd 2-wavelength polarization lidar system was installed at SNU campus (Seoul, Korea) in March 16, 2006, and has been operated as part of the AD-Net as well as the Japanese National Institute for Environmental Studies (NIES) lidar network (http://www-lidar.nies.go.jp). The SNU 2-wavelength polarization lidar system was developed by the Japanese National Institute for Environmental Studies (NIES). The SNU lidar is identical to the lidar systems distributed in the NIES lidar network. Technical supports (calibration and routine maintenance) of the SNU lidar were made by the NIES, especially by Dr. Nobuo Sugimoto. Detailed descriptions of NIES 2-wavelength polarization lidar systems (including SNU lidar system) and established history of high quality measurements (e.g., calibration, field maintenance and data processing, etc.) are well reported in the peer-reviewed literatures, especially Shimizu et al. (2004). Several references are now included.

Shimizu, A., Sugimoto, N., Matsui, I., Arao, K., Uno, I., Murayama, T., Kagawa, N., Aoki, K., Uchiyama, A., and Yamazaki, A.: Continuous observations of Asian dust and other aerosols by polarization lidar in China and Japan during ACE-Asia, J. Geophys.

Res., 109, D19S17, doi:10.1029/2002JD003253, 2004.

Sugimoto, N., Matsui, I., Shimizu, A., Uno, I., Asai, K., Endoh, T., and Nakajima, T.: Observation of dust and anthropogenic aerosol plumes in the Northwest Pacific with a two-wavelength polarization lidar on board the research vessel Mirai, Geophys. Res. Lett. 29, 10,1029/2002GL015112, 2002.

Sugimoto, N., Shimizu, A., Matsui, I., Itsushi, U., Arao, K., Chen, Y., Zhao, S., Zhou, J., and Lee, C.-H.: Study of Dust Transport Using a Network of Continuously Operated Polarization Lidars, Water, Air, and Soil Pollution, 5, 145-157, 2005.

Sugimoto, N., Shimizu, A. Matsui, I., Dong, X., Zhou, J., Bai, X., Zhou, J., Lee, C.H., Yoon, S.-C., Okamoto H., and Uno I.: Network Observations of Asian Dust and Air Pollution Aerosols Using Two-Wavelength Polarization Lidars, 23rd International Laser Radar Conference, July 2006, Nara, Japan, 851-854, 2006.

In addition, Kim et al. (2006) compared and validated the NIES 2-wavelength polarization lidar system with co-located MPL at Gosan, Korea during ABC-EAREX 2005 (http://abc-gosan.snu.ac.kr). Note that the lidar used in the work of Kim et al. (2006) is exactly identical to the SNU 2-w polarization lidar (i.e., system hardware and calibration and data processing). They reported that the aerosol extinction profiles were in agreement to within 0.0051 km-1 bias. A citation to Kim et al. (2006) is also now included.

Kim, M.-H., Yoon, S.-C., Kim, S.-W., Sugimoto, N., and Shimizu, A.: Comparison of Vertical Extinction Profiles Obtained from 2 Ground-Based Mie-Scattering Lidars at Gosan, Korea during ABC-EAREX2005, 23rd International Laser Radar Conference,

ACPD

7, S6875–S6886, 2007

July 2006, Nara, Japan, 449-450, 2006.

Current and past quick-look images of SNU lidar at SNU campus can be seen at the following web sites:

http://www-lidar.nies.go.jp/Seoul/index.html (current quick-look image)
http://www-lidar.nies.go.jp/Seoul/archives/ (Archives for past quick-look images)

To avoid confusion (e.g., citation of Murayama et al., 2001 for AD-Net, not the SNU lidar utilized in this study) and to reflect these changes, we have rewritten/added several sentences.

Reply to specific comments -b-

Because CALIPSO flies over the SNU site every 16 days (1-time per day and 1-time per night), as we mentioned in the paper, we had obtained 47 coincident profiles between the SNU lidar and CALIPSO from May 2006 to April 2007. Although the CALIOP measure the vertical profiles successfully, however, the availability of ground-based SNU lidar data is very limited due to unfavorable meteorological conditions (e.g., precipitation, thick clouds in boundary layer, and fog). Only 17 profiles of total 47 profiles (about 36 percent) are available for comparisons. In this study, therefore, we selected and showed 6 typical profiles for 3 different types of atmospheric scenes. A broader statistical study, as suggested by this reviewer, will be possible if we accumulate more data. Also, the reviewer8217;s suggestion for comparing and contrasting the performance of the CALIPSO retrieval schemes when operating on (relatively) high SNR nighttime data versus low SNR daytime data is very good point. But it will be certainly well-timed after CALIOP extinction profile is released for public

ACPD

7, S6875–S6886, 2007

Interactive Comment

by the CALIPSO science team. These referee8217;s concerns have been included in a revised manuscript. For your guidance, all quick-look images of SNU lidar are linked at http://www-lidar.nies.go.jp/Seoul/archives/ .

Reply to specific comments -c-

We have added color coded time-height images of CALIOP and SNU lidars for all cases. We also updated related text.

Reply to specific comments -d-

It8217;s a good comments. In a revised manuscript, we have applied an identical molecular normalization method for both in CALIOP and ground-based SNU lidars. We have introduced it as new terminology 8220;apparent scattering ratio (Rapp)8221;. A molecular normalized Rapp profiles have calculated by using the total attenuated backscatter (beta), and then the aerosol and cloud layer structures have compared. The Rapp is only attenuated by aerosols and clouds, not air molecules. A molecular normalization was taken between 5 and 6 km for cases 1 and 2, and between 3 and 4 km for thick cloud case (case 3). Descriptions of the theoretical background, calculation procedure of Rapp and related figures, text and discussions have been changed in a revised manuscript.

Reply to specific comments -e-

CALIOP level 1 data and level 2 aerosol and cloud layer products have different vertical/horizontal resolution. In this paper, we averaged the closet 20 profiles of

ACPD
7, S6875–S6886, 2007
Interactive Comment

level-1 CALIOP data, which is corresponding to about 6.6 km horizontal coverage and 1 second sampling duration. As reviewer suggested, however, the averaging for 18 profiles of level-1 CALIOP data seems to be a better choice. The horizontal coverage of 18 profiles is about 6 km (18 61620; 0.333 km = 5.994 km) below 8.2 km altitude, and corresponds well with the level 1 data above 8.2 km altitude (1 km horizontal resolution). In addition, we used the average of 6 profiles of CALIOP level 2 cloud layer top and bottom height products, because the CALIOP level 2 cloud layer data have 1 km horizontal grid. That is, 6 profiles of CALIOP level 2 cloud products cover the same horizontal distance (6km). Note that we did not use the CALIOP level 2 cloud layer data with 333 m horizontal resolution, because the vertical range is limited to 8.2 km. It was not enough to illustrate cirrus clouds. Meantime, level2 CALIOP aerosol layer products with 5 km horizontal resolution, which is the highest resolution data, are used in this study. With respect to the averaging for 18 profiles of level-1 CALIOP data, we have changed related information/calculation in Figures 1 4. Also, we have changed related sentences.

Reply to specific comments -f-

It8217;s good comments. As we mentioned above, we have added color coded time-height images of CALIOP and SNU lidars. Please see the reply for specific comments -c-. The reviewer8217;s suggestion for meso-scale variations of tropospheric aerosols (i.e., largely homogeneous over the small spatial and temporal scales) reported in the work of Anderson et al. (2003) are very good. The spatial inhomogeneity of PBL aerosols along the CALIPSO track is not distinct in the color coded time-height images of CALIOP. In addition, it is hard to proof it with showing other observation data. So, we have removed the discussion on spatial inhomogeneity of PBL aerosols along the CALIPSO track in a revised manuscript.

As we mentioned above, we have applied an identical method for molecular normalization both in CALIOP and ground-based SNU lidars and normalized both lidar signals for air molecular transmission. We have introduced it as new terminology 8220;apparent scattering ratio (Rapp)8221;. Based on the calculation of Rapp profiles, we have discussed signal attenuation between two lidars. Please see the reply for specific comments -d-. It should be noted that the contribution of ozone have not considered in this study.

We have not known the calibration errors in the CALIPSO data when we analyzed CALIOP data and started to write the paper. Although an evaluation of the effectiveness of the CALIPSO calibration scheme is a proper topic for a validation paper and is maybe important factor to explain the signal discrepancy, this drift has not properly compensated for in the CALIPSO data used in this study. We have added this point in revised manuscript.

Reply to specific comments -g-

We have reworded the sentences to give more descriptions of the temporal coincidences between SNU lidar and the CALIOP measurements. Also, as we mentioned above, we have added color-coded time-height images of the SNU and CALIOP data, with the location of the CALIPSO coincident data clearly marked.

Reply to specific comments -h-

The first question of the reviewer is due to our mistake in the expression of the sentence. We means relative large variations of the CALIOP-derived [beta prime 532] above the boundary aerosol layer, not small variation. However, this discussion

ACPD
7, S6875–S6886, 2007

Interactive Comment

EGU

has removed in the Rapp profile comparison in a revised manuscript. Regarding to second points, we agree to the reviewer8217;s comments. Discussions on strong spatial and vertical inhomogeneous distributions of aerosols and multiple scattering from the molecular atmosphere and/or whatever stratospheric aerosols have removed in a revised manuscript.

[Technical corrections]

We appreciate the close corrections of English grammar throughout the manuscript.
These English corrections have all been implemented.
As we mentioned above, we have made significant changes by including corrections for molecular attenuation as well as calculations of aerosol extinction profiles from CALIOP backscatter data. We have updated the figures and text to reflect these changes. After this, as recommended by the referee 3, we have explored the corrections for English grammar and expressions.

Reply to page 11208, line 1
As the reviewer said, this article is not presently the first CALIPSO validation paper. Therefore, we have eliminated the wording 8220;the first8221; in the article, but added sentences regarding the McGill et al. (2007) validation paper in JGR as follows:

Recently, McGill et al. (2007) present initial airborne validation results that cloud layer top determinations from CALIPSO are found to be in good agreement with those from the Cloud Physics Lidar (CPL) onboard NASA ER-2 research aircraft. The minimum detectable backscatter levels are also in excellent agreement with those predicted prior to the CALIPSO launch.

ACPD
7, S6875–S6886, 2007

A citation to McGill et al. (2007) is also now included.

Reply to page 11209, line 24, line 26
It8217;s good comments. In response to above 2 points, we have reworded and changed it as follows:

CALIOP is a nadir-pointing instrument which is built around a diode-pumped Nd:YAG laser. While the CALIOP transmitter emits polarized light at both 1064 and 532 nm (pulse energy - 110 mJ) with a pulse repetition rate of 20.25 Hz, polarization discrimination in the receiver is only done for the 532 nm channel (Winker et al., 2004, 2007).

Reply to page 11210, line 15
We agree to the reviewer8217;s concern. However, we have no other alternatives to determining background light levels, because the maximum detection altitude was set to 18 km altitude for SNU lidar. This is the reason why we estimate the background noise of SNU lidar from upper most 100 data points (17.4 18 km).

Reply to page 11210, line 27
As we mention above, SNU have two lidar systems. One is the Micro Pulse Lidar (MPL; SES Inc., USA), which have been permanently deployed at Gosan (33.29žN, 126.16žE), Korea, as part of the NASA Micro Pulse Lidar Network (MPL-NET; http://mplnet.gsfc.nasa.gov) since spring of 2005. Another lidar system used in this study was installed at Seoul National University (SNU) campus (Seoul, Korea) in March 2006, and has been operated as part of the AD-Net as well as the Japanese National Institute for Environmental Studies (NIES) lidar network (http://www-lidar.nies.go.jp).
Current and past quick-look images of SNU lidar at SNU campus can be seen at the

ACPD
7, S6875–S6886, 2007

Interactive Comment

following web sites:

http://www-lidar.nies.go.jp/Seoul/index.html (current quick-look image)
http://www-lidar.nies.go.jp/Seoul/archives/ (Archives for past quick-look images)

Please see the reply for specific comment 8220;-a-8221; for details of SNU lidar system.

Reply to page 11211, line 3
In stead of Winker et al., 2004 article, we have added a reference to the CALIPSO Quid Pro Quo Validation Plan (by Kovacs and McCormick, 2005) in the revised manuscript.

Reply to page 11211, line 21
In a revised manuscript, we have showed the profiles of apparent scattering ratio as well as aerosol extinction coefficient, but not averaged them with vertically. So, the reviewer8217;s concern is no more valid in the revised manuscript.

Reply to page 11212, lines 13 14
This statement based on little enhancement of CALIOP-derived signal. As reviewer indicated, however, it is not clear at this point. We have removed it in the revised manuscript.

Reply to page 11212, line 19
There presently is no reference/publication for the application of the maximum gradient method on the determination of layer top and bottom heights in this study. However, the maximum gradient method was successfully applied for the determination of

ACPD
7, S6875–S6886, 2007

aerosol mixing height (i.e., PBL top height; Kim et al., 2007). Although the maximum gradient method deployed for slightly different object, a citation to Kim et al. (2007) is also now included.

Reply to page 11212, line 26

As we mentioned in paper, CALIOP data have different spatial resolution. We averaged the closet 18 profiles of level-1 CALIOP data, which is corresponding to about 6.0 km horizontal coverage and 1 second sampling duration. Corresponding to the horizontal coverage of level-1 data, we used the 6 profiles of the top and bottom heights of cloud products. These 6 profiles cover 6 km horizontal distance, because the CALIOP level 2 cloud layer data have 1km horizontal grid. Meantime, we did not use the CALIOP level 2 cloud layer data with 333 m horizontal resolution, because the vertical range is limited to 8.2 km. This is not enough to illustrate cirrus clouds.

Reply to page 11213, line 18

It8217;s good comments. Contrary to other 2 cases (25 Nov 2006 and 12 Jan 2007), relative large discrepancies in vertical structure of the cirrus between two lidar signals maybe caused by spatial/temporal mismatching of the averaged profiles as well as ground-based signal attenuations due to thick boundary aerosol layer. Therefore, we have added the sentence for this point in a revised manuscript:

Reply to page 11215, line 1

It8217;s good comments. We have changed the scale used in Figure 5 as a log scale.

8226; page 11215, line 7

The SNU makes the vertical profile every 15 min with 6 m vertical resolution. As we noted in the paper, the measurement sequence of SNU lidar is such as that

ACPD

7, S6875–S6886, 2007

Interactive Comment

it runs 5 min, and then stops working during the next 10 min. Although the pulse repetition rate is 10 Hz, the SNU lidar produce only averaged single profile after 5 min measurements (total 3000 shoots). That is, it is impossible to retrieve SNR for highly temporal-resolved single shot.

Reply to in closing„
Patrick Chazette, one author of this article, is presently a member of the CALIPSO science team. However, we added/changed some sentences of acknowledgments to the CALIPSO science team as well as this anonymous reviewer (see below).

We are grateful to the entire CALIPSO science team for providing CALIOP data and Dr. Nobuo Sugimoto (National Institute for Environmental Studies, Japan) for technical support of the SNU lidar. The authors also greatly acknowledge the valuable comments and suggestions from anonymous reviewers.

Response to the discussion for analyzing the signal level discrepancies is given in the reply of specific comments 8211;f-. Please see it.

We really appreciate his/her valuable comments and suggestions, and close investigations of English grammar. Thank you so much again. -Authors-

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Interactive comment on Atmos. Chem. Phys. Discuss., 7, 11207, 2007.