1041 **VISUALIZATION OF 3D AERPSOL DISTRIBUTION WITH SATELLITE AND GROUND OBSERVATION DATA ON GOOGLE EARTH**

Kwon-Ho Lee[1,2*], Sung-Kyun Shin[2], Mi-Kyung Choi[1]

[1]Dept. of Atmospheric & Environmental Sciences, Gangneung-Wonju National University(GWNU), Gangneung 25457, Rep. of Korea

[2]Research Institute for Radiation-Satellite(RIRS), Gangneung-Wonju National University(GWNU), Gangneung 25457, Rep. of Korea

1. INTRODUCTION

Ground-based active Light Detection and Ranging (LIDAR) and passive satellite observations have been offered a great potential to monitor atmospheric aerosols with their enhanced spatial and temporal resolutions. The synergetic use of these passive and active remote sensing techniques can devote to provide multi-dimensional distribution and timely variations of atmospheric aerosols. Until present, a large number of datasets from earth observing satellites and ground-based remote sensing instruments such as sun-photometer and LIDAR have been used to characterize the aerosols over East Asia (e.g. Lee et al., 2007; Anderson et al., 2003; Tatarov et al., 2012).

The aerosol optical properties retrieved from passive remote sensing is still limited in deriving the profile data in a pathlength. For example, satellite or ground–based remote sensing observations have been providing the aerosol optical thickness (AOT, τ) defined as the integral form of the aerosol extinction coefficient (AEC, σ) along an atmospheric column. Various satellite remote sensing techniques have been developed to retrieve AOT (Lee et al., 2009; Kokhanovsky, and de Leeuw 2009; Kokhanovsky et al., 2007; Li et al., 2009). However, passive remote sensing cannot measure AEC profile directly. To resolve the vertical profiles of AEC, there were attempts to derive the AEC profiles from AOT by using an analytic model (Wong et al., 2009; Qiu et al., 2005). They used the aerosol scale height (ASH) derived from the fitting of vertical extinction profile from the LIDAR observations. Based on the analytic model with ASH, satellite derived AOT in a pixel can be vertically resolved. Recently Lee et al. (2014) have introduced the visibility derivation from AOT retrieved from the MODerate-resolution Imaging Spectroradiometer (MODIS).

In this study, we describe the satellite retrieved extinction profile in a regional scale. To derive the ASH from the ground observation data, exponential fitting functions are considered. The paper also summarizes the volumetric reconstruction of the aerosol distribution to visualize data, and suggests how these exported data can allow near real-time aerosol monitoring and observation of the horizontal and vertical distributions in region of interest.

* Corresponding author address: Kwon-Ho Lee, Gangneung-Wonju National University(GWNU), Ganengeung 25457, Rep. of Korea, E-mail(kwonho.lee@gmail.com)

2. AEROSOL RETRIEVAL

Combining satellite and ground observation data provides better understanding of the distribution and transport of aerosols, which can be used to visualize the air quality information. In this study, the vertical profiles of the aerosol AEC, the ASH (z_a) was determined from the LIDAR observation data. ASH is defined as the height of an exponential profile at which the values of the AEC is decreased exponentially at the surface level. The extinction coefficients were derived from AOT with the aerosol scaling height (ASH) defined as a measure of decreases of atmosphere aerosol over a distance. A numerical description of the model is first estimating the ASH by equation (1):

$$\tau_a(\lambda) = \sigma_a(0,\lambda) \cdot z_a \left[1 - exp\left(-\frac{z_{max}}{z_a}\right)\right] \quad (1)$$

where z_{max} is the maximum height of aerosol layer, $\sigma_a(0,\lambda)$ is a wavelength aerosol extinction coefficient at the surface level. When the large number of z_{max} is used, exponential term in equation (1) will be close to zero. Thus, ASH is derived from the simplified equation (1).

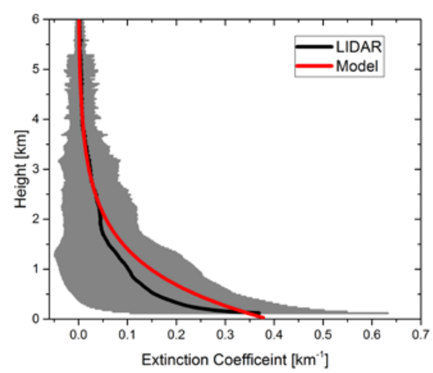

Figure 1. Averaged aerosol extinction profiles from a LIDAR versus modelled extinction profile based on aerosol scale height during June 2016.

As a case study, the modelled and observed AEC profiles are compared as shown in Figure 1. The LIDAR measurement at Seoul, Korea were obtained from the Asian dust and aerosol lidar observation network (AD-NET). In Figure 1, modelled AEC profile (red line) agrees soundly with the LIDAR measured AEC profile in June 2016. The observed and modelled AEC profile have a correlation of 0.98.

After determined ASH, AOT data can decompose as AEC profiles. We used the MODIS derived AOT data by SaTellite Aerosol Retrieval (STAR) algorithm (Lee and Kim, 2010) were used. Basically, the algorithm uses the spectral mixing model and separation technique for surface reflection correction (von Hoyningen et al., 2003), and spectral shape matching for aerosol model selection from predefined look-up tables (LUTs) (Lee et al., 2007). Thus, aerosol reflectance obtained by subtracting Rayleigh and surface terms from TOA reflectance.

3. VISUALIZATION

Volume data layers, derived from the satellite and modeling data explained in Section 2, were transformed into the Keyhole Markup Language (KML) code for visualization in the Google Earth^{TM} (hereafter, GE). Synergetic observation based spatial aerosol information is a valuable tool for regional or local scale air quality monitoring as well as estimation of possible source-receptor regions. Those information for the visualization can provide additional tools for approaching the atmospheric aerosol study. In particular, GE with scientific data layers enable us to communicate scientific data and research findings in a multivariate perspective (Yu and Gong, 2012).

The satellite derived AOT images and vertically resolved extinction profiles were visualized on GE. Generated volume data composed of three components (i.e. latitude, longitude, and elevation of pixels). These information with geometry data were used to generate KML file for visualization on GE. GE is challenging tool for managing and visualizing 3D geospatial data in a virtual environment. In this study, we derived MODIS AOT over Northeast Asia (100°E–140°E, 20°N–50°N). AOT values were converted into AEC profiles with ASH database acquired from the ground based observations (see Figure 2). Thus, AEC profile at a given satellite pixel can be expended whole AOT pixels and three dimensional volume data were constructed. This volumetric data construction is a new approach using spatially retrieval of AOT and vertically resolved extinction from both satellite and ground based observations.

As shown in Figure 2, implementing this method to visualize volume data covering a wide area on virtual globe is an effective way to monitor local air quality. A framework to visualize an integration of aerosol retrieval data by the analytical model based on the non-linear exponential fitting with AOT retrieved from the MODIS and ground-based surface visibility was assessed over study region. It was suggested that the model is applicable because it can support the costly instruments. Additionally, exported aerosol data into GE, the method can allow near real-time vertical aerosol distribution sampling and enable convenient visual observation of aerosol variations.

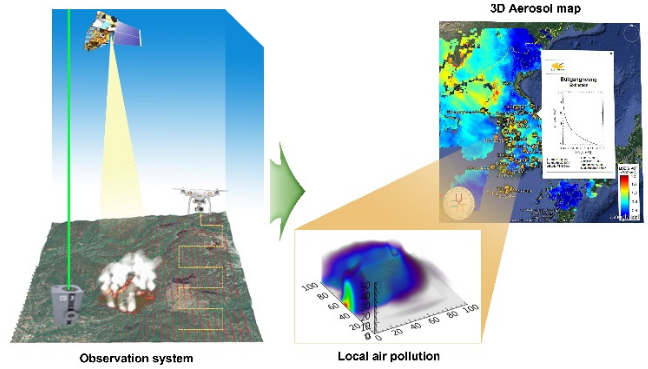

Figure 2. Data Sources and flow for development of volumetric dataset.

4. DISCUSSION AND CONCLUSION

This study presented a synergetic approach to derive and visualize the horizontal AOT and vertical profile of AEC using satellite and ground-based remote sensing data. Combining of multi-sensor, -dimensional observation data acquired from satellite and ground-based remote sensing observations, and analytic modelling data can construct volume unit of aerosol information which are used in GE's input for the visualization. The derived AEC with AOT values at different geolocation were fully linked in this visualization platform. These results provide promising results for air quality monitoring. Limitations of the method are that the analytic model is more accurate in clear sky, non-elevated dust condition, where further improvement is needed and will be modified in the near future.

ACKNOWLEDGEMENTS

This work was funded by the Korea Meteorological Administration Research and Development Program under Grant KMIPA2015-2012 and "Development of Geostationary Meteorological Satellite Ground Segment(NMSC-2014-01)" program funded by NMSC (National Meteorological Satellite Centre) of KMA(Korea Meteorological Administration). The authors also would like to thank DAAC/NASA and GSFC/NASA for the use of MODIS, and AD-NET LIDAR data.

5. REFERENCES

Anderson, T.L., Masonis, S.J., Covert, D.S., Ahlquist, N.C., Howell, S.G., Clarke, A.D., et al. (2003) Variability of aerosol optical properties derived from in situ aircraft measurements during ACE-Asia. J. Geophys. Res.-Atmos., 108. doi: 10.1029/2002JD003247

Kaufman, Y.J., Wald, A.E., Remer, L.A., Gao, B.C., Li, R.-R., and Flynn, L. (1997) The MODIS 2.1-mm channel correlation with visible reflectance for use in remote

sensing of aerosol. IEEE Transactions on Geosciences and Remote Sensing 35, 1286–1298.
Kokhanovsky, A.A. and de Leeuw, G. (eds) (2009) Satellite Aerosol Remote Sensing Over Land, Springer-Praxis, Berlin, p. 388.
Kokhanovsky, A.A., Breon, F.M., Cacciari, A., Carboni, E., Diner, D., Di Nicolantonio, W., Grainger, R.G., Grey, W.M.F., Holler, R., Lee, K.-H., Li, Z., North, P.R.J., Sayer, A.M., Thomas, G.E., and von Hoyningen-Huene, W. (2007) Aerosol remote sensing over land: a comparison of satellite retrievals using different algorithms and instruments. Atmos. Res., 85 (3-4), 372–394. doi: 10.1016/j.atmosres.2007.02.008.
Lee, K. H., Li, Z., Kim, Y. J., and Kokhanovsky, A. (2009) Aerosol monitoring from satellite observations: a history of three decades, Atmospheric and Biological Environmental Monitoring, edited by: Kim, Y. J., Platt, U., Gu, M. B., and Iwahashi, H., Springer, 13–38, doi:10.1007/978-1-4020-9674-7.
Lee, K. H**.**, Y. J. Kim, W. von Hoyningen-Huene, and J. P. Burrows, (2007) Spatio-Temporal Variability of Atmospheric Aerosol from MODIS data over Northeast Asia in 2004, Atmos. Environ., 41(19), 3959-3973. doi:10.1016/j.atmosenv.2007.01.048
Lee, K.H. and Y.J.Kim (2010) Satellite remote sensing of Asian aerosols: a case study of clean, polluted and dust storm days, Atmos. Meas. Tech., 3, 1771-1784, doi:10.5194/amt-3-1771-2010.
Lee, K.H., Kim, Y.J., von Hoyningen-Huene, W., and Burrow, J.P. (2007) Spatio-temporal variability of satellite-derived aerosol optical thickness over Northeast Asia in 2004. Atmos. Environ., 41: 3959-3973. doi: 10.1016/j.atmosenv.2006.03.050
Lee, K.H., Wong, M.S., Kim, K.W., and Park, S.S. (2014) Analytical approach to estimating aerosol extinction and visibility from satellite observations, Atmospheric Environment, 91, 127-136.
Li, Z., Zhao, X., Kahn, R., Mishchenko, M., Remer, L., Lee, K.-H., Wang, M., Laszlo, I., Nakajima, T., and Maring, H. (2009) Uncertainties in satellite remote sensing of aerosols and impact on monitoring its long-term trend: a review and perspective. Ann. Geophys., 27 (7), 2755–2770. doi: 10.5194/angeo-27-2755-2009.
Qiu, J., Zong, X., and Zhang, X. (2005) A study of the scaling height of the tropospheric aerosol and its extinction coefficient profile. Journal of Aerosol Science, 36(3), 361-371.
Tatarov, B., Müller, D., Noh, Y.M., Lee, K.H., Shin, D.H., Shin, S.K., et al. (2012) Record heavy mineral dust outbreaks over Korea in 2010: Two cases observed with multiwavelength aerosol/depolarization/Raman-quartz lidar. Geophys. Res. Lett., 39. doi: 10.1029/2012GL051972
von Hoyningen-Huene, W., Freitag, M., and Burrows, J.B. (2003) Retrieval of aerosol optical thickness over land surfaces from top-of-atmosphere radiance. Journal of Geophysical Research, 108 (D9), 4260.
Wong, M.S., Nichol, J.E., and Lee, K.H. (2009) Modeling of aerosol vertical profiles using GIS and remote sensing. Sensors, 9(6), 4380-4389.
Yu , L. and P. Gong, (2012) Google Earth as a virtual globe tool for Earth science applications at the global scale: progress and perspectives, International Journal of Remote Sensing, 33, 12, 3966-3986