Multipurpose use of ceilometer: Estimating visibility, Rain occurrence, and Aerosol property

Jae-In Song[1] (Jaein_song@yonsei.ac.kr), Seong Soo Yum[1], and Eunha Lim[2]

[1]: Department of Atmospheric Sciences, Yonsei University, Seoul 03722, Korea
[2]: National Institute of Meteorological Sciences, Seogwipo-si 63568, Korea

1. Introduction

- In this study, we suggest a method to estimate visibility and aerosol mass concentration, and to detect precipitation using a ceilometer
- We applied the method and compared results to the PWD, PARSIVEL, and in-situ PM_{10} measurement
- Data were obtained from
  - National Center for Intensive Observation of severe weather (NCIO) of Korea,
  - Eastern North Atlantic (ENA) of Azores,
  - And Manacapuru (MAO) of Amazon

2. Site & Instrumentation

- The data used in this study is achieved from three different sites (NCIO, ENA, MAO)
- Each site has distinguishable environmental characteristics, due to their locations. (Fig. 1)
- Table 1 shows the environmental characteristics and instrumentation of each site

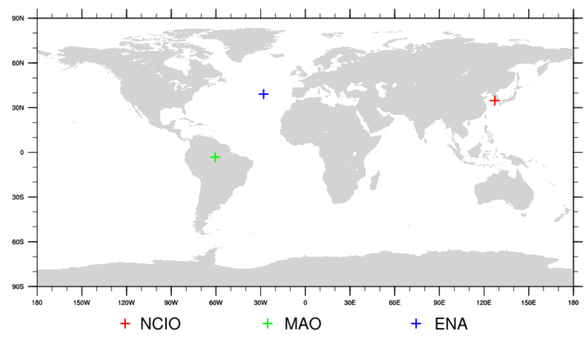

Figure 1. Locations of the three sites

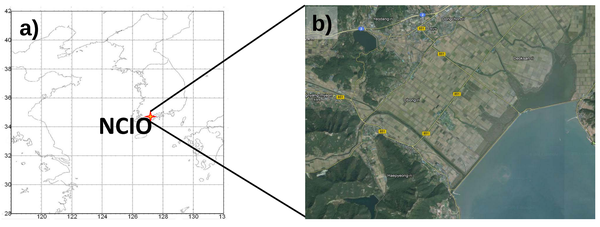

Figure 2. a) Map around Korea and location of NCIO,
b) Satellite picture around NCIO

Table 1. Characteristics and instrumentation of each site

	NCIO	ENA	MAO
Environmental Characteristics	Continental Coastal	Pristine Marine	Tropical Forest
Observation Period	Oct. 2014 ~ Oct. 2015	Jan. 2015 ~ Dec. 2015	Jan. 2015 ~ Dec. 2015
Ceilometer (resolution)	**Vaisala CL51 (10 m)**	Vaisala CL31 (30 m)	Vaisala CL31 (30 m)
Visibility meter	**Vaisala PWD-20**	Vaisala PWD-22	Vaisala PWD-22
Disdrometer	OTT Parsivel 2	OTT Parsivel 2	OTT Parsivel 2
PM_{10} Observation	**O**	**X**	**X**

3. Visibility Calculation

- Visibility can be calculated by eq. 1, where V is visibility, S_{RH} is Lidar ratio that depends on RH, β is backscatter coefficient of the 1st gate measured from a ceilometer.
- Relationship between S_{RH} and RH can be calculated from the data obtained from ceilometer and visibility meter
- Relationship between Lidar ratio and RH varies by site due to the different aerosol types (Fig. 3)
- Visibility estimation using ceilometer agreed well with that of visibility meter at NCIO, but not so at MAO and ENA (Fig. 4)

$$V = \frac{3}{\beta S_{RH}} \qquad \text{Equation(1)}$$

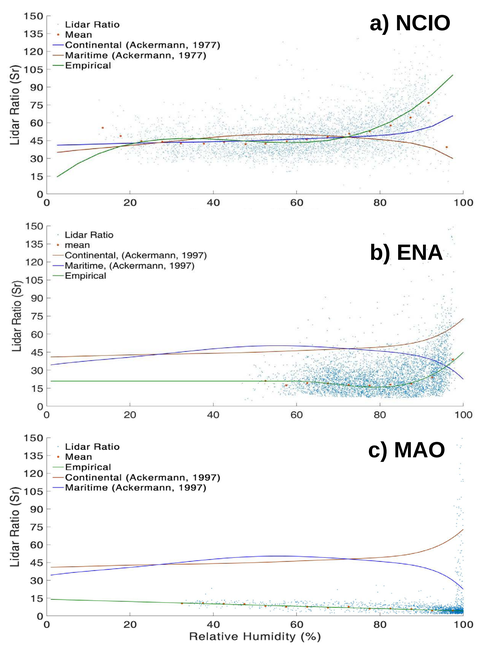

Figure 3. Relationship between Lidar Ratio and RH at (a) NCIO, (b) ENA, (c) MAO

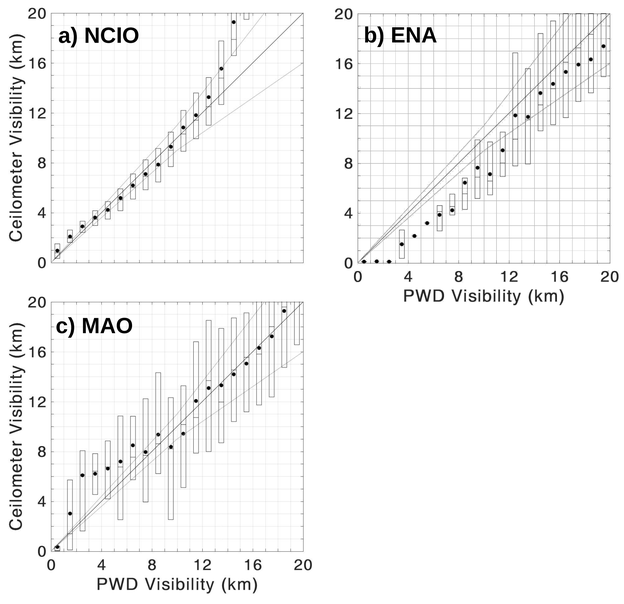

Figure 4. Comparisons between Visibility measured from PWD and retrieved from ceilometer at (a) NCIO, (b) ENA, (c) MAO

4. Precipitation Detection

- Precipitation can be detected using backscatter profile
- Using mean of backscatter coefficient for 0 – 100 m and 200 – 300 m, the threshold to detect precipitation is determined (table 2)
- Critical success index shows unsatisfactory result
- Considering imperfectness of the rain detection by Parsivel or AWS, the result is good enough to complement other precipitation detection observation
- Retrieved visibility and precipitation detection by ceilometer can complement traditional observation (Fig. 5)

Table 2. Threshold and critical success index for precipitation detection for each site

	NCIO	ENA	MAO
Threshold of 0 – 100 m	1.98 X 10^{-2} m^{-1} sr^{-1}	1.012X10^{-2} m^{-1} sr^{-1}	5.34X10^{-3} m^{-1} sr^{-1}
Threshold of 200– 300 m	3.96 X 10^{-2} m^{-1} sr^{-1}	1.012X10^{-2} m^{-1} sr^{-1}	5.34X10^{-3} m^{-1} sr^{-1}
Critical Success Index	0.64	0.61	0.53

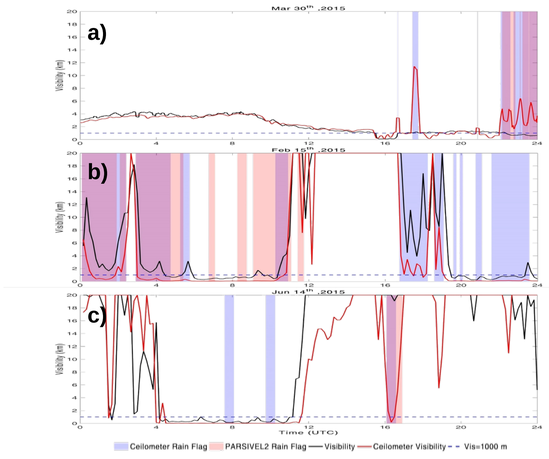

Figure 5. Comparison between the observation retrieved from ceilometer and PWD (visibility) and Parsivel (rain flag) at (a) NCIO, (b) ENA, (c) MAO

5. Aerosol Mass Concentration

- Aerosol concentration was measured at Suncheon, where is 30 km away from the NCIO (Fig. 6)
- Relationship between backscatter coefficient and PM_{10} concentration was different from that of Munkel et al. (2007) (Fig. 7 (a))
- Tendency and mean value were similar with each other (Fig. 7 (b))

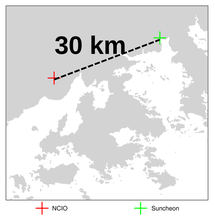

Figure 6. Location of Suncheon site and distance from NCIO

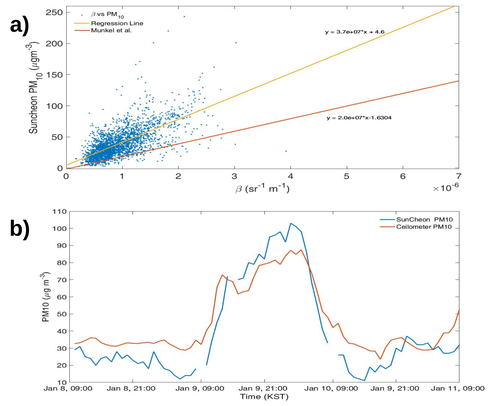

Figure 7. Results of PM_{10} estimation:
(a) Relationship between β and PM_{10}
(b) Time series of retrieved PM_{10} and measured PM_{10}

6. Discussion

- Visibility Estimation, and rain detection worked
  - Well at NCIO, and not so at ENA and MAO
  - Different resolution of ceilometer might influenced
- PM_{10} estimation shows good agreement, but it must be adjusted for each site
- All these estimations are highly influenced by aerosol types.
- Formation, development, and dissipation of fog involved with cloud can be investigated. (Fig. 8)

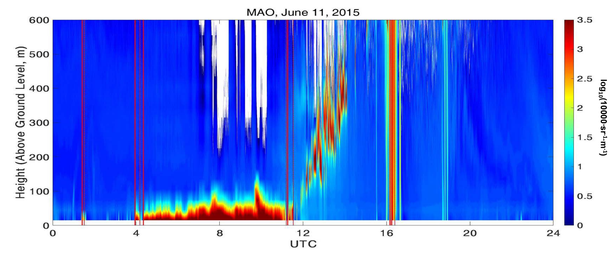

Figure 8. Backscatter profile from the data shown in Fig.5 (c)

7. Summary and Conclusion

- Estimation using ceilometer of
  - Visibility: good when resolution is high
  - Rain detection: limited, but can complement
  - PM_{10}: presents good trend, but not precise
- All the estimations depend on their aerosol types
- Ceilometer is an adequate instrument to research fog formation and dissipation

8. References

Ackermann, J. (1998). The extinction-to-backscatter ratio of tropospheric aerosol: A numerical study. *Journal of atmospheric and oceanic technology*,*15*(4), 1043-1050.

Münkel, C., Eresmaa, N., Räsänen, J., & Karppinen, A. (2007). Retrieval of mixing height and dust concentration with lidar ceilometer. *Boundary-Layer Meteorology*, *124*(1), 117-128.

9. Acknowledgement

This work was supported by “Development of Geostationary Meteorological Satellite Ground Segment” program funded by NMSC (National Meteorological Satellite Centre) of KMA(Korea Meteorological Administration)

국립기상과학원 연세대학교 YONSEI UNIVERSITY