Analysis of Aerosol and Cloud Relationships in Accordance with the Static Stability

Byung-Gon Kim[@], You-Joon Kim[@], Mark A. Miller[#], Lim-Seok Chang[$], and Qilong Min[&]

[@] Department of Atmospheric Environmental Sciences, Gangneung-Wonju National University, Gangneung, 210-702, Korea (bgk@gwnu.ac.kr)

[#]Department of Environmental Sciences, Rutgers University, NJ 08901, [$]National Insititue of Environmental Research, Incheon, 404-708, Korea

[&]Atmospheric Science Research Center, State University of New York at Albany, 251 Fuller Road, Albany NY, 12203

ACI Dependence on Meteorology

McComisky et al. [2009] measured various aerosol-cloud interactions (ACI) under various environmental conditions and varying meteorological conditions at Pt. Reyes (PTR), which demonstrated the remarkable discrepancy of regional meteorological environments and its role in aerosol-cloud interactions.

Shao and Liu [2009] showed ACI could be misleading when aerosol abundance and meteorology vary in a coherent fashion using the satellite remote sensings.

As an effort for the understanding of when/where aerosol-cloud interactions (ACI) are facilitated/suppressed, aerosol and cloud relationships (ACR) are examined in accordance with the distinctive different stability conditions between Pt. Reyes (PTR) and Southern Great Plain (SGP).

LWP Variability

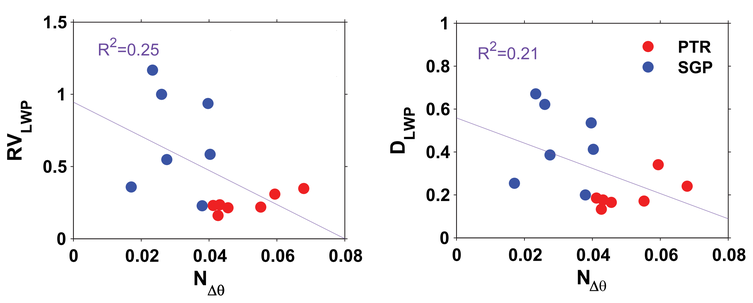

Fig. 1. Relationships of relative variability (RV) and dispersion (D) with the static stability ($N_{\Delta\theta}$) for PTR (red) and SGP (blue) together.

$$RV_{LWP} = \frac{LWP_{75\%} - LWP_{25\%}}{LWP_{50\%}} \qquad D_{LWP} = \frac{SD_{LWP}}{\overline{LWP}} \qquad N_{\Delta\theta} = \frac{\theta_{ML+500} - \theta_{ML}}{\overline{\theta}}$$

The relationship of $N_{\Delta\theta}$ to RV and D of PTR LWP appears to be consistently lower than SGP LWP. RV and D in LWP exhibiting negative correlation with the normalized static stability (Fig. 1).

Histograms of the normalized LWP clearly show 2.5 greater kurtosis of PTR than that of SGP, consistently less variable being LWP of PTR clouds than that of SGP clouds (Fig. 2).

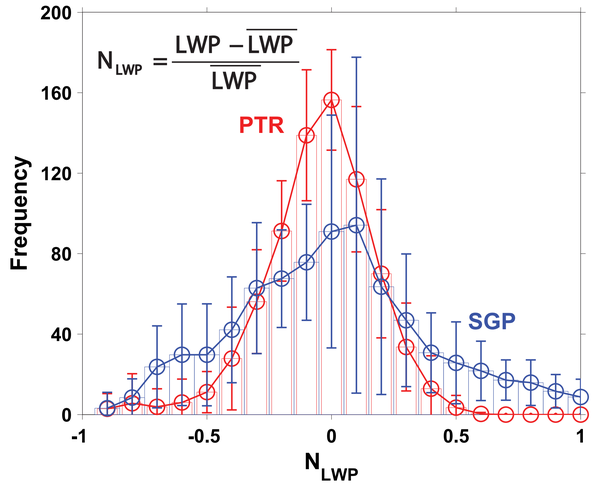

Fig. 2. Histograms of normalized LWP (N_{LWP}) of PTR (red) and SGP (blue) with the whisker denoting its standard deviation.

Aerosol and Cloud Relationship in Accordance with Stability

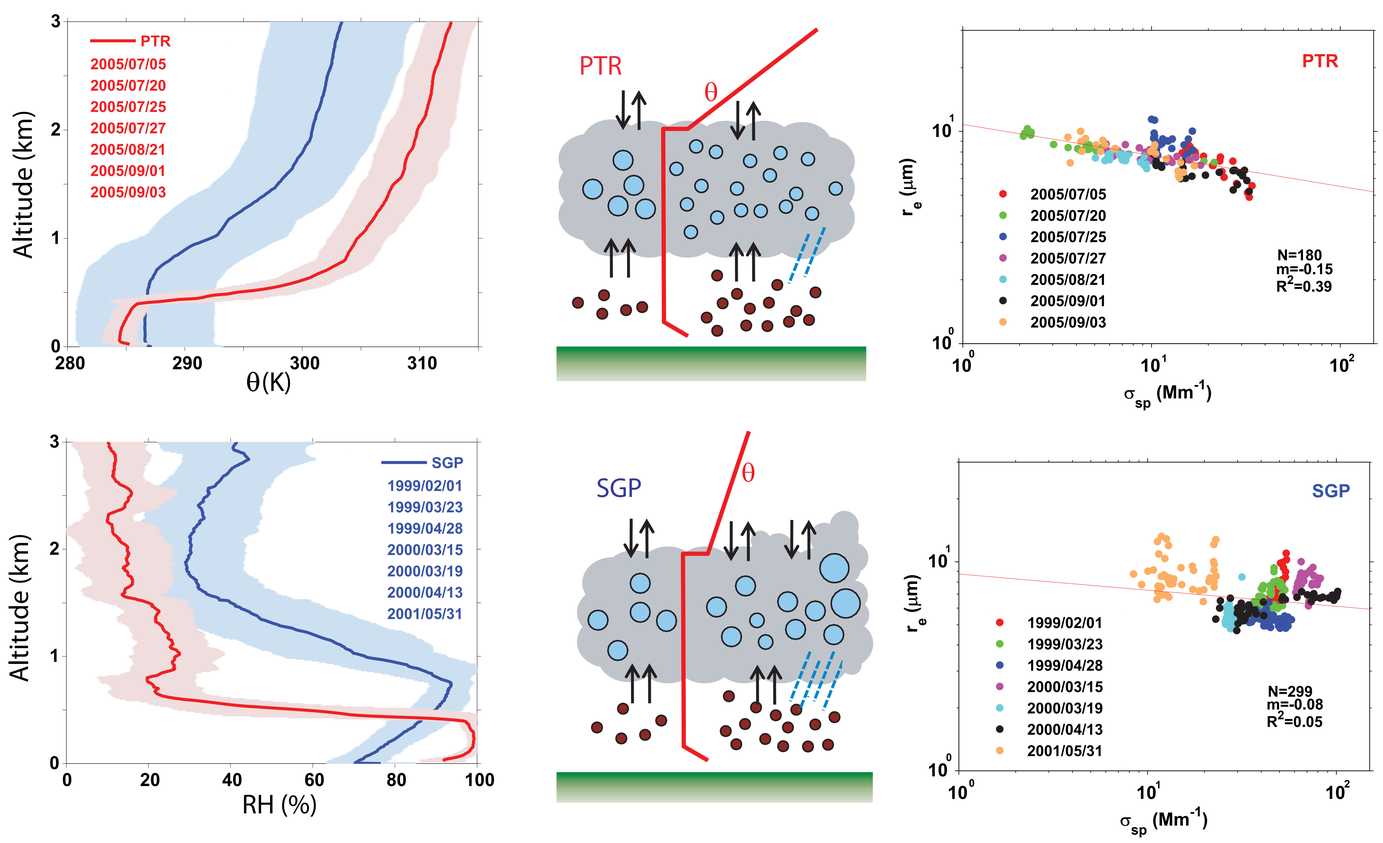

Fig 3. (Left panel) Level-averaged vertical profiles of potential temperature (θ) and relative humidity (RH) at PTR (red color) and SGP (blue color) with the standard deviation as shading. (Middle Panel) Schematic diagram of aerosol-cloud interactions in accordance with the stability condition above the clouds. (Right panel) Relationship of cloud drop effective radius (r_e) with aerosol light scattering coefficient (σ_{sp}) of PTR (left) and SGP (right).

PTR clouds have 2 times greater inversion strength capping above the mixed layer top than SGP (Fig. 3 left).

Notably a significant correlation of r_e with σ_{sp} is clearly seen even in the individual cloud scale at PTR by inspecting one season data only of 2005 (Fig. 3 right), which had been hardly identified at SGP from the previous works.

We hypothesize (Fig. 3 Middle) that the stronger inversion strength could suppress the cloud LWP variability, since inversion strength is believed to play a rigid lid above the cloud top.

Discussion

1. We do not deal with aerosol composition effect, such as, the influence of sea-salt on cloud drop activation. But in order to minimize this influence of coarse sea-salt effect on ACI, σ_{sp} for less than 1μm only has been used.
2. Average relative humidity above the cloud top also could influence cloud microphysics. But 20 ~ 30% differences of average RH seem to be less critical for ACI in comparison with those in Ackerman et al. [2004] ranging from 10% ~ 70% between dry and humid conditions.
3. The current even-integrated remote sensing could not segregate aerosol-cloud-preciptation feedback mechanism each other and interdependence due to their complexity and measurement artefacts.

Overall the positive correlation between α and $N_{\Delta\theta}$ is exhibited, which implies that the stronger the stability, the greater the adiabaticity of clouds (Fig. 4).

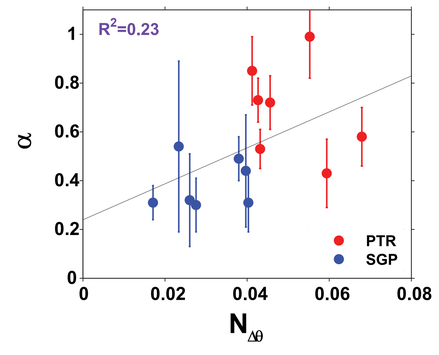

Fig. 4. Relationship of adiabaticity (α) with the normalized static stability ($N_{\Delta\theta}$) of PTR and SGP together.

Conclusion

1. Cloud microphysics such as size is closely related with aerosols below the stronger stable condition along with suppressing cloud macroscopic variability and keeping the cloud close to being adiabatic during its evolution.
2. Certainly aerosol influence on cloud droplets is much more dominant and clearly discernible in less-variable stratocumulus clouds, since masking effect is minimized.