9.3 **SEASONAL AND SPATIAL COMPARISONS BETWEEN CLOUD AND AEROSOL OPTICAL PROPERTIES DERIVED FROM SATELLITE REMOTE SENSING IN NORTHEAST ASIA**

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1. INTRODUCTION

The subject of aerosol-cloud interactions has received prominent attention because of still higher uncertainty in estimating its climatic forcings and its possible climatic implications (IPCC 2007). Kim et al. (2008) asserted that aerosol chemical and physical properties, cloud dynamic and turbulent characteristics, and the aerosol-cloud interactions should be considered together when evaluating the aerosol indirect effects, since the underlying mechanisms appear to be dependent upon each other, and accounting for them is impossible with the current understanding of aerosol indirect effect. Although the various studies on the aerosol indirect effect have been carried out all over the world, relatively few focuses have been put on the Northeast Asian region, which has frequently suffered from the transport of various anthropogenic air pollutants that probably could have an influence on cloud properties and further the associated climate forcing. Certainly detailed and integrated careful observations are needed to understand the complex coupled mechanisms of aerosol-cloud interaction and its radiative forcing (Jin et al., 2005; Tripathi et al., 2007), but these strategies have not been applied to the region yet. The first step to aerosol indirect study in Northeast Asia is to have an overall understanding of the current state of aerosol and cloud optical properties derived from ground- and satellite-based remote sensings available since early 2000.

2. METHOD & DATA

Mainly Moderate Resolution Imaging Spectrometer (MODIS)/Terra level 3 data with the spatial resolution of 1º are used for this study. The analysis is mainly confined to aerosol optical depth (τ_a), liquid-phase cloud optical depth (τ_c), liquid-phase cloud effective radius (r_e), cloud top pressure etc. around Korea. Korea is frequently exposed to long-range transport pollutants coming from the rapidly-developing China, which possibly could modify the relevant cloud microphysical properties. In order to investigate spatial coherence of the cloud properties corresponding to aerosol optical properties, The analysis region is divided into 4 regions (Figure 1) such as A1 (118-121E & 35-38N), A2 (122-125E & 35-38N), A3 (126-129E & 35-38N), and A4 (130-133E & 35-38N), since there seems to be strong horizontal gradient of aerosol optical depth (τ_a) such as Figure 1.

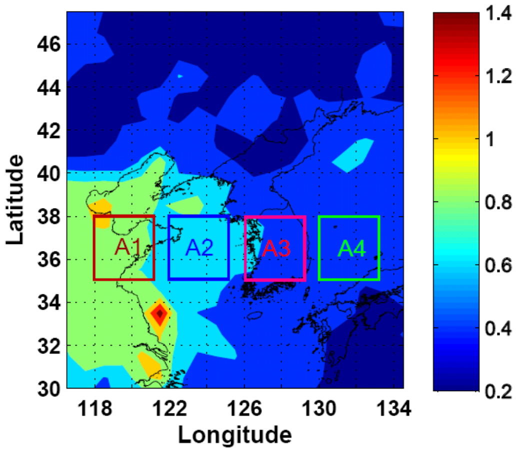

Figure 1. Horizontal distribution of τ_a in springs and the map of analysis domain (A1, A2, A3, and A4).

3. RESULT

3.1. *Horizontal Gradient of τ_a*

First of all, there seem to be no annual increasing /decreasing trends of τ_a from MODIS in the downstream region of China, which is also confirmed by the aerosol robotic network (AERONET). Meanwhile, horizontal distributions and box plots of τ_a for the different region show the substantial horizontal gradient from China to Korea, especially with the strong difference between A1 ~ A2 and A3 ~ A4 (Figures 1 & 2), which could represent the evidence of the anthropogenic influence downstream of China in the perspective of seasonal average.

Meanwhile, τ_c is highest over A3 in summer, while highest over A4 in winter, probably attributable to the frequent deep convection over the Korea inland in summer and the warm current influence in East Sea in winter, respectively (not shown). This also implies that cloud properties be firstly determined by the meteorological and regional climate variability.

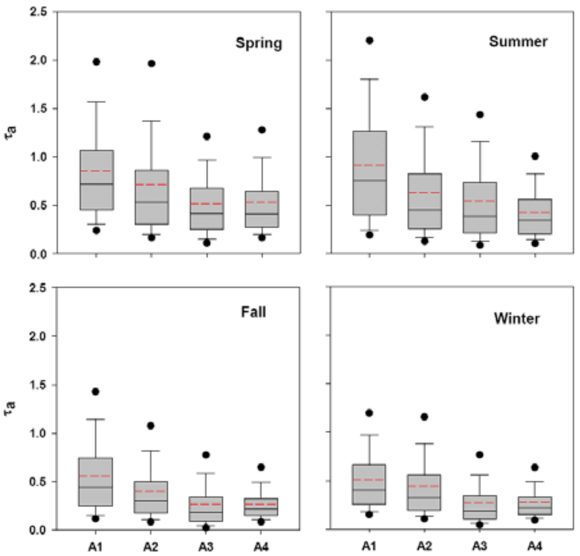

Figure 2. Box plots (1%, 5%, 25%, 50%, 75%, 95%, 99%) of aerosol optical depth (τ_a) over each region (A1, A2, A3 and A4) with the different seasons. Dashed line denotes the mean of τ_a.

3.2. *Seasonal Spatial Comparisons*

In Northeast Asia, the flows persistently advect continental anthropogenic air from China to Japan, inducing a large spatial variation in most of seasons, which could make it possible to study the main characteristics of aerosol-cloud interactions using even long-term average data. Specifically the relationship of τ_a to r_e on the monthly-average basis has been examined in Figure 3, which shows the negative correlations, only in summer and most significant associations over the Yellow Sea (A2), but overall vague signals in the other seasons and/or regions.

Note that relative variability (normalized interquartile range) in τ_c is generally lowest whereas relative variability in τ_a is higher in summer, implying that the cloud variability in summer tends to be relatively suppressed and the variability on aerosol loadings appears to increase over the Yellow sea. The highest ratio of both variabilities might increase the efficacy of aerosol-cloud interaction in Northeast Asia.

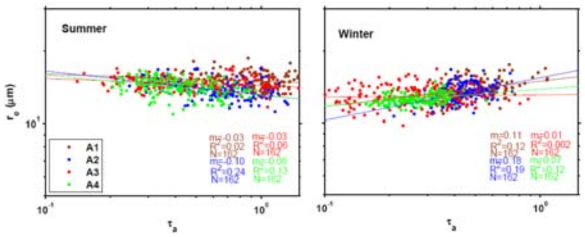

Figure 3. Comparisons of r_e with τ_a on the monthly average basis for each region in summer (left) and winter (right), respectively.

4. Summary and Conclusions

In this study, we found strong horizontal gradients of τ_a found from west to east in Northeast Asia for the entire seasons using satellite remote sensing. However, no spatial coherences of τ_c and r_e are shown corresponding to the variations of τ_a on the larger spatial domain. Meanwhile, τ_c seems to be mostly controlled by the regional meteorological pattern.

Some significant negative correlation between τ_c and r_e is exhibited on the monthly average basis in summer and specifically over the Yellow Sea, which might be associated with relatively larger variation of τ_a and smaller variation of τ_c compared to other regions. This is the possible evidence of the facilitation of aerosol-cloud interactions over the Yellow Sea, downstream of China.

Future study will focus on the efficacy and sensitivity of aerosol indirect effects in Northeast Asia using short-term data such as Atmospheric Brown Cloud (ABC) campaign.

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