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How Does Tropospheric Aerosol Affect Twilight Colors?

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The color of clear-sky twilight normally gradates from red near the horizon to blue for the zenith, which is caused by spectral variation of scattering and extinction processes by atmospheric molecules and aerosols while the solar radiation is transported from the sun under the horizon. It is well known that the scattering by stratospheric aerosols and the absorption in the ozone layer strongly affect the twilight colors. However, the influence of tropospheric aerosols on the color of the twilight sky is not well understood.

We took photographs of twilight sky at a mid-latitude site (Sendai, Japan) on clear days in December 2011, by a digital camera. We also obtained optical and physical properties of aerosols using a sun photometer and other ground-based instruments. For the civil twilight period with solar elevation angle between 0 and –6 degrees, the color distribution with respect to the view elevation angle was analyzed for the sky with the same azimuth as the solar direction by decomposing the photograph signal of each pixel into red, green, and blue components. The color ratios, ratios of intensities of each light component, characterize the color. The colorimetric analysis of the images revealed that the density of aerosols changes the color ratios particularly for directions near the horizon.

Spectral radiances and the color ratios were simulated by using a radiative transfer model for spherical shell atmosphere taking account for multiple scattering and refraction by air density variation. As a standard condition of aerosols in the site of corresponding season, we assumed stratospheric aerosols ($75\%H_2SO_4$) with optical thickness (τ) of 0.015 and tropospheric aerosols with τ= 0.17, which consist of soot, water-soluble, dust and yellow-sand. The simulation results qualitatively show that the color of the twilight sky tend to be bluer as the solar altitude becomes lower and as the view elevation angles becomes larger. The color depends on the optical thickness of tropospheric aerosols. A sensitivity test with gradually changing τ of tropospheric aerosols from zero to twofold value of the standard one shows that the strongest red color appears for atmosphere with total$\tau \approx 0.1$ and any other conditions such as a aerosol-free troposphere and a polluted troposphere with dense aerosols exhibit weaker red.

It is suggested from the comparison between measurement and simulation that tropospheric aerosols strongly affect colors of twilight sky near the horizon. In the conference, we will discuss the effects of particle type and vertical distribution of tropospheric aerosols on twilight colors.