INTENSIVE OBSERVATION OF SAND AND DUST STORMS USING GROUND-BASED FOURIER TRANSFORM INFRARED SPECTROSCOPY IN ANMYEON, KOREA

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ABSTRACTS

In order to analyze hyper-spectral properties of Sand and Dust Storm (SDS), dust observation experiment has been performed at the Korea Global Atmosphere Watch Center (KGAW) in Anmyeon form early March to middle of May, 2007. We measured down-welling radiances by using ground-based Fourier Transform Infrared Spectroscopy (FT-IR) at the time of overpass of AIRS. And radiative transfer model simulation has been carried out to estimate the effects of size distribution, components, and altitude of SDS over the high resolution infrared spectrum in the range of 500-1500 cm^{-1} with a line-by-line radiative transfer model and compared them with FT-IR and AIRS/Aqua observing data.

KEY WORDS: Sand and Dust Storms, Hyper-spectral Properties, Fourier Transform Infrared Spectroscopy, Observation Experiment

1. INSTRUCTION

Sand and Dust Storms (SDS) blow up from arid or semi-arid region of China and Mongolia and are transported over the Korean Peninsula through westerly winds. It is a significant impact on the atmospheric radiation budget as well as causing societal and economical problems because of large amount of dust. However, we have a limited knowledge of the distributions and the physical, optical and hyper-spectral properties of SDS although many study have been carried out by many researchers. Thus an intensive observational experiment was conducted to understand the hyper-spectral properties related to the size distributions, components, and altitude of the SDS. In this experiment we try to investigate hyper-spectral properties of SDS or aerosols with observation and simulation data at surface and space.

This paper addresses 1) the theory of high spectral resolution infrared observations, 2) the detailed design of experiment and 3) preliminary results for hyper-spectral properties.

2. THEORY AND METHODOLOGY

Fourier Transform Infrared Spectroscopy (FT-IR) is one of the most powerful techniques available for analytical hyper-spectral properties of the SDS. The radiative transfer equation for up- and downward infrared radiance is given by the following two equations.

$$I_\lambda(\tau) = (\varepsilon_\lambda - 1)B_\lambda(T_g)\gamma(\tau_g,\tau) + B_\lambda(T_\tau) - \int_{\tau_g}^{\tau}\gamma(\tau_g,\tau)\frac{dB_\lambda(T_t)}{dt}dt \quad (1)$$

$$I_\lambda(\tau) = B_\lambda(T_\tau) - \int_{0}^{\tau}\gamma(\tau_g,\tau)\frac{dB_\lambda(T_t)}{dt}dt \quad (2)$$

Where I_λ, ε_λ, B_λ, T_g and $\gamma(\tau_g,\tau)$ are observed spectral radiance, spectral emissivity, spectral Planck function, the surface temperature, spectral transmittance at wavelength λ from altitude τ_g to τ, respectively. The measured spectral radiance affect by each parameter which is characterized by size distribution and

composition of SDS or aerosols. Thus we could estimate the hyper-spectral properties from simulation.

2.1 MEASUREMENTS

Measured downwelling radiance is calibrated with bracket radiometric calibration method (Lubin, 1994; Stephens, 1994; Revercomb *et al.*, 1988). The method assumes that blackbody emissivity is one, and that the instrument responds linearly to an influx of radiance. Calibrated radiance permits the conversion of uncalibrated measured radiance to calibrated radiance in standard radiometric units ($W/m^2\ \mu m$) by dividing by the responsivity, then adding the instrument self-emission (Andrew *et al.*, 1996).

2.2 SIMULATIONS

To estimate of hyper-spectral properties for the SDS, radiative transfer model simulation has been carried out. Optical Properties of Aerosols and Clouds (OPAC) software package are employed for the simulation of different sizes and components of dust particles (Hess and Schult, 1998). And meteorological data (from radiosonde, Vaisala RS92) was used as input. The profiles of aerosol optical properties (extinction coefficient, single-scattering albedo, asymmetry parameter) of the dust particles and meteorological data are used as input to the radiative transfer model (Kyungpook National University, KNU-LBL). The model calculated hyper-spectral up- and downwelling radiance in the infrared wavenumber range from 500 to1500 cm^{-1}. The calculated results were compared with downwelling radiance using ground-based FT-IR and upwelling radiance from AIRS/Aqua satellite data.

3. OBSERVATIONS

The dust observation has been performed at the Korea Global Atmosphere Watch Center (KGAW) in Anmyeon from early March to middle of May, 2007. Figure 1 indicated detailed experimental design. In order to understand hyper-spectral properties of SDS, down-welling radiance was measured by using ground-based FT-IR and got up-welling radiance from AIRS/Aqua satellite when SDS break out. And radiosondes, "Micro Pulse Lidar" (MPL), and "Optical Particle Counter" (OPC) are used to measure for vertical profiles of temperature, relative humidity, altitude of dust layer, and aerosol properties.

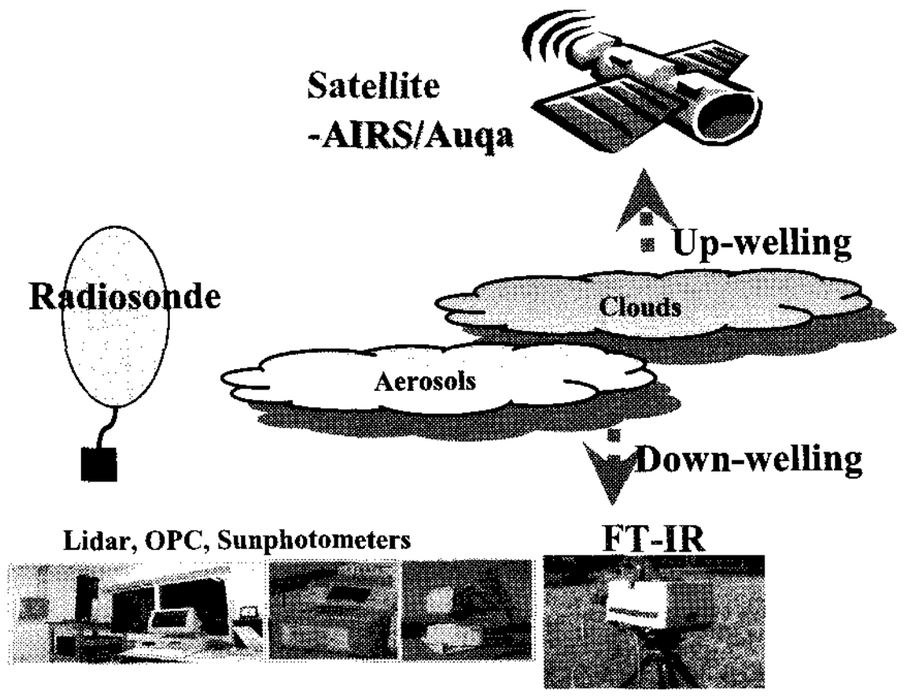

Figure 1. Schematic diagram of the experimental design.

4. RESULTS

We have got the various profiles of hyper-spectral downwelling radiance due to change of weather such as clear sky, fog, low- and high-level cloud, dust outbreak, and so on.

Figure 2 and 3 shows an example of downwelling and upwelling hyper-spectral spectrum profile in the clear sky condition that is measured on 21 April 2007 at 12:36 LST and 14:17 LST, respectively. Blue line indicated that calculated radiance with Maritime Clean aerosol type in the figures. The difference between measured and calculated spectrum means that the estimated input parameters (size distribution, refractive index, and aerosol amount) are not characterized accurately the real atmosphere and surface in the simulation.

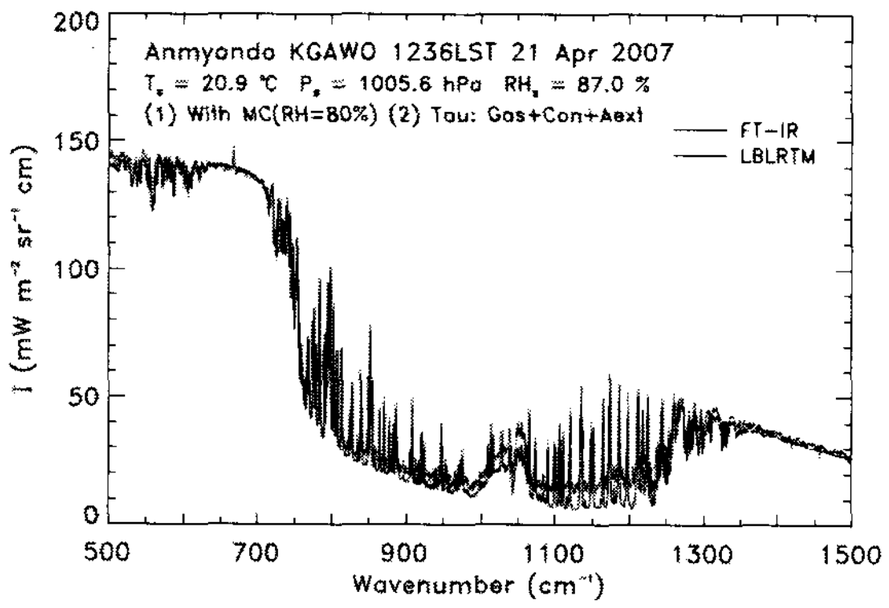

Figure 2. Measured downwelling radiance (red) at Anmyeondo on 21 Apr. 2007 at 12:36 LST and simulated radiance (blue) using radiosonde data launched at 12:26 LST. Maritime Clean (MC) aerosol type is used for simulation.

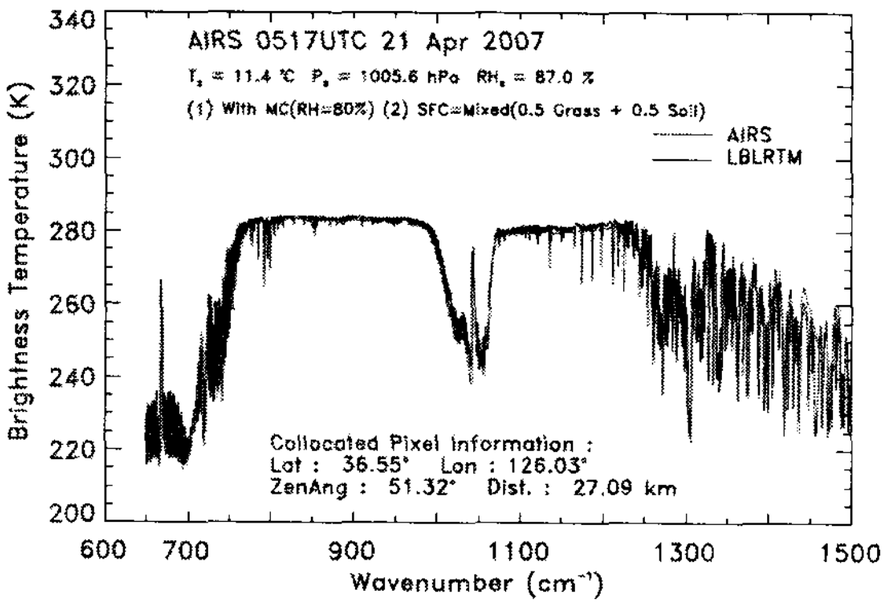

Figure 3. Measured upwelling spectrum (red) by AIRS at 14:17 LST on 21 Apr 2007 near Anmyeondo and simulated spectrum (blue) using radiosonde data at 12:26 LST. Surface is 50% of soil and 50% of grass. MC aerosol type is used.

5. SUMMARY AND FURTHER WORK

The up- and down-welling hyper-spectral properties have been determined simultaneously using ground-based FT-IR measurement and satellite observations at high spectral resolution. The observed downwelling and upwelling radiances are compared with model calculations. The comparison results show that each case (clear sky, fog, low- and high-level cloud, dust outbreak) has large discrepancy on absorption and emission lines of spectrum. Also calculated spectrum was different from measured spectrum due to limited input in the simulation. The hyper-spectral characteristics should be carefully calculated and the optical properties of each particles and surface type to understand of the real atmosphere should be collected with caution.

In the future, an effective forward radiative model should be implemented properly to understand the hyper-spectral characteristics. For this purpose, more sensitivity tests are needed for the different surface type, temperature, and humidity profiles because those are significantly affect on magnitude for the hyper-spectral properties. And then a valid model should be developed to describe composition, size distribution, and vertical profile for the aerosols and clouds in real atmosphere due to limited information in OPAC.

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Acknowledgements

This study was supported by "Development of the satellite data processing technique (III)" of National Institute of Meteorological Research (METRI). And we are grateful to the KGAW staffs.