COMPARISON OF OBSERVED AND SIMULATED INFRARED HYPER-SPECTRAL CHARACTERISTICS OF ASIAN DUST

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I. INTRODUCTION

- ***Backgrounds :*** Asian dust are significant impact on the atmospheric radiation budget as well as causing societal and economical problems because of large amount. However, we have a limited knowledge of the distributions and the physical, optical and chemical properties of Asian dust even though many study have been carried out. Fourier Transform Infrared Spectroscopy (FT-IR) is one of the most powerful techniques available for analytical Infrared hyper-spectral properties of the SDS.
- ***Objectives :*** To understand the Infrared hyper-spectral properties related to the size distributions, compositions, a layer altitude and optical depth of the Asian dust with observation and simulation data in surface and space.
- ***Methodology :***
  1. Intensive dust observation has been performed at the Korea Global Atmosphere Watch Center (KGAW) in Anmyon, Korea during spring season. Downward radiance was measured by using ground-based FT-IR and got upward radiance from AIRS/Aqua satellite when Asian dust break out. And radio-sonde, "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.
  2. To estimate of hyper-spectral properties for the Asian dust, Atmospheric and Environmental Research Inc.'s Line By Line Radiative Transfer Model (AER-LBL RTM) has been carried out (http://rtweb.aer.com/main.html). And the calculated results were compared with the measured data.

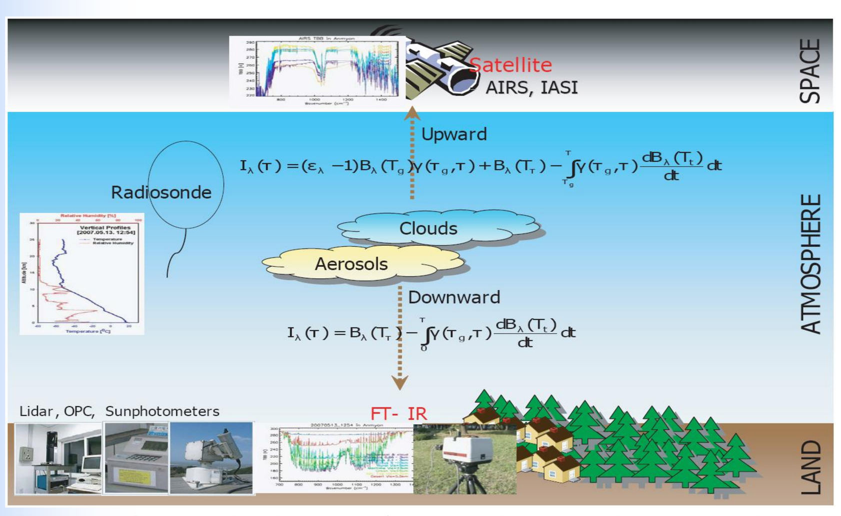


Figure 1. Schematic diagram of the detailed experimental design.

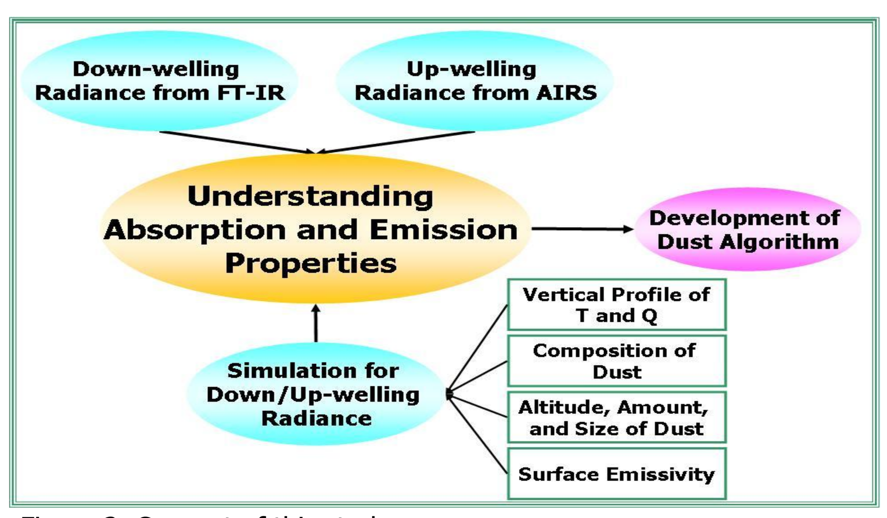


Figure 2. Concept of this study

II. INTENSIVE OBSERVATION

- The dust observation has been performed 9 times during spring season from 2007 to 2009. Table 1 indicated number of observed data set using ground-based micro FT-IR. We measured the various profiles of Infrared hyper-spectral downward radiance. Also, we measured aerosol number concentration, aerosol vertical profile, and PM10 concentration.

Table 1. Experimental periods and number of observed data for FTIR and Sonde.

	Periods		Blackbody		SKY	Sonde	Condition
	Year	Date	Warm	Cold			
1st	2007	03.31. – 04.01.	18	12	32	2 (V)	Dust
2nd		04.03. – 04.04.	14	12	75	2 (V)	Clear
3rd		04.20. – 04.21.	93	50	43	3 (2V ,1G)	Fog
4th		05.08. – 05.10.	36	35	186	7 (G)	Cloud
5th		05.11. – 05.14.	20	20	135	3 (V)	Fog, Rain
6th	2008	04.24. – 04.28.	31	32	133	9 (V)	Cloud
7th		05.20. – 05.21.	5	5	20	1 (V)	Fog, Cloud
8th		05.28. – 05.31.	28	28	159	7 (V)	Fog, Dust
9th	2009	03.15. – 03.16.	12	12	40	3 (G)	Dust
T		9	257	206	823	37	

V : Vaisala, G : Graw radio-sonde sensor

Infrared Signature of Dust

a. Downward Spectrum

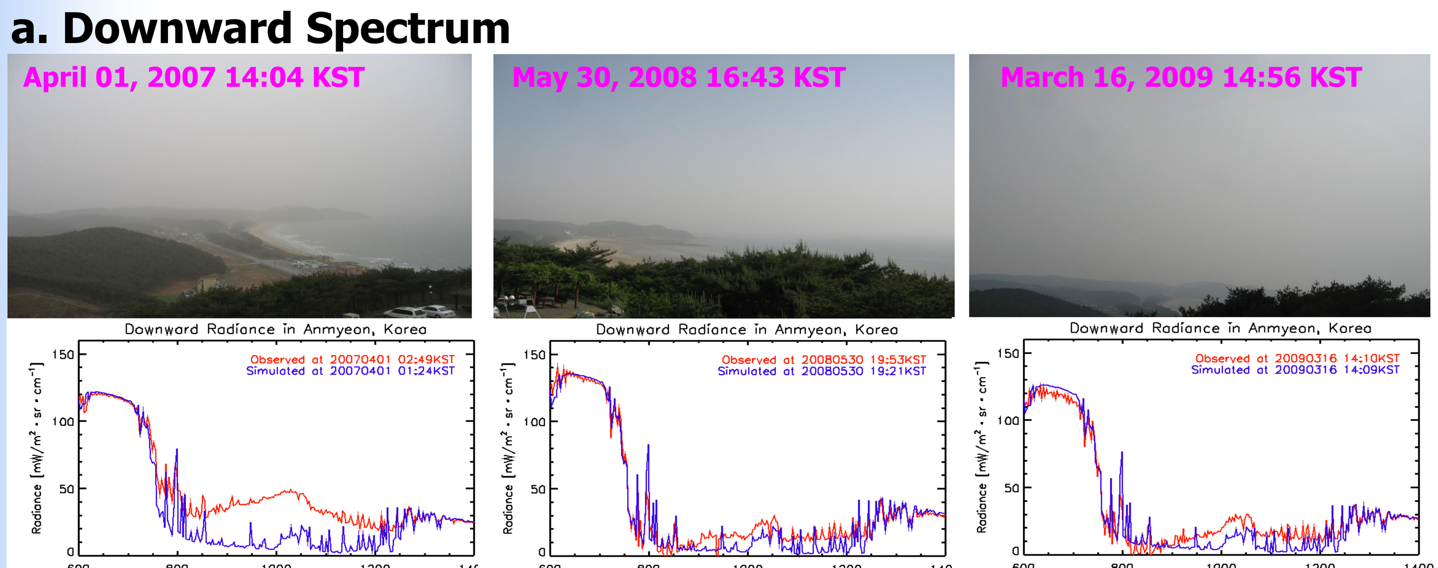
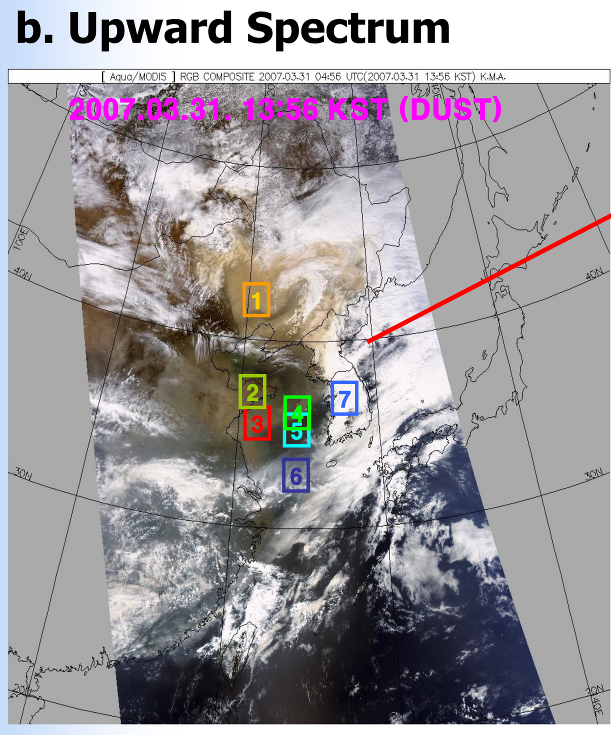
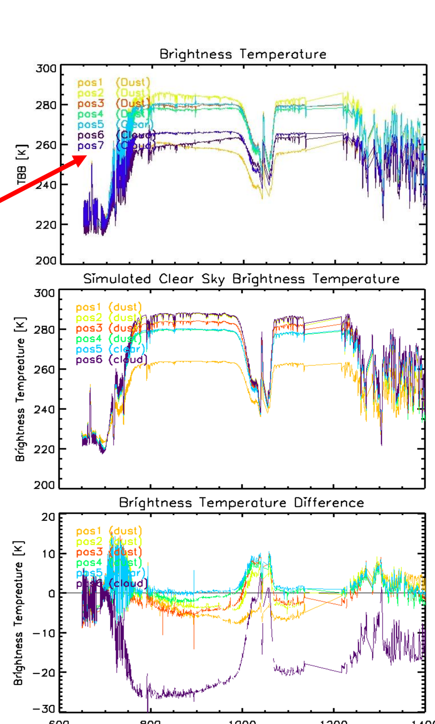


Figure 3. Upper three pictures show the sky condition taken at 14:04 on 1 April 2007 (left), 16:43 on 20 May 2008 (middle), and 14:56 on 16 March 2009 (right). Lower three figures are results of FT-IR observation and clear sky simulation. The spectrum in the 800-1000 cm^{-1} region is featured with a positive slope and negative slope in the 1100-1200 cm^{-1} region compared with clear sky spectrum.

b. Upward Spectrum





	Latitude	Longitude
Pos1 (Dust)	43.0	121.5
Pos2 (Dust)	37.0	121.0
Pos3 (Dust)	35.5	122.5
Pos4 (Dust)	36.5	124.5
Pos5 (Clear)	35.5	124.5
Pos6 (Cloud)	33.5	124.5

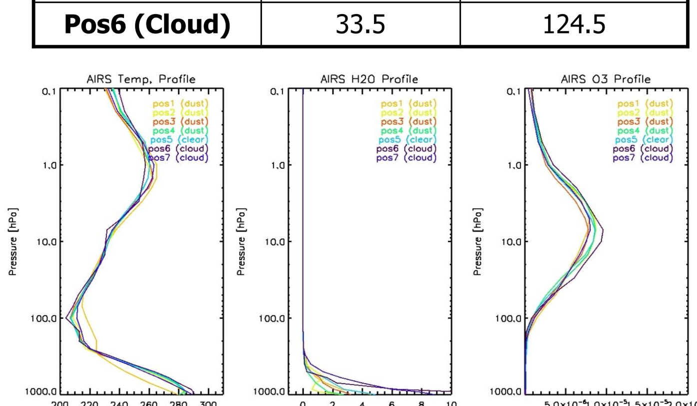


Figure 4. RGB composite image of MODIS/Aqua and AIRS/Aqua brightness temperature spectrum at 13:56 KST on 31 March 2007. Under the dust condition, the spectrum in the 800-1000 cm^{-1} region is featured with a negative slope and positive slope in the 1100-1200 cm^{-1} region compared with clear sky spectrum. Unlike the case for the dust, the spectrum in the 800-1000 cm^{-1} region is positive slope in the cloud condition.

III. SENSITIVITY TEST

- Sensitivity study was performed with AER LBL RTM to understand theoretical up- and down-ward hyper-spectral signatures of Asian dust. To do this, we parameterized size distribution and refractive index using observed data.

Mie Calculation

a. Size Distribution

$$dV/d\ln R = \frac{C}{\sqrt{2\pi}\ln\sigma}\exp\left[\frac{-\ln(r/\bar{r}_v)^2}{2\ln\sigma^2}\right]$$

Geometric mean radius = 1.5㎛
Geometric standard deviation = 1.5

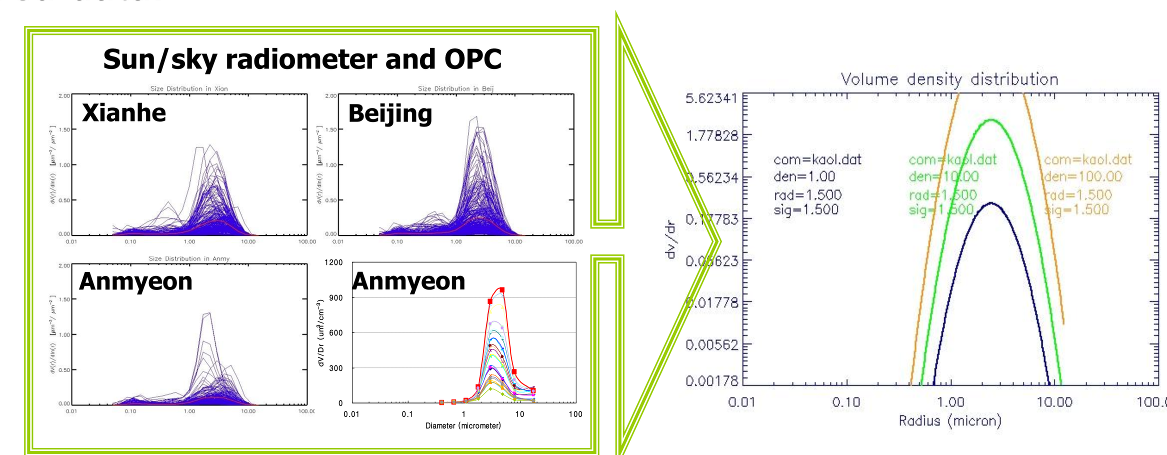


Figure 5. Parameterization of dust size distribution

b. Refractive Index

Table 2. Parameterization of complex refractive index

Mineral Composition	Refractive Index (Wavelength)	Mineral Composition	Refractive Index (Wavelength)
Quartz	0.20 ~ 300.0	Dolomite	2.00 ~ 200.0
Hematite	0.20 ~ 300.0	Gypsum	0.20~25.0
Sand	0.20 ~ 300.0	Kaolinite	0.20 ~ 25.0
Magnetite	0.10 ~ 119.5	Montmorillonite	0.20 ~ 25.0
Calcite	2.00 ~ 200.0	Pyroxene	0.20 ~ 200.0

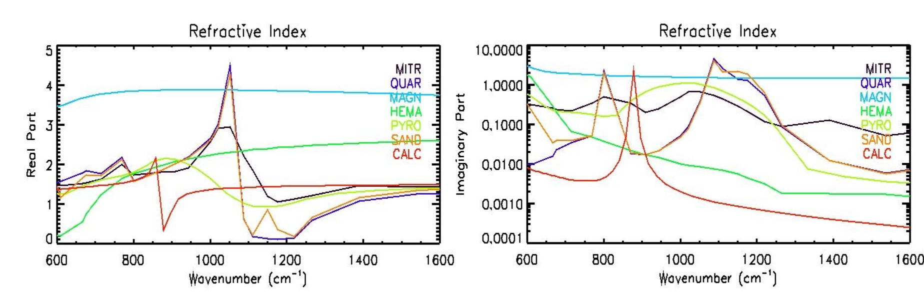


Figure 6. Complex refractive index with wave number

Line by Line Radiative Transfer Model

- Figure 7 show the dependence of Infrared spectrum on the optical depth, size distribution, altitude, composition and T&Q profiles of Asian dust. Results show that dust was transfigured the **slope and magnitude** for the downward (left column) and upward (right column) brightness temperature spectrum.

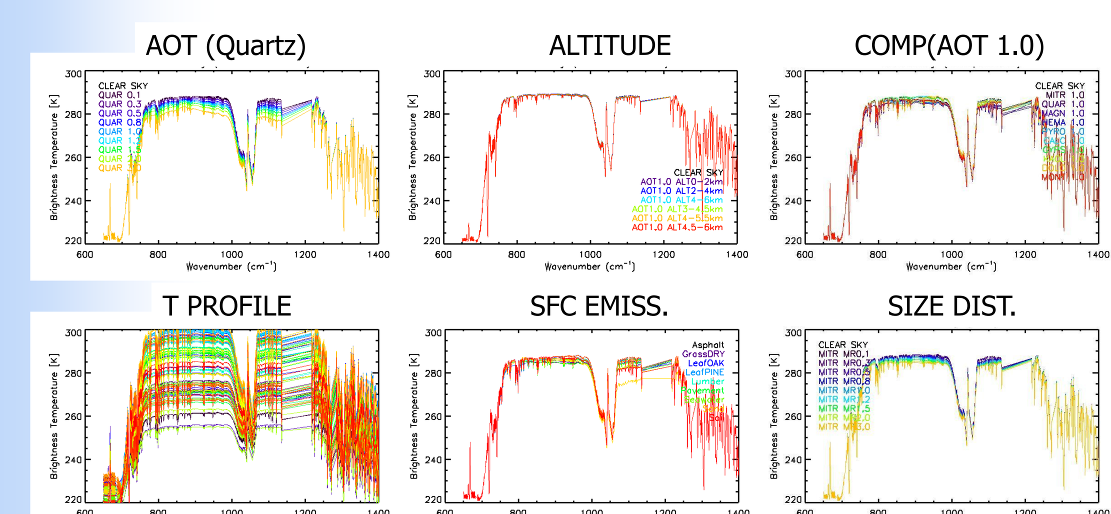


Figure 7. Simulated Brightness temperature for a various conditions of Asian dust with AER LBL RTM.

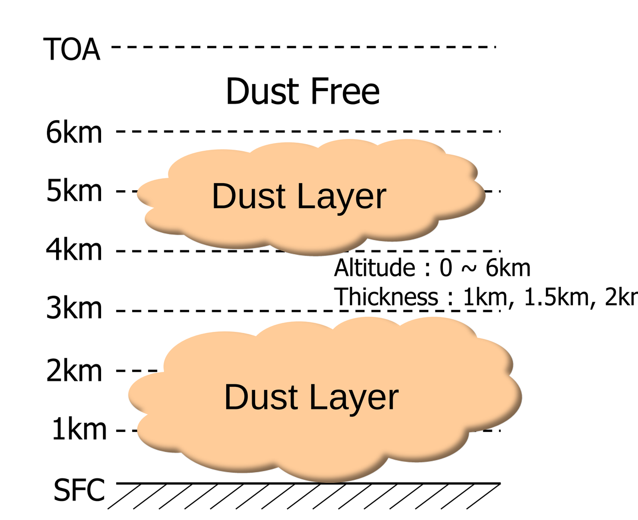


Figure 8. Example for parameterization of Asian dust layer altitude.

Principle Component Analysis

- To characterize the simulated hyper-spectral spectrum for the various Asian dust condition, **PCA** is carried out. Results show that **each dust property has the intrinsic eigenvector and eigenvalue**.

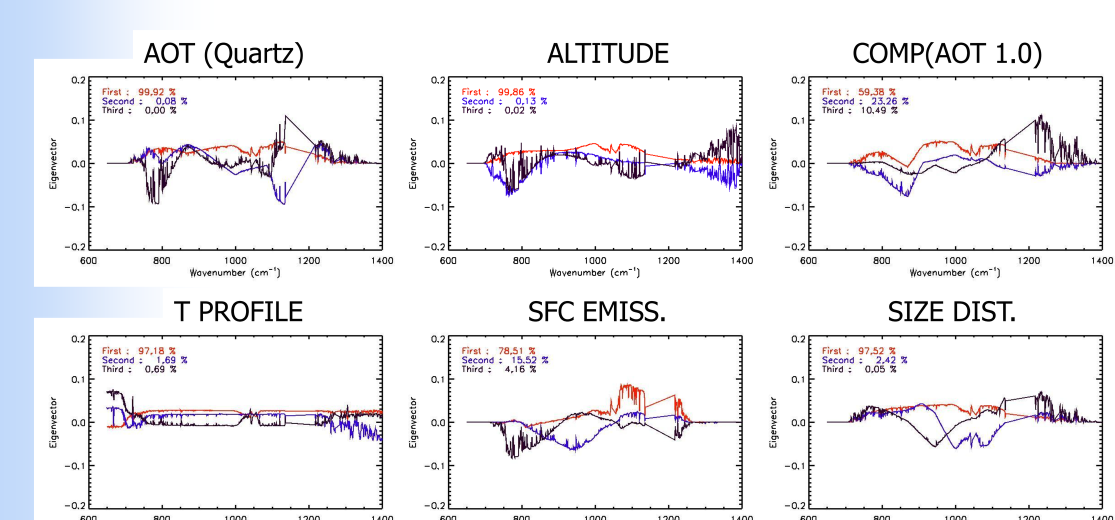


Figure 9. Eigenvector and % ratio of eigenvalue for a various conditions of Asian dust with AER LBL RTM.

$$EOF\ \ Coefficient = \sum_{i=1}^{N_{ch}} TB_i\,\hat{e}_i$$

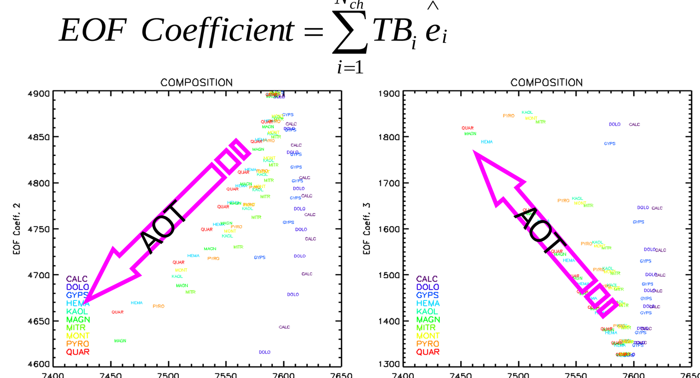


Figure 10. Physical meaning of EOF Coefficient. As increasing EOF coefficient 1 and 2, AOT is decrease. However, EOF coefficient 3 is proportional to AOT.

IV. SUMMARY AND FURTHER WORK

- The downward and upward hyper-spectral radiance have been determined simultaneously from ground-based FT-IR and satellite with high spectral resolution.
- We have got the various profiles of hyper-spectral downward and upward radiance with wavenumber due to change of weather such as clear sky, fog, low- and high-level cloud, dust outbreak, and so on.
- The observed upward brightness temperatures were compared with model calculations. The calculated clear sky spectrum was different from measured spectrum due to dust effect.
- Sensitivity test has been carried out to understand hyper-spectral properties of the dust for the various conditions with radiative transfer model. Results show that each dust property has the intrinsic eigenvector and eigenvalue.

- More sensitivity tests are needed for the various conditions (surface type, temperature and humidity profiles), since are significantly affect on magnitude and slope for the hyper-spectral properties. And the optical properties (size distribution, optical depth, altitude and composition) of each dust particle should be selected with caution to understand the real atmosphere.

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