Concept for determining aerosol layer height using UV-Vis O_4 absorption bands

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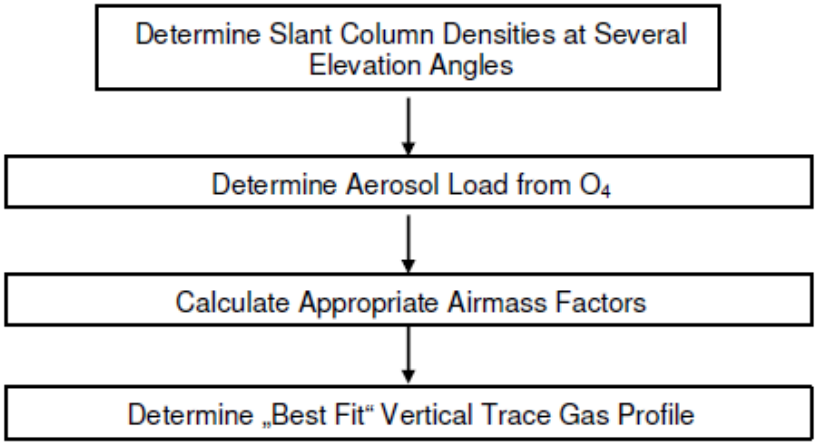
Introduction

- Aerosol optical depth (AOD), one of widely observed values of aerosol amount, is defined by vertically integrated amount. For this reason, AOD observed by optical measurement partly explained the aerosol concentration at surface.
- The correlation coefficient (R) between AOD and PM was calculated less than 0.6 (Guo et al., 2009), and PM estimated by AOD from satellite is partly correlated with real PM (Liu et al., 2005), although these previous studies considered hygroscopic growth and aerosol variability. One of the cause about this problem is lack of information for aerosol vertical distribution.
- Wagner et al. (2002) and Friess (2004) showed the aerosol height estimation using O4 slant column densities based on the ground-based measurement (MAX-DOAS). However, because the aerosol height signal is not stronger than aerosol optical properties, aerosol height retrieval based on space born measurement is still a challenging issue.
- This study investigated possibilities to utilize O_4 information as a tool to identify aerosol heights from space born sensors using simulated hyper-spectra radiance at TOA, and O_4 is estimated by the DOAS technique.

DOAS analysis – O4 band

- O4 is a good indicator for the aerosol load.
- O4 is a function of air concentration, so that this dimer offers in principle an excellent opportunity to determine the aerosol load of the atmosphere.
- Azimuth dependence : For homogeneous absorber, AMF is independent of the azimuth angle.



(Hoenninger, 2004)

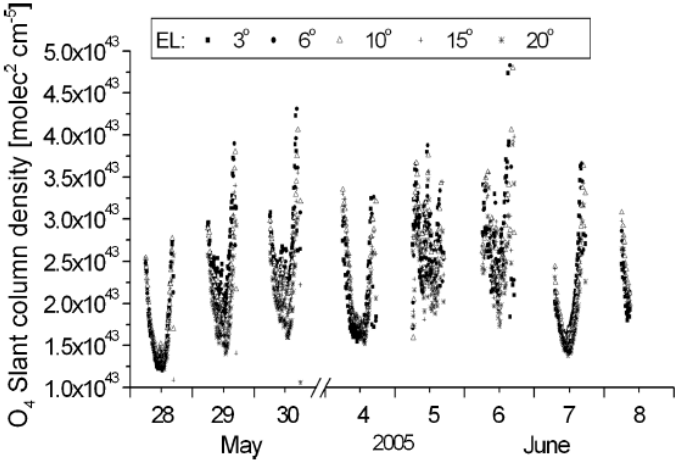


FIG. 2. Temporal variations in O_4 SCD values obtained at EL = 3°, 6°, 10°, 15°, and 20° during measurement period (28–30 May and 4–8 June 2005).

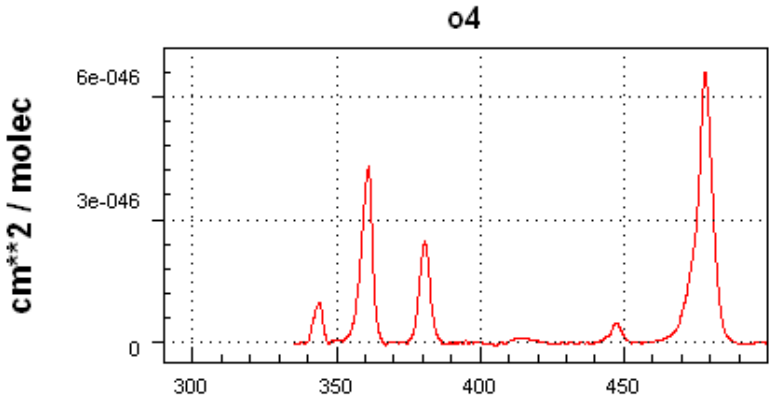
(Lee et al., 2009)

Radiance Simulation using RTM

- OPAC Aerosol Model

- Dust type Aerosol (OPAC TYPE : MITR)
- Scattering type aerosol (OPAC type : WASO)
- Wavelength : 330 ~510 nm

[Wavelength Dependence optical properties]



- Vertical distribution of aerosol
- Exponential Function

- Using cross-section :

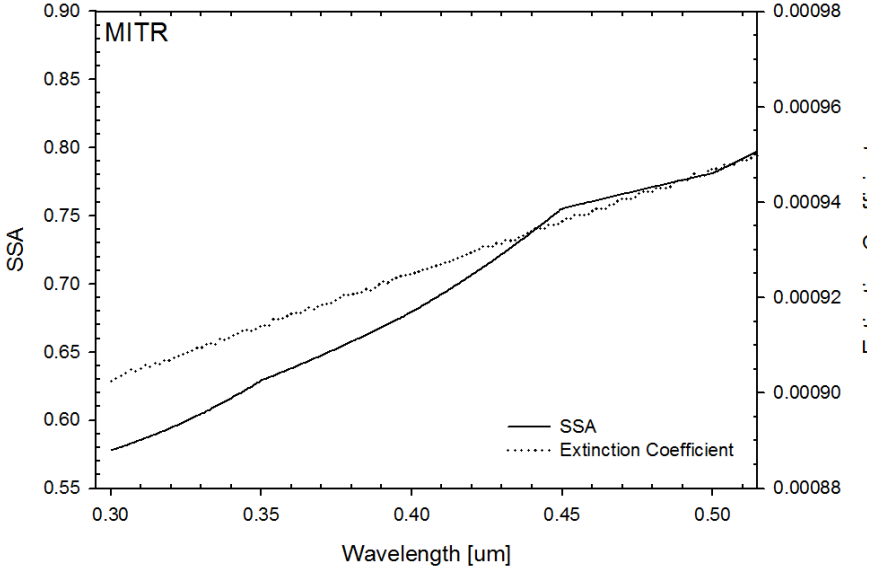
- O_3 (223, 243, 273 K) , NO_2 (220, 294 K),O_4 (herman)

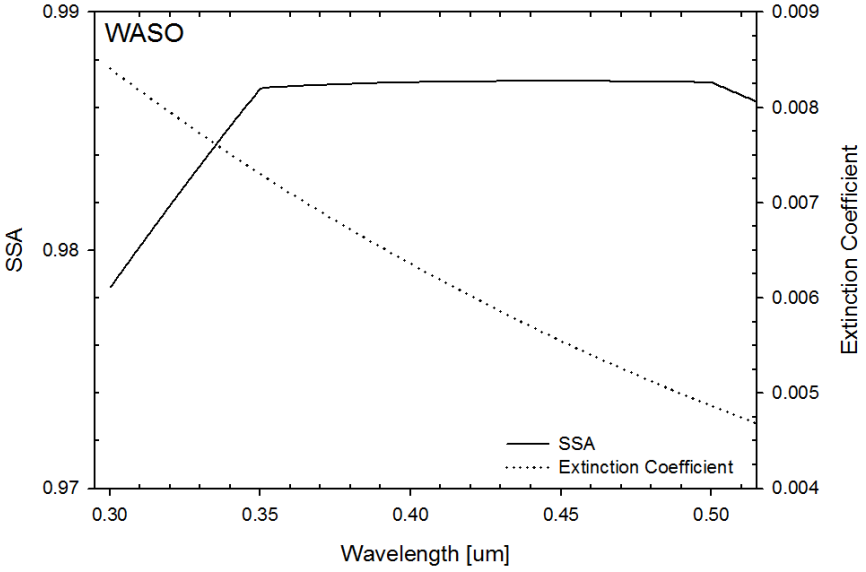
- Analyzed band (Using Window) :

- 340 nm (335~350 nm), 360 nm (350~370 nm), 380 nm (370~390 nm), 470 nm (460~486 nm)

Aerosol Optical Properties

- Based on OPAC aerosol model (Size distribution, Refractive index), single scattering albedo and extinction coefficient were estimated using Mie code.
- MITR and WASO types of aerosol model were selected by considering dust and scattering fine aerosol, respectively.
- Optical properties were estimated by the spectral resolution of 0.6 nm.





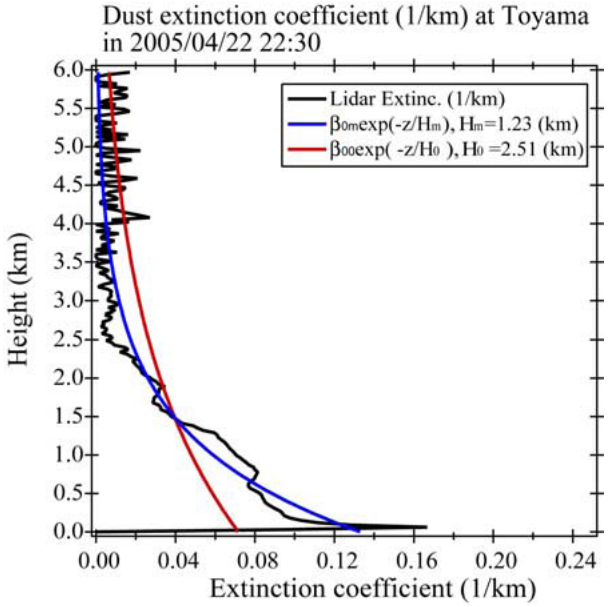
Dust vertical distributions

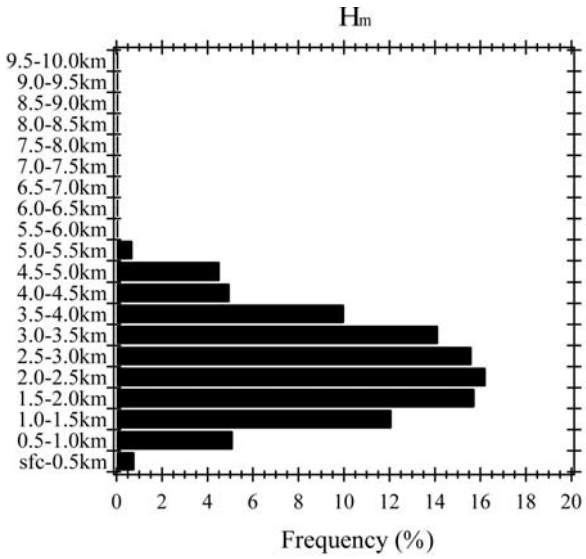
- Hayasaka et al. (2007)

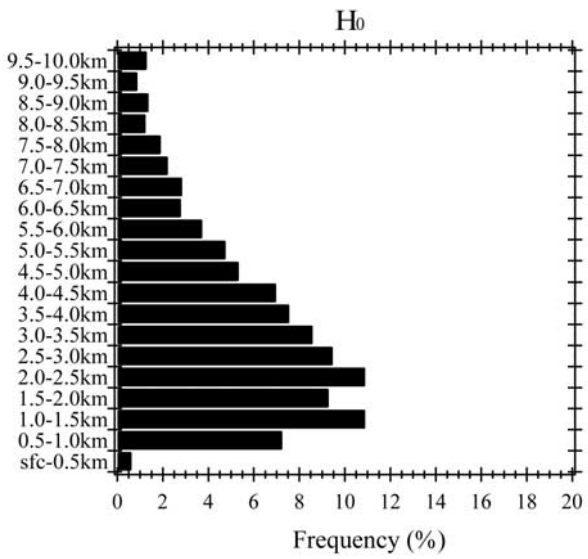
- Dust extinction coefficient at Toyama observed by lidar

- Vertical distribution of dust extinction coefficient is pseudo-exponential.

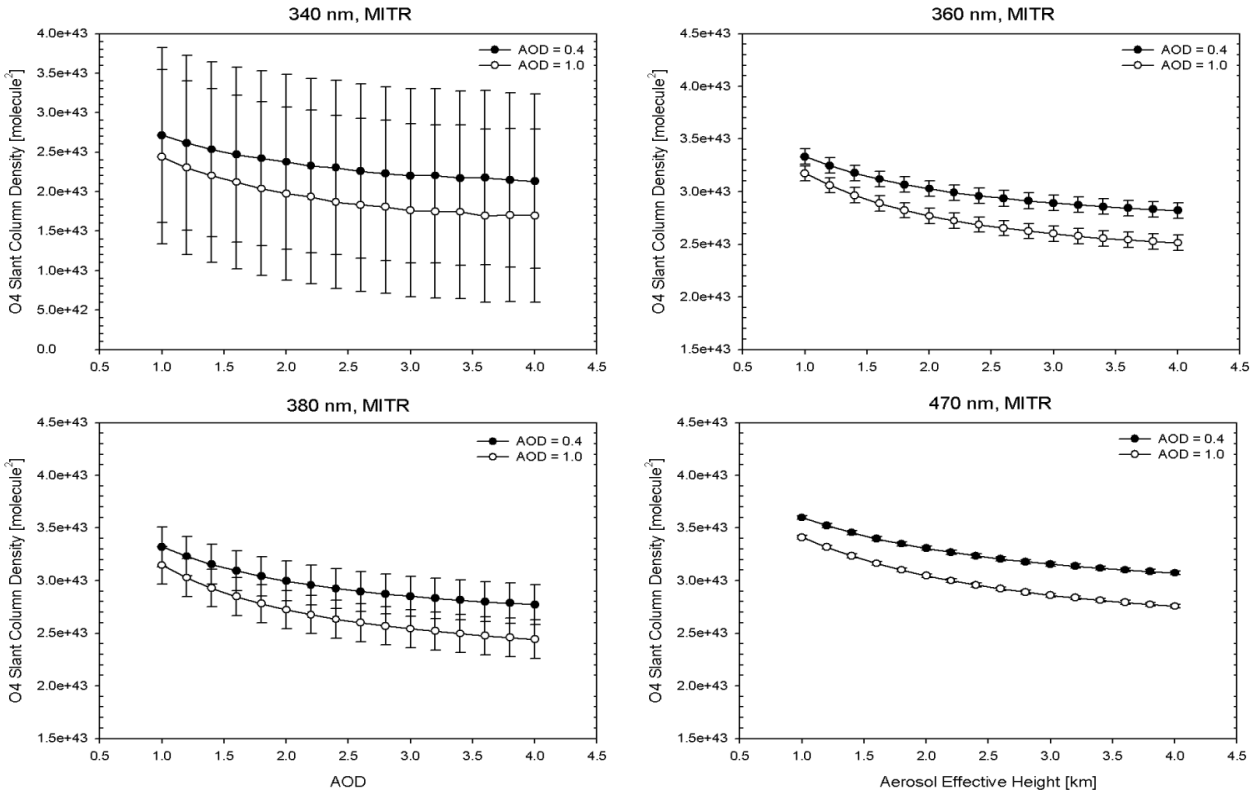
- Effective height is ranged from surface to 5.5 km.







Result – Height vs O4 SCD



- 340 nm : Fitting error is 10 times larger than the sensitivity of height
- 360 nm : 8% of SCD change (dH = 1km), fitting error is estimated from 3 to 5 %.
- 380 nm : Theoretically, sensitivity of height is larger than fitting error, but its optical depth of O4 is too small to retrieve from satellite.
- 470 nm : 6.7~9.7% of SCD change (AOD = 1.0, dH = 1 km)

Result – AOD vs O4 SCD

Difference of estimation [%]	O4 dSCD (dH = 1 km, AOD = 0.4)	O4 dSCD (dH = 1 km, AOD = 1.0)
MITR	5.2	7.0
WASO	6.5	9.7
COPO	4.5	6.7

Difference of estimation [%]	O4 dSCD (dAOD = 0.2, H = 1km)	O4 dSCD (dAOD = 0.2, H = 3km)
MITR	1.5	2.8
WASO	2.6	4.4
COPO	0.2	0.7

Height Error (km) [dAOD = 0.2]	Best	Worst
MITR	0.21	0.54
WASO	0.27	0.68
COPO	0.03	0.16

- This study considers only the O4 SCD from the estimation of 470 nm.
- The cases for AOD were considered 0.4 and 1.0, the cases for effective height of aerosol is considered 1 km and 3 km.
- O4 dSCD is defined the difference of the estimated O4 SCD as the AOD (or effective height) is changed by the value of dAOD (or dH).

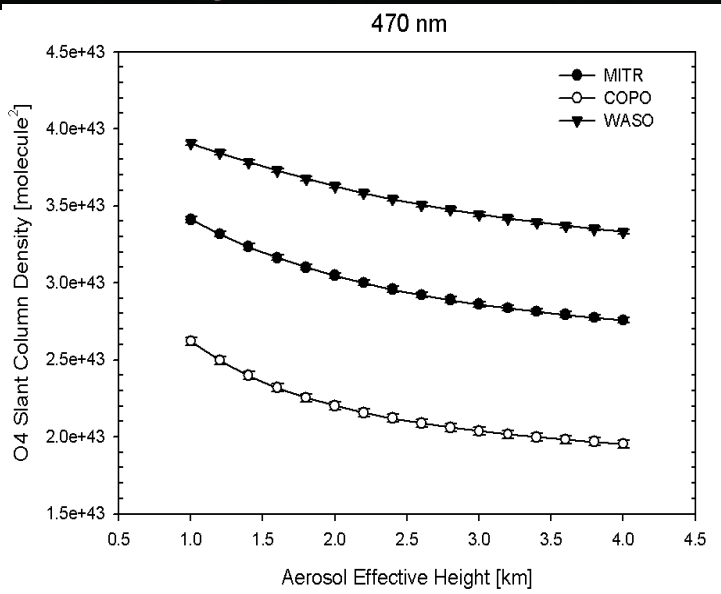
O4 SCD Error due to SSA (-10%)

- The O4 SCD at the same conditions of AOD and vertical distribution is changed by the aerosol optical properties, especially its scattering properties.
- Estimated O4 SCD is a function of SSA.

  - SSA : COPO < MITR< WASO

  - O4 SCD : COPO<MITR<WASO

- 300 m of height errors were occurred as 10% of SSA change.



- Case : Z = 3km, AOD = 0.4

Difference of estimation [%]	O4 dSCD (dH = 1 km)	O4 dSCD (dSSA = 10%)	Height Error (km)
MITR	5.2	-1.6	-0.31
WASO	6.5	-2.1	-0.32

- Case : Z = 3km, AOD = 1.0

Difference of estimation [%]	O4 dSCD (dH = 1 km)	O4 dSCD (dSSA = 10%)	Height Error (km)
MITR	7.0	-2.1	-0.30
WASO	9.7	-3.5	-0.36

O4 SCD Error due to estimation process

- Effect of Optics Shift

Difference of estimation[%]	Optics shift (±0.02 nm)	Optic shift (Considering squeeze)
MITR	0.01	0.01
WASO	0.00	0.00
COPO	0.01	0.01

- Effect of fitting Error

Difference of estimation [%]	MITR	WASO	COPO
O3 (228;243 K)	-0.01	0.01	-0.01
O3 (228;273 K)	0.01	0.00	0.01
O3 (243;273 K)	0.09	0.05	0.13
NO2 (220 K)	-0.02	-0.01	-0.02
NO2 (273 K)	0.07	0.01	0.09

O4 SCD Error due to Strat. O3 (±10%)

- Case : Z = 3km, AOD = 0.4

Difference of estimation [%]	340 nm	360 nm	380 nm	470 nm
MITR	0.46	0.01	0.00	0.00
WASO	0.55	0.13	0.12	0.09

- Case : Z = 3km, AOD = 1.0

Difference of estimation [%]	340 nm	360 nm	380 nm	470 nm
MITR	0.46	0.01	0.00	0.00
WASO	0.76	0.30	0.27	0.16

- Case : Z = 1km, AOD = 1.0

Difference of estimation [%]	340 nm	360 nm	380 nm	470 nm
MITR	0.43	0.01	0.00	0.00
WASO	0.64	0.22	0.20	0.12

O4 SCD Error due to Trop. O3 (±10%)

- Case : Z = 3km, AOD = 0.4

Difference of estimation [%]	340 nm	360 nm	380 nm	470 nm
MITR	-0.01	0.00	0.00	0.00
WASO	0.15	0.12	0.12	0.09

- Case : Z = 3km, AOD = 1.0

Difference of estimation [%]	340 nm	360 nm	380 nm	470 nm
MITR	0.00	0.00	0.00	0.00
WASO	0.39	0.29	0.27	0.17

- Case : Z = 1km, AOD = 1.0

Difference of estimation [%]	340 nm	360 nm	380 nm	470 nm
MITR	-0.01	0.00	0.00	0.00
WASO	0.28	0.21	0.20	0.13

O4 SCD Error due to NO2 (±10%)

- Case : Z = 3km, AOD = 0.4

Difference of estimation [%]	340 nm	360 nm	380 nm	470 nm
MITR	0.00	0.00	-0.01	-0.01
WASO	0.15	0.12	0.12	0.09

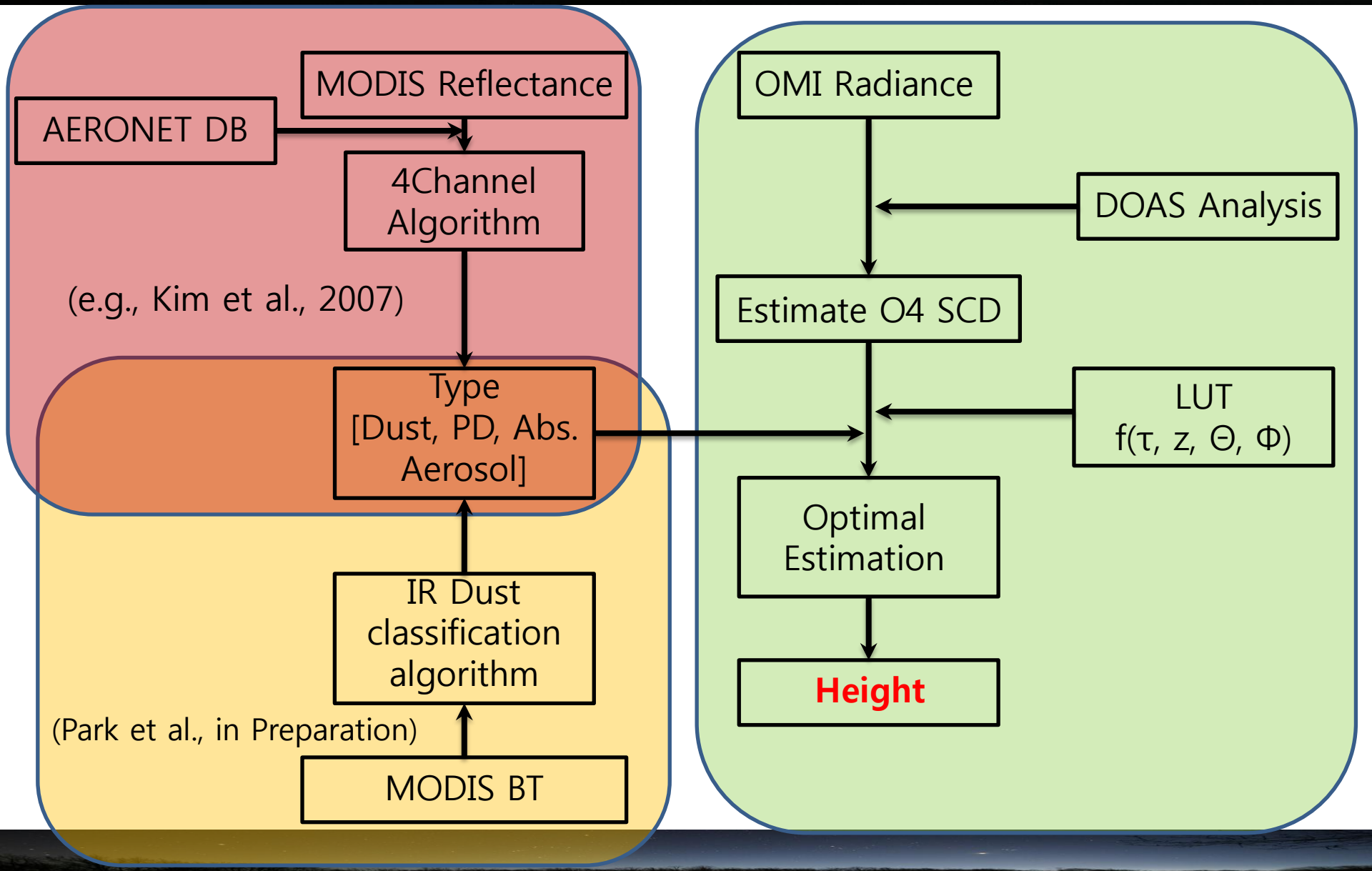
- Case : Z = 3km, AOD = 1.0

Difference of estimation [%]	340 nm	360 nm	380 nm	470 nm
MITR	0.00	0.00	-0.01	-0.01
WASO	0.40	0.29	0.26	0.16

- Case : Z = 1km, AOD = 1.0

Difference of estimation [%]	340 nm	360 nm	380 nm	470 nm
MITR	0.00	0.00	-0.01	0.00
WASO	0.30	0.21	0.19	0.12

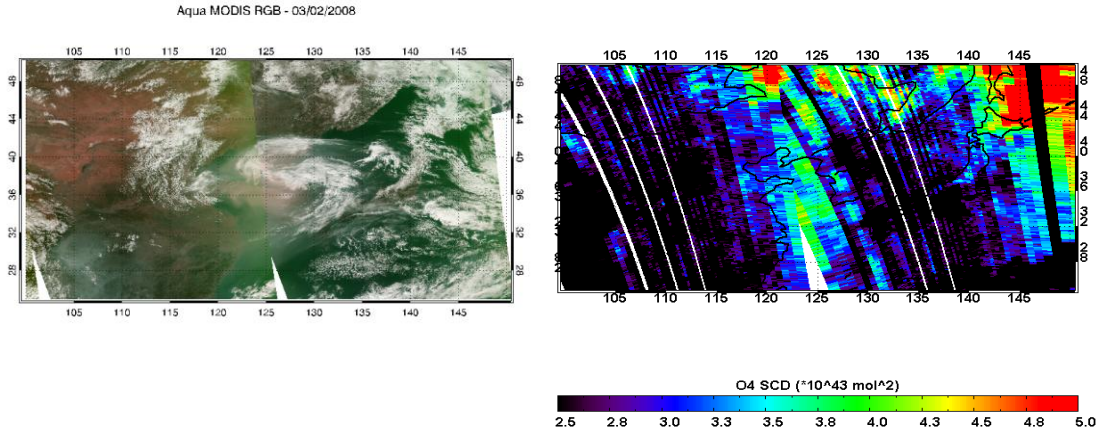
Flow chart of alpha version algorithm



Conclusion & Future Study

- O_4 retrieval over UV and VIS, the DOAS technique is useful for the aerosol height estimation based on space-borne measurements.
- The factors of fitting errors influence the estimation accuracy at 340 nm, but negligible at 360, 380 and 470 nm. However, 360 and 380 nm are insufficient for the height estimation.
- Effects of DOAS fitting and atmospheric gases and optics shift are found to be negligible for O4 SCD estimation at 470 nm. However, aerosol optical properties largely affect the O4 SCD estimation.
- Future Study

- Case studies over East Asia is being carried out after development of a Look-Up table between O4 SCD and aerosol height.



Thank you for your attention!