Improvement of radiation (sky radiometer) measurements system for providing GCOM-C1 validation data

Akihiro Yamazaki (PI)
E-mail: akyamaza@mri-jma.go.jp

Hiroshi Ishimoto (CI)

Akihiro Uchiyama (CI)

Meteorological Research Institute (MRI),

Japan Meteorological Agency (JMA)

Introduction

- Aerosol optical properties are very important in the studies of global and regional climate changes. SKYNET ground based observation network is well known aerosol-cloud monitoring network in East Asia which use sky radiometer (POM-01 or POM-02 manufactured by PREDE Co., Ltd.) for the purpose of aerosol radiative forcing studies. The aerosol optical properties which sky radiometer observes are retrieved by SKYRAD.PACK (Nakajima et al., 1996).

- We have installed sky radiometer in Tsukuba, Fukuoka, and Miyakojima, Japan.
- We improved SKYRAD.PACK version 4.2 and developed software to apply the inversion method to the maximum likelihood method (Kobayashi et al., 2006).

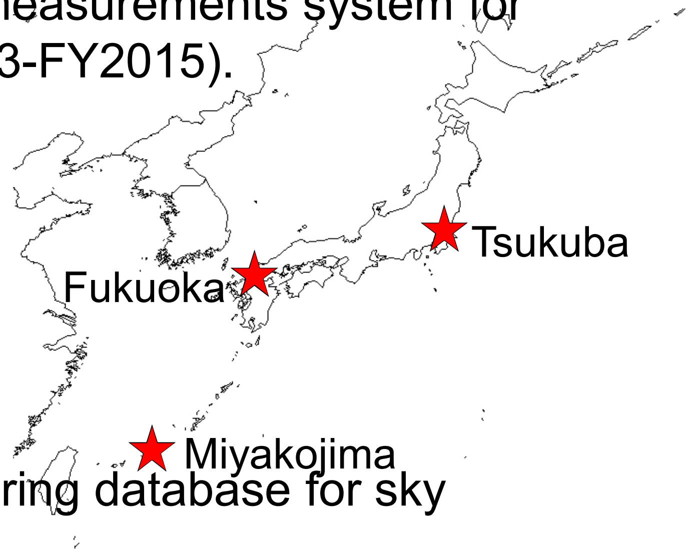
- Improvement of radiation (sky radiometer) measurements system for providing GCOM-C1 validation data.

Topics

- Research plan
- Calibration of sky radiometer
- Temperature dependency of sky radiometer
- Inter-comparison between calibration constants (VS_0 , VS_0TC and VI_0)
- Analysis of sky radiometer observed data by using our developed software (MRI-MLM). Dust event case.
- Future work

Research plan

- Improvement of radiation (sky radiometer) measurements system for providing GCOM-C1 validation data (FY2013-FY2015).
  - Observation site (sky radiometer)
    - Tsukuba
    - Fukuoka
    - Miyakojima (SKYNET)



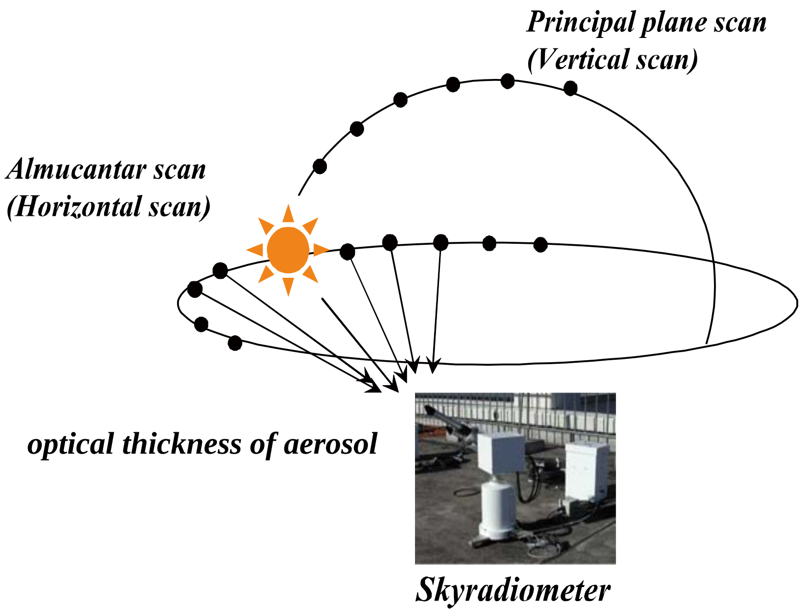
- Construction of non-spherical particle scattering database for sky radiometer (FY2013-FY2015).
  - Non-spherical particle scattering database is developed by Dr. Ishimoto (PI#211).

- Improvement of non-spherical particle scattering model (FY2015).

Sky radiometer POM-02

- Sky radiometer measure both direct solar flux and sky radiance.
  - Wavelength: 340, 380, 400, 500, 675, 870, 940, 1020, 1225, 1627, 2200 nm

- Retrieved aerosol optical properties by SKYRAD.PACK (Nakajima et al., 1996).
  - aerosol optical thickness (AOT)
  - volume size distribution
  - single scattering albedo (SSA)
  - complex refractive index



Calibration of sky radiometer

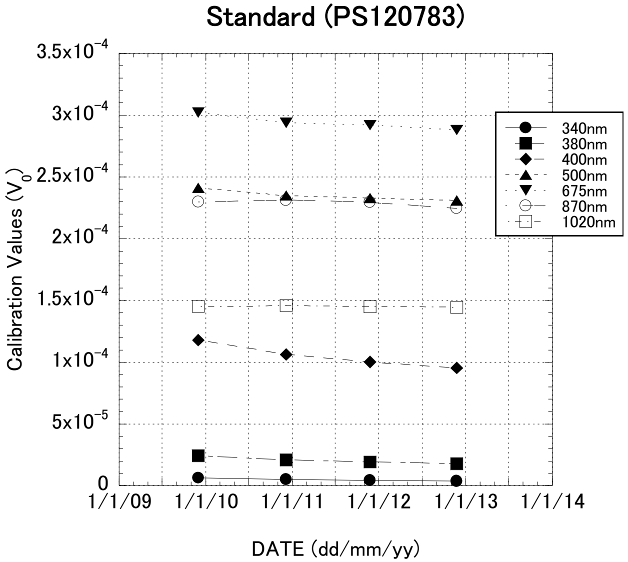
- MRI standard instruments are calibrated annually by the Langley method using the data obtained in Mauna Loa Observatory (MLO), NOAA ESRL-GMD.
  - JFY2013 2013/10/29 – 2013/11/25
- Standard sky radiometer POM-02 is calibrated in less than 1% error.
- Inter-comparison of sky radiometer in MRI.
  - JFY2013 2013/12/09 – 2014/01/04

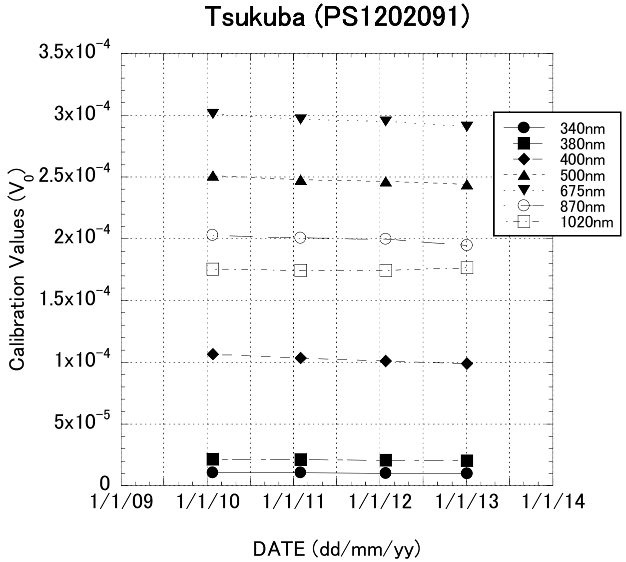
Standard sky radiometer POM-02 is calibrated in MLO.

Inter-comparison of sky radiometer

Calibration of sky radiometer

- Langley method
  - Standard : Calibration constant V_0 error < 1%
- Inter comparison
  - Tsukuba : Calibration constant V_0 error < 1%
- Temporal variation of calibration constant (V_0) : 3 years
  - Standard : 340〜400nm ≈ 5〜16% , 500〜1020nm ≈ 0.3〜5%
  - Tsukuba : 340〜400nm ≈ 6〜8% , 500〜1020nm ≈ 0.7〜4%



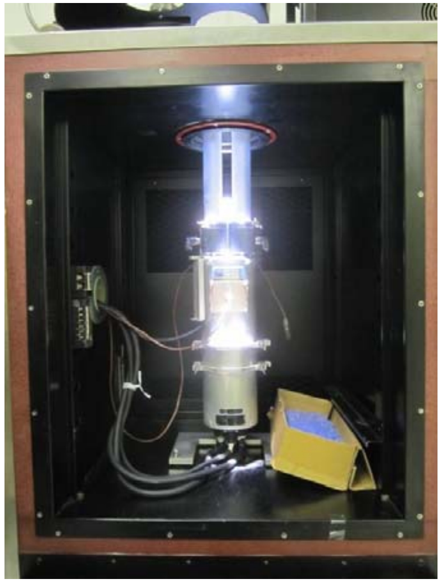


Relative temperature dependency of the sensitivity

We investigate temperature dependency of the sensitivity.

Sky radiometer POM-02 was tested in an ambient temperature range over 40 ºC down to -20 ºC using by Temperature control box irradiated by a light source of about 1 kW/m^2. Sky radiometer POM-02 monitors temperature of filter turret (TFT). The measurements are made in the steady state, and fixed TFT (Ambient T= 20ºC) is selected as the reference temperature.

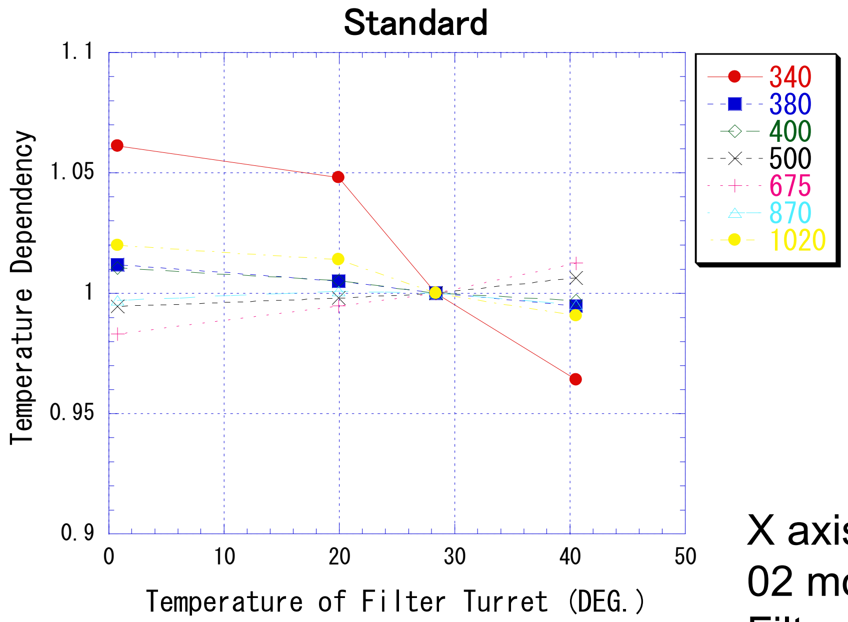
Temperature control box



Sensor of sky radiometer

Sky radiometer POM-02 monitors temperature of filter turret.

Relative temperature dependency of the sensitivity

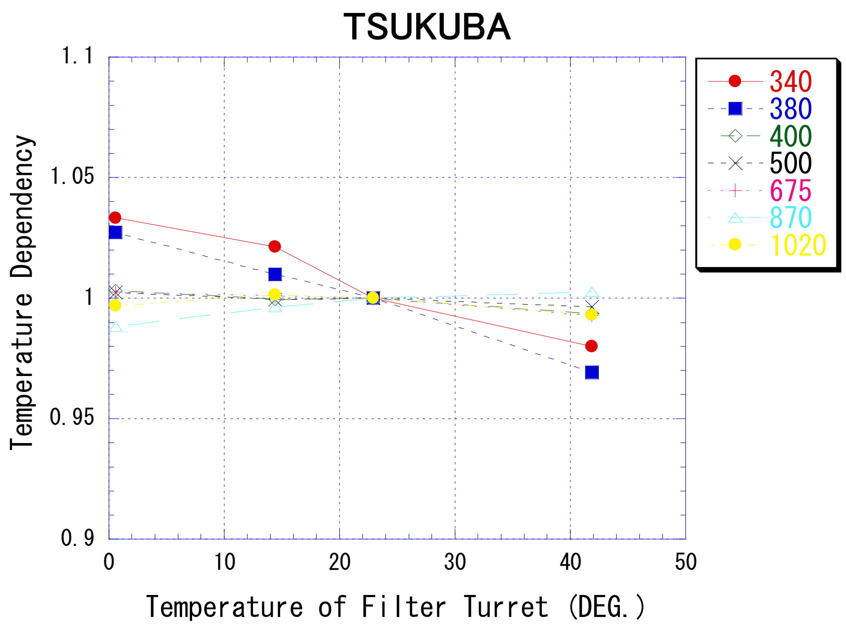


X axis : Sky radiometer POM-02 monitors Temperature of Filter Turret (TFT).

Standard sky radiometer

TFT(°C)	AT(°C)	340nm	380nm	400nm	500nm	675nm	870nm	1020nm
40.5	39.3	0.964	0.995	0.997	1.006	1.013	0.995	0.991
28.4	20.6	1.000	1.000	1.000	1.000	1.000	1.000	1.000
19.9	1.3	1.048	1.005	1.005	0.998	0.995	1.001	1.014
0.8	−17.9	1.061	1.012	1.010	0.995	0.983	0.997	1.020

Relative Temperature Dependency of the sensitivity



Tsukuba sky radiometer

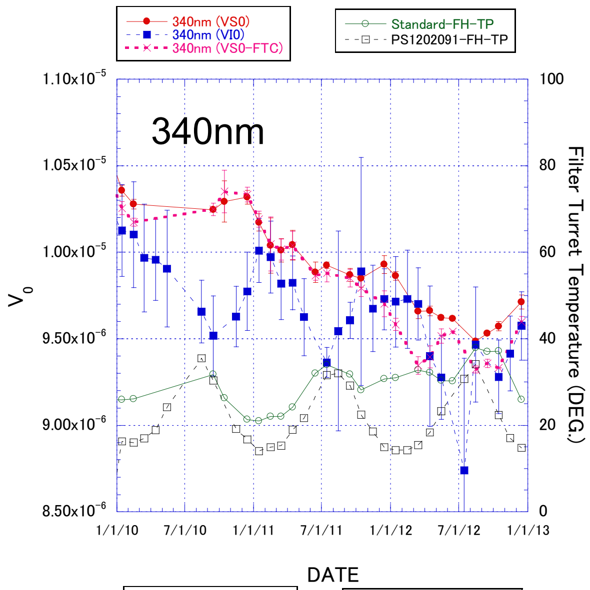
TFT(°C)	AT(°C)	340nm	380nm	400nm	500nm	675nm	870nm	1020nm
41.9	38.9	0.980	0.969	0.994	0.996	0.993	1.003	0.993
22.9	20.3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
14.4	0.5	1.021	1.010	0.999	0.999	1.001	0.996	1.001
0.6	−15.1	1.033	1.027	1.003	1.002	1.003	0.988	0.997

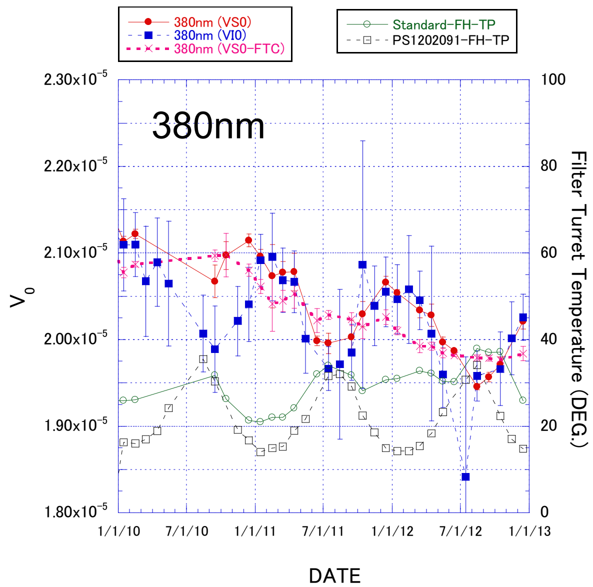
Inter-comparison between calibration constants (VS_0 , VS_0TC and VI_0)

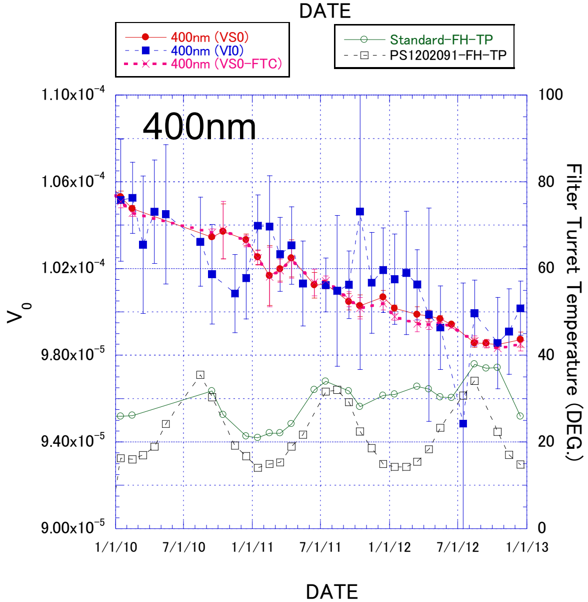
- Side-by-side inter-comparison between MRI standard and Tsukuba sky radiometer were conducted from 2010 to 2012.
- We investigate differences of calibration constant (VS_0), calibration constant takes into account temperature dependence of sensitivity (VS_0TC), and calibration constant retrieved by Improved Langley Method (VI_0).

- Improved Langley Method (VI_0) was proposed by Nakajima et al., 1996. Improved Langley method of calibration is based on data concerning both direct and diffuse radiation.

Temporal variation of VS_0, VS_0TC and VI_0



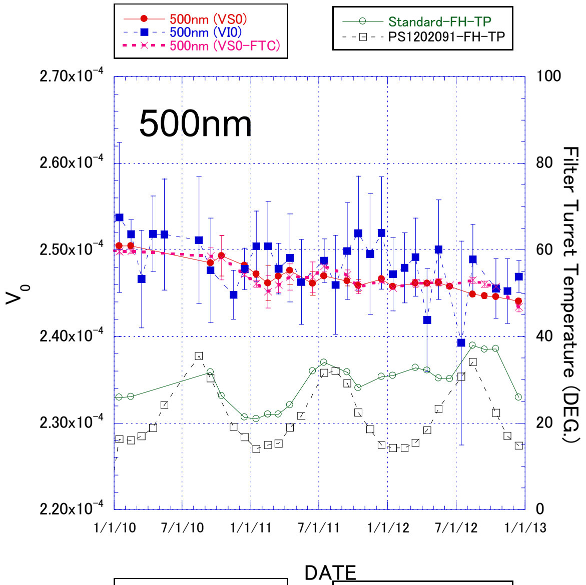


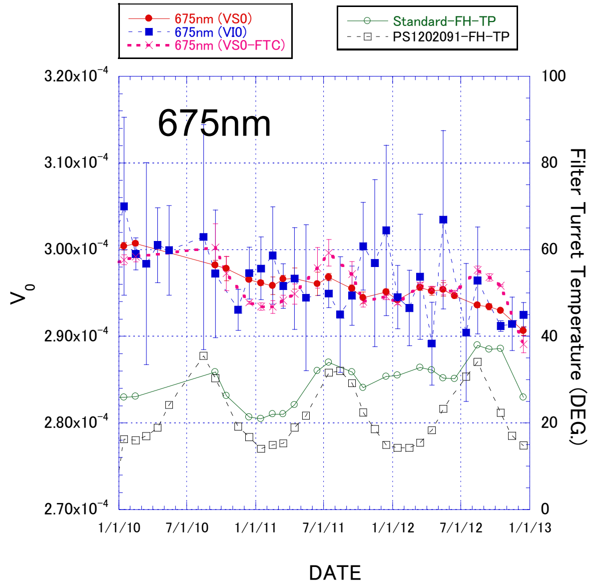


VS_0 (Red)
VS_0TC (Pink) : correction TP
VI_0 (Blue) : Improved Langley Method
Standard TFT (Green) : 12～34 ºC
Tsukuba TFT (Black) : 14～36 ºC

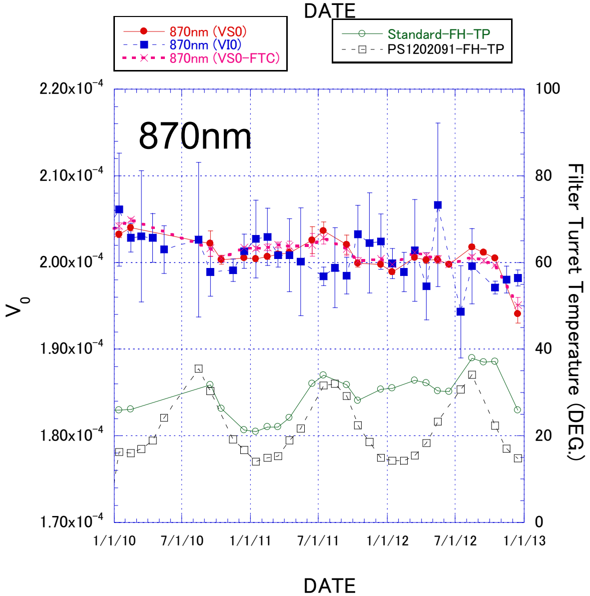
The variation in VI_0 at 340nm is larger than VS_0 and VS_0TC.

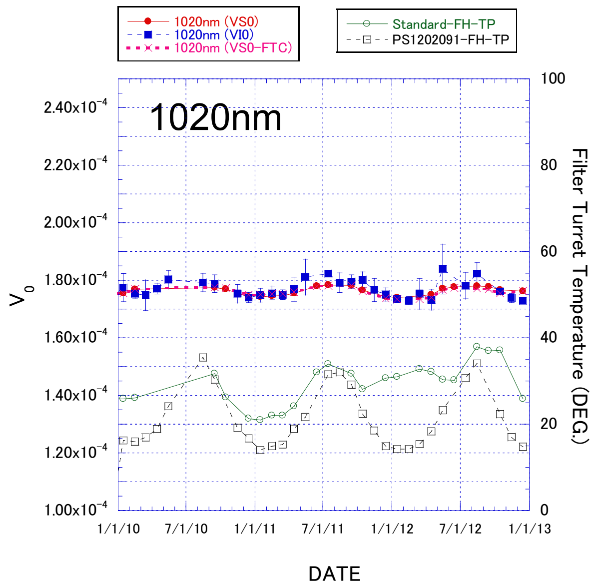
Temporal variation of VS_0, VS_0TC and VI_0





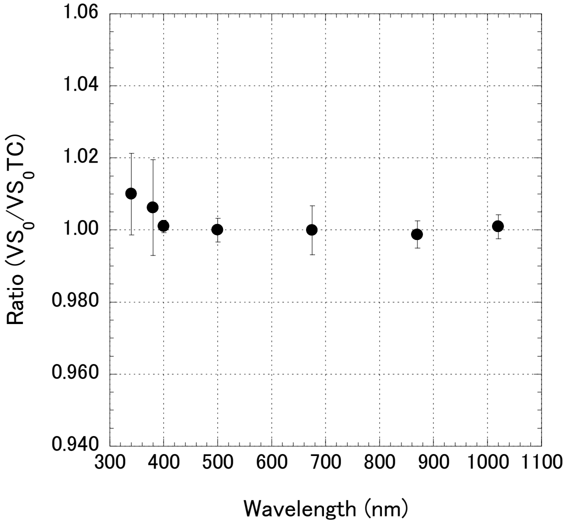
VS_0 (Red)
VS_0TC (Pink)
VI_0 (Blue)



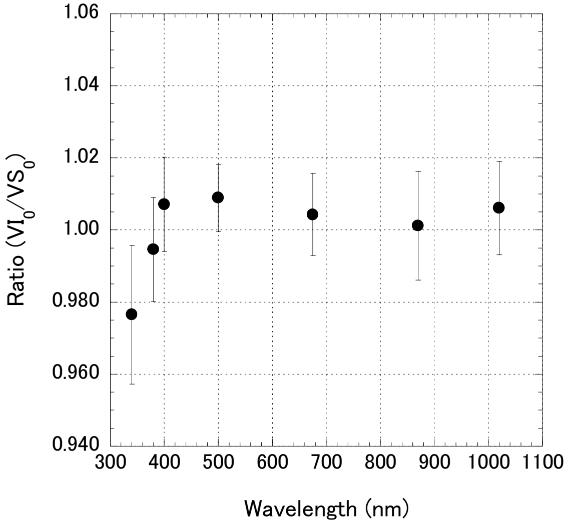


VS_0, VS_0TC and VI_0

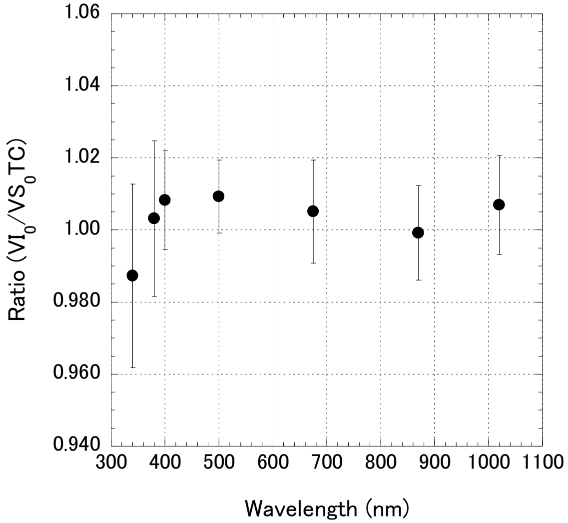
VS_0 / VS_0TC



VI_0 / VS_0



VI_0 / VS_0TC



VS_0 : Inter-comparison
VS_0TC : Inter-comparison (Temp. corrected)
VI_0 : Improved Langley method

	340nm	380nm	400nm	500nm	675nm	870nm	1020nm
Ratio (VS_0 / VS_0TC)	1.010	1.006	1.001	1.000	1.000	0.999	1.001
RMS (VS_0 − VS_0TC)	0.012	0.012	0.002	0.003	0.005	0.003	0.003
Ratio (VI_0 / VS_0)	0.977	0.995	1.007	1.009	1.004	1.001	1.006
RMS(VI_0 − VS_0)	0.022	0.011	0.011	0.009	0.009	0.011	0.010
Ratio (VI_0 / VS_0TC)	0.987	1.003	1.008	1.009	1.005	0.999	1.007
RMS(VI_0 − VS_0TC)	0.021	0.016	0.012	0.010	0.011	0.010	0.011

Observation site

- Meteorological Research Institute (MRI) in Tsukuba, JAPAN
- 36.056N,140.125E (Tsukuba is 60km away from Tokyo.)
- 25m ASL

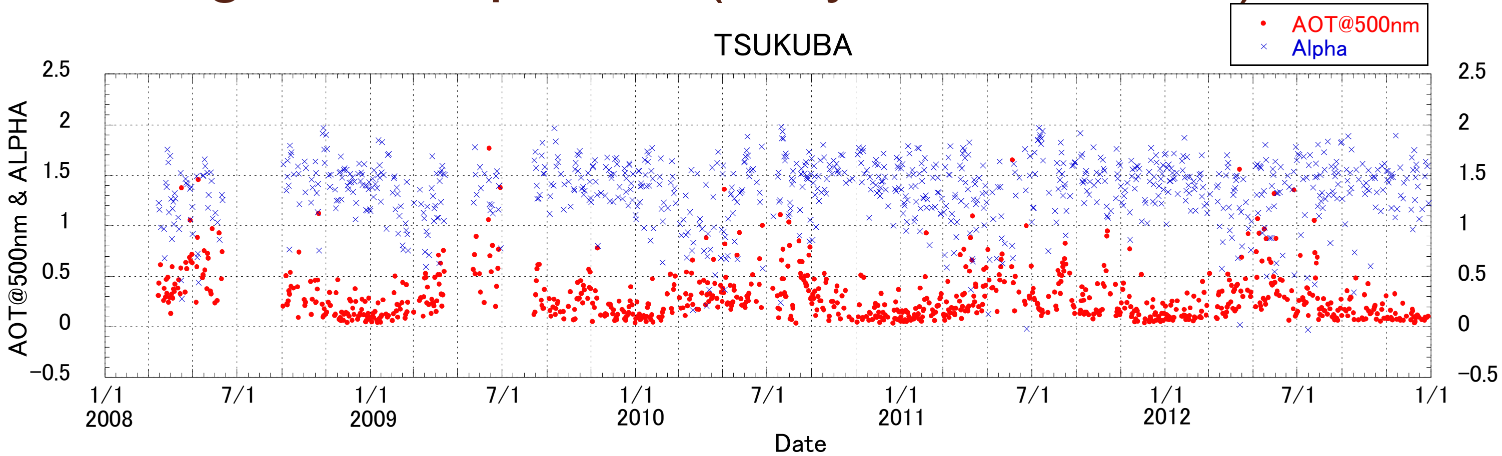
- Skyradiometer POM-02
  (PREDE Co., Ltd.)

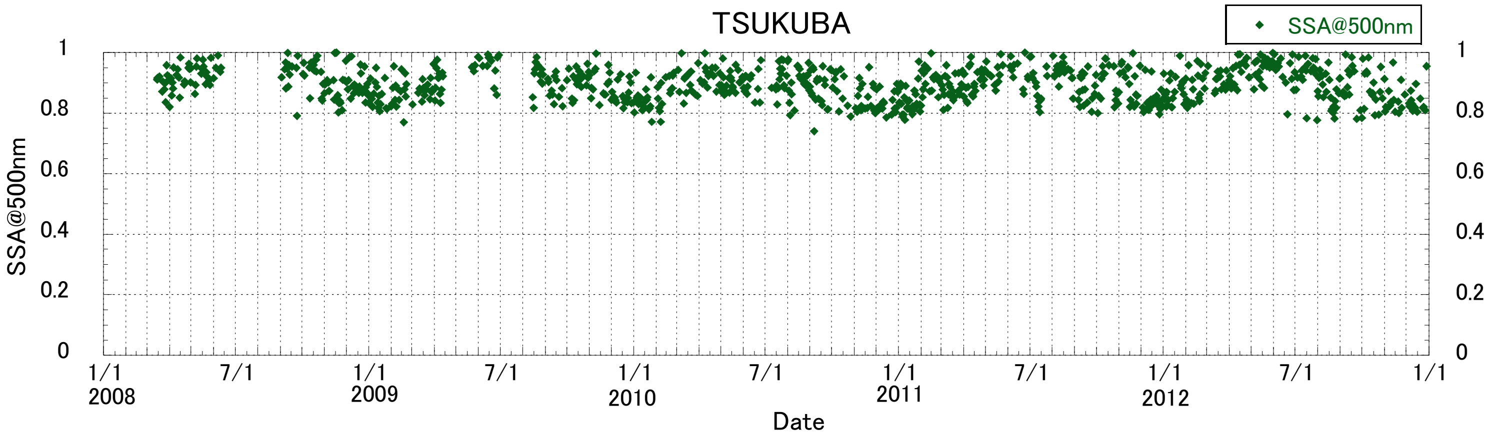
Data analysis

- Software
  - MRI-MLM version 1.1 (improved SKYRAD.PACK version 4.2 and developed software to apply the inversion method to the maximum likelihood method by MRI (Kobayashi et al., 2006).)
- Cloud screening
  - CSSR ("Cloud Screening of Sky Radiometer data" developed by SKYNET) version 1.1 (Khatri and Takamura, 2009)
- Calibration constant (V_0) for direct radiation
  - Compared with MRI standard instrument calibrated annually by the Langley method using the data obtained in Mauna Loa Observatory (MLO), NOAA ESRL-GMD
- Meteorological DATA
  - Surface pressure and the total ozone amount in Tsukuba (Aerological Observatory close to MRI)

Temporal variation of Aerosol optical thickness (AOT@500nm), single scattering albedo (SSA@500nm), Ångström exponent in Tsukuba from 2008 to 2012.

AOT@500nm, SSA@500nm, and Ångström exponent (daily mean values)





Seasonal variation

AOT@500nm is increasing in summer and decreasing in winter.

Ångström exponent is decreasing in summer and increasing in winter.

SSA@500nm is decreasing in winter.

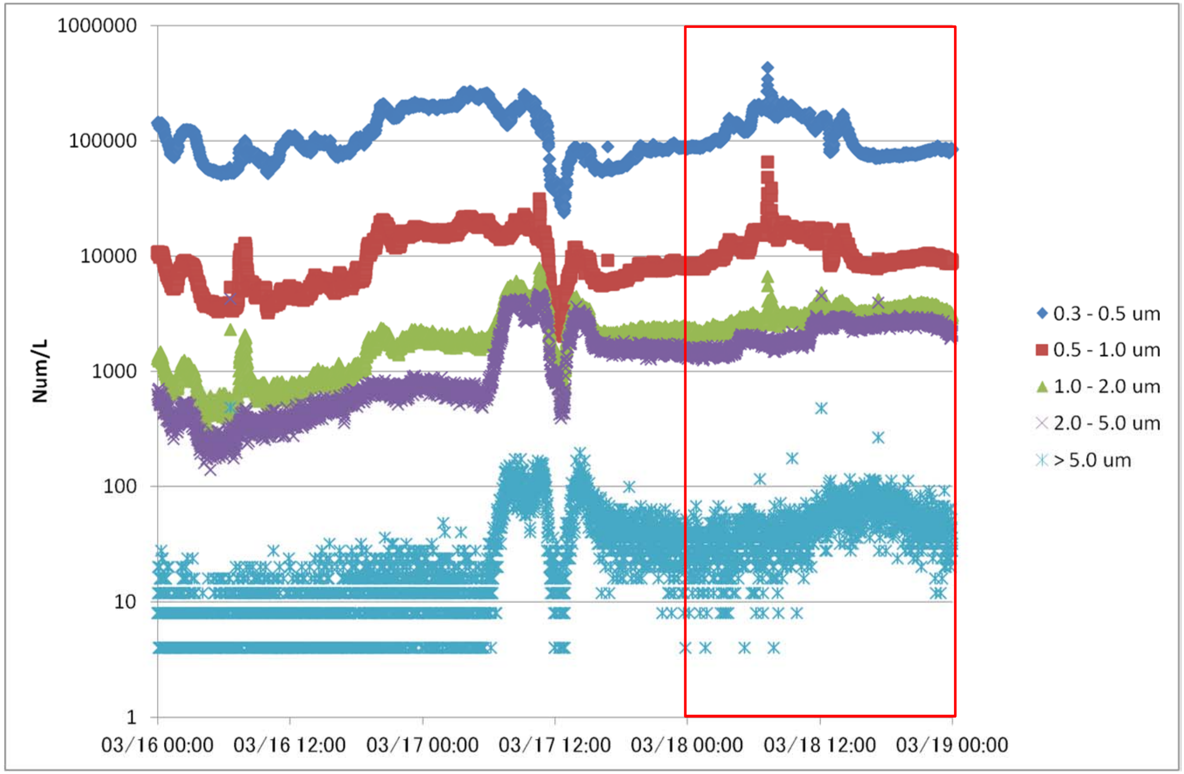
Case study

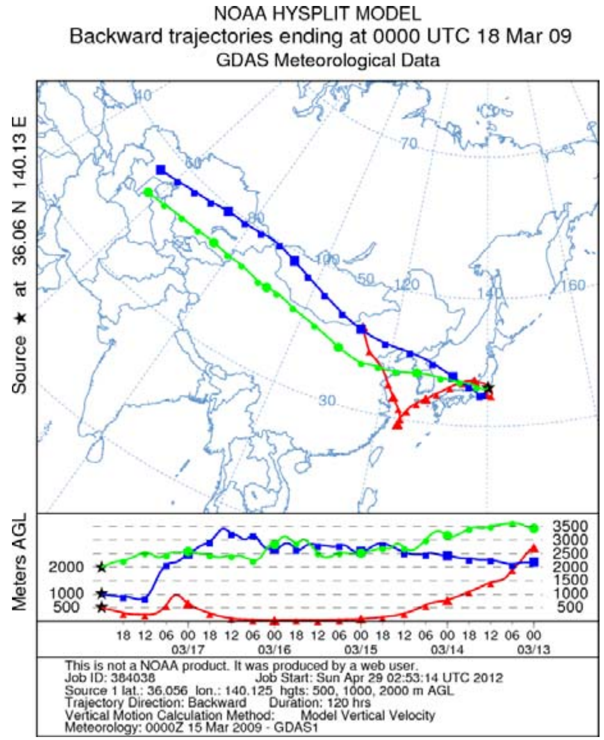
The analysis of using sphere (Mie theory) and spheroid model.

We improved MRI-MLM (Kobayashi et al., 2010) to use spheroid model (Dubovik et al.(2006)) .

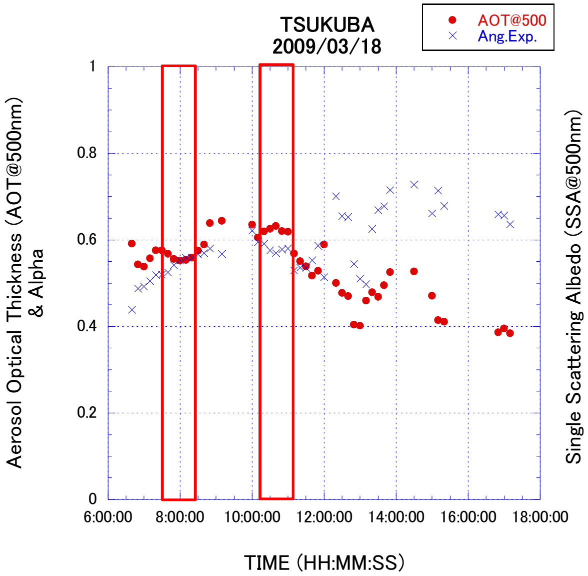
Case study (Dust event: Tsukuba, 2009/03/18)

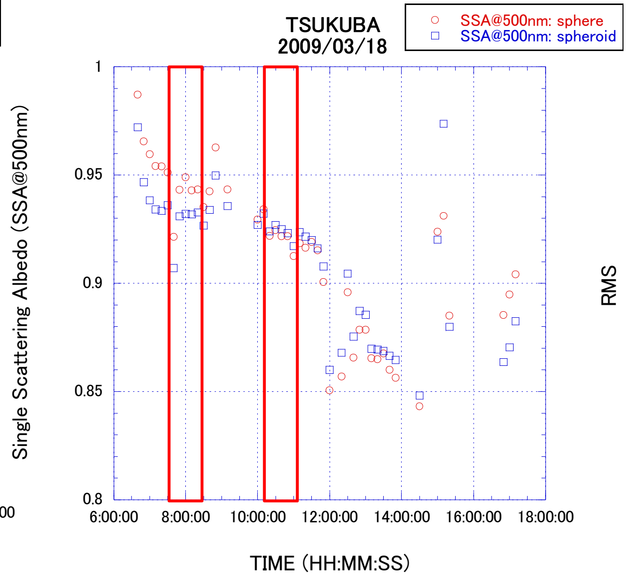
OPC RION KC-01D

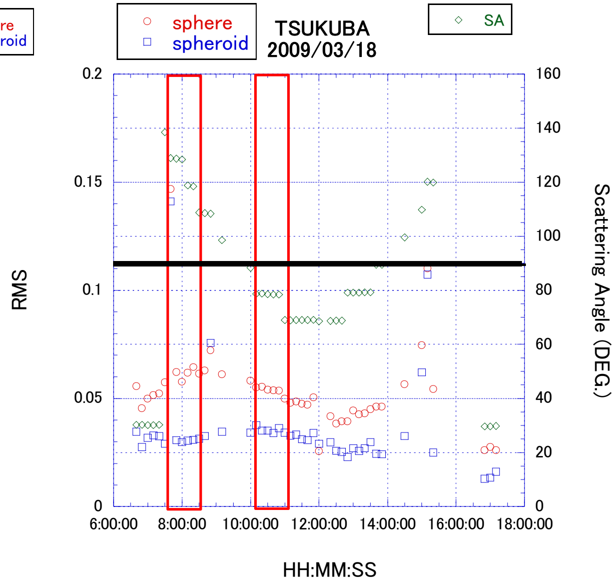




Case study (Dust event: Tsukuba, 2009/03/18)







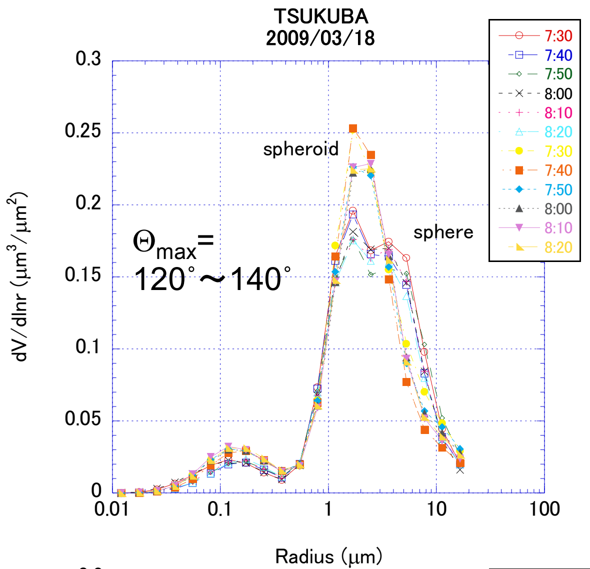
・AOT@500nm (Red)
・Alpha (Blue)

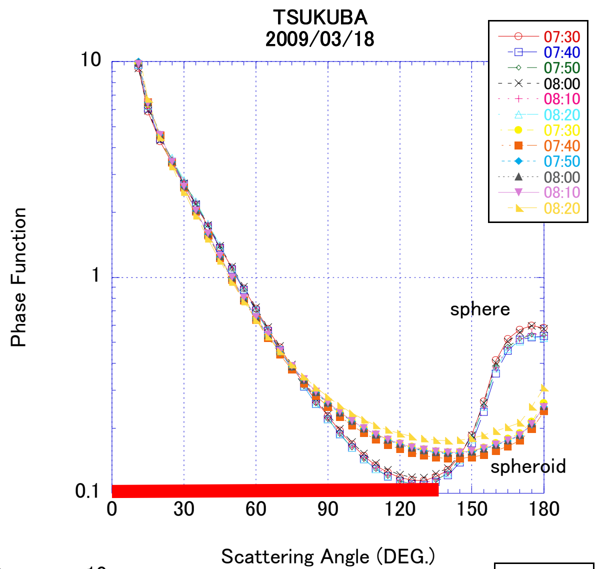
・SSA@500nm
Sphere (Red)
Spheroid (Blue)

・ RMS deviation between OBS and retrieved $R(\Theta,\lambda)$
Sphere (Red)
Spheroid (Blue)
・OBS maximum scattering angle

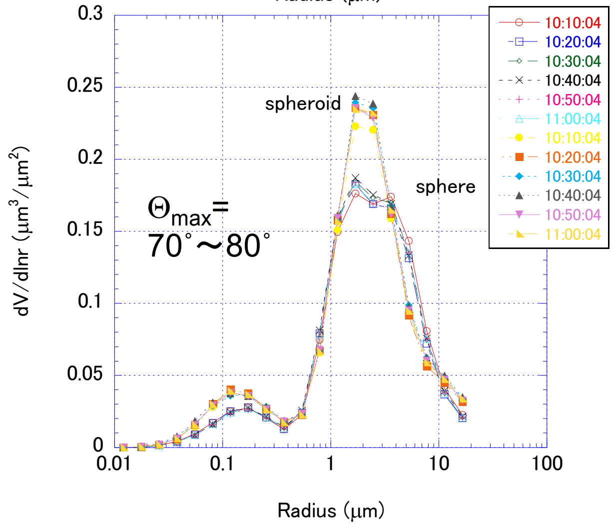
RMS : $\Theta_{max} > 90^o$, the RMS of the sphere is larger than that of $\Theta_{max} < 90^o$.
SSA@500nm : $\Theta_{max} > 90^o$, differences of SSA@500nm between the sphere and the spheroid are large.

Case study (Dust event: Tsukuba, 2009/03/18)

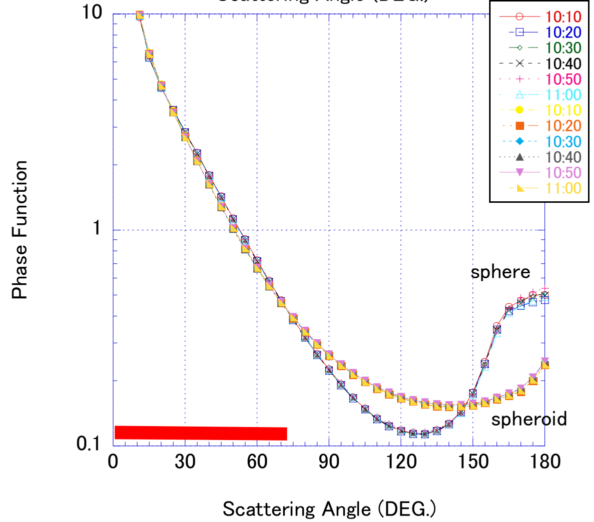




The differences of retrieved phase function between the sphere and the spheroid are large at Θ > 90º.



▪Volume-size distribution



▪Phase function

The information about the backscattering angle range is important for accurate analysis of aerosol optical properties (sphere or non-sphere).

Summary

- MRI standard sky radiometer is calibrated by the Langley method using the data obtained in MLO. And Tsukuba sky radiometer is calibrated by inter-comparing it to the standard instrument.
  - Calibration values (V_0) : Differences / 3years
    - Standard : 340～400nm ≈ 5～16% , 500～1020nm ≈ 0.3～5%
    - Tsukuba : 340～400nm ≈ 6～8% , 500～1020nm ≈ 0.7～4%

    - Transmittance of lens in UV region was deteriorating.

      ➡ Exchange to the new lens has been completed.

- Relative temperature dependency of the sensitivity
  - Temperature dependencies of standard and Tsukuba sky radiometer are less than 1%, at 400, 500, and 675nm.
  - Another wavelengths
    - Standard : less than 6 %
    - Tsukuba : less than 4%

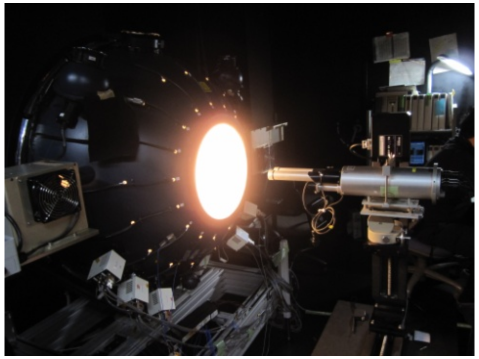
Summary

- We investigate differences of calibration constant VS_0, VS_0TC takes into account temperature dependence of sensitivity, and calibration constant retrieved by Improved Langley Method (VI_0).
  - RMS of VS_0 - VS_0TC is less than 0.012.
  - RMS of VI_0 - VS_0 and VI_0 - VS_0TC are less than 0.022 and 0.021, respectively.

- Retrieval results of dust event case
  - It is important to use the sky radiance data that covers a wide range of scattering angles (greater than 90°) in order to accurately estimate the effect of dust-like aerosol (non spherical particles).

Future work

- Calibration of sky radiometer using an integrating sphere.
  - A sensitivity calibration of sky radiometer was performed using an integrating sphere belonging to JAXA in December 26, 2013.
  - Need to evaluate calibration data.



JAXA integrating sphere
(2013/12/26)

- Analysis of sky radiometer observation data installed in Tsukuba, Fukuoka, Miyakojima in JAPAN and sufficient investigation of aerosol optical properties retrieved by spherical and non-spherical shapes aerosol model.

- Construction of non-spherical particle scattering database for sky radiometer.
  - Non-spherical particle scattering database is developed by Dr. Ishimoto (PI#211).

Thank you for your attention!

References

1) Nakajima, T., Tonna, G., Rao, R., Holben, B.N.: Use of sky brightness measurements from ground for remote sensing of particulate polydispersions, Appl. Opt., 35, 2672–2686, 1996.
2) Kobayashi, E., Uchiyama, A., et al.: Application of the Statistical Optimization Method to the Inversion Algorithm for Analyzing Aerosol Optical Properties from Sun and Sky Radiance Measurements, J. Meteor. Soc. Japan,Vol. 84, No.6, 1047-1062, 2006.
3) Khatri, P. and Takamura, T.: An Algorithm to Screen Cloud-Affected Data for Sky Radiometer Data Analysis, J. Meteor. Soc. Japan, Vol. 87, No. 1, 189-204, 2009.
4) Kobayashi E, Uchiyama A, Yamazaki A and Kudo R. Retrieval of Aerosol Optical Properties Based on the Spheroids Model. J. Meteor. Soc. Japan; Vol. 88: No.5, Doi:10.2151/jmsj.2010-505, 2010.