Reply to comments

We would like to thank you for reading our manuscript and commenting on it.

The comments are copied and shown below in italic.

Comment.

Anonymous Referee #2

Received and published: 1 May 2018

The paper describes in-field and laboratory calibrations of POM-02 sky radiometers used by SKYNET aerosol Network. The first method includes Langley-plot "zero airmass" intercept determination at high altitude Mauna Loa observatory for the POM-02 (Calibration reference) instrument with following calibration transfer to other instruments on-site (e.g., at Tsukuba site). The second on-site calibration method includes Improved Langley calibration (IML), without using reference instrument. Temperature effect on the calibration constant is shown to be important in the UV (340nm and 380nm) and shortwave infrared (2200nm) spectral channels. The temperature sensitivity varies for different instruments. The temperature effect on visible and NIR channels is generally small (< 0.5% for a typical temperature range).

The paper is of general interest for ground-based aerosol measurement community and could be published after major revision.

General comments:

The main manuscript should be clarified focusing on main conclusions, while supporting material (technical details, tables and plots) could be moved to the supplement.

Clarify calibration adjustment to account for changing sun-Earth distance.

English should be improved.

References need to be updated.

Figure quality needs improvements

==>

Reply

We wrote a lot of things, so the contents are discursive. However, one of the reviewers requested more explanations. In the first revision, we would like to keep it as it is now. Also, since there was nothing we wrote about our Langley method, we would like to write it in the main text.

Before submitting the final version, we will receive corrections in English by native speaker of English.

We attach slightly enlarged figures to the revised manuscript.

Specific comments:

Describe how spectral response functions were measured.

==>

Reply

We have not measured the spectral response function of the filter by ourselves.

When we purchased POM-02, we requested the manufacturer to attach a response function as material.

The nominal specifications of the response functions are shown in Table 1.

Table ### Nominal filter specification

Channel No.	Wavelength (nm)	FWHM(nm)	Max. Transmittance	Blocking	Blocking wavelength	Detector
–	315(±0.6nm)*	3.0(±0.6nm)	>30%	$1.0x10^{-5}$	200 – 1200 nm	Si photodiode
1	340(±0.6nm)	3.0(±0.6nm)	>30%	$1.0x10^{-5}$	200 – 1200 nm	Si photodiode
2	380(±0.6nm)	3.0(±0.6nm)	>30%	$1.0x10^{-5}$	200 – 1200 nm	Si photodiode
3	400(±0.6nm)	10.0(±2.0nm)	>30%	$1.0x10^{-5}$	200 – 1200 nm	Si photodiode
4	500(±2.0nm)	10.0(±2.0nm)	>30%	$1.0x10^{-5}$	200 – 1200 nm	Si photodiode
5	675(±2.0nm)	10.0(±2.0nm)	>30%	$1.0x10^{-5}$	200 – 1200 nm	Si photodiode
6	870(±2.0nm)	10.0(±2.0nm)	>30%	$1.0x10^{-5}$	200 – 1200 nm	Si photodiode
7	940(±2.0nm)	10.0(±2.0nm)	>30%	$1.0x10^{-5}$	200 – 1200 nm	Si photodiode
8	1020(±2.0nm)	10.0(±2.0nm)	>30%	$1.0x10^{-5}$	200 – 3000 nm	Si photodiode
9	1225(±2.0nm)**	20.0(±2.0nm)	>30%	$1.0x10^{-5}$	600 – 3000 nm	InGaAs photodiode
10	1627(±2.0nm)	20.0(±2.0nm)	>30%	$1.0x10^{-5}$	600 – 3000 nm	InGaAs photodiode
11	2200(±2.0nm)	20.0(±2.0nm)	>30%	$1.0x10^{-5}$	600 – 3000 nm	InGaAs photodiode

FWHM : Full Width at Half Maximum

* : 315 nm channel is not used by JMA/MRI.

** : 1225 nm channel is used by JMA/ MRI.

Replace "near-infrared" with "shortwave infrared": for > 1-micron channels

==>

Reply

We replaced "near-infrared" with "shortwave-infrared".

Suggest replacing "SVA" with commonly used Field of View (FOV)

==>

Reply

We use the term SVA for the magnitude value of FOV.

The term SVA was used in Nakajima et al. (1996), and it is familiar to users of POM-02.

We gave the following explanation to the term SVA after line 71.

"According to Nakajima et al. (1996), this paper uses SVA as a term representing the magnitude value of the field of view."

Improved Langley method (IML) should be clearly explained – see comments L359-379

==>

Reply

Please see below.

L21: indicate temperature climatology in Tsukuba

==>

Reply

We added location information and range of monthly mean temperature.

" at Tsukuba ((36.05°N, 140.13°E), the range of monthly mean temperature 2.7 to 25.5° C)."

L23: Is this accuracy at Tsukuba or Mauna Loa?

==>

Reply

It is at Mauna Loa.

We rewrote the sentence.

L25: quantify V0 uncertainty in UV-VIS-NIR and degradation (V0 time drift?)

==>

Reply

We added the value of time degradation

"The degradation of V_0 for shorter wavelengths (−10 to −4% per year) was larger than that for longer wavelengths (−1 to nearly 0% per year)."

L26: Clarify that this is accuracy of calibration transfer only during best stable atmospheric conditions. Indicate time intervals for calibration transfer

==>

Reply

We rewrote as follows.

"The coefficient of variation (CV, standard deviation/mean) of V_0 transferred from the reference POM-02 was 0.1 to 0.5%. Here, the data was simultaneously taken every 1 minute on a fine day, and data with an airmass less than 2.5 were compared."

L33: change to short infrared

==>

Reply

We replaced "near-infrared" with "shortwave-infrared".

L35: this sentence does not belong to the abstract

==>

Reply

We rewrote sentences in line 31 to 37 as follows.

"The modified Langley method was attempted to calibrate the 940 nm channel using onsite measurement data. The difference from V_0 based on the Langley method of V_0 was better than 1% on selected stable and fine days. The General method was also attempted to calibrate the shortwave-infrared channels (1225, 1627, and 2200 nm) using onsite measurement data. The differences from V_0 based on the Langley method of V_0 were 0.8, 0.4 and 0.1% in December 2015, respectively."

L37: Quantify accuracy for each channel.

==>

Reply

Please see above.

L59: Column average effective aerosol characteristics∶∶∶

＝＝＞

Reply

We replaced with “aerosol characteristics” with “column average effective aerosol characteristics”.

L68: add references

＝＝＞

Reply

We add reference.

L71: SVA is usually called Field of View (FOV)

＝＝＞

Reply

We use the term SVA for the magnitude value of FOV.

The term SVA was used in Nakajima et al. (1996), and it is familiar to users of POM-02.

We gave the following explanation to the term SVA after line 71.

“According to Nakajima et al. (1996), this paper uses SVA as a term representing the magnitude value of the field of view.”

L74: Provide instrumental reference.

＝＝＞

Reply

We add instrumental reference.

L135: which temperature sensor is used to start the heater?

＝＝＞

Reply

We added “near the rotating filter wheel” after “the temperature”.

L136: "... the instrument is heated: ..." – to what temperature? When does the heater stop ?

==>

Reply

We added the following sentence after line 136.

"When the temperature exceeds the threshold, heating is stopped."

L139: use "shortwave infrared"

==>

Reply

We replaced "near-infrared" with "shortwave-infrared".

L142: inside temperature[s]?

==>

Reply

We replaced "inside temperature of instrument" with "temperature near the rotating filter".

L146, Fig 1: Explain why if the temperature control setting was 20C , the inside temperature was 30C when the ambient temperature was 20C?

==>

Reply

We added the following sentences to the explanation of Fig. 1 after line 145.

"Since heat is generated from the electric circuit inside the POM-02, the internal temperature exceeds 20 °C even if the ambient temperature is less than 20 °C. The heater stops when the inside temperature of the POM-02 exceeds 20 °C. However, since there is no cooling function, the temperature inside the POM-02 rises as the ambient temperature increases. When the ambient temperature is very low, the temperature does not rise to 20 °C because the heater capacity is insufficient. For example, when the ambient temperature was about −20 °C, the internal temperature was about 0 °C."

L153: : : : wavelengths shorter than 1020nm : : :

＝＝＞

Reply

We rewrote it.

L 157 "near-infrared region" – common name is "shortwave -infrared region"

＝＝＞

Reply

We replaced "visible" with "visible and near-infrared"

And, we replaced "near-infrared" with "shortwave-infrared"

L161: "change in the temperature less than 1.5%" -> "change in the instrument response less than 1.5%"?

＝＝＞

Reply

We replaced "the temperature" with "the instrument response".

L188, Fig.4: Specify units in Y axis , e.g. counts per second? – this is usually a large number: explain scaling.

＝＝＞

Reply

The unit of data recorded in the file is A.

We redrew Figure 4.

L197-248, Table 1: Explain units for calibration constant (V0) ? Table 1: Explain if correction for changing Sun-Earth distance was applied to daily V0s?.

＝＝＞

Reply

We added unit.

We explained in the text that the calibration constant is the output of the radiometer to the extra-terrestrial solar irradiance at the mean earth-sun distance (1AU).

L204 The [standard] error

==>

Reply

SD/Mean is called coefficient of variation or relative standard deviation.

"ERR" is not appropriate.

We replaced "error" with "CV".

L210 "is large ∴∴" – quantify

==>

Reply

We rewrote line 210 and 211 as follows.

"Based on the ratio of (GABS,NTPC)/(GBAS,TPC) (= (Case 3)/(Case 4)), the effect of the temperature dependence on the 340 and 2200 nm channels were about 3 and 5%, respectively."

L222" without consideration of the temperature ∴∴" –for MLO conditions only

==>

Reply

We inserted the following sentence after line 223.

"The results shown here are the results obtained using the data taken at MLO."

L233"was replaced" -> were replaced

==>

Reply

We do not think that "The lens" is a plural form.

L240: What are reasons for such large V0 changes ?

==>

Reply

We are only users of POM-02. Not all information is received from the manufacturer of POM-02. Therefore, I do not know the reason for clear. We showed the fact that V0 tended to change over time. Users of POM-02 should be aware of this.

L244: It would be useful to show monthly V0 values (corrected for sun-Earth distance) in fig.5.

==>

Reply

V0 shown in Fig. 5 is the output of the radiometer to the extra-terrestrial solar irradiance at the mean earth-sun distance (1 AU).

L250: "Accuracy of [V0 calibration] transfer by direct solar measurement"

==>

Reply

We rewrote it.

L267 5. Improved Langley method - Add paragraph describing IML here

==>

Reply

At the beginning of section 5, we moved most of section 5.2.

L289 IML value[s]

==>

Reply

We rewrote it.

L295: delete "by"

==>

Reply

We deleted "by".

L330 layer -> atmospheric column optical thickness

==>

Reply

We replaced “layer” with “atmospheric column”.

L322 5.2 Review of Improved Langley method – move this section up after L267

==>

Reply

We moved most of this section to the beginning of section 5.

The description related to Figure 9 was moved to Section 5.1.

L325 The solar direct irradiance at the surface [normal to the solar beam]

==>

Reply

We inserted “normal to the solar beam”.

L330 zenith angle, and [tau] is the layer optical thickness. – total atmospheric optical thickness (Rayleigh plus aerosol plus gases)

==>

Reply

We replace “layer optical thickness” with “total atmospheric optical depth”

331 The single scattering by aerosol in the almucantar - replace “by aerosol plus molecular (Rayleigh) scattering in the almucantar “

==>

Reply

We replaced “aerosol” with “aerosol and molecular “.

L340 direct solar [voltage] measurement

==>

Reply

We rewrote the sentence as follows.

“The sensor output for the direct solar measurement can be written as follows.”

L341: Equation (3) neglects forward scattered radiation into the FOV

＝＝＞

Reply

We are writing in the text (line 342 and 343) that the contribution of scattered light in the field of view is ignored.

L341-345: Equations (3) and (4) should include Earth-sun distance (see eq. (19))

＝＝＞

Reply

We included earth-sun distance in eq. (3) and (4).

We also rewrote eq. (1) and (2) and F0 is the value at 1 AU.

L353: Explain how tau or tau_scat can be obtained independently from the V0 ?

＝＝＞

Reply

tau and tau_sca can be obtained from eq. (5) and (6).

In the SKYRAD package, in the retrieval process for the Improved Langley method the single scattering and multiple scattering components are estimated by solving the radiative transfer equation. Once the single scattering component is retrieved, tau and tau_sca can be estimated (see eq. 10).

L359:Explain how tau is obtained ?

L360: Explain how tau_scat is obtained?

＝＝＞

Reply

The method for obtaining tau and tau_sca is the IML method.

For details, please see the original paper Tanaka et al. (1886) and Campanelli et al. (2004).

L367: SVA ->FOV (common name)

==>

Reply

See above.

L368: ".. is the [radiometer output (voltage) due to] direct solar irradiance [at the surface]

==>

Reply

We inserted "radiometer output due to".

*L375: "Once the single scattering component is retrieved, m*tau and m*tau_scat are estimated" - Solving radiation transfer equation is only possible if tau, Phase function and tau_scat are known. Explain how tau, P(scat) and tau_scat are obtained?*

What are introduced uncertainties due to assumptions about unknown aerosol refractive index, size distribution, modeling of aureole forward scattered radiation?

==>

Reply

In this paper, we briefly explained the principle of IML method.

For details, please see Tanaka et al. (1986), Campanelli et al. (2004) and Skyrad package itself.

We rewrote sentences between line 373 and 378 as follows.

"In the SKYRAD package, given initial value of column particle volume size distribution $dV/d\log r$ and complex refractive indexes, τ, $P(\cos\Theta)$, and ω_0 are calculated. On the basis of these single scattering properties, the multiple scattering term (second term on the right side) in eq. (10) is evaluated, and the single scattering term (first term on the right sides) in eq. (10) can be obtained. The new $dV/d\log r$ is retrieved from the single scattering term in eq. (10) by the inversion scheme. Using the retrieved $dV/d\log r$, τ, $P(\cos\Theta)$, and ω_0 are calculated, and reconstruct the observed values, and then the error is calculated. Until the error satisfies convergence condition, the above procedure is iterated. In the above procedure, the complex refractive indexes for each channel are fixed and the measurement data with a scattering angle of less than 30 degrees are used."

*L379 "Once m*tau is obtained," – explain how tau is obtained before knowing calibration constant V0? Is another co-located radiometer used to derive tau?*

==>

Reply

Please see above.

L380-381 do not use capital for single scattering albedo: W0

==>

Reply

The single scattering albedo must be a value between zero and one. However, W_0 is frequently greater than 1. Therefore, it is only a constant for fitting. To distinguish between ω_0 and W_0, W_0 was used.

We replace sentences between line 380 and 384 with the following sentences.

"$\ln V_0$ is determined by fitting to $\ln V = \ln V_0 - m\tau_{sca}/W_0$. Comparing this equation with eq. (8), W_0 must be single scattering albedo. The single scattering albedo is defined as the ratio of the scattering coefficient to the extinction coefficient. Therefore, the single scattering albedo must be a value between zero and one. However, W_0 is frequently greater than 1. Therefore, it is only a constant for fitting. To distinguish between ω_0 and W_0, W_0 was used."

L384 "W0 is frequently greater than 1." – are these unphysical retrievals used for calibration?

==>

Reply

There seems to be something wrong with the Skyrad Package procedure.

We focus only on pointing out that there are problems.

Solving the problem is a future task.

L387 Figs. -> Fig.9

==>

Reply

We fixed it.

L389 "V0 values with errors less than 0.01" – Is this error in ln(V0) ?

==>

Reply

We add the explanation of "error".

L393, Fig9(c): In this plot was V0 corrected for the changing sun-Earth distance?

==>

Reply

We redrew Fig. 9(c).

V0 is the value at the Earth-sun distance 1AU.

L398 "∶ ∶ ∶are systematically overestimated". – please, clarify this statement

==>

Reply

We delete sentence from line 397 to line 399.

Â ˘nÂ˘n L414 " [and spectral response function of the] radiometer are necessary"

==>

Reply

We added "and spectral response function of the".

L438: Table 4: Provide units for Vsun and V0

==>

Reply

We added unit for Vsun and V0.

L444-455: Fig 10: Compare with more recent sources of high spectral resolution extra-terrestrial solar irradiance, e.g. https://www.cfa.harvard.edu/atmosphere/publications/Chance-Kurucz-solar2010-JQSRT.pdf

==>

Reply

We added Chance and Kurucz (2010) to Fig. 10.

The value is a mean value weighted by the response function of a triangle with FWHM of 10nm.

L466: which takes [into] account . . .

==>

Reply

We fixed it.

L488-490: Use tau_aer in Eq (19) and 490

==>

Reply

We replaced tau with tau_aer.

L492. "..is interpolated from the optical thicknesses at 870 and 1020 nm" – explain interpolation method, e.g. linear, power law?

==>

Reply

We added the following sentence after 492.

"When interpolating τ_{aer} at 940 nm, τ_{aer} was assumed to be proportional to $\lambda^{-\alpha}$, where λ is wavelength."

L496: explain how R is calculated?

＝＝＞

Reply

We showed reference.

Nagasawa, K. 1981: Tentai no ichi keisan (Position calculation of celestial bodies), Chjin Shokan, p. 239 (in Japanese).

The literature is written in Japanese, but it is often used by Japanese researchers.

We inserted the following sentence in line 497.

"For example, R can be calculated with a simplified formula by Nagasawa (1981), m can be calculated with the formula by Kasten and Young (1989), and τ_R can be calculated with the formula by Asano et al. (1983)."

L497-499: explain how coefficients a and b were calculated?

＝＝＞

Reply

See Apendix.

Details of the method for determining the coefficients a and b are described in Uchiyama et al. (2014).

L504-505: explain units for calibration coefficients?

＝＝＞

Reply

We added unit.

L548: use tau_aer

＝＝＞

Reply

We replaced tau with tau_aer.

L640: "seasonal variation of 1 to 3%." – Correcting for sun-Earth distance ?

＝＝＞

Reply

In this paper, calibration constant V0 is the output of the radiometer to the extra-terrestrial solar irradiance at the mean earth-sun distance (1 AU). And, when temperature correction is applied to the sensor output, it is the value at the reference temperature.

Technical comments:

L559-560: Equations (24) and (25) can be combined.

==>

Reply

We deleted eq. (24).

L585: "∶∶∶ is an alternative to the Langley method." – extension of Langley method?

==>

Reply

This expression was not appropriate.

We rewrote this sentence as follows.

"The method shown here is the next best solution."

L629: " The annual variation of the calibration constants∶∶∶" – The long-term changes

==>

Reply

We replaced "annual variation" with "long-term changes".

Fig 1 caption: "inside temperature[s]"

==>

Reply

We replaced "temperature" with "temperatures".

Fig.4. Check the Y units: be counts per second? What is the scaling factor?

==>

Reply

The unit of sensor output is A (Ampere).

Fig.5. Show monthly V0 values to check V0 seasonal dependence

==>

Reply

The V0 values shown in Fig. 5 are values determined on the basis of measurements made at MLO once a year. There are no monthly values. We cannot show the monthly V0 values. The change in the V0 values is smooth and can be interpolated.

Fig. 8 Too small axis labels. Suggest scaling Y axis for clarity

==>

Reply

We enlarged the figures.

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2017-432, 2018.