Interactive comment on “Preflight Calibration of the Chinese Environmental Trace Gases Monitoring Instrument(EMI)” by MinJie Zhao et al.

We would like to thank you for the insightful comments. Our responses to the comments are given below.

General comments:
The manuscript entitled “Preflight Calibration of the Chinese Environmental Trace Gases Monitoring Instrument (EMI)” by Zhao et al. describes the method of the preflight wavelength and radiometric calibration efforts for the EMI instrument. Moreover, it provides an estimate of the expected, on-orbit signal to noise ratio for one particular solar zenith angle. In my opinion, this manuscript provides valuable information to the community, but requires careful modifications before it is published. My detailed comments are:

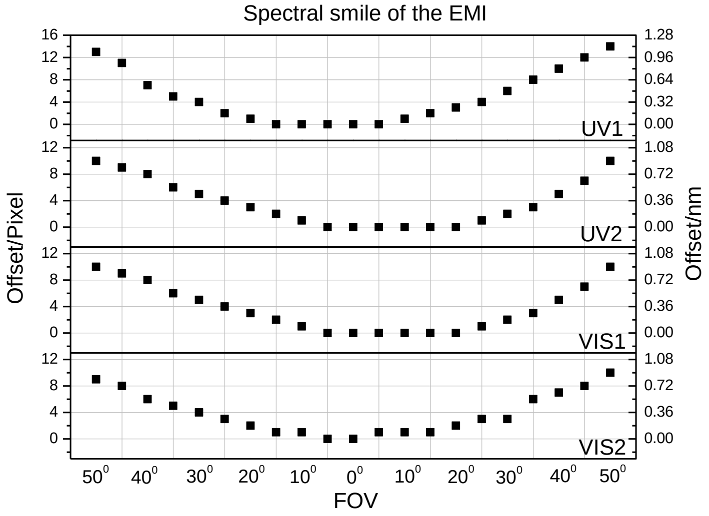
(1) There are several editorial and vocabulary issues, possibly due to a language barrier, that make the manuscript hard to read and sometimes result in the incorrect meaning. Please proof-read the manuscript carefully. Several examples are listed in the following:
a. “integral time” should be “integration time”
b. The symbol “～” is used throughout the manuscript to describe “from/to” intervals or ranges. The correct symbol to use is “-“.
c. The word “data” is used to describe “measurements”. For example, “: : :determined by 20 spectral response data: : :” should be modified to “determined using 20 spectral response measurements: : :”. Similarly, “One hundred observed data is obtained: : :” should be modified to read: “One hundred measurements were obtained: : :”
d. “: : :the spectral response function is better than 0.03nm.” should be modified to “the full width at half maximum (FWHM) of the instrumental line shape function is less than 0.03nm.”
e. Throughout the manuscript, the abbreviation “FWHM” is used for the FWHM of the instrumental line shape function (ILS). Whenever it is used, it has to be made clear that it describes the ILS and not the width of some other function.
f. In section 3, gain steps between 0-63 are introduced which result in different gain values within the CCD readout electronics (A/D converter). However, the word “Gain” is used for the digital gain steps and the word “magnification” is used for the actual gain value. I strongly encourage the authors to describe the values 0-63 as “gain steps” (or something similar) and the factor with which the raw signal is multiplied as “gain” or “gain value”. In the community, the word “magnification” is almost exclusively used for optical magnifications, which can result in confusion here. Please

do not use “magnification” in this context.
g. The words “accuracy” and “precision” (and sometimes “non-stability” or “variety”) are sometimes used interchangeably and often wrongly in this manuscript. Please familiarize yourself with the different meanings of accuracy and precision and use them appropriately. Do not use non-stability or variety.
h. I assume the CCD names are “e2v: : :” not “EV2: : :”
i. The dark signal is incorrectly defined in line 288. The common way to define the signal that is obtained when no photons enter the instrument is to add the “bias value” and the “dark signal”, where the dark signal is the dark current multiplied by the integration time. The dark noise is typically the noise component that is caused by this dark signal, in this case, the shot noise of the dark signal.
j. Figure number is missing in line 366.
k. The unit Watt is typically abbreviated with a capital “W”, not a lower case “w”.
l. Equation number is missing in line 428. In fact, the equations are not numbered at all. Please assign equation numbers to all equations.
m. Please use the greek letter μ to indicate thousandths not the letter u.
n. Figure number is missing in line 430.

Response:
Many thanks for the careful and professional commenting. Firstly, the comments a-n have been corrected in the paper. Secondly, the paper is carefully modified.

(2) It is not sufficiently clear what the wavelength shifts shown in Figure 3 are. Do they represent an additional offset that is included in the polynomial function which is determined for the center?

Response:
The wavelength shifts in Figure 3 are measured by the tunable laser in the spatial dimension with the interval of 5° .



The wavelength (pixel) shift enlarges from the CFOV to the edge FOV. The UV1, UV2, VIS1, and VIS2 wavelength (pixel) shifts of the edge FOV are 1.12 nm (14 pixels), 0.9 nm (10 pixels), 1.2 nm (10 pixels), and 1.3 nm (10 pixels), correspondingly. For the L1b processor of the EMI，the spectral smile effect will be calibrated using a spectrum-matching technique.

(3) The manuscript states that the CCDs for the visible channels do not have any temperature control. Since the dark current depends strongly on the CCD temperature, it would be very helpful to quote the expected temperature variations of these detectors throughout the orbit and as a function of orbit beta angle. In addition, it would be helpful to refer to the strategy of periodic dark measurements at this point, so the reader understands how this potential problem is mitigated.

Response:

The CCDs for the visible channels do not have independent temperature control, but they work in a constant temperature environment. The temperature is similar to that in the visible spectrometer, which has temperature control. Thus, the change of CCD temperature is not a problem.

(4) The authors state: “The offset is fairly const, *: : :*” I believe they mean “The bias value is constant,*: : :*” This is generally a good assumption for well-designed electronics. Have the authors quantified the precision of the bias values?

Response:

The read-out register within the CCD has an excess of 16 blank pixels, which can be used to measure the electronic offset on the ground. The measurements show that the offset is not constant but drifts with time (about 0.5%). Therefore, the electronic offset is obtained per measurement frame in-orbit, and the electronic offset correction is implemented in the L1b data processor.

(5) I do not understand the traces in the top two panels of Figure 8. For a constant dark current and a constant bias value, the difference between the measurements with 0.5s and 1.0s integration time should be half of the difference between the measurements with 1.0s and 2.0s integration time. Please explain.

Response:

The pixels in the readout register cannot be used to accomplish the binning due to the full well limitation. In this case, the pixel binning is accomplished in the Field Programming Gate Array. Fast readout frequency is needed for the process. The fast readout frequency leads to signal distortion. Therefore, the difference between the measurements with 0.5 and 1.0 s integration times is not half of the difference between the measurements with 1.0 and 2.0 s integration times. Based on the signal distortion, we have obtained absolute radiance calibration key data at different integration time on the ground. The calibration key data are used for the L1b data processor.

(6) A reference for MODTRAN should be included

Response:

A reference for MODTRAN have been included in the paper.

(7) The denominator of the equation on line 414 should be the standard deviation. Thus, the term in the sum needs to be squared. I assume that the actual calculations were performed correctly.

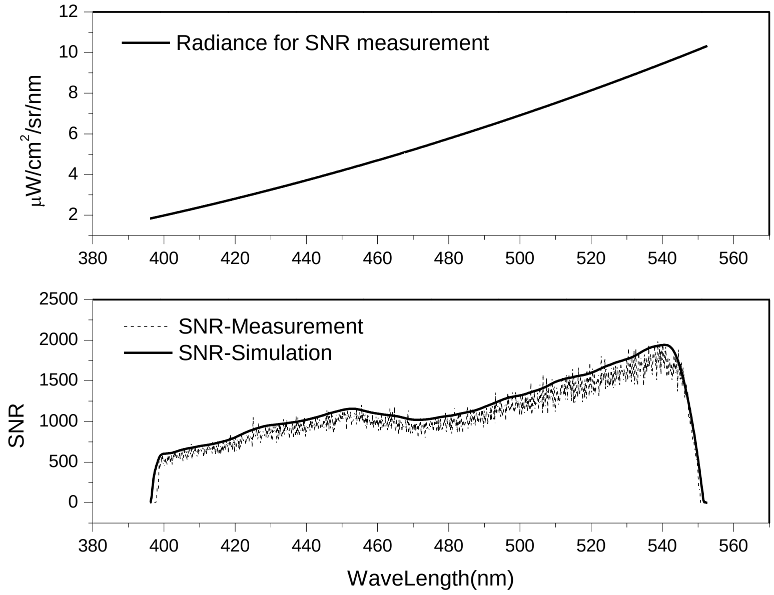
Response:

The equation in the paper has been corrected. We have confirmed that the actual calculations were performed correctly.

(8) The authors state that the measured SNR in figure 13 is departing from the simulation between 460-500nm due to lower transmittance of the instrument (filter) in this range. However, if the equation in line 394 includes the proper transmission function, this effect should be included in the simulation. Please explain.

Response:

The equation in line 394 includes the proper transmission function. But for the SNR-simulation, the transmittance of the filter is not included as we want to analyze the effect of the filter on SNR. The simulation SNR included the effect of the filter is shown in following figure.



(9) It is not clear to me how the PRNU can provide a significant contribution to the lower than expected SNR, unless it is varying in time (line 432). Please explain.

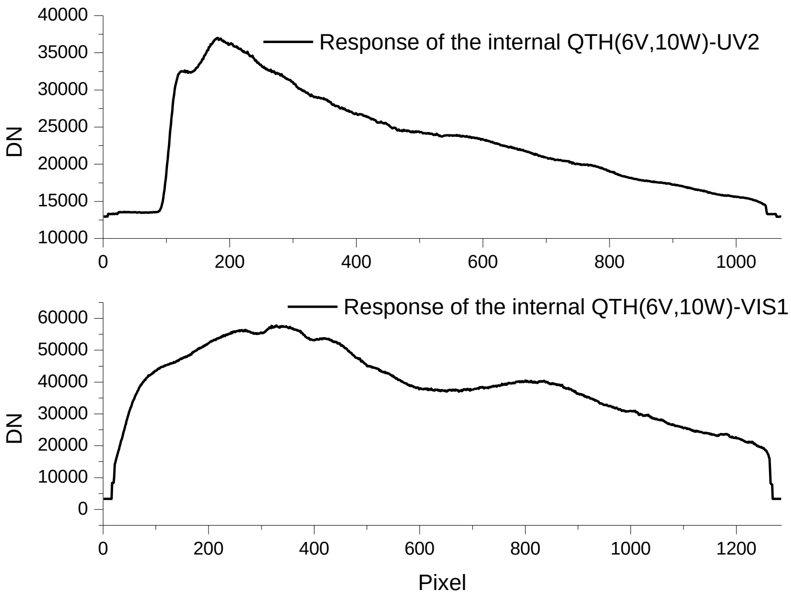
Response:

The PRNU is not varying during the SNR measurement, and will not provide a significant contribution to the lower than expected SNR. There are two main factors: the light source for the SNR measurement and the pixel response of the EMI. The PRNU has been corrected in the paper.

(10) If I understand correctly, the pre-flight, radiometric calibration of EMI was not conducted under flight-like vacuum and possibly thermal conditions. If this is the case, please address in more detail how the in-flight calibration will be used to accomplish absolute radiometric calibration of the flight data.

Response:

The pre-flight, radiometric calibration of EMI was not conducted under flight-like vacuum and possibly under thermal conditions due to the limitation of the calibration facility. The EMI on-ground response to the quartz tungsten halogen WLS (6 V, 10 W) is displayed in following figure, which uses UV2 and VIS1 as examples.



The EMI in-orbit response to the quartz tungsten halogen will be obtained after the launch. The change between the on-ground and in-orbit responses is used to correct the preflight radiometric calibration, which in turn is used to accomplish the in-flight absolute radiometric calibration of the flight data.

(11) Finally, while the manuscript shows the performance of the instrument on the ground, the reader is not told what the actual performance requirements are. Presumably, the instrument performance requirements are driven by the scientific objectives. Comparing the measured/estimated performance (e.g. SNR) with the mission requirements would make the conclusion much stronger.

Response:

We have added the performance requirements to the introduce section and added the on-ground calibration results in the conclusions section.

Performance requirements

Spectral range: UV1:240–315 nm; UV2:311–403 nm; VIS1:401–550 nm; VIS2: 545–710 nm;

Spectral resolution: <0.55 nm;

Accuracy of the on-ground wavelength calibration: <0.05 nm;

Accuracy of the on-ground radiometric calibration: <5%;

SNR:

UV channel: >200 (@1.27 $\mu W / cm^2 / sr / nm$)

VIS channel: >1300 (@10.89 $\mu W / cm^2 / sr / nm$)

Conclusions

The spectral and radiometric response performance of the EMI is obtained by preflight calibration. The on-ground calibration results are shown as follows:
Spectral calibration results:
UV1: 236.44–317.28 nm with the spectral resolution ⩽0.45 nm;
UV2: 306.08–407.12 nm with the spectral resolution ⩽0.49 nm;
VIS1: 395.50–552.63 nm with the spectral resolution ⩽0.48 nm;
VIS2: 534.63–712.90 nm with the spectral resolution ⩽0.49 nm;
The final accuracy of the wavelength calibration is <0.05 nm.
Radiometric calibration results:
UV1: 4.64%, UV2: 4.63%, VIS1: 4.43%, VIS2: 4.42%.

The on-ground calibration results meet the performance requirements of the EMI.

The EMI in-orbit simulation $SNR_{simulation}$ is obtained by the radiance $R_{simulation}$ at an albedo of 0.3 and solar zenith of 60 °. The in-orbit simulation SNR at the radiance of 1.27/10.89 $\mu W / cm^2 / sr / nm$ can be achieved by the following equation:

$$SNR = SNR_{simulation} \cdot \sqrt{\frac{R}{R_{simulation}}} ,$$

where R is 1.27 for UV channels and 10.89 $\mu W / cm^2 / sr / nm$ for VIS channels.

For the in-orbit simulation SNR at the radiance of 1.27/10.89 $\mu W / cm^2 / sr / nm$, the results are presented in the following table.

In-orbit simulation SNR at the requirement radiance

Channel		**SNR (simulation)**	**SNR (requirements)**
UV2	330nm	328	200
	360nm	356	200
	390nm	388	200
VIS1	420nm	1860	1300
	480nm	1900	1300
	540nm	2040	1300
VIS2	560nm	2200	1300
	620nm	2300	1300
	680nm	2400	1300