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Atmospheric Measurement Techniques Discussions
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Interactive Comment

Interactive comment on "Quantification of atmospheric visibility with dual digital cameras during daytime and nighttime" *by* K. Du et al.

K. Du et al.

kdu@iue.ac.cn

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The authors appreciate the two anonymous referees' constructive comments that are helpful for improving the quality of this manuscript. Below are point-to-point responses to the comments. The referees' comments are numbered and the corresponding author's responses are provided after each comment.

Anonymous Referee #1 (1) General comments: A number of methods have been developed to measure visual range (VR) using a single camera. This work presents a new method based on a two-camera system in which both cameras are aimed at the same object but at different distances. Only the distance between the two cameras needs to be known as opposed to the distance from the camera and one or more tar-

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gets, as in single camera systems. The advantages of this method compared to the others are that pre-calibration of the cameras using a visibility meter is not required and the method is relatively independent of the positioning of the camera relative to the objects used to measure the VR. These advantages make this system easier to deploy in an ad hoc fashion. The theory upon which the VR measurement is based is sound, and the authors demonstrate its feasibility with a small field study. I have a few concerns that should be addressed prior to publication.

Response: The reviewer summarized the exact key points that were intended to be delivered in this manuscript. Please see below for our responses to his/her specific concerns.

Specific comments: (1) The authors regularly use “visibility” when they mean visual range, light scattering, or light extinction. Throughout the manuscript visibility should be replaced with the proper term.

Response: Usually, visibility is interpreted as visual range, which is the furthest distance of a black object where the observer could visually discern it from its contrasting background(1). Under different circumstances and for different applications, this “visual range” concept has been interpreted with different terms, such as atmospheric visibility at the threshold contrast of 0.02 by Koschmieder(2) , meteorological optical range (MOR) or runaway visual range (RVR) at the threshold contrast of 0.05, according to the World Meteorological Organization (WMO)(3). Most researchers have used a contrast threshold of 0.02 to determine the atmospheric visibility.1 To make our results comparable to calculations of visibility reported by others, we selected the threshold contrast of 0.02 in this study. We understand that light scattering, which contributes most to light extinction in the ambient atmosphere, is an important factor affecting visibility. In the revised manuscript, we will provide the definition of the terms for clarity and use the appropriate term.

References: 1. William Malm (1979): Considerations in the Measurement of Visibility,

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Journal of the Air Pollution Control Association, 29:10, 1042-1052. 2. Koschmieder, H. Theorie der horizontalen sichtweite. Beitr. Phys. Atmos. 1924, 12 (33-53), 171-181. 3. Guide to Meteorological Instrument and Observing Practices, Fourth Ed., Secretariat of the World Meteorological Organization, Geneva, Switzerland WMO-No. 8, TP. 3, 1971.

(2) While not clearly stated, it appears that the authors use jpeg images from the cameras as opposed to raw images. The jpegs can be highly processed images, introducing nonlinearities between pixel values and exposure times under various lighting conditions. They attempt to reduce some of this error by adjusting the zoom in both cameras so that they have similar fields of view. However, this may not fully account for all of the error introduced due to the in-camera image processing. These errors need to be further discussed in the manuscript. Ideally, the authors should repeat the field study using a camera with both raw and jpeg images so that they can better assess the errors introduced by in-camera image processing, at least for that one camera.

Response: It is true that jpeg images were compressed that could lead to nonlinearities between pixel values (PVs) and exposure times. To address this nonlinearity issue, we conducted calibration for each camera by taking pictures of a homogeneously lighted surface at different exposure times and fixed aperture size (i.e., F8.0). The resulting pixel values and exposure times were analyzed using non-linear regression to characterize the correlation between pixel value and exposure time specific to the camera that was used. This procedure was repeated under the same conditions but at different lighting levels and we found that the camera response curves (i.e., ln(PV) vs. ln(exposure time)) were parallel to each other for PVs from 30-200 (Figure 1), which indicated that those correlation can provide consistent results for the ratio of radiances received at two spots in the same picture using the method described by Fig. 2 in the manuscript.

To further validate the above inference, we conducted the following tests: 1) Calibrate the camera response curves using both jpeg images and raw images (Figure 2). 2)

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Take photos of a number of objects with contrasting backgrounds using the same camera but saving the images in both jpeg and raw format. 3) Quantify the contrasts of the objects using the jpeg images and raw images using the corresponding response curves (Figure 3). The comparison shows that as long as the camera is calibrated, and the photos taken by that camera are saved in the same format, the method is capable of providing consistent results of contrast, with average difference below 6%.

Figure 1 Camera response curves calibrated at three different levels of lighting condition

Figure 2 Camera response curves calibrated using JPG format (left) and RAW format (right)

Figure 3 Contrasts for the same group of targets and background, determined using 1) JPG based camera response curve with JPG images and 2) RAW based camera response curve with RAW images

(3) The authors use VR estimates from a Vaisala PWD 20 VR meter against which to evaluate their camera system. The Vaisala PWD 20 is a forward-scattering instrument and therefore does not account for light extinction due to absorbing aerosols. However, their camera system does. The authors need to discuss this error and provide some information as to how important absorbing aerosols are in their field experiment.

Response: The review is totally correct that Vaisala PWD 20 measures light scattering by the aerosols, which usually accounts for about 90% of the total extinction in ambient atmosphere(4). So the visibility meter estimates extinction with an assumed single scattering albedo, which would introduce error if the actual albedo of the ambient aerosols is different from the assumed one. Thus, DOM-vis has the advantage over scattering-based method by measuring light extinction, which will yield more realistic estimation of visibility. Additional discussion will be added to the revised manuscript to talk about this issue.

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Reference: 4. Kus, P. Physical and chemical properties of laboratory and ambient aerosols related to climate change. Ph.D. Dissertation, University of Illinois at Urbana-Champaign, Urbana, IL. 2003

(4) The authors make the case that their method is more flexible and adaptive for field measurements. This is an important attribute of the method. However, it would be very interesting to know if this method is more or less accurate than the other methods currently in use. This could be assessed by comparing VR measurements from the two-camera system to estimates from one-camera systems and the Vaisala PWD 20. I think such a comparison would be a valuable addition to the manuscript.

Response: In the revised manuscript, selected photos will also be analyzed using the one camera method and compare to DOM-vis and PWD-20.

(5) Page 48, line 18: “overcast sky” should be “uniformly overcast sky”. Also, it says that the equilibrium radiance model for uniform illumination assumes negligible absorption. It is not clear as to why absorption needs to be small and the referenced Molenar et al. (1994) paper does not mention this assumption. This needs to be clarified in the manuscript.

Response: The text will be revised according to the reviewer’s suggestion. As for the equilibrium radiance model, we re-checked Molenar’s paper. The assumption is “uniform illumination” instead of negligible absorption. The manuscript will be corrected in the revision.

Technical Corrections: 1) Page 44, line 12: there is an extra “to”. 2) Page 47, line 4: “methods” should be “method”. 3) Page 48, line 4: “such like” should be “such as”. 4) Page 51, line 25: “actually” should be “actual”.

Response: The text will be revised according to the reviewer’s suggestion.

Interactive comment on Atmos. Meas. Tech. Discuss., 6, 43, 2013.

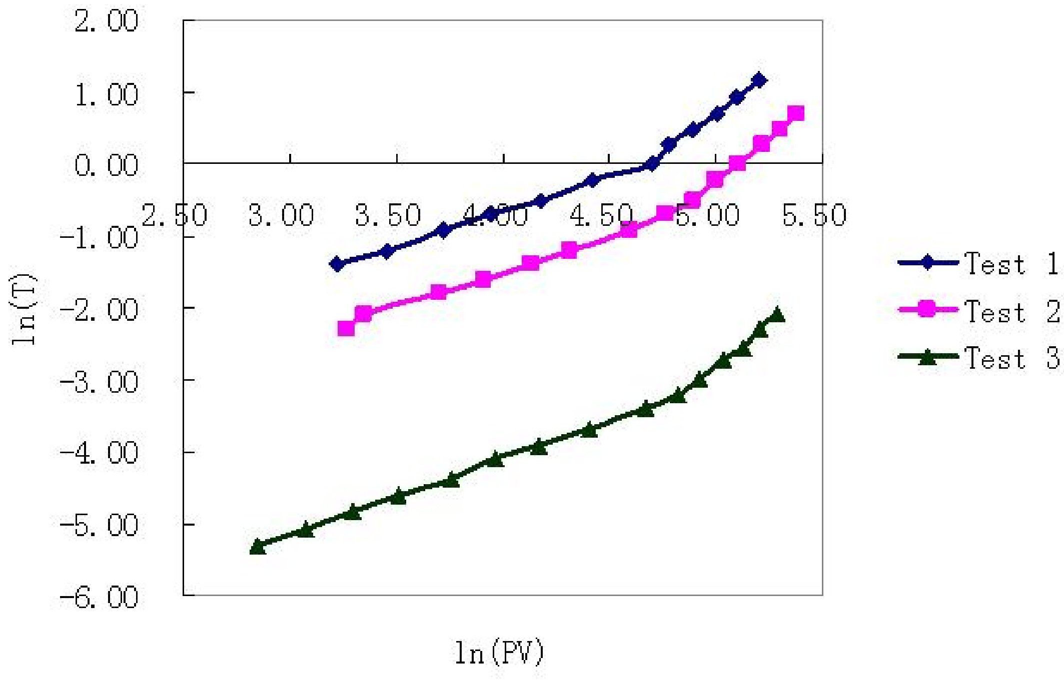

Fig. 1. Figure 1 Camera response curves calibrated at three different levels of lighting condition

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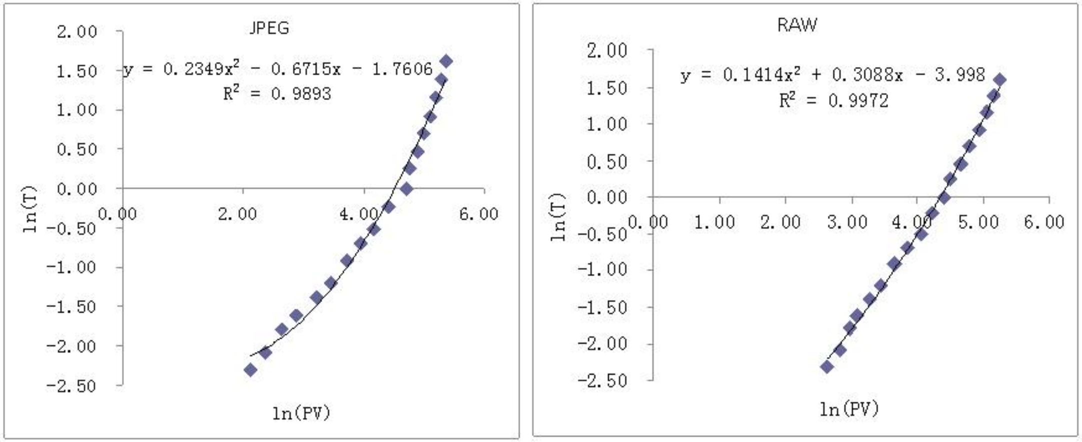

Fig. 2. Camera response curves calibrated using JPG format (left) and RAW format (right)

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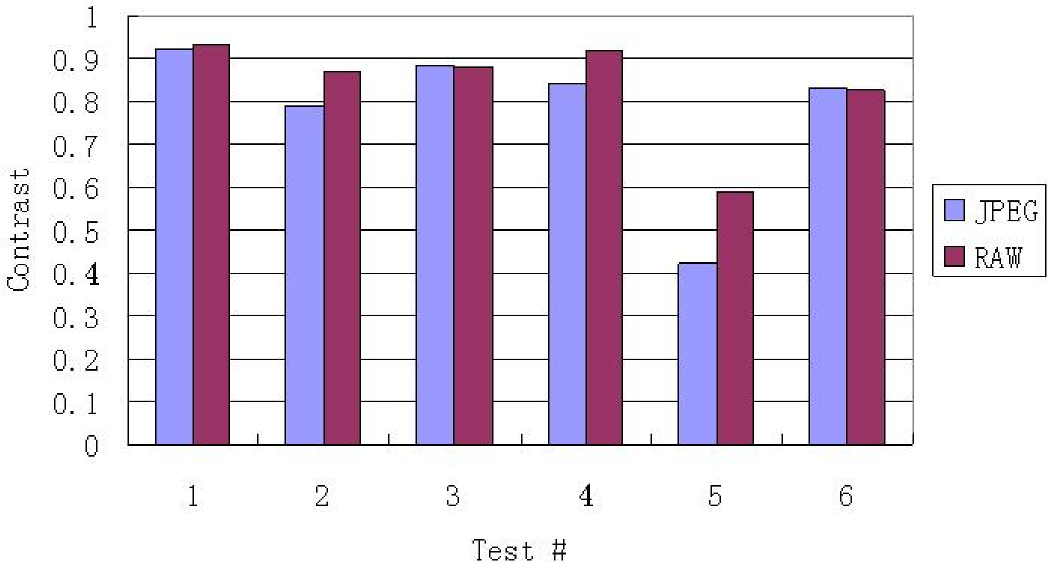

Fig. 3. Contrasts for the same group of targets and background, determined using 1) JPG based camera response curve with JPG images and 2) RAW based camera response curve with RAW images

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