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Interactive comment on "Preliminary investigations toward nighttime aerosol optical depth retrievals from the VIIRS day/night band" *by* R. S. Johnson et al.

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The authors present a concept paper for a nocturnal aerosol optical thickness retrieval using the VIIRS Day Night Band (DNB). The new VIIRS channel offers the possibility of retrieving nighttime aerosol loading from an imager, which is unquestionably needed by the community. The key concept is the use of the contrast between bright artificial lights from Earth city sources and nearby areas without artificial light. It is a nice concept, worthy of publication, though the concept is far from implementation into an operational product. The three cases with comparison to before/after pairs of AERONET day time observations are sufficient examples for a concept paper. However, I cannot under-

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stand a few key elements of the paper and the sensitivity analysis requires expansion. I will call these minor revisions because overall the authors have a good, publishable, concept. My criticisms below are significant but should not overly color the perception of the paper.

We would like to thank the reviewer for the positive and supportive comments.

I also want to point out a few major difficulties of applying this concept operationally that are not mentioned in the paper. High in my concern is the very broad wavelength band encompassed by the DNB. Hidden in this broad band are gas absorption bands. The oxygen-A band is mentioned, but water vapor is not, and water vapor is going to play a large confounding role in turning this concept into something quantitatively useful on a large scale. No mention of the possibility that water vapor may change from the night that I_a is obtained from the night that I_{sat} and I'_{sat} are obtained is too glaring an omission. No mention of the DNB's broad spectral band is made at all.

We would like to thank the reviewer for making this point. We have accordingly changed the discussion on the top of pg. 594 to state, "Although, there will be some inherent uncertainty in this assumption since the DNB response function, full width at half maximum from 0.5 to 0.9 μm, includes the oxygen A-band. A future study should consider the impact of the oxygen A-band, as well as other absorbing bands such as water vapor, on the proposed algorithm."

Also, pg 594 line 22 has been appended with, "In future studies, some factor like C should also be included to account for differences in water vapor content between various nights."

Another issue is the question of adjacency effects, pixel sizes and distances from light sources. If the contrast is calculated from two adjacent pixels, then the "dark" pixel will have elevated radiance from the "bright" pixel, due to scattering of the light by the atmosphere into the field of view. How far apart do the "dark" and "bright" pixels have to be? If the contrast is calculated from pixels very far apart then there is the danger

of the atmosphere (including both aerosol and absorbing gases) changing between dark and bright. How far apart is too far apart? And does pixel size matter? Some of this is handled implicitly by how Ia pixels are chosen in the three examples, but an explicit discussion with appropriate figures would provide a more complete quantitative understanding.

Pixel size with the VIIRS DNB band is not an issue because pixels are approximately 0.75 by 0.75 km across the entire domain of the image. As for the proximity of the selected background sample to the city, the impact of this proximity was investigated by choosing three background samples, I 'sat, each night. These background samples varied in distance from the nearby city. Note, that we expanded this part of the study from our previous version by selecting additional background samples each night at all three locations. At Grand Forks, we have also varied the background sample size to study the sensitivity of the retrieved τ to background sample size. See the response to the next comment for more detail.

There are two places where I cannot understand what the authors did.

1. bottom of page 595, continuing into the top of page 596. This is where there is an attempt to quantify an error of the method, except I cannot understand what this error is. They write, "The absolute relative error of each sample" What is the sample? "The three sample mean as truth". Are they simply calculating the standard deviation from the three colored blocks northwest of the airport in figure 1e? Is this a sufficient sample size? Wouldn't it be better to calculate the truth and standard deviation from a larger set of pixels outside of the city lights in the image? "The absolute value of the relative error for the three samples over the course of the study period was approximately 0.06". Is this 6% of the radiance? Of the retrieved AOT? "This results in an 11% error at Grand Forks." Is this then 11% of AOT and the other radiance? How do we get from 6% uncertainty for radiance results in a 11% uncertainty of AOT?

Why wasn't something similar done at Capo Verde and Alta Floresta? Capo Verde

looks fairly uniform as long as you stay on the island, but the "background" around Alta Floresta appears sufficiently variable to deviate significantly depending on where you put your green squares. Is Figure 2a moonlit? The authors mention obtaining higher signal to noise on moonless nights. Would it be more illustrative to show two images of Alta Floresta at different stages of the moon? Is the "error" described by this standard deviation a function of moon phase? These are all important questions to ask and answer as quantitatively as possible in a concept paper.

We would like to thank the reviewer for pointing out the lack of clarity in this section. In response to this comment, additional background samples at Cape Verde and Alta Floresta were obtained. As suggested by the reviewer, we have conducted sensitivity tests not only by varying background sample locations, but also by varying the background sample size for a more complete understanding of how the uncertainties in the background sample selection impact errors in retrieved τ. Furthermore, we understand that our previous discussion was confusing, and therefore, the section has been rewritten for better clarity. The following discussion has been included in the new version of the paper.

"To determine the impact of choosing one background sample over another on the retrieved τ, two additional supplementary background samples were collected each night at each of the three sites (shown as yellow in Figures 1c, 1e, and 2b). The choice for the location of these background samples was random. The motivation for selecting these supplementary background samples is to estimate the possible error introduced to the retrieval by the fact that a selected background sample might not represent the true background.

We first studied the impact of using different background samples that varied in spatial proximity to the city light source. To study the impact of the different background samples on retrieved τ, we looked at the differences in the quantity Isat – Isat' (ΔI) using the different background samples. It is shown later in section 4.2 that the relative change in ΔI translates into uncertainty in τ due to changes in ΔI. This means that by using the

same Isat (city signal) and different I'sat values (background signals) that the change in ΔI translates into the uncertainty in τ due to changes in the background sample. Thus, we calculated the relative change in ΔI from using the various background samples each night at each location. For each location, we averaged the absolute value of these relative differences over the whole study period. The results are shown in Table 1, and they indicate the average maximum possible uncertainty in τ due to varying the background sample as a function of proximity to the city. These values ranged from approximately 0.01 at Grand Forks and 0.03 at Cape Verde. Similar uncertainties in τ were found for nights with and without moonlight, indicating that moon fraction is less of an issue for estimating I'sat values. The reason why I 'sat has such a small impact on the uncertainty of the retrieved τ is that ΔI, the difference between Isat and I 'sat, is what matters to the optical depth retrieval. I 'sat constitutes just a small portion of ΔI since Isat is typically several times to several magnitudes larger than I 'sat.

The average maximum uncertainty in τ of 0.03 was further validated by calculating τ, not corrected for the diffuse transmission of light, with each of the three background values each night. For each city, the average absolute difference between the values of τ using the supplementary background samples and the primary background sample was indeed less than its respective value shown in Table 1.

Another similar study was performed at Grand Forks except instead of varying the distance of the background sample from the city source, the size of the background sample was changed. The primary sample size was increased from 4 pixels (shown as green in Figure 1e) to 64 pixels (shown as blue in Figure 1e). The average change in retrieved τ due to this enlargement was less than 0.01."

2. Handling of the direct to total Ia ratio constant, k. We are shown two sets of results in the end, one for direct only and one that applies values of k that accounts for the contribution from the diffuse light. The values of k are calculated for each example for 19 values of AOT, assuming an aerosol model. How are these 19 values of k used in the retrieval? I don't understand. There should be 19 values of k, dependent on

the AOT. As aerosol loading increases, k should decrease. There must be an iterative procedure and some type of minimizing a cost function, then to solve Eqn. 7. No mention of this is made in the paper. This is a glaring omission.

We would like to thank the reviewer for pointing out this lack of clarity. For the purpose of this concept of demonstration paper, we used a first order approximation for obtaining k. That means we took the original τ value without the k correction as input and interpolated between the 19 calculated k values to find an approximate k correction value for our input τ. With this estimated k value, we recalculated τ according to Eq. 7. This recalculation of τ was only performed once, and there was no iterative procedure; this was merely a first order approximation. The purpose of not including an iterative process is because there are uncertainties unaccounted for in the final retrieved τ. Therefore, an iterative process of matching k to τ will introduce cumulated uncertainties in the final retrieved τ. We have added the following discussion to the text.

"For the purpose of this concept of demonstration paper, we used a first order approximation for obtaining k. That means we took the original τ value without the k correction as input and interpolated between the 19 calculated k values to find an approximate k correction value for our input τ. With this estimated k value, we recalculated τ according to Eq. 7. This recalculation of τ was only performed once, and there was no iterative procedure; this was merely a first order approximation. The purpose of not including an iterative process is because there are uncertainties unaccounted for in the final retrieved τ. Therefore, an iterative process of matching k to τ will introduce cumulated uncertainties in the final retrieved τ."

Finally, I was very happy to see an attempt of a sensitivity study, but it doesn't provide sufficient information. There should be information on both relative and absolute errors on AOT retrievals from uncertainties of the inputs. Also the discussion about relative uncertainty decreasing as AOT increases does not make sense for the parameter, k. The uncertainty, dk, itself, should increase as AOT increases. k is dependent

on aerosol model. What if you have the wrong aerosol model? It will not make any difference if AOT =0.1, but it will make a very large difference if AOT=1.0. Look at Figure 5. Mostly the k correction improves agreement with AERONET, but at Alta Floresta, the k correction only makes things worse as the season progresses and AOT increases. Another point here is that water vapor steadily increases at Alta Floresta as the season progresses. If the original value of Ia were made in early August, water vapor could be adding to the amount of retrieved AOT by the end of September.

We thank the reviewer for the valuable insight. The reviewer has a legitimate point, and we have revised the discussion accordingly.

The text "The uncertainty of retrieved τ, based on Eq. 10, is not a function of τ." was changed to "The uncertainty of retrieved τ, based on Eq. 10, is not a direct function of τ.".

We also added the following text.

"Aside from the theoretical uncertainty analysis, a preliminary empirical uncertainty analysis was also conducted for I 'sat (or ΔI by varying the background) and Ia as discussed in the previous sections. We have summarized the results of these uncertainties in Table 3. In addition, we approximated k using the desert, urban, and biomass burning aerosol models from the 6S radiative transfer model for Cape Verde, Grand Forks, and Alta Floresta, respectively. We find an average relative change in k (Δk/k) of approximately 0.1 between the smoke and dust aerosol models. An average (Δk/k) of approximately 0.04 is found between the smoke and urban aerosol models. Such a change in k values corresponds to a 0.04 to 0.1 uncertainty in τ based on Eq. 10. We have included the Δk/k estimation in Table 3 as well.

Table 3 does not include an estimate for the uncertainty in τ due to the factor C because the use of C was not deemed to be necessary at Alta Floresta or Cape Verde from the results shown in Fig. 3. C was used at Grand Forks; however, C was also used to adjust the moonless night Isat values for extrapolating an estimated Ia value for determining

the uncertainty in τ due to Ia. Thus, for Grand Forks the uncertainty in τ due to C is partially included in the uncertainty due to Ia. An extensive number of observations are needed to carefully study the relationship between Ia and C, which might be unique to an individual city. We leave the full study of the interaction between Ia and C to a future paper.

We want to remind the readers that both the theoretical and empirical uncertainty analyses in this section are rather simplified approaches. Uncertainties in aerosol properties (k) and the true city signal (Ia) may vary as τ increases. For example, the wrong aerosol model may be chosen for the k correction, which would have a greater impact with larger values of τ because k may be a function of τ. With regard to Ia, a larger uncertainty may exist in estimating Ia for a region that is consistently covered with thick aerosol plumes than for a relatively clear region. Also, omitted terms such as can become less insignificant as τ increases. Therefore, the actual performance of the retrieval process needs to be further evaluated using ground based nighttime aerosol observations (e.g. Berkoff et al., 2011)."

Berkoff, T. A., Sorokin, M., Stone, T., Eck, T. F., Hoff, R., Welton, E., and Holben, B.: Nocturnal aerosol optical depth measurements with a small-aperture automated photometer using the moon as a light source, J. Atmos. Oceanic Technol., 28, 1297–1306, doi:10.1175/JTECH-D-10-05036.1, 2011.

The results of the sensitivity study should be logically laid out with values for each of the studied parameter uncertainties, and how those values were estimated, and then the resulting total uncertainty on the retrieved AOT. It would also be helpful to see how sensitive the results are to night-to-night variations in water vapor also. This cannot be done till the DNB is represented as the broad spectral band that it is and not a monochromatic value at 0.7 m. In my opinion, either there needs to be a lot more words in the discussion identifying the over simplification of the concept presented here, or to bite the bullet and do a sensitivity study with a broad band DNB. By no means should the reader be left with the impression that we'll soon be getting quantitative aerosol

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retrievals at night from the DNB.

Agreed. However, to do a thorough uncertainty analysis, both reliable ground-based observations of aerosol and water vapor properties are needed, which are not available for this study. Indeed, such a study is needed and deserves to be a paper of its own. However, the reviewer has a very good point, and we have modified the text to emphasize the concept as shown from the answer to the previous question.

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/6/C332/2013/amtd-6-C332-2013-supplement.pdf

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