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The Langley ratio method, a new approach for transferring photometer calibration from direct sun measurements

Antonio Fernando Almansa et al.

Correspondence to: Antonio Fernando Almansa (f-almansa@cimel.fr)

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Supplement S1. Calibration coefficient sensitivity study

The following are the details of a sensitivity study we conducted to estimate the effect of the variability of AOD and AE on the calibration constant (V_0) obtained with the LR method.

First, we created a set of synthetic measurements by applying the Bouguer-Lambert-Beer equation (equation 1 of the article) for a range of τ values, both for the master photometer with CWL λ_M ($V_{\lambda M}$) and for the field photometer with CWL λ_F ($V_{\lambda F}$). To generate this set of synthetic measurements, we assumed that the contribution from Rayleigh scattering and gas absorption remains constant, while the contribution due to aerosols varies. Thus, for the master aerosol contribution, we considered a range of AOD values ($\tau_{\lambda_M,a}$) randomly distributed in a normal distribution characterized by their mean and standard deviation. For the field instrument, the AOD was calculated from the master instrument using the Ångström law, that is:

$$\tau_{\lambda_F,a} = \tau_{\lambda_M,a}\left(\frac{\lambda_F}{\lambda_M}\right)^{-\alpha} \qquad (1)$$

where α is the Ångström exponent. In this case, we have also considered a range of α values randomly distributed in a normal distribution characterized by their mean and standard deviation.

Once these synthetic measurements were generated, we calculated $V_{0,F}$ from $V_{0,M}$ after applying the LR method (see equation 5 of the article). We performed 1000 evaluations of Equation 5 for each set of random values (every set has 10 values, the minimum number of data used for a LR calibration for airmasses between 2 and 5), characterized by the average and the standard deviation of $\tau_{\lambda_M,a}$ and α ($<\tau_{\lambda_M,a}>, \sigma(\tau_{\lambda_M,a}), <\alpha>$ and $\sigma(\alpha)$). Subsequently, we calculated the standard deviation of $V_{0,F}$ obtained from the 1000 evaluations.

The range of values we considered included five values for $<\tau_{\lambda_M,a}>$ (0.02, 0.05, 0.1, 0.25 and 0.5), four values for $<\alpha>$ (0.1,0.5,1.0 and 2.0), 100 values for $\sigma(\tau_{\lambda_M,a})$ (ranging from 1 to 20% relative to the average) and 100 values for $\sigma(\alpha)$ (ranging from 1 to 50% relative to the average). These values are consistent with the actual measurements obtained in Valladolid and Izaña stations. The analysis has been focused on the CWL pair at 675/500 nm, where λ_F = 675 nm and λ_M = 500 nm. The results are presented in Figure S1.

In Figure S1, the variability of $V_{0,F}$ is represented on a color map, showing the standard deviation of $V_{0,F}$ relative to the Average ($\sigma(V_{0,F})/\langle V_{0,F}\rangle$), plotted against the standard deviations of $\tau_{\lambda_M,a}$ and α relative to their averages ($\sigma(\tau_{\lambda_M,a})/<\tau_{\lambda_M,a}>$ and $\sigma(\alpha)/\langle\alpha\rangle$) for various average values of $\tau_{\lambda_M,a}$ and α ($<\tau_{\lambda_M,a}>$ and $\langle\alpha\rangle$), resulting in a total of 20 subfigures. Panels from left to right correspond to increasing $\langle\alpha\rangle$ values, and panels from up to down correspond with increasing $< \tau_{\lambda_M,a} >$. The variability in $V_{0,F}$ ($\sigma(V_{0,F})/\langle V_{0,F}\rangle$) is displayed on a logarithmic color scale, where bluer shades indicate lower variability and redder shades indicate higher variability.

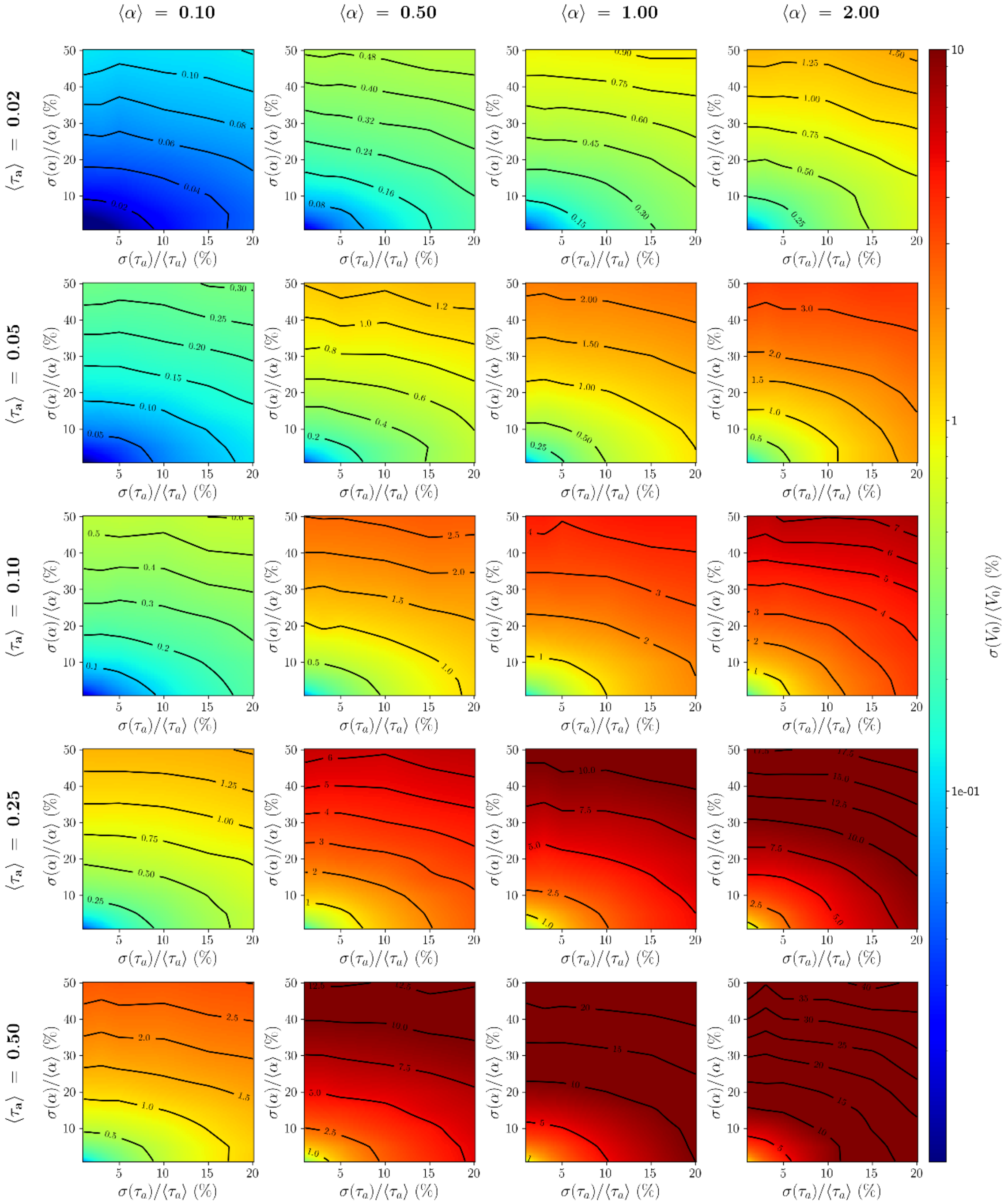

Figure S1: Colormaps representing $V_{0,F}$ variability as $\sigma(V_{0,F})/\langle V_{0,F}\rangle$ as a function of the standard deviations of τ_a and α relative to their averages ($\sigma(\tau_{\lambda_M,a})/ < \tau_{\lambda_M,a} >$ and $\sigma(\alpha)/\langle\alpha\rangle$) for a set of average values of $\tau_{\lambda_M,a}$ and α ($\langle\alpha\rangle$ = 0.1, 0.5, 1.0, and 2.0) and ($< \tau_{\lambda_M,a} >$ = 0.02, 0.05, 0.1, 0.25, and 0.5) for the 675/500 CWL pair, where λ_M=500 nm. Panels from left to right correspond to increasing $\langle\alpha\rangle$ values, and panels from top to bottom correspond to increasing $< \tau_{\lambda_M,a} >$ values. $\sigma(V_{0,F})/\langle V_{0,F}\rangle$ is displayed on a logarithmic color scale, where bluer shades indicate lower variability, and redder shades indicate higher variability.

In the first place, as expected, the results depicted in the figure show that an increase in any of the different parameters ($< \tau_{\lambda_M,a} >, \sigma(\tau_{\lambda_M,a}), < \alpha >$ and $\sigma(\alpha)$) leads to an increase in the variability of $V_{0,F}$. For clean conditions ($< \tau_{\lambda_M,a} >$ <=0.02), the variability of $V_{0,F}$ remains below 1% (except for $< \alpha >= 2$ and σ(α)/⟨α⟩ higher that 30%). For very low values of ⟨α⟩ (<=0.1) and $< \tau_{\lambda_M,a} >$ (<=0.1), $\sigma(V_{0,F})/\langle V_{0,F} \rangle$ remains below 1%, regardless of the variability in $\tau_{\lambda_M,a}$ and α (within the study range). For high values of ⟨α⟩ (>= 1) and $< \tau_{\lambda_M,a} >$ (>= 0.25), $\sigma(V_{0,F})/\langle V_{0,F} \rangle$ is almost always greater than 1% (except in unrealistic cases where the variability in $\tau_{\lambda_M,a}$ and α is extremely low). For the rest of the intermediate cases, $\sigma(V_{0,F})/\langle V_{0,F} \rangle$ would generally have values below 10%, reaching lower $\sigma(V_{0,F})/\langle V_{0,F} \rangle$ values (below 5%) depending on the variability in $\tau_{\lambda_M,a}$ and α. In general, it can be stated that the method should not be applied when $< \tau_{\lambda_M,a} >$ >= 0.25 and ⟨α⟩ >= 1, where λ_M=500 nm.