Atmos. Meas. Tech. Discuss., 8, C2543–C2548, 2015
www.atmos-meas-tech-discuss.net/8/C2543/2015/

Atmospheric Measurement Techniques Discussions

Interactive comment on "Reconstruction of high resolution time series from slow-response broadband solar and terrestrial irradiance measurements by deconvolution" *by* A. Ehrlich and M. Wendisch

A. Ehrlich and M. Wendisch

a.ehrlich@uni-leipzig.de

Received and published: 13 August 2015

Many thanks to Dr. Kiedron for the additional comments which we think were very helpful. Especially the suggestion to reduce the Gibbs phenomena did give a new view on how to present the theoretical background of the deconvolution in combination with the applied moving average filter.

The detailed replies on the reviewers comments are given below.

The reviewers comments are given italicized while our replies are written in roman letters. Citations from the revised manuscript are given as indented text.

Detailed Replies

(1) Definition in eqs.(4) needs to be corrected. The limits on t (two intervals) should be swapped.

We think Eq. 4 is correct. A specific measured data point is effected by the values before the data point is measured. That means back in time. Therefore, the kernel is defined for times before the time t of the data point. In other words, a measurement point includes the history of the time series before the actual measurement. Switching the times limits would mean that the current data point is the convolution of future data. What is not possible. We therefor did not change Eq. 4.

(2) Interval-wise deconvolution (p.5186, lines 10...) begs the question how the deconvolution is performed in overlap areas. How the solution are "glued" or "blended" in transitory areas?

The description of handling the overlap was somehow unclear. We extended it by:

> A section length of $(10+2)\cdot t_{\text{split}}$ including an overlap of $2\cdot t_{\text{split}}$ to glue the single sections, was chosen for further investigations in this paper. For example, in case of a response time of $\tau = 4$ s the section length is about 6 minutes, the overlap 1 minute. The overlap is used for the computation of the deconvolution only and rejected when gluing the section into the final entire time series.

(3) Gibbs phenomena (p.5191, line 9...). The Gibbs phenomena can be significantly reduced at slight loss of resolution by modifying deconvolution scheme. For example eqs.(9) can be apodized which is related to Lanczos sigma factors. Other methods like

using wavelets seems to be well established approach.

We are very thankful for this comment as it showed, that we did not present the equation of the reconstruction (inverse Fourier transformation) properly. As mentioned in the manuscript, we did apply a moving average filter to reduce the amplification of noise in the deconvolution. The filter was not applied for results in Figure 3 presenting the reconstructed box-car functions. Mainly because we intended to illustrate the dependence of the magnitude of the oscillations by the Gibbs phenomena for different sampling frequencies. Applying the moving average filter did significantly reduce the Gibbs phenomena as now presented in the new Figure 3. However, in the revised manuscript, we additionally added the equation for the inverse Fourier transformation as applied in this study including moving average and cut-off frequency. This might help to better understand how filter and cut-off frequency act in the reconstruction algorithm. The additional section reads:

> By inverse Fourier transformation of $\mathcal{F}\{x\}$ the original time series $x(t)$ can be derived,
>
> $$x(t) = \int_{-\infty}^{\infty} \mathcal{F}\{x\} \cdot e^{i \cdot 2\pi f \cdot t}\, \mathrm{d}f. \tag{1}$$
>
> In practice, the reconstruction may fail when instrument noise is artificially amplified. To suppress these effects, an additional low pass filter (moving average) is applied and the inverse Fourier transformation calculated only from frequencies below a specified cut-off frequency f_c. The fourier transform of a moving average (boxcar function) with window length of T_m in units of seconds is given by the sinc function what finally results in the inverse transformation,
>
> $$x(t) = \int_{-f_\mathrm{c}}^{f_\mathrm{c}} \mathrm{sinc}\left(T_\mathrm{m} \cdot f\right) \cdot \mathcal{F}\{x\} \cdot e^{i \cdot 2\pi f \cdot t}\, \mathrm{d}f. \tag{2}$$

The moving average acts similar to the sigma approximation proposed by the reviewer. In fact, the Lanczos sigma factors are identical to the fourier transform of the box-car function of the rectangular moving average filter. That is why the filter can easily be applied in the frequency domain by multiplying the factors to the fourier coefficients of the time series. To better present the effect of the moving average filter in the revised manuscript, we added a comparison of results with and without filter in the laboratory study reconstructing the box-car function (Figure 3). The section was extended by the following discussion:

> The oscillations can be reduced by applying an additional moving average filter as described in Eq. 9 which acts similar to the sigma-approximation often used to eliminate the Gibbs phenomenon. Applying filter with window length $T_\mathrm{m} = 1/f_\mathrm{c}$ did significantly improve the results shown in Figure 3 (red lines). The magnitude of the oscillations is reduced but consequently the width of the step slightly increases to about 1 s what is still in the range of the inverse of the cut-off frequency. As this might be different in other cases, the use of a moving average filter has always to be weighted in each individual case with the negative consequence of a reduced temporal resolution caused by the smoothing. Similar to the results without filter, the remaining oscillations again become larger when the sensor noise is increased due to a reduction of the sampling frequency.

The use of moving average filter has always to be weighted with the reduced temporal resolution due to the smoothing. Figure 1 given below gives a closer view on one step of the reconstructed box-car function. Obviously, the oscillations are reduced but also the step width increases due to the smoothing. In this case the slight increase of the step width is not significant compared to the reduction of the oscillations. But in other configurations this might be vice versa. E.g., for the study investigating influence of oscillation frequency (section 3.3.2, Figure 5) we still did not apply a moving average filter for the given reason, that the filter would cause a reduction of the oscillation amplitudes if the window length is to large and oscillations are to small. All other reconstructions were performed with filter as specified in the individual sections.

Interactive comment on Atmos. Meas. Tech. Discuss., 8, 5179, 2015.

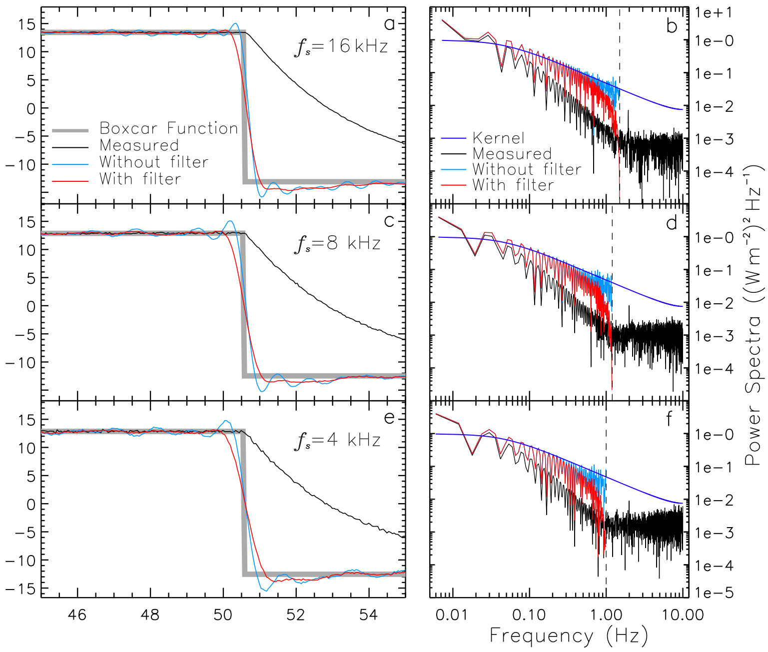

Fig. 1. Comparison of the reconstruction with and without moving average filter for the box-car function. Results are shown for different sampling frequencies.