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Atmospheric Chemistry and Physics Discussions

Interactive comment on “Downscaling of METEOSAT SEVIRI 0.6 and 0.8 micron channel radiances utilizing the high-resolution visible channel” *by* H. M. Deneke and R. Roebling

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We thank referee 2 for his time taken to review our manuscript, and his thoughtful comments which helped us to improve the initial version. In the following, we will respond to each of the issues raised by him/her:

Specific Issues:

R2, 1) Section 3.3, Spatial response functions: Do you only use the spatial response function (point spread, PSF) for the lores data to re-sample hires data? That is, do you smooth HRV data with the original SEVIRI lores PSF? This would mean an "over-smoothing" of the image. Lores and hires PSF both describe the collection of the real spatial radiance distribution into lores or hires pixels. That means, starting from a hires image you would have to deconvolve the image with the hires PSF, which would give you an estimate of the original radiance distribution measured by the sensor. Only then you could apply the lowres PSF to re-sample the data to produce a lores HRV version comparable to the other two chan- nels. If you consider all of this and I just didn't get it, please clarify this in the section. Otherwise please correct it or explain why you don't have to do it.

Reply: Actually, the referee raises an important point. We agree that an over-smoothing occurs if only the MTF/PSF of the LRES channels is considered, as the HRV channel is smoothed due to its MTF. However, we have taken this point into account in the implementation of our algorithm, and have unfortunately forgotten to describe this point in the text. Instead of de-convolving the HRV radiance field with its MTF, as suggested by the referee, we use the ratio of LRES MTF to the HRES MTF to take this effect into account in one single step.

Original: In our downscaling algorithm, the HRVIS image is filtered with the MTF as low-pass filter to simulate an LRES image. This filtering operation is carried out in the frequency domain by multiplication of the Fourier transform with the MTF. High-frequency vari- ability not resolved by the LRES images is then found as difference of unfiltered and filtered HRVIS image.

Revision: In our downscaling algorithm, the HRV image is filtered with a low-pass filter to simulate an LRES image. This filtering operation is carried out in the frequency domain by multiplication of the Fourier transform with an effective MTF. This is obtained from the average MTF of the 0.6 and 0.8 micron detectors, divided by the HRV MTF. The division is done to account for the fact that the HRV image is already smoothed due to its imperfect spatial response, and avoids a separate de-convolution step.

R2, 2) Don't the MTF/PSF you use only apply for the sub-satellite point? The averaging for Western Europe must be much coarser? For Europe it might even be much better

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to average over 3x3 HRV pixels instead of using a much too narrow sub-satellite PSF. You have to discuss that. If your use of the PSF doesn't introduce noticeable errors for your method, you might not need to consider the PSF at all. Then you would hardly need section 3.3!

Reply: Two separate aspects are raised in this comment. First, the MTF/PSF is determined by the angular resolution of the SEVIRI detectors, and the HRV resolution exceeds the narrowband resolutions by a factor of 3 over the entire disk. Hence, the reviewer is right in that the spatial/frequency scales given is only valid at nadir, and the spatial resolution decreases with increasing viewing angle. As the difference in angular resolution is a fixed factor, however, our procedure can be applied without changes for the full SEVIRI disk, and the procedure does not need to be modified for off-nadir viewing geometries. To stress this point, we have added the following sentences in section 3.3:

It has to be realized that the MTFs and point spread functions shown in Fig.2 are in fact determined by the angular resolution of the individual SEVIRI detectors. The spatial scales and frequencies specified in this paper refer to the spatial resolution at nadir, and a reduction in resolution for off-nadir viewing geometries needs to be accounted for separately. As the angular resolution of the HRV and narrowband channels remains constant over the entire SEVIRI disk, the change in viewing geometry does not affect our downscaling algorithm.

R2, 3) page 10714/ line 18: introduce the term "Nyquist" frequency in section 3.1

Reply: Added definition of the Nyquist frequency in a new paragraph at the beginning of section 3.1, and slightly modified the old first paragraph.

Original: The discrete Fourier transform fk,l of a 2-D image fx,y consists of Nx $\times$ Ny samples, and projects the original image onto an orthonormal basis set of sinusoidal waves with circular frequencies of [math notation skipped]. Vectors ω and x can be used . . .

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Revision: A 2D image fx,y consisting of Nx $\times$ Ny discrete digital samples is considered here. The sampling frequency limits the maximum frequency which can be captured by the image. This limit is equal to half the sampling frequency, and is called the Nyquist frequency. The discrete Fourier transform fk,l of the 2D image consists of Nx $\times$Ny samples, and projects the image onto an orthonormal basis set of sinusoidal waves with circular frequencies of [math notation skipped]. Vectors ω and x can be used ...

R2, 4) 10718/ 25f: Does that mean that you do not use the elegant Fourier space possibilities you introduce but just find the solution by trying out? Do not discuss methods you don't use (sec. 3.2 needed?).

Reply: The question raised that we do not use the Fourier method can be answered with NO. Indeed, we indeed do correct for shifts > 0.5 HRV pixels by shifting the HRV region. However, the Fourier method helps us avoid "trying out" various shifts, and is used to align images at the sub-pixel scale, i.e. for shifts less than 0.5 pixels. Hence, sec. 3.2 is needed. We have modified this section to clarify these points.

Original: In addition, it is more accurate to account for integer HRVIS pixel shifts by changing the subregion of the HRVIS image instead of adding a phase shift to the Fourier transform.

Revision: In addition, if the HRV pixel shift exceeds half a pixel, the subregion of the HRV is changed to minimize the phase shift used for the Fourier-based image alignment.

R2, 5) 10719/ sec. 4. in general: You do use the statistical terminology which is introduced only in Appendix B. E.g. "slope" is hardly mentioned in section 3.5, but prominently discussed in sec. 4. This way it is hard to follow without reading the appendix, exactly which should not happen when you decide to use an appendix. You either have to give the reader more information ïňĄrst (from the appendix) or you have to shorten the discussion at these points (and maybe move things into the appendix).

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Reply: We agree that we have introduced too little of the statistical background. We have now inserted an equation which defines the slopes for linking narrowband and HRV high-frequency variability in the main text, We hope that the statistical terminology has become clearer through the following changes:

Original: In Appendix B, general formulae are derived for calculating the slope (Eq. B.6) and the expected fraction of explained variance (Eq. B.8) of the linear model minimizing the least-squares deviations based on fundamental relations of bivariate statistics are derived.

Revision: The goal is to find the optimal slopes $S(r_{06})$ and $S(r_{08})$ for linking high frequency variations Δr in the HRV and the narrowband channels:

$$\Delta r_{06/08} = S(r_{06/08}) \times \Delta r_H. \tag{1}$$

In Eq. B.6, general expressions for calculating these slopes $S(r_{06/07})$, which minimize the least-squares deviations are derived, based on bivariate statistics. Also, the expected fraction of explained variance for this linear model is given in Eq. B.8.

Technical corrections:

R2, 6) page 10736/ Fig 2: "res1" fragment

Reply: Corrected Latex macro (missing slash), so "res1“ is changed into $1 \times 1\,km^2$ to specify the spatial resolution of the HRV channel in the figure caption.

R2, 7) 10716/ 13: the term "FIR" is not introduced

Reply: The term FIR has been introduced on the previous page as "finite-impulse response“ filter.

R2, 8) 10718/4 No sentence. Obviously this sentence is a bit too long.

Reply: Indeed, we have rewritten this sentence as follows:

Original: In Appendix B, general formulae are derived for calculating the slope (Eq. B6) and the expected fraction of explained variance (Eq. B8) of the linear model minimizing the least-squares deviations based on fundamental relations of bivariate statistics are derived.

Revision: In Appendix B, general formulae for the linear model which minimizes the least-squares derivations are derived. We present expressions for calculating the slope (Eq. B6) and the expected fraction of explained variance (Eq. B8).

R2, 9) 10722/1 Typo. "0.5x4.8" -> "4.8x4.8"

Reply: Actually, this is not a typo. 0.5×4.8^{-1} refers to the limit imposed by the Nyquist frequency. To stress this point, and to avoid similar conclusions by the reader, we have changed this sentence to read:

Original: ... all Fourier coefficients with a frequency $0.5 \times 4.8km^{-1}$ were set to zero ...

Revision:... all Fourier coefficients above the Nyquist frequency ($\frac{1}{2} \times 4.8^{-1}\, km^{-1}$) were set to zero ...

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 10707, 2010.

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