# Response to reviewer's comments on "Techniques for analyses of trends in GRUAN data" by G. Bodeker and S. Kremser

In each case the reviewer's comment is repeated in blue with our response in black.

<u>Response to reviewer #2</u>
P11964, L8: It is pointed out that choosing the number of Fourier pairs to use 'is a judgment call'. Given the pedagogical approach of this paper it would be useful to provide some further instruction or point to further methods that can be applied to help one determine this more subjectively.

This is a good suggestion. We have added the following additional sentences to this section of the manuscript to provide further guidance: This is, in part, a judgement call. For terms where a robust seasonality is expected e.g. the mean annual cycle as represented by the seasonality in the offset coefficient ($\alpha$), 3 or 4 Fourier pairs could confidently be fitted without the danger of fitting spurious seasonal structure. For the seasonality in the trend ($\beta$ coefficient), this depends on our expectation – if we expect the trend to be the same through all seasons, then the $\beta$ coefficient need not be expanded in Fourier pairs at all. If the trend shows clear seasonality but that seasonality is sinusoidal in nature, then 1 Fourier pair would be sufficient. The less sinusoidal that seasonality is in structure, the more Fourier pairs are needed to capture that structure. For the QBO ($\gamma$ coefficient), where some seasonality in its effect is expected, but where that seasonality may not be clearly present in the data and is not purely sinusoidal, 2 Fourier pairs would likely be the appropriate balance between avoiding over-fitting but capturing the seasonality in the QBO's effect on the data. For ENSO and SOLAR, because their effects are seldom seasonally dependent (or too weak to detect in the data), they are usually not expanded in Fourier pairs.

Sect. 2.3: This section would become clearer if the different elements of fig. 3 were referred to so as to better illustrate the points being made. For example (P11964, L27-28 continued on to P11965, L1), it is not entirely clear why the same but opposite cannot be said of the red line, even though the calculated trend is not significant.

We have added the following text to the manuscript to clarify this: 'i.e. the negative tendency contribution from the solar cycle shown in panel (d) of Figure 3 (blue line) is mirrored by the positive linear trend (blue line) in panel (b) of Figure 3. Similarly, positive solar cycle tendencies are matched by negative linear trends (red lines in Figure 3)'.

Sect. 6.2: The explanations in this section are somewhat difficult to understand. For example, the trends in May at _13km are smallest in the all-orthog fit, but only the all or reduced fits are discussed – the explanation in 'interpretation 1' is tricky to interpret in itself.

We have added to this section, and reworded it, to improve the clarity.

Also in this section, the last paragraph referring to the 12:00 UTC results feels somewhat superfluous. It doesn't help further illustrate what is already discussed in this section, nor does the inclusion of fig. 8.

We agree with the reviewer and have shortened this final section and removed Figure 8.

The conclusions are very short, which, to some extent is understandable given the nature of the paper. However, it would likely make sense to again point out what is so clearly discussed

in the abstract: – that a proper understanding of how to analyse GRUAN data is necessary to make full use of the enormous effort put into determining measurement uncertainties, etc.

We have added one sentence to the conclusions to reiterate this point.

Minor comments:
P11961, L18: Why is the ENSO basis function so specifically given as the 'normalised Tahiti minus Darwin SLP'? Given that there are several ENSO indices as well as several options for including QBO or solar cycle basis functions, it perhaps makes more sense to leave this out.

We have made the necessary changes in the text to clarify this.

P11963, L16: Maybe it's worth pointing out how many Fourier pairs are used in the equation shown in L18?

We have included the number of Fourier pairs and the sentence now reads: These requirements are met by expanding the coefficient in Fourier series, e.g. the trend coefficient $\beta$ is expanded in two Fourier pairs as…

P11964, L15: The grey shaded area is referred to earlier in the sentence and it would make sense to refer to the vertical error bars in terms of the fits to the individual months.

This is a good suggestion. The sentence now reads: The uncertainty on the trends is also smaller when the seasonality is accounted for using Fourier series (grey shaded area in Fig. 2) compared to fitting individually to each month (uncertainties shown as vertical error bars in Fig. 2).

P11964, L24: The significance of trends is discussed but no values are given in the text, nor are the values shown in fig 3b referred to – this might be useful to the reader to better illustrate the point. It may also be useful to point out that it is the blue line?

We do list the trend values and their $1\sigma$ uncertainties in panel b of Figure 3. We have now referred to those numbers in the text so that the reader will more easily connect these values and what we are saying in the text. The sentence now reads: Even though the time series was constructed to have no trend, one of the four trend results (listed in panel (b) of Fig. 3) is found to be statistically significantly different from zero at the $1\sigma$ level (blue line in Fig. 3).

Fig. 5: The text in this figure is very small, particularly of the colour bar.

We have increased the font size.

Fig. 7: Putting the numbers on the colour bar horizontally would greatly improve readability.

Done.

Grammar/typographical errors:

P11965, L11: Fig 3a was probably meant to be referred to rather than Fig. 3b.

We have corrected this error.

P11966, L4: I am by no means a mathematician, but it is not clear why when substituting the X into Eq. 2 there is a – rather than a +. (This is again the case on L11 of the same page).

Thank you for catching this error. We have now included the missing '-' in the equation on line 29 pg. 11966 when solving for *X*.

P11968, L3-4: : : : e.g., Steinbrecht et al. (2003) and Sioris et al. (2013), : : :[the brackets are missing].

We have included the missing brackets.

P11971, L4: The reference to Weatherhead et al. (1998) can be written as W98.

Done.

P11971, L24: : : :, and that are not affected by: : : [that are rather than to be; affected rather than effected].

We have corrected this error.

P11971, L27: Uncertainties [capital U].

Done.

P11972, L6: No [capital N].

Done.

P11972, L12-13: approaches [rather than approach].

Done.

P11977, L28: Should interpretation (2) not rather be referred to?

Yes, and we have corrected that error.

Fig. 2 caption: : : :(shown in inset): : : [including these brackets would make the caption easier to understand].

That's a good suggestion and we have implemented it.