Anonymous Referee #1

The present manuscript presents an accurate analysis of the use of the Waveform Skewness Index, as compared to the traditional (sliding) skewness coefficient and its dependence as a function of the sliding period, presenting possible drawbacks of this skewness estimator. Authors also study the robustness of the link between El-Niño skewness and AIR and also between TNI and AIR using the proposed Waveform Skewness Index. Significance tests of those links (measured by correlations) are assessed by Monte-Carlo experiments. The manuscript is very well written and complements very well previous recent works of the authors, presenting original material being thus suitable for NPG. It is believed however, that the manuscript can be further improved after considering a few points of reflection.

1) Pg. 2, lines 3-4. Skewness of a time-series is not an exclusive feature of non-linear systems as authors implicitly supposed to. As an example, we can simply consider a stochastic linear process driven by a non-Gaussian skewed noise where the noise skewness comes as a function of the signal skewness and of the signal autocovariance function (e.g. Pires and Hannachi 2021 (PH21 in the sequel))

The authors agree that we need to clarify that waveform skewness could arise from other processes besides non-linear ones. As such, a few sentences will be added in the methods section to comment about other sources of waveform skewness.

2) Pg. 3 In the paragraph (line 8-13) it is opportune to mention the test of nonlinearity of the El-Niño, followed in PH21. It relies on the standardized difference between the El-Niño bispectrum and the bispectrum of a linear non-Gaussian process fitting El-Niño reproducing the same spectrum and skewness.

The authors appreciate the referral to that test. It will now be mentioned on Page 3.

3) pg. 4, line 4 Add a reference for trans-Niño index (e.g. Trenberth and Stepaniak 2001).

The missing reference will be added to the revised manuscript.

4) pg. 4 Line 7 '. . .implicated has an SST pattern' must be '. . .implicated as an SST pattern' ?

Thank you for pointing out the typographic error. It will be corrected in the revised manuscript.

5) Pg.5, Eq.4 divide by s3.**

Thank you for pointing out the typographic error. It will be corrected in the revised manuscript.

6) Pg. 5 line 17. Say in text that the tested length N in the computation of the sliding skewness was 20 months to facilitate its comparison with the periods 8,16 and 32. It seems that the effect of oscillations on the skewness estimation appears to be significant only when the largest Fourier period in the time-series is of the order of N or some when some long-term trend id present. Please comment that aspect.

The authors agree that the effect of the oscillations is only significant when the period of the oscillation is roughly greater than or equal the chosen sliding segment length. We will add a few sentences in the revised manuscript to reflect this observation, as it could help researchers decide an appropriate segment length to use their analyses.

7) Pg 7, line 13 siding → sliding

Thank you for pointing out the typographic error. It will be corrected in the revised manuscript.

8) Pg. 7, Sec. 3.3. The Waveform skewness timeseries is a modified timeseries keeping some characteristics of the original raw timeseries. What in effect is kept? For instance, how much is correlation and coherency spectrum? Could you develop some considerations about this issue.

The authors agree that it would be important understand what components of the original time series remain after the transformation to waveform skewness. This topic will be explored in the revised manuscript by correlating the transformed time series with the original one. A few sentences will be added to inform the readers about how much the transformed time series differs from the original time series.

9) Pg. 11 Lines 15-18. You should stress that similar El-Niño auto-bicoherence with identical triads of periods was obtained by Pires and Hannachi (2021) in its Fig. 9a.

The authors appreciate the referral to the Pires and Hannachi (2021) paper. We will add a discussion about how our results compare to those of Pires and Hannachi (2021) in the revised manuscript.

10) Fig. 9 Indicate the meaning of line colors (JJ and AS seasons).

Color scheme will be described in the revised manuscript.

11) Pg. 9. The series x3(t) given by Eq. 11,12 is very interesting to test the phase synchronization and the time-varying skewness, through a quadratic growing (not stationary) amplitude of the P3 component. This kind of model raises the idea of another model that it will be very worth to test. In fact, skewness may not uniquely come from phase synchronization but also from a correlation between the amplitude gamma(t) and the phase phi3(t) which should oscillate instead of being taken constant. The bispectrum sum over bi-frequencies equals the skewness. However, the bispectrum can be decomposed into a phase synchronization term and the above referred correlation term, thus putting in evidence the two possible mechanisms of generating skewness. For details see Sec. 5.1.1 of Pires and Hannachi (2021), in particular the decomposition in its Eq. 12.

The authors thank the reviewer for pointing out the interesting relationship between a bi-spectrum and the covariance between amplitude and phase. The authors agree that it is an important topic, but the authors are concerned about including additional experimental tests in the manuscript because the manuscript already includes 13 Figures. Given this concern, we will instead include an example in the supplementary material that highlights how correlaton between phase and amplitude can crate waveform skewness.

References

Carlos A. L. Pires & Abdel Hannachi (2021) Bispectral analysis of nonlinear interaction, predictability and stochastic modelling with application to ENSO, Tellus A: Dynamic Meteorology and Oceanography, 73:1, 1-30, DOI: 10.1080/16000870.2020.1866393