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Comment on gi-2021-13

Anonymous Referee #2

Referee comment on "Assessment of the influence of astronomical cyclicity on sedimentation processes in Eastern Paratethys based on paleomagnetic measurements using Discrete Mathematical Analysis" by Boris Dzeboev et al., Geosci. Instrum. Method. Data Syst. Discuss., https://doi.org/10.5194/gi-2021-13-RC2, 2021

I recommend that this paper be returned to the authors so that they may

1) consider estimation of uncertainty / significance for consistency analysis
2) consider estimation of uncertainty / significance for periodicity matching
3) clearly state assumptions required to relate external forcing to sediment deposition rates
4) remove material (eg. DMA) that is not directly required for analysis.

++++ Summary +++++

The abstract states that:

"the main objective of this study is to apply Discrete Mathematical Analysis (DMA) to the development of the methodology of cyclostratigraphy."

with a concise summary of cyclostratigraphy provided subsequently in lines [90-105].

In this study, three Fourier analysis methods are used to identify variations in magnetic susceptibility of geological sediments. Fourier results are compared to periodicity estimates obtained with a different method: "constancy" analysis.

The first method described in lines [106-119] is essentially standard Fourier analysis that is well suited for detecting harmonics in evenly sampled data.

The second method is the Lomb-Scargle periodogram which was designed to deal with unevenly
spaced or gappy data.

The third method (REDFIT) is an extension of the Lomb-Scargle method to include the presence of background red noise.

Some results are shown in section 3 for a reference data set:
[189-190] "This series contains the last 400,000 years of the record in 1,000-year increments (Figure 1)."

Some discussion of the selection of this data set would be nice:
[190-191] "This series was chosen for demonstrating the application of spectral methods as
it has been comprehensively studied."
Does this mean that periodicity in this data set is well understood? Citation(s) would seem appropriate.

The Fourier and Lomb-Scargle power spectra are similar but not identical.
In the limit of regular sampling the results should be the same. This
indicates that there must be some data gaps or uneven spacing, which is not
consistent with the description of the data set.

Periodicity detection is also carried out with "constancy" analysis as described
in a fairly abstract presentation [155-184] that does not address uncertainties
or significance estimates.

The largest minimum in Figure 3 occurs at 115,000 which is within 10% of the
largest Fourier result. Other minima are not particularly noteworthy
("strong" [182]), and overall there is not an unambiguous 1:1 match with all of the
Fourier results.

For this data set constancy analysis seem reasonably effective for the largest
amplitude periodic variation, but is otherwise not clearly superior to the Fourier
methods.

The analysis is then applied to two sediment layers (41.2 and 30m respectively) at 20cm spacing.
Results appear much noisier than first example. All Fourier methods are generally in agreement
with spatial periodicity of 3.97m and 22.52m for first, 7m for second. As before, the Lomb-Scargle
results should be the same as classic Fourier analysis for evenly spaced data but is not.

Constancy analysis for the first layer has a fairly clear minimum around 3.6m and a very weak
minimum at 15.2m; the second layer has a decent constancy minimum at 7m.

The authors assert that:
[299-301] "These signals correspond to the precession and obliquity cycles.
The 3.6 m peak corresponds to the precession periodicity (19–24 thousand years). The 7 m peak
corresponds to the periods of changes in the angle of inclination of the Earth’s axis
(41,000 years)."

However, it is first necessary to address the question of why both layers do not exhibit
exactly the same periodicities.

As noted by [Sinnesael et al 2018 Paleoceanography and Paleoclimatology, 33, 493–510]
"In practice, sedimentation rate rarely changes in a uniform way.
Moreover, the response of the climatic system can change the amplitude ratio
among the astronomical components of the original insolation forcing signal."

Different deposition rates might be in effect for each of the two layers, which might help explain the different observations. In fact, there could in principle be significant variations which could map astronomical periodicities to sediment variations with significantly different power spectra. If the mapping is sufficiently non-linear as to change the periodicities between layers then it could also cause distortion within layers, which could invalidate any hope of matching sedimentary periods with Milankovitch cycles.

Finally, DMA is not clearly defined in this report or in what is supposed to be a canonical reference [Agayan et al 2018].

DMA is introduced in lines 146-154:

"The proposed technique is based on DMA [Agayan et al., 2018]. The new method is an original technique for analysing discrete data, developed at the GC RAS. DMA is a series of algorithms united by a common formal basis: fuzzy comparisons of numbers, a measure of proximity in discrete spaces, and a discrete limit. DMA was developed to create discrete equivalents of the concepts of classical mathematical analysis: for example, limit, continuity, smoothness, connectivity, monotonicity, and extremum. DMA methods and algorithms have proven to be useful in numerous studies related to the processing and analysis of various [...] data."

Similarly bold statements occur near the end of the paper:

[311-315] "It is necessary to say in conclusion a few words, about the mathematical apparatus of DMA [Agayan et al., 2018]. It is being developed at the Geophysical Center of the Russian Academy of Sciences and forms the basis of the methodology for searching periods in the series of cyclostratigraphic data presented in the article. It is important to emphasize that DMA is a direction of modern applied systems analysis [Zgurovsky and Pankratova, 2007]."

[316-320] "DMA has all the necessary tools to generate mining algorithms for geological and geophysical data, including searching for hidden periods / cycles. Based on fuzzy sets and fuzzy logic, DMA has the ability to convey expert ideas about the structure, morphology, monotony, and other of studied data series. Thus, DMA enables a systematic approach to the analysis of complex data series of Earth sciences."

While this may be true, none of it is supported by the results of this paper.