Clim. Past Discuss.,
doi:10.5194/cp-2015-188-RC2, 2016

Climate of the Past
Discussions

Interactive comment on "Testing the impact of stratigraphic uncertainty on spectral analyses of sedimentary series" *by* Mathieu Martinez et al.

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Received and published: 24 March 2016

1. Introduction

Martinez et al. explore the problem of uncertainties that arise from the intersection of variable sedimentation rate and sampling errors in the analysis of Milankovitch-forced stratigraphy. This work provides important guidance for stratigraphers faced with decisions on how to sample cyclic sedimentary sequences in a way that optimizes recovery of paleoclimate signals. This represents a significant contribution to the study of paleoclimate spectra.

2. The error model

The authors call on the gamma probability density distribution to characterize strati-

graphic sampling. Here there could be more explanation, e.g., a simple illustration of the problem, i.e., in Figure 1 add a diagram of a hypothetical stratigraphic section, different sampling sequences, and their histograms – perhaps the same ones as presented in Figure 2); in Figure 1 caption indicate "gampdf(x, k, Θ)" and label horizontal axis as "x". The models presented in Figure 2 displayed in F, G and H: what values of k and Θ do these correspond to?

3. The geological datasets

Two typical cases are presented, from Cretaceous and Devonian cyclostratigraphic outcrops that were previously sampled and analyzed, with publicly available datasets. This allows the reader to directly replicate the uncertainty modeling presented in this paper, for use as a template for other datasets and parameters.

4. Implementation of the models in the stratigraphic-uncertainty tests

This reviewer can personally attest to the difficulty in measuring a consistent thickness for the same outcrop by different researchers - in my experience in one case: 112 m vs. 132 m! For overturned sections, any dip error committed will contribute to a positive bias in stratigraphic thickness measurements. There is undoubtedly such a problem in the steeply dipping Cretaceous section at La Charce examined in this paper.

On issues concerning methods, it is important to restrict interpolation to mean or median rate when applying AR noise models with MTM spectra (such as used in SSA-MTM Toolkit). The Devonian section has a mean sample rate of 0.38 m – not clear what the median rate is – and this is much larger than the interpolation to 0.01 m. The Cretaceous section has a mean sample rate of 0.20 m, so has a similar problem. The authors should recalculate the MTM analysis with interpolation to the median sample spacing of the two sections. (The red noise spectra will be significantly different because of the way the autocorrelation lag-1 coefficient is calculated.) The other parameter that requires reporting is whether "log" or "linear" fitting was enabled in the calculation of robust red noise for the MTM spectra.

5. Application to a sum of sinusoids

This section quantifies the loss of power at high frequencies with increasing uncertainty of (variability in) the sample step sequence for a simulated sum-of-sinusoids series.

The absence of windowing in the Lomb-Scargle (LS) spectra would be expected to result in higher spectral variance compared to multitaper-windowed MTM spectra, and may account for the elevated grey spectra from the LS Monte Carlo simulations (compared to those of the MTM spectra). Interestingly, for 10% and 15% σ, loss of power occurs at practically the same frequencies in both MTM and LS spectra. Would it be possible to indicate the expected variance in Nyquist frequency for the 3 cases (5%, 10%, 15%) in order to understand the accuracy of the MTM and LS spectra?

A new order of the graphs in Figures 2 and 3 might benefit the presentation:

âĂć New Figure 2: display Figs. 2F, G, H only, and explain how these relate to k and Θ (or put them into a Figure 1B). âĂć New Figure 3: in top row, display Fig. 2A, B, C, D; bottom row display Fig. 3A, B, C, D. âĂć Figs. 2E and 3E could be placed into a new figure.

What did we learn from this exercise and how will it help with the interpretation of the geological datasets to follow?

6. Application to geological datasets

The MTM spectrum of the Devonian series (Figure 4D) shows a robust red noise model with extremely elevated low frequencies, implying that a "log" fit was calculated in SSA-MTM Toolkit, and that the model suffers additionally from the 0.01 m interpolation (see comments for Section 4). Some of the text in this section about differences in red noise calculations (which by the way are not meaningfully explained) may not be needed once the interpolation problem is addressed.

7. Discussion

The main point of this study is that sampling is the critical decision that must be made when evaluating a stratigraphic sequence for paleoclimate signals. Almost all problems can be controlled with high-density sampling, e.g., 6-10 samples per putative precession cycle. It appears that one can easily expect 5% errors in stratigraphic position measurements, which combined with sedimentation rate variations, will mix the highest frequencies of a sampled sequence. Thus we are always alarmed at how low in power – and misaligned – precession cycles are in stratigraphic spectra. In the end, one never knows if a sample that has been collected has been assigned to its true stratigraphic position. This is an important limitation that is under-appreciated by the geological community and the authors should be commended for tackling this problem.

A number of issues have been left unexplored: (1) how does systematic sample position error, such as can occur with receded marls alternating with prominent limestones in outcrops, affect stratigraphic spectra; (2) can astronomical tuning bypass the positional uncertainty problem (notwithstanding the recent approach described in Zeeden et al., 2015); and (3) how does the positional uncertainty problem affect the red noise model estimates?

Other comments

Lines 23-24: The Multi-Taper Method (Thomson, 1982) might be more accurately characterized as a spectrum estimator that is based on the Fourier Transform – not as a derivative of the Fourier Transform.

Line 27: A recent massive improvement to the Jacob's staff in outcrop studies is terrestrial laser scanning with precision positioning at the mm level (Franceschi et al., 2011; Franceschi et al., 2015).

Line 101: Change to "Pas et al., 2015".

Lines 264- 265: what does the output of the "long-term trend of the variance" look like, and what was used to compute the "LOWESS regression with a 10% coefficient"?

Line 350: For monotonous stratigraphy yielding Milankovitch signal see also Latta et al., 2006.

Line 355: Change “require” to “requires”

Line 361: Delete “Note than”.

Supplementary Fille: R package dplR appears to be used but not referenced in the main text. R is used to calculate REDFIT– is it provided in the dplR package?

References

Franceschi, M., Penasa, L., Coccioni, R., Gattacceca, J., Smit, J., Cascella, A., Mariani, S., and Montanari, A. (2015), Terrestrial Laser Scanner imaging for the cyclostratigraphy and astronomical tuning of the Ypresian–Lutetian pelagic section of Smirra (Umbria–Marche Basin, Italy), Palaeogeography, Palaeoclimatology, Palaeoecology, 440, 33–46, doi: 10.1016/j.palaeo.2015.08.027

Franceschi, M., Preto, N., Hinnov, L.A., Huang, C., and Rusciadelli, G. (2011), Terrestrial laser scanner imaging reveals astronomical forcing of the early Cretaceous Tethys realm, Earth and Planetary Science Letters, 305, 359-370, doi:10.1016/j.epsl.2011.03.017

Latta, D.K., Anastasio, D., Hinnov, L.A., Elrick, M.E., and Kodama, K.P. (2006), A record of Milankovitch rhythms in lithologically non-cyclic marine carbonates, Geology, 34, 29-32, doi: 10.1130/G21918.1

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