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Interactive Comment

Interactive comment on "Identification of the accretion rate for annually resolved archives" *by* F. De Ridder et al.

F. De Ridder et al.

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In the name of all authors, I acknowledge the very helpful comments of the referee. I accept all comments.

1. Uncertainty estimation

Indeed, an estimate of the error on the reconstructed chronology is not included. We had originally decided not to include this. This is also the main critic of the other referee. We will prepare and include a Monte-Carlo simulation and a linearized uncertainty analysis to meet these critics.

2. Robustness

The robustness of this method can be analyzed in three cases:

A. In the presence of only stochastic noise. If the noise level increases, the MDL criterion should lower the complexity of the signal and time base model. So, theoretically,

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the method should never fail in reconstructing the chronology. However, at a certain signal-to-noise ratio it should reject any variation in the time base as being significant. We will have to implement a Monte-Carlo simulation to check this theoretical reflection. This will also be included in the final manuscript.

B. In the presence of weather/climate noise, noise inherent in the proxy record. This method will handle this kind of noise as white noise (i.e. it will try to reconstruct with a flat spectral content with some harmonics). If more complex noise is present in a particular record, like red noise (with a decreasing spectral content as function of the frequency), this can cause model errors. For such types of noise, I see two possible solutions:

(i) capture this noise with a low order polynomial model, assuming that these variations in the proxy are sufficiently slow, so that the time base distortion has hardly any influence on the parameters of this polynomial model. Once this trend is subtracted, the method proposed in this paper can be applied. Possibly, this strategy can be iterated (in a relaxation algorithm).

(ii) the signal model can be expanded with this polynomial model, so that the MDL criterion can also determine the number of parameters needed to describe such trends. This is, from a theoretical point of view the best solution, but I fear that the calculation time will become too long.

C. In the presence of model errors (like pointed out by A. Juillet; see short comment on this manuscript). It can be possible that certain records consist of frequency modulations, which are significantly above the noise level. Suppose for example that a record is periodic, but that the frequency differs from year to year. In such case, the frequency modulation will be processed as a perturbation of the time base and will not be noticed. However, at this moment I see hardly any workable alternative: how can an investigator detect frequency modulation if the time base is unknown? Only if additional information about the time base is available, like growth bands, frequency modulations can be detected. Such information can be implemented in the model for the time base as additional constraints. In that case it is possible to identify a time base for periodic signals with frequency modulations.

3. Elimination of jargon

We will do our best to eliminate the statistical and signal processing jargon and give non-technical descriptions elsewhere.

4. Bruggeman's paper

Bruggeman (1992) proposed a method, which optimizes simultaneously the time-depth relation and a linear dynamic model that links global ice volume with solar insolation. I agree that both methods are related and the resemblances and differences will be pointed out. They assumed that the relation between the proxy and insolation is linear and time invariant (LTI), so that the signal parameters can be optimized in the frequency domain. Such LTI systems change only the amplitude and phase of the input-frequencies and do not generate new frequencies (Pintelon and Schoukens, 2001). The most important difference is that this model estimates the system (input-output relation) and age-depth relation simultaneously, while our approach does not identify the system (only the signal is identified). Because we limit ourselves to LTI systems only the periodicities appearing in the input have to be optimized, which can be done with this type of algorithm. Therefore, our approach can be seen as a preprocessing step, before interpreting the causes of variation.

Concerning the time base reconstruction, several similarities and differences can be pointed out:

A. Bruggeman used essentially several anchor points of which the date was optimized. In order to get smooth accretion rate profiles, he proposed to use cubic spline interpolation. If the order of the splines in our approach would be set equal to zero, both construction of the time base distortion would be identical.

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B. He used an objective function, which is on the one hand a very powerful tool to incorporate several constraints, but uses coefficients, which cannot be optimized.

The first term in this objective function minimizes the mismatch between measurements and model, which we have used too. The second penalizes deviation from the first guess for the age-depth relation. We do not penalize such deviation, because I cannot come up with good arguments why my guess should be better then that of someone else. The third term penalizes for non-smoothness in the age-depth relation. This type of penalty is also incorporated in our approach: if the age-depth relation is not smooth, a large number of Spline basis functions have to be used (b is large). This high complexity will be penalized by the MDL model selection criterion. The fourth penalty term makes it possible to introduce some anchor points, of which the date is fixed. This is not incorporated in our approach, although it should be possible to do so (these anchor points can be handled as additional constraints). The fifth term is related to the system and not to the time base and will not be discussed. The sixth term penalizes for time inversion. This is a problem we encountered as well and circumvented with the inequality constraint optimization.

C. My most important critic on their approach is that the six terms of the objective function are weighted and that these weights have to be chosen by the user, while problems like time inversion should have an infinite weight (how can we compare the importance of time reversal to mismatch?). Nevertheless, this is a impressive paper, which have to mentioned in the final manuscript.

5. Splines

We can describe how the splines are defined and constructed in an appendix. The code has been written in matlab, which is a commercial software packet. If one would like to use splines an additional spline toolbox has to be bought. To avoid this, we have written a small spline library, able to construct one and two dimensional splines, the Jacobians etc... If someone would be interested, I can send this library.

6. The phase demodulation technique

The phase demodulation technique is the non-parametric version of this method. I will provide a brief description in the manuscript. It has the advantage that no initial guesses for the parameters are necessary, but time reversal can occur and no balance is made between useful information and noise. So, this method is an improved version of the phase demodulation.

7. From when onwards do we need to take the constraints into account?

The constraints become active is the sample period between 2 samples has become smaller than 20% of the average sample period. This 20% is a arbitrary boundary. If the timing of two subsequent observations coincides, the accretion rate will be infinite, which is not realistic. So at a certain accretion rate we have to control the further evolution of the time base during the optimization process. This was set to 20% of the average, which means that the maximum allowed accretion rate is about 5 times the average one. This parameter can be changed if necessary. However, I would like to point out that the MDL criterion has not selected models where the constraints where active, so on the results presented in this paper, this 20% will have no influence. We will incorporate these details in the manuscript.

8. The theoretical maxima for h and b

The theoretical maxima for h and b are given by the number of observations, N. $h+b<=N$. However, the refined MDL model selection criterion (De Ridder et al., 2005, de Brauwere et al, 2005) will never select this most complex model. In practice, the maximum complexity of the signal model, h, is limited by the sampling frequency (Nyquist- frequency). As a rule of tumb, hmax equals the average number of samples a year. Otherwise the highest frequency of the signal model will become larger than the Nyquist frequency (Pintelon and Schoukens, 2001). Suppose for example that we have a record of about 10 samples a year, so the sampling frequency is 10/year. Assume that the proxy record has an annual period with a frequency of 1/year. This means that hmax is 10, which equals the average number of samples. However, in theory this parametric method is also able to identify harmonics, whose frequencies are above the Nyquist frequency, but this solution will not be unique. For the complexity parameter bmax, it is harder to provide a rule of tumb. From my experience, I would suggest that for each basis function at least 5 to 10 observations should be available. So, start with N/10, with N the number of observations. However, if the model selection criterion would select this maximum, the calculation should be restarted with a higher complexity. These considerations will be implemented in the manuscript.

9. Clams

The clams used in this study (Gillikin et al., 2005) did not preserved growth increments. So, these can, unfortunately, not be used to validate the method. These records are dated using the non-parametric phase demodulation method (De Ridder et al., 2004). Anyway, we will document these measurements better in the final manuscript. In the proposed model, we have assumed that the signal is periodic, without relating this directly to temperature or salinity. The temperature varied between 8 °C (winter) and 14 °C (summer), quite regularly. The salinity changed between 23 and 30, less sinusoidal than the temperature, but still periodic. For a detailed discussion, we refer to the work of Gillikin et al. (2005).

References

Bruggemann, W., 1992, A minimal cost function method for optimizing the age-depth relation of deep-sea sediment cores, Paleoceanography, v. 7, p. 467-487.

Gillikin, D. P., F. De Ridder, H. Ulens, M. Elskens, E. Keppens, W. Baeyens and F. Dehairs, 2005 , Assessing the reproducibility and reliability of estuarine bivalve shells (Saxidomus giganteus) for sea surface temperature reconstruction: implications for paleoclimate studies. Palaeogeography Palaeoclimatology Palaeoecology, v. 228, p. 70-85.

Pintelon R. and Schoukens J., 2001, System Identification A Frequency Domain Approach, IEEE PRESS, New York.

Interactive comment on Biogeosciences Discussions, 3, 321, 2006.