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Interactive comment on "A probabilistic model of chronological errors in layer-counted climate proxies: applications to annually-banded coral archives" *by* M. Comboul et al.

Anonymous Referee #2

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Summary: This report summarizes the results from an investigation of dating errors in annually-resolved paleoclimate proxy archives with a focus on coral records and the impact of these dating errors in resolving interannual to multi-decadal variability in single record and in a multi-record coral network reconstructions. This topic has not been explored in depth in previous studies and will provide useful insight to paleoclimatologists who reconstruct proxy records and well as others who use these records to generate multi-proxy reconstructions that span spatial scales from regional to global. Overall, the paper is well written, a bit technical with the necessary modeling and statistical treatments that may be difficult for readers without a statistical and modeling background. The results of this paper are important and a must read for any working

with proxies based on layer counting but I fear the technical language may alienate some readers, especially those who really need to read this paper and to consider the findings in their own work. Granted, it is not the author's duty to educate everyone who may read the paper and I appreciate that are making the Matlab code available for others to use. Yet, a little more explanation of what and why they are doing will help those with less statistical and time series analysis training. For example: I applaud the authors for showing their spectral plots as variance preserving and that the area under the spectrum can be interpreted directly. Numerous other authors use spectral tools without fully understanding what they mean and write papers about how they have high amounts of multi-decadal and centennial scale variability when they do not. Those authors will show the spectrum as just power because that is all the software program they are using will allow them plot (e.g., SSA-MTM toolkit).

An example of this disconnect is the comment posted by Anne Julliet-Leclrec, too many coral-based paleoclimatologists focus on the biomineralization on the millimeter-scale and how an annual-density band forms. Yes, it is important to understand these processes, but it has been shown that the geochemical variations in the coral skeletal material correspond to the density banding patterns when properly sampled. Furthermore, the subannual dating, whether or not January is really January or March, do not really matter on the longer time scales, granted they can influence a monthly-resolved calibration. If the authors could include a secondary experiment showing the month-to-month date assignment error does not produce large influence on interannual to centennial time scales that would eliminate concerns with subannual dating uncertainties. I have performed these experiments on a smaller scale with my own data and found no shifts in my spectral analysis but I did not perform that analysis not to the level as the submitted paper. A figure showing the subannual uncertainties are separate from the annual dating errors, missing or double counted years, would help inform those working with subannually resolved records.

My other suggestion for the paper is to include in the discussion the influence of lin-

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early interpolating the data to constant time steps. Linear interpolation tends to alter the higher frequencies depending on the level resampling, over sampling produces a stepper spectral slope whereas undersampling a flatter spectral slope, see Schulz and Stattegger (1997). I have experimented with this in coral data and I did not find an influence for periodicities > two years. Granted, if the coral worker is using a constant sampling interval and the linear growth rates have variations or trends, this could produce artificial shifts in the record but I am not sure what the sensitivity would be.

Items to be addressed:

Page 6080 item #2 Line 12: It would be useful to mention here that tree-ring reconstructions are many replicated records whereas varve sediments, ice cores, and corals are not. Another item is mention, perhaps in the discussion, is that corals are not layered as in sediments or ice cores, but are biological origins with a "sclerochronometers" in their skeleton, as are trees. Trees are easier to sample because they have concentric growth along a main axis. Corals do not; they grow in three-directions and have complex morphologies such as branching corals. Massive corals grow slower than branching corals and essentially fill in the space between branches. Growth direction can change quickly and coring the colony to achieve the best core with the representative "sclerochronometer" takes experience and luck. Some cores are better than others, and looking at the x-rays can quickly tell you if you will have a good chronology, see Alibert and Kinsley (2008). Look at the x-rays and figures in the supplemental material with the multiple paths.

Page 6081 line 20 Other papers to consider for banded records: Breitenbach, S. F. Climate of the Past, 8, 2012, 1765-1779 doi:10.5194/cp-8-1765-2012.

Carre et al., Clim. Past, 8, 433–450, 2012 www.clim-past.net/8/433/2012/ doi:10.5194/cp-8-433-2012.

Page 6083 line 18 Another item that is prevalent in coral x-rays are stress bands (Hudson et al., 1976) or apparent secondary bands (Barnes and Lough, 1990; Barnes and

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Taylor, 1993) that are artifacts of slab depth and growth orientation. The geochemistry is typically not altered with the so called stress bands or apparent secondary bands but studies that use density banding or luminescent banding as the proxy would have greater occurrences of these false years. Coral cores with x-rays revealing continuous "horizontal" layers down core will have less dating error than cores with the growth direction changing direction, see previously mention Alibert's x-rays. More core breaks and discontinuous sampling paths lead to more dating error.

Page 6084 line 8 This is confusing, the initial date, (t1) is the known or youngest data of the coral, if collected live (as stated in page 6083, line 6), how can t1 be off by 10 years? I think you have the initial and final dates (at 100 years) mixed up. Be clear on which direction time is moving i.e., youngest and oldest, instead of "initial".

Section 2.2 There are coral records based on every other sample or annual samples (Dassié et al., 2013; Linsley et al., 2006; Linsley et al., 2008; Wu et al., 2013) or 5-year sampling intervals (Calvo et al., 2007; Hendy et al., 2002). Skipping every other sample (to save analytical cost) could potential alias the time series analysis or lead to more missing years. More people are using these methods to save money (and program managers think it OK to do so) but there is a potential to add more dating error to records. Could you perform simulations that addressing these sampling methodologies and whether are not they are good practices.

Page 6091 This is interesting finding. Could this explain why PDO reconstructions do not agree with each other before 1900, even the tree-ring records?

Check order of figures and first mention in the text. Fig 4 in mentioned in the text before Fig 3.

Page 6098 line 17 I agree that raw chronologies would be helpful, at least before they are interpolated to constant time intervals. Raw depth data can be complex, corals are not sediments cores and they can have many sampling paths. Additionally, every lab group "splices" their records differently as well as they use different sampling methods.

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Some older records and even some more recent records are “punch” drilled with a drill press, or hand milled with a Dremel tool, or sampled continuously with a computer aided machinery (CAM) connect to a micromill. Fortunately, many labs are moving towards CAM micromills that produce the cleanest continuous geochemical records.

Page 6099 second item This can be quantified by looking at x-rays and the sampling paths. Most studies now include x-rays at least as supplementary material. The # of breaks between cores = possible missing time, # of paths = increase in the # of double counted years or missing years between paths, Intervals with uncertain growth structures = distance is approximates time missing or duplicated (this is difficult to assign a $\pm$years). Some cores will be very good with little time missing whereas others are very messy, thus more dating error.

Figure 1 panels c and d This is a fossil coral with U-Th date. It looks like the U-Th dating uncertainty is not included since the top ($\sim$1703) does not show accumulated error. I understand this exercise was to look at cumulative dating errors, but this coral is shown with the calendar age and those dates with vary as well. Additionally, did Kim date the top of coral and is there just one U-Th date or more than one? Add a marker to indicate where the U-Th date was taken from (assuming it is from a single annual density band). This is important for reconstructions using dead corals to extend the chronology back in time by splicing records together.

Fig. 4 It took me a little bit to understand this figure. You have missing intervals in (b) but no additional years or double counted years. I think the y-axes on panel a) and b) should have the number dropped since it appears they are not meant to be mean shifted time series (most coral records have the means removed for multi-record reconstructions). Panel (c) is still not clear to me, you are starting a 0 or 50 on the x-axis?

Figure 6 The high frequencies have the white noise floor that shows up in some tree-ring records.

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