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Interactive Comment

Interactive comment on "Was the Little Ice Age more or less El Niño-like than the Mediaeval Climate Anomaly? Evidence from hydrological and temperature proxy data" *by* L. M. K. Henke et al.

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We thank the reviewer for their detailed review. We have broken down the comments into numbered sections followed by our responses.

1. The selection of candidate proxy records (Tables 1 and 2) seems to me to be incomplete and somewhat arbitrary. There are, for example, many more relatively long-term coral-based sea surface temperature (SST) reconstructions available in the NOAA Paleoclimate data base for the Pacific and Indian Oceans than those considered by the

authors.

[this is largely the same as our response to reviewer 2's comment 4.] We endeavoured to include all precipitation and temperature proxies currently publicly available for the study region. As reviewer 1 notes, there are indeed several coral records available that were not included in this study. The reason for this is that it was stated explicitly in the associated publications that the recorded d18O signal was in fact a combination of SST and SSS (or SST and precipitation). Most authors also state that it is not possible to disentangle the two climate variables (McGregor & Gagan 2004, Hereid et al. 2013, Osborne et al. 2014) While this is not an issue when, for example, one is using the single proxy as a recorder of ENSO events in a location where SST and SSS have the same-sign impact on the d18O of the coral, it does present a problem for our method of reconstruction. As we are using temperature- and precipitation-specific EOF patterns, we need proxies that are as univariate as possible (i.e. only respond to one of these two climate variables). Nevertheless, we will perform another online search to ensure we incorporate any relevant records that we may have missed.

2. There does not appear to be any screening of the various climate proxy records for their exhibiting a significant relationship with ENSO indices over the observational record period as, for example, undertaken by Li et al (2013) and Emile-Geay et al (2013). This would seem to be a crucial first step.

[this is largely the same as our response to reviewer 2's comment 4.] The answer to this second point raised by reviewer 1 leads on from the previous. The point is that we use any precipitation or temperature proxy, and have their contribution to the reconstruction decided by the EOF weighting. The empirically informed add-one-in algorithm further informs the usefulness of the proxies in reconstructing the ENSO-like signal. If a certain proxy is also significantly influenced by other climatic oscillations, for example, it would be less likely to be included in the final proxy network (Section 4).

3. The authors exclude several potential candidate proxy climate records on the basis

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of ‘dating error’ but there is no explanation, as far as I can see, how this was assessed. How, for example, was the ‘dating error’ determined for the Cole et al (1993) coral record (Table 1) when this is an annually-resolved and well-dated record?

As noted in the manuscript, the choice to exclude records with a dating error >=60 years is somewhat arbitrary but chosen as it is twice the averaging period of 30 years. We apologise if it was not clear how this dating error was then determined for individual proxies. We took the dating error from the original publications where it was reported, and else referred to age model results as found in the raw data files. In the latter case the maximum error reported for the past 2000 years was used – for longer records, larger errors further back in time were thus not taken into account as they are irrelevant for the period of interest.

As reviewer 1 has spotted, there is indeed no reason to exclude Cole et al. 1993 based on its dating error. This was a mislabelling; the reason for exclusion should have been listed as length since this record is only ~100 years. To ensure a suitable length of normalising period (i.e. where all proxies overlap), short proxy records are generally rejected by the add-one-in algorithm (Section B1). We thank reviewer 1 for pointing this out and will fix this in the revised manuscript.

4. The authors present their ‘reconstructions’ as 30-year averages (Figure 1). It is unclear to me how a 30-year average ENSO can be reconstructed when ENSO is a high-resolution climate signal operating on âĹij2-7 year timescales. Also, past and future ENSO variability is not just about changes in the mean state, it also should encompass a measure of variability and the frequency and intensity of the two phases (i.e. El Niño and La Niña).

[this is the same as our response to reviewer 2’s comment 1.] Both reviewers raised the issue of reconciling 30-year averages and the interannual ENSO timescales. Our aim here was not to comment on ENSO interannual variability, frequency or amplitude as did Li et al. (2013) and Emile-Geay et al. (2013), but rather ENSO-like climate

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change similar to many long-term, lower resolution proxy studies (cf. Moy et al. 2002, Conroy et al. 2008, Yan et al. 2011). This was clearly not conveyed very well and we apologise for the confusion caused. We absolutely agree that it is not possible to translate this directly into ENSO variability, frequency and intensity and thank the reviewers for highlighting the need to clarify this. Our interest is in the extent to which climate change was El Nino-like or La Nina-like during the past 1000 years. Part of the motivation for this is the paper of Yan et al., 2011a, which suggests that precipitation proxies indicate El Nino like change while temperature proxies indicate La Nina like change. Our understanding of current climate suggests that this is unlikely, but it would be very important if true. In the revised manuscript, we will therefore emphasise that our interest is in understanding El-Nino-like climate change rather than changes in the periodicity and intensity of the ENSO cycle in both the Introduction and Discussion sections.

5. Although the separate precipitation- and temperature-based reconstructions could be informative, why did the authors not develop a combined proxy reconstruction? Maybe the sum is greater than the parts?

Reviewer 1 makes a good point about combining the precipitation and temperature reconstructions potentially being more informative as an overall reconstruction of El Nino-like climate change. However, as we mention in our response to comment 4, a major objective of this study was to investigate the apparent discrepancy between temperature and precipitation proxies as highlighted by Yan et al. (2011), and for this, separate reconstructions are necessary.

6. Complete citations should be provided for all proxy data sets used (could be as Supplementary Material).

All proxy records listed in Tables 1 and 2 are included in the References for the paper.

7. Specific comments We thank reviewer 1 for their thorough comments. We address several individually below:

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Page 5550, lines 10-11: IPCC (2013, Chapter 5) delineates the MCA as 950-1250AD and the LIA as 1450-1850AD. I suggest the authors modify their time periods accordingly to this standard.

We chose our definition of the MCA and LIA according to Yan et al. (2011)'s definition, as this paper was a main starting point for this work. We will however test the sensitivity of our results to this definition in the revised manuscript.

Page 5554, lines 6-10: We still need some measure of the fidelity of these reconstructions to assess how well (or not) they are reproducing observed variations. Page 5555, lines 10-12: But the argument can also be made that longer but lower resolution proxy climate series are less likely to capture the inter-annual climate variability associated with ENSO. Page 5559, lines 3-6: Would some of these potential problems be filtered out by only using proxy climate records that have an ENSO signal in the observational record? Page 5560, lines 2-3 and lines 6-10: Surely you can still compare the time series of the reconstructions with observational records; it is not just about changes in the mean state of ENSO but also variability, intensity and frequency of extremes (El Niño and La Niña). Page 5566, lines 7-11: But comparisons could be made for the overlapping parts of the different ENSO reconstructions? Page 5572, lines 13-15: I think the authors need to convince the readers that 30-year averages are able to capture the inter-annual variability associated with ENSO.

See comment 4 on long-term vs. interannual trends.

Page 5554, line 24: 'proxy precipitation'; Also see General Comment 1 above querying whether the authors have really assembled a comprehensive data base of available proxy climate records. Page 5561, lines 24-25: As indicated in General Comment 1, I think there were many more potential SST proxies that the authors could have used. Page 5564, lines 18-21: See earlier comments about several other SST proxies being available for the tropics.

See comment 1 re: proxy selection.

Page 5555, lines 3-4: What were the criteria used by Mann et al. (2008)?

The criteria are cited in Section A. We chose not to list them in the main text for brevity.

Page 5555, lines 5-7: See General Comment 3 above requiring how 'dating errors' were determined. Also, what is the 30-year averaging period referred to here?

See comment 3 re: dating error. The 30-year averaging period simply refers to the fact that all proxy records are averaged (or interpolated) to 30-year resolution.

Page 5556, line 1: Why was SST not used rather than air temperature as ENSO is primarily a SST (and surface atmospheric circulation) phenomenon?

This is a great point. We will take this suggestion on board and use a blend of SSTs over the ocean and air temperatures over land.

Page 5556, line 12: What was the full period for the observational records?

The full period is AD 1870-2010 (Page 5555 line 22).

Page 5556, lines 12-14: What was the 'common period' used to standardize the proxy climate records?

The common period for the proxies is simply the period where all proxies have data. The actual dates shift depending on the network; however it is always at least 100 years long.

Page 5556, lines 16-17: Did the time series of these EOF's show significant relationships with commonly used indices of ENSO (e.g. the SOI or Niño 3.4 SST index)?

Yes they do. The PCs associated with these EOFs indeed showed a significant relationship with ENSO indices, which should indeed have been mentioned in the text. We compared the 20CRv2 temperature and precipitation PCs with NINO3.4, MEIext and SOI; Rˆ2 values ranged from 0.59 to 0.81.

Page 5557, lines 21-22: How do these training and validation periods relate to known

PDO-driven variations in ENSO strength and variability?

It is indeed known that PDO modulates ENSO on multi-decadal timescales. However, it would be difficult to get a good view of this in the 20CRv2 dataset, or even GCM simulations. As we will not be using 20CRv2 for calibration and validation in the revised manuscript but instead will use GCM last millennium runs (see responses to reviewer 2) the relationship between the original calibration-validation period and PDO is not relevant anymore. Nevertheless, we will investigate and discuss relationships between reconstructed PDO timeseries and our ENSO-like reconstructions in the GCM simulations.

Page 5565, line 1: ‘consistent positive correlation’ – between what?

Between the GCM’s temperature and precipitation PCs (Page 5564 line 25-27).

Page 5571, lines 16-17: Do the authors mean temperature and precipitation reconstructions?

Yes, this refers to instances where the original authors have translated the proxy (e.g. d18O) into temperature or precipitation already.

Page 5574, lines 2-21: How much variance was explained by EOF 1 for the temperature and precipitation data sets?

The 20CRv2 precipitation EOF captures 13.6% of the variance; the temperature EOF captures 16.4%.

Page 5593, Table 1: Provide more details in the caption, e.g. what calendar year ‘start’ and ‘end’ refer to; also please provide full references (Supplementary material?) for cited papers and data sets. Page 5594, Table 2: as for Table 1

Start and end years here are in Year BP; this will be added to the captions. Full references are already included in the References list.

The remaining comments are generally aesthetic and will be taken on in the revised

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manuscript:

Page 5550, line 3: ‘centred in the equatorial Pacific’ rather than ‘over’.

Page 5550, line 4: make it clear that there are two phases of ENSO which produce different surface climate anomalies throughout much of the tropics and, via teleconnections, to some higher latitude locations.

Page 5550, line 8: ‘have produced different/dissimilar reconstructions’ rather than ‘varying’.

Page 5550, line 13: ‘Empirical Orthogonal Function (EOF)’.

Page 5551, line 4: Indicate where these SST and surface pressure patterns occur.

Page 5551, line 10: Where did these deaths occur?

Page 5551, line 16: ‘variability’ rather than ‘trends’.

Page 5551, lines 21-22: There have, however, been recent modelling studies which do provide insights into how ENSO variability may change in a warming world (e.g. Power et al., 2013; Cai et al., 2015 a,b).

Page 5551, line 24: ‘proxy climate records’ rather than just ‘proxy records’.

Page 5552, lines 11-12: Provide references to support this statement

Page 5552, lines 20-21: Spell out AMOC and NAO.

Page 5552: I think this introduction should include a clear description and review of the various recent reconstructions of ENSO indices and the extent to which they agree or not (e.g. Braganza et al. 2009; McGregor et al., 2010; Li et al., 2013; Emile-Geay et al., 2013). This should appear before considering possible drivers of changes in ENSO variability.

Page 5553, line 1: Which ‘discrepancies’? Also change ‘trends’ to ‘variation or variability’ as ‘trend’ tends to imply a uni-directional change.

Page 5553, line 5: Provide reference(s) for previous statements.

Page 5553, line 15: ‘into past climate variability’ – it is not just climate ‘events’.

Page 5554, line 15: ‘reconstructions’ rather than ‘proxies’.

Page 5557, lines 27-28: Reference for ‘coefficient of efficiency’?

Page 5560, line 18: What is a ‘coherent trend’?

Page 5561, line 15: Label and refer to figure components as Figure 3a and 3b rather than ‘top’ and ‘bottom’.

Page 5562, line 3: Which ‘maps’? refer to specific figure.

Page 5563-5564: Given the inconclusive nature of the LOO results, why spend so much space discussing them?

Page 5564, lines 11-13: The statement ‘The two ENSO reconstructions.........’ contains two negatives which makes it hard to follow – does it mean they provide evidence of agreement?

Page 5599, Figure 1: Is the 30-year a simple or weighted average?

Page 5601, Figure 3: Provide colour scale bar for EOF loadings; label a) and b).

Page 5604, Figure 6: Not very comprehensible figure.

Yours faithfully,

Lilo Henke

References Conroy, J. L., Overpeck, J. T., Cole, J. E., Shanahan, T. M., & Steinitz-Kannan, M. (2008). Holocene changes in eastern tropical Pacific climate inferred from a Galápagos lake sediment record. Quaternary Science Reviews, 27, 1166–1180. doi:10.1016/j.quascirev.2008.02.015 Emile-Geay, J., Cobb, K. M., Mann, M. E., & Wittenberg, A. T. (2013). Estimating central equatorial pacific SST variability over the

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past millennium. Part II: Reconstructions and Implications. Journal of Climate, 26, 2302–2328. doi:10.1175/JCLI-D-11-00511.1 Hereid, K. a., Quinn, T. M., Taylor, F. W., Shen, C. C., Edwards, R. L., & Cheng, H. (2013). Coral record of reduced El Niño activity in the early 15th to middle 17th centuries. Geology, 41(October), 51–54. doi:10.1130/G33510.1 Li, J., Xie, S.-P., Cook, E. R., Morales, M. S., Christie, D. a., Johnson, N. C., . . . Fang, K. (2013). El Niño modulations over the past seven centuries. Nature Climate Change, 3(9), 822–826. doi:10.1038/nclimate1936 McGregor, H. V., & Gagan, M. K. (2004). Western Pacific coral δ18O records of anomalous Holocene variability in the El Ni??o-Southern Oscillation. Geophysical Research Letters, 31, 1–4. doi:10.1029/2004GL019972 Moy, A. D., Seltzer, G. O., Rodbell, D. T., & Andersons, D. M. (2002). Variability of El Niño/Southern Oscillation activity at millennial timescales during the Holocene epoch. Nature, 420, 162–165. doi:doi:10.1038/nature01194 Osborne, M. C., Dunbar, R. B., Mucciarone, D. a., Druffel, E., & Sanchez-Cabeza, J. A. (2014). A 215-yr coral δ18O time series from Palau records dynamics of the West Pacific Warm Pool following the end of the Little Ice Age. Coral Reefs, 33, 719–731. doi:10.1007/s00338-014-1146-1 Yan, H., Sun, L., Wang, Y., Huang, W., Qiu, S., & Yang, C. (2011). A record of the Southern Oscillation Index for the past 2,000 years from precipitation proxies. Nature Geoscience, 4(9), 611–614. doi:10.1038/ngeo1231

Interactive comment on Clim. Past Discuss., 11, 5549, 2015.