

## ***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.***

**Anonymous Referee #1**

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General comments:

El Niño-Southern Oscillation (ENSO) events are the major source of inter-annual climate variability in the tropics and, through teleconnections, some higher latitude locations. Understanding how ENSO varied in the past contributes to our understanding of how it may change in the current, rapidly warming world. There have also been several published studies over the years which have attempted to reconstruct past ENSO variability; two recent examples are Li et al (2013) based on tree rings and Emile-Geay et al (2013) based on multi-proxies.

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The authors present two ENSO reconstructions based on proxy temperature and precipitation records extending back  $\sim$ 1500 years BP using an EOF-based weighting scheme. The resulting reconstructions are presented as “30-year” averages and the authors attempt to address the question as to whether ENSO variability was more or less El Niño-like during the Medieval Climate Anomaly (MCA) compared with the Little Ice Age (LIA). Although this is a laudable attempt, I feel that the study is flawed for a number of reasons:

- 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.
- 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.
- 3) The authors exclude several potential candidate proxy climate records on the basis 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?
- 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  $\sim$ 2-7 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).
- 5) Although the separate precipitation- and temperature-based reconstructions could

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be informative, why did the authors not develop a combined proxy reconstruction? Maybe the sum is greater than the parts?

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

Specific comments:

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, 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.

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.

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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, 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 5554, line 15: 'reconstructions' rather than 'proxies'.

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

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?

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

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

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

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)?

Page 5557, lines 21-22: How do these training and validation periods relate to known PDO-driven variations in ENSO strength and variability?

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

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 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 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 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 evi-

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dence of agreement?

Page 5564, lines 18-21: See earlier comments about several other SST proxies being available for the tropics.

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

Page 5566, lines 7-11: But comparisons could be made for the overlapping parts of the different ENSO reconstructions?

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

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

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

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.

Additional References: Cai W et al (2015a) Increased frequency of extreme La Niña events under greenhouse warming. *Nature Climate Change*, doi: 10.1038/NCLIMATE2492.

Cai W et al (2015b) ENSO and greenhouse warming. *Nature Climate Change*, doi:10.1038/NCLIMATE2743.

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McGregor S et al (2010) A unified proxy for ENSO variability since 1650. *Climate of the Past* 6:1-17.

Power S et al (2013) Robust twenty-first-century projections of El Nino and related precipitation variability. *Nature*, doi:10.1038/nature12580.

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