

Interactive comment on “The early Spörer Minimum – a period of extraordinary climate and socio-economic changes in Western and Central Europe” by Chantal Camenisch et al.

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Thank you very much for your detailed review.

Main points:

Title: A point brought forward multiple times concerns the usage of the term "early Spörer Minimum", which also appears in the title. For clarification, we will improve the definition and usage of the different time periods in the introduction. Further, the title of the manuscript will be changed to "The 1430s: A period of extraordinary internal climate variability during the early Spörer Minimum and its impacts in Northwestern and Central Europe".

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Geographical region: Following the reviewers, we will change this (also in the title) to “Northwestern and Central Europe”.

- Below we answer the comments point by point.

Review 1

The discussion paper titled "The early Spörer Minimum - a period of extraordinary climate and socio-economic changes in Western and Central Europe" submitted to Climate of the Past by Camenisch et al. aims to provide an end-to-end analysis of the interconnected histories of climate and society during the winter-cold decade 1430-1440 in Northwestern and Central Europe. The authors provide evidence of climatic anomaly for this period based on multi-proxy and multi-site climate archives and from an ensemble of global climate simulations; they provide evidence on economic and social disturbances during and after this period based on documentary sources. # Assessment This paper address relevant scientiñÅc questions within the scope of CP. It presents a novel combination of existing climate and historical data; bringing the historical socioeconomic data into a climate context and to the readership of CP is relevant. The conclusions drawn from the combination of the different data sources should be better substantiated, the manuscript could beneñÅt from more careful statistical statements and rigorous application of signiñÅcance level choice and evaluation. The literature cited is plentiful but appropriate, the abstract summarizes the paper well, but suffers from inconclusive statements; also the title should be improved. At several places, more information (that is in the SOM or "not shown") needs to be provided. The presentation is well structured, the language is ñĆuent, but it lacks precision. Mathematical symbols in the appendix are poorly typed and chosen. All ñÅgures are of insufñÅcient quality for publication. I don't see much value in ñÅgs 1, 4b, 6, 7, and 9 in the main manuscript. The SOM is lacking a title and summary.

- The technical shortcomings listed will be clarified.

Recommendation For scope, novelty and relevance I recommend to accept this pa-

per. For accuracy, precision, language, ãñAgures, and conclusiveness the paper needs to be revised thoroughly.

- The quality of the figures suffered during the copying into the word file which was then uploaded to Copernicus. The quality will be better in the final version.

Detailed comments ## Page 1 Title: as the short comment states, please reconsider your terminology with "Spörer Minimum" and early SPM; I would suggest also to ãñAnd more distinct names for the period 1300 to 1700 versus the early part of this, esp1430-1440. The geographical name is not correct; your region of investigation is rather Northwestern and Central than Western and Central Europe Authors: The list of authors is very long, although this study is not presenting original research but rather relies on data/simulations that have already been published. Why is there such a long author list, and have all contributed to the manuscript? I suggest to move some to the acknowledgment section and clarify their contribution, if not directly related to research design, data production, analysis and writing of the paper.

- Title: See above. We agree that the list of authors is very long but all of them contributed substantially in the one or the other way to the paper. This is why we will not change it.

l 38: not everyone might understand end-to-end, neither is your understanding necessarily the same as for people from other backgrounds. This should be deãñAned.

- End-to-end will be replaced with systematic.

Page 2 ll 4-6: consequence ... in order to be prepared. I did not see this chain of causation substantiated in the main text.

- We will improve this part regarding the granaries in the main text.

ll 7f: "Climate model simulations show .. internal variability" You demonstrate that it is *not* volcanic activity, and conclude then that this must be internal, but there could be other external forcings. (see below) Also, the climate model simulations look at cold

winters, not that specific decade.

- We assume that the reviewer hints at land use changes. See below (p.6/l.2). Still note that the model simulations are fully coupled, consequently each simulation develops its own internal variability which is not necessarily in lockstep with reality. Consequently, it is not meaningful to focus on that specific decade.

ll 8f: You do not test the hypothesis formally and don't conclude anything on this hypothesis later. I suggest to delete this sentence.

- Hypothesised will be replaced by suggested.

ll 12: "affected the socioeconomic system". Did all of them have effects, this is speculative

- we will add "might have".

ll 12f: "cold resulted from forcing" imprecise; maybe the coldness can be attributed to forcing?

- "Resulted from" will be changed to "can be attributed to".

ll 14: "in the background" wrong "in"

- Will be corrected to "against the background of".

ll 17: "include" and "inter alia" is redundant

- we will delete "inter alia"

ll 19: "negative" is a valuation, which should be avoided

- ok

ll 20: "all of which provoked", needs cautionary "may have", not all impacts provoke measures

- Will be replaced by "many of which provoked".

Il 28f: "climatic and documentary" sources. These sources should not be connected by "and", as one points to an analysis tool or discipline and the other to a material. Rather than "climatic archive" we have archives that record aspects of climate ...

- we will change that

Il 30: "devastating" avoid valuation

- Will be deleted.

Page 3

Il 1: "more descriptive" is too general, be precise

- we will change that into "descriptions"

Il 6: "punctuated" by

- Will be changed.

Il 8: "substantially" this is not substantiated or quantified

- Will be deleted.

Il 9: "devastating" valuation

- Will be deleted.

Il 13-15f: "low temperatures could destroy the winter seed" .. "combined with no or almost no snow cover". But your analysis does not include winter precipitation! This statement should have a reference.

- We will add the reference (Pfister 1999) and emphasise that only temperature was analysed.

Il 15 "usually had an effect". Citation needed.

- It is the same citation as in the next sentences (Camenisch 2015b). This is why we

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did not repeat it. If necessary, we will add it.

Il 19 "*with* regard to"

- Done.

Il 20 "and other" is too imprecise. The many societal changes that the paper later recounts should be mentioned. Otherwise, this sentence gives the impression that climate is the better understood, or more important driver of societal reactions.

- Examples will be added.

Il 23 wording "replace crop failure", do you mean "recover from" or "mitigate"?

- mitigate

Il 29, 32f: "SPM was a period of rather cold" versus "only the Maunder Minimum was a coherent cold phase". This conflict should be resolved.

- Clarified to "only the Maunder Minimum was a globally coherent cold phase".

Page 4

Il 3: "major cooling happens after 1450" what is the relevance of this?

- It illustrates that the models are able to reproduce the climatic conditions following strong volcanic eruptions.

Il 3. "Taken at face value," colloquial.

- Will be deleted.

Il 4. "contradict" I don't see evidence for contradiction yet, since above, you argue that there are "other" impacts at work, too

- Will be rewritten

Il 11: "dramatic change". Is not seen, it is one period of many with changes, has no

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long-lasting consequences

- Will be rephrased.

Il 28: "very moist early LIA". I don't see this in fig 2 Il 29: "context of entire millennium". Elaborate on Büntgen and Ammans findings and provide this context.

- Sentence will be deleted

Il 30ff: "is rather diagnostic for" needs citation.

- changed to 'variability illustrates (cumulative) volcanic forcing or internal (unforced) variability'

Page 5

Il 1: "Summers in the early SPM (1421–1450)". Previously, the early SPM was defined as 1431-1440 ???

- Will be clarified in the introduction

Il 2: "see supporting". Where shown in supporting material?

- Shown in: Fig. S1 (Reconstructed European summer temperature anomalies (w.r.t. 1961-1990) for the years 1430-1439. For further information, see Euro-Med2k Consortium, in press)

Il 15-18: high seasonality could also indicate hot summer and normal winter, or medium cold winter and medium hot summer. Be clearer everywhere about your definition of high seasonality in combination with cold winter.

- Agreed. The respective definition is given in the figure captions; we will try to make this clearer.

Il 19: "Figure 3 shows". I don't see this (see figure comments) well enough.

- Since we have both summer- and winter time series for only very few locations, we

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refrained from showing the seasonality.

Il 20ff: Why do you show this in a figure if your data base is insufficient? A simple statement would be enough.

- The data base is insufficient to draw strong conclusions. But it is still valuable information, offering an idea of the hydroclimatic conditions during the investigated period.

Il 31f: HIST and CNTRL are explained but not the "con" postfix used in the figure. Please elaborate on these four simulations

- The "con" in "conditional" is now underlined. Details about the simulations are outside the scope of the paper and can be found in the stated publications (Keller et al., 2015; Lehner et al., 2015)

Page 6

Il 2: "in land use" Which land use scenario do you use? In PMIP both the KK10 and HYDE are available and have very different land use forcings for your time period (see Fig 3a in Kaplan et al. 2011). A discussion on this should be included, also on the potential external forcing effect of land use (e.g. widespread deforestation by the 15th century in Central Europe). This may well be one of the "other" external (and anthropogenic) drivers of cold spells.

- In the simulation we use the reconstruction by Pongratz et al. (2008) and Hurtt et al. (2011) which are merged in the year 1500 AD. During the 15th century, land use change in Northwestern and Central Europe is a very gradual and steady process. There is no indication that these changes could have implications on the climatic conditions on such large spatial scales as investigated here.

Il 6.: I see no relevance in the 31-year filtered data series. Remove.

- Due to the strong volcanic forcing the minima in solar forcing are hardly visible in the regular time series. Therefore, we prefer to leave it.

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Il 7: "There are large uncertainties". In what quantities? Are they related to natural variability, or to uncertainties in parameter estimation, or to subgrid or other not resolved processes? - Will be rewritten.

Il 14: "models simulate an average decrease" provide reference

- This refers to the analysis conducted here, consequently there is no reference. Will be clarified.

Il 30: reference fig S2; better: Show the ensemble average and range, and the CESM runs you analyse later for Tjja, Tdjf and seasonality in a new figure in the main text. leave S2 with the details of all models in the SOM.

- Maybe there was a misunderstanding. Sentence will be clarified.

Il 32ff: Provide results from a statistical test on the significance of the observed differences. Il 34: if 56% of years with large seasonality coincide with very cold winter, then 44 % should correspond to very warm summers. This seems not significant to me (but you could provide results from a test here.) # Page 7 Il 3: "external forcing does not affect modelled seasonality in Europe". Better: TSI, volcanic and GHG forcing do not affect ... (Land use is not considered, see discussion above). Can this statement be upheld without the statistical tests required earlier in this paragraph?

- Our argumentation builds on the fact that unforced control simulations (without external forcing) and transient simulations (with external forcing) show the same/comparable signals. These signals are not necessarily statistically significant which, however, does not affect the main message. Land use: see above.

Il 6: "cold winter decades". It is not discussed how robust this analysis is, the figure S3 should be referenced, what is the motivation for the choice "5 out of 10" and "cooler than mean-1 sigma" and the 600 year baseline? It is expected that in a normal distribution 2 out of 10 are cooler than 1 sigma, could you provide a more objective (reference!) analysis of the clustering of successively cold winters or many winters within a decade?

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- Will be clarified.

Il 8f: "years with strong seasonality show anomalously cold winters in Europe". By definition, as seasonality is not independent of cold winter temperature. Why show annual mean in Fig 6? Rather show seasonality. Why show at all, as the spatial finding (colder on land in winter) is easily report in text and the figure has not added value.

- Years with strong seasonality do not necessarily result from cold winters, they could also originate from extremely warm summers in combination with average winters. The figure illustrates that – at least in this specific model – this is not the case. Further, annual values are shown to give the reader an impression of the model performance.

Il 17: "seasonality ... shows ... a reduction in seasonality after an eruption". No, in figure 7, the seasonality anomaly *after* the eruption is close to zero. Only *at* the eruption, seasonality is visibly (but is this significant) reduced. I don't see any significance in the seasonality trends shown in Fig 7, could you report this more objectively?

- Correct the response is in the year of eruption – will be changed accordingly. We will check the statistical significance.

Il 21: "periods of frequent volcanic eruptions" You analysed not frequent eruptions, but the 10 strongest eruptions, without considering frequency . . .

- As the response to the strong volcanic eruption is only found in the year of the eruption a first order estimation is that in periods of frequent strong volcanic eruptions just multiple repeats this response and this leads to a period of low seasonality. Will be clarified.

Il 24: "strongly" provide reference.

- Will be added.

Il 25: "collapse" is a loaded word, considered biased by many historians, try to rephrase.

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- Ok.

page 8

Il 1: "attributed" climate impacts cannot be attributed to a model!

- Will be rephrased.

Il 3: why "mainly"? What else?

- There are also younger sources which tell the events from a later epoch (e. g. second half of 15th or 16th century). Possibly, those sources are not as reliable as the contemporary sources.

Il 5: "Monocausal explanations are never sufficient" commonplace statement.

- Will be deleted.

Il 6: "reasons for these climate impacts" unclear. Reasons for the impact that climate had on society? or other reasons for impacts that are also interpreted as climatic?

- Will be rephrased.

Il 11: "could be drunk" citation needed.

- Dawson 2009, as in the subsequent sentence.

Il 12: "winters during the 1430s" which ones exactly?

- We will give more precise information.

Il 14 "From 1424 to 1433 two flood and five drought years occurred," What is the long-term expected frequency of floods and droughts?

- We will try to add more information but maybe this would go too much into details.

Il 20: "problems" too general. What kind?

- Will be rephrased.

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Il 22f: "This temperature and precipitation pattern is also indicated by the models (see Fig. 6)". It is not valid to compare the coldest winters within the 600 year climate simulation with the historic winters in early SPM. Also, flood and precipitation is not comparable, neither are drought and temperature. Frequency and mean values are incomparable. This needs to be worked out in more detail, or Figure 6 can simply be removed.

- Will be rephrased.

Il 22 "the models". Only one model result is shown

- We delete the plural.

Il 25 "several years" which ones precisely?

- Will be added where possible and reasonable.

Il 34: "area of Berne" provide year.

- Ok.

Page 9

Il 8: the "North" might be unknown to non-English.

- Of England. Should be clear from the context.

Il 9: what is "sweet wine"?

- A certain type of wine. Should be clear from the context.

Il 16: cite Hungarian National Archives, not undefined acronym HNA

- Ok.

Il 19: "Europe's population sank to its lowest levels"

- Will be rephrased.

Page 10

Il 10: "organised" in what year?

- This is rather too detailed and not the scope of the paper.

Il 11: "Thus". Conjunction misused.

- Will be rephrased.

Pag 11

Il 6: "were known" are known?

- Will be rephrased.

Il 7: "as a reaction to the continuous rainfall" needs citation

- The entire paragraph is Bauch 2015.

Il 13: the uncapitalized word "gypsy" is wrong here, the capitalized version Gypsy associated with ethnic or racial slur and is to be avoided. Prefer "Romani", or at least use "then called" / "derogatorily termed" when using the word "Gypsy" Il 14: "purely negative" is not precise and objective wording, rephrase.

- Yes of course. We apologize for this mistake. It happened while we were shortening the text. The author of this paragraph provided a correct version.

Il 24f: "several wars aggravated the already tense situation". The authors make it sound, as if the social situation aggravated the root-causal climatic situation. I don't believe they want to convey this interpretation, but this needs to be sorted out. I believe that the authors want to say that climate stress aggravates the situation for already vulnerable societies. That way, the root cause is the social situation, and the trigger or aggravation comes from the climate impact (as clearly shown on page 12 Il 6).

- Will be rephrased.

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Page 12

Il 17: "did not escalate into a demographic repeat" the demographic depression 1430 was the only one (as stated before by the authors). What is meant by this statement?

- The famine of 1316-1322 was an extremely severe demographic catastrophe and historians, especially medievalist would compare any famine to that one of 1316-1322. Will be clarified.

Il 24f: "Mutually reinforcing" sound like "circular arguments", maybe rephrase.

- Will be rephrased.

Il 25- next page: The relevance of herring for the period 1430-1440 is not demonstrated. The section is interesting but not relevant and could be removed.

- The paragraph provides a different view on the investigated time period. We prefer to leave it, but will be rephrased.

Page 13

Il 15ff: "This strong increase in the seasonality of temperature suggests that, despite normal climatic conditions in the growing seasons, terrestrial ecosystem productivity was substantially decreased during this decade." This has not been conclusively shown.

- Will be rephrased.

Il 19: "caused by internal natural variability in the climate system rather than external forcing". This has not been shown, as land use was not considered and the evidence concentrated on ruling out volcanic forcing.

- Will be rephrased.

Il 27: "restrictions on the brewing of beer." This has not been shown

- Will be added to the main text.

Il 32: " This period demonstrates .. a multitude of factors are needed". From the evidence presented, this cannot be concluded.

- Will be rephrased.

Page 14

Il 1: "threatening" is valuation, not objective.

- Will be deleted.

Il 6: "Western", better Northwestern

- Ok.

Il 16: Style of equation poor. Choice of variable names, T1, T2 sxy nx, ny, syz non-standard. Typography not helpful for understanding. Use subscripts, proper roman/upright versus italic symbols, better weighted font sizes in equation. Avoid accent above x,y to denote mean (a bar would be more standard). A point is not a multiplication dot! Il 17: Symbols don't match those in equation, see above. Il 22: see above, poor equation style. zscores is not explained

- Will be adjusted.

Figure 1 Not needed.

- This figure keeps together the different parts of the paper. It shows how the results of different disciplines are linked together in the question of the examined period. We prefer to leave the figure in the paper.

Figure 2 Graphical resolution of figure is poor. Please add (short) author information to legend, such that it is more easily seen when records from the same author appear in multiple panels. Adjust font to match the style of the journal

- Figures 2 and 3 will be combined, the author information added to the caption.

Figure 3 Most important figure, also requires major overhaul. -adjust font to match

the style of the journal -use consistent font sizes -add seasonality diagnostic to facilitate comparison -consider decadal moving average to provide smoother picture (and less visual clutter) -improve graphical representation of eSPM -annotate LIA and SPM periods -add markers for volcanic eruptions -add author and geographic information to legend -for 40 decades/observations, a p-value of $1-1/40 = .975$ (i.e. approx 3 sigma) is appropriate to detect "anomalous" cold/hot periods (Thomson 1990), so extend color range to $\sigma = 3$; the current choice highlights even small (1 sigma) excursions that are expected to be realized in 32% of the observations Reconsider the entire figure with respect to the main conclusions the reader should draw from it. Give the important parts (1430-1440) more room and contrast, help by providing seasonality diagnostics.

- Figures 2 and 3 will be combined, the author information added to the caption. The color range will be changed to 3 sigma. Since we have both summer- and winter time series for only very few locations, we refrained from showing the seasonality diagnostic. To keep the focus on the 1430s, and to preserve the overall clarity and readability of the figure, we do not annotate LIA, SPM and specific volcanic eruptions (the latter are difficult since we show decadal means).

Figure 4 -part a) could be moved to SOM, at better resolution and consistent font -part b) is irrelevant and should be removed

- We prefer to keep the figure as it is; see above.

Figure 5 The rightmost panel is not legible. gray and blue (CTL) cannot be seen. There is a mismatch between the CTRL and CTL acronyms in figure and text. Postfix "con" is not explained (it should be conditional), PDF (probability density function) is not explained either. -adjust font to match the style of the journal -use consistent font sizes and font colors -avoid duplication of data from HIST in rightmost panel

- Acronyms/prefixes will be adjusted; PDF will be explained. Our argumentation builds on the fact that unforced control simulations (without external forcing) and transient simulations (with external forcing) show the same/comparable signals. This is illustrated

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by the left panel; we prefer to leave it like it is.

Figure 6 -not needed here, move to SOM -adjust font to match the style of the journal -use consistent font sizes and font colors -poor graphical resolution -abbreviations temp and precip are inconsistent with text -units are missing from color backgrounds -do not use divergent color map for temperature -consider relative anomaly instead of absolute anomaly -poor color choice in P anomaly: red (more) and blue (less) contrast with common perception of red (hot, dry) with blue (cold, wet); especially, since blue in precip mean plot indicates wetness.

- Will be adjusted. The figure is an illustration of the potential climatic conditions during the investigated time period. We prefer to not move it to the SOM.

Figure 7 -Move to SOM -adjust font to match the style of the journal -use consistent font sizes and font colors -poor graphical resolution -motivate 10-90% confidence shading -highlight CESM results.

- Will be adjusted. We prefer to not move it to the SOM

Figure 9 -adjust font to match the style of the journal -use consistent font sizes and font colors -poor graphical resolution It is difficult to relate the dates to the values. The positioning of year labels along the x-axis is unclear; vertical grid lines would guide the eye, or choosing the bar plot for salt with small gaps between bars. The y-scale is inappropriate. Percentage deviations should be presented on a logarithmic scale, such that doubling (200%) and halving (50%) have equal distance to the reference. The reference should have a horizontal line. The eSPM decade should be visually marked. Extreme events could be annotated if historical accounts are provided by the authors.

- Will be adjusted.

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