

Dear Tim Heaton, we thank you for having taking time to carefully read our paper and for the valuable propositions of improvements you suggest in your comment. In the next lines we try to answer to all points discussed in your review.

### **1. Improved introduction and clarification of notation**

The analysis of GHD times series is since the end of the 19<sup>th</sup> century a long-lasting and very well-known method of investigation in the field of historical climatology. Accordingly, all aspects of the organisation of the wine harvests have been fully discussed in the previous literature (Lavalle 1855, Dufour 1870, Le Roy Ladurie 1971, Labbé-Gaveau 2011, Daux et al. 2012). In our article, section 2.4 provides a fully detailed description of the organisation of the harvest in the region of Beaune since the end of the Middle Ages. Considering this, and the fact that we have to limit the length of our text to the standard maximum of the review, it would be superfluous to add one or two paragraphs describing the harvest process in details. Thought, we agree that there can be some difficulties to interpret the meaning of certain terms, like the distinction between "GHD" and "ban dates" for example, and that some clarifications are needed. We have then improved the introduction in that sense.

### **2. Consistency of determining the GHD**

This is a critical point concerning the setting of the series. You rightly point out that the period 1507-1699, for which Beaune GHD are extracted from deliberation protocols of the church of Notre-Dame of Beaune, constitutes the less reliable part of the series. In this period we actually had to estimate for each year a "probable" opening date of the harvest, for documentary records of the church provide only the date of the meeting in which the estate managers of the institution had to anticipate the upcoming harvest. Before 1582, as the given date is the date of the last meeting before the vacancy of the canons chapter for the harvests, we add three days to this dates, i.e. the standard interval between two meetings. After 1583, the protocols inform on the organisation of food supplies for harvesters, so that we added 8 days to this date. The accuracy of these estimations, though we must admit some uncertainties, is confirmed with the comparison of fragmentary preserved official ban dates set by the city of Beaune for some few years within this period, as summarized in Table 1 :

*Table 1 : Comparison between dates of the last meeting of the Notre-Dame of Beaune church chapter before the grape harvest and the official ban harvest set by the city council (1554-1620)*

	1554	1555	1557	1558	1569	1574	1583	1613	1617	1619	1620
Ban dates set by the city council of Beaune	3 Sep	19 Sep	7 Sep	6 Sep	9 Sep	13 Sep	5 Sep	21 Sep	27 Sep	20 Sep	25 Sep
Dates given by the protocols of the church of Notre-Dame	23 Aug	13 Sep	3 Sep	2 Sep	2 Sep	15 Sep	1 Sep	18 Sep	20 Sep	6 Sep	16 Sep
Estimated dates	26 Aug	16 Sep	6 Sep	5 Sep	5 Sep	18 Sep	8 Sep	26 Sep	28 Sep	14 Sep	24 Sep

This table will be provided as supplementary material in the final version of the article. Furthermore, it must be noticed that when an official ban dates set by the city council of Beaune was available in the documentation, we always integrate this date in the series.

### **3. Harmonisation of time series**

The harmonisation of the time series before and after 1718 is also a critical problem. The choice to add 7 days to all dates of the Beaune GHD time series before 1718 is based upon the observation that the mean Beaune GHD is 20<sup>th</sup> of September in the period 1354-1717 and 27<sup>th</sup> of September in the period 1718-2018 (see Tab 1, discussion paper). We suggest that this uniform delay reflects an anthropogenic changes affecting the setting of the harvest date. Otherwise it would have mean AMJJA temperature reconstructions with maxima and minima c. 1°C warmer before 1718 than afterwards on the decadal scale, even though temperatures measurements available in France since 1658 do not provide any evidences of such a warming during the period 1658-1718. Moreover, extra-regional GHD times series (Switzerland, Jura, Czech Lands) during comparable time span (1599-1875) shows different patterns of evolution. On the one hand all series are more stable, and we observe on the other hand a general trend for later, and not earlier, GHD in the pre-XVIII<sup>th</sup> century period (Tab. 2).

Table 2 : Mean GHD in Beaune (this article), Aubonne (Angot 1885), Salins (Angot 1885), Switzerland (Wetter et al. 2013) and Czech Lands (Mózný et al. 2016).

	Period 1: 1599-1717	Period 2: 1718-1875	Difference of days between period 2 and period 1
Beaune mean GHD	21 Sep	28 Sep	+7
Aubonne (Jura) mean GHD	21 Oct	18 Oct	-3
Salins (Jura) mean GHD	11 Oct	9 Oct	-2
Swizz mean GHD	20 Oct	15 Oct	-5
Czech Lands mean GHD	14 Oct	14 Oct	0

We assume first that the more unstable time series is the one which have to be homogenised. Secondly it appears that we should logically add some days to the Beaune GHD time series before 1718. We acknowledge however the hypothesis that this rupture is approximatively synchronous with a change in our documentary sources, i.e. the changeover from protocols of the Church to the deliberation of the city council of Beaune. It is actually a matter of discussion to what extent this rupture reflects a documentary bias or not.

Two arguments can nonetheless alleviate this concern. First, the fact that mean Beaune GHD was earlier in pre-18<sup>th</sup> century period is observable in the 14<sup>th</sup> and 15<sup>th</sup> centuries as well (Tab. 3). For this period, the data have been collected up to 1507 from a third kind of archival material, i.e. the accounting documentation of Notre-Dame estate, providing direct information about the exploitation of the vineyard and then not questionable regarding their reliability. It confirms then the reliability of the protocols used for collecting 16<sup>th</sup> and 17<sup>th</sup> centuries GHD.

Table 3 : Evolution of non-homogenised mean Beaune GHD over centuries

	14 <sup>th</sup> c.	15 <sup>th</sup> c. (until 1507)	16 <sup>th</sup> c. (after 1507)	17 <sup>th</sup> c.	18 <sup>th</sup> c.	19 <sup>th</sup> c.	20 <sup>th</sup> c.
Mean Beaune GHD (non homogenised)	22 Sep	20 Sep	20 Sep	20 Sep	<b>25 Sep</b>	<b>30 Sep</b>	<b>27 Sep</b>

Secondly, the fact that the rupture is also synchronous with a very important change in Burgundian viniculture practices is striking and suggests a very probable anthropogenic explanation that we have expressed in the paper. As in most of all prestigious vineyards throughout Europe, the style of Beaune wines shifted at that time towards stronger and more long-term keeping wines in comparison with previous centuries, which might eventually led winegrowers to harvest a bit later in order to pick up fully matured grains. It does not exist any document ordering a general delay of the harvest in the beginning of the 18<sup>th</sup> century, as you rightly suggest could be a proof. However, this evolution of the practice has been largely documented in the literature (Dion 1959, Lachiver 1988).

At this point, we think that the historical approach of carefully assessing the raw material is the more reliable methodology.

#### 4. Statistical modelling

Thanks for the input. We will be more explicit in the formulation of the model. For instance, it is the natural logarithm that is used in our transformation. Note that the transformations are used for modelling GHD from temperature. Here is a more complete description

Modeling GHD from temperature:

$$\text{Model A} \quad D = c_0 + c_1 T_{\text{Mar}} + c_2 T_{\text{Apr}} + c_3 T_{\text{May}} + c_4 T_{\text{Jun}} + c_5 T_{\text{Jul}}$$

$$\text{Model B} \quad D' = c_0 + c_1 T_{\text{Mar}'} + c_2 T_{\text{Apr}'} + c_3 T_{\text{May}'} + c_4 T_{\text{Jun}'} + c_5 T_{\text{Jul}'}$$

Modeling April to July temperature from GHD (note that this is done in T and D, not T' and D', so the manuscript is correct):

$$\text{Model A} \quad T_{\text{AMJJ}} = c_0 + c_1 D$$

$$\text{Model B} \quad T_{\text{AMJJ}} = \sum T_{\text{AMJJ},i} w_{i,j} / \sum w_{i,j}$$

where  $i$  are the 7440 preindustrial model years in CCC400 and  $w_{i,j}$  is the weight each model year gets for each reconstruction year. We will then rephrase Model B for temperature in a Bayesian formulation, as suggested by the reviewer, and will add this to the description. This is a helpful suggestion.

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