Clim. Past Discuss.,
https://doi.org/10.5194/cp-2020-87-RC3, 2020

Climate of the Past
Discussions

Interactive comment on "Reconstructing past hydrology of eastern Canadian boreal catchments using clastic varved sediments and hydro-climatic modeling: 160 years of fluvial inflows" *by* Antoine Gagnon-Poiré et al.

Anonymous Referee #3

Received and published: 26 August 2020

This study by Antoine Gagnon-Poiré and colleagues entitled "Reconstructing past hydrology of eastern Canadian boreal catchments using clastic varved sediments and hydro-climatic modeling: 160 years of fluvial inflows" presents an interesting counterpart to rainfall-runoff modeling approaches that aim at expanding instrumental streamflow datasets for multi-decadal analysis of hydrological variability. Indeed, this study based on varved sediment sequences aims at producing long river discharge records (>100 years) to support, help refine or contradict paleo-hydrological records offered by the modeling approaches.

The strength of this study is clearly provided by the very high-quality analysis of the varve record and the robustness of the sediment chronology. Varve boundaries are clearly defined through high-quality startigraphical analysis combined with CT images and state-of-the-art microscopy-based grain size analysis. Varve counts are consistent between the cores of different locations, and they are supported by independent 137Cs dating. The varve record thus offers an annual view into past changes without chronological constraints, which is a major advantage for developing a proxy-climate or proxy-hydrology models.

Varve stratigrahical analysis further allowed to select the best varve parameter (i.e., meaningful season) to compare with hydrological data. The proxy-hydrology correlations have been significantly improved by selecting the thickness of the detrital layer (DLT) instead of total varve thickness (TVT), thus reducing potential noise; spring discharge being the main driver for sediment erosion and transport in the nival catchment of Naskaupi River. In this context, Figure 11 is very stunning, and shows how a varve record can best be exploited to look at micro-meteorology and lower-than-seasonal resolution river hydrodynamics; this is novel.

However, although the quality of the sedimentary investigation is very robust, general important comments relate to the methods to produce the paleo-hydrological record and its regional signal. I hope that these major comments will be well received and accepted, and that they will be of good use to improve the present manuscript.

#General comments

Normalizing total varve thickness (TVT) is interesting when several sediment cores are collected at the same location => thus to reduce local error in the proxy-hydro/climate relationship. However, merging TVT from a proximal (more sensitive, thus with larger amplitude) and distal record (buffering large changes in river discharge, recording annual change in hydrodynamics and only sensitive to the most intense discharge events) is neither properly justified in the text, nor fully appropriate. It gives the impression that the different records were merged in the way that the correlation with hydrometric data would be maximize, at the cost of process understanding. A great example is losing the downward trend in TVT from NAS-2 by merging its record with NAS-1, which has no trend. The same applies to (and I would say particularly applies to) P99D0. Mean values are strongly driven by NAS-1, the proximal coring site. As such, it is not surprising to find the best correlation for Qmax to NAS-1 (proximal) and for Qmean to NAS-2 (distal). Overall, there is no mechanistic logical explanation in merging TVT, DLT or P99D0 from the three cores to help maximize the correlation. This is particularly the case integrating BEA core, for which it is argued (L604) that "it is quite unlikely that the sedimentary input from the Naskaupi River contributed to sediment accumulation at the mouth of the Beaver River" (i.e., BEA core). L443: There is no clear explanation on why the post-anthropogenic watershed modification would support the discarding of NAS-1 in the TVT, DLT and P99D0 normalization of the cores. It further supports the impression that the best records were merged in the way that the correlation with hydrometric data would be maximize, at the cost of process understanding. L461: Table 3 is named Table 1….it took me some time to realize that Table 3 was not missing, while being important and largely cited.

#General comment on the comparison between sedimentary data and hydrological variables

Q vs SSC are always presented as a log-log linear regressions. The same should applied to DLT vs Q, likely to P99D0 vs Q. From the scatterplot presented in Fig 8, it is likely that the general proxy-hydrometric relation follows a DLT=f(log(Q)), or a log(DLT)=f(log(Q) relation rather than a linear relation. See Warrick (2015) and references therein, or Thurston et al. (2020). This should be tested as it has major implications on statistical yields in the sediment-hydrological relations.

Warrick, J. A. (2015). Trend analyses with river sediment rating curves. Hydrological Processes, 29, 936–949. https://doi.org/10.1002/hyp.10198

Thurston et al. (2020). Modelling suspended sediment discharge in a glaciated Arctic catchment–Lake Peters, Northeast Brooks Range, Alaska. https://doi.org/10.1002/hyp.13846

#General comment on the regionalization of the signal

The merging of the different watersheds of the region is interesting, but I don't think that the quantitative analysis is relevant. This is exemplified by the low correlation of r=0.49 (even though significant) between the Naskaupi River and the Eagle station. This means that the discharge data from the Naskaupi River can only explain 24% of the variance in Eagle discharge data, independently from the sediment context. Removing Eagle from this merging exercise will not solve this issue. Each watershed is sensitive in its own way not only to specific climatic (evidence is missing that the climate in the Naskaupi region is representative of a broader region, not only through correlation between hydrometric station data) but also to geomorphic conditions that are not integrated into the daily climatic series of the CemaNeigeGR4J model (such as slope, erosion susceptibility, potential geological difference, orientation…), and that can differ significantly within the 500x500km grid used in this manuscript. A more detailed analysis of the different watershed, their runoff response (timing, strength, duration, sensitivity to snowmelt vs rainfall) would merit further investigation. L241: "These four streamflow series (Tab. 2) show strong positive correlations with Naskaupi River discharge", one expects to see these strong positive correlations. Figure 3 presenting the location of the different catchment for regionalization of the findings would have benefited an additional panel with daily streamflow time series for each catchment as in Figure 2, for instance.

#General comments on the calibration-in-time model

A proxy-hydrology calibration model is built for the period 1978-2011, and reconstructed back to 1876. Post 1972 (River deviation) shows that the system has changed hydrologically with discharge reduced by a factor 2. This should also be true sedimentologically, and a few points are in line with this (contre-)hypothesis: clear change in the preservation of DLT in NAS-2, change in the mean P99D0 record of NAS-1, change in mean and variance of DLT and TVT of BEA-1, and most significant change for TVT and DLT post 1972 in NAS-2. These observations thus contradict the sentence L580 "River sediment input seems to have been quantitatively and spatially constant." The principle of stationarity being not respected hydrologically, it is doubtful that the calibration model post anthropogenic modification remains valid for the preceding period. Deeper discussion are required on this topic, e.g., by proposing evidence that the sediment record (through TVT, DLT, or best P99D0) is not significantly affected by this change and can be used to infer river hydrodynamics prior 1972.

L604: "it is quite unlikely that the sedimentary input from the Naskaupi River contributed to sediment accumulation at the mouth of the Beaver River" is in contradiction with L440 : "data from core BEA-1 (1856-440 2016), NAS-1 (1856-2016) and NAS-2 (1968-2016) have been normalized and averaged to produce mean TVT, DLT and P99D0 series" to be compared to the Naskaupi River hydrometric station. This questions the selection of BEA-1 in the merging approach of the sedimentary data.

Moreover, the justification that Naskaupi River discharge does not affect BEA-1 location is made by the fact that (L598-608) "the absence of any traces of the 1972 CE marker bed at the Beaver River mouth (BEA-1) supports this hypothesis." This argument is not admissible, especially with regards to the previous discussion (L583) that the "flood(s) of the years 1972 CE has (have) remobilized newly available sediments and deposited a thick and coarse-grained turbidite on the lake floor". It is indeed likely, with regards to the sedimentary facies of cores NAS, that the 1972 flood transported coarse material that plunged in the river proximal and extended as hyperpicnal flow following the lake Bathymetry (NAS-1 to NAS-2), thus not affecting BEA core location. However, discussion about flood hydrodynamics and annual river discharge in terms of sediment transport should be decoupled in the discussion.

The argument that a decline in varve thickness is also observed post 1972 in BEA, thus

related to a natural hydro-climatic signal can be true, but seems superimposed to the effect of the Naskaupi River diversion, especially for cores NAS. While discreet peaks of sediment proxy (TVT, DLT, P99D0) for the different sediment cores are consistent (occurring at the same date), the variance, mean, and trend in these data are not comparable enough to allow the merging. Also, the three records from the three cores respond totally differently to the pos-1972 hydrological changes: lower mean for BEA-1, higher mean and increase variance for NAS-1, lower mean + decreased variance + decreasing trend for NAS-2. Suggestion: change point analysis (mean, variance and trend) can be performed on each times series, both from the hydrological and sedimentary variables. This would give statistical support to visual information.

Finally, I am really surprised to see a 5-year running mean for the reconstruction of hydrological data. As the varve chronology is more than robust, through its coherence between the different locations and perfect correspondence with 137Cs, it is a pity that annual time series are not reconstructed. This choice of smoothing the data needs to be justified. Running mean in lake sediment studies are generally used to account for the error in the varve chronology, with statistical justification for significant improvement of the proxy-climate correlations (cf. Von Gunten et al., 2012). + Figure 10 compares the rainfall-runoff model and sedimentary data at annual resolution, with no lag (L624). This gives again the impression that correlation values are maximized at all cost.

von Gunten, L., Grosjean, M., Kamenik, C. et al. Calibrating biogeochemical and physical climate proxies from non-varved lake sediments with meteorological data: methods and case studies. J Paleolimnol 47, 583–600 (2012). https://doi.org/10.1007/s10933-012-9582-9

#General comment on the rainfall-runoff modeling approach

A key point of this review is the comparison between sedimentary data and modeling. The rainfall-runoff modeling for each catchment is merge to a single ANATEM time series (Fig. 10) and compared to the sediment properties of the varves. This ANATEM time series is based on the pre-determination of single catchment area, then extended for the whole studied period. However, the Naskaupi river watershed pre- and post-1972 is different (smaller after the 1972 river deviation) and should be adapted in the modeling; producing two time series (i) 1880-1971, (ii) 1973-2011. This likely explains that stronger correlations found between e.g., DLT and ANATEM for the period 1972-2011 (r=0.54) compared to the preceding period (r=0.31).

#Specific comments

L68: to reconstruct daily. . .

L73: “Long hydro-climatic series based on natural proxies in the study region are rare and limited to tree-ring”. What have all these studies produced? What conclusions ? Is the aim of the present study to comfort previous finding, to increase spatial coverage? This does not say why clastic lake sediment are better than tree rings or pollen data (which is suggested here) Aren’t tree-ring records not enough? Are they all from the Labrador region? Are the hydroclimate records consistent with each others? Answering these question would help re-shaping the sentences in explaining what makes clastic varves so specific and powerful.

L76: “clastic” are not defined prior to this mention

L79: Remover ‘The’ between area and into

L81: Amann et la., should be et al.,

L231 : remove ‘used’ form the title

L245: Suggested change; ‘This allows to extend instrumental data series for the period 1969 to 2011, and fill in data for the missing years.’

L252: title could be simply, e.g., varve properties and hydrological variables

L456: “data show significant ($p < 0.01$) strong positive correlation.” Remove ‘strong’, especially referring to $r = 0.49$ in brackets, this is not a strong correlation, especially in

such hydrological context.

L478: ” The significant correlation between reconstructed Q-mean and Q-max values and observed discharge data validates the predictive capacity of the model.” I don’t see how the fact that Qmean and Qmax correlates validates the proxy-Q model.

L496: “demonstrates that the Grand Lake varved sequence is robust and contains a regional signal.” You mean the hydrological reconstruction is robust? I would not say that $R2 = 0.41$ is robust. Remove ‘robust’ and keep ‘contains a regional signal.

Q-mean and Q-max are sometimes written with a capital M (e.g., Q-Mean), sometimes not (Q-mean). Please stay consistent.

L595: it should read ‘indicate that the capacity of spring discharge to transport fine sediment and its ability to float ice to Grand Lake decreases due to the decrease in water supply.’

L650: please consider changing ‘robust’ for ‘best proxy’

L697: extracted from

L706: change “could help to better our reconstructions” to ‘could help better refine these reconstructions”

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