CHRONO ENVIRONNEMENT

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Besançon, February 10th 2013

Subject:
Manuscript number cp-2012-142,
submission of the revised version

Dear Nathalie Nebout,

Please find attached the revised version of our manuscript entitled “Orbital changes, variation in solar activity and increased anthropogenic activities: controls on the Holocene flood frequency in the Lake Ledro area, Northern Italy”, which we submit after revision for publication in the Special Issue “Holocene changes in environment and climate in the central Mediterranean as reflected by lake and marine records” in Climate of the Past.

In this revised version of the manuscript we addressed all the remarks from the two referees and we thank them for these constructive comments. As suggested, we detailed the sedimentological description of the core and we discussed more geophysical and geochemical data in order to better document the background sedimentation and sedimentary event deposits processes. Then we considered also comments from Referee 2 about the Mid-Holocene events and the LIA and we precised our interpretations about the late Holocene flood frequency increase according to Referee 1 propositions. Finally, we completed the references list with referee's suggestions and the text has been reviewed by "American Journal Experts" (English editing and translation services) for English language editing.

Unfortunately, it was impossible to observe the present-day "natural" dynamic of floods to reinforce our interpretation. The regulating activities during hydropower production since 1929 AD have probably modify the temperature of the water column and probably prevent from generation of hyperpycnal flood and recent human infrastructure on river corrections in the catchment area have been very efficient to reduce the impact of flash-flood events on lacustrine environments.

All other suggestions to improve the text or figures were taken into consideration and the responses to specific remarks are listed in the following point by point response.

Yours sincerely,

Boris Vannière & co-authors

Reply to Gerardo Benito (Referee 1)

Thanks to Gerardo Benito, we have followed his suggestions by taking into account the comments that have improved the quality of the manuscript.

General comments:

1. It is evident that the authors did not prepare the manuscript for submission carefully at all:
-There is neither line nor page numbering.
This has been corrected.

-Authors do not reference the figures adequately in the text. i.e Fig 2b cited in the text before 2a, Fig 8 before Fig 7
These have been corrected.

-References do not follow a similar format, and some of them are missing both in the text and in the reference list
These have been corrected.

-Figures are not numbered
This has been corrected.

Once corrected these edition mistakes, I would suggest the revision of the manuscript by an English native speaker. The English is readable but it could be improved considerably.
The manuscript has been corrected by "American Journal Experts" (English editing and translation services) for English language editing.

2. The background sediment facies description is not entirely clear to me. Are the calcite and organic debris layers annually laminated? You do not state this in the text but in Wirth et al. (2012) –a workshop contribution mentioned in your reference list- they describe it as a varved record in the title. The authors hypothesize with the seasonality of the floods but, in my opinion, there is a big assumption in this. Seasonality of palaeofloods is very difficult to know and it is only possible to confirm it with an understanding of the sedimentary record base on microscopic inspection of thin sections and/or sediment traps in order to know the sediment dynamics during the annual cycle. The authors suggest that the calcite layers are deposited in spring during the increase in biological activity in the lake, is there any previous study about it? how do you know that there are not algae diatom blooms favouring calcite precipitation during autumn?. On top of that, you mention that the top clayish layer form the flood deposits are difficult to distinguish from the organic debris layer. Then, how can you say that flood layers are topped with the organic layer debris if you cannot difference them? If the authors do not provide more sedimentological information and additional description concerning to the lake sediment dynamics I would strongly suggest to delete the seasonality interpretation of the flood record in the manuscript and the climate implications (i.e., NAO as a forcing mechanism controlling storminess in the area).
More information about the background sedimentation has been added and the text. We add a figure 1a with the entire cores sediment images and lithology and figure 2a has been completed. About the seasonality and NAO forcing mechanism: this has been deleting and will be the main subject of a next paper in preparation (Wirth S.B., Gilli A., Simonneau A., Ariztegui D., Vannière B., Glur L., Chapron E., Magny M. & Anselmetti F.S., Seasonality of floods in Northern Italy during the past 2100 years: Interplay of solar forcing, variations in NAO, and ENSO influence), yet available in the Stefanie Wirth's PhD thesis: Wirth S.B. (2012) "The Holocene flood history of the Central Alps reconstructed from lacustrine sediments: Frequency, intensity and controlling climate factors", Chapter 4. Dissertation ETH No. 20860, ETH Zurich, Zurich, Switzerland.

3. This manuscript is a core based study from two long sediment cores retrieved in proximal and distal areas. I miss an additional figure showing both Holocene sequences (not just the gravity cores) and their correlation. This figure should also incorporate the 14C ages and lithological columns (and perhaps additional colour-based proxies discussed in the text). Perhaps a new figure 1b below the seismic profile. As the figures are not numbered it is difficult to follow the paper. Where is figure 3b (threshold value with a Gaussian mixture model)??
A figure 1b has been added: it represents the core sediment images, lithology and the position of radiocarbon ages of cores Ll08-1 and LL08-2.
There is no Figure 3b – this is a writing error corrected by 4b (Gaussian mixture model).

4. You have presented a 137Cs chronology with a possible slump affecting the topmost sediments. I wonder, correcting the sediment duplicate, if you could compare flood deposits with the instrumental record or direct measurements in gauging stations from the rivers feeding the lake. If the sediment record has an annually

lamination it could support the interpretation of the so-called flood deposits. I am aware that this is a difficult task because of the lake sediment dynamics alterations due to the construction of the pumped-storage plant, but large floods should also be recovered during the XXth centuries besides anthropogenic disturbances.
It was impossible to compare instrumental record with sedimentary data for two reasons that we explain in the text adding the following information:
"During the 20th century several river corrections have been installed in both tributaries of the lake in order to reduce the effects of flood events. Indeed, they are two temporary torrential tributaries and their drainage network is marked by canyons on steep slopes favouring intense gully erosion. On the River Ponale, between Lake Ledro and Lake Garda, the pumped-storage plant “Centrale idroelettrica del Ponale” was built in 1928-1929. Water is pumped in penstocks from Lake Garda to Lake Ledro, which is 532 m higher. This artificial water regulation strongly modifies the sedimentary dynamics. Consequently, the sedimentary record since 1929 cannot be compared to the older parts of the record or used as a reference."
"The last thick flood deposit recorded in the cores is dated to 1920±20 AD. In the 20th century, the sedimentation appears strongly modified by the human control: hydropower production since 1929 AD can modify the temperature of the water column and prevent from hyperpycnal flood occurrences and/ or recent human infrastructure on river corrections in the catchment area have reduce the impact of flash-flood events on lacustrine environments; consequently, the record cannot be used for palaeoenvironmental reconstruction."

5. I ask the authors to reconsider the climate interpretation of the palaeoflood record based on the frequency of allocthonous detrital events. The authors link the increase in flood frequency during the Late Holocene with a decrease in a seasonal contrast of insolation, which started several centuries before the increase in flood frequency (in graph 8 it seems to be a delayed response of ca 500 years). Magny et al., 2012 already shown this control for the long term development of higher lake levels in Lake Ledro. Nevertheless, the authors do not provide either an explanation of the time delay nor climatic explanations for the increase in the storminess in relation to the orbital forcing at a millennial scale. In the other hand, authors should first consider the human control on the flood frequency and not only on the amount of sediment delivery to the lake because of changes in land use and deforestation. They have found nice evidences of human occupation during the Bronze Age in the Lake Ledro shoreline coinciding with the increase in the flood deposits frequency. In my opinion, this would enhance the effectiveness of the lake system to record flood deposits under a strong anthropogenic influence in the lake catchment that would increase the sensitiveness of the lake to record smaller precipitation events hindering the climate signal.
It’s really difficult to argue about a 500 yr delay keeping in mind the radiocarbon age uncertainty and time lag of ecosystems response to climate forcing. In that way it is also difficult to say if Human or climate is the main factor driving flood activity. The sections 4.3 and 4.4 have the respective role to discuss about the possible impact of each factor on the Ledro’s flood record. But we conclude also the section 4.4 with the following text: “*During the period 4000-3000 years ago, the Bronze Age population was most likely large enough to contribute to a widespread and strong increase in land erosion. The major change in the hydrological regime that traduces the Neoglacial initiation and that is recorded in particular by lake-level variability (Magny et al., 2012) at Lake Ledro, probably leads to the flooding increase. This shift in flood frequency c. 4000 cal BP is thus the results of both forcing factors.*”
We think that we can’t choose with this series, which of climate or Human activities is the main factor driving flood activity. Yes, after c. 4000 cal BP, the lake Ledro system to record flood deposits under a strong anthropogenic influence in the lake catchment, but Lake level increase is also attested and traduces more precipitations during this period that have certainly leads to flood frequency increase.

Specific comments:
I include some specific comments, as the manuscript is not numbered, I will try to allocate them according to the page and line number and/or sections of the pdf I have received.

Title: I would delete orbital forcing from the title
In the text one section is dedicated to this possible orbital control that justifies mention in the title of the paper.

Abstract: Modify according to the general comments suggested above. Make it shorter 1pag; line 15: Late Holocene instead of last third of the Holocene
The abstract is now slightly shorter (368 => 262 words) and the proposed change has been done.

Introduction
2pag; lines 21-28.Authors discuss that during the Holocene Thermal Maximum, southern European ecosystems experience great changes that contrasts with the Bronze period, that experience a social development. What do you want to say? Please, rewrite it.
We changed "In contrast" by "*In addition*".

2pag. Line 23: change Matthew et al., 2008 for Matthews and Dresser (2008)
That has been done.

2pag. Line 27: You cited a PAGES newsletter article (Vanniere et al., 2010). It is a not index journal without a proper reviewing process. I suggest deleting this reference.
That has been done.

2pag. Line 31: delete “anthropogenic”
That has been done.

3 pag. Line 13: change “detritital” for “detrital”
That has been done.

Material and methods
Study site: I do not understand why the study site is in the material and methods section. In addition, I find the climate description of the study very poor. I would suggest to add an ombrothermic diagram of the area based on a close meteorological station and describe the hydrological cycles and the type of precipitation in the area. I think that the climate information explained in the discussion (pag 17, lines 10-19) should be added in the study site.
We modified the title of the section: "Site, materials and methods". We move climate information from the discussion to this "Study site" section. Unfortunately, no more recent reference is available in this area for climate data.

Pag4 lines 1-2 are you describing the littoral sediments? Specify it
We change the sentence in order to precise that all the sedimentation in the lake is dominated by autochthonous carbonate. But we will not detail here the sediment characteristics; this section is just a presentation of the lake. In that way the rime are clearly visible from the shore and describe the site. We will complete thereafter (section 3.1) in the paper the sedimentary deposits characterisation with core analyses.

Pag 4 lines 3-6. Please, describe the vegetation of the area as an altitudinal succession.
That has been done.

Seismic survey and coring: Authors should add information about the length of the long cores. Also provide the labels of the gravity cores. If you use and standard UWITEC gravity corer you do not need to further describe the diameter of the PVC liners enlarging the manuscript unnecessarily.
These have been corrected.

Geophysical logging: Is there any reason why you did not measure the magnetic susceptibility together with the bulk density using the GEOTEK multi sensor core logger before splitting the sediment core?
The magnetic susceptibility measured on whole cores with a loop offers a lower stratigraphic resolution than magnetic susceptibility measured with the point sensor on split cores (2 cm versus 0.4 cm); that the reason why we measured Gamma density and magnetic susceptibility in two times.

Geochemical analyses: Pag.5 lines 19. You introduce fig 2b before fig 2a
This has been changed.

Pollen analyses: You have not included Stockmaar (1971) in the reference list
This has been changed.

Results
Subchapter 3.1
Pag 6.last line: I would include geochemistry in the heading 3.1 as you are describing the XRF data
This has been changed.

In this section authors discuss about the seasonality of the floods and cite the Piànico-Sèllere record, which is a well-undertood paleolake varved record, as discuss in the general comment 2, authors do not provide enough information about either concerning the nature of the background sediments nor about the annual sediment dynamic cycle in lake Ledro, please, add more information or consider deleting this information.
More information about the background sedimentation has been added and the text. Figure 2a has been completed. About the seasonality: this has been deleting and will be the main subject of a next paper in preparation (Wirth S.B., Gilli A., Simonneau A., Ariztegui D., Vannière B., Glur L., Chapron E., Magny M. & Anselmetti F.S., Seasonality of floods in Northern Italy during the past 2100 years: Interplay of solar forcing,

variations in NAO, and ENSO influence), yet available in the Stefanie Wirth's PhD thesis: Wirth S.B. (2012) "The Holocene flood history of the Central Alps reconstructed from lacustrine sediments: Frequency, intensity and controlling climate factors", Chapter 4. Dissertation ETH No. 20860, ETH Zurich, Zurich, Switzerland.

Authors define the dark brown facies (flood deposits) as graded facies, how is this grading?, finning upwards, coarsening upwards, both?. Please, add more information and not only refer as Simonneau et al., this volume as the description of floods deposits is key in this study. Moreover, you comment several times about the grain-size pattern in both types of allochthonous facies but you do not provide quantitative data. If you have not performed direct grain-size measurements you should include in the text that they are based on visual observations.
Detailed information about laser grain size analyses have been added in the text: " Laser grain size analyses shows that the mean grain size in most of these sedimentary event presents inverse (coarsening upward) and normal (fining upward) grading (mean grain-size < 30 µm; detailed data are presented in Simonneau et al., this volume). Some deposits are however only characterized by normal grading. For all, they are not well sorted, except at the top of the deposits where we can observe sometimes the formation of a thin clay cap." And "In addition to these flood deposits, a second sedimentary event type can be observed as light grey-brown homogeneous deposits (Figure 2a). The mean granulometry of these event layers is finer, better sorted and no graded (mean grain-size < 25 µm; Simonneau et al., this volume)".

Authors also discuss in this section about the correlation of flood layers in the proximal and distal cores (Table 2). I miss further explanations to explain the 20% lack of detrital layers in the distal deposits.
We complete the ask as follow: "Visual correlations between master cores LL08-1 and LL08-2 show that flood-event deposits are quasi-systematically thicker in core LL08-2, i.e. at the more delta-proximal location. In other words, a part of deposits were too thin to be detected in the delta-distal core LL08-1 or are not recorded by a sedimentary deposit because the flood intensity was too low and sediments don't reach this position. Thus 20% more flood event deposits have been identified and counted in core LL08-2 compared to core LL08-1."

Subchapter 3.2
Authors interpret the two 137Cs upper peaks as a slump deposit that duplicates the sequence. In Figure 2a you have related this mass movement with an earthquake in 2004 but you do not mention this in the text.
We complete the text: The chrono-stratigraphic position of this slump on the top of the gravity core suggests that it is linked with a really recent events and we hypothesis that is the result of the last earthquake recorded in the region in 2004."

You are discussing sedimentation rates after removing the allochtonous input to the lake. I would suggest to add percentages of the external sediment input to the lake in relation to the background sedimentation based on the age models shown in Fig 3.
We calculated and plotted this but it not really adds complementary information: period of maximum allochthonous inputs into the lake identified by this parameter correspond to periods marked by the thicker floods events deposit i.e. 6000-5000 and 3500-2500 cal BP. We already discuss about these thick floods deposits in the text. So we didn't keep this because it doesn't improve our study.

Subchapter 3.3
I found the colour data processing methodology very interesting and innovative.
Thanks

Pag 10.lines 15-17: Authors comment that flood signal does not depend either on the core location nor the counting methods based on the low amount of variability in the signals obtained from the two cores. However, the proximal core records a 20% more flood event deposits than the distal core, which suggest that core location is key to record the complete flood record.
Yes there is a difference of 20% in the number of flood deposits detected between both cores but this difference is not perceptible in the temporal distribution of the floods deposits; in other words this 20% floods deposits undetected in the distal core records are equally distributed in the sequence and then doesn't change the flood frequency reconstruction through time obtain from both records.
Text have been change to better explain our idea: "*The 20 % supplementary flood event deposits identified in the proximal-delta core LL08-2 are well distributed along the series and doesn't introduce difference between both LL08-1 and LL08-2 flood frequency record's.*"

Pag 10.Line 18. I would say, based on Figure 5, that the flood frequency increase at 4000 cal BP instead of 4500 cal BP
We changed for 4500-4000 cal BP keeping in mind the radiocarbon ages uncertainty.

Subchapter 3.4
Pag 11; line 15: I think “endogenic” is more adequate than “autochtonous” to define the material deposited/precipitated biologically or biogeochemically within the lake.
We changed for “autigenic”.

Pag 11; line 15:“Before” instead of “after”
We correct the sentence where there was a mistake in chronological information:
“*Autigenic sedimentation becomes dominant between 2800 and 1200 cal BP*.”

Pag 11; line 19: If you consider 1200-1400 cal BP should be 550-750 AD instead of 500-700 AD.
This has been corrected as suggested.

Discussion
Subchapter 4.1:
I miss a more exhaustive explanation dealing with the different factors that could affect the sediment delivery to the lake, both climatic and anthropogenic. It is clear that land uses changes lead to higher sedimentation rates by increasing the run-off due to deforestation, larger areas of bare soil, etc. Concerning the climate, it would be very interesting to discuss the sediment transport and remobilization in the catchment under different climate scenarios. Humid periods are supposed to increase the run-off in the watershed but, what happens during arid periods. Lake catchment should also be prone to soil weathering and erosion by splash, wetting-drying cycles, etc, ultimately leading to a higher sediment delivery to the lake (from source to sink) Are those thicker events corresponding to arid periods and lower lake levels? (at c. 6500-5500, 5000, 3500, 2500 cal BP). Addressing this issue would add additional value to the discussion.
Actually, this point have been already discuss and the hypothesis presented at then end of section 4.1: “*the rarest, thickest events (> 5 cm) seem to occur during periods of low or moderate flood frequency, such as those at c. 6500, 5500, 5000, 3500, 3200, 2500 cal BP, which may reflect strong remobilisation and discharge of material stocked in the watershed during a low flooding period.*”

In addition, as suggested above, you could also add percentages of the allochthonous input to the lake during different phases, both human and climatic subchapters 4.3 and 4.4.
We calculated and plotted this but it not really adds complementary information: period of maximum allochthonous inputs into the lake identified by this parameter correspond to periods marked by the thicker floods events deposit i.e. 6000-5000 and 3500-2500 cal BP. We already discuss about these thick floods deposits in the text. So we didn't keep this because it doesn't improve our study.

Subchapter 4.3:
You cite figure 8 before figure 7
This has been corrected.

Subchapter 4.4:
See general comment 5 and consider rewrite this chapter. The last sentence on section 4.4 concludes that orbitally driven climate changes are primarily driving the increase in the flood frequency. As you do not have either robust results that confirm this hypothesis nor a climate explanation for it, and because of the large expansion of human population during the Bronze Age I would consider anthropogenic activities the main cause leading to a higher sensitiveness of the lake ecosystem to record flood deposits in relation to higher run-off and sediment availability in the catchment.
We think that indeed the role of human activities in flood activity increase is significant but it is difficult to chose one forcing factor against the other, so we correct our final paragraph as follow: “*During the period 4000-3000 years ago, the Bronze Age population was most likely large enough to contribute to a widespread and strong increase in land erosion. The major change in the hydrological regime that traduces the Neoglacial initiation and that is recorded in particular by lake-level variability (Magny et al., 2012) at Lake Ledro, probably leads to the flooding increase. This shift in flood frequency c. 4000 cal BP is thus the results of both forcing factors.*”

Subchapter 4.5
Pag 17- lines 2-4. I would be careful with this linkage between solar irradiance and flood frequency. You are making this assumption based on a radiocarbon chronology with a non-negligible error and grouping flood records every 50 years, therefore, it is very risky to make this relationships without a high resolution record.
We modified the text to say that this is a working hypothesis that needs further studies to be confirmed:” *But this hypothesis is based on chronological correlation with important uncertainty and further studies are necessary to confirm it*.”

Pag 17- line 8. Hu et al., 2003 is not in the reference list.
This has been corrected.

Last paragraph. As discussed in general comment 2. You do not provide robust data and/or explanation to be able to discuss the seasonality of the flood deposits. On top of that you cite a study (Wirth et al., 2012) that is not published. Therefore, authors should provide further explanation and new data in the manuscript or the discussion of the seasonality of flood deposits, its climate implications and control mechanisms (i.e NAO) during the last millennium should be avoided.
About the seasonality and NAO forcing mechanism: this has been deleting and will be the main subject of a next paper in preparation (Wirth S.B., Gilli A., Simonneau A., Ariztegui D., Vannière B., Glur L., Chapron E., Magny M. & Anselmetti F.S., Seasonality of floods in Northern Italy during the past 2100 years: Interplay of solar forcing, variations in NAO, and ENSO influence), yet available in the Stefanie Wirth's PhD thesis: Wirth S.B. (2012) "The Holocene flood history of the Central Alps reconstructed from lacustrine sediments: Frequency, intensity and controlling climate factors", Chapter 4. Dissertation ETH No. 20860, ETH Zurich, Zurich, Switzerland.

Conclusions
Conclusions should be modified according to the general and specific comments.
This has been done.

References
-There are some references cited as "(this volume)" that are not specified in the reference list whether they are accepted, in reviewing process, just submitted, etc
This has been completed.

-References of the same author should be order chronologically
This has been corrected.

-The referencesGobet et al. (2003)and Feng Sheng Hu et al (2003)are not cited in the text
This has been corrected.

-Hu et al (2003) and Stockmaar(1971) in the text but not in the reference list
This has been corrected.

-The references are not in the same format
This has been corrected.

-Wirth et al (2012) is a workshop contribution, due to the importance of this citation in the text, and considering that it has not been through a reviewing process I suggest deleting this reference from both, the text and the reference list.
This has been corrected.

Figures
Fig. 1. Write in the figure caption what the blue and green lines represent
These line have been remove, it was a mistake.

Fig. 2a.change "scans" for "sediment core images". Add lithological columns for the sediment cores
We change the figure caption as suggested. Explain and illustrate the lithology and the different facies of this sedimentary sequence is the aim of this figure; because there is a repeated succession of laminated facies and sedimentary event deposit and because this layers are inframillimetric to centimetric, it is impossible to draw a lithology for the entire core; that the reason why we propose zoom with lithological information and text for the description.

Fig 3b not included
It was a writing error, corrected by 4b.

Fig. 5. I would add grey bands indicating the high flood frequency periods in the graphs showing the entire Holocene record. In the bottom graph spanning the last 1300 years I would include bands showing the main climate phases (DACP,MCA, LIA, XXth century).
It is difficult to add some grey band because there are already grey envelops that figure the variability of the signal from cores and methods of quantification. Therefore this figure just illustrates results of quantification and is not used to discuss and interpret the signal. Figure 7 include floods frequency curves with trends and

events, which are used to compare with other records and discuss about chronology of flood frequency increases.
We complete anyway the graph spanning the last 1300 years with bands showing the main climatic phases and include this also in the caption.

Fig. 6. Write in the figure caption what the shaded bands means. Periods of high human impact in the cachtment?
We complete the caption as suggested.

Fig 7. What do the grey bands represents?
Periods of floods frequency increase – we complete the caption also.

Tables
Table 1: what are the numbers in brackets in the third column? Write it in the figure caption
This has been corrected.

Reply to Ana Moreno (Referee 2)

Thanks to Ana Moreno, we have followed her suggestions by taking into account the comments that have improved the quality of the manuscript.

1. Lack of detailed sedimentological description. In spite this paper can be considered a "sedimentological paper", the description of the lacustrine sediments is very poor. This is the main limitation of the study of Lake Ledro sediments presented in this manuscript.
We added a more detailed description of both the background sedimentation and the sedimentary events in section 3.1. Figure 2a has been also completed. This aspect will be also detailed in another publication in preparation (Wirth S.B., Gilli A., Simonneau A., Ariztegui D., Vannière B., Glur L., Chapron E., Magny M. & Anselmetti F.S., Seasonality of floods in Northern Italy during the past 2100 years: Interplay of solar forcing, variations in NAO, and ENSO influence), yet available in the Stefanie Wirth's PhD thesis: Wirth S.B. (2012) "The Holocene flood history of the Central Alps reconstructed from lacustrine sediments: Frequency, intensity and controlling climate factors", Chapter 4. Dissertation ETH No. 20860, ETH Zurich, Zurich, Switzerland.

Several issues should be improved:

a. First, to assert the annual (or seasonal) character of the lamination a monitoring study (installing sediment traps, for instance) or/and a petrographic characterization (SEM, microscope) of thin slides are mandatory. For example, it is said that white laminae correspond to the carbonate precipitation in the lake that occurs mostly in summer. Allochtonous origin for the carbonate is also frequent in a limestone-rich catchment area, as this one, so the presence of detrital carbonate must be ruled out before giving a biogenic interpretation to the white laminae. In addition, the sedimentation of the gray layer is attributed to winter season, but without any proven evidence. A sedimentological and geochemical characterization of pairs of laminae, in a similar way than presented in other papers from laminated sequences (Brauer et al., 2008; Corella et al., 2012; Martin-Puertas et al., 2012) is recommended.
About the seasonality: this has been deleting and will be the main subject of a next paper in preparation (Wirth S.B., Gilli A., Simonneau A., Ariztegui D., Vannière B., Glur L., Chapron E., Magny M. & Anselmetti F.S., Seasonality of floods in Northern Italy during the past 2100 years: Interplay of solar forcing, variations in NAO, and ENSO influence), yet available in the Stefanie Wirth's PhD thesis: Wirth S.B. (2012) "The Holocene flood history of the Central Alps reconstructed from lacustrine sediments: Frequency, intensity and controlling climate factors", Chapter 4. Dissertation ETH No. 20860, ETH Zurich, Zurich, Switzerland.

b. Second, more explanations are necessary regarding the identification of flood layers. The method proposed here to identify flood layers is based on the color of the sediment. However, the authors state several times in the manuscript that geophysical and geochemical data make possible to distinguish events. Why don't they use those proxies (with more compositional meaning than the color) for the statistical analyses of frequencies? Or at least, to check the results obtained from the color analyses? In fact, XRF core scanner measurements were already obtained with a sampling of 0.2 mm, likely detailed enough to resolve the presence of laminae. Again, more detailed sedimentological description is necessary to see if there was erosion or not within flood layers and "background" laminations.
We complete the 4.1 discussion section as follow in order to explain why colour appear as the best and unique proxy for flood signal analysis: "*The colour data represent a more valuable proxy than geochemistry measurements, which are affected by long-term changes in the background sedimentation with the increase in terrestrial inputs since c. 4000 cal BP (Figure 6). Therefore mineral elements, like Si, K, Fe and Ti that characterize flood deposits present a asymmetric profile within the facies and don't allow thus to use them for automatic selection and counting (Figure 2b). Only Zr seems to discriminate well flood deposits but we measured this element only at 2 mm resolution along the core that not enough to catch the detailed signal. Finally, we observed that this is allochthonous organic matter that better discriminate flood deposits from the background and this is allochthonous organic matter that gives the dark-brown colour to the flood deposits. This explains why colour data and the red component appear as the best proxy to extract and quantified flood signal*."

c. Third, the presence of slumps must be considered carefully. From the number and intensity of Cs peaks, it seems evident that there was a slump duplicating the sedimentary sequence in the uppermost part of the record. However, are there any other evidences to detect other similar slumps that may happen in other sections? How can the authors rule out the presence of other slumps?
We complete the text with the following information which explains how we are confident with this record: "The 2004 slump deposit is laterally associated with a hummocky acoustic facies identified at the western edge of the lake basin on seismic profiles (Figure 1). No other hummocky facies are identified in the lake basin and no other tilted facies have been observed in the sequences. Therefore, these two coring sites

where selected on seismic profiles away from chaotic acoustic facies produced by mass wasting deposits or from any hummocky acoustic facies (Simonneau et al., this volume). We are thus confident that no others slump deposits are intercalated within the sediment cores."

2. Forcing mechanisms. In the manuscript the authors discuss climate mechanisms at different time scales and also consider human influences on the catchment to explain some changes in the flood frequency or intensity. Although this discussion is particularly profuse and correct, I add some ideas that the authors may want to include:

a. The main hydrological change in the record is observed after 4500-4000 cal BP when a sudden increase in flood frequency is observed; this change must be regarded as a change in the trend rather than a particular event associated to the 4200 yr event. This change is associated to a response to orbitally-driven insolation (see also (Magny et al., 2012)) while human influence is discarded (in spite of the presence of a Bronze settlement near the lake and evidences of deforestation from the pollen data). The main arguments put forward by the authors are (1) that there was a clear hydrological change marked by an increase in lake level and (2) since a similar change is observed in many other Southern Europe locations the common cause must be climatic. It is always difficult to tip the scale favouring climate or anthropic impact but in this case, there are enough data (from the sequence and in other nearby records) to discuss in depth this issue. Other changes in the catchment area (any variation in the tributaries??) should also be also discussed in relation to this large hydrological change. To me, more emphasis on this important and clear inflexion point in the hydrological pattern is missing.
Yes we are agree that this inflexion point in the tendency is not an event and in particular not the “4200 yr” event. Magny et al., 2009 have explain how this period c. 4500-4000 cal BP is either a transition period at high latitude with a general trend toward wetter climate condition and include at lower latitude a dry event, which is the “4.2kyr” event.
We have no information (from seismic profile) about variations in the tributaries. Because we can propose arguments that indicate the possible human and climate impact on palaeofloods activity, we conclude that is it impossible with this study to choose one main driver against the other. In that way we change and complete the end of section 4.4.: “*During the period 4000-3000 years ago, the Bronze Age population was most likely large enough to contribute to a widespread and strong increase in land erosion. The major change in the hydrological regime that traduces the Neoglacial initiation and that is recorded in particular by lake-level variability (Magny et al., 2012) at Lake Ledro, probably leads to the flooding increase. This shift in flood frequency c. 4000 cal BP is thus the results of both forcing factors.*”

b. In the discussion of Early to Mid-Holocene events, some confusion is produced among “abrupt events” and “general trends” in the record. For example, the authors consider three events (three clustering of flood events) at 8000, 7500 and 7000 cal BP but they are compared to reconstructed summer or sea surface temperature trends. Those concepts can not be mixed.
I’m no sure to understand because there is no mention of “abrupt events” in section 4.3 “early to mid-Holocene flood frequency” discussion. We compare a period marked by three flooding increase at lake Ledro to climate reconstruction during the same time lag. We know that the reconstructed summer or sea surface temperature found in the literature as “trends”. But this perception of the temporal variability depends of the nature of the palaeoclimate signal: flood or fire represent events in time and here we reconstructed the frequency with a nice temporal resolution; Sea surface or summer temperature presented in the cited paper are decennial mean that describe climate tendency but this tendency is probably an average of a variability. So we think that is possible to compare a clustering of three shorts period of flood frequency increase with the reconstructed trend of the regional climate. It is really usual to propose such comparisons in palaeoscience – it’s probably non perfect but the low and indirect data available make sense to proceed like that.

c. The increase in floods during the LIA is linked to the persistent negative mode of the NAO, as reconstructed in Trouet et al. (2009). I suggest the authors to plot the Trouet’s data to clearly mark the similarities with the Lake Ledro flood frequency reconstruction. In addition, an explanation about the influence of NAO in Spring (or a reference) for the studied area would be desirable.
About the seasonality and NAO forcing mechanism: this has been deleting and will be the main subject of a next paper in preparation (Wirth S.B., Gilli A., Simonneau A., Ariztegui D., Vannière B., Glur L., Chapron E., Magny M. & Anselmetti F.S., Seasonality of floods in Northern Italy during the past 2100 years: Interplay of solar forcing, variations in NAO, and ENSO influence), yet available in the Stefanie Wirth’s PhD thesis: Wirth S.B. (2012) “The Holocene flood history of the Central Alps reconstructed from lacustrine sediments: Frequency, intensity and controlling climate factors”, Chapter 4. Dissertation ETH No. 20860, ETH Zurich, Zurich, Switzerland.

Minor comments and suggestions:

Although English is not my mother-tongue, I recognize some sentences that are not fully clear (although readable). I would suggest the authors to consider the revision of the manuscript by an English native speaker.
We correct the unclear sentences as suggested by the referee. Therefore, the manuscript has been reviewed by "American Journal Experts" (English editing and translation services) for English language editing.

Abstract
It is too long and with too much detail. There are some sentences similar to the ones written in the Methods section. As an example, lines 8-11 are not necessary. - The last third of the Holocene change by Late Holocene or After 4500 cal BP.
The abstract is now slightly shorter (368 => 262 words) and the proposed change has been done.

When talking about “centennial time scale” (line 21), reference to longer periods such as Neo-glacial or Little Ice Age should be avoided in relation to “events” (ca. 4500 and 500 cal BP). Authors sometime mix “events” with “longer periods” (see above).
We wanted to say centennial time scale changes occurred after ca. 4500 and 500 cal BP – So we corrected the sentence in this sense to be clear.

Introduction
Line 14, Page 4703: In contrast to this period. Why in contrast? Not clear, please rewrite.
We changed "In contrast" by "*In addition*".

Lines 7-10, Page 4704: Not always. Please, rewrite.
We changed for "*Sometimes, lake sedimentation may be very good at preserving river-flood activity …*".

Material and methods
Line 11-12, page 4705: a detailed description of the sediments is necessary in this manuscript, not only about the rim.
We change the sentence in order to precise that all the sedimentation in the lake is dominated by autochthonous carbonate. But we will not detail here the sediment characteristics; this section is just a presentation of the lake. In that way the rime are clearly visible from the shore and describe the site. More information about the background sedimentation has been added and the text (section 3.1). Figure 2a has been completed.

2.4. Geochemical analyses:
What about the other elements not presented here? Was the XRF signal too low, noisy, not significant? Please, explain
Yes for other element the signal was very low, “flat” i.e. doesn’t change and sometime very noisy. So because they don’t offer discriminate information we chose not to figure and present them. We add a sentence in the text to explain this: “*We present here only elements that offer a significant variability without too much noise*.”.

Was it possible to sample for ICP-AES analyses at the scale of the lamination? The authors may need to explain why did not use “traditional” XRF instead of ICP-AES.
We sub-sampled laminated part of the cores i.e. where there wasn’t sedimentary event visible. Thus these samples include all the sedimentary layers that characterize the laminated or background facies.
The ICP-AES measurements were made initially for lead quantification (the question was: is the archaeological settlements were associated with lead signal?) – Results were negative, we didn’t detect lead signal: sediment present lead concentration below the level of detection even with high resolution ICP measurements. Then, we used the results of the ICP-AES to propose quantified elementary signal for the background sedimentation.

The procedure followed to count laminae is not explained in methods.
We didn’t counted the laminae, this is not the aim of this paper. This aspect will be also detailed in another publication in preparation (Wirth S.B., Gilli A., Simonneau A., Ariztegui D., Vannière B., Glur L., Chapron E., Magny M. & Anselmetti F.S., Seasonality of floods in Northern Italy during the past 2100 years: Interplay of solar forcing, variations in NAO, and ENSO influence), yet available in the Stefanie Wirth’s PhD thesis: Wirth S.B. (2012) “The Holocene flood history of the Central Alps reconstructed from lacustrine sediments: Frequency, intensity and controlling climate factors”, Chapter 4. Dissertation ETH No. 20860, ETH Zurich, Zurich, Switzerland.

Results

Fig. 3: I don't understand the differences among "auto" and "naked-eye" differences in the construction of the age model. Please, improve figure caption with more clear explanation.
We complete the figure caption's with this sentence: "*For detailed explanation of both sedimentary events counting methods see section 3.3.*"

Line 15 in page 4713: the comparison among "auto" and "naked-eye" counting methods is not clear to me in Figure 5. Specially, for core LL08-2 differences in both methods seem pretty important.
We complete the text with this sentence: "*However, the mean results obtained from both cores and methods show only thin grey-bands of uncertainty and the box-plot illustrate similar distribution of values (Figure 5 & Table 2), which indicates the low amount of variability in the signals obtained from the two cores.*"

Discussion
Figure 6: consider to add marks for the four time periods considered in the text
Grey band are already draw on the figure to show the time periods considered in the text.
Some grey bands have been added to figure 5.

Line 26, page 4717. Should be read 20th century (not 19th).
Correction has been done.

Line 26-28, page 4717 (last paragraph of 4.2 section). The most recent part of the record was not used for paleoenvironmental reconstruction due to the presence of a slump. Add this fact.
The slump is not the problem, we have remove it from the sedimentary record studied. To better explain, we complete as follow: " *In the 20th century, the sedimentation appears strongly modified by the human control: hydropower production since 1929 AD can modify the temperature of the water column and prevent from hyperpycnal flood occurrences and/ or recent human infrastructure on river corrections in the catchment area have reduce the impact of flash-flood events on lacustrine environments; consequently, the record cannot be used for palaeoenvironmental reconstruction.*"

Figure 8 is cited before Figure 7
Change has been done.

Lines 9-13, page 4720: incomplete sentence.
We corrected the text as follow: "*Hoffmann et al. (2008; Figure 7) show from the compilation of a database of 506 fluvial ^{14}C ages from Germany that, after 4500-4000 cal BP, the increased soil erosion is at least partially due to the Bronze Age growing population and intensive agricultural activities and cannot be unequivocally attributed to climate*."