Reply to specific comments of Referee Michi Strasser, MARUM, Univ. Bremen,

We thank Michi Strasser (Marum, Bremen University) for his helpful and constructive review. Five main points were raised, which are addressed point for point in the following. In addition we followed all technical corrections and stated how we react on the comments.

Comment #1: Quantification/Discussion of uncertainties in lake level reconstruction

First of all we corrected and unified all depth values given for lake levels below present water level to 60 m and 35 m, respectively.

The referee was wondering about uncertainties of our reconstruction and also requested a more detailed discussion about other factors that could have influenced lake level fluctuations within Lake Ohrid. He further asked about other regions within Lake Ohrid where evidences for a lake level change are still present today and can possibly confirm our findings from Ohrid Bay area.

To answer the first part of the question we added a paragraph within the "Paleoenvironmental reconstruction" chapter that evaluates whether subsidence (tectonically induced by the active graben or by sediment load) could have alter the value for the present position of seismic reflections and Lithofacies that we identified and used for our reconstruction in Ohrid Bay. In short we can exclude any subsidence because we choose Ohrid Bay as an area that only experienced little long term subsidence due to its tectonic setting as a hinged margin (see discussion in revised paper). Subsidence caused by sediment load can be negligible because the amount of sediment, size of the margin, and time span are just too small to have an effect that is measurable with our methods.

In a second step we took a look to the northern and southern area where one would expect delta structures that could also be used for lake level reconstruction. Although we can find a deltaic structure in the southern area offshore where the river Cerava enters the lake, it is tectonically altered. Furthermore only a few seismic lines are available and no core data that would allow a detailed analysis of lake level reconstruction in that area. In the north problems that anticipate lake level reconstructions are different. First of all there is no river entering the lake hence sediment input is probably too small to form terraces by prograding sediment deposition. Widespread mass movement events are the more serious problem in the northern part. Downslope transportof reworked sediments leads to a loss of important seismic stratigraphic information.

<u>Paragraph added to the manuscript:</u>

"By now we have shown that our data can be used to reconstruct paleoenvironmental conditions in Lake Ohrid since the penultimate glacial period. In the next paragraph we want to discuss what other factors could influence our findings and show why the area at Ohrid Bay is the only area in Lake Ohrid suitable to investigate lake level fluctuations. Ohrid Bay is comparable to a hinged margin setting that comprises deposition of sediments on the opposing side of an active margin. Within the eastern major boundary fault complex the broad and gently dipping margin offshore Ohrid Bay is comparable to a relay ramp forming a linkage of two segments between overlapping faults (Gawthorpe and Leeder, 2000). Sedimentation on hinged margin is more sensitive to slight changes in lake level and wind or current driven suspension, and hence depositional sequences are characterized by more profound unconformities than at the base of escarpment margins (Cohen, 2003). Although the major boundary fault is a focal area for sediment accumulation due to its highest long-term rate of subsidence, it is rather difficult to correlate depositional sequences in between individual sub-basins within this

complex fault zone. The basement at Ohrid Bay, in contrast, was created well before the oldest sampled sediments were deposited. In addition we do not observe active faults within our sediment echosounder profiles. We are aware that we did not include subsidence caused by sediment load due to compaction processes because numbers given in literature are average values for higher dimensional margins with sediment thicknesses of several hundred meters over time spans not less than 1 Myr. Therefore the effect of subsidence in Ohrid bay is negligible.

Our detailed survey by means of echosounder profiling and bathymetric mapping of almost the entire lake floor revealed that Ohrid Bay is the only area suitable for investigating lake level fluctuations. One would assume that such deltaic structure as observed offshore the City of Ohrid could also be found in the northern shore area or offshore Sveti Naum where the river Cerava enters the lake. The latter area shows a huge delta structure but unfortunately it is altered by tectonic forces anticipating an interpretation in terms of lake level fluctuations. In addition, no core information is available for this part of the lake, which is essential to date prominent reflectors in the sediment echosounder data. The northern area on the other hand is not suitable for two reasons. No river enters Lake Ohrid in that area hence there is a lack of depositional material. More importantly, this area has experienced several events of mass movement resulting in a downward transport of reworked material and hence the loss of useful stratigraphic information. "

Comment #2: Interpretation of seismic unit G / Lithofacies II and the concept of sequence stratigraphy

The referee was challenging our interpretation of seismic unit G on both terraces. It is obvious that Lithofacies II on the lower terrace is 120 cm thicker than on the upper one. Additional we have identified two more tephra layers within Lithofacies II (core 1201, lower terrace). Another difference is that chara fragments on the upper terrace are more intact than on the lower one. Hence we evolved our reconstruction a bit more on the period MIS 4, 3, and 2 as suggested by the referee and even included two additional lake level stages within that period. At the beginning of MIS 4, 3, and 2 Lake level covered only the lower terrace because tephra X5, and c-20 are missing on the upper terrace but no exact depth can be given. Later on the water level must have risen again because tephra layer CI/Y-5 is found on both terraces. We also adapted figure 8 and included two additional steps.

Paragraph added to the manuscript:

"Lithofacies II has been identified in both cores but with slight differences in composition indicating that time and depth of deposition slightly changed. In core 1201 on the lower terrace the chara fragments were less abundant and intact pointing to higher energy regime during deposition. Furthermore the finely dispersed OM and $CaCO_3$ was less than in Lithofacies II of core 1200. Our interpretation is that the water level at the beginning of the last glacial period (MIS 4, 3, and 2) was about 30 m or less so that sediment got deposited mostly on the lower terrace. Broken fragments within Lithofacies II of core 1201 indicate a transport of material from the upper terrace before final deposition. At the end of the last glacial period the water level must have risen and finally covered also the upper terrace what also explain that we found intact chara fragments within core CO1200. Another indication for a lake level rise within the last glacial period is the difference in thickness and age between the cores within the same Lithofacies. In core 1201 (lower terrace) Lithofacies II is 120 cm thicker and comprises two additional ash layers (C-20, X-5) that could be dated to 80 ka and 105ka, respectively beside CI/Y-5-tephra that was also identified in core 1200 (upper terrace)."

Comment #3: Seismic stratigraphy vs Lithostratigraphy (Basin-to-Ohrid Bay correlation)

It was not clear to the referee how we defined and correlated our seismic units especially within the southern area to Lithofacies within Ohrid Bay. To make it clear for all reader we included a chapter in the method part explaining how we defined our seismic units (from A-oldest to H-youngest) starting in the southern area with sediments that overly the basement to sequences in Ohrid Bay that only show the most recent depositions. Whereas a direct correlation of cores within Ohrid Bay with sediment echosounder data was possible it was impossible to trace reflections from the Ohrid Bay into the southern area. Hence we used an additional core in greater water depth comprising similar Lithofacies as identified in Ohrid Bay. These Lithofacies could be assigned to seismic reflections that cross the core location and afterwards they could be traced through the central basin into the southern area.

Paragraph added to the manuscript:

New chapter was added in the method part:

"Seismic stratigraphy and Corelation with cores

In total we defined 8 seismic units named from A (oldest unit overlying the basement) to H (most recent deposition only found in Ohrid Bay). Seismic sequences identified within the sediment echosounder profiles in Ohrid Bay could be directly assigned to Lithofacies described in cores CO1200 and CO1201. A major fault at the southwestern end of Ohrid Bay anticipated a direct tracing of prominent reflections within the sediment echosounder data in Ohrid Bay through the central basin into the southern area. For that reason we used additional lithological data available from CO1202 (Vogel et al., 2010) below this fault in a water depth of 145m comprising the same Lithofacies as found in CO1200 and CO1201 of this study. This approach allowed correlating seismic signals observed in Ohrid Bay into the deeper part of the lake."

Comment #4: Subaqueous springs and lake level fluctuations:

The referee was confused about position and data given for subaqueous springs within Lake Ohrid area. Subaqueous springs are only described in some literatures but actual depths are missing. Hence we revised the chapter introducing subaqueous and subsurface springs into Lake Ohrid. We also adapted figure 2 and 9 with respect to these springs described in the introduction part. For our lake level reconstruction and the discussion of its influence to the biodiversity only one area is of major importance. Albrecht and Wilke (2008) described punctuated endemism (species that have only be found in that restricted area) and coexisting water that enters the lake in form of an subaqueous spring into Lake Ohrid at Veli Dab (see figure 9 for position). Hence we changed our discussion and now focus on this area in order to discuss lake level fluctuations and their influence on areas with subaqueous springs and punctuated endemism (see revised paper).

Paragraphs added to the manuscript:

Introduction part:

"Karst aquifers, charged from precipitation on the surrounding mountain ranges and from its sister Lake Prespa, enter Lake Ohrid as sub-aquatic springs (~49%) in water depth up to 150 m (Matzinger et al., 2006, Albrecht and Wilke, 2008, Matter et al., 2010,) and as surface springs (51%, Fig. 2,

Albrecht and Wilke, 2008). Four main areas of such sub-aquatic springs have been described so far: Kalista, Elesec, Veli Dab, and Sveti Naum (Albrecht and Wilke, 2008, Matter et al., 2010, Fig. 2). Surface springs can be found within the spring lake at Sveti Naum Monastry and sister spring complex Zagorican/Tushemist and some minor in the northern area of Lake Ohrid (Popovska and Bonacchi, 2007, Albrecht and Wilke, 2008, Fig. 2). In addition to karstic inflows, water enters Lake Ohrid by rivers and direct precipitation (Matzinger et al., 2006). At present, the Sateska and Cerava Rivers are the main riverine inflows to Lake Ohrid. Water leaves Lake Ohrid through the River Crn Drim (~60%) and by evaporation (~40%, Matzinger et al., 2006, Fig. 2). No significant riverine inlets are found in close proximity to Ohrid Bay."

Discussion part:

"The effect on the coastlines for the significant lake level fluctuations since the penultimate glacial period is illustrated in figure 9. Reconstruction of these ancient coastlines shows that only relatively small areas are affected by a 60 m drop in lake level. However, these areas are important for the endemism in Lake Ohrid (Albrecht and Wilke, 2008). For example, species have been identified as being endemic to the area around the sub-aquatic spring of Veli Dab (Fig. 9, Albrecht and Wilke, 2008). A minor drop in lake level probably results in a desiccation of this area and destruction of the habitat. On the other hand the initial drowning of that area can possibly be linked to the time where the punctuated endemism evolved. Although it is highly speculative it shows that lake level fluctuations can have an influence on the biodiversity within Lake Ohrid."

Comment #5: Non-unique interpretation of Lithofacies III

This comment also refers to another short comment of Jens Holtvoeth who challenged our interpretation that the last interglacial period was warm and dry. We studied a paper of Lezine (2010) as suggested by Jens Holtvoeth and found that he suggested a humid climate with expanded tree cover and soil stability in the surrounding mountains of Lake Ohrid. Therefore we modified our interpretation:

"The high amount of authigenic carbonate and the absence of clastic material within Lithofacies III indicate a warm climate and also support humid conditions favoring Mediterranean tree cover and related soil stability in the surrounding mountains as suggested by Lezine et al. (2010). Warm climate conditions during the last interglacial period are reported from to other paleoclimate records (Tzedakis et al., 2003; Martrat et al., 2004; Allen and Huntley 2009; Vogel et al., 2010a)."

Technical corrections: ***(corrections made are in italic)***
Page 3652
Line 2: steep-sided - *changed*
Line 6: ….at ca. 32 and 55m water depth - *changed*
Line 8: Define abbreviation when used for the first time (MIS = marine isotope stage) - *done*
Line 11: "shallower areas": it is not clear to me to what "shallower" is referring to here? – *changed in: in areas with shallower water depth*
Line 13: ….clearly image several…… - *changed*
Line 16: water-filled body - *changed*
Page 3653
Line 10: climate-sensitive - *changed*
Line 14: Matzinger et al., 2007 is missing in the reference list - *included*
Line 19: climate-related - *changed*
Line 25: (Martens, 1997) - *changed*
Page 3654

Line 14: erosional surface of TST? (see specific comment #2) – *As the term transgressive system tract is not used in this manuscript I deleted the sentence completed*
Line 21: organogenic vs. organic (check!) - *we changed the word to "organic"*

Page 3655
Line 4: consider providing approximate depth estimation for BG-readers not familiar with TWT – *at this point the reader has to accept just to get the abbreviation, later I convert TWT in depth by giving an example of sedimentation rate and so on, so I think at the end of the manuscript this is clear to everyone.*
Line 24: precipitation in the surrounding mountain ranges - *changed*
Page 3658
Line 4: Check TOca! If correct define abbreviation – *we corrected the typing error*
Line 17: depth ranges given in text are not the same as depth ranges given in table 2! Make sure this is consistent
Page 3659
Line 2: depth range given in text is not the same as depth range given in table 2! Make sure this is consistent
Line 4: ICP: define abbreviation when used for the first time - *done*
Line 17: ZAF correction: define abbreviation when used for the first time - *done*
Line 24: 15 m water depth - *changed*
Line 25: …in an east-west direction, data? show a second….. – *seismic data included*
Page 3660
Line 12-13: "The distribution of macrophytes in littoral areas of Ohrid Bay is traceable by side scan sonar data." How? I cannot see anything particular in the Side Scan Sonar data shown in Figure 3. Or is it the patchy appearance indicating some low backscatter areas on the upper terrace? It´s hard to see on the figure. Please considering changing contrast of the image to highlight this observation. – *it is highlighted on the picture….*
Line 16: "The net of seismic lines" should be "the grid of seismic lines" - *changed*
Line 18: Add space between 100 m – *this was a problem in editing, I will check while proof reading the manuscript.*
Line 22: At this stage, it is not clear how seismic units where defined (e.g. here it starts with seismic unit E) – see specific comment # 3 – *see reply to comment #3*
I changed all reflectors in reflections
Line 23: reflector should be reflection
Line 24: …and a toplap surface as upper boundary - *changed*
Line 27: missing word?: Sub-unit E2, characterized (or similar?) by prograding clinoforms with…… - *Sub-unit E2 forming a prograding clinoform with medium amplitude reflections (Fig. 4) is stacked on top of sub-unit E1.*
Page 3661
Line 3: dipping in which direction? E.g. ….indicate slightly basinward-dipping strata? - *changed*
Line 8: lakeshore should be paleo-lakeshore in order not to confuse readers, shouldn´t it? – *here the present lakeshore was ment*
Line 9: A prominent horizon (prominent in respect of what? A high-amplitude refelction?) – *changed in high amplitude horizon*
Line 13-15: Sentence? missing words? The cores recovered…..are 2.63 and 5.97 m long? - *The cores recovered from the terraces in Ohrid Bay, measured after correlation by lithological core descriptions and XRF data and of individual core segments 2.63m (Co1200) and 5.97m (Co1201), respectively*
Line 28: Fig. 2 should be Fig. 6 and or table 2: - *changed*
Page 3662
Line 5: (remove "to") This indicates …insufficient bleaching…..or post-sedimentary - *done*
Line 14: mollusk shells or their fragments - *done*
Line 4 (OM) define abbreviation when used for the first time - *was defined here already*
Page 3663
Line 13: what is OT0700-1? Here and also later in the text? Sample numbers? How defined? Or thephra-chronology? – *some remarks included*
Page 3664

Line 11: …..Lake Ohrid reflecting significant…..or …..Lake Ohrid that reflect significant….. – *I chose the first one*
Line 12: reflectors should be reflections
Line 14: reflectors should be reflections
Line 14: …each wedge that are numbered as 1 to 5 - *changed*
Line 17: reflections-bounding clinoform structures - *changed*
Line 21: reflectors should be reflections
Line 22: reflectors should be reflections
Line 23: reflectors should be reflections
Page 3665
Line 1: reflectors should be reflections
Line 7-8: "bottomset of the lower terrace assigned to Lithofacies IV (Vogel et al., 2010b)"
This is confusing, and I suggest rephrasing (see specific comment #3 above) – *see reply to comment #3*
Page 3666
Line 1-2: "….clastic material, …..,along with relative large and in combination of the width of the lower terrace, implies……."
Meaning of the sentences? Is there (along with relative large…?) a part missing? - c*hanged to Sentence should read as followed: High amounts of coarse silt to sand-sized clastic material in Lithofacies IV in combination with the width of the lower terrace, implies sedimentation close to a river mouth over a significant time span.*

Line 3: "..close to a river mouth" is it that you infer the lower terrace to have formed in a deltaenvironment? –

If yes, why not say so? – *it is just another way of saying it.*
Line 12: Galicica Mountains: not shown on Fig.2. consider indicating it in the upper right corner of the figure. – *figure has been adapted*
Line 20: Table 1 should be Table 3 - changed
Page 3667
Line 7: reflectors should be reflections
Page 3668
Line 6: Based on the superposition of HST 7 on top of…….. - *changed*
Line 22: Looking at Figure 9, the springs discussed in the text appear to me to be above today´s – lake level. Is this correct? If so, I do not understand the relationship between springs and lake level fluctuation between 0 and -60m? (see specific comment #4 above) *I revised all I said about the springs and adapted the figure accordingly, see reply to comment #4*
Pages 3672 – 3677 References:
Matzinger et al., 2007 (cited in page 3653, Line 14) is missing in the reference list - *added*
Reference Watzin et al., 2002 as listed in the reference list is not cited in the manuscript - *excluded*
Page 3678:
Table 1: 1954 AD: I think to remember that the reference datum for radiocarbon dating is set to 1950 AD?. Therefore, I wonder about the given age of 1954 AD. Please check? - *As written in the text the sample mentioned in table 1 is likely to be contaminated with modern 14C. Samples containing this modern 14C are according to the Leibniz AMS facilities at Kiel University per definition younger than1954.*
Page 3679:
Table 2: Please indicate: What is burial depth? How was it calculated and what is the reference depth?
Please indicate abbreviation De and Do
Page 3680:
Table 3: The term LGM is very confusing, because, in fact, Lithofacies II may actually cover the whole last glacial period (MIS 4-2) in core Co1201. Also, please check interpretation of systems tracts from seismic Unit G (see specific comment # 2) – *see reply to comment #2*

Page 3682:
Figure 2: Consider labeling “Ohrid Bay” on the figure – *we labeled both study sites with 1 and 2 another labeling of Ohrid Bay is therefore not necessary*
The gray line indicating the boundary between Macedonia and Albania is hard to see, consider changing line style or color. – *I changed it to yellow and made it thicker*
Figure Caption, Line 2: …can be divided into six morphological sections - *changed*
Figure Caption, Line 4-5: Red dashed line indicated the two study areas – *no change needed*
Page 3683:
Figure 3: indicated patches of macrophytes are not visible? (see also technical comment to Page 3660 Line 12-13) – *the term with an arrow is on the image*
Figure Caption: The second last sentence “An outline of …….” is redundant and can be deleted - changed
Page 3684:
Figure 4b: “evidence for subaerial location” should be “evidence for subaerial exposure” – *figure adapted*
Figure 4c: Please indicate meaning of the two colored lines (blue and red) in the figure caption – *I explained the colors in the caption*
Page 3685:
Figure 5: Check labeling of radiocarbon ages! Shouldn´t it be cal yr BP?
The term “dropstone” in the figure legend is misleading because it may be misunderstood as ice-rafted debris
Page 3686:
Figure 6: Check labling of radiocarbon ages! Shouldn´t it be cal yr BP?
The term “dropstone” in the figure legend is misleading because it may be misunderstood as ice-rafted debris
In this case cal yr BP would be misleading since it only applies to radiocarbon ages but not to tephra (Ar/Ar, K/Ar), ESR and IRSL ages. The figure caption faces this issue by stating that 14C ages are calibrated 14C ages. The term „dropstone“ is not restricted to marine environments and used here since we believe that coarse grained gravel is transported by ice floes from the shore to deeper parts of the basin.
Page 3687:
Figure Caption, Line 4: ….evolution with a stepwise lake level rise since….. - *changed*
Please indicate meaning of the two colored lines (blue and red) in the figure caption – *I gave the same explanation for the colors as for figure 4*
Page 3688:
Figure 8: Consider showing an additional sketch illustrating lake level conditions during the early phase of the last glacial period (see specific comment #2 above) – *I adapted the figure 8 as well as the text, see reply to comment #2*