Response to referees of "Mass movement deposits in the 3.6 Ma sediment record of Lake El'gygytgyn, Far East Russian Arctic: classification, distribution and preliminary interpretation"

Referee #1

This paper described mass movement deposits in Lake El'gygytgyn. The different facies are well described, the interpretation is sound, but the paper is too descriptive and is missing some creativity to make it a great paper. As such, I recommend the moderate to major revision described below to improve the paper considerably by pushing it to another level. My main point is that while the paper present interesting and sound transport mechanisms and deposits, it currently lacks the determination of the trigger mechanisms (changes in sedimentation rates, lake level fluctuations, etc.) of the different units. Discussing the trigger mechanisms of the different events would make it a much stronger and valuable paper, not to mention that an impressive paleoclimatic dataset is being developed as part of this project.

We have added a chapter (5.2) where we discuss possible triggering mechanisms. Unfortunately, this chapter could be written only in a general sense, since we have very limited data for inferring possible triggers.

For example, the authors could try to find links with changes in climate, sedimentation rates, lake level fluctuations, permafrost thawing?, etc. – all the possible agents affecting slope stability. Such links would also complement the other papers in the special issue. Below are a few ideas as a starting point:

1) Make some statistics. For example, look at the frequency of the various events vs. time, thickness of the various events vs. time, etc.. Treat the events as a type (turbidite, debris flow, etc.) or as a whole. Look at the papers by Blumberg et al. (2008) or Maslin et al. (2004) for example.

2) Make graphs of downcore variations (and/or some frequency graphs) vs. age for the whole period and/or for the different periods discussed in the text and compare these graphs with:
-changes in sedimentation rates -a proxy of precipitation -a proxy of temperature -a proxy of permafrost thawing ? -a proxy of lake level changes -the Northern Hemisphere 18O record - etc.

We have compared the frequency of individual types of MM vs. age and included a graph (Fig. 9) showing the distribution and thickness of various MMD types versus time. In the graph, we compare it also to the sedimentation rate and the LR04 stack. Unfortunately, we only have incomplete information concerning changes in precipitation and temperature, based upon a transfer function on pollen assemblages in the Pliocene but only a small part of the Quaternary part of the record, and no data for permafrost thawing. Additionally, there is only very limited information of the past lake level changes. The majority of the known past lake levels are higher compared to the present lake level and the oldest terrace (+40m) has an approximate age of MIS 7.

Referee #2

Overall Quality of the Paper

Sauerbrey et al. present this very nice paper in Climate of the Past Discussions that provides a detailed description and chronology of mass flow deposits in the 3.6 million year core record from Lake El'gygytgyn. I've followed the progress of this project and have seen several of the recently published papers from the Lake E drilling project and this current paper gives a context for the paleoclimate record with details on the complete sedimentation history in the basin. The authors provide a good background section and then give detailed description of the five mass movement deposits types that occur in the pilot and longer drill cores. In this section the details of the sedimentology of each of the MDD types are defined by a graphic with high resolution core scan photographs, and magnetic susceptibility and GRAPE density determined from Geotek MSCL analysis. The text provides a detailed description for each of the MDD facies. This section is a valuable contribution in a general sense, providing paleoclimatologists who are working with marine and lacustrine sediment cores with a protocol for assessing the amount and role of mass flow deposits in the sedimentary records. The remainder of the paper details the occurrence of the various facies through the Pliocene and Pleistocene in terms of their percentage of occurrence through time in terms of numbers of events and thickness in the overall sediment record.

Specific Comments:
p. 472 How do lake level changes influence sedimentation pattern? On the one hand, raising lake level, as you've indicated in the text opens up channels that are occasionally blocked and allow sediment transport to the lake. On the other hand, during low stands, rivers and waves can rework coarser grained shoreline deposits. I would suspect that direct correlation involving determination of terrace age and core level would be needed to properly assess this question.

> *We discuss the influence of lake-level changes in a new chapter about the possible triggering mechanisms (5.2.). At this stage, a direct correlation of past terraces, whose ages are not very well known, and sediment core is not possible but we hope to address this issue in a later paper.*

Although it's obvious from previous papers (esp. Melles et al., 2012 in Science) that the Holocene record is short, can you at least state what's going on in the current interglacial as far as MMD's? In the more near-shore cores, where there is a higher sedimentation rate, is there more evidence that is not apparent in more distal sites?
In the text it's mentioned that the recurrence interval for MMD's is something like 11.7k in the late Pleistocene but not sure there is mention of the Holocene.

> *We have added a few sentences concerning the Holocene part of the record. This part of the record, recovered within the scope of the site survey, was already investigated for MMDs in detail by Juschus et al. (2009). They identified two turbidites during the Holocene, which have occurred ca 1 ka apart, while during the rest of the Holocene no events have taken place. Juschus et al. (2009) additionally investigated the association of the Holocene turbidites in the central lake with MMDs in the near-shore area of Lake E.*

The paper is overall excellent but it mostly finishes with a list of the numbers and thickness and thickness percentages through time without addressing potential causes.
What triggers the movement of the sediment?
Is the region sensitive and the sediment in the basin responsive to earthquakes?
Is the main cause of the flows an instability of the sediment pile along the lake shelf-floor transition?
If so, do these periods relate to periods of higher sedimentation during warmer periods?

Can this be determined or are the sedimentation rates based on the current age model too coarse to address this question?

We have addressed these questions in the revised version of the MS, where we have added a section (5.2) about possible triggering mechanisms.

Technical corrections

1. I would suggest using the word while instead of whilst where it appears in the text and figure captions.

We have replaced the word 'whilst' with 'while' in the text as well as in the figure captions.

2. I also suggest using overlying rather than overlaying.

Corrected.

3. P. 471 line 21-22 insert "during the snow-free summer season"

Inserted.

4. P. 472 line 4 Perhaps "highlands" is a more appropriate word choice for 50m to 450m "mountains".

'Mountains' changed to 'highlands'.

5. P. 472 line 29 I suggest using "number of inlet streams" than "amount of inlet streams"

Changed.

6. P. 473 line 5 Replace "It is concentrated" with "Sediment transport is concentrated..."

Changed.

7. P. 473 line 25 replace "It is characterized..." by "Facies B is characterized..."

Changed.

8. P. 477 line 5 Relace "even tough..." with "Even though..."

Corrected to 'Even though'.

9. P. 477 Line 21 Delete comma after areas

Comma deleted.

10. P.478 line 26 insert bent instead of bended

Changed.

11. P. 481, line 15, comma after the word advance,

Added.

12. P. 486 line 12. Is this supposed to be “warm to exceptionally warm”?

Yes, corrected to ‘exceptionally warm’.

13. P. 489 line 6 I would suggest “greater water depths” rather than higher water depths.

We follow the suggestion and changed the text to ‘higher relief of the impact crater and greater water depth’.

All the figures are appropriate and in good shape. In the captions, the words whilst, overlaying and bended can be replaced with while, overlying and bent respectively.

These words were replaced as suggested.

The only other comment that in its original size., Figure 8 is impossible to read. In a pdf online you need to zoom to 300% and then it’s good. If this works for the journal then it’s ok!

The figure is planned to be printed on two full journal pages in the final paper, much larger than in the CPD version, making it fully readable.

Referee #3
M.A. Sauerbrey et al.

General comments

The manuscript addresses a very interesting and important theme. It describes mass flow deposits, their classification and occurrence during the amazingly, 3.6 Ma long, continuous record of El’gygytgyn. Disastrous events, triggered by earthquakes, such as historic devastating quakes within the Hellenic Arc or the 2011- Tohoku tremor offshore Sendai ask for a better understanding on formation, geometry and systematics of mass flow deposits. This paper could contribute well to fill these gaps in knowledge. It is clearly organized and most of the figures are understandingly plotted and needed. Nevertheless, the ms needs modifications and adjustments to improve its significance and readability. In its present form the paper is too ‘texty’ and descriptive. Introduction of tables would enhance readability and understandability. The somewhat lengthy description and classification of litho-types seem to be valid just in proximity to the coring sites. There is little discussion on the development of individual MMDs from a proximal to their distal location. This would improve the plain description of MMDs, with a generic interpretation of a proximal debrite, progressing into a distal turbidite. The descriptive text and the conceptual model of fig 7 should in more details elaborate on the erosional power (and re-deposition of sediments) of different MMs within the lake. The recently published paper of Talling et al. 2012 could be a perfect base for the interpretation/classification of depo-types of turbulent density flows. Pros and cons of complete and incomplete Bouma-cycles should be used in the ms for a less general interpretation of El’gygytgyn MMDs and their comparison to BOUMA-sequences.
A major shortcoming of the ms is the absence of results of grain size measurements. Although magnetic susceptibility and GRAPE density of the different litho-types are adequately presented in well drawn figures, a comprehensive classification would need specific data on

grain sizes. Figure 8 cannot be read and should be deleted.

As already mentioned for review 2, we added text for the development of the MMDs in the lake center based on debris flows at the lake slope, based upon the work carried out by Juschus et al. (2009) on the Holocene MMDs.
We compare Lake El'gygytgyn turbidites to the classification of Talling et al. (2012) and also shortly note how lacustrine turbidites differ from their marine counterparts.
Figure 8 is not deleted, since it is readable when published as a full-page figure. This figure is regarded as indispensable, because it provides a visualization of all MMDs identified, and thus is of great importance for all scientists working on the record.

Detailed comments
p. 467 shorten title to 'Mass movement deposits in the 3.6 Ma sediment record of Lake El'gygygygyn'

We shortened the title as suggested.

p. 469 line 9; add reference on flat basin plain deposits: Sturm & Matter 1978

Added.

line 14; MMD may also be used for correlation of different cores within a basin

We've added this

line 19; add reference on flood- /slide-induced deposits: Blass et al. 2005

Added

line 26; exchange 'widely' by 'generally'

Changed

line 29; Brigham-Grette et al. 2013? or 2012? as in reference list

The correct year of this reference is 2013. This has been corrected in the text and reference list.

p. 470 lines 20-29; avoid introduction of an additional term ('densite'), which is not used anymore

Changed to 'grain flow deposit'.

p. 471 line 18; '. . .wide and broad. . .'⇐what??

We rephrased the sentence to 'The most prominent feature of the catchment area of 293 km^2 (lake 110 km^2) is an alluvial plain in the west and north that consists of multiple fans.'

line 22; what is '. . .widely narrow and shallow. . .'?

The sentence was rephrased to 'Characteristic to the lake is its shallow shelf (< 10 m) that is mostly < 100 m wide, with the exception of the southern and southeastern part of the lake, where it widens to ~ 1 km.'

p. 472 line 27; '. . .and aeolian transport as well as by gravitative. . .'

Changed.

p. 473 lines 15ff; clarify understanding by using a table for facies description and percentages

Showing facies percentages in the Pliocene part of the record, which suffers from poorer recovery, would likely give a false image of the facies distribution, as it is possible that the gaps in recovery are not equally divided between all facies types. Additionally, since some facies occur only in the Pliocene part and not in the Quaternary, showing facies percentages for the Quaternary would be misleading. We refer to Melles et al. (2012) and Brigham-Grette et al. (2013) for more detailed description on various facies types and their distribution in the record.

line 27; Brigham-Grette et al. 2013? or 2012? as in reference list

See answer above.

p. 477 lines 3ff; show evidence for the complete BOUMA-cycle Ta to Te; mostly Tc and Td are missing in lake sediments; see Sturm & Matter 1978

As mentioned above, we have compared the turbidites to the classification by Talling et al. (2012) and noted that sedimentary structures of turbidites in lacustrine environments are often poorly developed and hence Tc is not found at Lake El'gygytgyn.

p. 481 line 10-11; rephrase 'Debris flows are the coarsest sediments. . .'

We rephrased to ‚Debrites are the coarsest sediments...'

line 20; Strachan 2008 not in ref.list

This reference was added to the reference list.

p. 483 lines 20ff; use table to show percentages of MM-events

We have added a table (Table 1) showing a summary of the Quaternary mass movement deposits.

p. 484 line 13; coarser sediments during warmer climate are caused by higher sand content? or by diatom scales?

The slightly coarser sediments deposited during warmer climates are due to coarser clastic input. Coarse silt and very fine silt fractions appear to be dependent on climate (Francke et al. 2013). We specified this statement and have added this note to the revised version.

line 20; use capitals

Corrected.

p. 485 line 3; use capitals

Corrected.

p. 486 line 12; complement sentence '. . .warm to exceptionally ??? climate phases. . .'

Completed to 'exceptionally warm climate phases…'.

lines 22ff; use table to show percentages of MM-events

We have added a table (Table 2) showing a summary of the Pliocene mass movement deposits.

p. 487 line 18; use capitals

Corrected

p. 488 line 15; use capitals

Corrected

p. 489 line 6; 'higher relief of catchment'? 'greater water depth'? ⇐rephrase

We changed the text to 'higher relief of the impact crater and greater water depth'.

p. 490 line 1; 'Deposits of MME have frequently reached the coring site. . .' ⇐rephrase

Rephrased to 'Mass movement deposits have frequently reached the coring site...'.

p. 491 lines 1-2; delete obvious statement; or formulate specific questions, which should be investigated

Statement was deleted.

References

Belyi 2001 not in txt

This reference is used in Fig. 1 caption.

add Blass et al. (p. 469); A. Blass, F.S. Anselmetti, M. Grosjean and M. Sturm. The last 1300 years of environmental history recorded in the sediments of Lake Sils (Engadine, Switzerland), Eclogae geol. Helv. 98 (2005) 319–332.

Added.

Bøe et al. 2004 not in txt

This reference is in on p.469 line 9.

Brigham-Grette et al. 2005 not in txt

This reference is on p.472 line 14.

Brigham- Grette et al. 2012 or 2013 (see txt)

Reference corrected: Brigham-Grette et al. 2013.

Kopsch 2005 not n txt

This reference is used in Fig. 1 caption.

Nowaczyk et al. 2007 not in txt

This reference on p.483 line 14.

Schwamborn et al. 2012 or 2013 (see txt)

The correct reference is Schwamborn et al. 2012 and it was corrected.

add Strachan 2008 to reference list (p. 481); L. J. STRACHAN. Flow transformations in slumps: a case study from the Waitemata Basin, New Zealand. Volume 55, Issue 5, pages 1311–1332, 2008

Added.

add Sturm & Matter 1978 to reference list (pp. 469, 477); Sturm, M. and A. Matter (1978). "Turbidites and Varves in Lake Brienz (Switzerland); deposition of clastic detritus by density currents." Int.Assoc.Sedimentol.Spec.Publ. 2: 147-168.

This reference was already in the reference list.

add Talling et al. 2012 to reference list (p.); PETER J. TALLING, DOUGLAS G. MASSON, ESTHER J. SUM- NER and GIUSEPPE MALGESINI Subaqueous sediment density flows: Depositional processes and deposit types. Sedimentology (2012) 59, 1937–2003

Added.

Figures

Fig. 4; in txt replace ‘co-genetic’ by ‘co-generic’

The referee probably meant Fig. 6 text. We’ve replaced ‚co-genetic’ with’ co-generic’ in Fig. 6 text.

Fig. 8; delete figure, as details of cannot be read

As mentioned above, we do not want to delete this figure, since it is very important to the community working on Lake El’gygytgyn. It will be readable as a full-page figure *in the final paper. In addition, the figure benefits from colors that we have added to make the figure more readable.*