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Climate of the Past Discussions

Interactive comment on "A 500 kyr record of global sea level oscillations in the Gulf of Lion, Mediterranean Sea: new insights into MIS 3 sea level variability" *by* J. Frigola et al.

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We would like to thank Jamie Austin for the helpful and constructive comments and technical corrections provided on our manuscript "Clim. Past Discuss., 7, C2342–C2348, A 500 kyr record of global sea level oscillations in the Gulf of Lion, Mediterranean Sea: new insights into MIS 3 sea level variability". Our comments and answers to J. Austin suggestions follow below.

General comments:

1. The referee states that the main contribution of the manuscript is adding good chronostratigraphic control to sequence stratigraphy of the Gulf of Lion (GoL) continen-

tal margin and for that reason he would like to have seen more tie points between the borehole data and the seismic profiles (this point also relates to specific comment on Figure 2 caption). We can ensure the referee that the seismostratigraphic control of the GoL margin is fairly consistent (indeed, it is probably one of the best in the world), and that the borehole location was selected after examining and correlating a large number of seismic reflection profiles and background information, so that there is no bias by the fact that we show only one seismic reflection profile to illustrate our manuscript. Some relevant theses and papers are cited in the Reference section of our manuscript as part of the above mentioned background information. We think J. Austin is fully aware of this as he has a good knowledge of the area. While improving the chronostratigraphical framework of this margin is an important objective of the manuscript, our main aim is to discuss the paleoceanographic implications of orbital and millennial-scale sea level oscillations on the sedimentary outbuilding of the GoL margin, and vice versa, to elucidate such sea level oscillations from the sediment record. With this purpose in mind, the manuscript focuses on a robust oxygen isotope chronostratigraphy and on borehole records of grain-size and geochemical composition. Grain-size oscillations observed in PRGL1-4 borehole were crucial, together with the oxygen isotopic chronology, to re-define the main seismostratigraphic units through identification of key reflectors corresponding to abrupt changes in the silt/clay ratio record. Visually correlation between seismic reflection profile and borehole data showed in Fig. 2 has the objective of illustrating how the observed changes in grain-size data have a clear expression in terms of seismic reflectors, thus demonstrating the necessity of having this kind of data to improve current understanding of sequence stratigraphy in continental margins. We also have to mention that correlation between seismic reflection profiles and borehole data was the central topic of Jouet (2007) PhD Thesis and are part of a paper already accepted (Jouet et al., accepted). The vertical resolution of the seismic profile is about 1 m with a penetration around 500 ms and correlation of seismic profile with core data is based on a seismic velocity analysis NMO (Jouet, 2007). In addition, it is also unnecessary overlap, and given the main scope of our paper, that we think it wouldn't be appropriate deepening into these aspects, which at the end will represent a deviation of the main target of the paper. In any case, this would correspond to a different paper (e.g., the one by Jouet et al., accepted).

2. The referee thinks that we do not demonstrate with data that the HS sedimentological mechanisms proposed (e.g., DSWC) actually affect silt/clay size distributions and, some lines below, he expresses his doubts about why increases in the silt/clay ratio on the upper slope of the GoL should correspond to a sea level rise, since his instinct tells him that a decease (sic) in distal fluvial input (caused by such a sea-level rise) would lead to a DECREASE in silt-clay ratio (i.e., more clay) at the outer margin location at which the borehole is sited. This is a key-point of the manuscript and we think it is duly addressed in the text. Our results show that a Regressive Progradational Unit (RPU) initiates with an abrupt increase of the silt/clay ratio that, corresponds to a glacial/interglacial transgression, according to the oxygen isotopic chronostratigraphy. Silt/clay ratios during the full interglacial period (HS) are higher than in the following glacial period, which is opposite to what the referee suggests. We may guess that the referee's interpretation could work in narrow shelves where prodeltaic deposits occur close to the shelf break. However, in the modern GoL shelf there is almost no net sedimentation beyond the Rhone prodelta seaward limit (PSL) due to the action of bottom currents (Sierro et al., 2009). The PSL offshore boundary of the Early Rhone Deltaic system was located 40 km from the coast at a water depth of 90 m, while today's one is located at about 7 km from the coastline at a water depth of 30 m. A strong littoral drift transports westwards sediments released at the mouth of the Rhone River. Offshore the PSL the reduced sedimentation rate results in the formation of a Condensed Layer (CL). Our borehole is located in the upper slope at 110 km from the coastline in a depth of 300 m, i.e., far away from the actual PSL. Therefore, the influence of river-derived fines during interglacial HS is much reduced or null and oceanographic processes have stronger influence on sedimentation, as demonstrated by recent works on present-day processes acting in the GoL margin (Canals et al., 2006), which are becoming a reference for other margins too. Consequently, HS periods are characterized

by the formation of CLs as showed by the total (carbonates included) fine sand record of Sierro et al. (2009), which are coincident with high values in our silt/clay ratio. These results also evidence the formation of a CL during present HS, as observed in the upper centimetres of upper slope core MD99-2348 (Sierro et al., 2009 and this study). One further point to be highlighted is that the carbonate-free silt/clay record adds information about the energy of the environment, given that biogenic components have been removed. The silt/clay ratio demonstrates that the supply of coarse particles to the borehole location in the upper slope did not cease during HS. This is why, to explain the observed silt/clay record, we invoke in our manuscript a combined mechanism in which fluvial and oceanographic processes act simultaneously. To make it short, changes in fluvial inputs due to sea level oscillations and subsequent deltaic migration alone do not explain the oscillations observed in the silt/clay ratio, as also pointed by the referee. Other processes are then required to explain the observed results, which are unarguable. Recent investigations on the hidrodynamics of the GoL and the activation of erosive processes on the shelf because of eastern storms and DSWC events gave the most consistent answer to understand how sea level oscillations control, also in the past, the ability of the margin to activate erosion on the continental shelf. Sea level oscillations do that by determining the volume of water stored in the shelf, which is a fundamental parameter regulating the likelihood of DSWC events to occur and the impact in terms of sediment remobilisation of eastern storms and DSWC. The imprint of these high-energy processes in modern sediment transport and accumulation over the slope has been demonstrated consistently, so that there is no reason to think that they did not have similar impacts during older HS (Canals et al., 2006; Dennielou et al., 2009; Gaudin et al., 2006; Heussner et al., 2006; Lastras et al., 2007; Palanques et al., 2006; Pasqual et al., 2010; Sanchez-Vidal et al., 2008, 2012; and many other).

3. The referee asks about the suitability of the Red Sea Level curve used (Rohling et al., 2009) (this point is also related to specific comment on Figure 3 caption). This sea level record has been selected simply because to date it is the best reconstruction of global sea level oscillations for the studied time interval.

4. The referee points that Table 1 is barely mentioned and doubts about its inclusion in the manuscript. We agree about this point and we have decided to eliminate the table since details about the age model are already described in the text.

Specific comments:

1. The description on the use of Ca as an indicator of fluvial discharge of fine-grained sediments has been improved in the text.

2. The referee asks if the new "units" are also bounded by sequence boundaries in all cases. Accordingly to our data, mainly grain-size and oxygen isotopic chronology, the new units could be interpreted as regressive progradational units delimited by sequence boundaries in the upper slope and in the shelf, in all cases. However, in the shelf some of those boundaries are overlapping, which means that some transgressive deposits were totally eroded during younger regressive episodes (Jouet, 2007).

3. The referee asks to quantify the correlation of our silt/clay ratio with the DO cycles since he does not think this is perfect. It also seems that there is a misunderstanding on how DO cycles are shown in Fig. 5. DO cycles are noted in Fig. 5a as numbers for the warm Greenland InterStadials (GIS) and with grey bars for the cold Greenland Stadials (GS) and HE. What we want to express by saying that there is a perfect coupling between sea level variability, as indicated by increases in the silt/clay ratio, and all DO cycles, included the shortest ones is that our silt/clay ratio shows increases for each of the warm GIS during MIS 3. This peak to peak correlation has been visually described and is common to such type of correlations in the way we did, so that we think it is not necessary to quantify them. In any case, we have changed perfect peak to peak coupling by consistent peak to peak coupling to avoid some of the connotations of the term perfect.

4. Figure 1 caption. The referee suggests specifying the sequences/reflectors with their correspondent absolute ages in Table 1. Main reflectors separating RPU are already shown in Fig. 2, where they are marked as the physical expression of

glacial/interglacial transitions of the last 500 ka. And finally, table 1 has been deleted as suggested by the referee.

5. Most of the technical corrections suggested by the reviewer have been applied to the manuscript.

References

Canals, M., Puig, P., de Madron, X. D., Heussner, S., Palanques, A., and Fabres, J.: Flushing submarine canyons, Nature, 444, 354-357, 2006.

Dennielou, B., Jallet, L., Sultan, N., Jouet, G., Giresse, P., Voisset, M., and Berné, B.: Post-glacial persistence of turbiditic activity within the Rhône deep-sea turbidite system (Gulf of Lions, Western Mediterranean): Linking the outer shelf and the basin sedimentary records, Marine Geology, 257, 65–86. 2009.

Gaudin, M., Berné, S., Jouanneau, J.-M., Palanques, A., Puig, P., Mulder, T., Cirac, P., Rabineau, M., and Imbert, P.: Massive sand beds attributed to deposition by dense water cascades in the Bourcart canyon head, Gulf of Lions (northwestern Mediterranean Sea) Marine Geology, 234, 111-128, 2006.

Heussner, S., Durrieu de Madron, X., Calafat, A., Canals, M., Carbonne, J., Delsaut, N., and Saragoni, G.: Spatial and temporal variability of downward particle fluxes on a continental slope: Lessons from an 8-yr experiment in the Gulf of Lions (NW Mediterranean), Marine Geology, 234, 63, 2006.

Jouet, G.: Enregistrements stratigraphiques des cycles climatiques et glacio-eustatiques du Quaternaire terminal-Modélisations de la marge continentale du Golfe du Lion, Laboratoire Environnements Sédimentaires, Géosciences Marines, Ifremer, Brest, France, 443 pp., 2007.

Jouet, G., Berné, S., Sierro, F. J., Bassetti, M. A., Canals, M., Dennielou, B., Flores, J. A., Frigola, J., and Haq, B. U.: Geological imprints of millennial-scale sea-level changes, Terra Nova, accepted, 2012.

Lastras, G., Canals, M., Urgeles, R., Amblas, D., Ivanov, M., Droz, L., Dennielou, B., Fabrés, J., Schoolmeester, T., Akhmetzhanov, A., Orange, D., and García-García, A.: A walk down the Cap de Creus canyon, Northwestern Mediterranean Sea: Recent processes inferred from morphology and sediment bedforms, Marine Geology, 246, 176-192, 2007.

Palanques, A., Durrieu de Madron, X., Puig, P., Fabres, J., Guillen, J., Calafat, A., Canals, M., Heussner, S., and Bonnin, J.: Suspended sediment fluxes and transport processes in the Gulf of Lions submarine canyons. The role of storms and dense water cascading, Marine Geology, 234, 43-61, 2006.

Pasqual, C., Sanchez-Vidal, A., Zúñiga, D., Calafat, A., Canals, M., Durrieu de Madron, X., Puig, P., Heussner, S., Palanques, A., and Delsaut, N.: Flux and composition of settling particles across the continental margin of the Gulf of Lion: the role of dense shelf water cascading, Biogeosciences, 7, 217-231, 2010.

Rohling, E. J., Grant, K., Bolshaw, M., Roberts, A. P., Siddall, M., Hemleben, C., and Kucera, M.: Antarctic temperature and global sea level closely coupled over the past five glacial cycles, Nature Geosci, 2, 500, 2009.

Pont, D., Simonnet, J.P., Walter, A.V., 2002. Medium-term Changes in Suspended Sediment Delivery to the Ocean: Consequences of Catchment Heterogeneity and River Management (Rhône River, France). Estuarine, Coastal and Shelf Science 54, 1-18.

Rohling, E. J., Grant, K., Bolshaw, M., Roberts, A. P., Siddall, M., Hemleben, C., and Kucera, M.: Antarctic temperature and global sea level closely coupled over the past five glacial cycles, Nature Geosci, 2, 500, 2009.

Sanchez-Vidal, A., Pasqual, C., Kerhervé, P., Calafat, A., Heussner, S., Palanques, A., Durrieu de Madron, X., Canals, M., and Puig, P.: Impact of dense shelf water cascading on the transfer of organic matter to the deep western Mediterranean basin, Geophysical Research Letters, 35, doi:10.1029/2007GL032825, 5, 2008.

Sanchez-Vidal, A., Canals, M., Calafat, A.M., Lastras, G., Pedrosa-Pàmies, R., Menéndez, M., Medina, R., Company, J.B., Hereu, B., Romero, J., Alcoverro, T.: Impacts on the deep-sea ecosystem by a severe coastal storm, PLoS ONE, 7 (1), 1-7, 2012.

Sierro, F. J., Andersen, N., Bassetti, M. A., Berné, S., Canals, M., Curtis, J. H., Dennielou, B., Flores, J. A., Frigola, J., Gonzalez-Mora, B., Grimalt, J. O., Hodell, D. A., Jouet, G., Pérez-Folgado, M., and Schneider, R.: Phase relationship between sea level and abrupt climate change, Quaternary Science Reviews, 28, 2867-2881, 2009.

Interactive comment on Clim. Past Discuss., 7, 4401, 2011.