Reply to referee #2

In this study Pastor et al described the early diagenesis of organic matter (OM) in the Rhone prodelta. In situ-measurements and model data were used to understand the burial and mineralization efficiency at different water depths and the relative proportion of oxicvs anoxic mineralization. The paper is well organized and it reads well. Given the implications of this study and the role of river-dominated margins in the global cycling of reactive elements I strongly suggest this paper for publication in Biogeosciences.
On the other hand, I have one major criticism. My concern is mainly focused on the model and on his meaning in this river-dominated margin. Specifically, OMEXDIA was developed and applied in systems whose steady-state nature allowed assumptions concerning both OM origin and sedimentological processes. In stationary conditions, the model generates steady state profiles of several parameters including oxygen, ammonium, nitrate, oxygen demand units organic carbon and particulate carbon. However, sedimentation in the shallow Rhone prodelta is highly episodic and I have hard time to understand how the OC burial, for example, can be assessed in sites characterized by event-deposition. In the open ocean, steady state accumulation rate can be assumed and confirmed by down-core profile of short-lived radionuclides (e.g., Epping et al., 2002, Progress in Oceanography; VanWeering et al., 2002 Progress in Oceanography).
Conversely, a series of geochronologic studies carried out in the Rhone prodelta showed his non-steady accumulation characterized by transient sedimentary signals >10 cm in shallow waters (20-30 m). Thus, how a 10-cm long sediment core can be representative of the burial in this system? Furthermore, despite the episodic supply of sediment, there are well characterized periods when the balance between accumulation and erosion is in favor of the latter (Marion et al. 2010), affecting the down-core profile of particulate OM. Similarly event-beds exhibit contrasting sediment texture, another factor that affects the down-core distribution of reactive OM.
Therefore, I do understand that model assumptions are important for his proper implementation. However, some of these assumptions (such as the steady-state accumulation, no erosion, same sediment texture) do not actually find evidence in the current literature. Other examples include the bioturbation and OM origin. In the model Pastor et al assumed an ubiquitous mixed layer 13 cm thick based on SPI data (Desmalade, oral communication). However, it's hard to believe that the bioturbation just off the Rhone mouth (20 m) is the same as in the deep prodelta (90 m). For example, recently Drexler and Nittrouer (2008) using x-radiographs have grouped the Rhone prodelta in three sub-regions defined as physically stratified (i.e. laminae), partially stratified and bioturbated consistent with the conceptual model (accumulation vs bioturbation) developed by Wheatcroft et al. (2003, Progress in Oceanography). Similarly, the OM reactivity in the model is somehow simplistic accounting for non-reactive (burial), relatively labile, and particularly labile. However, it is well established that OM in marine sediments is extremely heterogeneous and exhibit a wide range of C/N ratios and reactivities that result in the selective preservation during diagenesis.

Reply: As the reviewer underline, when modeling a complex system, assumptions and simplifications have to be made. Some parameters of the model have therefore less influence on the results than others. In this paper, the most important parameters to adjust (i.e. organic matter flux and reactivity, bioturbation and precipitation term…) were based on a set of sensitivity analysis (Soetaert et al, 1996).

Other parameter as the mixed layer depth has very little effect on the modeled results, and thus has been fixed to a unique value of 13 cm to facilitate the later coupling between sediment and water column. Indeed, the measured mixed layer was 13 cm for all the stations except station A where it was less than 5 cm (Desmalades, pers. Com). No change on the modeling results are observed when changing this number. This mixed layer depth represents only the layer in which the bioturbation rate (Db) stay constant and then it decreases below (Berner, 1980; Aller, 1982; Boudreau, 1997). Although the mixed layer depth was constant among the stations, the Db coefficient (bioturbation rates) in the model are, as pointed out by the reviewer, highly variable throughout the stations, with low bioturbation rate at station close to the mouth and higher rates offshore (see also pastor et al 2011, CSR).

3 pools of organic matter is a common feature in early diagenesis modeling. As suggested by the reviewer, integrating more organic matter pools is possible when focusing on the quality of the organic matter (and if the dataset allows to calibrate the model). Nevertheless, Pastor et al (2011) demonstrated that in this area, and for this particular campaign, the dominant input of organic carbon was terrestrial, and that it was difficult to characterize the more labile fractions probably responsible for the consumption of the fast pool of organic matter. In addition, the main goal of this paper was to assess the overall benthic mineralization of the organic matter. Hence, the authors chose to define only 2 pools of degradable organic matter, undoubtedly missing some information about the OM origin but allowing therefore a reasonable budget assessment.

No change in the sediment texture of the downcore sediment has been clearly observed in this study (visual core observation) and porosity profiles were used to account for changes in the sediment pore water content (precisions added in §2.7).

As highlighted by the reviewer, it is clear that accumulation rates are not continuous in time within the prodelta, due to quick deposition and resuspension processes (e.g. flood, storms). Nevertheless, they are so high (20-40 cm/y) that individual layers are quickly buried by other ones, even after large deposition events (cf Cathalot et al 2010). The values used in this work are considered as an average out of major flood events that are responsible for most of the sediment deposition. The values were therefore estimated from literature, originating from 210Pb profiles which give a smooth averaged value (De Madron et al, 2000, 2003, Zuo et al, 1997).

In brief, the authors should do a better job in explaining their assumptions. I definitely think that insights coming from this study are extremely interesting but I strongly suggest the authors to better justify their assumptions making sure that the reader is aware of the dynamic nature of this system. In fact, this is the first time that OMEXDIA was applied in a river-dominated margin and therefore the authors should explicate all their assumptions and relative consequences/interpretations taking into account the peculiarity and sedimentological features of the environment studied.

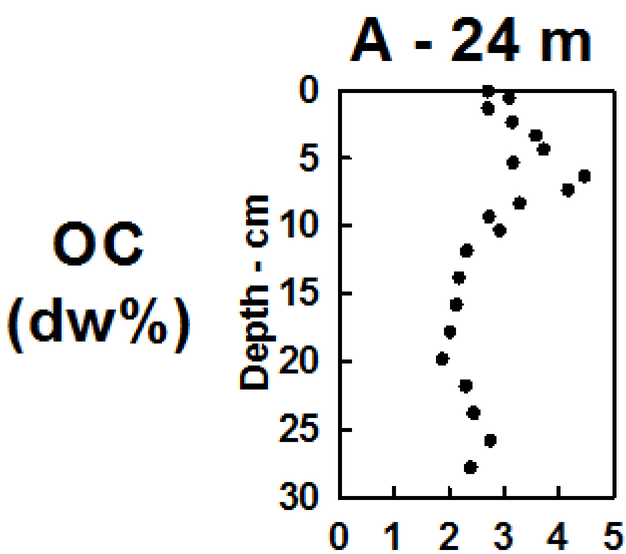
Reply: As suggested by the reviewer, some supplementary information was added at the beginning of the discussion to better explain the dynamic nature of the system and justify the authors' assumptions.

Specific details

- Given the not well constrained asymptotic down core content of OC, wouldn't it be better to come up with several potential scenarios? Maybe some literature research might help to define a series of asymptotic values (at least for a few stations). Burial occurs on long time scales and likely the thicknesses of sediment core collected just off the river mouth corresponds to seasonal deposition. So if nothing can be found for the Rhone prodelta I would suggest using asymptotic values of similar study areas (i.e. prodeltas having comparable mass accumulation rate and OC). I still think that Figure 4 must be shown but it should contain at least a supplementary Figure b that considers other asymptotic values. Would it be possible?

Reply: Concerning the asymptotic OC content, the authors would like to underline that the fit here are shown on 10 cm, but the total modeling work was assessed down to 40 cm depth. The sediment cores were between 20 and 30 cm long, so the downcore OC content used in the model was taken between 20 and 30 cm (see figure below for station A). At station A, the OC profile is highly variable through depth due to deposition events. It is therefore very inlikely that an asymptotic value is ever reached in this kind of station. We then chose to average the downcore value. The same kind of profiles is observed in the amazon delta (Aller et al 1996) down to 8 m depth and the asymptotic OC value has also been roughly averaged (r^2=0.44). In the case of the Rhone River, the burial is largely related to the accumulation rate which varies a lot between cores. Therefore, our estimates represent maximum burial efficiencies. Thus, as pointed out by the reviewer, these burial efficiency values are not absolute and should be used with caution when attempting to assess net OC budget for the area. Nevertheless, we also consider that using values from other deltaic system could be confusing and not particularly relevant given that similar hydrological systems do not have systematically the same biogeochemical status (change in the OM reactivity, bioturbation, bacterial communities…).

Precisions on this matter have been added on §3.3.



- The reader might find useful some formulas throughout the text as in Epping et al., 2002 (Progress in Oceanography). A table with all terms and acronyms used in the text it would be handy. In addition, the authors might consider to display a simple table showing the main pathways of organic matter degradation and reactions (aerobic respiration, denitrification, reoxydation of reduced ions, etc)

Reply: As suggested by the reviewer, one table with the equations used in the model (R1 to R6) and the parameters and constants values were added (new Table 2) to clarify the model description. This is also explain in §2.7.

- The last paragraph is over two pages long and it should be split into two separate sections.

Reply: As suggested by the reviewer, this last section was split in two distinctive sections.

Finally, I recommend the authors to read the following papers before starting the review process:

- Drexler T.M and C.A. Nittrouer. Stratigraphic signatures due to flood deposition near the Rhone River: Gulf of Lions, northwest Mediterranean Sea. Continental Shelf Research 2008

- Miralles J, M. Arnaud, O. Radakovitch, C. Marion, X. Cagnat. Radionuclide deposition in the Rhône River Prodelta (NW Mediterranean sea) in response to the December 2003 extreme flood. Marine Geology 2006

- Marion C., F. Dufois, M.Arnaud, C.Vella. In situ record of sedimentary processes near the Rhone River mouth during winter events (Gulf of Lions, Mediterranean Sea).Continental Shelf Research 2010

Reply: As suggested by the reviewer, these references have been added to the discussion part.