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Interactive comment on "Preservation of terrestrial organic carbon in marine sediments off shore Taiwan: mountain building and atmospheric carbon dioxide sequestration" *by* S.-J. Kao et al.

Anonymous Referee #3

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This manuscript reports organic carbon characteristics in surface sediments offshore of Taiwan that are influenced by hyper- and hypo-pycnal deposition of terrestrial materials emanating from fluvial systems on the island.

The study builds on several prior observations that have revealed extensive export of carbon from Taiwan and other islands of Oceania, particularly when tropical cyclones make landfall and strip vegetation and friable bedrock from the steep catchments. The quantities of organic carbon (OC) discharged to the ocean by these processes, and the nature of their dispersal, via hyperycnal flow during the most intense events when the bloated rivers are loaded with suspended sediment and debris, suggest dramatic and efficient transfer of terrestrial OC to the surrounding ocean. What has remained

less clear is the fate of this material upon entering the ocean. The fate of terrestrial OC discharged under hyper- versus hypo-pycnal also remains particularly uncertain.

The authors show data from sediment traps and cores which provide strong evidence for efficient transfer of terrestrial OC, of both fossil and non-fossil (biospheric OC) origin, to marine sediments in locations adjacent to Taiwan that are impacted by hyperpycnal sediment delivery. Stable carbon and radiocarbon characteristics are used to distinguish between inputs of OC from the terrestrial biosphere and fossil components from erosion of underlying bedrock, as well as to account for marine organic matter contributions to the sediments. The measurements indicate highly efficient transfer and burial of both fossil and non-fossil (i.e., derived from recent vegetation) carbon under hyperpycnal flow. The results also suggest that preservation of terrestrial carbon delivered via more diffuse hypopycnal flow is also efficient (> 70%).

Overall, I think this is an interesting and important contribution, with solid interpretations and significant implications for our understanding of the carbon cycle and geologic controls on terrestrial carbon export and burial in ocean sediments. The results and relationships that are observed strongly support the authors' conclusions of high terrestrial OC burial and high overall OC preservation efficiency in regions influenced by both hyper- and hypo-pycnal sediment supply from Taiwan Island. I hope the following comments and questions will help to further improve what in my view is already a strong contribution.

Units:

The paragraph beginning on line 14 of Page 180 ("The Himalayan orogeny . . .") contains a range of values for the size and flux of materials. The units used to describe these values vary (Tg, Mg, Pg). While I can appreciate that the values change dramatically depending on whether these values relate to reservoir sizes or fluxes of sediment or, I find it a bit confusing to switch between the units. I would propose sticking with one or maximum so the reader can more readily inter-compare between values.

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Gaoping Canyon sediment trap:

- With respect to the 600m sediment trap deployed in the Gaoping Canyon, is it known whether the trap is subject to any trapping biases in particle types as a function of hydrodynamic processes over the trap funnel (e.g.. Buesseler et al 2007 J. Mar. Res. 65 345-416)? Specifically, if there are changes in current velocity (e.g., as a consequence of hyperpycnal flow), this might potentially change trapping efficiency, and could give rise to compositional biases in the materials collected depending on trap geometry and flow velocity.

- The observation that relatively large, mineral-free organic detrital material (woody debris) is included in material intercepted by the trap deployed in the submarine canyon (page 190, line 6) is intriguing given expectations that might be expected to be have a higher bouyancy. It would be helpful to know whether this woody debris was visible to the naked eye or was microscopic in size (i.e., approximate dimensions). The fact that this debris sank to the sediment trap depth implies it must have been water-logged. Given the short residence and transit times of terrestrial materials in the Taiwan watersheds, where might such material reside for sufficient time to become water logged?

- In addition to the water depths of the sediment trap moorings, it would be useful to know the distance above the seafloor that the sediment traps were placed in order to gain an appreciate thick the sediment plume.

POC (and DOC) export & burial:

- In examining the methods followed, I note that sediments were rinsed to remove salts, and also centrifuged after acidification (a typical procedure for sediments). Both of these procedures will remove readily desorbable organic matter. While this may reflect a minor component of the total organic carbon, this is not always necessarily the case (Keil et al 1994 Nature 370 549-552). Given the very rapid transfer of young, fresh carbon from the terrestrial biosphere associated with storm events, it would be interesting to speculate whether this entrains a significant proportion of labile organic

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matter sorbed to the mineral load, and what the fate of this might be under hyperpycnal and hypopycnal flow?

- In the context of the question of loss of, versus replacement of OC, it might have been useful to examine whether there are changes in the organic carbon loadings normalized to mineral surface area (i.e., work by L. Mayer, as well as Hedges & Keil) for sediments deposited under different flow regimes. Did the authors make such measurements?

- In addition, I am curious why nitrogen-to-carbon ratios were not examined given that a sharp contrast is likely to exist between fresh (protein-rich, and nucleic acid-rich) marine organic matter and terrestrial organic matter. Of course, selective degradation processes may modify the N/C ratios of the source materials but given the short transit times and rapid burial processes that appear to be occurring these effects may be minimal and such measurements may have provided additional constraints on inputs.

Carbon dynamics during storm events:

Although this is mostly beyond the scope of this manuscript, the authors to bring up the link between warming (i.e., CO2-driven) increases in tropical cyclone activity and the enhanced burial of terrestrial OC as a factor that provides a negative feedback (page 194, line 24). However, enhanced storm activity also likely significantly increases air-sea gas exchange as a consequence of increased wave energy/activity and bubble formation, resulting of enhanced transfer of CO2 from surface waters to the atmosphere. It is not clear to me which of these effects - as well as those associated with controls of CO2 on terrestrial productivity, and hydrological processes on export – may be most important. This is clearly a complicated system characterized by both positive and negative feedbacks.

How does sediment and carbon discharge vary across the duration of a tropical storm event? I would assume that initially the river behaves hypopycnally before transitioning to hyperpycnal flow (when suspended sediment concentrations are > 40 g per liter), and

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then as the storm subsides it could return to hypopycnal conditions? Is this the case, and does the nature of the organic matter (fossil vs non-fossil) change? Over such a storm, what fraction of the discharge is hyperpycnal and what fraction is hypopycnal?

While most sediment ($\sim$ 60-70%) is discharged under hypopycnal conditions (page 181, line 27), what are proportions of organic carbon discharged under hyper- vs-hypopycnal discharge?

There appears to be only one sample - a box core – that was collected from a water depth of only 160 m from the thalweg of the Gaoping Canyon. This leaves open the question concerning the fate of OC transported and deposited further downslope as a consequence of hyperpycnal discharge? Are the authors able to comment on this?

Specific points:

Page 180, Line 12: "... which are not represented in current models of the carbon cycle"

Pg 189 Lines 18-24. It is mentioned that the under-sampled region off the east coast of Taiwan exhibits low O2 concentrations (leading to conservative estimates of terrestrial carbon burial). To what water depth do these low O2 levels persist (i.e., is this an oxygen minimum zone?)? Is low oxidation expected to extend to the very deep regions (e.g., > 5000m)?

Page 190, Line 5. $\sim$ 600m does not really constitute "deep waters", but rather mesopelagic depths.

Page 191, Lines 23,24: I would re-phrase "...and so the patterns in the data are not consistent with terrestrial OC loss, nor selective (OCnon-fossil, Fig. 4b) or pervasive (OCnon-fossil and OCfossil Fig. 5b)" to "and so the patterns in the data are not consistent with either selective (OCnon-fossil, Fig. 4b) or pervasive (OCnon-fossil and OCfossil Fig. 5b) loss of terrestrial OC.

Figure 1: while the dots are a guide, it would be useful to indicate (a) the location

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of specific rivers, (b) the main trajectories for hyperpycnal flow, and (c) the general trajectories for hypopycnal flow.

In Figures 2, 3 & 4, it would be helpful to keep the x-axis scale the same (for one it is -19 to -27 permil (Fig 4) and others it is -19.5 to -27 permil (fig 2 & 3).

Figure 5. Instead of “Radioactive isotopic compositions of organic carbon (D14Corg, permil)” it would be more straightforward to say “Radiocarbon contents of organic carbon (expressed as D14Corg, permil)”.

Table S3. It would be useful in this table to list the water depth at which sediment cores were collected.

Interactive comment on Earth Surf. Dynam. Discuss., 1, 177, 2013.