Point-by-point reply to the comments

1. Editor Initial Decision: Reconsider after major revisions (26 Apr 2014) by Dr. Paola Passalacqua

Item 1.1: “Based on the reviewers’ comments and my own reading, I decided to ask you to submit a revised manuscript addressing all the comments received by the reviewers. The topic is important and timely and the comments received will be useful to improve your manuscript.”

Reply: Every comment was considered in the revised version, as detailed point-by-point hereafter.

Item 1.2: “Let me stress here that the problem of data uncertainty is important and if that information is not available, I would recommend discussing its impact on the results.”

Reply: Done. See below reply to item 2.1.

Item 1.3: “Detailed sections on the model and boundary conditions should be present as well”

Reply: Done. See replies to items 2.2, 2.3 and 3.4.

Item 1.4: “I echo the reviewers in the need of improving the quality of the presentation, with particular attention to distinguishing conclusions of your analysis and inferences. I suggest you to separate ‘Discussion’ and ‘Conclusions’ in two sections which will help in this regard.”

Reply: Done. See replies to items 2.5 and 3.3.

Item 1.5: “The introduction will also need to be expanded to appropriately cite the relevant literature on tidal processes.”

Reply: Done. See reply to item 2.4.

2. Reply to the comment by M. Sassi, referee

The authors thank the referee for agreeing with the general line of reasoning of the manuscript, for his 5 suggestions (items 1-5) and his specific comments to improve the paper.

Reply to item 2.1: About the uncertainties of discharge and sediment concentration measurements, the following paragraph was added (§ 3.1) and the number of significant figures in Tables 1, 3 and 4 was reduced according the referee’s suggestion:

“Measurements were conducted following the standards of the IMHEN (Institute of Meteorology, Hydrology and Environment) belonging to the Ministry of Natural Resources and Environment (MONRE), which apply all over Vietnam, in each gauging station, with the same protocols. NHMS provided daily discharge from water depth, which was measured every minute. Regular calibrations of the water depth-discharge rating curve were conducted (several times a month) at key stations of the Red River, using reels (every 20 meters across the river section, at 5 depths over the water column) and, more recently, ADCPs. Water was sampled along a water column representative of the cross section to determine SSC after filtration on pre-weighted

filters of 0.45 μm porosity: once a day at 7h AM local time during low discharge, twice a day or more during floods. Detailed cross-sections of velocity and SSC were gauged once a day during high floods. The data were quality-controlled by the Hydrometeorological Data Center (HDC).
Independent validations of discharge estimates (by ADCP) and SSC estimates (by filtration techniques) were conducted by Dang *et al.* in 2008 (Dang et al, 2010; Dang, 2011) on the Red River at Son Tay. Their study shows (1) that daily SSC concentrations and Q provided by the MONRE can be considered accurate with 10-15%, and (2) that the scatter error was probably random rather than systematically-biased (see e.g. Fig. 47 of Dang, 2011). Consequently, and considering the method proposed by Meade and Moody (2010) on the Missisipi River, the annual suspended sediment flux estimates in the Red River may be considered accurate within 5-10% (Dang et al., 2010). As stated by Whiteman et al (2011), a high frequency of measurement is more important than a decrease in random error in trend detection. As the integration of daily data (which are already values averaged from several measurements over the day during floods) over seasons or years largely smoothed out random variation. In the present paper, considering this uncertainty, the precision given on river discharge and suspended sediment flux is limited to 0.1 $m^3 s^{-1}$ and 0.1 t yr^{-1}, respectively."
+ references added: Meade and Moody (2010), Whiteman et al (2011), Dang (2011)

<u>Reply to item 2.2:</u> A new sub-section 3.3.2 was added which includes the following new information on the river sections used to implement the model:
"In order to setup the model, the Red River system was designed under a network which includes the main rivers (Fig. 2) from data such as river section and bed elevation collected by the NHMS. To implement our model, 783 river sections provided by the MONRE were used: 51 sections of the Da River, 27 sections of the Thao river, 19 of the Lo River, 156 of the Red River, 44 of the Thai Binh River, 34 of the Luoc River, 31 of the Duong River, and 421 of other rivers or channels of the network (Fig. 2)."

<u>Reply to item 2.3:</u> The sub-section on "calibration and validation" of the model (§ 3.3.4) was rewritten following:
"Local values of Manning's *n* were chosen at different locations along the river to obtain the best fit between measurements and simulations. The resulting calibration was obtained with a decreasing roughness coefficient from 0.035 $m^{-1/3}$ s (upstream) down to 0.02 $m^{-1/3}$ s (downstream), by local best-fit at the gauging stations. No assumption on the type of global decreasing from upstream to downstream (neither linear, exponential nor other) was done, but a linear variation was applied to determine *n* between two adjacent gauging stations."

<u>Reply to item 2.4:</u> As suggested, explicit evidence of tidal mechanisms was added in the revised version. In section 2.4, the following text was included:
"Tidal mechanisms are key processes on water distribution in deltas, since they may alter by several percents the river discharge division in bifurcations amongst distributaries (from 10% at the apex to 30% seaward in the Mahakam delta, Indonesia; Sassi et al., 2011). Tidal mechanisms are also key processes of sediment transport in estuaries (e.g. Allen et al. 1980, Dyer 1986, Dronkers 1986). In the middle and lower estuaries, deposition is mainly driven by the dynamics of the turbidity maximum zone, whose presence and dynamics are governed by the coupling between river discharge and tidal propagation (e.g. tidal pumping and/or

density gradients; Sottolochio et al., 2001). Tidal pumping is caused by the asymmetry of tide, with shorter and more energetic flood periods than ebb periods, and longer high slack water periods than low slack waters, thus favoring deposition near the turbidity maximum (Allen et al., 1980; Uncles et al., 1985; Dyer, 1986; Dronkers, 1986). Fluid mud consolidates slightly during neap tides (Dyer, 1986).

Lefebvre et al. (2012) showed that sediment deposition induced by tidal pumping in the Cam-Bach Dang estuary (Fig. 1) can be up to three times higher during the dry season relative to the wet season. During the dry season, the net sediment flux at the river mouth is positive from the sea to the Cam-Bach Dang estuary, bringing back into the estuary particles brought by previous floods (Lefebvre et al., 2012).

In this study, tidal propagation within the estuaries is included in the numerical model and tide is taken into account through its boundary conditions in the river mouths."

The introduction was also revised.

+ reference added: Sassi et al., 2011

Reply to item 2.5: Previous estimates by Pruszak et al (2005) and Luu et al. (2010) were very informative ; in the same way, we hope that our results could also be helpful for other researchers working on the Red River system. Therefore, we think that the Tables should be kept in order to bring information (1) for the decision makers (harbour authorities, ministry of environment, ministry of transportation etc), (2) for researchers who will improve these estimates with new tools in the future.

As suggested by the reviewer, 3 more figures were added to illustrate some significant results from Tables 1, 3 and 4 and improve the readability of the paper: Fig. 5 to 7.

As suggested too, the discussion was broken in 3 subjects so as to improve the readability. 2 subjects that were in the "discussion and conclusion" of the original version shifted towards the "results" section (new sub sections 4.4 and 4.5), since they provide new data and new results rather that subjects for discussion.

3. Reply to the comment by J. Shaw, referee

Reply to items 3.1, 3.2: This paper is the first to provide the distribution of water and sediments within the 9 distributaries of the Red River, one of the biggest rivers in the world (ranked 9th by Milliman and Meade 1983, in terms of sediment input to the ocean). We thank the referee for agreeing that in itself it is an important aspect of the paper.

Reply to item 3.3: In the revised version, results are clearly separated from discussion. The effect of tidal pumping in the Cam-Bach Dang estuary is a result detailed in Lefebvre et al (2012); this effect is now described in § 2.4 and in the new § 5.5. The enhanced siltation in the Haiphong harbour, evidenced from the volume of sediments dredged by the harbour authorities, is a new sub-section of results (§ 4.4). The role of the combined new water regulation and tidal pumping is now clearly mentioned as a possible origin of this increased siltation in the discussion, at the end of § 5.5, following:

"In this context, two possible origins of enhanced siltation caused by the new water regulation can be envisaged: (a) lower discharges in wet period, and (b) higher discharges in dry season. (a): by limiting flow during floods, the HBD regulation decreased sediment transport capacity of the rivers - especially in the higher floods that flushed the river bed - thereby enhancing deposition in the river, with the knock-on effects of obstructing the boat traffic and the outgoing tidal waters out (Tran et al., 2002). (b): the observed slight increase of river discharge during the dry season after the impoundment of the HBD (Red and Duong Rivers, Fig. 5b) likely enhanced the tidal asymmetry and the associated tidal pumping (Allen et al., 1980; Dyer, 1986). Mechanisms (a) and (b) may superimposed. However, as shown in Lefebvre et al. (2012), deposition in the estuary mainly occurs in dry season. The changes of Q, turbulence and SSC variability caused by dam regulation and dam retention may have moved the turbidity maximum zone in dry season.

Unfortunately, no data are available on the location of the extreme turbidity maximum before HBD impoundment, and we are not able to assess if the extreme turbidity maximum in the northern branch of the Red River estuary moved after the impoundment of the HBD towards the harbour estuarine area. The combination of a new water regulation and tidal pumping is a possible origin of this increased siltation. This hypothesis is only an assumption, opening up new avenues of research."

Reply to item 3.4: Additional information on the value of SSC at the boundaries during flood tides was given in § 3.3.3, following:

"The value of SSC at the ocean boundaries during flood was obtained from the available measurements. Continuous measurements on periods longer than the spring-neap tide cycle were performed in the Cam and Van Uc Rivers in March (dry season) and August (wet season) 2009 at the Cam River mouth and at the Van Uc River mouth. The averaged SSC at the Cam mouth during flood tide was 52 mg L^{-1} in the dry season and 61 in the wet season, while it was 60 mg L^{-1} in the dry season and 95 mg L^{-1} in the wet season in the Van Uc River. Other series of measurements were performed at 1.5m below the surface and 1.5m above the bed during one tidal cycle at the Cam, Bach Dang and Dinh Vu river mouths (Dinh Vu is located just downstream of the confluence between Cam and Bach Dang) in the wet season in 2008, and in the dry season in 2009 (field campaigns presented in Rochelle-Newall et al 2011, Lefebvre et al. 2012, Mari et al. 2012). During flood tides, at 1.5m below the surface, the averaged values lay in the range 72-162 mg L^{-1} in the wet season and 28-72 mg L^{-1} in the dry season. At 1.5m above the bed, they were higher by 4 to 75 mg L^{-1}, depending on the neap-spring tidal cycle. SSC values were always higher at the beginning of flood (just after low tide) than at the end, just before high tide.

As no measurements were available for the other river mouths, we decided to fix in our calculations a constant value of 50 mg L^{-1} at each river mouth over the whole year during flood periods. This value is within the range and the order of magnitude for the Cam, Bach Dang and Van Uc Rivers. »

As this point is crucial to improve estimates of sediment fluxes, we also added one sub-section in the discussion (§ 5.3 "Boundary condition"), following:

« Although the value of 50 mg L^{-1} fixed at the river mouth during flood periods enabled the calculation of estimates of sediment flux, this arbitrary value likely underestimates the sediment flux from offshore to the estuary, and thus estuarine siltation. To improve the accuracy of sediment flux estimates, the measurement of SSC at river mouths during flood tides is strongly encouraged in future work. »

Reply to item 3.5: Concerning the increased siltation in the estuary (which is a result and not an assumption), see the previous reply. Concerning sand transport, the following sentence was added in § 2.5:

"The estuaries are mainly composed of silts, and sand is estimated to be, on average, 10% of the surface sediments in the mouths of the Red River (Tran and Tran, 1995)."

The conclusion was also modified so as to include :

"Although the estimates of water and sediment discharge can be improved in the future (e.g. measuring SSC at the river mouths during flood periods, taking into account bedload transport, etc), this paper is the first to provide…"

reference added: Tran and Tran, 1995

Reply to item 3.9: The abstract was revised accordingly.

Reply to item 3.10: Three groups of distributaries ("northern", "middle", "southern") were introduced in Table 3 so as to compare our results to previous estimates by Pruszak et al. (2005) and by Luu et al. (2010) who did not consider every mouth but 3 groups (Luu et al. 2010) or one "northern" group and 5 mouths (Pruszak et al., 2005). The sentence was rewritten as follows:

"Their percentage for the Van Uc-Thai Binh system (37%) is very close to our estimate before 1979 for the whole Duong-Thai Binh system (38.6% for Cam, Bach Dang, Lach Tray, Van Uc and Thai Binh), and for the Tra Ly as well (10% by Pruszak et al., 2005, versus 8.4% in our calculation)."

Reply to item 3.13: The former sections 2.5 and 2.6 were revised. See reply to item 2.4.