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Interactive Comment

Interactive comment on "Effects of Three Gorges Reservoir (TGR) water storage in June 2003 on Yangtze River sediment entering the estuary" *by* Z. X. Chu and S. K. Zhai

Anonymous Referee #2

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1) General comments This is a potentially interesting paper, as it highlights a short period of time in which the currently world's largest dam in one of the world's largest river basins is put into service for the first time. Being able to observe such an event is quite uncommon and provides an opportunity to actually observe with daily data the effects of the actual operation of such a huge dam on suspended sediments entering the estuary. The topic is relevant to HESS, as some of the recent papers on the topic have appeared in this journal as well. The paper is relatively short, not uncommon for HESS, only the number of figures (no tables have been provided) is rather limited. Unfortunately, the paper is not always well written and uses, despite of being rather short, a lot of words for something that could, at least graphically, be much better

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expressed. Regrettably, the results presented in the paper are nearly not discussed at all. To conclude, this paper can be highly interesting, provided the authors give more information and include a largely broadened discussion. I recommend potential acceptation with major revisions.

2) Specific comments General issues Some changes caused by reservoirs are quite obvious (as the ones described in this paper), others only occur over longer time scales (not the scope of this paper). The World Commission on Dams (www.dams.org) states that retention of sediments by reservoirs is a well-known phenomenon (the estimated global storage volume is 8 400 km3, compared to 1 200 km3 in natural rivers (Vörösmarty et al. 1997, Friedl & Wüest 2002)), but the extent varies greatly and is comparatively higher for smaller dams. Down-stream effects of river damming are often overlooked and although substantial knowledge exists on the causalities, it is often difficult to proof cause and effect over large distances (Friedl & Wüest 2002). Most studies focus rather on general comments or problems related to sediment retention, mainly over longer time periods (such as for the Nile by Kempe 1988, 1993, Stanley & Warne 1993, or the discussion on the Nile delta plains by Stanley 1996), due also to the inherent difficulty of interpreting daily sediment data on very short time periods. Possibly more detailed descriptions of reservoir operations are available in engineering journals, but this is not the scope of the paper. Whereas numerous studies are available for smaller rivers, relatively few studies are available on impacts of dams on downstream flow and sediment regimes for large rivers, especially in SE Asia (Lu & Siew 2006). The Yangtze (or Changjiang) sediment transport has received quite some attention from the scientific world (e.g. general description by Chen et al. 2001, upstream parts described by Lu & Higgitt 1998, 1999) and the Three Gorges Reservoir (TGR) in particular are potentially one of the best cases to illustrate how dams and reservoirs impact sediment flux to oceans (Yang et al. 2006 b). This topic has raised a lot of interest and has been covered by a number of recent papers (Yang et al. 2004, Dai et al. 2005, Yang et al. 2005, Gong et al. 2006, Yang et al. 2006 a, Yang et al. 2006 b), some of which have appeared in HESS, making the present paper rele-

vant for HESS as well. Unfortunately, the paper misses some fundamental information. The introduction misses at least a short description of the Yangtze discharge and sediment flow regime, including controlling factors as climate, relief (as can be found in the Yangtze literature). The text mainly describes or resumes the figures provided, but these findings could not always be reproduced by the referee. Moreover, the results are lacking a subsequent discussion that could largely corroborate the findings. Such a discussion has to include remarks on the tributaries entering the Yangtze, and potential further sediment traps such as Lake Dongting and Lake Poyang, between the outlet of the TGR and Datong station just before the estuary, 1 800 km downstream (such as the sediment budget presented by Yang et al. 2006 b). As the paper aims to highlight effects of TGR on sediments entering the estuary, using data from only 2 stations (at TGR and downstream at Datong) leads to highly speculative results that have to be underpinned. It is probably difficult to discern all controlling factors when looking at data on a daily basis as one would have to collect data on reservoir operation on at least the most important reservoirs on the tributaries of the Yangtze. Other papers have now started to evaluate direct effects of TGR storage on the Yangtze estuary (e.g. Yang et al. 2005, Gong et al. 2006). Additionally, it would be highly interesting to include comparisons to different river basins impacted by big reservoirs, in similar or different climatic and geomorphological conditions, also during initial operation stages of the reservoirs, if such data is available.

Title The title could be more careful (what about the remaining river stretch between TGR and Datong; including Lake Dongting and tributaries), e.g. Yangtze River's Three Gorges Reservoir (TGR) water storage in June 2003 : possible effects on sediment entering the estuary

Abstract (and similarly in the main text), missing (already in the abstract): what is the meaning of 'stored water' (before, after dam closure), absolute retention volume in June ? What does 'pre-water storage' mean - does this mean 'pre-storage phase', 'with water discharge increasing' (can't be seen in Figure 2, and why 'increasing') ? When (in

June ?) and where (Datong ?) have the unnaturally clear waters have been observed ? ("TGR sedimentation" not "resulted" by, but "caused by the", add "temporary (!) water storage). The sentence "The results show ..." can be shortened, as the results only show expected outcomes (or delete the sentence). Then "As to be awaited, the temporary water storage brought ... during the TGR water storage ..." the follow-up "and in the second half year of 2003" doesn't seem to be corroborated by the data shown in Figure 3 ! Before last line in the abstract (line 23, page 1554) : the last word in the line ("than") makes the whole sentence unclear : meant was (?) "the real" (below TGR ?) sediment load" - which, where, for which lapse of time ? (27 May - 2 July ?) compared with the estimated normal total sediment load ? The number presented at the end of the abstract (2 456 x 104 t) is based on a very rough estimation and should thus not be treated as a result.

Main Text : Missing very much (at least a short description and references should be provided) : description of the flow and the sediment that is transported with it, between the dam and Datong, over 1 800 km, at an average flow velocity of ??, where does the river deposit sediments (clear water where ?) when the sediment supply suddenly ceases. One would like to know more about the "buffering and hysteresis processes" (page 1561, line 4). Figure 2 (comparing curves a) and b)) seems to indicate that the propagating river wave is practically not existent, i.e. closing the water supply upstream reduces the water arriving downstream (over a 1 800 km distance) almost instantly (within 14 days), whereas the (immediate, see Figure 2) opening effects can be observed in Datong after 14 days only, over about another 14 days (continuous increase). Section 4.1.1. should clarify and discuss this, but doesn't. The numbers stated in this section should be more clearly and completely be observable in the Figure (Graph A of the discharge shoes neither pre- nor post- values). And most important : the comparison of the events 'upstream' with those 'downstream', the discussion of possible causes of the delayed effects 'downstream', doesn't happen. Crucial is - and should thus be stated clearly - that nearly the whole sediment transport of the Yangtze concerns suspended sediments (only $<$ 0,05 % not). As a result, the volume of

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sediment transported depends decisively upon the volume of water transported. More interesting is thus the concentration of suspended sediment in the water (especially since the total suspension volume is a derived / calculated number from sediment concentration and water volume - this should already be stated earlier, i.e. section 3, page 1557 line 13, and not only in the first sentence of section 4.1.2.). Why does the sediment concentration increase / decrease with the water volume, depending on which factors (flow velocity, degree of turbulence, ...). A paragraph should state if this is all trivial, known since long, or could this be new, or new evidence for something not very well known. What are the particularities of the Yangtze ? Fuggle & Smith (2000) state that 126 000 km2 of middle and lower Yangtze reaches are now protected by 3 600 km of main levees and 30 000 km of tributary levees, flood-prone areas concern 75 M people, floods usually happen once every 10 years. Lake Dongting is mentioned as effective sediment trap. Decisive for the impact of the dam will be, what happens when the water in the reservoir flows very slowly, standing nearly still, and how much of a) bedload and b) the suspended sediment will settle and stay ? An estimation of sediment carried through the reservoir (Fuggle & Smith 2000) initially is 30 % (long and narrow reservoir, high flow velocity during flood season), this proportion should be even higher later as sediment builds up - increasing flow velocity further; continued supply of sediments from rivers downstream TGR ? What about any plans to regularly flush the reservoir, e.g. at low flow stages downstream ? In the reservoir, during the (relative) calm of the water body the suspended sediment will slowly sink and settle, i.e. the concentration of suspended material should decrease in downward direction, and possibly increase in the bottom half (if the sinking sediment isn't subtracted from the water column by sedimentation) ; what is the knowledge on this ? This question is important if at the dam itself the water outlets are situated at vertically different points. In this context the question to p.1556, line 24 to p.1557, line 8 : what are 'diversion bottom water outlets', what 'deep outlets' ? What is the position of these 'outlets' with regards to the sediment transport ? The situation at the dam (section 2, reservoir background : "elevating pool level to 135 m") doesn't express anything if the base

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level of the Yangtze at the same point is not known or expressed. Does the sediment retention during the initial operation stages of the reservoir correspond to what has been predicted by the engineers who did the feasibility studies (such as Canadian Yangtze Joint Venture (1988)) ? Can this be compared to what has been actually measured ? A striking (= clear water ?) discrepancy (over-proportionate increase of water volume with relatively slow increase of sediment transport and concentration) can (Figure 2, C vs. C and D) only be observed between the ˜27.06. and the ˜3.7. and again from the 14.7. on. Is this distinctive feature significant or mere coincidence ? Does an explanation for this behavior exist ? Similar question for the period of May 15 to May 22 in the pre-dam phase (what has been done by the engineers during that period ?). Concerning the whole section 4.2. : interesting are not necessarily the numbers only (they can be observed from the Figures), but the connection / correlation between water discharge and sediment concentration, resulting in the total sediment transport. The supply (water as well as sediments) of the tributaries between TGR dam and Datong is mentioned too late, only in the last part of the concluding remarks. After all they supply as much water as the Yangtze at TGR, but nearly no sediment. This sounds doubtful and these statements should at least be corroborated by some source material. Some material is mentioned in the specific remarks. Some HESS readers might not be familiar with engineering terms such as 'dispatching stage', 'diversion bottom outlets / deep outlets' etc. - can they be clarified somehow ?

Specific remarks - p.1555 line 5-6: "Pearce 1991". More recent data is available: (the interesting figure is the sediment trapping by reservoirs, not only the discharge trapping; Beusen et al. 2005 estimate 13 % of sediment trapping by reservoirs, Syvitski et al. 2005 global trapping of sediment load by reservoirs is 20 %, including small reservoirs it rises to 26 %, Vörösmarty et al. 1997, 2003 : 40 % of river discharge dammed and 30 % of sediment discharge , several large basins such as Colorado and Nile are completely trapped - p.1555 line 8-9: deltaic degradation could possibly be compared to the outcomes by Ericsson et al. (2006), this part could then also be part of the discussion. Following Ericson et al. (2006), primary determinants of effective sea level rise in 70 % of world-wide deltas are probably decreased accretion of fluvial sediment due to reservoir sedimentation and runoff loss from irrigation. - p.1555 line 10: "... in China ..." - "continent" is not needed as China is no 'continent' - p.1555 line 14: impounded sediment as a problem is obvious, but needs explanation / or inverse sentence - p.1555 line 17-18: the ranking numbers of the Yangtze (3rd longest etc.) - for water discharge and sediment load - are these values at natural or anthropogenic state ? - p.1555 line 23-24 (geochemical composition and related effects): elaborate on that or drop - p.1556 line 1: "... many people..." - awkward writing - p.1556 line 2: "... project should be given up" (delete : "or be put off") - p.1556 line 7: "TGR, sedimentological studies" ... + line 8 "... and are still ..." - p.1556 line 8: "Many scientists and departments ..." needs to be underpinned with references - p.1556 line 9: "... sediment problems ..." "prototype observations" is a bit diffuse and very general, but understandable and acceptable in the context. - p.1556 line 10: "... model experiments ..." (plural) - p.1556 line 10: "... what on earth..." is awkward scientific writing - p.1556 lines 22-23: "(above mean sea level at Wusong located in Shanghai)" should be moved to line 18, after "...pool level of 175 m)" - p.1556 line 24-25: what is the meaning of "adjusting" and what are "diversion bottom water outlets" ??? - p.1556 line 26: Gezhou Dam is mentioned and should therefore be added in Figure 1 if possible - p.1557 line 3: "... was controlled at ..." is awkward writing, could be "... was controlled to be between ..." - p.1558 line 8: "...than..." is not understandable, should be replaced by "compared to" or "as against". The same happens more often later (p.1559 line 9 + 10, p.1560 line 22) - p.1558 line 22-23: this is an example of missing discussion. These numbers (stated here as results only) should be discussed more profoundly in the missing discussion section. What are the causes for these variations (other tributaries, dam operation, climate variability) ? - p.1559 line 6 (again in line 13): replace "understated" by "underestimated" - p.1559 line 7: measured is SSC, the sediment load is calculated ! - p.1559 line 8: total sediment load: this is another example of potential discussion later in the paper. How does this number compare to contributions from other tributaries ? - p.1559 line 10: should be "... tends to increase..." - p.1559 line 10-11: "Actually, according to historical data..." sounds contradictory, although in the context it is clear what the authors want to say. One would only like to know which period is covered by "Actually", and which by "historical data" ? - p.1559 line 12-13: estimation method very rough. Can be OK but if over 3 month period then please check with precipitation data, other tributaries data etc. If the authors have access to unpublished data on the discharge and sediment stored in the reservoir at the beginning of June 2003 (p.1560 lines 12 and 19), then why not use them instead of the crude estimation used here - p.1559 whole paragraph from line 4 to 13: as I understand from other papers, daily data is available for long time series and for different stations (Yangtze River Water Conservancy Committee, Ministry of Water Conservancy of China began systematic, daily surveys in the 1950's, e.g. Bureau of Changjiang Hydrography (2003)), so a natural state could be more closely evaluated and sediment budgets can be calculated for the mid-lower reaches of the Yangtze ? Or at least for different time periods. The given reduction value (2456 x 104 t) will then probably really reveal to be underestimated. This is another example of potential subject for discussion. - p.1559 line 16-17: The first part of the statement "Similarly to the tendency of sediment load, the SSC at Datong naturally increased ..." (why "naturally" - what does this mean here ?) doesn't make much sense, as the sediment load is calculated here using the SSC. - p.1559 line 21-22: again: why ? At least give tentative explanation in discussion section. - p.1560 line 14: shouldn't it read "... when compared with that in June 2002 and the ..." ?? - p.1560 line 16: should read "... in 2002 and 2001 and especially in 2003..." - p.1560 line 18: The beginning of the sentence is not really understandable. The unpublished data should be explained in more detail (compare the general comments for the text and the question concerning the events in the pre-dam phase (Figure 2, first time period) - p.1560 line 19 (and p.1561 line 3): unpublished data –> possibility to include here as otherwise cannot be verified ? - p.1560 line 22: it is not "the real total sediment load" that was reduced, this value is based on a the crude estimation described above ... - p.1560 line 23: "... which also explained..." doesn't make sense: 2 parallel cases without any further explanations or additional information don't explain one each other, if not one of the 2

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is explained further. - p.1561 line 2-3: this value (124 x 106 t) has been published by Yang et al. 2005 and seems to be available at http://www.irtces.org/nishagb_2003.asp - p.1561 line 5 + line 8: 'somewhat' instead of 'some'; this observation only really holds for August 2003 at Datong, September to December are at least in the same range as 2002 (see comments for Figure 3) - p.1561 line 12: "... Due to a large part / share of suspended sediment ...", missing word - p.1561 before section 5 (concluding remarks): Missing discussion. Such discussion could include discussion of the sediment budget downstream of TGR (as done by other authors, e.g. specifically as on Lake Dongting by Dai et al. 2005, or more general on the whole Yangtze as by Yang et al. 2006 b), comparisons with other rivers, from same / similar climates, other climates, ... Comparisons may be possible with papers by e.g. Lu & Siew (2006) on the Mekong (although available data seems more sparse for their study), their study mentions more studies that could be used for comparisons, although they seem to be more on smaller rivers. Sklar (2000) also resumes some studies of dam effects (before and after closure) on ecohydrology of large scale river basins. Dai et al. (2005) reports on the importance of Lake Dongting (downstream TGR) : sediment flux would be 26 % higher at Datong for the 1956-2003 period if without Lake Dongting, but values dropped after completion of TGR in 2003. In 2003, the amount of sediment deposited in Lake Dongting was 10 % of the sediment discharge at Datong. Influence is supposed to be even lower in the future. Dai et al. (2005) also mentions that Chen et al. (2003) studied potential TGR effects on Lake Dongting, but following the title, it should also cover potential effects on the estuary, so please use these studies for comparison ! (seems to be available in Chinese only, so could not be verified by the referee). They also mention that Dai et al. (2005) already studied direct TGR effects during initial operation (seems also to be in Chinese with English abstract only), they report sediment trapping of 0.1 billion tons of sediment from June to September 2003. - p.1561 line 16-25: just restates the abstract - p.1562 line 2-3: "... dam output the natural upstream ..." - awkward writing - p.1562 line 3-5, and lines 10-12: these statements are critical for this article and should be examined and discussed. This has been done by Yang et al. (2006 b) using a simple model (see also below). The hysteresis usually observed (highest sediment transport in rising limb of a flood) is not observed for the Yangtze, following CYJV (1988). The statements should thus be underpinned with more references (such as Chen et al. 2001) and be discussed more in detail. Gong et al. (2006) undertook an oceanographic investigation of the East China Sea before and after the first filling of TGR. Sediment load decreased by about 55 % at Datong after June 2003, following their study. River discharge decreased by about 9 % only (recent Datong data), but flow may be stored during flood seasons to be released later. In 2003, Yichang and Datong sediment loading were decreased by 80 % and 50 % respectively, compared to historical mean (Bureau of Changjiang Hydrography). 3 papers in particular discuss the sediment flux variability in the Yangtze: * Yang et al. 2004: surface erosion area increased by nearly a factor 2 between 1950's and 2001 (due to population increase). Sediment yield increased by 30 % in the first 6 decades of the 20th century. The increase was accelerated between 1950 and 1960. Sediment flux maximum in the 1960's. Then decrease to less than 1/2 of the 1960's value until 2003. The main reason is the construction of dams (no increased sedimentation in lakes and canals, no water discharge decrease, no water diversion influence). Water and sediment fluxes at Datong are 2.04 and 0.86 times that at Yichang (just downstream TGR) respectively (Yang et al. 2002). Total storage capacity of Yangtze reservoirs amounts to approximately 22 % of annual flow discharge into the estuary by the end of 2003 (i.e. after TGR initial operations). * Yang et al. 2005: impact of 50 000 dams: 22 % of Yangtze river runoff is stored, strong decrease of sediment supply since the 1950's, the growth of intertidal wetland (important for claiming land for Shanghai expansion) has dramatically decreased. Degrading of intertidal wetlands happens when the sediment discharge rate falls below a certain threshold. The sediment discharge rate will be below this threshold in coming decades due to TGR and other new dams. Predicted for the normal operation stage from 2009 on are 70 % retention of sediment load from upper reaches. Middle and lower reaches have regulatory effects. Sediment discharge at Datong was 206 x 106 t/yr at Datong in 2003 (also available at http://www.irtces.org/nishagb_2003.asp). "In 2002 and 2003, net erosion was observed in the middle and lower reaches of the Yangtze River. ... In 2003, sediment discharge was 98 x 106 t/yr at Yichang and 206 x 106 t/yr at Datong." Net erosion was 68 x 106 t/yr between Yichang and Datong when considering sediment supply from tributaries between Yichang and Datong of about 40 x 106 t/yr. Deposition in reservoirs is more rapid in the upper reaches (including TGR) of the river than in the middle and lower reaches. * Yang et al. (2006 b) have established a detailed sediment budget for the past 55 years and after TGR, including tributaries. More than 40 % of decrease in sediment flux have been observed since the 1950's and 60's in sediment transport, but slight water increase at Datong. 3 phases of reduction are distinguished : i) 1968 closure of Danjiangkou Reservoir on the Hanjiang tributary, ii) numerous dams and water-soil conservation works in the Jialingjijang catchment after 1985, iii) TGR project started operating in 2003. Following the design plan for TGR, 70 % of sediment discharge will be trapped during the first 2 decades after 2009, then, over the first 100 years, $>$ 44 % will be retained. They remark that using only Yichang and Datong data makes it difficult to establish a sediment budget. Prior to 2002, all Changjiang catchment dams save one (Gezhouba dam) were located on tributaries. At Yichang 2003-2004, a 60 % decrease relative to 1986-2002 sediment loads, and 85 % relative to 1951-1968 values, has been observed. At Datong 2003-2004, the annual load is 180 mt/yr, i.e. a 160 mt/yr (30 %) decrease relative to 1986-2002 values, and 310 mt/yr (60 %) decrease relative to 1951-1968 values. They observed that "as sediment loads at Yichang after 2002 sharply reduced much earlier than that was expected, the river channel erosion in the middle and lower reaches seems to happen first in the Changjiang history". But drastic sediment reduction in upper reaches occurred already before TGR operation. The correlation between Yichang and Datong sediment load varies with different time periods (correlation is higher since Danjiangkou dam construction on the Hanjiang tributary). - p.1562 line 7-9: the reduction is mainly visible in August only (from the figure supplied, if other data available please supply in revised version). - p.1562 from line 15 on: instead of "since" the TGR water storage ..., better: "during and after..."; then "... is undoubtedly attributed to", better "is undoubtedly caused by / due to ... sedimentation of suspended sediment with the TGR during closure of the dam outlets ...". Also the word "regulation" seems erroneous here, meant is (?) "despite the buffer effects along the 1 800 km between the TGR dam and the estuary entrance at Datong". This outcome can be doubted based on the observations from this paper alone. Much more discussion is needed (see above).

Figures: - Figure 1: * Add a scale ! * Gezhou Dam (just downstream of TGR, is 'Gezhouba' in other papers - is this the same reservoir ?) and Qingxichang station are missing and should be added in the figure. - Figure 2: * The terms 'pre-water storage', 'preparation for ...', 'normal ...', 'post-water storage' apply to all 4 curves - this should be made more clear graphically. What do these terms mean for the through-flow of water at the dam itself ? Shortening of water supply, part-closure / damming ?, complete closure, then part re-opening, after ... These questions are answered, though not very clearly, in the text (p.1556, line 24, to p.1557, line 8). What are 'diversion bottom water outlets', what 'deep outlets'. What is the significance of the position of these 'outlets' with regards to the sediment transport ? - Figure 3: * Why are the curves not shown, as far as possible, for whole years (January - May data are missing), so that the entire discharge and sediment flux regimes can be observed ? At least May should also be placed on the figure (that's where the storage starts!) * Comparison of (1953 - 2000) 47-year means with only two normal (??) years (2001, 2002) doesn't allow many observations on the probably great variability of the 3 data sets (water, sediments, SSC) - i.e. the curves are not very meaningful. Yang et al. (2006 a) provide an analysis of annual time series of sediment supply (1951-2004). They observe obvious fluctuations of annual sediment load at Datong, consistent with water discharge and precipitation in most cases. Construction of other reservoirs upstream TGR will decrease sediment load entering TGR and thus also the load entering the sea. * What about trends in the average data (construction of many reservoirs in the time period depicted) ? E.g. Yang et al. (2006 b) have well described the history of the sediment flux in the Yangtze river, distinguishing different historical phases of decreasing sediment flux over time. If these periods cannot be distinguished in Figure 3, then at least variation bars (showing standard deviation and / or quartiles / percentiles of the flux distribution should be shown for the monthly averages from 1953 to 2000 in order to get an idea of the flux variability) should be added. See also comments above. * Following Figure 3, 2002 had a relatively wet 'wet season', but below average sediment load, why ? * Following the figure, in 2003 only August was significantly lower than the other months (for sediment load and concentration) when compared to 2001 and 2002. How can this behaviour be explained ? * Typing error in the date scale: 'Auc' should be replaced by 'Aug'

3) Technical corrections (typing errors etc.) - Typing error in scale of Figure 3 ('Aug' instead of 'Auc') - Missing references (listed in the text but not in the reference list): * p.1555 line 6: Milliman & Syvitski (1992) is missing in the reference list * p.1555 line 21: Yang et al. 2003 is listed as from 2002 in references list (or are these 2 distinct papers ?) * p.1556 line 4: Nof (2001) is missing in the reference list * p.1556 line 7-8: Hu (2000) is missing in the reference list

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