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Hydrology and Earth System Sciences Discussions

Interactive comment on "Variation in turbidity with precipitation and flow in a regulated river system – River Göta Älv, SW Sweden" *by* G. Göransson et al.

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The comments and observations provided by P. Owens are greatly appreciated and will improve the paper.

- The English will be proof read again for errors.

- It is true that turbidity is reflected by local conditions and may change regardless of flow condition, and that is also likely one of the explanations for the low correlation with flow. Seasonal changes, landuse, sediment sources, ion content, etc. have impact. However, if a larger part of Tu consist of particulate matter (clay, silt), there should be some correlation with flow and precipitation. These particles start to move when the shear stress acting on the particles becomes larger than the critical shear stress. The shear stresses in the studied river valley are in most cases created by the flowing water, either as river water or surface runoff, meaning that there should be some connection to water (or more correct, to flow velocities). For the studied river, the turbidity at each of the stations follows nicely each other with an increased downstream, which can be seen in Fig. 1. The Figure shows turbidity with a moving average of 14 days. It has not been possible within this study to look further into the content of Tu and analyse the various sources, but it is definitely a recommendation for future work in order to find better explanations.

- The number of samples for correlation between Tu and SSC is 12, a rather low number and a few samples are also affected by ship traffic. The samples were taken in 2010 and 2011 at one of the stations (Garn) and for another related study. There is thus a large uncertainty in the correlation between Tu and SSC, and the content of organic matter. We will make that clear in the paper. In this study we have used Tu data from the years 2002-2007 and we actually lack data on the correlation between Tu and SSC for these years as this is not routinely measured. That is also one of the reasons why focus in the study is more on Tu rather than on SSC. However, in order to fully understand the sediment dynamics it is recommended with an investigation on the correlation between these two variables. We will make this clear in the paper.

- The referee feels that the importance of turbidity as key fluvial parameter is to some extent downplayed in the paper. That has not been the intention and we can emphasise this point in the discussion.

- Hysteresis is mentioned as a good tool to understand the behavior of SSC/Tu with Q and to identify key processes. When we look at the data, we can see that there is a "memory" in turbidity and that the levels are dependent on previous events. Analysis of hysteresis has not been done in this study but could be done in future, preceded by an extended analysis of the correlation between SSC and Tu, and it is a good suggestion to explain what we cannot explain today. For curiosity, hysteresis analysis was done for a couple of occasions (three), maybe too long time intervals, see Fig. 2. The randomly chosen occasions indicate the influence from both flow and precipitation on turbidity and its variation.

- The travel time from the lake to the down most gauging station (Lärjeholm) varies between 1.5-5 days. The elevation from the sea to the lake is 44 m, regulated at locks. This information will be included in the paper.

- The turbidity is monitored continuously at stationary turbidimeters that read turbidity every 100 millisecond (100 millisecond → minute mean → daily mean).

- It is true that the river flow in the southern branch is calculated as the differences between the river flow in Nordre Älv and at the lock in Lilla Edet. The river flow is measured by the hydro power company and that is the data that has been used. The influence from the tributaries on the river flow in the southern branch has thus not been accounted for. The mean flow in Gårdaån is about 1 m3/s, in Grönån 4 m3/s, and should not have a significant influence on the overall flow in the southern branch (Göta Älv).

- Including extremes and outliers is not really as harsh as it sounds, we realize that it needs clarification and rewriting. All Tu data has been checked for anomalies. This is routinely done by the experienced staff at the control room at the water intake each year and incorrect data is removed before the data is further delivered to the Water Quality Association of the river Göta Älv (GÄVVF). Remaining outliers may thus be real but different. The effect of single outliers is somewhat muted because the sample size is fairly large (N>100). However, the analyses that includes a short time period (N < ca 30) were carefully chosen to be representative. If extreme situations would be excluded, then the data between Oct 2006 and May 2007, for example, would be excluded, a period of extremely high flow levels that lasts for a long period of time. It does not seem reasonable to exclude such periods, but to analyse them instead. We

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have been looking at the data and there is nothing that indicates that there should be a large number of outliers that would have impact on the overall results and conclusions (also, several statistical analyses have been done that is not included in the paper due to limited space).

- Thanks for the observation on contradicted message. The input from lake Vänern is not insignificant and has large influence on the base level in turbidity, however, it is not the main delivery of sediment, true. We will correct the text.

- The floodplain as a sink for sediment has not been investigated and we do not know how much sediment that may settle (or may be eroded) on the floodplain during large flooding and overbank flows but certainly, sedimentation ought to occur here as well. There is a lot we do not know about the sediment dynamics along the river. When this study started, the only study on sediment dynamics before this was one from 1968 on the hydrology and morphology. In 2011, the results from a landslide risk analysis along the river (that also included the impact from erosion on slope stability) increased the knowledge but still, much is left without answers.

- The tables will be clarified with respect to T, P, WL and Q.

- A scale will be added to Fig. 1.

- Figure 2 (sediment budget): The figure shows estimated net sediment budget based mainly on the results from a study that took place in 1968. That particular study concluded that bank erosion dominates upstream Lilla Edet and bottom erosion dominates downstream Lilla Edet. However, based on our results the sediment budget should be reassessed and updated. We will include this in the revised manuscript. In general, the sediment upstream Lilla Edet consist of glacial clay that is very firm. The post glacial material has been eroded. The sediment downstream Lilla Edet is softer and consists of post glacial clay above the glacial material. Layers of sand and silt occur. In general and along the whole river stretch, the river bed surfaces consist of a thin layer of larger grains (silt, sand, stones) above the clay, indication erosion, or possibly transportation

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(abrasion may occur). At one location north of S. Nol, a delta evolved during the last deglaciation. The delta consists of sand which is also seen in the bottom sediment. There is not much investigated in the river Nordre Älv but a few sediment samples near the city of Kungälv indicate quite soft clayish materials. With the knowledge we have today, the sedimentation along the river is believed to be very low. Most sediment settles in the harbor area and estuary of Gothenburg, and in the estuary of Nordre Älv. It is however possible that more sedimentation occur in the Nordre Älv than we know today, it is also possible that the river bed in Nordre Älv, as well as just upstream the branching, acts as a transportation bed. The suspended matter that comes from lake Vänern originates most likely from washed out materials.

- Figure 9 will be corrected.

The study is based on existing data which mean that one do not have full control of the data. This is an uncertainties we need to relate to, of course. There is a water right from the 1930s that regulates the maximum discharge from Lake Vänern to 1030 m3/s in order to prevent from bank erosion and flooding. Typically the discharge capacity increases with increasing water level in an upstream lake, however this is not the case with the Lake Vänern. To conclude, there is a lot we do not know about the river system and its processes. The work done here is a first step to increase the understanding based on available data and we believe that the approach used could be a good starting point. The comments from both reviewers give valuable input to the performance of further studies. Thanks. As a parenthesis, the variation in river flow increased after the river regulation in 1930, and increased even more after the 1980 when energy from oil decreased while that from hydro power increased.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 255, 2013.

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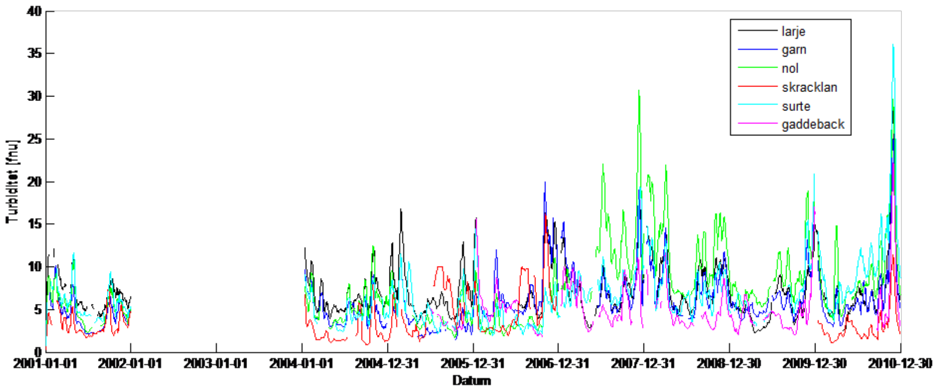

Fig. 1. 1. Measured turbidity at the gauging stations, 2001-2010

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Interactive Discussion

Discussion Paper

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Hysteresis

March 6-23, 2003, an example of good correlation

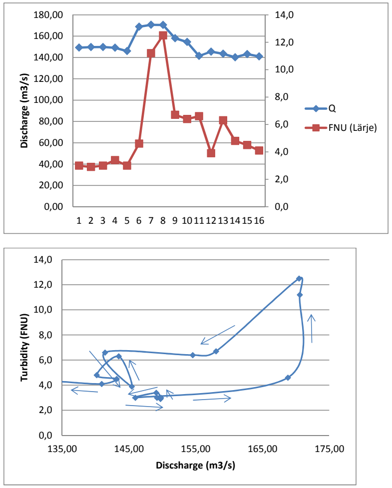

Fig. 2. 2a. Example of hysteresis

13 Jan – 24 Febr, 2002

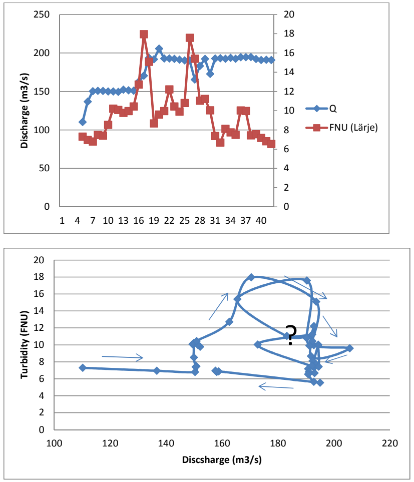

Fig. 3. 2b. Example of hysteresis

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