Dear Editor Prof. Huthnance,

Thank you for sending me the manuscript: "Quantifying the impacts of the Three Gorges Dam on the spatial-temporal water level dynamics in the Yangtze River estuary" by Huayang Cai for review, which I read with great interest.

The authors apply a linear regression model to the tidally averaged water level in the Yangtze estuary to investigate the effects of the Three Gorges dam. The authors find that their regression model predicts the water level in the Yangtze reasonably well. They find that since construction of the dam, low flows have increased while flows during transition from the high to the low flow season have decreased.

The topic is very relevant and the manuscript was interesting to read. The applicability of a regression model to predict water levels in tidal rivers agrees with my own experience in this field. The text and figures are of high quality.

However, the regression model applied here is relatively simple, at least much simpler than previously applied models. This certainly makes it easy to grasp the results, especially for readers who are not experts on the topic. However, this also makes it difficult to identify the physical drivers behind changes in the water levels, and might introduce systematic errors. Below, I provide suggestions on how these issues can be verified and mitigated, if necessary.

Kind regards,

Methods

- The regression model includes both discharge and water level at the upstream station. As they depend on each other, the model is not parsimonious. As a consequence, the columns for Q and z_{up} of the regression matrix will be close to collinear so that small changes (errors) in the data can result in large changes in the coefficients α and γ even if the fit is good. Possible changes of the coefficients over time might thus be regression artefacts. This should be ruled out by verifying that Q_{up} and z_{up} are not strongly correlated.
    - If the correlation is weak, then the model is robust, but then it would be insightful to elaborate on why the upstream water level and discharge are unrelated. The comment "*influenced by the dynamics of [] tributaries*" (l. 119) is unclear. The water

level is uniquely determined by the backwater curve as long as the daily averaged water level does not change rapidly in time. Therefore, tributaries upstream of the inflow boundary influence downstream levels only through their discharge. Do the authors refer to tributaries downstream of the upstream station?

  - If the correlation is strong, then it is better to replace the terms $\alpha Q + \gamma z_{\mathrm{up}}$ with the non-linear term $a Q^b$. This model is less ambiguous. In my personal experience, the coefficients a and b of the non-linear model also give much more insight into the influence of the river discharge on the mean water level along tidal rivers.

- The regression model does not include the effect of the tides on the mean water level. However, this effect is not negligible during periods of low river flow (*LeBlond*, 1978). This introduces a systematic error. As the Three Gorges dam increased river discharge during the low flow season, this can bias the results. It is, therefore, reasonable to include the influence of tides on the mean water level in the regression model. For example, *Kukulka and Jay* (2003) suggest the regression model linear in h^3:

$$h^3 \approx a\, Q_{\mathrm{river}}^2 + b\, |z_{\mathrm{tide}}|^2 + c,$$

while (*Kästner et al.*, 2019) suggested linearizing the backwater equation, which can be readily approximated in a regression model linear in h (or z).

- The independent variables are not normalized in the regression model so that the coefficients have very different magnitudes ($O(\alpha) = 10^{-5}$ while $O(\beta) = 1$). It is thus not obvious which predictor (downstream or upstream level) has the largest influence at a particular location. This can be revealed by normalizing the independent variables by their standard deviation before the regression:

$$z = z_0 + \alpha\, Q/\mathrm{std}\,(Q) + \beta\, z_{\mathrm{down}}/\mathrm{std}\,(z_{\mathrm{down}}) + \gamma\, z_{\mathrm{up}}/\mathrm{std}\,(z_{\mathrm{up}})\,.$$

This is preferable to the order in the study, where variance is normalized after the regression.

- Interpolation of slopes and uncertainty estimates (Figure 4 and 5, lines 190ff)

  - There is a mistake in the slope calculation. The values should be in the order 10^{-5}, not 10^{-8}. The distance between the stations was probably not converted from km to m.
  - Determining the slope from by higher-order (Hermite) interpolation is not meaningful here. This is because the error (of the

slope) is amplified at the interpolated values between the stations. As a consequence, the interpolated slope has unrealistic local extrema at the midpoints between stations (Figure 5). The error of the cubically (Hermite) interpolated slope at the midpoint between stations is about 1.8 times as large as the errors of the levels at the stations. Since the error of the levels is about 10%, the error of the slope is about 20%. The local maxima of the slope, as well as the difference between the pre- and post-TGD period as indicated in Figure 5 are therefore insignificant. The interpolation error (of the slopes) can be considerably reduced by calculating the slopes at the midpoint between two stations and then linearly interpolating the slopes between the midpoints. In this case the error of the slope is only 0.7 times that of the error in levels. If the authors want to retain cubic interpolation, then the spurious extrema can be suppressed by fitting the 4 coefficients of the cubic polynomial with all 5 stations in a least squares manner.

- As the model is not parsimonious, it might fit well even if the regression coefficient are uncertain, as multiple parameter combinations can result in similar good model performance. A good way to assess the uncertainty is bootstrapping (*Efron and Tibshirani*, 1994). Simply split the time series into blocks comprising of one month, this reduces the effect of serial correlation. When there are n blocks, randomly choose $\sqrt{n}$ blocks and fit the model. Repeat this a few hundred times. The standard error is simply the standard deviation of the estimated parameters. The standard error of the coefficient, predicted levels and slopes can then be indicated indicated with error bars in Figure 3 and 5. The cubic interpolation results in larger errors at midpoints between sections, so errors bars are best placed there.

Minor

Title estuary → upper estuary

35 The term "analytical solution" is misleading, as the water level is still determined by (numerically) integrating an initial value problem (eq. 22 in *Cai et al.* (2016)).

44 *Kukulka and Jay* (2003) should be referenced here, as an important regression model for the mean water level of tidal rivers.

45 *"these methods suggest that water level dynamics in estuaries are highly nonlinear and nonstationary"* This sounds as if water levels in tidal are

difficult to analyse and predict, and that looking at tidal cycle/average is a novel idea. However, there is a large amount of publications how water levels can be approximated well on a cycle-by-cycle basis, see the works of the groups of Savenije, Godin, Jay, Hoitink, and Friedrichs.

49 The reference to Darcy is dubious. Even if the surface level can be predicted by a linear regression model, it is still turbulent flow (quadratic flow resistance), which is very different from groundwater flow (linear flow resistance).

89 Mark Gaoqiaoju on the map in Figure 1

93 *"we mainly concentrate on the tide-river dynamics"* This is not the case, since, as commented by me before, the tidally induced water level offset is not included in the regression model.

110 Mention here, which of the stations where chosen as the upstream and the downstream end (Datong and Gaoqiaoju?).

169 *"linear"* is misleading here. The water depth in the upstream estuary most likely scale like $h \approx Q^{2/3}$. The non-linearity is just hidden by including z_{up} in the regression model.

248 The conclusion *"[at the downstream stations] tide dominates [the tidally averaged water leve]"* sounds odd, as the regression model applied in this study does not explicitly account for the tidally induced water level offset. It only includes the tidally averaged water level at the seaward station. However, at the river mouth the tidally induced water level offset is negligible as it integrates along the estuary, c.f. *Kästner et al.* (2019) and *Cai et al.* (2016). So, no meaningful conclusion about the tidal influence can be drawn. The model probably indicates that fluctuations of the sea level unrelated to tides, such as wind, ocean-temperature and ocean-salinity, dominate the mean water level dynamics near the sea. It would be insightful to actually determine the tidal influence by including it explicitly in the regression model.

248 The river discharge influences the salinity gradient, and with it the variation of the water level at the reference station at the sea (*Savenije*, 2012). The influence on river discharge on the downstream stations might thus be larger than indicated by the model.

257 This paper has → We have

263 It was shown → We show

271 How relevant are (seasonal) changes of roughness and bedforms, due to changes in water and sediment supply by the dam?

Figure 2 It would be more meaningful to plot $(z_{\text{pred}} - z_{\text{obs}})$ vs z_{obs} and to use smaller dots which do not overlap that much. This would reveal better any systematic variation.

Figure 3 Add subplots titles, like Discharge, Downstream level, Upstream level so that the figure can be interpreted without looking up the meaning of the coefficients α, β, γ.

Figure 3 begins from Jiangyin $\rightarrow$ upstream of Jiangyin

Figure 7 The average annual average hydrograph of the post-TGD period is corrupted by high-frequent fluctuations of the hydrograph. The graph would be clearer if the fluctuation is removed it through by smoothing with a sliding window. A triangular window with a width of 30 days seems appropriate. Smooth the data for the pre-TGD period as well, for better comparison.

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