Hydrol. Earth Syst. Sci. Discuss., 10, C8110–C8114, 2014
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Hydrology and Earth System Sciences
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10, C8110–C8114, 2014

Interactive Comment

Interactive comment on "Determining slack tide with a GPS receiver on an anchored buoy" *by* M. Valk et al.

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Received and published: 5 March 2014

Dear reviewer #1,

Thank you very much for your detailed reading and the many suggestions made to improve our paper. In your review you raise two issues related to the two basic assumptions that you marked a) and b): a) under 'no net force' on the buoy-chain system, the chain is completely relaxed as shown in Fig.4 (position labelled as position 2), and b) zero net flux (slack tide) coincides with zero net forces on the buoy-chain system.

a) Indeed there are in principle an infinite number of positions of 'no net force' whereby the chain hangs slack. The chain can in principle be coiled-up on the estuary bottom. However, at the moments of slack (be it HWS or LWS), there is only one possible

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position. This follows from simple reasoning. When the tide approaches slack and as the stream velocity reduces, the buoy gradually moves from the extreme extension to the position of rest (position 2), pulled by the weight of the chain. On the estuary bottom, the chain remains tense until the last moment, as a result of the gradually reducing flow drag on the buoy. Only when the velocity drops to zero will the chain hang vertically. This process is identical, although symmetric, for both HWS and LWS. Even if the chain experiences drag as well, this does not change the process, as long as slack occurs simultaneously over the depth.

b) This brings us to your second point. What if the drag on the chain is substantial and if the slack does not occur simultaneously over the depth. In an estuary with a longitudinal salinity gradient, the logarithmic velocity profile of turbulent flow is disturbed by gravitational circulation. This implies that during flood, the velocity distribution over the vertical is almost constant and that slack occurs almost simultaneously over the depth. During ebb, however, the stream velocity near the bottom is substantially lower than near the surface as a result of gravitational circulation and the bottom slacks earlier than the surface. Near LWS, this might cause the chain to experience an inland drag while the buoy is still experiencing an outward pull. Although the drag on the buoy will be dominant, this may cause the chain not to be completely vertical under the buoy at the moment of slack. In our paper we do not take this factor into account, assuming that the drag on the buoy is dominant and that the effect on the position of the chain on the estuary bottom will be minor.

In the final paper we shall add a few paragraphs to briefly discuss these issues.

We would like to thank you for your detailed editorial improvements, which we shall all incorporate in the final paper.

With regard to 'some notes on the manuscript' we provide a reply below on the following main issues. Typos and other suggestions will be taken into account in the revision of the manuscript.

Page 16 (and also the comment on page 18 on the total standard deviation), where error spreading includes an uncertainty component for the slack tide extension / position. Typically the slack tide extension will be determined once, at the start of the experiment / measurement campaign. Therefore there is no variability in this component over the measurement campaign. However, taking a global view, and knowing that the way of determining the slack tide extension is not perfect (uncertainties in anchor position and chain length for instance) imply that the resulting slack tide extension carries some uncertainty. If one would be able to check it with a perfect ground-truth, one will find some deviation. Hence, to provide realistic (overall) performance figures of the method, also in an absolute sense, we need to account also for this uncertainty.

P.16 l.8. The buoy dynamics are defined as the motion that the antenna experiences due to the interaction of the buoy with the wind and waves. We determined this value with a highly accurate GPS system (we could neglect the measurement error) during the one week measurement campaign. This implies this value is only valid for a certain sea state.

P.16 ll. 21-28 The GPS sampling frequency is 1 Hz, and the observed GPS positions are not perfect (hence we account for that in Eq (5)). Next the buoy is not just floating/flowing with the water current, there can be waves, and in particular wind may cause the buoy to tilt, so - even when the observed GPS position would be perfect - we do not observe the position representing the center of mass of the buoy, as the GPS antenna is fixed on top of the buoy.

The window of Figure 6 is chosen in such a way that the buoy is in a stationary position. As Figure 6 shows there is no significant trend, only a high frequent noise signal (caused by the buoy dynamics). It is chosen that the maximum duration (almost 2 hours) – is representative for the entire dataset (7 days). However, indeed for extreme weather conditions this value might be larger.

The buoy has a diameter of 2.60 m and the height would be approximately 3 meters above the water line.

Indeed, most buoy dynamics will be greater for a larger sea state – this correlation is not investigated.

P.18 ll.17-18. Standard deviations can be summed in a quadratic manner given the fact that they are uncorrelated.

P.19 ll.11-12, P.20 ll.3-4 and Fig. 9 First we obtained an average buoy trajectory based on multiple tidal cycles. Next, we determined the probability of detection (gamma) for each position of the buoy (the buoy position is a function of time). Thresholds on the slack position have been set (see Figure 7). As the buoy progresses over the trajectory the probability of detection increases.

P.21 ll.18-19. This paper presents a method to estimate the moment of slack tide. However, the mentioned standard deviation details the phase lag, which is also determined by High or Low Water. The detection of high or low water is done with a certain accuracy, and propagates into the estimated phase lags. Therefore, we conclude that the estimated standard deviation of slack tide is better than the standard deviation of the phase lag.

P.21 L.21. This is done with a moving average filter set to 300 seconds.

P.21 ll.26-27. Yes, we could include figures of non-smoothed velocity in order to support this statement. .

P.22 ll.15-16. That data is not available, only cross sections are measured during the yearly RWS discharge measurements.

P.23 ll.21. This paper presents a method to estimate the moment of slack tide. However, the mentioned standard deviation details the phase lag, which is also determined by High or Low Water. The detection of high or low water is done with a certain accuracy, and propagates in to the estimated phase lags. Therefore, we conclude that the estimated standard deviation of slack tide is better than the standard deviation of the

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phase lag

P.23 l.27. This is demonstrated in figure 10.

P.24 l.2. Decimeter level i.e.. 0.1 – 0.2 m

Fig. 8. This is explained on P.19 l.15-20

Fig. 12. Please, provide a label for the abscissa. Will be included in the next revision.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 13743, 2013.