Earth Surf. Dynam. Discuss., 1, C338–C351, 2013
www.earth-surf-dynam-discuss.net/1/C338/2013/

Interactive comment on "Observations of the effect of emergent vegetation on sediment resuspension under unidirectional currents and waves" *by* R. O. Tinoco and G. Coco

R. O. Tinoco and G. Coco

tinocor@unican.es

Received and published: 28 November 2013

Response to Anonymous Referee #1 comments on "Observations of the effect of emergent vegetation on sediment resuspension under unidirectional currents and waves"

28 November 2013

Authors: Tinoco, R.O. and Coco, G.

The authors are thankful for the reviewer's insightful and constructive comments. All raised concerns are being addressed and it will certainly result in a better manuscript. The response to specific comments and technical corrections are covered below.

Specific comments:

1. The concentration measurements were made at a single height, 5 cm above the bed, a height which is a significant fraction of the 16 cm total water depth. It can be argued that the authors' use of the terms sediment resuspension

"threshold" and "critical velocity" for sediment resuspension is, if not incorrect, at least misleading. My reasoning is the following. Though not explicitly discussed by the authors, the dynamical role of smooth-sided round cylinders protruding vertically from a mobile bed is in my opinion, at least in part, to inject vertical vorticity into the nearbed flow, and thereby provide a mechanism for raising particles from the bed higher into the water column than would otherwise be the case. Thus, in the absence of cylinders and therefore a strong source of vertical vorticity, particles would be resuspended to lower heights. With a single sensor at a fixed height quite high in the water column, it seems quite conceivable to me that, when cylinders were absent and/or at very low densities, material actually in suspension – but lower in the water column – would have passed under the sensor undetected. Consequently it is not obvious to me that the critical velocities estimated by the authors can be directly compared to the values predicted by the standard semi-empirical formulae (i.e. Table 3 vs Table 4).

We agree with the reviewer that the manuscript would certainly improve if we addressed with more detail the dynamical role of the cylinders. We would like to add a new reference (Nepf and Koch, 1999) and text in the form of:

"For the denser cases, even at low speeds, scour begins to occur, the wake behind each cylinder contributes to lifting the sediment, interacting with the adjacent wakes and the reduced current, allowing for the sediment to stay in suspension for the instruments to capture. Nepf and Koch (1999) observed a similar behavior, with vertical secondary flows generated by vertical pressure gradients behind obstructions protruding from the bottom of a rigid bed.".

With respect to the height of the instrument, we agree with the reviewer that the measurements should be made as close to the bed as possible. However, with the OBSs used for our experiments, the 5cm above the bed is the closest we can get with the proposed, least intrusive configuration, without having the sensors buried in the sand

during the experiments. Even with such a physical limitation, we consider the results to be representative of the impact of the array of cylinders in sand transport and resuspension, and also a good indicator of thresholds in the absence of obstructions: while one can visually determine thresholds of motion by looking at grains beginning to roll, as done in benchmark works as Manohar 1955, Vincent 1959, Carstens et al. 1697, Rance and Warren 1698, or Madsen and Grant 1976, with the inaccuracies and subjectivity that it involves, finding resuspension thresholds is even more complicated, and the use of OBS gives us a good way to measure it. We would like to modify the manuscript to include:

In the Laboratory experiments section:

"The distance of 5 cm above the bed was determined by the physical dimensions of the instruments, such that the sensors were not in contact with the bottom and would not be buried in the sand during the experiments"

And in the Discussion - Currents section:

"The height of the measurements (5 cm above the bed) must also be considered, since the physical dimensions of the instruments prevent us from getting closer to the bed, where material could be already in suspension at lower elevations before the OBSs are able to record it."

2. In a related vein, the authors state on p.13 that their data in Figure 12 for the waves only, no cylinder case are consistent with the 0.112 m/s Komar and Millar estimate for the critical velocity for sediment resuspension. To me, the "threshold" would be defined by a sharp increase in concentration: i.e. an abrupt change in slope in the concentration-velocity relation. I look at Figure 12 and see critical values for n =0 closer to 0.3 and 0.2 m/s at x = 0 and x= 3 m respectively, which are a factor of 2 or more higher than 0.112 m/s. At first I thought there must be a typographical error in the text, but it seems not, as

Table 3 does indeed indicate an observed value of 0.12 m/s for n = 0. This 0.12 m/s estimate seems to me inconsistent with the data. The authors need to clarify/explain exactly how they obtained their threshold estimates from the data.

The thresholds were obtained from the data as the velocities at which the OBS started recording concentrations higher than the background levels. As the reviewer points out, for the case of waves there are clearer points where a drastic change in concentration is observed, but material was already in suspension before reaching those points.

A clarification would be added to read:

In Discussion -Currents:

"The determination of thresholds from experimental data can be a topic of discussion by itself. In our case, the thresholds were determined by finding the velocity at which the instrument starts recording concentrations higher than the background levels."

And in Discussion -Waves:

"We notice that an abrupt change in concentration is apparent for all cases at specific velocities, but the determined thresholds (velocities at which the concentration exceeds the background levels) occur at lower values."

3. The authors state that their experiments were carried out with monochromatic waves but the surface elevation time series' in Figure 13 indicate that the waves were definitely not monochromatic: i.e. they were either highly skewed or distinctly sawtoothed, depending upon cylinder density and location relative to start of the patch. In either case, the waves necessarily contain phase-locked harmonics and are therefore not monochromatic. I suggest "regular" or possibly "regular periodic" would be the correct term.

The authors agree with the reviewer, and the term "monochromatic" would be replaced by "regular" throughout the text.

4. Also on the topic of the character of the wave forcing, I understand from the text on the bottom of p. 10 that the waves shoaled after leaving the paddle due to the presence of a ramp leading to the sand bed, resulting in significant wave transformation even in the absence of cylinders. But, as indicated by the data in Figure 13, there are also very significant differences in the character of the waves depending upon whether or not cylinders were present: i.e. for n = 0 the waves were highly skewed, for n = 250/m2 they were highly asymmetric. I would like the authors to comment on the possible effects these differences in the 3rd-order wave statistics might have had on their observations of sediment resuspension, and the implications if any for wave-vegetation-sediment interactions in nature.

The paddle generated monochromatic waves, and they transformed as they passed through the altered bottom of the flume (ramps added to contain the sand) such that the nature of the waves was different once they reached the location of the array of cylinders. We would modify the manuscript accordingly, to read:

"Even when monochromatic, sinusoidal waves were generated at the paddle, shoaling due to the ramps built to contain the sand, and the changes in the bottom material: concrete-steel-sand result in significant wave transformation. In Fig. 13 it is noticed the skewed, saw-tooth shape nature of the waves as they reach the middle of the array (x_c=3m). The effects of velocity and acceleration skewness on sediment transport are an active area of research and, as pointed out by Hoefel and Elgar (2003) and van der A et al. (2010), are not well understood. However, it is known that as the waves enter shallow water (representative of the habitat of our considered species), sinusoidal waves can transform into skewed, saw-tooth shaped waves with a sharp front as the ones observed in Fig. 13, leading to higher onshore velocities that may result in onshore net transport. Since we do not have enough data to compare different skewness and asymmetry conditions, we limit the study to the measured velocities under the achieved wave conditions and their respective suspended sediment concentrations. ".

5. Several aspects of the experimental design need clarification. In Figure 2 the cylinders appear to be attached to a base plate beneath the sand. I would like to know much more about how the cylinders were emplaced, and the order in which things were done, in order to have a better grasp of the initial condition of the bed prior to each run. a) How was the sand surface prepared between the trials with different cylinder densities and runs at different flow speeds/wave heights within a trial? Was the surface re-flattened between trials, or between runs? b) Were the cylinders removed and replaced between runs, or were the cylinders installed at the highest density, and then selectively removed to produce progressively lower densities? c) Were replicate trials – i.e. trials with the same cylinder density but different random configurations – carried out?

We agree with the reviewer that the experimental section would greatly benefit with additional details. We would expand the description of the experimental series to read:

"The 0.40 m long cylinders were individually attached with screws to six 1 m long, 2 m wide PVC plates fitted to the bottom of the flume and later covered by the 0.20 m deep sand bed, creating the array of cylinders protruding 0.20 m above the bed. Three densities were considered to represent a sparse, intermediate and dense population: n={25,150,250}m^{-2}. The study began with the densest case, and selected cylinders were removed to achieve progressively lower densities. Once a cylinder was removed, it was not possible to install it again, such that a single random configuration was used for each density.".

"The sand was flattened manually before each series, using a floor squeegee for the non-populated areas and a cold water high pressure cleaner within the cylinders array, flattening again after the maximum velocity was studied.".

6. The cylinders were arranged in random patterns. Is there evidence in the literature indicating that the species being mimicked in these experiments – mangrove roots and fan worms – are similarly arranged at random in nature?

We based our distributions on reports of size and density, and on photographic evidence where no structured arrays were observed. We are aware of some species creating arrays in regular structures (e.g. mussel beds in van de Koppel et al. 2012) but we found no report of such behaviour for our selected species.

Technical corrections:

(i) I was puzzled by the use of the term "agitator" running at frequency fp (p. 8, top), whereas fp is indicated elsewhere as the "pump" frequency (Fig. 5), which would consistent with the "p" subscript. Figure 5 also indicates that the flow speed is proportional to fp, so it makes physical sense that it would be a pump, whereas agitator suggests a device used to introduce turbulence into the flow. If "agitator" is really what is meant, please clarify how it differs a pump. Else, if "pump" is what is meant, please use this term instead.

The term "agitator" would be replaced by "pump" for consistency.

(ii) On p. 9, the phrases "large alterations" and "significant scour" are used to

describe the deformations in the bed resulting in the decision to stop a trial. This terminology is woolly, and too many of us are guilty of its use, myself included. Here however, the authors' interest is in the sediment response to forcing in the presence/absence of vegetation interaction, of which bed deformation is a major component. Could the authors not therefore be more specific about what "large" and "significant" mean in this context?

Even small scour generates sand accumulation, and as water flows above these ripples, generates vortices that put sand in suspension even at lower velocities than required for a flat bed. (i.e. if we repeat the lowest velocity case after running the flume at maximum speed, without flattening once scour is present, the recorded concentration values are higher). Once this state is reached, we are past the threshold values sought and the series can be stopped. The manuscript should read:

"For each density, the series was stopped once scour became noticeable (see Figs. 3 and 4). Once sand starts accumulating behind the cylinders and bedforms start to appear, vortices are generated in the now perturbed bed, enhancing resuspension as compared to a flat bed case. Once such a state is reached, since we are past the threshold values sought, the series can be stopped".

(iii) p. 10 and later: "transversal" should be "transverse"

The corrections will be made accordingly.

(iv) p. 10, middle. The authors discuss the transverse standing wave induced by flow past the cylinders. Wouldn't the concentration peak be expected to pass the sensor twice per cycle, and therefore appear at twice the modal frequency in the Scc spectrum?

Two extra lines, at twice the modal frequencies would be added to Figure 7 to account for the reviewer's observation. No peaks are observed at twice the modal frequency in Scc. This is expected considering the instrument is oriented in the y-direction, such that with transverse waves, it can record a peak in the sediment lifted by its own wake only in one direction of the standing wave motion.

(v) p. 11, bottom, and later. The text states "To look at the correlation between the recorded velocities and concentrations, the frequency spectra are calculated: : :". This is incorrect. To investigate "correlation" between two time series one either computes the cross-correlation function, or the cross-spectrum.

Rather than the actual correlation, the authors want to show the observed similarities between both spectra. The text should read:

"To look for similar trends in the recorded velocities and concentrations, the frequency spectra are calculated..."

(vi) p. 12,line 6-7: "generated within the cylinders" should read "generated within the cylinder array"

(vii) p. 12, line 9: "that observed" should read "who observed"

(viii) p. 12, line 15: Suggest changing "the sole responsibles" to"solely responsible"

The corrections in points vi, vii and viii would me included in a revised version.

(ix) p.15, line 9-10. This sentence does not make sense. As stated in the first half of the sentence, there is a "clear distinction" which clearly depends on cylinder array density, so why would it be interpreted as "density independence" as stated in the second half?

The conflicting sentence should be removed, to read:

"The density of the array is a determining parameter on the early onset of sediment resuspension. There is a clear distinction between the resuspension behaviour of sparse and dense arrays.".

(x) Figure 5 caption. Please state the value of x at which these measurements were made. Also, there appear to be error bars within the symbols. Please state what they represent (i.e. are they possibly related to 5c above?).

The caption should be modified to state that measurements shown are at the center of the array (x_c=3.0m). Errorbars represent 95% CI.

(xi) Figure 6 caption. State the value of x at which these measurements were made. Also, it would be of interest to see these results for both values of x.

We would modify the caption to state that measurements are at the center of the array (x_c=3.0m). For the case of currents, only the values at the middle of the array are presented, once a development length has been passed.

(xii) Figure 7 caption. Modes 1 and 2 are indicated here, but these are the

frequencies of modes 2 and 3 given in the text on p.10. Please correct. Also, Sww is indicated in the caption, but Svv is the label on the Figure. Please correct.

The correction in the caption will be included in the final revised version to point to the correct modes, 2 and 3.

(xiii) Figure 7 and Figure 15 captions. Multiplying BOTH Svv and Scc by 10 to improve visualization as stated makes no sense. This could be accomplished by changing the y-axis limits.

We would modify the captions to make it more clear, to state that the actual magnitudes of S_{vv} and S_{CC} have been altered to improve visualization. Since only the frequencies were relevant for the point we want to make, we shifted the magnitude of each spectrum for an easier reading.

(xiv) Figure 15 caption. Please state what the green line is.

Captions would be modified to state that the green line indicates the period of the regular waves ($T = 2.5$ s).

(xv) Figures 3, 4, 9 and 10. Please state what the red line is. Also, I had to zoom in on these figures to be able to appreciate/see the scour and bedforms indicated by the green arrows. This will be fine I expect in electronic versions of the final paper, but will people reading the printed version be able to appreciate/see these changes? I suggest that the authors consider cropping the photographs vertically to remove the water surface, the upper 50% of the cylinders, and

the sediment subsurface, none of which are of much interest, and arrange the resulting images vertically in a page-wide stack so that the changes to the bed are revealed more clearly. Otherwise, unless blown up, these images are not very informative.

Images would be modified according to the reviewer suggestions, and the caption would state that the red line is a reference for the initial level of the flattened bed.

(xvi) Table 1. Please add a column listing the values of aD.

Two columns will be added to Table 1, including ad and aD.

(xvii) Table 2. Why list these parameter values for Hm > 0.05, when the results from these runs are excluded from the analysis, as stated on p. 9?

The nominal values for wave heights are 1-5cm, which were obtained at the paddle. Once the waves reach the measurement section, after passing the ramps, sand, and respective arrays, the measured wave heights are those shown in Table 2.

(xviii) Table 3 and 4 captions. Please state the value of x for which these numbers were computed.

We would modify the caption to state that measurements shown were taken at the center of the array (x_c=3.0m)

Added References

- Hoefel, F., and Elgar, S.; Wave induced sediment transport and sandbar migration, Science, 299, 1885-1887, 2003.
- Nepf, H.M. and Koch, E.W.; Vertical secondary flows in submerser plant-like arrays, Limnol. Oceanogr., 44, 1072-1080, 1999.
- van de Koppel, J., and Bouma, T.J., and Herman, P.M.J.:The influence of local- and landscape-scale processes on spatial self-organization in estuarine ecosystems, J. Exp. Biol., 215, 962–967, 2012.
- van der A, D.A., O'Donoghue, T., and Ribberink, J.S.: Measurements of sheet flow transport in acceleration-skewed oscillatory flow and comparison with practical formulations, Coast. Eng., 57, 331-342, 2010.