The authors thank the discussers for their interest and comments. The aims of the published work were

1. To examine the time development and mechanics of scour under simultaneous changes in water depth, speed and direction; and

2. To focus on the changes to flow intensity and the effect of these on the scouring process. The exact definition of equilibrium scour depth and generation of empirical formulae was not the aim of the study.

The authors suggest that the discussers may have misinterpreted the aim of the paper and thus the applicability of the data within it.

The discussers argue that the flattening of the curve in Fig. 12 cannot indicate approaching equilibrium since it does not account for the observed continuation of scour in the live-bed time steps. It is made clear that it is an approximate inference of equilibrium due to the limited number of tidal cycles. Continuing scour during the live-bed stages is present towards the end of the test, but the rate clearly reduces within each half-cycle (Fig. 12).

As stated, the average increase in depth reduced from 26 to 5% of the total depth in the last half-cycle. Furthermore, the clear water time steps do not introduce periods of zero scour; the majority of scour occurs in the live-bed time step, as expected, but scour is also observed in the non-live-bed time steps [Figs. 11(a and c) both show small changes in scour depth]. These periods also demonstrate the infilling and reshaping of the scour hole which is an important observation.

It is difficult to comment on unpublished data, and the discussers' Figure 1 is unclear, particularly the breaks in the data and the long period between ∼15 and 25 h when scour is absent. It should be noted that the authors' tests were not based on spring and neap tides; experimental conditions were set to examine the effects of tidal changes on the scour hole development, paying specific attention to the transition from clear-water to transitional to livebed conditions within a tidal cycle. The discussers present clearwater-only data in Fig. 1 and it is unclear how the flow, sediment, and cylinder parameters can be compared with the authors' data.

The discussers suggest that the choice of live-bed unidirectional flow for comparison will inevitably lead to a lower scour depth in tidal flow as two-thirds of the half-cycle is at conditions of lower scouring potential conditions. The comparison is intended to show that the flow intensity and direction affect scour development, which is supported by comparison with the unidirectional test. The sum of the live-bed time steps (totalling ∼2 h) do not show a similar scour depth to the unidirectional current. The authors inferred in the paper that this is related to changes in flow intensity and direction, which affect infilling and scour rates. These constitute two key independent variables in the authors' test and their effect on the scour time development process was a primary research question.

The authors have used a time-dependent scour model in a previous publication (McGovern et al. 2012), however, in this examination, it was the deliberate intention to compare the development of reversing flow scour with the development of unidirectional scour and predictions thereof. This was key to emphasizing the differences between unidirectional scour and reversing scour and thus it was appropriate to select unidirectional equations to enable that comparison.

It is not an expected result that the clear-water equation best fits the reversing scour data since its predictive capability for tidal conditions is not clearly demonstrated in the literature. The fact that neither the clear-water nor the live-bed equations provide a good fit supports the authors' suggestion that the processes involved in reversing scour are markedly different in their time development and mechanics to unidirectional scour; this is an important and novel result. Further, it is incorrect that two-thirds of each halfcycle were in the clear-water regime. The low-tide condition is transitional and the dominant bed regime is difficult to identify. One of the primary research aims was to identify the effect of time-varying flow intensity on the scouring process, which is why the flow intensities spanned a range of conditions known to affect scour development. Hence, the comparison in the paper is intended to help elucidate the differences between the mechanics of the reversing scour process by comparing the results with the unidirectional scour.

The authors also state that it may be an arbitrary relationship that the clear-water equation predicts the rate of reversing scour well; there is no indication that this means that the reversing current equilibrium depth is similar to that of the unidirectional clear-water depth, as discussed in the paper.

The authors are not fully able to comment on unpublished data and have some concerns with its use in comparisons with the paper. A full comparison is difficult if the field conditions are unknown. Uncertainties in the field data include, but are not limited to, the measurement time period, sediment type/stratification, wave conditions, and temporal changes in flow velocity, water depth, and direction. At present these are unknown and comparison to laboratory data can only be made with correctly scaled prototype conditions. Any extrapolation data is dependent on correct scaling and the results presented suggest lower scour depths in the prototype field. The authors clearly state that it is inappropriate to develop empirical equations from this data for those reasons and, in addition, encourage further investigation before any confidence in extrapolation to prototype is made.

The paper does clearly show that the mechanics and time development of scour in variable reversing flow is different to unidirectional flow. This is an important result that is not immediately apparent, particularly if field data does indeed show that the overall equilibrium depth is the same as unidirectional scour. Immediate installation and later retrofitting of scour protection requires knowledge of the extent of the scour hole and the shape and, particularly for the latter, the time to equilibrium; the authors' paper highlights that this may not be the same as for unidirectional scour and also elucidates that changes in flow speed, depth, and direction elicit dynamic responses in the shape of the scour hole that require further investigation.

Ripples are a potential scale effect, as the discussers suggest. However, it is not straightforward to quantify this. Furthermore, simply removing the ripples would replace one effect with another that is also not clearly quantifiable. Furthermore, the necessary artificial increase of velocity at laboratory scale leads to increased scour depths and rates. It is difficult to know the cumulative effect of each scale effect; one may reduce scour and the other may increase it. To leave the experiment as it is, the authors suggest that the scale effects are left as known phenomena, which encourages easier validation of future numerical models that can then be used for further investigation of the scale effects. Smoothing of ripples in numerical models may be subject to more difficulties.

The discussers state that their data on slope angles is apparently in agreement with the authors', and that this is not unexpected. However, the authors do not agree that this finding is clear from the literature. These results appear contrary to previous literature (e.g., Margheritini et al. 2006) and the key suggestion is that it is due to the variability of reversing flow intensity. This finding is important and suggests, regardless of equilibrium depth, the time development and shape of the scour hole in reversing currents is sensitive to flow variation. This may have an important implication on the shape of scour protection and its extent so needs to be further researched.

The presented scour-hole shape and time development data also suggest that the changes to the shape, slope, and extent under variable reversing currents are important considerations in the mechanics of the scour process that occurs in each time-step.

The authors made it clear that the suggested lower scour depth should be treated with caution, and invited further research to examine this. Therefore, we welcome further advances, data, and debate around this challenging topic

References

Margheritini, L., Martinelli, L., Lamberti, A., and Frigaard, P. (2006). “Scour around monopile foundation for offshore wind turbine in the presence of steady and tidal currents.” Proc., Int. Conf. on Coastal Engineering, ICCE, Coastal Engineering Research Council, Reston, VA, 2330–2342.

McGovern, D. J., Ilic, S., Folkard, A., McLelland, S., and Murphy, B. (2012). “Evolution of local scour around a collared monopile through tidal cycles.” Proc., Int. Conf. on Coastal Engineering, Coastal Engineering Research Council, Reston, VA.