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REPLY

Reply to the Comments of Bernard O. Bauer *et al.* (1995) on Velocity Structure and Sea Bed Roughness Associated with Intertidal (Sand and Mud) Flats and Saltmarshes of The Wash, U.K. *Journal of Coastal Research*, 10(3), 702–715.

Xiankun Ke, M.B. Collins and S.E. Poulos

Department of Oceanography
The University, Southampton Oceanography Centre
Southampton SO14 3ZH, U.K.

The comments made by Bernard O. Bauer *et al.* are constructive and provide additional references for the study: some of these were not available previously to the authors (*e.g.* Bauer *et al.*, 1992; Bergeron and Abrahams, 1992). Three particular questions were raised in the Discussion, which concerned: (1) the equations used for calculating the shear velocities (u_*) and roughness lengths (z_0); (2) inaccuracies introduced into the estimation of u_* and z_0; and (3) problems associated with the analysis of data collected over the intertidal zone and the conclusions drawn. Our responses to the various observations made are outlined below.

(1) Equations Used

In terms of their mathematical derivation, equations (2) and (3) presented by Bauer *et al.* (1995) are correct. However, equations (2), (3) and (4) of Ke *et al.* (1994) can provide approximate results if the correlation coefficient (r) between lnz and u is high *i.e.* the curves based upon backward and onward regressions are close to each other, eventually corresponding when r = 1.

In terms of representation of the physical processes involved, errors associated with the measurement of both x and y can exist. Therefore, both the backward and onward regression approaches are only approximate derivation and cannot satisfy perfectly the requirement of a Gaussian regression. With improvement in the measuring technology, we believe that instantaneous velocity profiles throughout the whole of the water column can be obtained; this may provide much higher certainty in the data interpretation and correlation coefficients (r). Alternatively, a new method of linear regression which takes both X and Y as independent variables can provide another solution (Gao, 1995). Under such conditions, it will then be irrelevant if height above the bed (lnz) or velocity (u) is taken as the X axis or Y axis in the regression procedure.

Based upon equation (4) presented in the Comments and when $r^2 = 0.8$, the potential errors caused by backward regression of u_* should be 25%; this compares with more than 50%, which has been claimed.

Backward regression, not onward regression, was used in the study as it is consistent with the approach adopted in earlier studies elsewhere *cf.* Dyer (1986). The results of the present study would be comparable then with those of earlier investigations in other marine environments.

(2) Inaccuracies in the Analysis

Although a critical correlation factor (r^2) of 0.8 was used in the study as being representative of logarithmic flow conditions, most of the backward regressions have $r^2 > 0.9$ (*e.g.* mean r^2 are 0.96, 0.91 and 0.97 for Stations 1, 2 and 3, respectively) (see Table 2, Ke *et al.*, 1994). Using the data collected at Station 3 as an example, the mean potential errors for z_0 and u_* caused by backward regression, compared to onward regression, are 16.6% and 3.3%, respectively. Adoption of the two different methods of analysis results in mean z_0 and u_* values of 0.32 cm and 0.80 cm/sec, and 0.28 cm and 0.78 cm/sec, respectively, for the sandflat at Freiston Shore in The Wash (Table 1). Thus, the errors introduced by the use of backward regression in this particular study are not as large as Bauer *et al.* (1995) have suggested, particularly in the case of u_*.

(3) Problems Associated with Data Analysis and Conclusions

The equations of Lettau (1969) and Wooding *et al.* (1973) have been used to derive z_0 from the scales of the bedforms in other investigations. Satisfactory results have been obtained, in comparison with z_0 values derived from velocity

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Table 1. *Onward and backward regressions of the velocity profiles for derivation of roughness length (z_o in cm) and shear velocity (u_* in cm/sec) at Station 3 (Freiston Shore, The Wash).*

Time	Depth	Velocity (cm/sec) at z(cm) above bed				Backward regression(2)					Onward regression(1)					Errors(%)+	
(BST)	(cm)	u_{82}	u_{41}	u_{21}	u_7	A	B	r	z_o	u_*	b_1	m_1	r	z_o	u_*	z_o	u_*
6:35	10				22.7												
6:45	45			13.8	11.0												
7:00	75	16.1	14.0	12.1	9.3	−1.50	0.37	0.99	0.22	1.09	4.07	2.71	0.99	0.22	1.08	0.4	0.1
7:15	100	14.5	13.8	11.7	9.2	−2.19	0.44	0.99	0.11	0.91	5.11	2.21	0.99	0.10	0.88	13.1	2.4
7:30	125	9.9	8.8	7.8	6.3	−2.46	0.70	0.99	0.09	0.57	3.54	1.43	0.99	0.09	0.57	0.7	0.3
7:45	140	7.8	6.5	6.0	5.0	−2.42	0.90	0.98	0.09	0.45	2.85	1.07	0.98	0.07	0.43	27.8	4.2
8:00	150	6.5	5.8	5.7	4.0	−2.06	0.96	0.96	0.13	0.42	2.39	0.96	0.96	0.08	0.38	55.9	8.6
8:15*	150	8.2	7.1	6.0	4.7	−1.36	0.71	0.99	0.26	0.56	1.94	1.40	0.99	0.25	0.56	2.8	0.7
8:30	150	8.4	7.1	5.4	4.6	−0.62	0.61	0.97	0.54	0.66	1.33	1.55	0.97	0.42	0.62	27.1	6.3
8:45	140	a10.3	7.0	5.3	3.9	0.81	0.37	0.95	2.25	1.09	−1.39	2.47	0.95	1.76	0.98		
		b	7.0	5.3	3.9	−0.23	0.57	0.98	0.79	0.70	0.58	1.68	0.98	0.71	0.67	11.3	3.6
9:00	125	11.9	10.1	8.3	6.3	−0.79	0.44	0.99	0.45	0.91	1.86	2.24	0.99	0.44	0.90	3.7	1.0
9:15	120	13.2	11.3	8.9	7.8	−1.14	0.43	0.97	0.32	0.94	3.14	2.20	0.97	0.24	0.88	33.3	6.6
9:30	80	a22.0	11.9	10.9	7.1	1.29	0.15	0.90	3.63	2.65	−4.51	5.38	0.90	2.31	2.15		
		b	11.9	10.9	7.1	−0.64	0.35	0.98	0.53	1.14	2.12	2.74	0.98	0.46	1.10	15.0	3.8
9:45	70		15.9	13.0	10.2	−1.24	0.32	0.99	0.29	1.27	4.11	3.11	0.99	0.27	1.24	8.2	1.9
10:00	35			16.2	12.8												
10:10	25				16.0												
Mean Values	Flood tide								0.15	0.66				0.13	0.32	16.8	2.7
	Ebb tide								0.45	0.88				0.32	0.85	14.5	3.4
	Co-tidal cycle								0.32	0.80				0.28	0.78	16.6	3.3

Note:
*HW time
a. Observed results; and b. data set used in the calculation: u_{82} at 8:45 was discarded in order to obtain an improved correlation coefficient between the data set; and u_{82} at 9:30 was discarded as the current meter was only just under water during the reading
+Errors are calculated in terms of $[\{(2)-(1)\}/(1)] \times 100\%$ ((1) and (2) are the values of z_o and u_* through onward regression and backward regression, respectively)

profiles (*cf.* SOULSBY, 1983; DYER, 1986). Hence, it is interesting to examine the application of such models to intertidal flat environments within the context of the present investigation, as z_0 values both from the velocity profiles and *in situ* measurements of bedforms have been obtained. For this geographical area, the z_0 values derived from the velocity profiles are much higher than those derived on the basis of the observed scales of the bedforms, particularly for the LETTAU (1969) equation. Even the deduction of an assumed 50% overestimation of z_0, in response to the use of backward regression, will not eliminate such differences. Moreover, it has not been our intention to provide a 'universal coefficient' for these equations, so that they can be used in intertidal flat studies; rather, to describe and compare a series of field observations. Other representations of roughness length (*e.g.* GRANT and MADSEN, 1982) and sources of seabed roughness are outside the original objectives of the study.

The main roughness elements on the mudflats of the area under investigation are the large-scale topographical features. For confirmation of this investigation, the results obtained from two new survey stations (in 1993) on the upper mudflat at Freiston Shore (The Wash) showed logarithmic profiles (with $r > 0.9$) over 60–90% of the tidal cycles and a mean z_0 of between 3.23–3.47 cm (using, in this case, backward regression) (KE, 1995). This pattern is similar to that derived for the lower mudflat (in 1992), as the associated topographical features are very similar (see Plate 1, KE *et al.*, 1994). Thus, the conclusion (2) of KE *et al.* (1994) is valid, but it should be noted that such a flow structure pattern may not necessarily be revealed during every tidal cycle.

The 'spike' in the z_0 value at HW + 0.5 hr at Station 3 is present only if all four current meter observations are used (see Figure 6(b), KE *et al.*, 1994). However, because the reading was particularly high, in comparison with the observations before and after, this measurement (M2, 82 cm above seabed) was removed in the plotting and calculation of the velocity profile and boundary layer parameters (see Figure 6(a) and Table 2, KE *et al.*, 1994). A similar procedure was adopted for the data at HW + 1.25 hr as the upper current meter (M2) was just within the surface of the water column during the reading. Hence, the current speed measured may have been affected by wind/wave action (Table 1).

The key to various current meter observations on the top diagram of Figure 6(b) was shown incorrectly, i.e. in wrong order, for which we apologize. Nonetheless, the spike (or higher value) of z_0 after HW has been observed at the boundary between the *Arenicola* sandflat and the upper mudflat at Freiston Shore not only in 1992, but also in 1993. This characteristic is considered to be caused by changes in the direction of the tidal current flow, in relation to the orientation of the bedforms (KE, 1995).

There should not have been any confusion concerning the calculations undertaken on the field data collected at Station 2. The removal of readings collected by current meter M2 was for the purpose of checking any improvement in the correlation coefficient and changes in the derived boundary layer parameters. With or without the inclusion of M2, apart from changes in the correlation coefficient, there are no large differences in the derived boundary layer parameters (*e.g.* z_0 values are similar and u_* values are 2.22 cm/sec and 2.32 cm/sec, respectively) (see Table 2, KE *et al.*, 1994).

In conclusion, the aim of the research undertaken and the paper published was to introduce the concept of flow structure within the boundary layer to intertidal flat areas, where sediment transport processes are very active. Likewise, the study is based upon field observations; these have been described and analysed. On the basis of the present discussion (see above), errors associated with derived mean values of z_0 and u_* (through the application of backward regression) are relatively small. Consequently, the results are representative of conditions prevailing at the sediment-water interface within the area investigated.

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