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APPLICATION OF WAVELET TECHNIQUES FOR THE DETECTION OF ENERGETIC FLOW EVENTS ASSOCIATED TO PARTICLE ENTRAINMENT

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Obtaining a better understanding of the processes that lead to the transport of coarse particles in fluvial, coastal and aeolian environments, is one of the fundamental problems in earth-surface dynamics. Near bed fluctuations exhibit a wide range of temporal and spatial turbulent scales, which may be associated to the entrainment of coarse particles exposed on the river bed surface.

This contribution initially reviews the recent theoretical developments (Diplas et al. 2008, Valyrakis et al. 2010, Valyrakis et al. 2011a, Valyrakis et al. 2012) and experimental results on the dynamics of initiation of motion of coarse particles. Those findings are extended by application of wavelet methods which are employed to extract the energetic flow events and derive characteristic statistical distributions of the features relevant to particle entrainment.

To this goal, a series of mobile particle flume experiments conducted at low mobility conditions (Celik et al. 2010, Valyrakis *et al.*, 2011a) are analyzed. The mobile particle flume experiments employ a He-Ne laser and Laser Doppler Velocimeter to obtain synchronous measurements of the temporal history of particle displacement and the longitudinal and transverse flow velocity components one diameter upstream of it. These records are analyzed to associate the dynamics of episodic particle entrainment to the passage of intermittently occurring near wall flow structures.

The application of the continuous wavelet transform is demonstrated and wavelet coefficient maps providing a representation of the instantaneous distribution of the energy of the flow signal are given. The continuous wavelet transform of the local streamwise velocity signal, $u(t)$, at a scale $\varphi>0$ and translation parameter, x, is defined as the convolution of $u(t)$ with ψ^*:

$$W_u(\phi, x) = \frac{1}{\sqrt{\phi}} \int_{-\infty}^{\infty} u(t)\psi^*\left(\frac{t-x}{\phi}\right)dt \quad (1)$$

where, $W_u(\varphi,x)$ corresponds to the value (or coefficient) of the wavelet transform and ψ^* denotes the complex conjugate of the basis (mother) wavelet function ψ, which has been scaled and shifted by φ and x, respectively. The square of the continuous wavelet transform ($|W_u(\varphi,x)|^2$) corresponds to the power of the signal. Thus, $W_u(\varphi,x)$ offers a representation of the energy content of the signal localized in time and frequency.

For example, a fraction of the time series of $u(t)$, shown in Figure 1a, is analyzed using equation 4 and Daubechies D3 as the mother wavelet. The corresponding plot of the continuous wavelet transform coefficients, for a range of smoothly varying scale and translation parameters, is illustrated in Figure 1b. The lower scales correspond to the high frequencies of the signal, while the higher scales refer to the slowly fluctuating components of the signal. Carefull observation of the displacement signal (Figure 1a) with the wavelet map (Figure 1b), reveals the existence of

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certain patterns with regard to when entrainment and deposition are initiated, corresponding to positive versus negative peaks (Figure 2b, Valyrakis *et al*., 2011b).

Emphasis is given on the characterization of the turbulent flow structures and the identification of the features of high energy flow events, just before and during particle entrainment and the role of strong sweep structures is delineated. It is observed that entrainment may be possible either due to single, high magnitude and duration flow events leading to rapid particle displacement, or triggered by a sequence of short-lived but still sufficiently energetic flow pulses, resulting to slower entrainments eventually.

It is shown, that sufficiently energetic and relatively long-lasting flow structures, with high enough energy over a range of wavelet scales are linked to flow events that entrain coarse particles. These results further support and are in agreement with the proposed energy based criterion for particle entrainment.

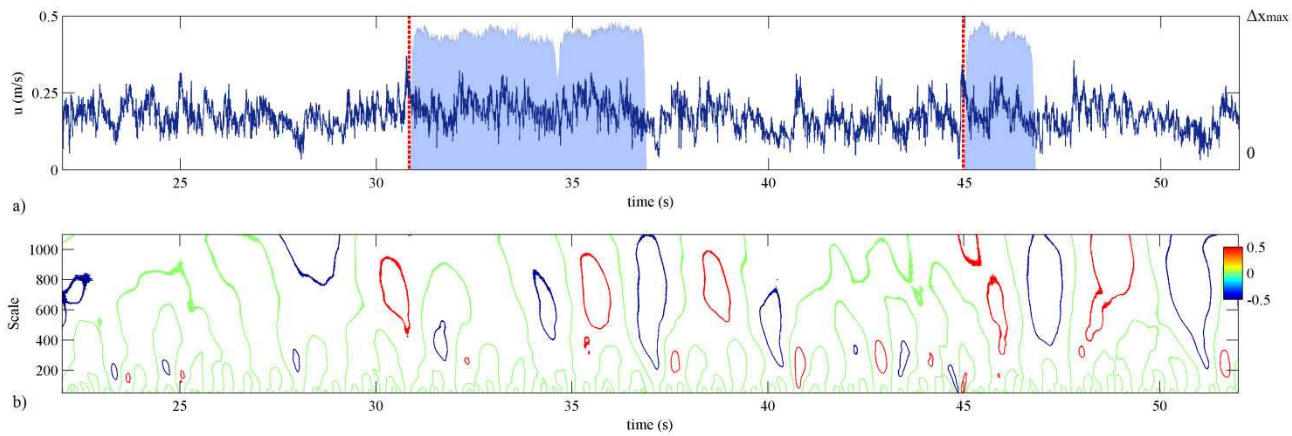

Figure 1 Illustration of the continuous wavelet transform of the streamwise velocity *u*: a) time history of *u* and of the displacement signal *Δx* (vertical dashed lines show instants of onset of entrainment), b) wavelet coefficient maps of the corresponding signal over a wide range of scales of interest.

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