KEYNOTE LECTURE
HIGH RESOLUTION 3-D ACOUSTIC DOPPLER VELOCITY AND SEDIMENT FLUX PROFILING IN LABORATORY AND ENVIRONMENTAL STUDIES: POTENTIAL AND LIMITS

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ABSTRACT

Different aspects of a pulse-to-pulse coherent 3-D acoustic Doppler profiling current profiler with resolution of the turbulence scales are presented. The potential of the instrument system for boundary layer studies in the laboratory, rivers and lakes is revealed.

An ultrasonic constant-beam-width transducer system (1 MHz) is introduced which is capable of generating an extended focal zone by electronically focusing the beam over the desired water depth range. Compared to a plane disc transducer, the higher beam directivity and the reduction in side lobe level leads to an increase of the signal to noise ration by up to 15dB and allows to significantly reduce undesirable spectral broadening effects. Signal treatment methods are discussed which will further reduce spectral broadening effects.

The potential of the same system in directly measuring instantaneous sediment concentration is demonstrated. The resulting acoustic particle flux profiler is a powerful tool for measuring simultaneously profiles of the instantaneous velocity and concentration over the entire water depth of a suspension flow by making use of the backscattering intensity in combination with the simultaneous Doppler phase information. It allows measuring quasi-instantaneous particle flux profiles with a sampling frequency of 25Hz in opaque liquids.

Using the focalised transducer, simultaneous 3-D velocity component profile measurements over the whole water depth are carried out in uniform, open-channel flow and in a small river. They verify existing laws for the distribution of mean velocity, turbulence intensities and Reynolds stresses. They also reveal the presence of coherent structures extending over the whole water depth both in the laboratory channel and in the central part of the river cross section. Coherent structures are aligned in the direction of the mean flow, showing no component in the transversal direction. In the lateral boundary layers of the river, wide adjustment zones are found in which the flow is strongly 3-dimensional.

Experimental results obtained in an open-channel, sediment-laden flow under capacity charge conditions document the event structure of sediment transport by the correlation between sediment concentration peaks and coherent flow structures. Higher order statistical properties of shear stress and of turbulent mass fluxes are compared. It is shown that the coherent structure dynamics are the same in clear water and in sediment-laden flows. Strong changes in the composition of the coherent structure cycle are observed between the near wall layers and the outer layers of the flow. Coherent structures of a burst cycle are found to be important contributors in the mass transport mechanism under highly turbulent flow conditions in open-channel flows. Nearly 50% of the suspended particle transport takes place in coherent structures, which occur during less than 30% of the time.