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Original
On the Very-Large-Scale Motions in Smooth-Bed Open-Channel Flows / Peruzzi, Cosimo; Poggi, Davide; Ridolfi, Luca; Manes, Costantino. - ELETTRONICO. - Vol. 21(2019), pp. 1-1. ((Intervento presentato al convegno European Geosciences Union (EGU) General Assembly 2019 tenutosi a Vienna, Austria nel 7–12 April 2019.

Availability:
This version is available at: 11583/2771414 since: 2019-12-04T18:12:58Z

Publisher:
Copernicus

Published
DOI:

(Article begins on next page)

Geophysical Research Abstracts
Vol. 21, EGU2019-17570, 2019
EGU General Assembly 2019

On the Very-Large-Scale Motions in Smooth-Bed Open-Channel Flows

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Bimodal distribution of the streamwise velocity pre-multiplied spectra in canonical turbulent flows (pipe, channel and boundary layer flow) is well documented in the literature. The two peaks of this distribution are associated with eddies of a defined size and they are called Large-Scale Motion (LSM) and Very-Large-Scale Motion (VLSM). These eddy structures are very important inasmuch they contain a significant fraction of the total kinetic energy of the flow. The LSMs and VLSMs size is proportional to the characteristic outer length scale of the flow δ (i.e. the radius, the channel half width and the boundary layer thickness); the former's length is a few δ while the latter is some tens of δ. However, little is known about their size and scaling in open-channel flows. The knowledge of LSMs and VLSMs in open-channel flows (i.e. rivers, tides and marine currents) is important, not only from a theoretical point of view, but most of all for their impact on key transport and mixing processes occurring in many geophysical flows (e.g., sediment dynamics, transport of nutrients, microorganisms movement, etc.). The present study aims to shed light into the dynamics of LSMs and VLSMs in open-channel flow through a laboratory study. The experiments were conducted in a recirculating open-channel flume 50 m long, 0.61 m wide and 1 m deep with a smooth concrete bed. During the experiments, the instantaneous velocity in the streamwise and bed-normal directions was measured with the aid of a 2D Laser Doppler Anemometer (LDA). The conditions in every experiment were that of fully developed smooth turbulent flow. The experiments were designed in order to highlight the influence of various relevant non-dimensional groups (presumably) involved on the LSMs and VLSMs dynamics. The main results are that the evolution of LSMs and VLSMs seems not to be affected by the Von Karman and the Froude Number (in the range of conditions analysed). As suggested also in the literature, the results hint that the non-dimensional parameter that mostly influences these vortices seems to be the aspect ratio. For values of the aspect ratio below 5 (that represent a condition of 3D motion, with the instauration of secondary flows in the flume), the size of these vortices is reduced by more than half with respect to a situation of an aspect ratio greater than 5.