SELF-SIMILARITY OF OPEN-CHANNEL TURBULENCE

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Abstract: Based on our previous modified log-wake law in turbulent pipes and boundary layers, we invent two compound similarity numbers *(Y,U)* where *Y* is a combination of the inner variable y^+ and outer variable ξ, and *U* is the pure effect of the wall. The two compound similarity numbers can well collapse mean velocity profile data with different Reynolds numbers into a single universal profile. We then propose an arctangent law for the inner region and a general log law in terms of *(Y,U)* for the outer region. Using asymptotic matching method, we obtain a self-similarity law that describes the mean velocity profile from the bed to free surface, and embeds the existing knowledge of the linear law in the viscous sublayer, the quartic law in the bursting sublayer, the classic log lag in the overlap, the sine-square wake law in the wake layer, and the parabolic law near the free surface. In particular, the proposed self-similarity law can well reproduce the velocity dip phenomenon. The proposed arctangent law, the general log law in terms of *(Y,U)* and the self-similarity law have been confirmed with the high-quality data, with different Reynolds numbers, including those of Nezu and Rodi, Lyn, Muste and Patel, Sarma et al., and the measurements of the Mississippi River. The proposed law can be used to establish an accurate stage-discharge relationship and accurately study bedload velocity and suspended entrainments.