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Modeling the mean flow and turbulence structures of vegetated flow based on double averaging procedure

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Rivers, wetlands and lakes with vegetation are of great research interest in flood control, contaminant transport, and biological conservation. While the near bed turbulence structures at the plant scales have significant effects on mass transport processes, resolving the flow field at individual blade scale still remains computationally impractical. This study developed a k-ε model to transform this 3D problem into a more tractable 2D problem by adopting a double averaging procedure. The conservation equations for emergent and submerged vegetated flows are averaged both spatially (horizontally) and temporally. To account for the stem scale turbulence, this model splits the TKE into shear kinetic energy and wake kinetic energy. The model has been validated against experiments of flow through emergent and submerged vegetation for mean velocities, turbulence intensities, Reynolds stresses, and different terms in the TKE budget. Results show that this model provides very good representation of the mean velocity and Reynolds stress. Additionally, it outperforms exiting k-ε models in the terms of TKE and dissipation rates, which are highly dependent on the stem scale both in submerged and emergent conditions. This model was also used to predict vegetation-induced mechanical energy loss in the term of Manning roughness coefficients, which show reasonable accordance with certain field observations. The proposed model is limited to flows with sufficiently large stem Reynolds number.