A tomography-based methodology for the mass transport characterization of snow is presented. Around forty samples, characteristic for a wide range of seasonal snow, are considered. Their 3D geometrical representations are obtained by micro-computed tomography and used in direct pore-level simulations to numerically solve the governing mass and momentum conservation equations, allowing for the determination of their effective permeability and Dupuit–Forchheimer coefficient. The extension to the Dupuit–Forchheimer coefficient is useful near the snow surface, where Reynolds numbers higher than unity can appear. Validation is accomplished by comparison with the experimental results of permeability already measured on the exact same samples, which were casted with dimethyl-phthalate in order to permit their later analysis using sublimation tomography. In addition, the anisotropy of the samples on multiple scales is determined. The methodology presented allows for the determination of snow’s effective mass transport properties, which are strongly dependent on the snow microstructure and morphology and cannot be described by only a few morphological characteristics such as porosity, pore or particle size. The calculated effective transport properties can be readily used in snowpack volume-averaged (continuum) models such as strongly layered samples with macroscopically anisotropic properties, for a wide range of environmental applications.