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DISCRETE ORDINATES SOLUTION OF THE RADIATIVE TRANSFER EQUATION AND MULTI-SCALE MODELS FOR THREE-DIMENSIONAL TRANSIENT PROBLEMS

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ABSTRACT Numerical methods for the solution of transient radiative transfer problems, in which the finite speed of light propagation must be accounted for, have received significant attention due to their practical relevance in several applications, such as for example in medical diagnostics and treatments. In these problems it is common to deal with strongly scattering media, where the diffusion equation (DE) is expected to perform well. However, the predictive accuracy of the DE becomes poor if the anisotropy of the scattering phase function is large, as well as near the boundaries and radiation sources. Therefore, the radiative transfer equation (RTE) is often preferred. However, several methods have been developed that combine the RTE and the DE, aiming at a more efficient and accurate solution procedure. Among them, two multi-scale models, referred to as micro-macro (MM) and hybrid transport-difusion (HTD) models, have recently been proposed and applied to one-dimensional problems. In these models, the radiation intensity is decomposed into macroscopic and mesoscopic components, yielding a set of two governing equations. The governing equation for the macroscopic component, which is independent of the direction of propagation of radiation, is solved using the standard finite volume method. The governing equation for the mesoscopic component is mathematically similar to the RTE, and may be solved using the same numerical methods used to solve the RTE, like the discrete ordinates method. The purpose of the present work is to extend these models to three-dimensional problems, and to assess their performance in either isotropic or anisotropic scattering media with collimated radiation. The results obtained reveal that the MM and HTD yield more accurate predictions of the transmittance signature than the RTE for isotropic or moderately anisotropic scattering media when first-order spatial/temporal discretization schemes are used, whereas they all perform similarly for second-order schemes. When the asymmetry factor approaches unity, good predictions are only achieved when accurate spatial and temporal discretization schemes are employed, and in such a case there seems to be no advantage in the use of the multi-scale models in comparison with the RTE, at least for the present test case.