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The Boundary Element Method - recent advances for electromagnetic scattering

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The Boundary Element Method (BEM), sometimes known as the Method of Moments, or Surface Integral Equation Method, is a well-established tool for simulating scattering problems in computational acoustics and electromagnetism. However, to date BEM has received relatively little attention from the atmospheric physics community, compared to other so-called "exact" methods such as Mie-Lorenz theory, the T-matrix method, the Discrete Dipole Approximation, and the Finite-Difference Time-Domain method.

In this talk we aim to demonstrate the potential of BEM for atmospheric physics applications, particularly in the simulation of light scattering by ice crystals. We have two objectives: (i) to report numerical results for 3D electromagnetic scattering simulations computed using the open source software library BEM++ [1], and (ii) to present 2D results for a novel "hybrid numerical-asymptotic" (HNA) BEM which permits accurate approximation with a small computational cost, even at large size parameters [2]. In doing so we hope to convince the audience that BEM is a serious and fast-developing competitor to the methods mentioned above.

BEM involves the numerical solution of a system of integral equations on the scatterer boundary, arising from an exact reformulation of Maxwell's equations via the Stratton-Chu formulae. Attractive features of BEM include: the reduction in dimensionality achieved by moving the problem to the boundary; the ability to handle complex geometries (e.g. ice crystal aggregates); and the recent development of powerful methods for solving the large linear systems of BEM equations arising in large-scale simulations.

BEM++ is a state-of-the art BEM software library, optimised for modern parallel computer architectures, which allows fast and accurate simulation of scattering problems. We present results for 3D electromagnetic scattering by a range of different ice crystal shapes at small to moderate size parameter, demonstrating that the performance of BEM++ in terms of accuracy and efficiency is highly competitive with established methods.

As with most "exact" methods, standard BEM becomes computationally expensive at large size parameters. In the second half of the talk we exhibit preliminary results for a non-standard HNA BEM whose computational cost is independent of size parameter. This method can be viewed as an extension of the PGOH method [3], in which the diffracted component of the boundary solution (neglected in PGOH) is computed using carefully chosen oscillatory BEM basis functions. Although the HNA BEM is limited to 2D at present, its potential extension to 3D could provide a method applicable across the whole size parameter range.

References

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