RAY TRACING FOR VISCOUSLY DAMPED WAVES IN THE THERMOSPHERE

RICHARD L. WALTERSCHEID 1, Michael Hickey 2

1 The Space Sciences Applications Laboratory, The Aerospace Corporation, El Segundo, CA
2 Department of Physical Sciences, Embry-Riddle Aeronautical University, Daytona Beach, FL

Ray tracing in the thermosphere is done using the eikonal equations where the movement of wave packets is predicted on the basis of group velocity. When the group velocity is a valid concept it is the same as the signal velocity, which in turn is the same as the energy flow velocity U = F/E, where F is the energy flux and E is the wave energy. For many systems of interest the group velocity is the same as the energy flow velocity. For highly dispersive waves and for dissipating waves however the association of group speed with energy flow can be problematic and in fact nonexistent [Walterscheid and Hecht, 2003; Thau , 1974]. Here we address the limits on the wave packet propagation by means of group velocity concepts in the thermosphere. We use a simple Boussinesq system to obtain analytical solutions (exact and approximate) for the group, signal and energy flow velocities and examine where they diverge. We then examine vertical group velocity obtained by means of various dispersion relations and compare them to the energy flow velocity U derived from our full-wave model. One can derive group velocity from the full-wave model by evaluating the change in vertical wavenumber with a change in frequency. The dispersion relation that gives the best agreement with this group velocity is one derived from the full linearized equations (HW). We find that all methods for calculating the group velocity break-down when the dissipation rate becomes comparable to the wave frequency, typically in the lower thermosphere. The group velocity calculations that are valid to the greatest heights are the HW and the Hickey-Cole dispersion relations [Hickey and Cole, 1987].

Hickey, M. P. and K. D. Cole., A Quartic Dispersion Equation for Internal Gravity waves in the Thermosphere, J. Atmos. Terr. Phys., 49, 889, 1987.

Thau, S. A., Linear dispersive waves, in Nonlinear Waves, ed. by S. Leibovich and R. Seebass, Cornell Univ. Press, Ithaca, N.Y., 1974.

Walterscheid, R. L. and J. H. Hecht, A reexamination of evanescent acoustic-gravity waves: Special properties and aeronomical significance, J. Geophys. Res., 108, 4340, doi:10.1029/2002JD002421, 2003

Ray tracing, thermosphere, dissipating waves

RICHARD L. WALTERSCHEID, Applications Laboratory, The Aerospace Corporation, El Segundo, CA