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Incompressible wave motion of inhomogeneous, compressible fluids in a gravity field

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We consider a particular class of linear and non-linear wave motions in fluids, in which pressure remains constant in each moving fluid parcel. The fluid is assumed to be inviscid, and wave motion is considered as an adiabatic thermodynamic process. An exact, analytic solution of linearized hydrodynamics equations is obtained that describes the wave motion in inhomogeneous, compressible, rotating fluids with piece-wise continuous parameters in a uniform gravity field. The solution is valid under surprisingly general assumptions about the environment and reduces to some classical wave types in appropriate limiting cases. Free waves in bounded and unbounded domains as well as excitation of wave fields by a point source are considered. Edge waves propagating along vertical and inclined rigid boundaries are found in rotating and non-rotating fluids. Allowance for three-dimensional variation of the sound speed and for arbitrary density stratification, including density discontinuities, makes the exact solution an attractive model of acoustic-gravity waves in a coupled ocean-atmosphere system. The new wave type complements classical exact solutions of linearized equations of fluid mechanics known as the Rossby, Lamb, Kelvin, and Poincaré waves, which provide much of the conceptual foundation of geophysical fluid dynamics. In addition to a wide class of exact solutions for linear waves, an exact solution of full non-linear hydrodynamics equations is found that describes a propagating wave in inhomogeneous, compressible fluids with piece-wise continuous parameters in a uniform gravity field. The fluid may have a free surface and a rigid boundary. Depending on the geometry of the problem, the solution has the meaning of either surface or edge wave. The exact solution describes a finite-amplitude wave in an otherwise quiescent fluid. Extensions to finite-amplitude waves in fluids with background currents are considered. Relation of the new exact solution for the non-linear wave motion of compressible fluids to the well-known Gerstner wave in incompressible fluids is discussed.