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On generalized linear flows: from compressible to sound-proof dynamics

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As acoustic motion is believed to be of minor importance in geophysical flow situations, several attempts have been made in past to construct sound-proof systems. The traditional anelastic and pseudo-incompressible equations are non-hydrostatic candidates of them. In an asymptotic expansion, thermodynamic reference profiles are introduced which depend only on the vertical coordinate and represent the dominant contribution of a hypothetical, resting basic state. Basically, the mass balance of the sound-proof systems is altered in a way that contributions due to perturbation pressure or perturbation density are neglected to inhibit acoustic motion. Recently, pseudo-incompressible equations based on a general moving basic state have been proposed. This generalization leads to a higher accuracy in the asymptotic expansion and to a comfortable opportunity for coupling large-scale, hydrostatic flows to non-hydrostatic motion. But, nevertheless, several important aspects of the generalized sound-proof systems are not well established.

In the line with this, the present study investigates linear flows in general moving basic states. Compressible as well as traditional anelastic and pseudo-incompressible dynamics for a resting basic state are revised. Energetics are discussed, casted in form of a Virial theorem and links to the variational formulation of the linear flow are deduced. Generalized Lagrangian mean theory is utilized to derive a general energetic measure. For compressible motion, it is composed of two parts: an acoustic energy and a generalized available potential energy. Consistently, the first is absent for sound-proof systems where the second is in exactly the same form for linear pseudo-incompressible dynamics. The derived available energy measure is a generalization of the well known available potential energy of internal waves, but depends on an arbitrary displacement vector in a 3D background pressure field. Generalized anelastic dynamics, if desired, can be constructed also satisfying the energetic structure. Relations between pseudo-energy, pseudo-momentum and the generalized energetic measure are established and the connection with the variational structure of the generalized linear flows is emphasized.