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QNSE THEORY OF ANISOTROPIC TURBULENCE AND DISPERSIVE WAVES IN STABLY STRATIFIED ATMOSPHERE AND OCEANS

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Atmospheric and oceanic flows feature anisotropic turbulence and dispersive waves on all scales. Small-scale turbulence is modified by internal waves, larger-scale turbulence comingles with inertial waves and on the largest scales turbulence interacts with Rossby waves and their off-springs. The dynamics of the turbulence-wave compound determines the character of the flow, its transport properties and energetics. Here, I will survey the progress achieved in understanding and modeling of turbulence – internal wave interaction using the quasi-normal scale elimination (QNSE) theory.

QNSE is a spectral theory that allows one to successively eliminate shells of small scale modes and analytically compute compensating changes in eddy viscosity and eddy diffusivity. With partial scale elimination, QNSE produces subgrid-scale parameterization for LES. When all fluctuating scales are purged, one obtains a spectral analogue of a Reynolds stress model. In this approach, turbulence and waves are not separated but accounted for as one entity.

Some of the prominent results of the theory are the derivation of the coupled, scale-dependent, vertical and horizontal eddy viscosities and eddy diffusivities; reproducing the dependency $Pr_t=f(Ri)$; demonstrating the absence of the critical Ri (in the sense of turbulence laminarization); analytical derivation of the vertical spectrum of the horizontal velocity and temperature; analytical derivation of the Osborn mixing model in the ocean; clarification of the role of turbulence and waves in mixing of momentum and scalars. In the limit of weak stratification, QNSE recovers early theories of stably stratified turbulence and shows how they need to be modified to account for flow anisotropy.