Geophysical Research Abstracts, Vol. 7, 00047, 2005
SRef-ID: 1607-7962/gra/EGU05-A-00047

A spectral closure-based model of turbulence for geophysical applications

S. Sukoriansky (1), B. Galperin (2), V. Perov (3)

(1) Mechanical Engineering, BGU, Beer-Sheva, Israel (Contact Email semion@bgu.ac.il), (2) Marine Science, USF, St. Petersburg, Florida, (3) Swedish Meteorological and Hydrological Institute, Norrköping, Sweden

Models of planetary, atmospheric and oceanic circulation involve eddy viscosity and eddy diffusivity, K_M and K_H, that account for unresolved turbulent mixing and diffusion. In the simplest approach, K_M and K_H are assumed constant; more elaborate schemes involve various closure assumptions which yield flow-dependent eddy viscosity and eddy diffusivity. The most sophisticated turbulent closure models used today for geophysical applications belong in the family of the Reynolds stress models. These models are developed for the physical space variables; they consider a hierarchy of turbulent correlations and employ a rational way of its truncation. The ultimate goal of these models is to relate the Reynolds stresses and turbulent fluxes to the gradients of the mean fields and, thus, obtain expressions for K_M and K_H. In the process, many unknown correlations are related to the known correlations via "closure assumptions" that are based upon physical plausibility, preservation of tensorial properties, and the principle of the invariant modeling. According to this principle, the constants in the closure relationships are universal, i.e., they can be found in simple, neutral and well-controlled experiments and then used, unchanged, in much more complicated flow configurations. Although a great deal of progress has been achieved with Reynolds stress closure models over the years, there are still situations in which these models fail. The most difficult flows for the Reynolds stress modeling are those that involve transitions and waves because these processes are excluded in the closure assumptions.

An alternative approach of deriving expressions for K_M and K_H can be designed in spectral space. We have developed a spectral model that produces expressions for eddy viscosity and eddy diffusivity based upon a self-consistent procedure of small-scale modes elimination. At present, this model can be applied to neutral, stable and

weakly unstable shear and shear free flows; however, it may be extended to other flow configurations as well. The procedure of small-scale modes elimination, or coarse-graining is based upon the quasi-Gaussian mapping of the velocity and temperature fields using the Langevin equations. Turbulence and waves are treated as one entity and the effect of waves is easily identifiable. In case of stable stratification, the model yields a dispersion relation for internal waves in the presence of turbulence, internal wave frequency shift due to turbulence, and the threshold criterion of internal wave generation in the presence of turbulence. In agreement with large amount of atmospheric, oceanic and laboratory data, the model indicates that there is no a single-valued critical Richardson number Ri at which turbulence is fully suppressed by stable stratification. Furthermore, the model shows that there exists a range of Ri, between, approximately, 0.1 and 1, in which turbulence undergoes remarkable anisotropization; the vertical mixing becomes suppressed while the horizontal mixing is enhanced. Although, at large Ri, K_H decreases and tends to its molecular value, K_M remains finite and larger than its molecular value. This behavior is attributable to the effect of internal waves that enhance the momentum mixing. In the Reynolds stress models, this feature is not replicated; $K_M \to 0$ at some value of $Ri < 1$ which differs from one model to another.

The new spectral model has been implemented in the $K - \epsilon$ format and tested in simulations of the stably stratified atmospheric boundary layers over sea ice. The results of these simulations are in good agreement with the data collected in BASE and SHEBA campaigns.