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# Co-spectral budgets link energy distributions in eddies to bulk flow properties


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## ABSTRACT:


Connections are explored between spectral descriptions of turbulence and the mean velocity profile in the equilibrium layer of wall-bounded flows using a modeled budget for the co-spectral density. As a starting point, the co-spectrum is derived using a standard model for the wall normal velocity variance and a Rotta-like return-to-isotropy closure for the pressure-strain effects in the absence of stratification. The approach establishes a relation between the von Kar an ($\kappa$), one-dimensional Kolmogorov (CK), and Rotta (A) constants, namely, $\kappa=(4A/7CK)-3/4$. Depending on the choices made about small-scale intermittency corrections, the logarithmic mean velocity profile or a power-law profile with an exponent that depends on the intermittency correction are derived thereby offering a new perspective on a long standing debate[a,b]. The same co-spectral budget is then generalized to include the effects of stable stratification so as to predict the mixing efficiency associated with eddy diffusivity for heat, or equivalently the turbulent Prandtl number (Prt). Stably stratified flows are fraught with complex dynamics originating from the scalewise interplay between shear generation of turbulence and its dissipation by density gradients. A large corpus of data and numerical simulations agree on a near-universal relation between Prt and the Richardson number (Ri), which encodes the relative importance of buoyancy dissipation to mechanical production of turbulent kinetic energy. The Prt–Ri relation is shown to be derivable solely from the co-spectral budgets for momentum and heat fluxes. Here, the ratio of CK to the Kolmogorov-Obukhov-Corrsin phenomenological constant, and a constant associated with isotropization of the production whose value (=3/5) has been predicted from Rapid Distortion Theory, explain all the macroscopic nonlinearities[c].


## BIOGRAPHY:

Gabriel G. Katul received his B.E. degree in 1988 at the American University of Beirut (Beirut, Lebanon), his M.S. degree in 1990 at Oregon State University (Corvallis, OR) and his Ph.D degree in 1993 at the University of California in Davis (Davis, CA). He is currently the Theodore S. Coile Professor of Hydrology and Micrometeorology at the Nicholas School of the Environment and the Department of Civil and Environmental Engineering at Duke University (Durham, NC). He served as an associate editor for Advances in Water Resources (1998-2014), Boundary Layer Meteorology (1998-present),Water Resources Research (2004-2009), the Vadoze zone journal (2000-2003) and served as one of the four editors-in-chief for Advances in Water Resources (2011-2014).