EMS Annual Meeting Abstracts
Vol. 11, EMS2014-491, 2014
14th EMS / 10th ECAC

Turbulence and organised structures in atmospheric convective boundary layer

Sergej Zilitinkevich (1,2,3), Nathan Kleeorin (3,4), Igor Rogachevskii (3,4), and Antti Hellsten (1)

(1) Finnish Meteorological Institute, Finland, (2) University of Helsinki, Finland, (3) Nizhny Novgorod State University, Russia, (4) Ben Gurion University of the Negev, Israel

Convective boundary layers (CBLs) in the atmosphere usually evolve against the stably stratified free flow. Strong mixing within CBL leads to formation of a thin, very stable turbulent entrainment layer (TEL) at the CBL upper boundary. TEL acts a kind of lid slowing down the CBL growth and causing development of large-scale organised structures. Observations in nature, direct numerical simulations and large-eddy simulations demonstrate that convective structures are characterised by very long life-times and narrower spectra, and resemble secondary circulations typical of laboratory experiments rather than large turbulent eddies.

Conventional turbulence-closure approach does not distinguish between turbulence and organised structures, formulates both in terms of statistical moments, and expresses the overall vertical transport similarly to usual turbulent transport – through local mean gradients and turbulent exchange coefficients, but introducing correction terms to account for non-local effects of structures. For convective flows, the most advanced turbulence closure theory based on conventional two-fold decomposition "regular mean flow + chaotic turbulence" has been developed by Canuto et al. (1994, 2001, 2008), Canuto (2002, 2009) and Cheng et al. (2002). They employed the system of budget equations for all second- and third-order statistical moments, carefully calibrated empirical constants of the theory, and achieved the best performance among turbulence closures of this type.

Alternative approaches based on deterministic treatment of organised structures have been applied by Schumann (1988), Sykes et al. (1993) and Zilitinkevich et al. (1998, 2006) to revise the near-surface heat/mass-transfer law for shear-free CBL, and by Jano et al. (2005a) to quantify structural transports in convective clouds. Zilitinkevich (1971, 1973) and Kader and Yaglom (1990) have found evidence of inverse energy transfer from smaller to larger scales in convective turbulence. Zilitinkevich et al. (1999) and Elperin et al. (2002, 2006) have demonstrated that conventional instrument of statistical moments is irrelevant to convective structures; and the latter interact with turbulence in precisely the same way as the mean flow. In the present paper we further extend these ideas to develop a turbulence closure theory based on the three-fold decomposition "mean flow + organised strictures + turbulence" in combination with analytical solution for convective cells and convective rolls in the shear-free and sheared CBL, respectively.