Large Eddy Simulation (LES) of neutrally stratified Planetary Boundary Layer (PBL).

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Introduction:

The turbulent boundary layer in rotating fluid is one of the most fundamental scientific field strongly required in a number of practical problems within meteorology and oceanography. LES have been applied to the PBL research since its emergence at the end of 1960s. LES models are an essential, indispensible part of geosciences.

The aim of the present work is simulation of neutral PBL for different values of surface Rossby number. To obtain different Rossby numbers values of roughness length from 1m to 0.0001m are chosen.

Set up and boundary conditions:

We focus on a PBL at the latitude of 50 degrees. Geostrophic wind velocity G equals 5 m/s. Both vertical and horizontal components of the Coriolis force are included. The flow is simulated with a grid of 128x64x128 points in a box of 4000x2000x1500 m in x-,y-, and z-directions respectively. Random noise of small amplitude for vertical component of velocity *w* on lower 10 layers, i.e. 117 m from the surface, is added to the initial conditions for initialization of turbulence. In all experiments the lateral boundary conditions are periodic, lower-boundary conditions are logarithmic wall law, upper-boundary conditions are stressless rigid lid. The run duration is 48 model hours. Averaging over last 24 hours is used to calculate basic characteristics of turbulence.

Fig.1: The dependences of geostrophic drag coefficient and cross-isobaric angle on Rossby number. Red squares denote results of LES runs, solid curves are anayitical dependences with empirical constants.

Results:

The results reveal that resistance laws, i.e. dependences of geostrophic drag coefficient and cross-isobaric angle on Rossby number, are confirmed (Fig.1). Sensitive measures of non-stationarity in the mean field are given in Fig.2. In an exact steady state situation, both Cu and Cv should be 1.0. Due to inertial oscillations, this regime is approached very slowly. In Fig.3-Fig.6 cyan, blue, red, yellow and green colors denote values of roughness lengths 1m, 0.1m, 0.01m, 0.001m and 0.0001m respectively. Spectra in Fig.7 show that the Kolmogorov's power law -5/3 is valid for the resolved scales, while in the subgrid interval spectra decay.

N	z_0, m	Ro	α, deg.	C_g	u_*, m/s	h, m
1	1	$4.27*10^4$	21.0	0.064	0.32	1361
2	0.1	$4.27*10^5$	15.6	0.049	0.246	1220
3	0.01	$4.27*10^6$	11.7	0.0395	0.198	1110
4	0.001	$4.27*10^7$	9.9	0.03266	0.163	990
5	0.0001	$4.27*10^8$	8.3	0.02778	0.139	829

Tab.1: Integral characteristics of neutral PBL for different Rossby numbers.

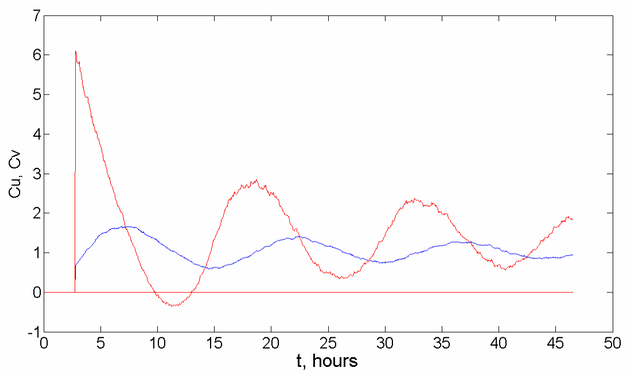

Fig.2: Deviations from steady-state conditions.

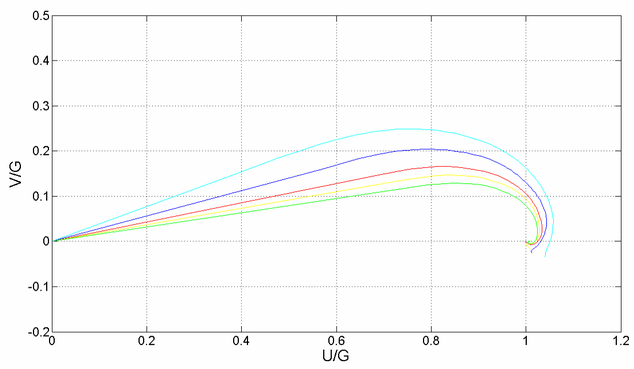

Fig.3: Ekman spirals for different Rossby numbers.

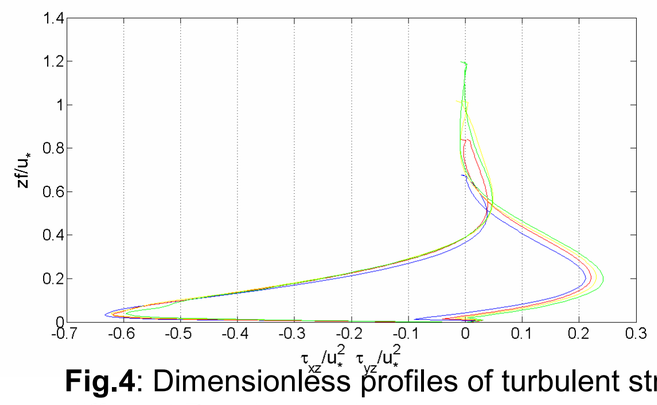

Fig.4: Dimensionless profiles of turbulent stresses for different Rossby numbers.

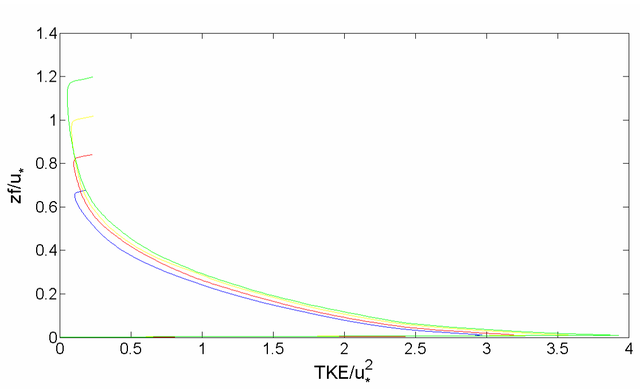

Fig.5: Dimensionless profiles of TKE for different Rossby numbers.

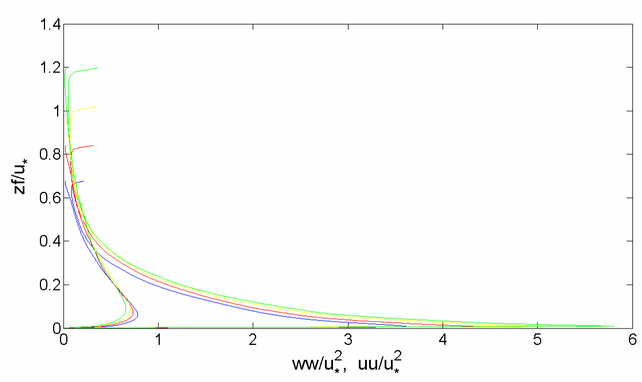

Fig.6: Dimensionless variances of velocity components for different Rossby numbers.

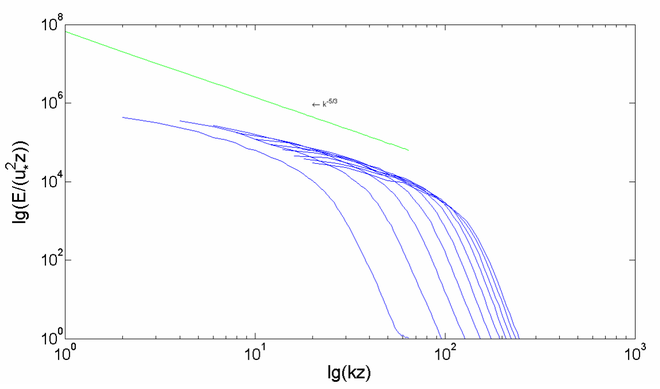

Fig.7: Dimensionless horizontal energy spectra of *u*-component of velocity at different heights.

Conclusions:

In present work results of simulation of neutrally stratified planetary boundary layer are given. The main results of simulation are:

- the resistance laws for neutral PBL are confirmed;
- velocity profiles, momentum fluxes profiles, turbulent kinetic energy, variances of vertical and horizontal velocity components are obtained.

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References:

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