# Description of single-column arctic stable boundary layer case for GABLS

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## Introduction

This case is based on the simulations presented by Kosovic and Curry (JAS 2000, Vol 57, 1052-1068). The boundary layer is driven by an imposed, uniform geostrophic wind, with a specified surface cooling rate and attains a quasi-steady state with a depth of between 150 and 250m.

The case has already been distributed for a LES intercomparison, where the basic aim is to contribute towards a quantification of the reliability of stable boundary layer LES. The purpose of this single-column intercomparison is to check what is the performance of any turbulence or vertical diffusion scheme for this shear-driven stably stratified case.

The basic phylosophy of this exercise is to make a run with every single-column model at exactly the same conditions as the LES, including physical setup and vertical resolution. This will make the comparison to the LES outputs more trustable.

However, if for any reason, this is not possible, runs in other configurations are accepted, provided that the initial state, the surface cooling rate and the physical setup is set as described. That is, other vertical grid meshes are accepted and will be treated separately. Single-column versions of operational models (either weather forecast or climate studies) are also welcome.

## Description

### The physical setup

- Vertical Domain: 400m minimum.
- Geostrophic wind: $U_g$=8m/s, $V_g$=0m/s, f=1.39e-04 $s^{-1}$ (corresponding to latitude $73°N$)
- Radiation scheme switched off (to minimize sources of discrepancy).
- Initial mean state: $u = U_g$, $v = V_g$ for z¿0m. $\theta$=265K for $0m \leq z \leq 100m$, then increasing at 0.01K/m to domain top, where the potential temperature is thus 268K.

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- For models requiring an initial TKE field, set it equal to $0.4(1 - z/250)^3 m^2/s^2$ for $0m \leq z \leq 250m$ and your minimum value above that.

- Surface boundary conditions: no-slip (wind= 0 m/s at $z_0$), with surface temperature (at z0) specified as 265K initially, decreasing continuously at a rate of 0.25K/h. Value of $z_0$ set to 0.1m for both momentum and temperature. If the boundary condition is implemented through surface similarity theory then, if possible, use the similarity functions below:
$$\frac{\partial u}{\partial z} = \frac{u_*}{\kappa z}(1 + \beta_m \frac{z}{L})$$
$$\frac{\partial v}{\partial z} = \frac{u_*}{\kappa z}(1 + \beta_m \frac{z}{L})$$
$$\frac{\partial \theta}{\partial z} = \frac{\theta_*}{\kappa z}(1 + \beta_h \frac{z}{L})$$
with $\kappa = 0.4$, $\beta_m = 4.8$, $\beta_h = 7.8$, where $L$ stands for the Obukhov length, $u_*$ is the friction velocity and $\theta_*$ is the surface temperature scale. This is not compulsory, but desirable.

- Other constants (if required): $g = 9.81 m\, s^{-2}$, reference potential temperature $\theta_0 = 263.5K$, reference density $\rho_0 = 1.3223 kg/m^3$.

**The standard discretisations** The standard case must be run at the same vertical resolution as the LES case, using 64 gridpoints (namely 6.25 m) until a height of 400 meters, with a timestep of 10 s. If a staggered grid is used, locate the mass point at 3.125 m and the first flux point at 6.25m.

**Tests on the discretisations** Previous tests have shown that timestep and vertical resolution play an important role in this case for some models. This is why the following sensitivity tests are also welcome: runs with timesteps of 60 s, 180 s and 300 s, and runs with vertical grid sizes of 25 m, 50 m and 100 m are proposed.

**Runs in operational configuration** Many turbulence or vertical diffusion schemes implemented in meteorological or climate models run in other conditions of spatial and temporal discretisation.

These schemes are also welcome in the intercomparison exercise, even if they cannot participate with a standard discretisation run. However, they must respect completely the physical setup of the case.

## Output required

The integration is to be run for 9 hours (32400s) with datasets A,B,C and D provided for two 1-hour averaging periods (7-8 hours and 8-9 hours) and identified as A8, A9 etc. Dataset E contains timeseries over the whole run, preferably with a sampling interval of 1 minute, although this is not critical. If your time step is larger, please send a value for time step. The boundary layer height is to be diagnosed as the height at which $(\overline{u'w'}^2 + \overline{v'w'}^2)^{1/2}$ falls to 5% of its surface value ($u_*^2$), divided by 0.95.

- For each of sets A, B, C, D and T, please interpolate each of the variables to the common vertical grid locations specified in variable 1 of each set, if necessary. The heights at which the variables locate do not have to be the same across all sets, however. Please, average every timestep of your run (not sampling).
- If the model uses pressure as the vertical coordinate, use $p_s = 1013.2hPa$, and the hydrostatic relation to provide the height in meters.
- If you send complementary results with different configuration than the standard proposal or your operational proposal, please describe it in the first record of each file and name it accordingly: for instance, set A8 with timestep of 180 s and vertical grid size of 50 m would be named "A8-180s-50m".
- Please provide each set as a separate formatted data file, the first record containing an string of up to 130 characters, giving your name and any identifying details for the run. The second record should contain a single integer giving the number of elements in each of the succeeding records (ie the number of levels, or times for Set E, for which the diagnostics are provided). Each variable of the sets must be written using E15.7 as the format for the WRITE statement. If a variable is not available, please set its values to -0.9999999E+07.
- SETS A, B, C, D, T: one line per vertical level, SET E: one line per instant (added)

( initial call: The data should be sent by email to joan.cuxart@uib.es by 25th July 2003.) Please, do also report any problem (doubt, comment or mistake in the present description) to the same e-mail address anytime.

**Set A - Mean profiles**

1. Height at which variables in this set locate ($m$)
2. x-velocity: $\overline{u}$ ($m/s$)
3. y-velocity: $\overline{v}$ ($m/s$)
4. Potential temperature: $\overline{\theta}$ ($K$)

**Set B - Turbulence variances**

1. Height at which variables in this set locate ($m$)
2. TKE ($m^2/s^2$)
3. potential temperature variance: $\overline{\theta'^2}$ ($K^2$)
4. u-variance: $\overline{u'^2}$ ($m^2/s^2$)
5. v-variance: $\overline{v'^2}$ ($m^2/s^2$)
6. w-variance: $\overline{w'^2}$ ($m^2/s^2$)
7. skewness: $\overline{w'^3}/\overline{w'^2}^{3/2}$ (dimensionless)

**Set C - Turbulence fluxes**

1. Height at which variables in this set locate ($m$)
2. x-momentum flux: $\overline{u'w'}$ ($m^2/s^2$)
3. y-momentum flux: $\overline{v'w'}$ ($m^2/s^2$)
4. potential temperature flux $\overline{w'\theta'}$ ($K\ \ m/s$)

**Set D - TKE budget (items 2-6 have units of ($m^2/s^3$))**

1. Height at which variables in this set locate ($m$)
2. shear production
3. buoyancy production
4. Total transport
5. Dissipation
6. Storage (TKE(end of hour) - TKE(start of hour))/3600 s.

**Set E - Time series**

1. Time ($s$)
2. Boundary layer height: $h$ ($m$)
3. Surface potential temperature flux: $\overline{w\theta'}_s(Km/s)$
4. Friction velocity: $u_*$ ($m/s$)
5. Monin-Obukhov length: $L$ ($m$)

**Set T - Turbulence scheme**

(This part was asked during the development of the intercomparison)

*SET T : descriptive part*

- a. Published reference of the scheme if existent.
- b. Define your run as:
  operational -and say the application;
  operational modified for GABLS,
  research pre-GABLS,
  research post-GABLS
- c. Short description of the model: first-order, tke+mixing length, tke + variance of T + mixing length,...
- d. If applicable, complete form of Km and Kh (m: momentum, h:heat)

- e. Constants used in Km, Kh, and in the TKE (C-epsilon, C-trans) and other equations
- f. If applicable, expressions for the mixing and the dissipation lengths.
- g. If used, describe any stability function.
- h. Bounded values: minimum values for the lengths, for the stability functions, for the TKE, value of the assimptotic length...
- i. Any special treatment near the ground: on the length, on the stability function, on the TKE equation (do you use e*=f(3.75u*)?)

*SET T: results part*
For the 9th hour: each parameter computed every timestep and averaged for the whole hour. Please in columns and using the same format as prescribed in the original description
(z-ini, par-1,..., par-n
...
z-fin, par-1,..., par-n)
fill empty values with -0.9999999E+07.

1. height ($m$)
2. Km ($m^2/s$)
3. Kh ($m^2/s$)
4. mixing length -$L_k$- ($m$)
5. dissipation length -$L_e$- ($m$)
6. flux Richardson number -$Ri_f$-
7. gradient Richardson number -$Ri_g$-
8. value of the stability function on momentum flux ($\phi_m$)
9. value of the stability function on heat flux ($\phi_h$)

Please make Km and Kh complete (including constants and the value of any stability functions) such that $K_m/K_h$ gives the real turbulent Prandtl number.

In what precedes, for a TKE scheme:
$Km = -Cm * \sqrt{e} * L_k * grad_z(U) * \phi_m$
$Kh = -Ch * \sqrt{e} * L_k * grad_z(T) * \phi_h$

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