BOMEX Shallow Cumulus Case
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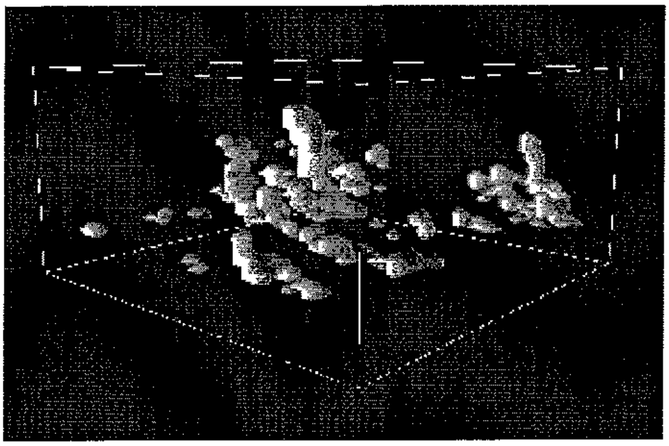

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Contents of the Case Description

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2. Summary of the Case

Since this will be the first intercomparison study on shallow cumulus convection, our objective in selecting a case was to keep it as simple as possible but yet realistic enough. In view of this we have selected BOMEX. This is a trade wind cumulus case with vertical profiles which are typical for a large part of the trade wind region. It is a simple case since there are: i) no mesoscale complications, ii) no transitions from/to or remains of stratocumulus and iii) from the observational point of view it is in a satisfying quasi steady-state, i.e. the small scale turbulent cumulus response is in balance with the large scale forcing. One obvious weak point of BOMEX is that there are little cloud data available for this case. The main intercomparison with observations therefore will be limited to average profiles and the various turbulent flux divergences.

During phase 3 of the Barbados Oceanographic and Meteorological Experiment (BOMEX) from 22 June to 30 June 1969 a detailed observational budget study in a 500x500 km^2 square near Barbados has been performed. Data were obtained from rawinsondes launched every 1.5 hr from four ships located at the corners of the BOMEX array. From these data large-scale heat and moisture budgets have been deduced (Holland and Rasmusson 1973; Nitta and Esbensen 1974). For the purpose of the intercomparison, we will concentrate on the undisturbed BOMEX period of phase 3 from 22 to 26 June during which non-precipitating cumuli were the only type of cumulus convection that was observed. Ideally we would like to initialize the LES model with the average observed profiles of u, v, theta_l and qt of this 5-day period and run the model using the diagnosed large-scale forcing. This is however not feasible since the temporal and spatial variations of the fields are such that an actual inversion, such as appears on most individual soundings, is not found in the mean soundings (Nitta and Esbensen 1974). Therefore, instead, we have selected from the BOMEX Rawinsonde atlas (1975) a mean profile of one individual ship over a shorter period.

We use the mean profiles of the Oceanographer, the most northern ship of the BOMEX square, averaged over 22 and 23 June during which a well defined steady state with a strong inversion was present. See section 3.2 for an explicit description of the initial profiles. From the BOMEX Low Level Atlas (1975) the oceanic surface values can be found. See section 3.3 for the explicit values. Our choice of the prescribed forcing is dictated by two conditions. Firstly, we want to choose the forcing as simple as possible in order to keep the case transparent. Secondly the forcing has to be realistic, i.e. in agreement with the diagnosed forcing. We prescribe three important forcings for the run:

1. the large-scale subsidence w
2. the radiative cooling
3. large-scale advection of q_t

See section 3.4 of the case description for the prescribed profiles of the forcings which are kept constant during the run.

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3. Model Setup and Initialisation

3.1 Domain Parameters and Boundary Conditions

For the **3d models** we give the following grid and boundary specifications:

- Domain Size:
  - Domain Width : 6400 m
  - Domain Length : 6400 m
  - Domain Height : 3000 m

- No. of Grid Points:
  - x grid points: 64
  - y grid points: 64
  - z grid points: 75

- Implying a Resolution:
  - dx = 100 m
  - dy = 100 m
  - dz = 40 m

- Boundary conditions:
  - Lateral: Periodic
  - Top : In order to minimize spurious reflection of upward propagating gravity waves, you may want to use a sponge layer for damping perturbations. The sponge layer should not start any lower than 200 m above the mean inversion height.
  - Bottom : Prescribed Fluxes. See section 3.3 for more details.

For the **2d models** the same boundary specifications apply. Use for the grid specifications:

- Domain Size:
  - Domain Width : 409600 m
  - Domain Height : 3000 m

- No. of Grid Points:
  - x grid points: 64*64 = 4096
  - z grid points: 75

- Implying a Resolution:
  - dx = 100 m
  - dz = 40 m

For the **1d models** the only relevant specification is the vertical resolution. We prescribe the same vertical resolution dz=40m as used for the 2d/3d-models in order to keep resolution effects out of the intercomparison as much as possible.

REMARK: It appears that some 1d-models have difficulties with the (high) 40m resolution because of "hard-coded" resolution dependancies. Therefore, *only* those 1d-modellers who really have insurmountable problems with the 40m resolution can use a more coarse resolution. In that case we request to use the ECMWF-standard resolution. In the Appendix one can find the level heights and the corresponding initial fields and forcings for this more coarse resolution.

3.2 Wind and Thermodynamic Profiles

Based on the observed profiles the following initial setup for the horizontal wind components (u,v), liquid potential temperature (theta_l) and the specific total water content (q_t) is proposed. Other profiles such as pressure, absolute temperature, etc, can be deduced assuming hydrostatic equilibrium. Initially, it can be assumed that there is zero liquid water (q_l=0.0), so that:

```
theta = theta_l
q_v   = q_t
```

(Tables with the profiles for the prescribed vertical 40m resolution can be found in the Appendix)

	u [m/s]
0 < z < 700	-8.75
z > 700	-8.75 + 1.8E-3 * (z - 700)

	v [m/s]
z > 0	0.0

	q_t [g/kg] -> qv
0 < z < 520	17.0 + (16.3 - 17.0)/(520) * z
520 < z < 1480	16.3 + (10.7 - 16.3)/(1480 - 520) * (z - 520)
1480< z < 2000	10.7 + (4.2 - 10.7) /(2000 - 1480) * (z - 1480)
z > 2000	4.2 - 1.2E-3*(z - 2000)

ql =0

	theta_l [K] -> theta
0 < z < 520	298.7
520 < z < 1480	298.7 + (302.4 - 298.7)/(1480 - 520) * (z - 520)
1480< z < 2000	302.4 + (308.2 - 302.4)/(2000 - 1480) * (z - 1480)
z > 2000	308.2 + 3.65E-3 * (z - 2000)

3.3 Surface Conditions

The sensible and latent heat fluxes are prescribed for the 1d, 2d and 3d models as:

```
wtheta = wtheta_l = 8 x 10^-3    K m/s

wqt    = wqv      = 5.2 x 10^-5 m/s
```

The momentum fluxes are prescribed by

```
uw     = -u(u*^2) / (u^2+v^2)^(1/2)

vw     = -v(u*^2) / (u^2+v^2)^(1/2)
```

where u* = 0.28 m/s and the velocities (u and v) are the values at the lowest grid point level in the model. This way, only the total momentum flux is fixed to u*^2.

REMARK: It appears that for some 1d-models it is not trivial to prescribe surface fluxes because of the use of implicit schemes. If this gives serious problems one can use an interactive surface layer scheme, *provided* that the fluxes remain within **10%** of the prescribed surface fluxes!

Additional surface characteristics:

```
             surface pressure:                   ps  = 1015    mb sea

             sea surface potential temperature:  ths = 299.1   K

implying a   sea surface temperature:            ts  = 300.375 K

             sea surface specific humidity:      qvs = 22.45   g/kg
```

3.4 Large Scale Forcing and Radiation

For all 3d, 2d and 1d models the large scale advection, subsidence and radiation are prescribed according to:

Large Scale Subsidence w [m/s]

Apply the subsidence on the prognostic fields q_t, theta_l, u and v. → pas sûre !

```
0    < z < 1500    -(0.0065/1500) * z

1500 < z < 2100    - 0.0065   + 0.0065/(2100 - 1500) * (z - 1500)

       z > 2100    0.0
```

Radiative Cooling, dtheta/dt (K/sec) — tadv

```
0    < z < 1500  -2.315 * 10^-5

1500 < z < 2500  -2.315 * 10^-5   + 2.315 * 10^-5 /(2500 - 1500) * (z - 1500)

       z > 2500  0.0
```

Remark: It appears that it is important for some 1d-models that above the inversion the heating due to subsidence is exactly compensated by radiative cooling (due to the relative long time-integration of 36 hours). We therefore prescribe that above the inversion, i.e. for z>2000 the prescribed radiative cooling is simply choosen to be minus the heating due to subsidential heating. In formula:

(d theta_l / dt)_rad = w_subs (d theta_l / dz)

For the 3d/2d-runs where the simulation time is much shorter this modification can be ignored.

Large Scale Horizontal Advection

The only significant diagnosed large scale advection term is a low level drying of about 1 g/kg day^-1 (Holland and Rasmusson 1973). We therefore prescribe a moisture tendency dq_t/dt in the subcloud layer due to horizontal advection of:

qadv = qadvh

```
0     < z < 300    -    1.2 * 10^-8 s^-1

300 < z   < 500    - ( 1.2 * 10^-8 - 1.2 * 10^-8 * (z-300)/(500-300) ) s^-1

      z   > 500    0
```

All other large scale advection terms should be put to zero.

3.5 The Geostrophic Wind

The zonal u-component of the geostrophic is decreasing with 1.8 * 10^-3 s^-1 corresponding with the observed wind above the mixed layer. The geostrophic v-component is assumed to be zero.

```
z > 0:    :  u_g = - 10 + 1.8 * 10^-3 * z         [m/s]

z > 0:    :  v_g = 0.0                            [m/s]
```

3.6 Initial pertubations

The 3d and 2d models are initialised with random fluctutions of theta_l and q_t at the lowest 40 levels given by:

```
theta          :        [-0.1     , +0.1    ] (K)
q_t            :        [-2.5*10^-2, +2.5*10^-2] (g/kg)

Initial subgrid profile of subgrid TKE:

TKE     0 < z < 3000   :        1 - z/3000  m^2/s^2
```

3.7 Other Parameters and Remarks

Latitude:	15	Degr. implying a
Coriolis parameter:	0.376 * 10^-4	s^-1
c_p	1005.	J kg^-1 K^-1
g	9.81	m s^-2
Rd	287.	J kg^-1 K^-1
L	2.5 * 10^6	J kg^-1
surface pressure	1015	mb

The microphysics parameterizations in the 2d and 3d modelss should be switched off.