8A.4 TOWARDS A THIRD INTERCOMPARISON CASE FOR GABLS USING CABAUW DATA

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1. INTRODUCTION

GEWEX Atmospheric Boundary Layer Studies (GABLS) was initiated in 2001. It main goal was defined as improving the representation of the boundary layer in regional and global models, based on a proper understanding of the relevant physics (Holtslag, 2003). To achieve this, two intercomparison studies have been performed so far, both focusing on the representation of the stable boundary layer (SBL).

The first study covered an academic case with moderate geostrophic forcing and prescribed surface temperature over ice. A parallel intercomparison of LES codes served as a reference to evaluate the results of the participating SCMs. The main conclusion was that operational models utilize higher mixing efficiencies than research models, thus missing the development of the upper inversion and overestimating the surface friction velocity (Cuxart et al., 2006; Beare et al., 2006).

The second GABLS case was based on observations from CASES99 (Svensson and Holtslag, 2006). Building upon the first case, it was now aimed to assess the ability of operational and research models to represent the diurnal cycle of the boundary layer. It was concluded that the models produces very different results in all parameters and differed substantially from the observations (Svensson and Holtslag, 2006).

A third intercomparison case for SCMs and LES has been set-up, based on observations from the Cabauw measurement site in The Netherlands. The focus of the current case will be on the representation of the decoupling around sunset, the subsequent development of the low-level jet (LLJ) and the morning transition. Contrary to previous GABLS cases, no surface temperature is prescribed, but the models are run in full coupling with the surface. Recent research shows that model results in stable conditions are strongly influenced by non-linear feedbacks in which the magnitude of the geostrophic wind speed and the related surface temperature play an important role (Holtslag et al., 2007). An accurate prescription of the large-scale atmospheric forcings should enable an evaluation of the SCM and LES results directly against observational data.

This paper describes the 'road to' GABLS3. After introduction of the measurement site in Section 2 the case selection procedure is clarified in Section 3. Characteristics of the final case will be discussed in Section 4, while the case-setup for the intercomparison will be presented in Section 5.

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2. CABAUW

Figure 1. *Photograph from the Cabauw 200 m tower to give an impression of the surroundings.*

The Cabauw measurement site is situated in the western part of The Netherlands (51.971°N, 4.927°E). Distance to the North Sea is more than 50 km in W-NW direction and changes in surface elevation are very small. The River Rhine flows 2 km south of the site. The environment is dominated by grassland, fields, scattered villages and tree lines (Figure 1). The terrain around the 200 m main tower is free from obstacles up to a few hundreds of meters in all directions. More details and site characteristics can be found in Van Ulden and Wieringa (1996) and Beljaars and Bosveld (1997).

The current measurement program included profiles of wind speed, wind direction, temperature, humidity and CO_2 along the tower (at 10, 20, 40, 80, 140 and 200m), as well as the full surface radiation and energy budgets. Moreover, the tower is equipped with turbulence instruments at four heights, which give profiles of the turbulent fluxes of momentum, heat, moisture and CO_2. A wind profiles/RASS system allows for observations of wind speed, wind direction and virtual temperature at levels exceeding the tower. Twice a day, radio soundings are available from De Bilt, which is located 25 km to the northeast. From 2001 on, most of these data sources are continuously available. Tower flux observations have become gradually available since 2003.

3. CASE SELECTION PRODEDURE

Six years of data were used to select a suitable case for GABLS3. To avoid unnecessary complexity, the case should be characterized by a stationary synoptic situation, clear skies and the absence of fog. After sunset, a moderate to strong SBL should develop with a distinct LLJ on top of it. For the development of a substantial LLJ, a moderate geostrophic forcing of about 7 ms^{-1} is favorable (Baas et al., 2008). A first selection was made by looking for cases with a geostrophic forcing between 5 to 10 ms^{-1}, with less than 3 ms^{-1} difference between the maximum and minimum geowind during the night, and a net long-wave radiation below -30 Wm^{-2} to guarantee cloudless conditions. From the 6 years considered, 28 passed these criteria. Next, for these cases the synoptic situation was inspected, as well as the water vapor deficits and the advective tendencies. The trend in the 200 m temperature was used to estimate the latter. After these procedures, nine potential cases remained.

The selection of a small subset of typical cases allows for deriving so-called generic features. These features can be used to distinguish between general characteristics and case-specific features. For example, Figure 2 shows time series of the 200 m wind speed. All cases show the general characteristics of an inertial oscillation. But in more detail, every case behaves differently due to subtle changes in, for example, the geostrophic forcing or the large-scale advection of momentum.

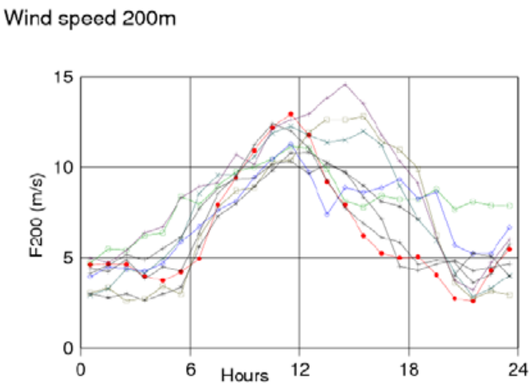

Figure 2. *Example of generic features. It is shown how an inertial oscillations typically develops for the given geostrophic forcing (~ 7 ms^{-1}) and clear skies.*

By inspecting the tower observations and synoptic maps, from the nine selected cases the most suitable case for GABLS3 was chosen. Contrary to other cases this final case shows no influence of mesoscale phenomena such as sea-breeze circulations or large jumps in the dew-point temperature.

4. CHARACTERISTICS OF THE GABLS3 CASE

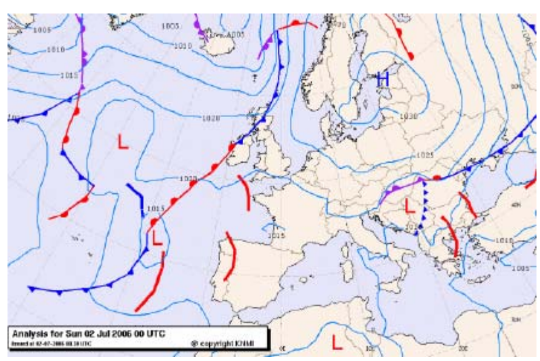

Figure 3. *Weather map showing the synoptic situation for GABLS3.*

The GABLS3 case (1 and 2 July 2006) is characterized by easterly flow near the surface around a high pressure area above the Baltic Sea (Figure 3). The large-scale synoptic situation is rather stationary. The geostrophic wind decreases with height and veers a little in the course of the night. An air mass with relatively dry air passes over the site at the start of the simulation period (12 UTC). From 00-03 UTC a small synoptic disturbance is advected over the site, resulting in variations in temperature, humidity and wind.

Both satellite observations and radiation measurements indicated cloud-free conditions. In the afternoon of July 1st a well-mixed convective boundary layer has been developed with a depth of almost 2 km, which is a rather high value for Cabauw. Because not much precipitation was recorded in the preceding month, the soil was relatively dry. This allowed for high values of the sensible heat flux, which caused the convective boundary layer to become quite deep.

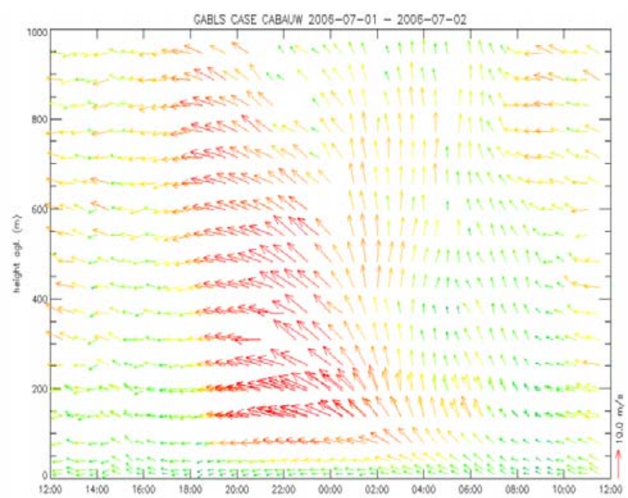

Figure 4. *Wind vectors as measured by the wind profiler. Between 100 and 800 m an inertial oscillation is clearly visible.*

Shortly before sunset, the temperature at 2 m reaches its maximum at 27°C (300 K). After sunset, rapid cooling occurs near the surface. The rapid decline of turbulence in the former mixed-layer, initiates a clear inertial oscillation in the wind. Figure 4 shows the wind vectors as measured by the wind profiler. The LLJ reaches its maximum strength of 12 ms^{-1} shortly before midnight. The height of the wind maximum is situated around 200 m above ground level. By the end of the night the potential temperature difference between 2 and 200 m in the tower is 9 K. The next morning the convective boundary layer is growing gradually until 10 UTC. At this time the cool nocturnal air has been warmed up, which enables a rapid grows of the mixed-layer in the next hour.

5. CASE SET-UP FOR SINGLE COLUMN MODEL INTERCOMPARISON

The simulation lasts 24 hours and starts at 12 UTC (12:20 local solar time) of the July 1st, 2006 and ends at 12 UTC the next day. The complete case set-up can be found on *http://www.knmi.nl/samenw/gabls/setup.html*

5.1 *Site characteristics*

Roughness length for momentum, z_{0m}, is derived from wind observations. To arrive at a roughness length valid for a horizontal scale of a few kilometers, use is made of wind gusts and standard deviation of the horizontal wind. This results in a regional z_{0m} of 0.15 m. Due to scattered obstacles like tree rows, this is larger then the local roughness of 0.03 m for the grassland around the Cabauw tower.

The physical mechanism that extract momentum from the flow by obstacles (pressure drag) is absent for temperature transport. Therefore, a local estimate of roughness length for heat, z_{0h}, seems to be appropriate. Roughness length for heat is derived from the observed surface radiation temperature of the local grassland, air temperature, and sensible heat fluxes. Thus, for z_{0h} a typical value of 1.5 mm is found.

5.2 *Initial conditions and soil moisture*

At the start of the simulation a dry air mass is advected over Cabauw. Using the corresponding sounding at 12 UTC to initialize the model will result in a too dry boundary layer and too low values for long wave incoming radiation. Since this first day time period is not of main interest for our evaluation, it was decided that this feature will not be forced to the model by prescribing advective tendencies, but by increasing the humidity content on the basis of the previous and next 00 UTC soundings and tower observations. This results in a more humid and higher boundary layer in the first hours of the simulation than actually observed.

Profiles of temperature and wind were initialized by tower observations in the lowest 200 m and smoothed radio soundings above.

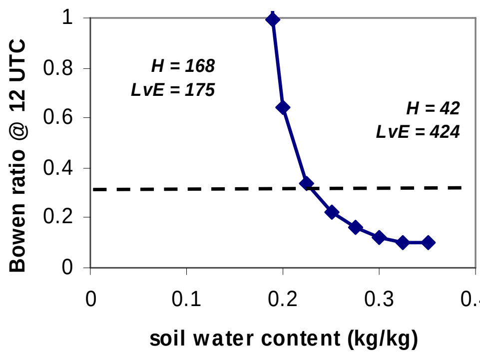

Figure 5. *Illustration of the sensitivity of modeling the sensible and latent heat fluxes for the soil moisture content.*

Surface evaporation from the grassland plays a dominant role in the daytime surface energy balance. Unfortunately, the evaporation depends strongly on the prescribed soil moisture content (Figure 5) and on the details of the soil vegetation scheme of the different models. Because only fixed amount of energy is available for evaporation and heating of the boundary layer, this implies that the soil moisture influences the evolution of the convective boundary layer. To make sure that the magnitude of the turbulent fluxes is in line with the observations, the soil moisture content should be chosen in such a way that at initialization the Bowen ratio equals 0.33.

5.3 *Dynamic tendencies and geostrophic forcing*

In the first two GABLS cases it was found that the complexity of real world boundary conditions and the lack of interaction with the surface, make it difficult to confront the models with observed evaluation parameters. To make a comparison with observations possible, care was taken to prescribe realistic advective tendency terms to the SCMs. These were estimated from both local observations and simulations of several 3D NWP models.

Geostrophic winds at the surface are estimated from a second order fit of pressure observations from 18 automatic weather stations in a radius of 100 km around Cabauw. A piecewise linear representation of the obtained time-series is used to force the SCMs. Several 3D simulations suggest that the geostrophic forcing decreases with height. Based on these model results, at 2 km a constant forcing of (u_g,v_g) = (-2,2 ms^{-1}) is applied. Between 2 km and the surface linear interpolation is performed. Preliminary SCM runs show that it is essential to include the changes in the geostrophic forcing in the model, in particular for the representation of the inertial oscillation.

From 00-03 UTC a small synoptic disturbance is advected over the site. This was found by inspecting the advection fields of the 3D simulations (Bosveld et al., 2008). As an example, Figure 6 gives the temperature advection for the GABLS3 period (the first 24 hours of the Figure).

The influence of these advective tendencies can be traced back in the 200 m time series from the tower. Although the main features are present in simulations from various 3D models, differences occur in timing and strength. Therefore, the prescription of the tendencies of momentum, temperature, and humidity are done subjectively based on observations and model results.

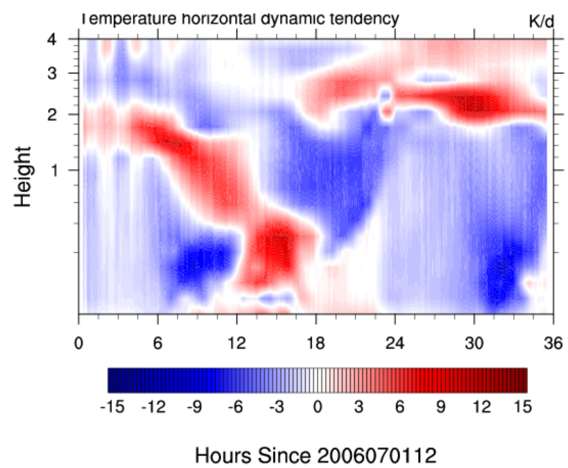

Figure 6. *Horizontal dynamic tendency of temperature in K/d as derived from a 3D simulation of RACMO, the regional climate model of KNMI. The first 24 hours correspond to the GABLS3 period.*

6. SUMMARY

A reasonable ideal 3rd GABLS case was found in the long observational dataset of the meteorological site Cabauw in the Netherlands. The intercomparison of SCMs aims to asses the ability of the models to represent the transition periods and the development of the low-level jet. To enable a meaningful comparison with observations, much attention has been paid to come to a realistic prescription of the large-scale atmospheric forcings. Contrary to previous GABLS intercomparison studies, no surface temperature is prescribed, but each participating model runs with its own soil-vegetation scheme. First results of the intercomparison are presented in Bosveld et al. (2008).

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