

Single-column modeling versus mesoscale modeling for an episode with three diurnal cycles in cases99

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1. INTRODUCTION

From previous studies it is obvious that single-column models are useful to study specific parts of the physics. A 1-D experiment can be conducted for various reasons: 1) intercomparison of different models or model versions 2) dedicated study of the performance of a particular part of the 3D model. 3) develop and quickly test model updates. During the GABLS experiments (Holtslag 2006) the first point is addressed extensively. Here we focus on the question: "How can we run a 1D-model with constraints from the 3D-model and what can we conclude from the results of the 1D and 3D model runs". In the GABLS2 experiment the performance of the wind profile with respect to the observations was rather poor. Contrarily a mesoscale 3D experiment revealed better results, especially for the nocturnal wind maximum. Is it possible to achieve a similar result for a single column model using output from the 3D model?

2. 3D/1D HIRLAM

In our experiment we use the HIRLAM model (Undén et al, 2002).

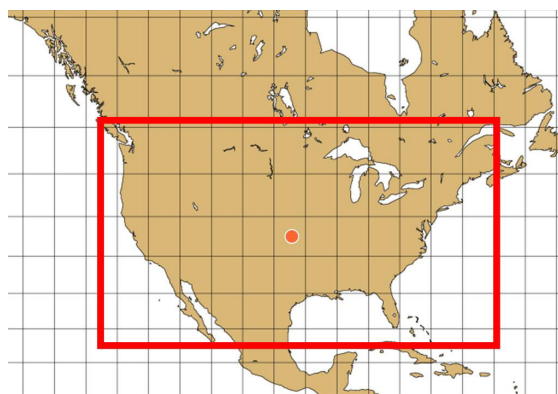


Figure 1: Integration area of HIRLAM and the location of Leon (Kansas)

The HIRLAM physics consists of: the ISBA surface scheme, CBR turbulence, Sarvijarvi

radiation and STRACO convection. For the surface processes a mosaic of tiles is used with five different tiles: water, ice and three land tiles. The ISBA scheme (Noilhan and Planton, 1989) is used for the three land-surface tiles: bare soil, low vegetation and high vegetation. Within the scheme there are twenty different vegetation types and 5 soil types. The fluxes of heat and moisture over land are highly dependent on the soil moisture, vegetation type and vegetation characteristics. The CBR scheme (Cuxart, Bougeault and Redelsberger et al., 2000) is a prognostic TKE scheme with a diagnostic length scale. This length scale has been adjusted for stable conditions according to the findings in the first GABLS intercomparison.

The 3D experiment domain is 406 by 306 points (see Fig. 1) with a resolution of 0.1 degree. The time step is 180 seconds. ECMWF analyses are used as boundaries with a time resolution of 6 hours. There are two experimental periods: The first one is the GABLS2 case-study and starts at 22 October 1999 1900 UTC and ends at 25 October 1999 0700 UTC. The second period is from 23 October 1999 1800 UTC to 27 October 1999 1800 UTC and has been carefully studied by Steeneveld et al., 2006. It comprises three typical archetypes of stable nocturnal boundary layer. For validation of the model we have used data from the CASES99 field experiment (Poulos et al., 2002).

The GABLS2 case-study starts from prescribed conditions which are kept as simple as possible. The surface temperature is prescribed and the surface water content and geowind are kept constant during the simulation. In order to allow a good comparison between the participating models the physics have been reduced, i.e. the surface and the radiation scheme have been switched off. Because no cloud formation occurs during the simulation the only remaining active component of the physics is the turbulence scheme.

For the second period we try to get the best possible results in the lowest 1000 meters with the 1D model. We use the full physical package and we also provide extra information from the 3D model. For example the initial

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profiles of temperature and moisture are now taken from the 3D model fields by bi-linear interpolation. In the 1D model we prescribe the actual wind just above the ABL from the 3D model. As we want to let the night time low level jet evolve freely, we do not prescribe the 3D winds just above the night time ABL, but above the level of the day time ABL with a correction for subsidence. The geostrophic wind (constant with height) is derived from the geopotential height of the 925 hPa height and prescribed through the entire column.

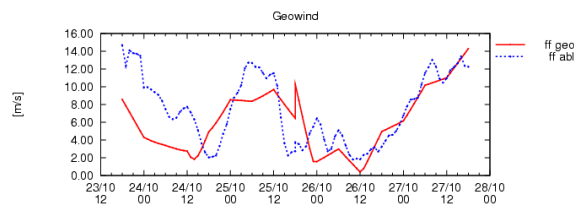


Figure 2: Time series (UTC) of the geowind derived from the 3D-model compared with diagnosed wind just above the ABL

In Fig. 2 the geowind as derived from the geopotential is depicted. In that picture also the diagnosed wind above the boundary layer is depicted. During the presented period the two wind speeds do not reveal a complete overlap, because the wind above the ABL is prone to inertial oscillations. Note the discontinuity in the geowind which is caused by a transition between two successive runs. The analysis of the next run does not guarantee a smooth transition of model variables.

3. RESULTS

A. Idealized case (GABLS2)

At first we present the results of the 1D model according to the GABLS2 recipe. The geowind is kept constant with $u=3$ and $v=-9$ m/s

In Fig. 3 the wind profiles are presented. Close to the surface the 1D model is resembling the observed radiosonde, but above 960 hPa there is hardly any correspondence with the observations. Increasing the number of vertical levels to 100 instead of 40 does not improve the results. Subsequently we diverted slightly from the GABLS2 recipe and switched the surface and radiation scheme on, but none of these changes had a positive effect. Then a mesoscale 3D run was made and the results revealed a much better match. It is obvious that the dynamic forcing and large-scale changes are important for this case. Also, the very local wind maximum just 100m above the surface is not found in both the 3D and the 1D runs.

B. Realistic case (Mesoscale Intercomparison)

In this case we try to improve the results from the 1D model by prescribing the dynamic constraints from the 3D model. We follow a mesoscale intercomparison experiment which was set up by Steeneveld (see session 8.8).

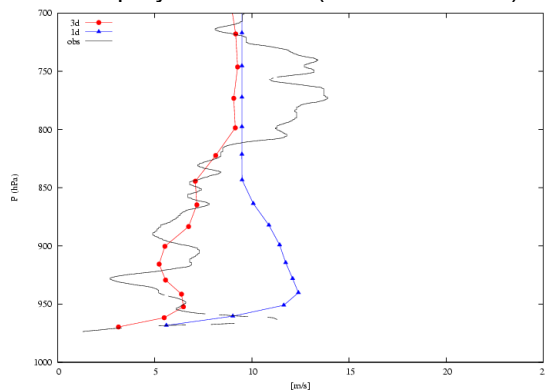


Figure 3: GABLS2 case 22 October 1999 19 UTC +36h wind speed valid at 24 October 1999 0200 LT with the 3D model (red circles), the 1D model (blue, triangles) and observations (black) from the radiosonde.

Results are presented which are valid at 25 October 1999 0200 LT and the nocturnal boundary layer is classified as turbulent (Steeneveld et al., 2006).

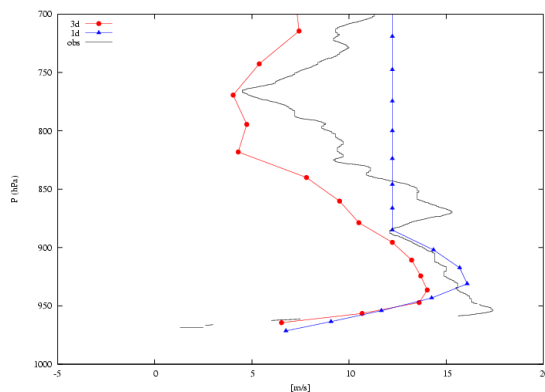


Figure 4: Mesoscale intercomparison case 23 October 1999 1800 UTC +37h wind speed valid at 25 October 0200 LT.

This means that mechanical turbulence is the dominant factor of the nocturnal boundary layer due to a stronger average wind than in the first case. From the observations a clear wind maximum can be seen in Fig. 4. The 3D run and the improved 1D run also show a wind maximum, but in the models the maximum is found at a higher level and the maximum wind speed is weaker. Note that 1D and 3D results are similar.

Both 1D and 3D model have a similar CBR scheme. Recently this scheme has been modified by turning the stress vector, causing a

larger Ekman pumping at the same stability (Tijm, 2004). This enables a decrease in turbulent mixing under stable conditions which results in a much better representation of the nocturnal jet. From Fig. 4 it is clear that both models (1D/3D) have their wind maximum on a too high level. Apparently there is still too much mixing. A promising technique to tackle this problem would be the application of a turbulence scheme with stability functions based upon QNSE (Sukoriansky, 2006).

C. Soil Moisture

Examining the latent heat flux in Fig.5 it appears that the 3D model (red line) overestimates this value. A swift sensitivity experiment with the well-tuned 1D model shows that the value of the soil moisture is a crucial factor. Decreasing the soil moisture with 10 percent gives a latent heat flux which coincides with the observed values. Note that this phenomenon occurs at 26 October 1999 1400 LT. We decided to rerun the 3D model in another setting.

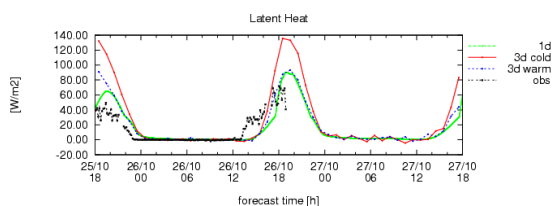


Figure 5: Time series (UTC) of the Latent Heat Flux

The model was started much earlier and run over many cycles to give the surface analysis time to adjust the soil moisture to give the best results possible. During the first run, which we call the cold start run, the initial values for the surface scheme are very close to climatological values. The rerun was conducted over a period of one week. In this way the observations of near surface variables have a larger influence on the soil variables.

In Fig. 6 it is clear that a significant difference appears in the soil moisture content. There is geographical spread in the difference but at the point of interest the soil moisture is less. All in all the latent heat flux benefits from this exercise. Since the latent heat flux is one component of the surface energy balance, we have checked the sensible heat flux and the ground heat flux. Both become in better agreement with the observations. The total effect of this modification is presented in Fig. 7 where a moisture profile is shown. The profile is valid at day time and the fluxes are relatively small.

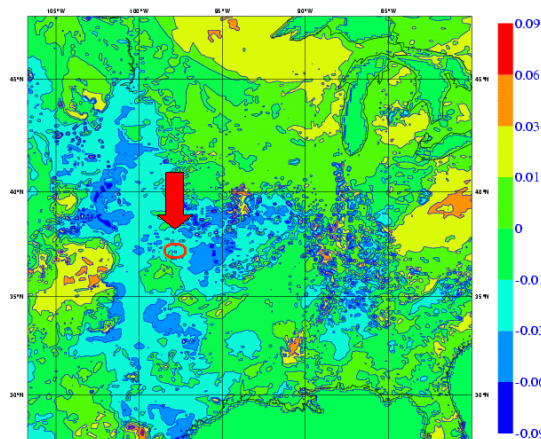


Figure 6: Soil moisture difference at 26 October 1999 1400 LT(+24h) between warm and cold run. The warm run shows less soil moisture at the observation site (Leon, Kansas)

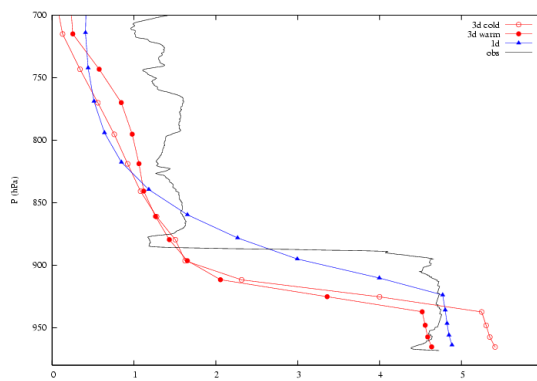


Figure 7: Moisture profiles of observation and the cold and warm run as well as the 1D run valid at 26 October 1999 1400 LT (+24h)

The beneficial effect of the improved latent heat flux during day time has worked out well. Reduced evaporation and mixing of the air has lead to a profile which is closer to the observations.

4. CONCLUSIONS

- Single column modeling is a useful tool to study the physics in more detail and for comparing models or model versions.
- The 3D model gives the best results and this implies that the dynamic forcing is important in the GABLS2 experiment
- Comparing with observations is a delicate matter and makes only sense if the dynamic constraints (geowind), are well described. For the selection of a case study the geowind should not vary too much.
- The nocturnal wind maximum is still too far from the surface in the 1D model as well as the 3D model. Even in this model version, with already reduced mixing, there is too much mixing in stable conditions.

5. OUTLOOK

Exchange processes in the nocturnal boundary layer have to be better described in the model. A new turbulence scheme with stability functions based upon QNSE shows potential (Sukoriansky 2006). The new K- ϵ model is able to simulate the complicated process of the formation and disappearance of low-level jets. First tests demonstrate promising results of predicted windprofiles. However more testing in a broader context is necessary. It is recommended to collect data of more case-studies to allow more experimentation.

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