P1.1 THE QUALITY OF HORIZONTAL ADVECTIVE TENDENCIES IN ATMOSPHERIC MODELS FOR THE 3RD GABLS SCM INTERCOMPARISON CASE

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1. INTRODUCTION

Advective tendencies in 3D atmospheric models are intimately coupled to the physical parameterization of the model. Although they represent genuine physical processes, it is not clear to what extent they correspond to the actual advective tendencies in the real atmosphere.

The accuracy of calculated advective tendencies becomes important in the simulation of atmospheric profiles with single-column models. (e.g. Bergot and Guedalia, 1994; Teixeira and Miranda, 2001). In some experiments these models are driven with advection terms derived from the analysis of 3D NWP models (Neggers 2008). The same issue also becomes important when interpreting column information from advanced meteorological profiling sites. In general, one would like to interpret the observed changes in the column parameters in terms of physical tendencies. This can only be done if we can correct, with a reasonable accuracy, for the effect of changes due to the advective tendencies.

Over the years, improvements in the parameterization of atmospheric processes, increase in model resolution, and the assimilation of more detailed observations have led to a better representation of the state of the atmosphere. Bosveld et al. (2004) compared horizontal advective tendencies as given by the KNMI regional climate model (RACMO), with tendencies derived from flux divergence observations from the Cabauw 200 m tower in the Netherlands. With a grid cell size of 25 km a reasonable agreement during daytime convective conditions was found for two selected days, one with advection and one without advection. This grid cell size assured that one land grid cell was situated between the Cabauw grid cell and the North Sea, preventing a significant horizontal diffusion in the model.

In this study we analyze advective tendencies for the GABLS 3rd stable boundary layer case (Baas et al, 2008). This case is the night from 1 to 2 July 2006 at Cabauw. During this night a small clear air disturbance passed over the Cabauw site resulting in changes in temperature, humidity and momentum that could not be related to local vertical physical processes. We intercompare three 3D atmospheric models (RACMO, HIRLAM and WRF) with respect to their advective tendencies and we compare the outcome of one of these models with the observed influence of advection on observations of Cabauw.

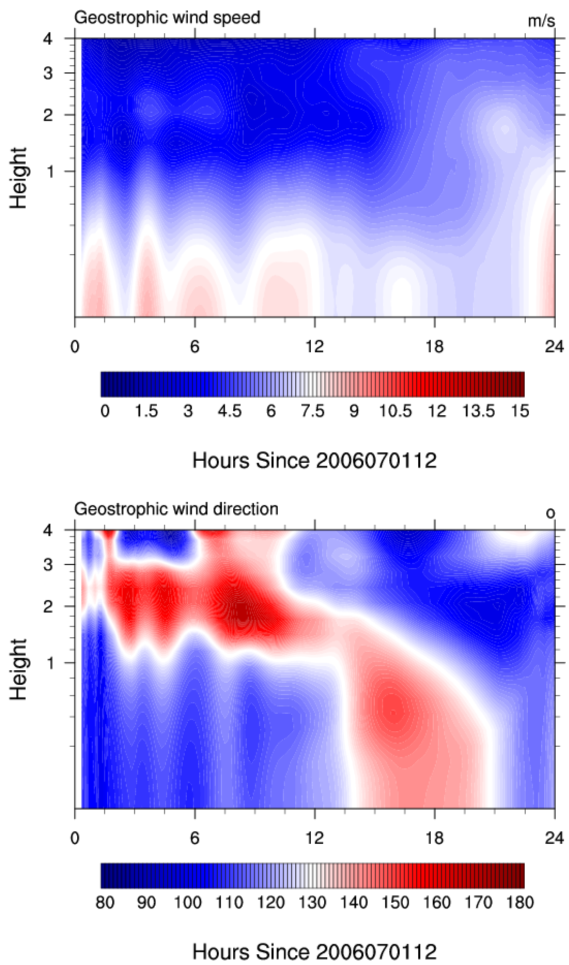

Figure 1 Geostrophic wind speed and direction as simulated by RACMO.

2. COMPARISON OF MODELS

Three different 3D atmospheric models have been used to assess the advective tendencies for the GABLS3 case (20060701 12 – 20060702 12 UTC). All these models are run in

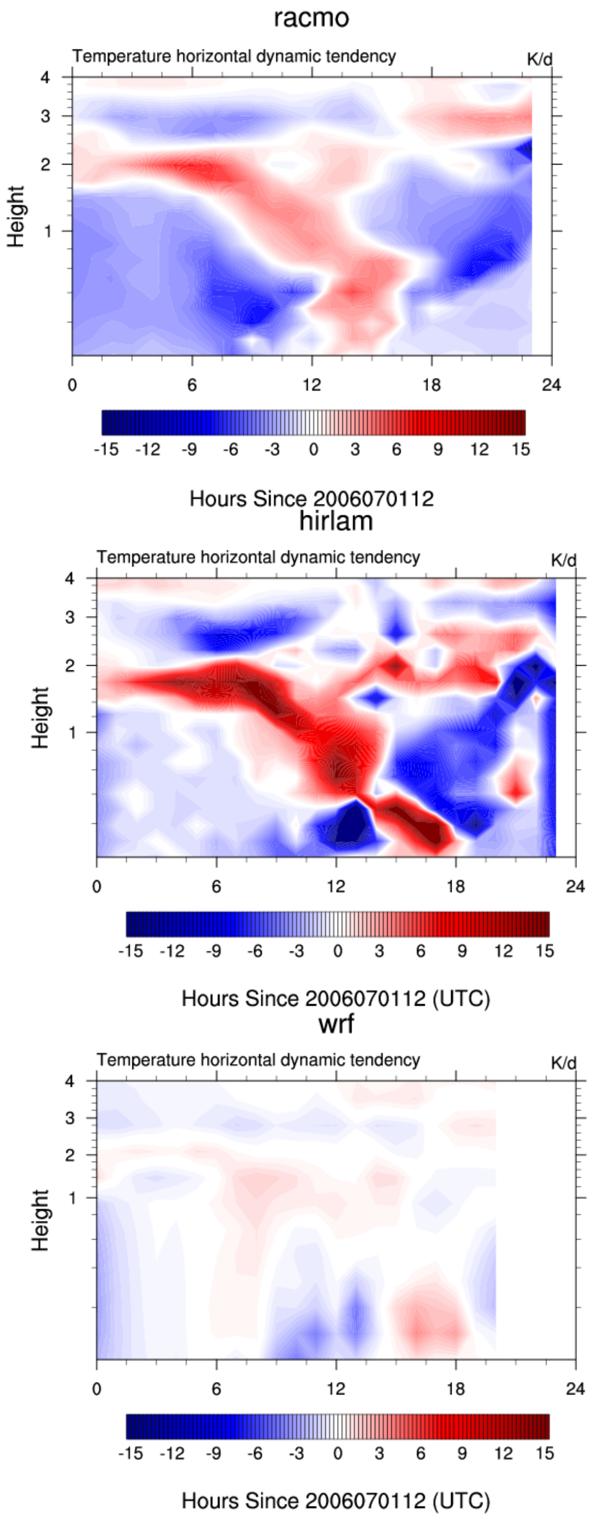

Figure 2 Horizontal dynamical tendencies of temperature.

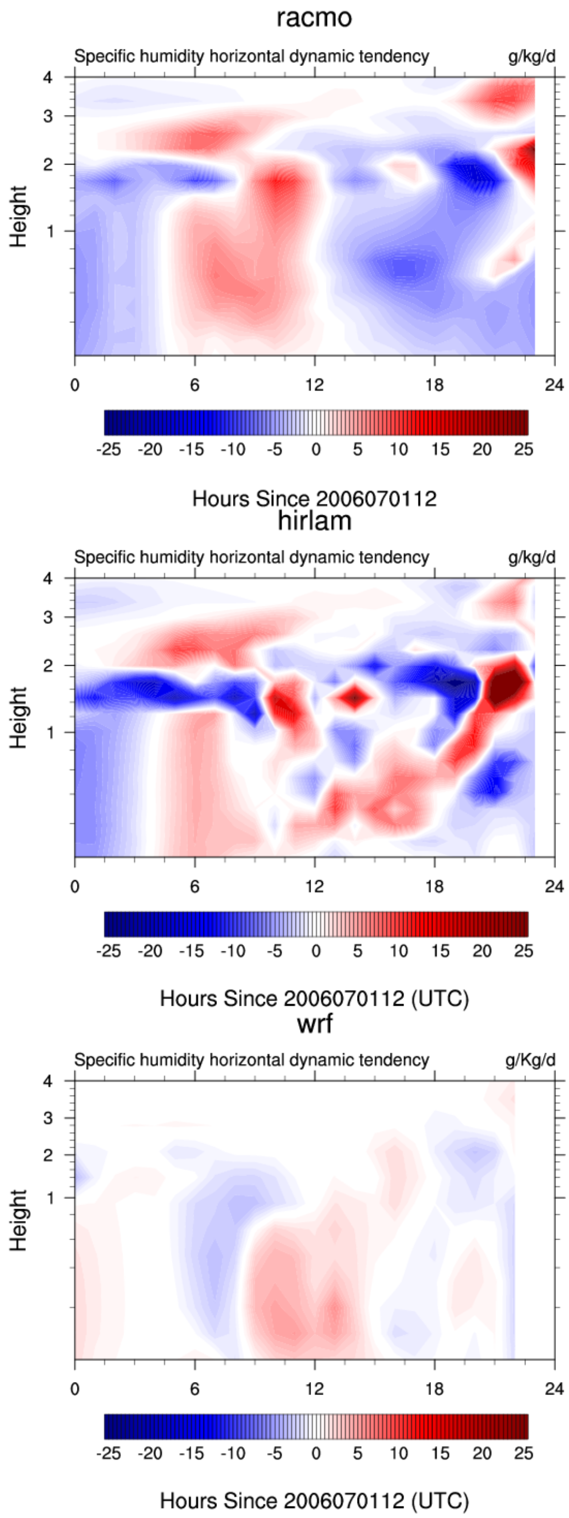

Figure 3. Horizontal dynamical tendencies of specific humidity.

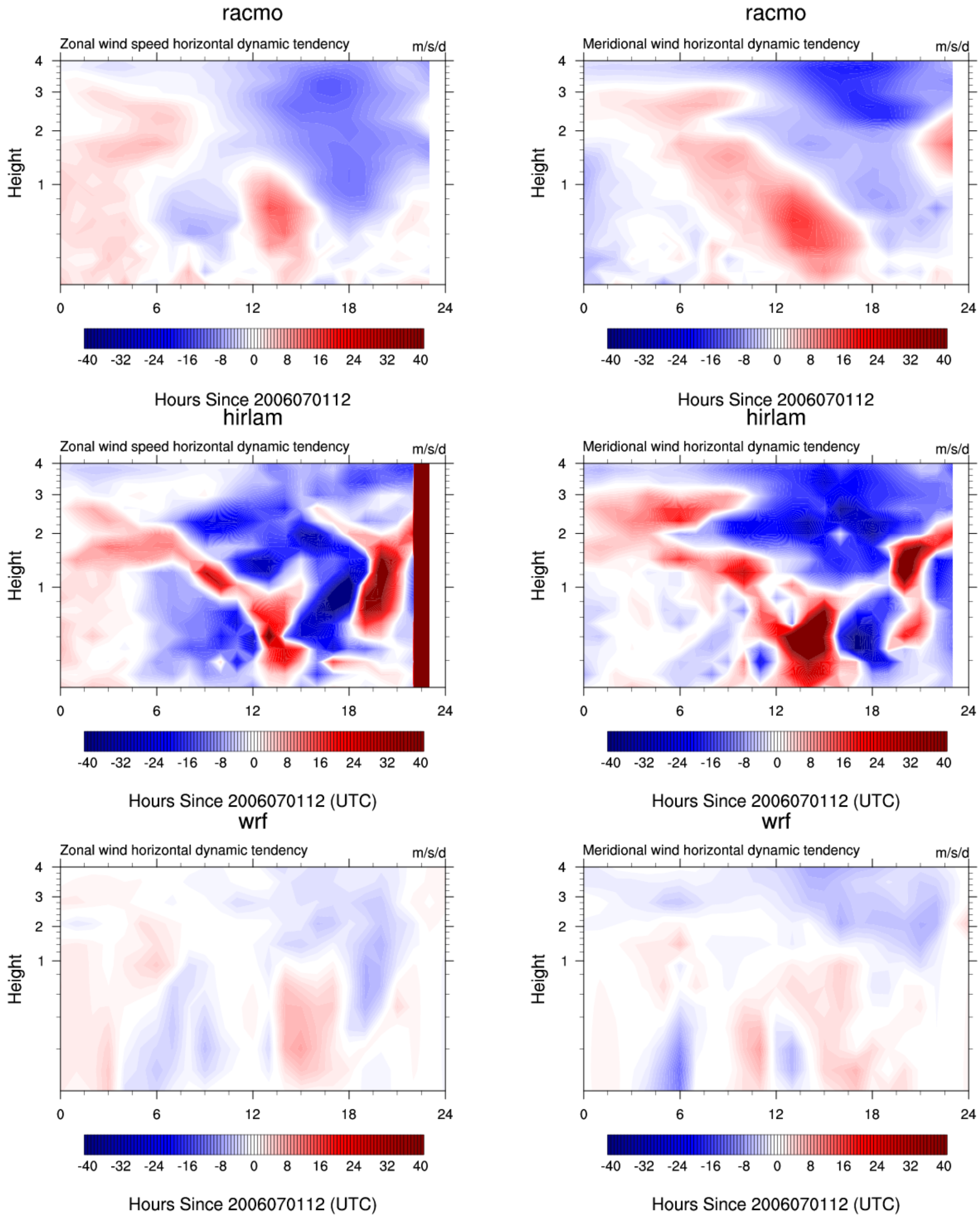

Figure 4. Horizontal dynamical tendencies of zonal wind (left panels) and meridional wind (right panels) for three models.

hind cast mode. Firstly, RACMO with initialization and lateral boundaries taken from ECMWF analysis. RACMO employs HIRLAM dynamics and ECMWF physics. It is run in 25 km horizontal resolution and 40 levels in the vertical. Secondly, HIRLAM which is also initialised and forced at the lateral boundaries by ECMWF analysis. It is run with 11 km resolution and 40 levels in the vertical. Both these models are hydrostatic. Thirdly, WRF 2.2 with initialization and lateral boundaries from NCEP-NFL analysis. It is run in a nested mode advection terms are taken from the 10 km resolution domain. WRF is a non-hydrostatic model. For RACMO and HIRLAM simulations started at 20060701 00 UTC. For WRF a start time of 20060630 12 UTC was used to get rid of a deviation due to spin up.

Horizontal dynamical tendencies are derived by applying the advective operator to the parameters of interest, here temperature, humidity and momentum. For the semi Lagrangian scheme of RACMO we also estimate the tendencies directly from the calculation of the dynamical equations. We have found the same results for the two methods.

The passage of a clear air disturbance during the simulated night is well illustrated in figure 1 which shows the geostrophic wind speed and direction. The geostrophic wind speed starts to increase at noon of the second day (which is after the case period), but the geostrophic wind directions shows a marked deviation during the night.

Figure 2 shows horizontal dynamic tendencies the temperature for the three models. A distinct warm advection is observed in RACMO and HIRLAM, which reaches the surface at midnight. HIRLAM gives a stronger signal then RACMO. WRF however does not show this feature.

Horizontal dynamical tendencies of specific humidity are displayed in figure 3. All three models show moisture advection during the first half of the night in the lowest part of the atmosphere. Details around midnight are different, with HIRLAM giving more small scale structures.

Figure 4 shows horizontal dynamic tendencies of the zonal and meridional wind. As for temperature, RACMO and HIRLAM show the same features although the details and strength differ again. WRF shows only a weak signal.

3. LOCAL OBSERVATIONS

Observed tendencies at one location are typically the sum of physical and dynamical tendencies. Deriving information on advective tendencies from local observations is only possible when we have detailed information on the physical tendencies. In general this information is not available. However, during stable conditions the air layer above the turbulent stable boundary layer becomes decoupled from the surface making the physical tendencies in the vertical column relatively small. Here we use this feature to qualitatively assess whether the advective tendencies from the models are actually observed at Cabauw. For this we observations at the 200 m level which for this night is well above the turbulent boundary layer.

We use a simple model in which the 200 m wind, temperature and specific humidity are initialized by the observed values at sunset and then integrated forward in time with the advective tendencies of RACMO for this height. For momentum the geostrophic wind and the Coriolis acceleration is taken into account. Geostrophic wind is taken from the network of automatic weather station in the Netherlands. We also applied this simple model with advective tendencies as they are, in the end, prescribed for the GABLS3 SCM case. For wind we also applied the model with no advection.

Figure 5 shows the observed and modelled temperature. A significant cooling is observed probably due to turbulent transport towards the surface and radiative cooling. A small wiggle is observed with an amplitude of 1 K which is also observed in the RACMO run. A piece wise linear approximation of the racmo dynamical tendency is used for the case description. Figure 6 shows the specific humidity. A well defined deviation with amplitude of 1 g/kg is observed around midnight, which is reasonable represented by RACMO. The case is described with a bit larger amplitude in dynamical tendency. Figure 7 shows a hodogram of the wind together with the observed geostrophic wind. Also shown is a model integration with RACMO advection and with no advection. Here we see that the effect of advection of momentum is quite complex due to interaction with the Coriolis force and the changing geostrophic wind. RACMO advection is not able to give a good representation of the observed 200 m wind. The dynamic tendency of the case is found by trial and error with this simple advective model.

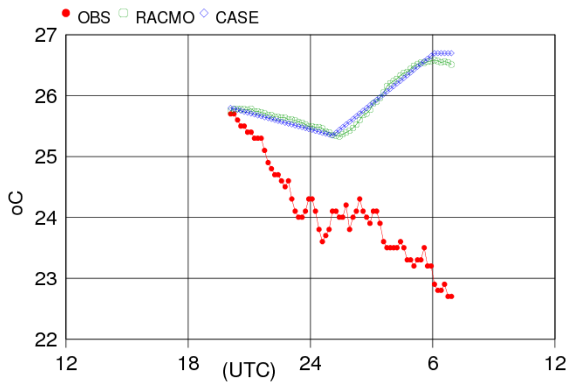

Figure 5. Temperature evolution at 200 m. Observations and when RACMO and CASE advection is applied on sunset temperature.

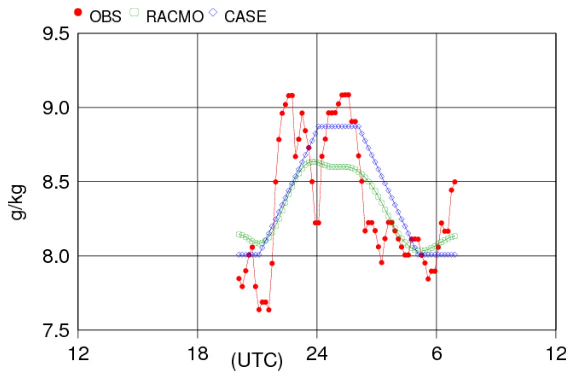

Figure 6. Specific humidity evolution at 200 m. Observations and when RACMO and CASE advection is applied on sunset temperature.

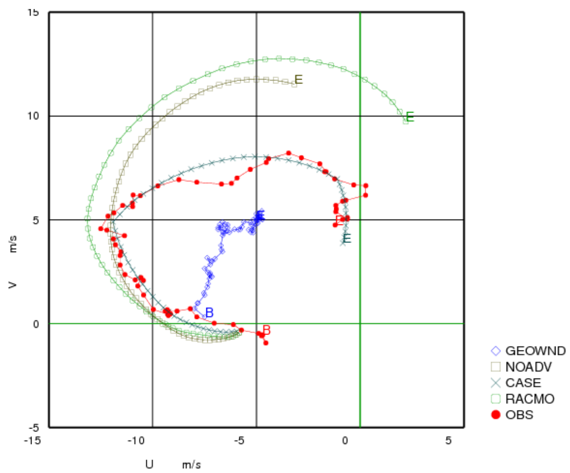

Figure 7. Horizontal wind evolution at 200 m. Observations and when RACMO and CASE advection is applied on sunset wind vector. Also shown is evolution when no advection is applied and shown is the geostrophic wind evolution. B indicates begin of time series (sunset) and E indicates end of time series (11 hours later). Timestep is 10 minutes.

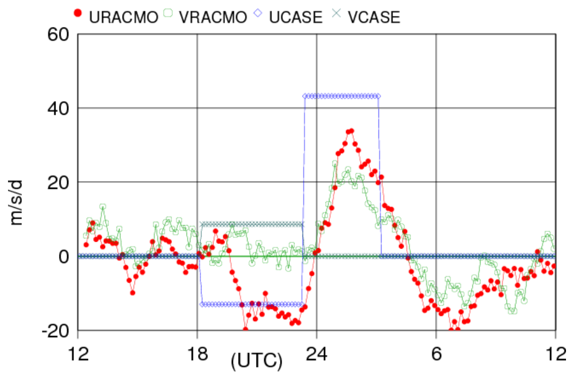

Figure 8. Zonal (U) and meridional (V) dynamical wind tendencies of RACMO and as described for the case.

Figure 8 shows zonal and meridional dynamical tendencies of RACMO and of the case. Especially the meridional component differ substantially.

4. DISCUSSION AND CONCLUSIONS

Comparing advective tendencies from 3D models shows that two of them (RACMO and HIRLAM) give comparable results although details and magnitudes may differ. The third model (WRF) shows much weaker tendencies. This might be explained by the longer integration time needed to avoid spin-up problems in this model resulting in a less good forecast or diffusion of sharp transitions in the horizontal fields.

No significant differences in advective tendencies have been found when comparing two versions of the same model (HIRLAM) with differing physical parameterizations, not shown here. This suggests that advective model tendencies for clear sky stable boundary layer conditions represent real world conditions. For more complex situations with for example clouds the dependency of dynamical tendencies on the actual parameterization might be much larger.

By using local observation at heights where the atmospheric flow is decoupled from the surface we have been able to assess the influence of advective tendencies on wind, temperature and specific humidity and to compare these estimates from observations with model output. From this comparison the advective tendencies have been derived that are prescribed in the GABLS3 SCM intercomparison and evaluation case.

For more information on this case see www.knmi.nl/samenw/gabls.

5. REFERENCES

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