Evaluating idealized AROME runs at different resolutions

LACE stay report
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1) Introduction

In the numerical weather simulation it is always an endeavor to run our model on the grid mesh with as high resolution as our technical background allows. In the case of AROME (Application of Research to Operations at MesoscalE), which is the object of this work, the operational grid size at the HMS (Hungarian Meteorological Service) is 2500 m. At Meteo France AROME has already been used with 1300 and 500 m grid size.

When we increase the resolution of a model we have to be conscious of the fact that the physical parameterization is not necessarily scale adaptive. In this work we try to diagnose the problems appearing in the AROME forecasts in an idealized case at different resolutions. The examination is based on Rachel Honnert's work: *A Diagnostic for Evaluating the Representation of Turbulence in Atmospheric Models at the Kilometric Scale.* J. Atmos. Sci., **68**, 3112-3131, where inter alia the ratio of resolved and subgrid TKE (turbulent kinetic energy) is discussed as a function of the grid size.

In order to get information about the AROME model's attribution at different resolutions, several runs were made. These simulations were made at the HMS before the LACE stay.

During the stay we evaluated the AROME outputs. As a result we can show the figures made from the data from these outputs. We can conclude from them that our idealized AROME runs do not simulate the selected case sufficiently so further work is needed.

2) Experiments

The selected idealized case, which we wanted to simulate, was the same case from the IHOP (International H_2O Project) campaign, which was used in Honnert's work. The initial and lateral boundary conditions were taken from her LES (large-eddy simulations) made by the MesoNH model. Because in these runs not the entire atmosphere was simulated (only the lower troposphere up to 5000 m), we had to extrapolate and partly use data from radiosondes.

The following grid sizes were used: 8000, 4000, 2000, 1000, 500, 250, 125 meters. The time steps length were respectively: 100, 100, 50, 20, 12, 6, 3 seconds. For every grid size was also made a case when the EDKF (Eddy Diffusion and mass-flux parameterization with Kain and Fritsch approach) was turned on and when it was turned off. The simulations were 415 minutes long.

It should be mentioned that runs at 500, 250, 125 m grid size crashed for an unknown reason so they were not used for our diagnostic. For the 125 and 250 m the crash is not a surprise because the AROME is not designed for a such high resolution, but for 500 m we plan to investigate what the problem was with the run.

To get the needed values from the outputs we used the EDF program and in the case of vertical velocity we first had to use the Full-Poss on the files. Then the computations and plots were made by R scripts.

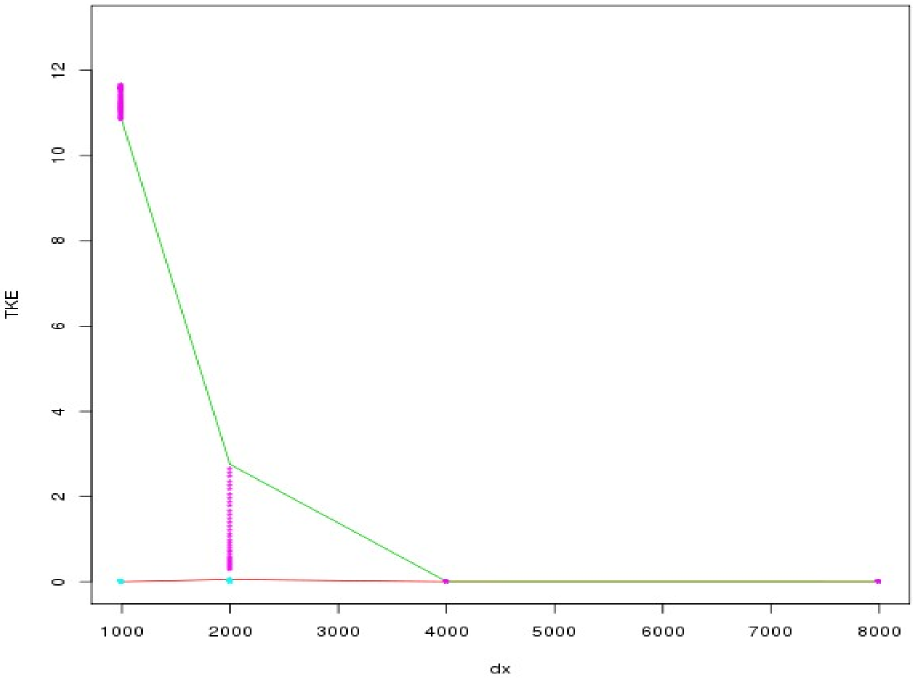
3) Results

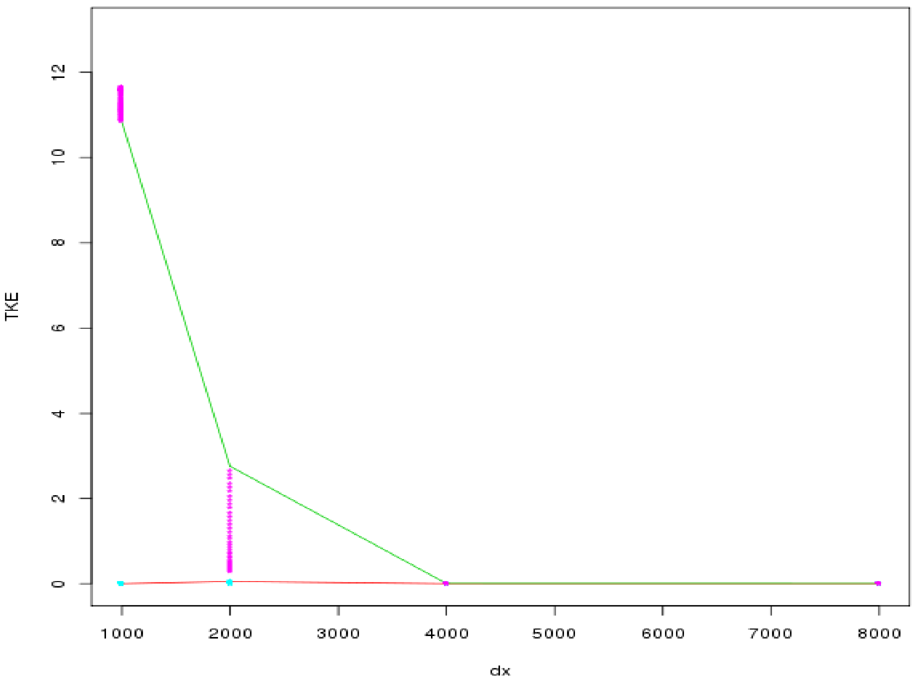
From the results we wanted to determine how the ratio of resolved and subgrid TKE depends on the resolution. The subgrid TKE is parameterized in AROME and it can be found in the output. However the resolved TKE had to be computed in every point by the equation:

$$TKE_{res}=\frac{1}{2}[(u-\langle u\rangle)^2+(v-\langle v\rangle)^2+(w-\langle w\rangle)^2] \quad ,$$

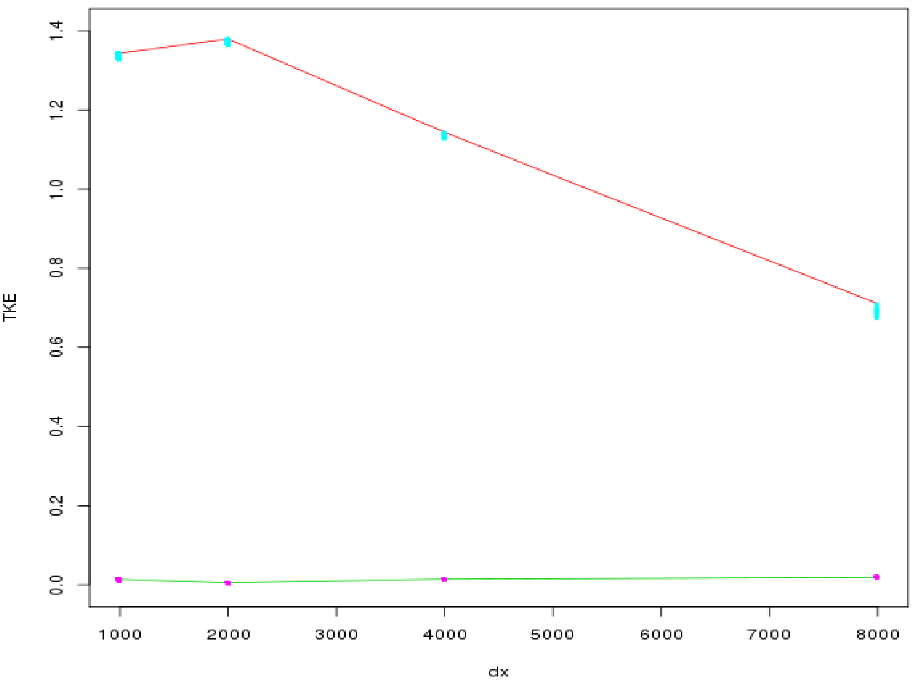
where u,v are the horizontal wind components [m/s], w is the vertical velocity [m/s] and the <> symbol means the average in space for the given vertical level. The total TKE is the sum of the subgrid and resolved TKE.

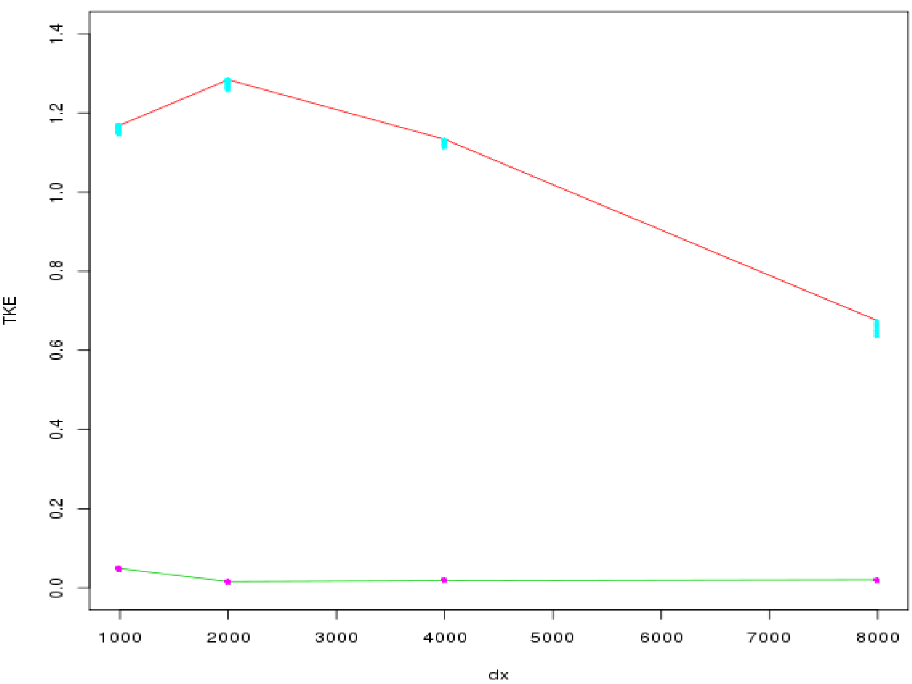
In the following the results of our diagnostics are shown:



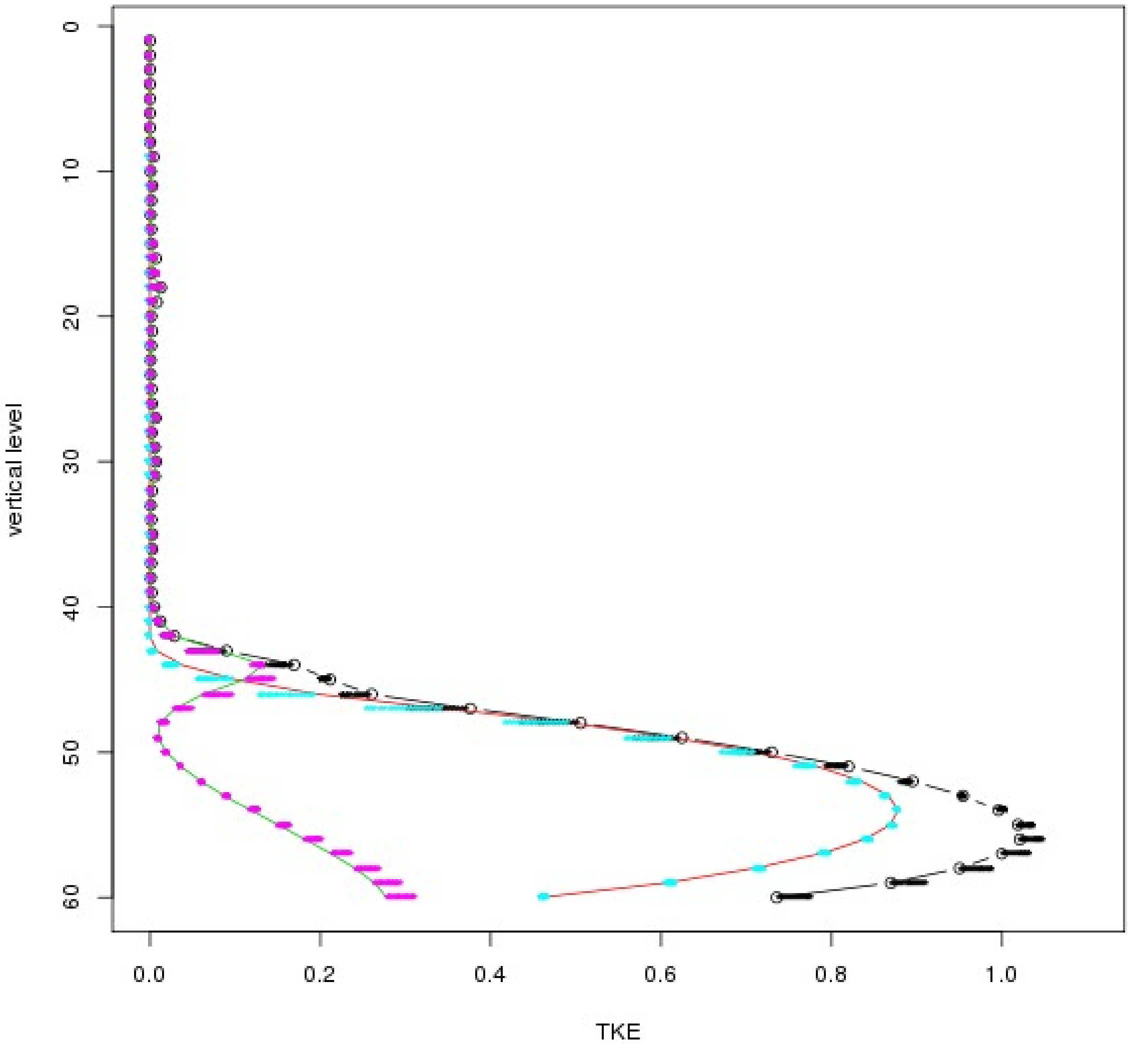


1) The average subgrid (red) and resolved (green) TKE [m^2/s^2] on the 30. model level at the end of the simulation. The points are the average subgrid (cyan) and resolved (pink) TKE values from the last half hour of the simulation. Up - EDKF is turned on, down - EDKF is turned off.

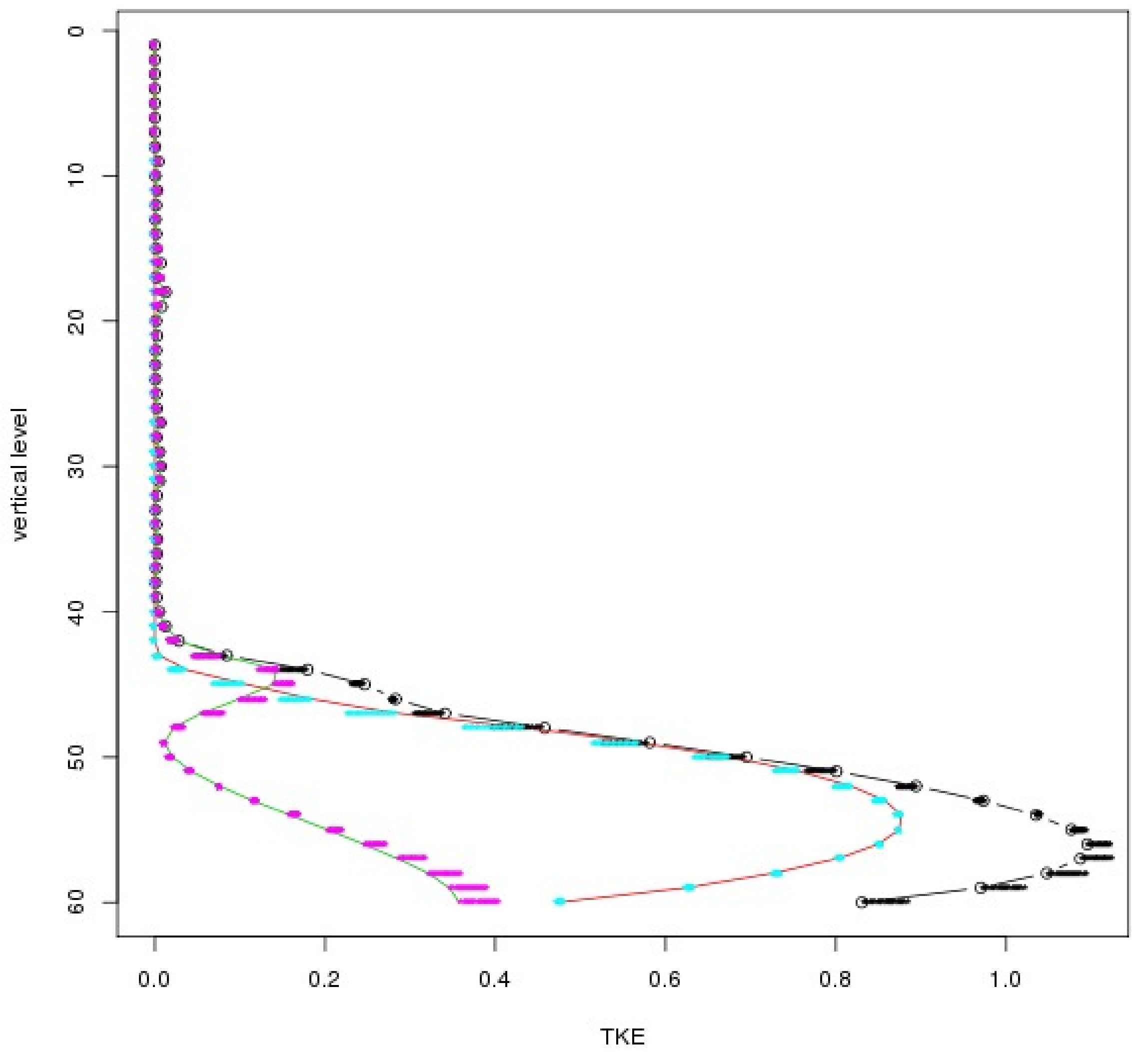




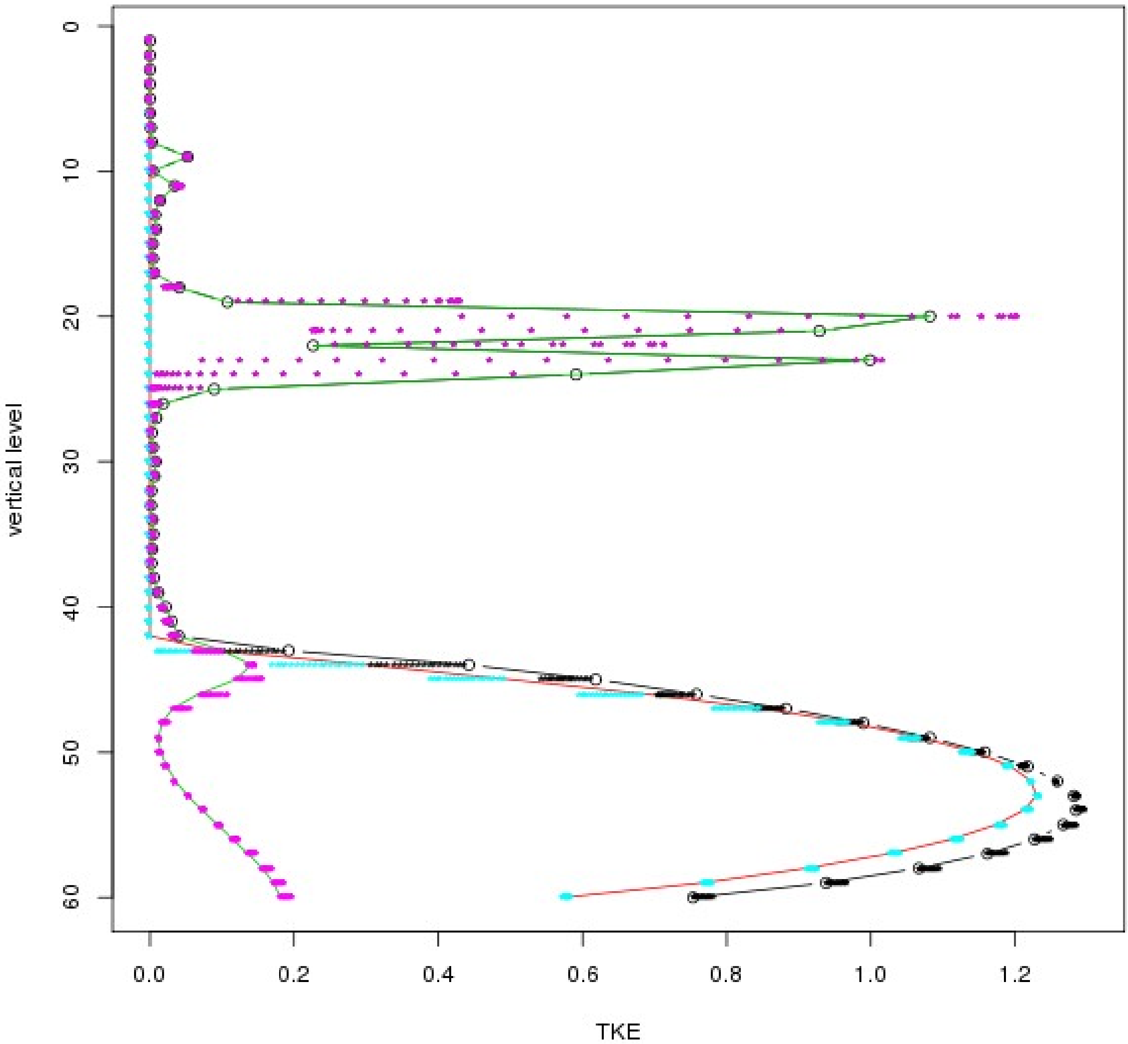
2) The average subgrid (red) and resolved (green) TKE [m^2/s^2] on the 50. model level at the end of the simulation. The points are the average subgrid (cyan) and resolved (pink) TKE values from the last half hour of the simulation. Up - EDKF is turned on, down - EDKF is turned off.



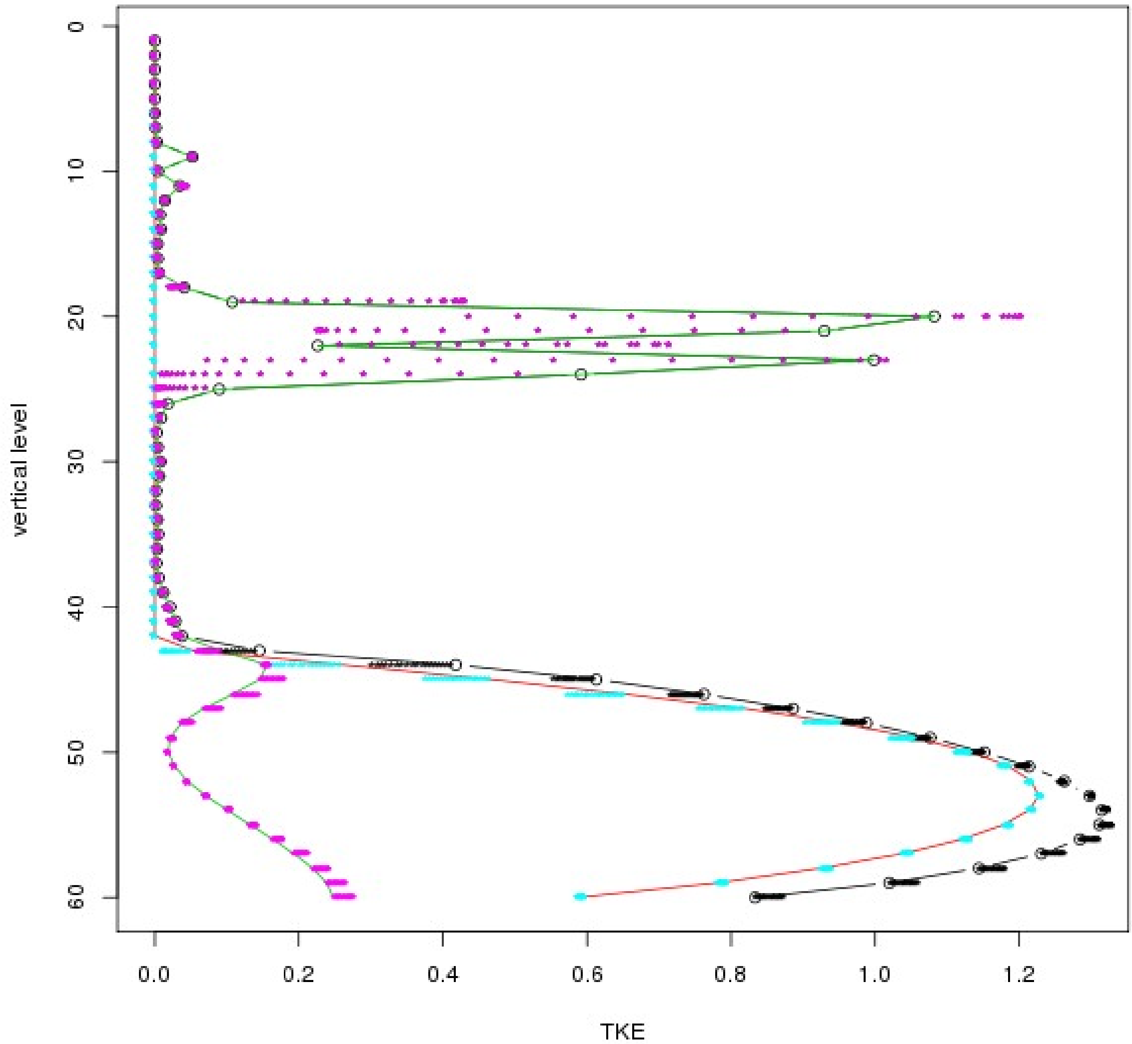
3) The vertical cross section of the average subgrid (red), resolved (green) and total (black) TKE [m^2/s^2] at the end of the simulation. The points are the average subgrid (cyan), resolved (pink) and total (black) TKE values from the last half hour of the simulation. The grid size is 8000 m and the EDKF is turned on.



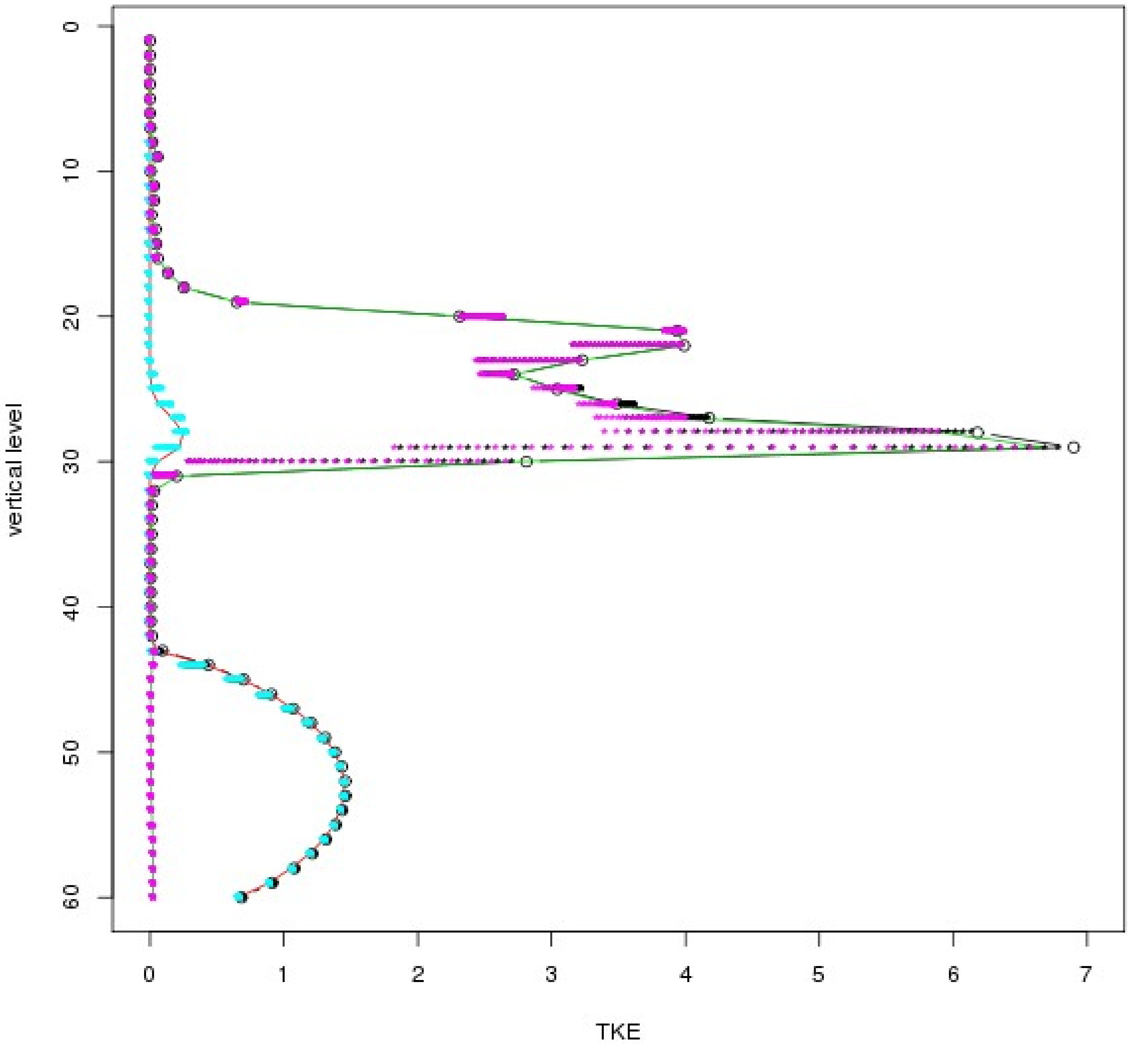
4) The vertical cross section of the average subgrid (red), resolved (green) and total (black) TKE [m^2/s^2] at the end of the simulation. The points are the average subgrid (cyan), resolved (pink) and total (black) TKE values from the last half hour of the simulation. The grid size is 8000 m and the EDKF is turned off.



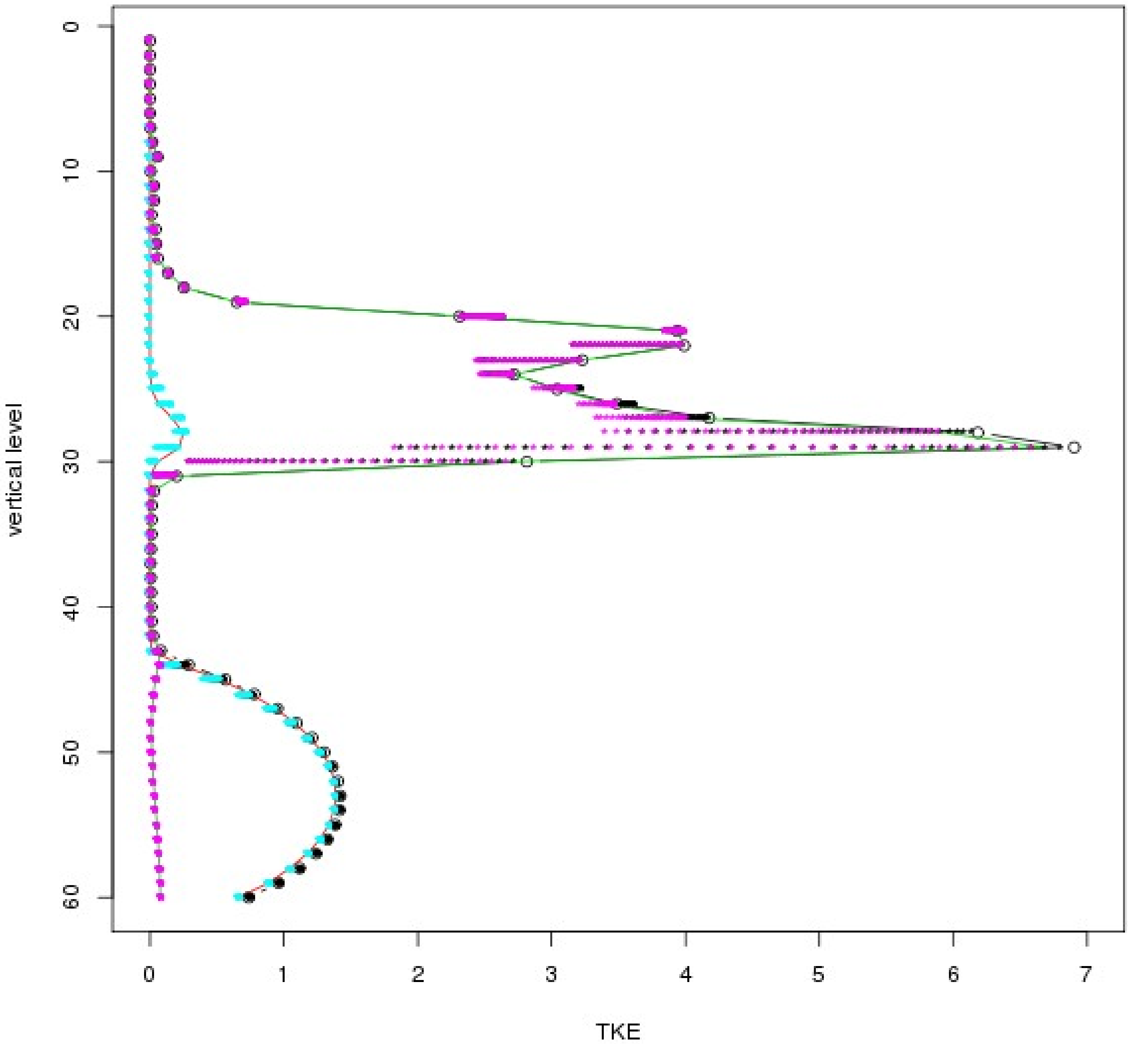
5) The vertical cross section of the average subgrid (red), resolved (green) and total (black) TKE [m^2/s^2] at the end of the simulation. The points are the average subgrid (cyan), resolved (pink) and total (black) TKE values from the last half hour of the simulation. The grid size is 4000 m and the EDKF is turned on.



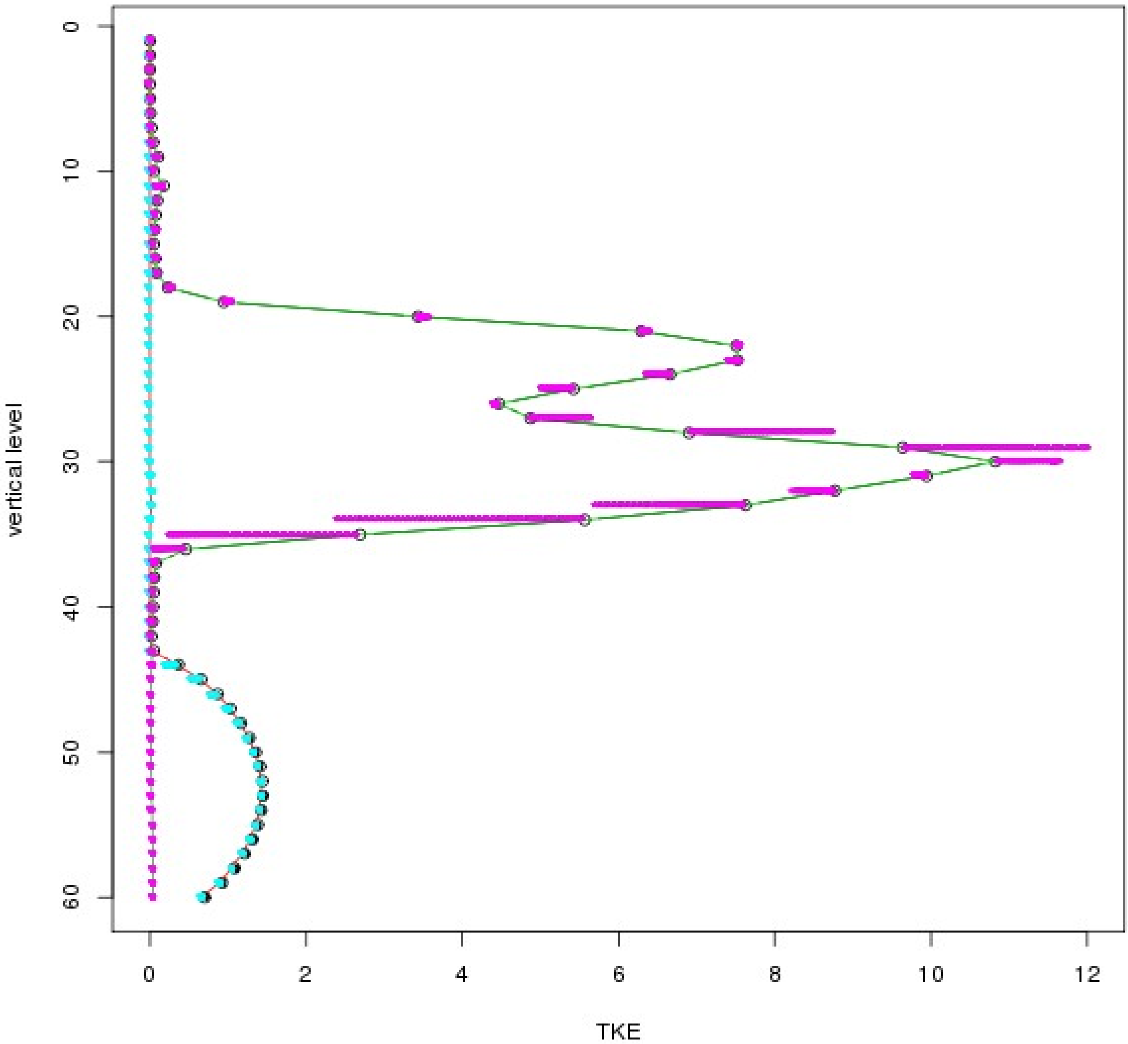
6) The vertical cross section of the average subgrid (red), resolved (green) and total (black) TKE [m^2/s^2] at the end of the simulation. The points are the average subgrid (cyan), resolved (pink) and total (black) TKE values from the last half hour of the simulation. The grid size is 4000 m and the EDKF is turned off.



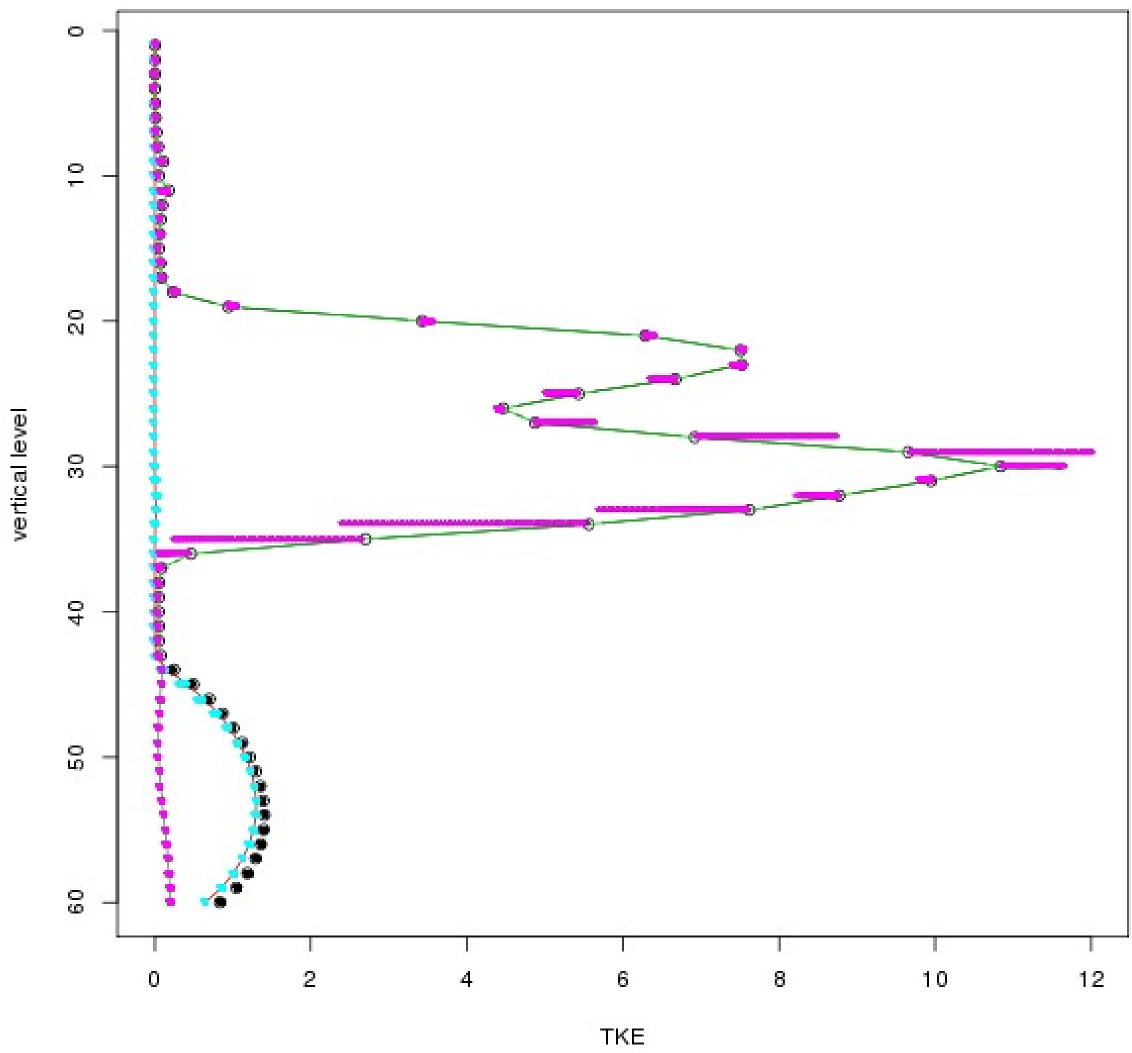
7) The vertical cross section of the average subgrid (red), resolved (green) and total (black) TKE [m^2/s^2] at the end of the simulation. The points are the average subgrid (cyan), resolved (pink) and total (black) TKE values from the last half hour of the simulation. The grid size is 2000 m and the EDKF is turned on.



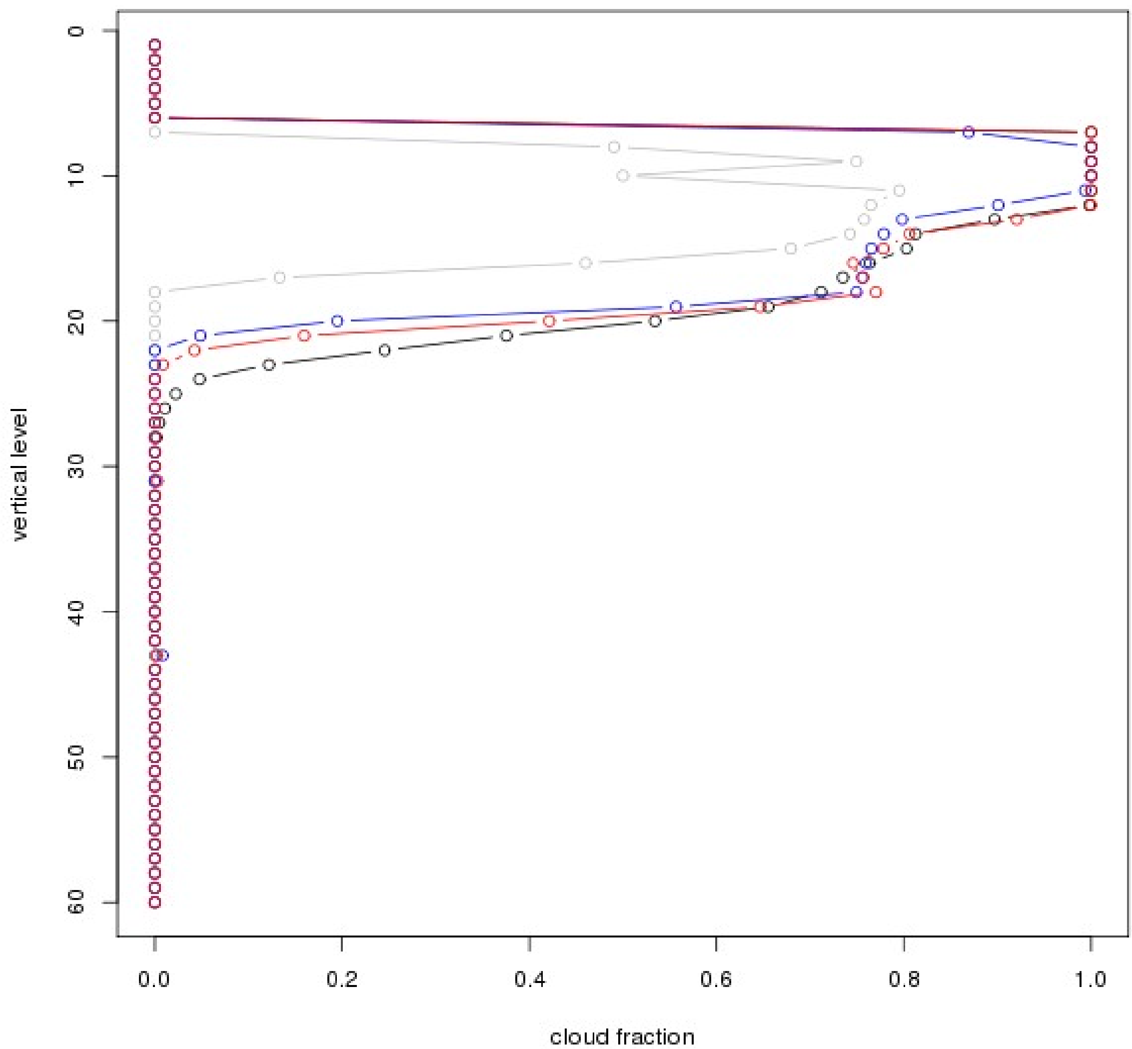
8) The vertical cross section of the average subgrid (red), resolved (green) and total (black) TKE [m^2/s^2] at the end of the simulation. The points are the average subgrid (cyan), resolved (pink) and total (black) TKE values from the last half hour of the simulation. The grid size is 2000 m and the EDKF is turned off.



9) The vertical cross section of the average subgrid (red), resolved (green) and total (black) TKE [m^2/s^2] at the end of the simulation. The points are the average subgrid (cyan), resolved (pink) and total (black) TKE values from the last half hour of the simulation. The grid size is 1000 m and the EDKF is turned on.



10) The vertical cross section of the average subgrid (red), resolved (green) and total (black) TKE [m^2/s^2] at the end of the simulation. The points are the average subgrid (cyan), resolved (pink) and total (black) TKE values from the last half hour of the simulation. The grid size is 1000 m and the EDKF is turned off.



11) The vertical cross section of the average cloud fraction of the simulations at 8000 m (gray), 4000 m (blue), 2000 m (red) and 1000 m (black) grid sizes. The cases with turned on and turned off EDKF are identical.

4) Summary

Figures 1) and 2) show the average subgrid and average resolved TKE as a function of the grid size. On the 30. model level (~3900 m height) the resolved TKE dominates and the EDKF doesn't influence the result, while on the 50. model level (~550 m height) the subgrid TKE dominates and the EDKF increases the subgrid and decreases the resolved TKE a little. According to Honnert's work our expectation was that the subgrid TKE will gradually decrease and the resolved TKE will increase when we decrease the grid size. This does not seem to happen in our cases. However it would be good to see what happens at lower grid sizes than 1000 m.

Figures 3) - 10) show the vertical cross sections of the average TKE. It can be seen, that in the lower atmosphere the subgrid TKE is bigger than the resolved TKE. It is noticeable that at 8000 and 4000 m grid size the resolved TKE has relatively high maximums around the 45. and at the ground level while at 1000 and 2000 m grid size they disappear. The solution of this anomaly is maybe connected with the fact that at 8000 (4000) m grid size we compute the averages only from 4 (16) grid points.

In the higher atmosphere the subgrid TKE almost in every case disappear (only at the 2000 m grid size shows something countable around the 32. level) but the resolved TKE grows with the resolution. At 8000 m grid size there is only a minimal resolved TKE while at 1000 m grid size the resolved TKE is one order higher than the subgrid TKE in the lower atmosphere. The crash of the 500 m grid size run can be connected whit this rapid growth of the resolved TKE.

If we compare the TKE at he same resolution, we see that the EDKF has effect only in the lower atmosphere. Here the EDKF as we expected increases the subgrid and decreases the resolved TKE.

Figure 11) is the vertical cross section of the average cloud fractions. In every case there is cloud layer around the 10. level. The problem is that the IHOP is a cloudless case.

We can conclude that our AROME runs should be investigated. We plan to find out the reason why it crashes at 500 m grid size and after that we want to make some other runs with more resolutions around 1000 and 500 m grid size. We also plan to simulate another idealized case: the ARM (Atmospheric Radiation Measurement Program).

5) Acknowledgments

I want to thank for all the help I got in Toulouse at CNRM, especially to Rachel Honnert, who leaded my work there.