Sensibility tests with LIMA scheme in fog cases

RC LACE stay report

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LIMA (Liquid Ice Multiple Aerosols) scheme is a two-moment microphysical scheme, which was developed in MESO-NH to improve modeling of the complex aerosol–cloud interactions. For now the scheme has been implemented in AROME model and the test of the scheme in AROME is still ongoing. During the stay cy45t1 was used.

This stay was dedicated to get to know the behavior of LIMA scheme in fog cases, because the new scheme usually gives less cloud than ICE3. Subgrid condensation is still missing from LIMA so ICE3 was run also without subgrid condensation. The studied case was the forecast from the run of 30th October 2016 00UTC over Garonne valley. Fog formed that day in the morning then dissipated during the daytime but next day fog formed again. In this situation LIMA experiment gives less low cloud than ICE3 (Figure 1-3). Both schemes were run at two horizontal resolutions: at 1250 m and at 500 m.
Based on the reference run (ICE3 at 1250m) there was no medium cloud this studied day and high cloud was also minimal in the model, so we could focus on the low cloud clover in our experiments.

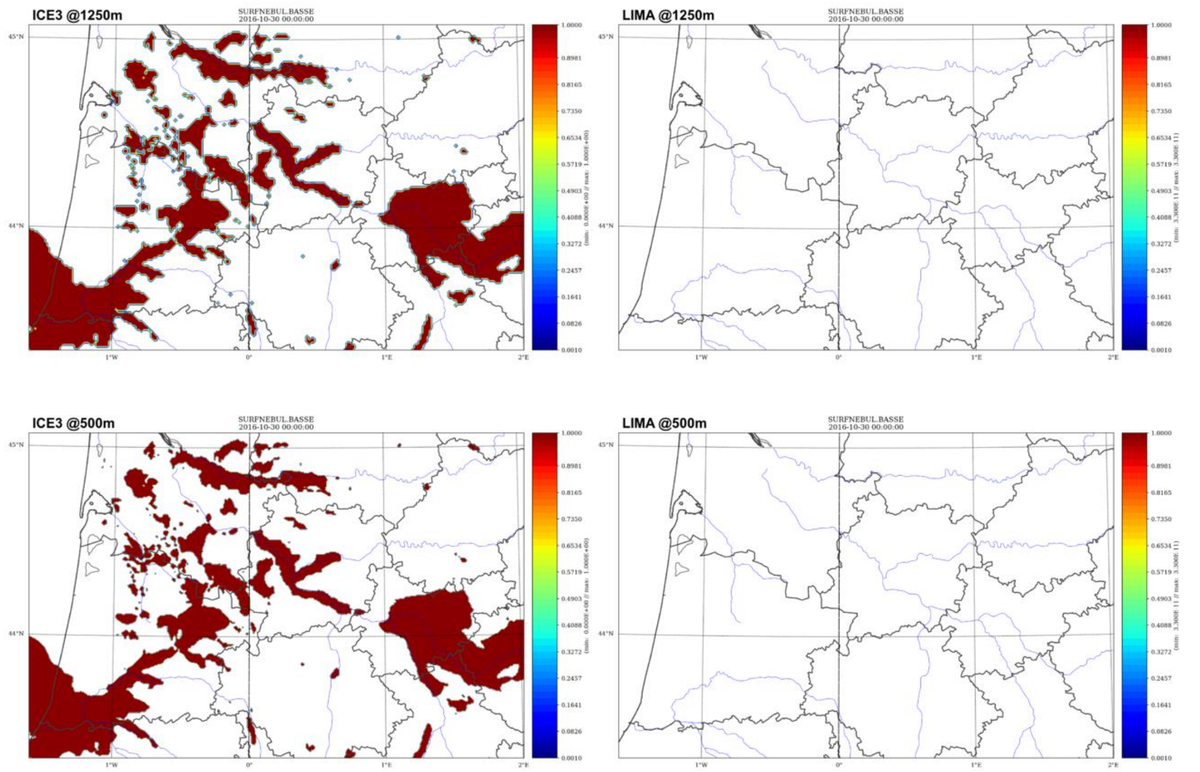

Figure 1:Low cloud cover fields on 30/10/2016 00UTC (initial state) in four cases: ICE3 (left) and LIMA (right) at 1250m (top) and 500m (bottom) resolution.

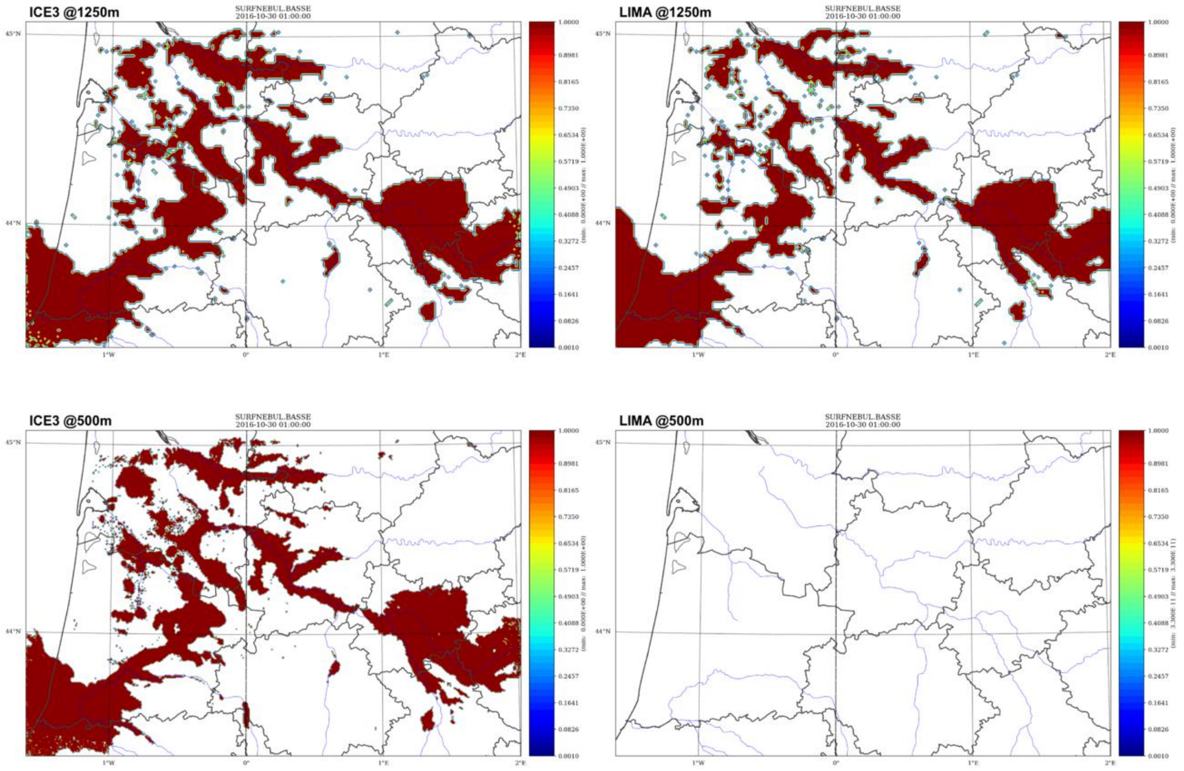

Figure 2: Low cloud cover fields on 30/10/2016 01UTC (+1h forecast) in four cases: ICE3 (left) and LIMA (right) at 1250m (top) and 500m (bottom) resolution.

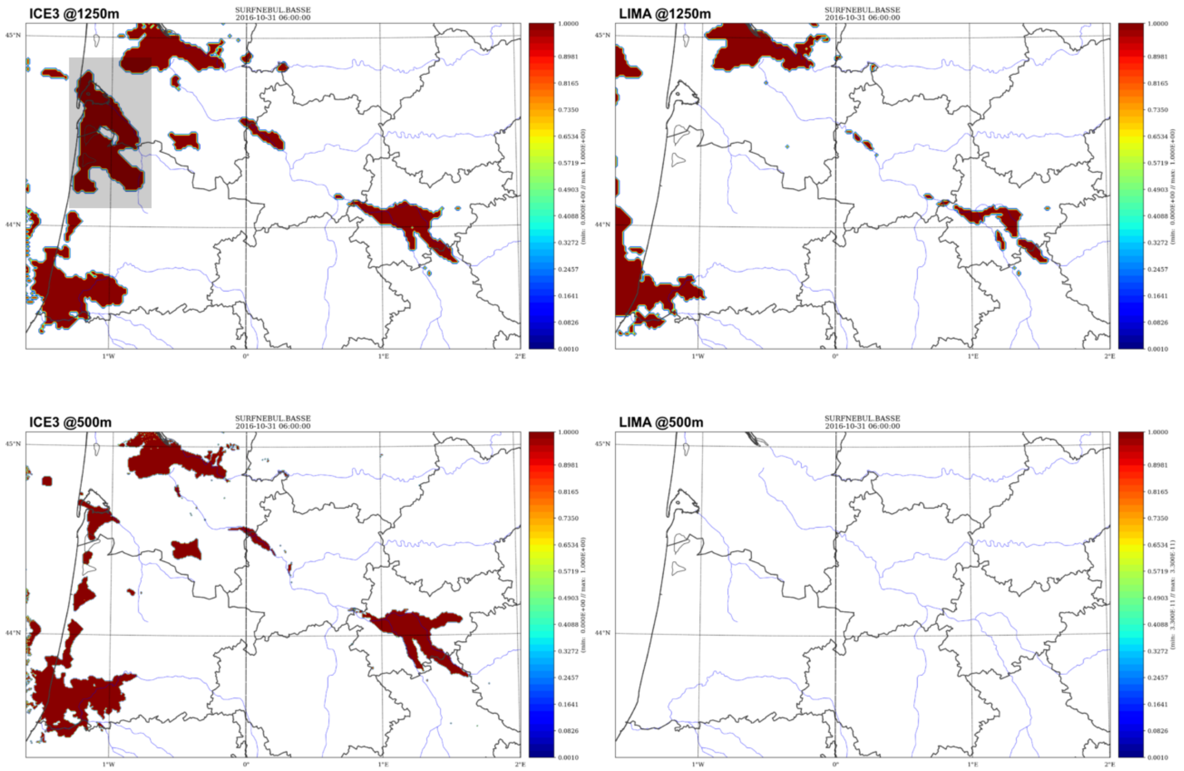

Figure 3: Low cloud cover fields on 31/10/2016 06UTC (+30h forecast) in four cases: ICE3 (left) and LIMA (right) at 1250m (top) and 500m (bottom) resolution. Grey rectangle shows the DDH domain.

Run with DDH

In order to understand the physics processes better, DDH budgets were studied, but at first some bugs had to be fixed in the DDH part when LIMA scheme was used. In order to find the source of the issues, a toy version of AROME model was tested on PC (very small domain, just a few vertical levels). Based on these test runs the following problems have been revealed:

- It turned out that the values of the new processes were set to 0 in modd_budget.F90 and these values have not been changed in aro_subudget.F90.
- In the previously mentioned routine the budgets of hail was set to true and in the case of LIMA the V??1 values were shifted because of this.
- Another problem was that VNT? values were six times in the DDH files, because this term was in a loop for hydrometeors in apl_arome.F90, so we put it outside of the loop.

Only one DDH issue still remain: in the case of LIMA the initial values of hydrometeors are still different from ICE3. This could be in connection with the fact that in case of LIMA the initial low cloud field is different from ICE3 (see Figure 1).

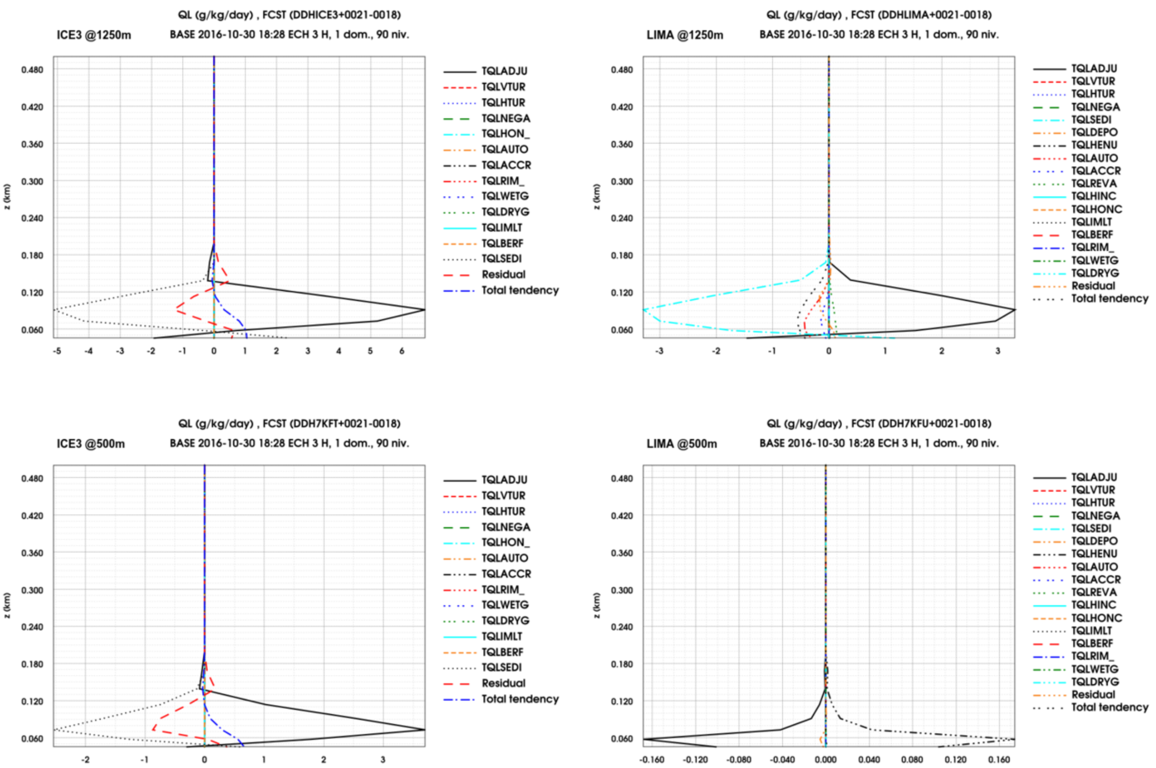

Figure 4: DDH budget terms of liquid water in four cases: ICE3 (left) and LIMA (right) at 1250m (top) and 500m (bottom) resolution. Please keep in mind that there are different budget terms for ICE3 and LIMA, so that the residual and total tendency are shown with different line styles. Legends can be found next to the actual subplots.

Figure 4 shows the budget terms of liquid water (QL) for the 4 experiments between +18h and +21h forecasts. The budgets in the case of LIMA scheme at 1250 m resolution indicate a negative total tendency, unlike ICE3 run, which has a positive tendency. It seems in LIMA the autoconversion process is too strong, so cloud droplets transform to rain drops which finally fall out. Figure 5 indicates the time evolution of LWC and it can be seen well that there is less liquid water in the case of LIMA experiment. Unfortunately LIMA at 500 m does not produce any low cloud so there is no LWC in this simulation. In its budget of LWC (Figure 4) there is a small term of HENU, which means the CCN activation process. This process is compensated by the adjustment process, so it seems that in this experiment the relative humidity is high, but it is still below 100%, so after the nucleation of CCN, the adjustment process removes the nascent droplets, because the grid cell is not saturated. Figure 6 shows clear that relative humidity is not enough close to the saturation to form cloud in case of LIMA at 500m. This strange behavior remained unclear during the stay. Afterwards it turned out that without the special dynamics settings (LPC_FULL,NSITER=2) LIMA can produce fog at 500m, and the final solution to be able to run with LPC_FULL and LIMA is simply to remove LPT GFL attribute from the namelist.

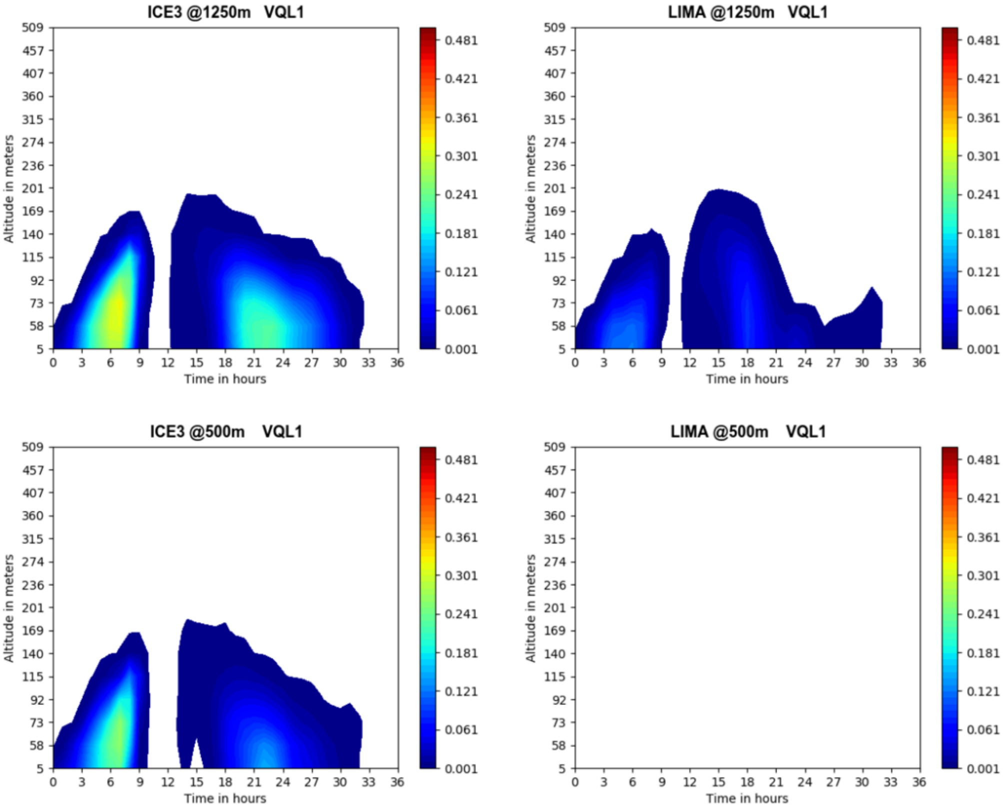

Figure 5: Time-height cross section of LWC in four cases: ICE3 (left) and LIMA (right) at 1250m (top) and 500m (bottom) resolution.

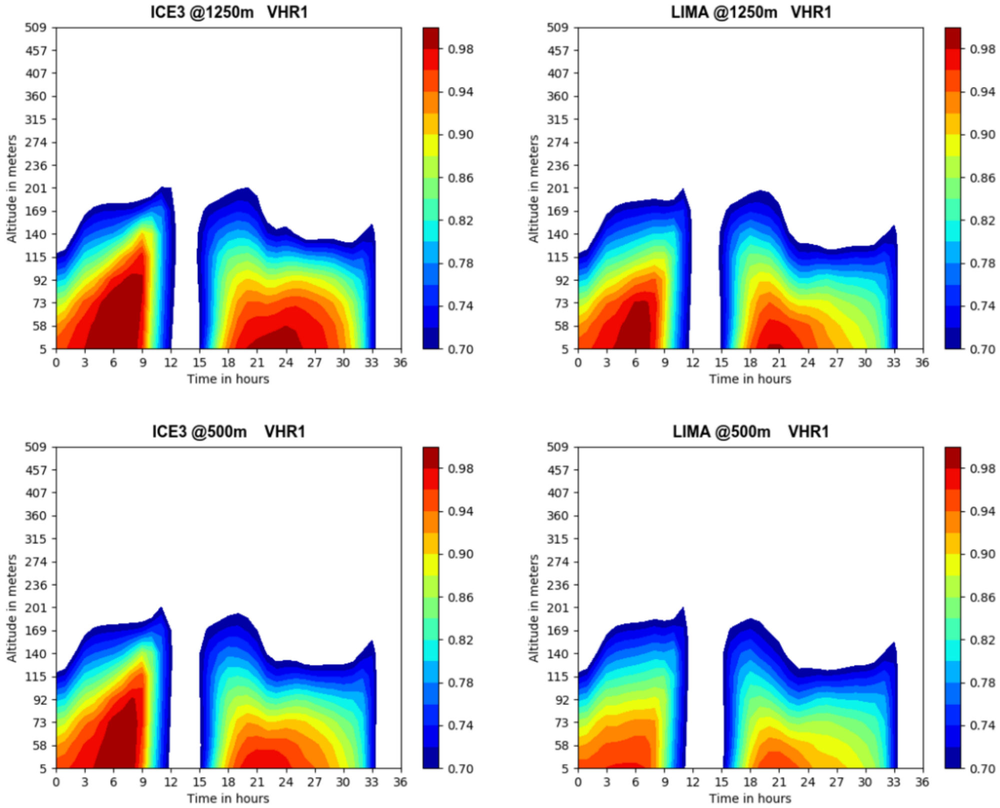

Figure 6: Time-height cross section of relative humidity in four cases: ICE3 (left) and LIMA (right) at 1250m (top) and 500m (bottom) resolution.

Run with different autoconversion methods

At Benoit Vié's suggestion a new experiment was carried out to decrease the autoconversion process in LIMA, which was already tested in his other simulations. It is based on the article of *Kogan (2013)*, where a different autoconversion approach was suggested for cumulus clouds. So lima_warm_coal.F90 routine was modified in the following way:

```
WHERE( ZRCT(:)>XRTMIN(2)  .AND. ZCCT(:)>XCTMIN(2))
   ZZW1(:) = -7.98 * 1.E10 * ZRCT(:)**4.22 * (ZCCT(:)*ZRHODREF(:)*1.E-6)**(-3.01)
   ZRCS(:) = ZRCS(:) + ZZW1(:)
   ZRRS(:) = ZRRS(:) - ZZW1(:)
   ZZW3(:) = - ZZW1(:) / (3.14/6*1000.*(100.E-6)**3)
   ZCRS(:) = ZCRS(:) + ZZW3(:)
END WHERE
```

At first D=100 µm was used, but the model crashed, so it was changed to D=50 µm (in the computation of ZZW3). It turned out that this size is too small, it should be greater than 82 µm, because the scheme assumes this threshold between cloud droplets and raindrops, so in this experiment each raindrops formed back cloud droplets via the rain evaporation process (see Figure 7).

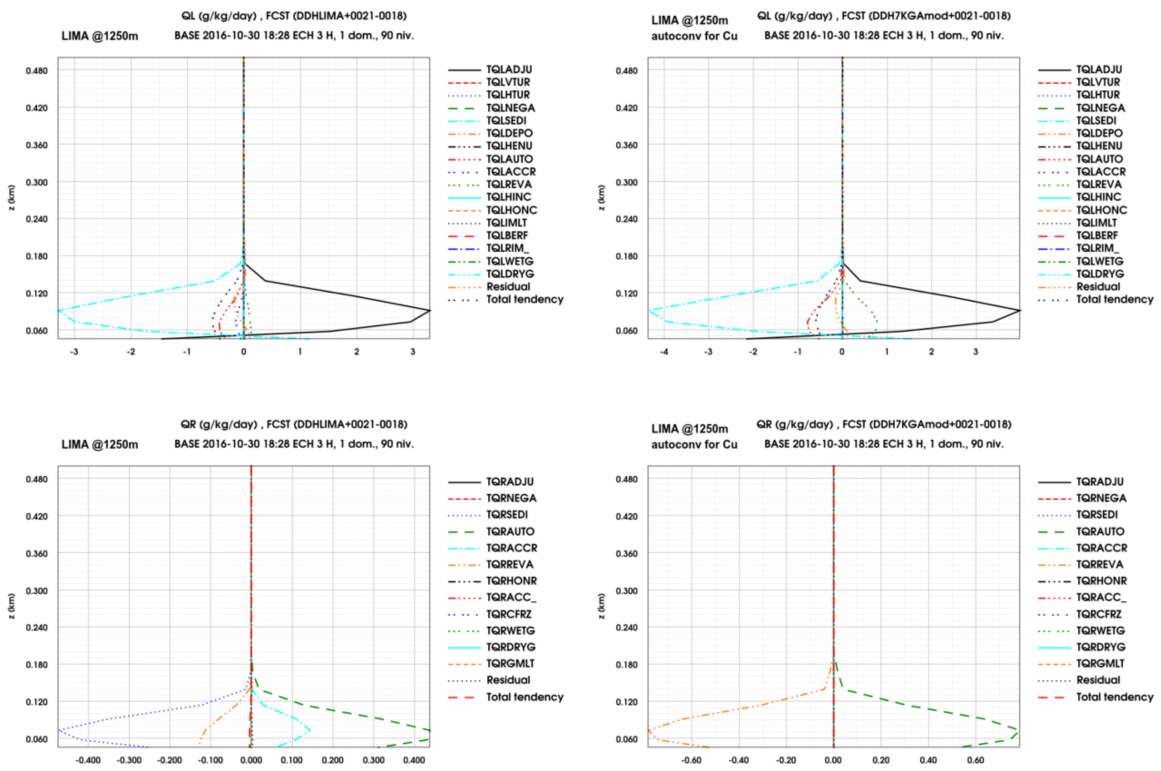

Figure 7: DDH budget terms of liquid water (top) and rain (bottom) in the reference LIMA run (left) and LIMA with the modified autoconversion function for cumulus (right). Each simulation was run at 1250 m resolution. Please keep in mind that there are different budget terms for the different variables, so that the residual and total tendency are shown with different line styles. Legends can be found next to the actual subplots.

LIMA was rerun with an another autoconversion approach too, which is used in Meso-NH warm two-moment scheme dedicated to high resolution simulations of stratocumulus (*Khairoutdinov and Kogan, 2000*). Here the diameter of raindrops was kept on 100 µm. This meant the modifications as described below:

```
WHERE( ZRCT(:)>XRTMIN(2)  .AND. ZCCT(:)>XCTMIN(2))
   ZZW1(:) = -1350. * ZRCT(:)**2.47 * (ZCCT(:)*ZRHODREF(:)*1.E-6)**(-1.79)
   ZRCS(:) = ZRCS(:) + ZZW1(:)
   ZRRS(:) = ZRRS(:) - ZZW1(:)
   ZZW3(:) = - ZZW1(:) / (3.14/6*1000.*(100.E-6)**3)
   ZCRS(:) = ZCRS(:) + ZZW3(:)
END WHERE
```

Figure 8 shows the DDH budgets for liquid water and rain. It can be seen that autoconversion process is still active, so rain drops are formed. As seen in Figure 9 the evolution of cloud fraction is very similar in the three LIMA experiment, so these modifications in the autoconversion process have not solved the problem yet.

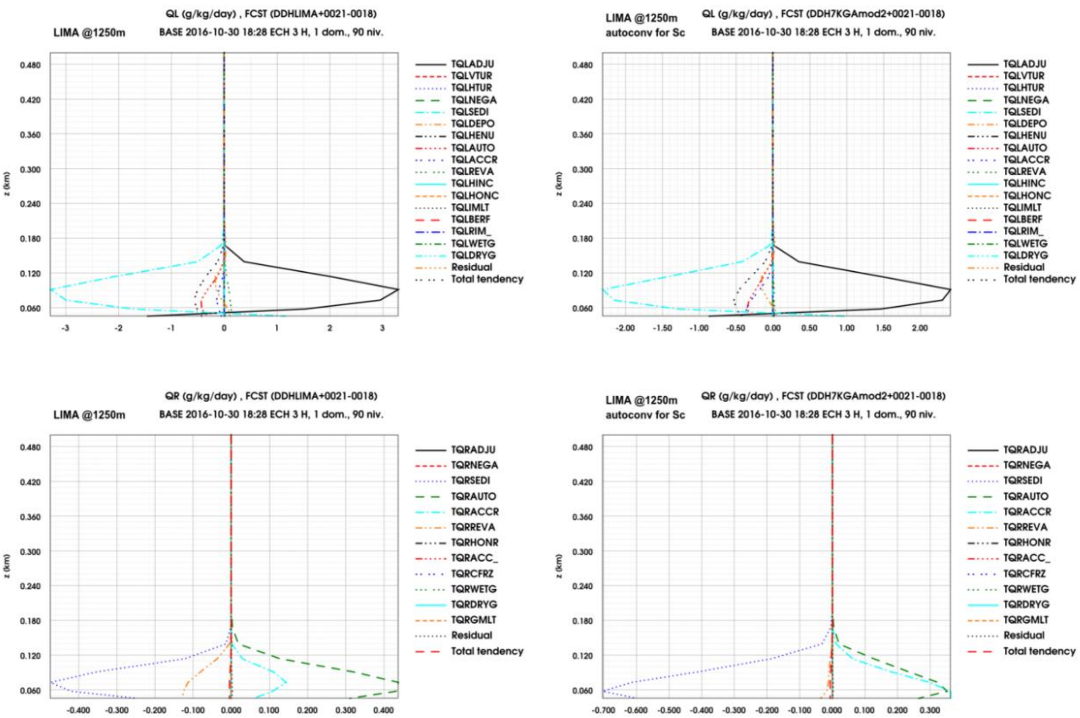

Figure 8: DDH budget terms of liquid water (top) and rain (bottom) in the reference LIMA run (left) and LIMA with the modified autoconversion function for stratocumulus (right). Each simulation was run at 1250 m resolution. Please keep in mind that there are different budget terms for the different variables, so that the residual and total tendency are shown with different line styles. Legends can be found next to the actual subplots.

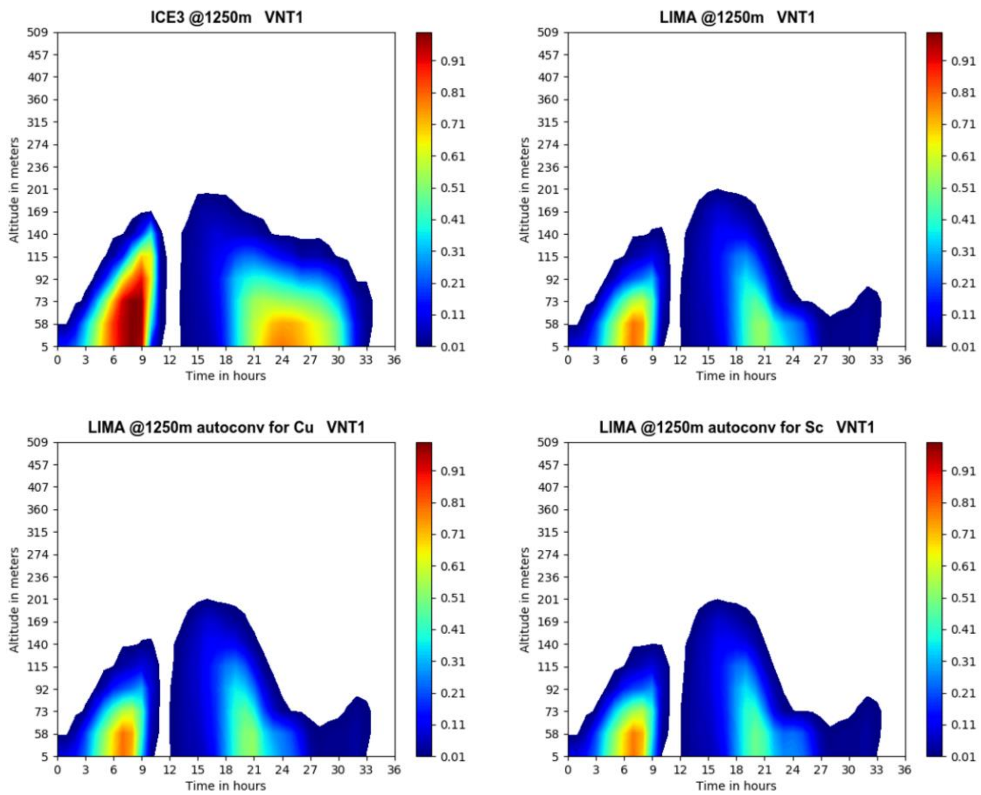

Figure 9: Time-height cross section of cloud fraction in the case of ICE3 (top left) and three cases of LIMA: original autoconversion function (top right), autoconversion for cumulus clouds (bottom left) and autoconversion for stratocumulus clouds (bottom right). Each simulation was run at 1250 m resolution.

Summary

The first half of the stay was dedicated to solve some issues in connection with DDH in the LIMA scheme, because DDH is a very useful tool to understand the behavior of the microphysics processes in the model. The second half of the time we tried to understand how LIMA scheme works in fog cases, why it gives less cloud than ICE3. The main finding was that the autoconversion process is too strong, so the falling raindrops decrease the liquid water content in the cloud. Two different autoconversion methods were tested, but the cloud cover did not change too much.

In the last few days of the stay it is came up that probably the reason of the empty initial low cloud fields (Figure 1) is that the set_conc_lima.F90 routine is called after the adjustment process that may cause the disappearing clouds, so we tried to call that routine before the adjustment, but this did not help to solve the problem. Finally, later Yann Seity found the solution of the issue in connection with LIMA run at 500 m resolution: it should be removed the LPT GFL attribute from the namelist.

Acknowledgment

I would like to thank Yann Seity for all his help and guidance during my stays from year to year. I found the discussions really useful with him and Benoit Vié this year again. I appreciated the help of Fabrice Voitus in DDH.

References

Khairoutdinov, M. F., and Y. L. Kogan, 2000: A new cloud physics parameterization in a large-eddy simulation model of marine stratocumulus. *Mon. Wea. Rev.*, **128**, 229–243.

Y. L. Kogan, 2013: A cumulus cloud microphysics parameterization for cloud-resolving models. *J. Atmos. Sci.*, **70**, 1423–1436.