Validation and testing of newest modifications in the ICE3/ICE4 microphysics scheme

RC LACE stay report

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Introduction

It is a known problem in AROME model that the microphysics scheme is sensible for the length of time step: e.g. larger time step is chosen the model predicts less precipitation. In the AROME cy40t1 Sébastien Riette prepared some modifications reducing this sensibility and meanwhile he fixed some bugs as well.

The OCND2 modification introduced by Karl-Ivar Ivarsson is a complex modification pack that mainly concerns the ice processes. It separates more rigorously the fast liquid water processes and the slower ice processes. Running the model with this option usually gives less ice crystal and more graupel and snow. The OCND2 option is implemented only to the AROME cy41t1 at Meteo-France.

These two modifications were compared through a winter case study where the scores showed large differences between OCND2 and REF run. The chosen date is 15th January 2015. To understand the effects of the modifications mean vertical profiles of the hydrometeors and DDH budgets were plotted. On all figures AROME cy41t1 was applied as reference, although reference runs are available on both cycles. However we did not experience too much difference between cy40t1 and cy41t1, so for the sake of simplicity the newer version was used in the comparisons.

Because the two improvements works different model cycles, we took an attempt to merge the two modifications for the cycle 41t1 to study the combined effect, but unfortunately the model always became unstable, and during the stay we could not figure out the reason of the problem.

Case study: 15th January 2015

On 15th January 2015 a depression was situated over the United Kingdom that caused cloudy, rainy weather in Northern France too. In Figure 1 it can be seen the high, medium and low cloud cover in case of the studied modified model runs. In the high cloud cover we can see large differences between OCND2 and REF, but in the medium and low cloud fields the ICE3mod run shows deviations from the reference mainly. The 2m-temperature fields (Fig 2) seem very similar in the three cases, difference fields show the deviations better: it is well seen that OCND2 is cooler, while ICE3mod is a little warmer than the reference.

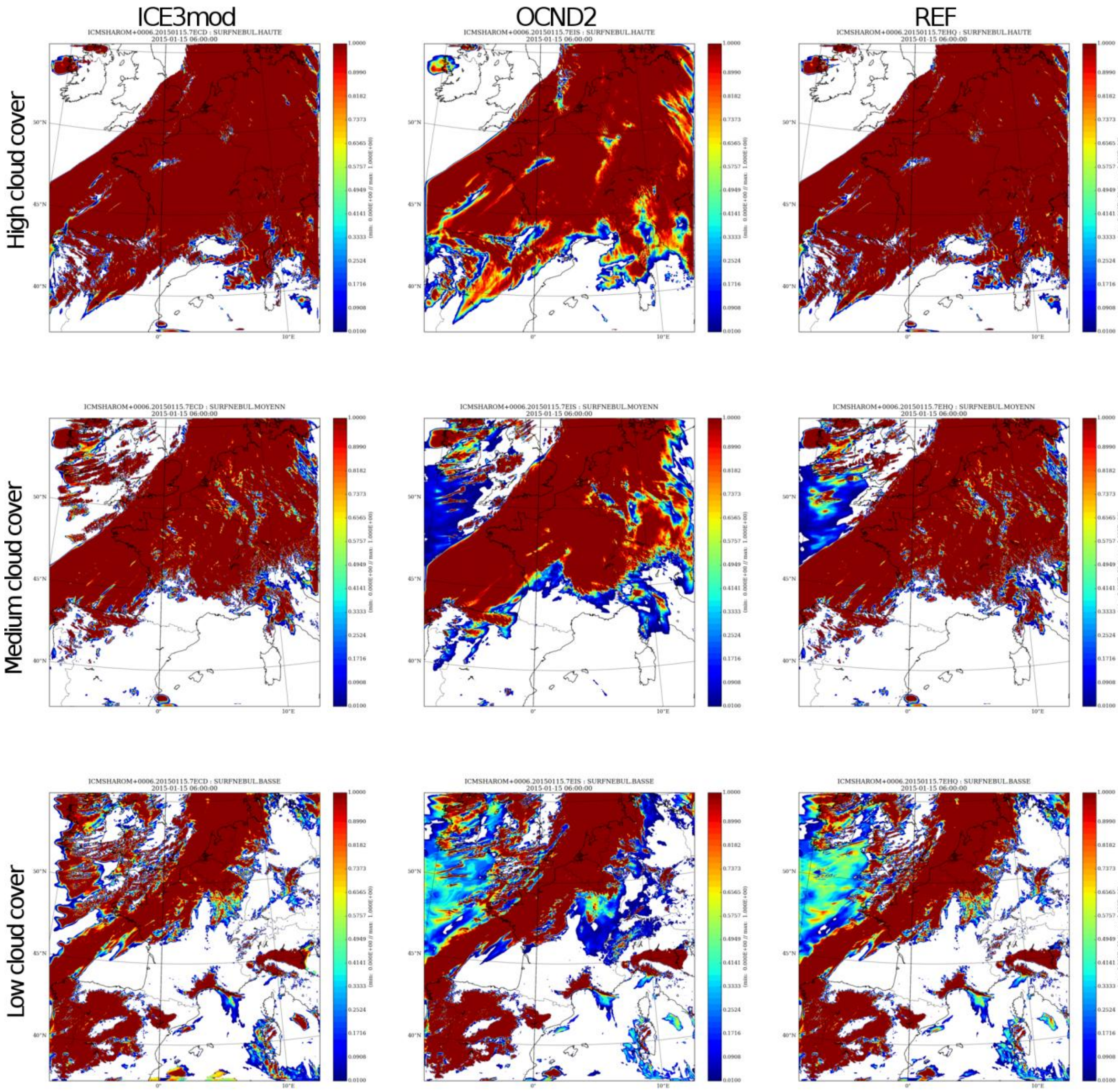

Figure 1: Cloud cover fields of ICE3mod, OCND2 and REF on 15/01/2015 at 06 UTC.

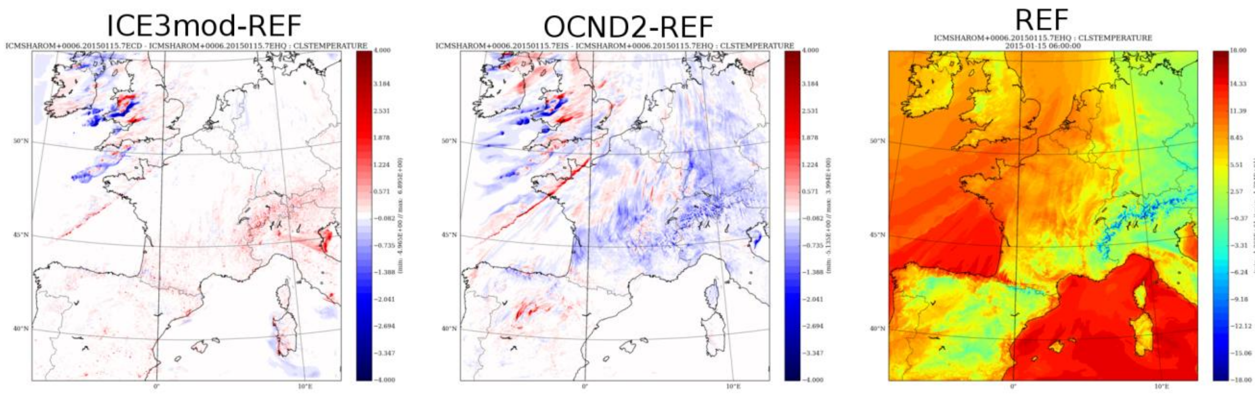

Figure 2: Temperature field of REF and temperature-difference fields in case of ICE3mod and OCND2 on 15/01/2015 at 06 UTC.

ICE3mod vs. reference

In the Figure 3 mean vertical profiles of the hydrometeors can be seen. The ICE3mod has the biggest impact on the liquid water, and almost no impact to ice crystals. There is a little more snow and a little less graupel in the mean vertical profile of ICE3mod. If we examine the processes closer through DDH budgets (see QG budget in Fig 4), large impacts can be experienced in the below processes:

- riming by cloud droplets (brown)
- melting of aggregates (green) (melting of graupels)
- wet growth of graupel (pink) – because of bug fix

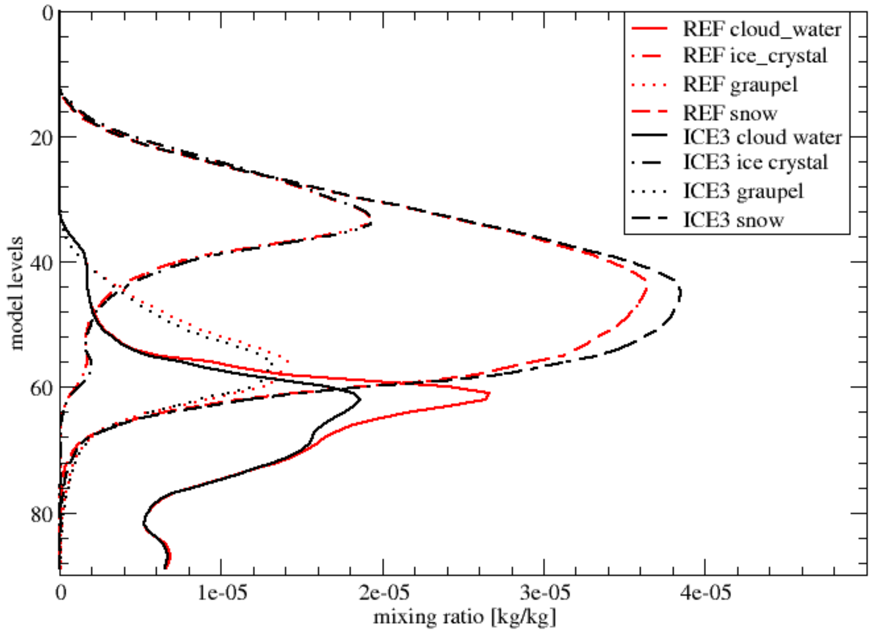

Figure 3: Vertical profiles of hydrometeors in case of ICE3mod (black) and REF (red) on 15/01/2015 at 06UTC over the whole domain.

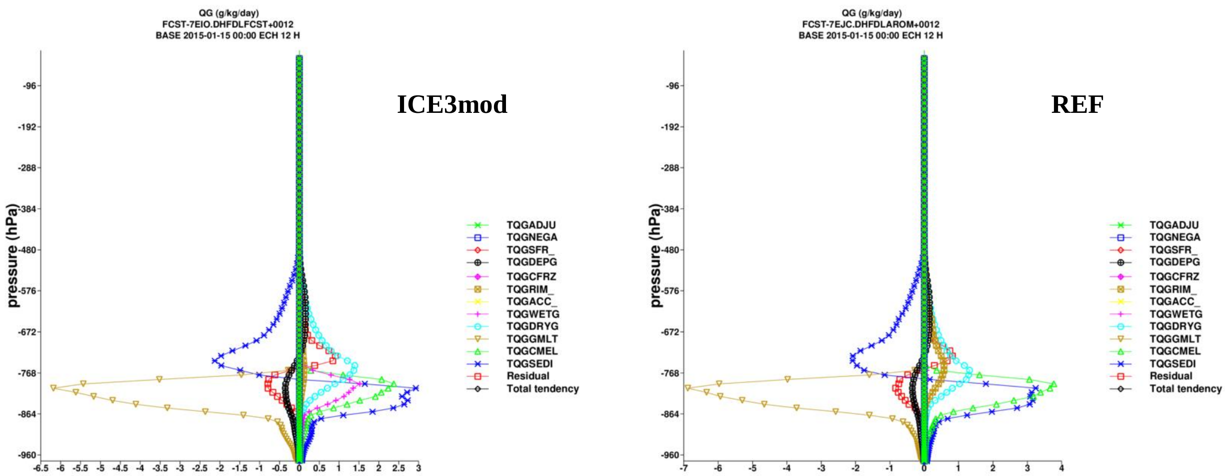

Figure 4: DDH budget of graupel in case of ICE3mod and REF.

OCND2 vs. reference

Some missing parts were realized in the OCND2 code implemented in cy41t1:

- ZCOLF (collision factor cloud liquid to snow / graupel) and ZACRF (collision factor cloud liquid to rain) arrays were not used anywhere

- the modified autoconversion function of cloud droplet to rain was not implemented

After adding these modifications to the code we can experienced the below changes in the vertical profiles of hydrometeors (Fig 5): liquid water content was increased, snow was decreased but still produced more than in REF, while graupel was increased. The modified autoconversion function causes the presence of more liquid water. The new form is much flatter than the original version (Fig 6). The original function is a linear assumption:

$$P_{RC} = k \ \max(r_c - \frac{q_{crit}}{\rho_{dref}}, 0)$$

The modified version is originated from the KK00 two-moment scheme:

$$\frac{\partial r_r}{\partial t}\bigg|_{AUTO} = 1350.r_c^{2.47} N_c^{-1.79}$$

The equation was amended with an inhomogeneity multiplier factor, which was set to 3. If this factor is increased to 30, it can be got similar autoconversion function to the original one.

Two-dimensional fields indicates more clouds in the fixed version of OCND2, especially in the low clouds, while the difference of 2m-temperature is also positive but still the reference temperature field is warmer (Fig 7) on this chosen day.

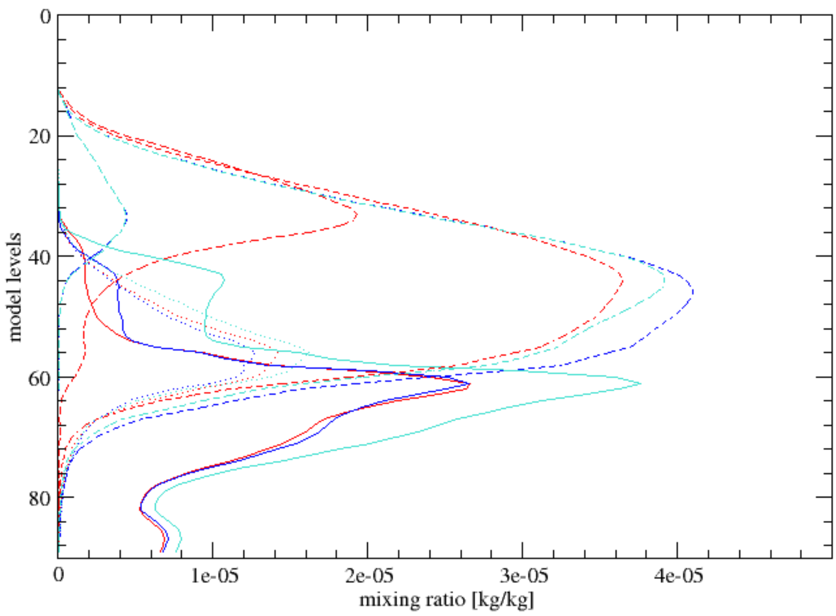

Figure 5: Vertical profiles of hydrometeors in case of OCND2 (blue), fixed OCND2 (turquoise) and REF (red) on 15/01/2015 at 06UTC over the whole domain. See the legend on Fig 3 for the identification of hydrometeor types.

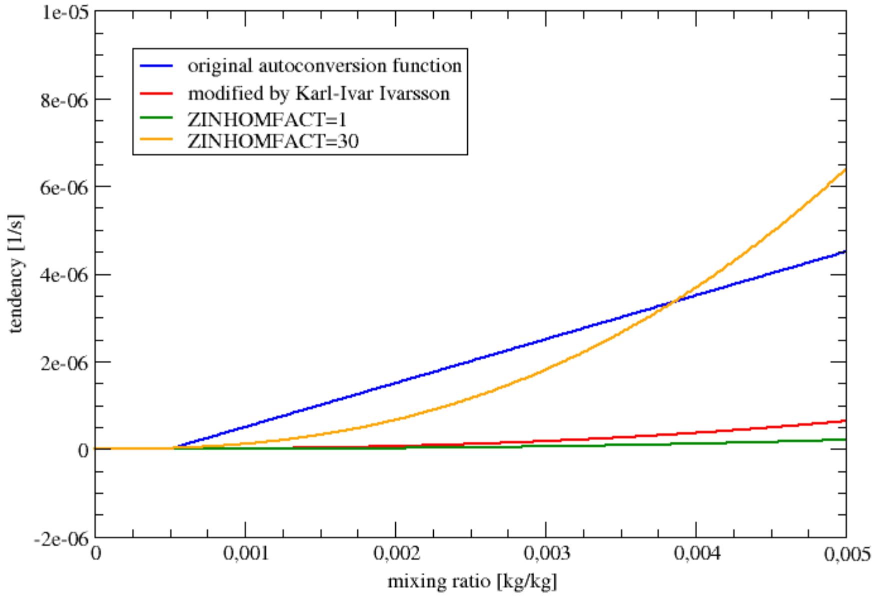

Figure 6: The original and the modified autoconversion function of cloud droplet to rain.

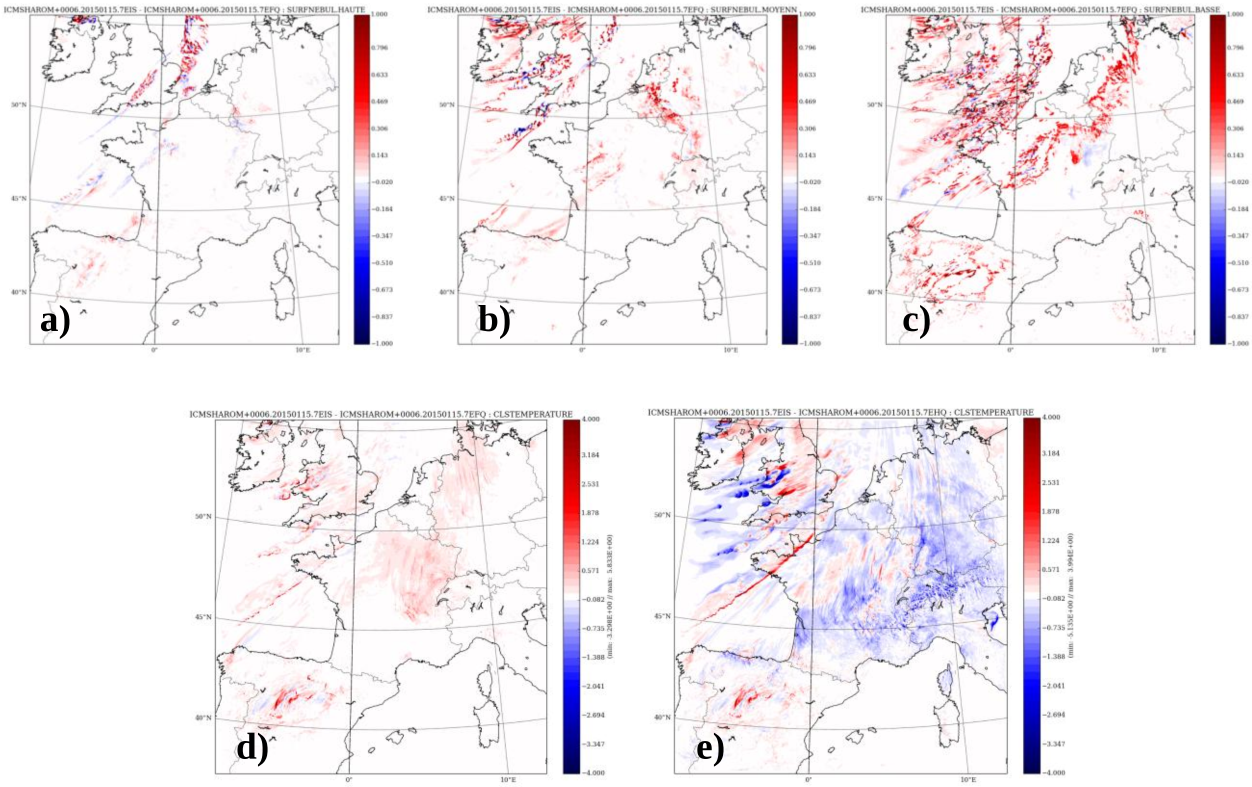

Figure 7: 2D difference fields between the fixed OCND2 and the original version (a-d): a) high cloud, b) medium cloud, c) low cloud, d) 2m-temperature, e) 2m-temperature difference field between fixOCND2 and reference.

Figure 8, 9 and 10 show the DDH budgets of ice crystals, liquid water and snow, respectively. On the left hand side there are budgets from the fixed OCND2 and on the right hand side from the reference. As we saw on the vertical profiles, the amount of ice crystals changed the most with the OCND2 option, so the DDH budgets completely changed as well. One of the modified processes is the Bergeron-Findeisen effect, so it is no surprising to see differences in its budget.

We can see lots of changes in the budget of liquid water: previously mentioned Bergeron-Findeisen effect appears here too, furthermore there are differences in the riming processes and the dry growth of graupel. These differences can be seen on the DDH budget of graupel with positive sign as well (not shown). The reason of the decrease of the amplitude of riming probably is the smaller value of ZCOLF. If OCND2 is false, this multiplier factor is 1, but in the case of OCND2 the factor is between 0.01 and 1. Therefore the available liquid water rather is transformed to graupel by dry growth.

Because the autoconversion function between cloud water and rain was modified, changes in this process obviously happen. Because the modifications concern all of solid phases, so the budget of snow shows differences for the effect of OCND2: sedimentation and deposition alter besides riming.

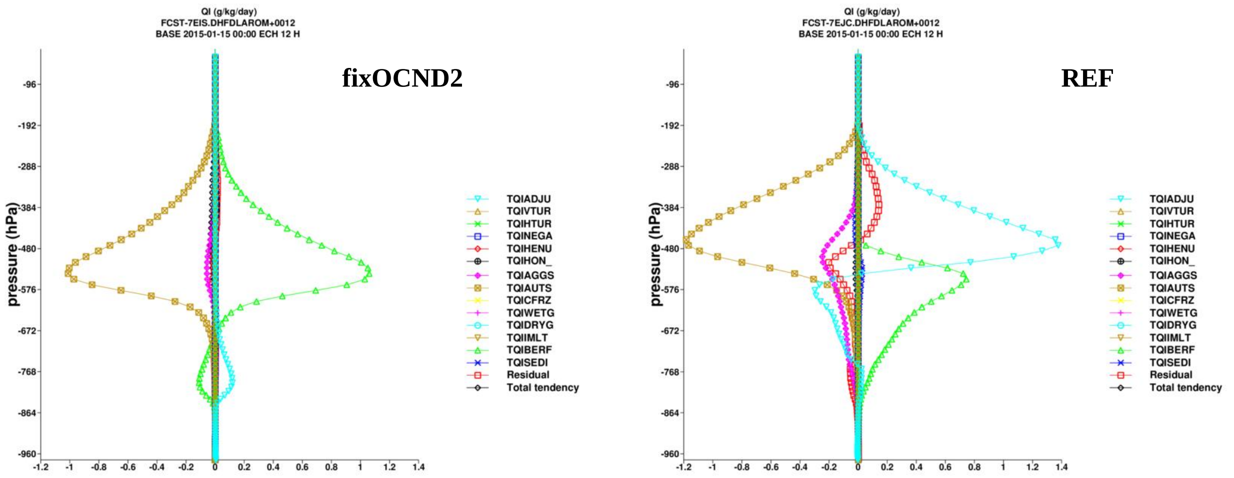

Figure 8: DDH budget of ice crystals in case of fixed OCND2 and reference.

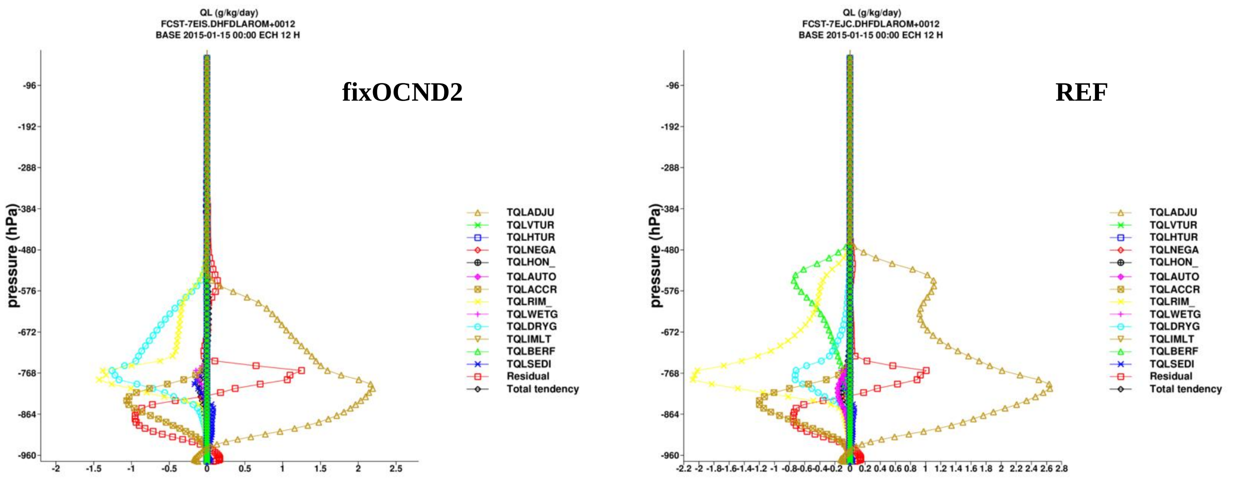

Figure 9: DDH budget of liquid water in case of fixed OCND2 and reference.

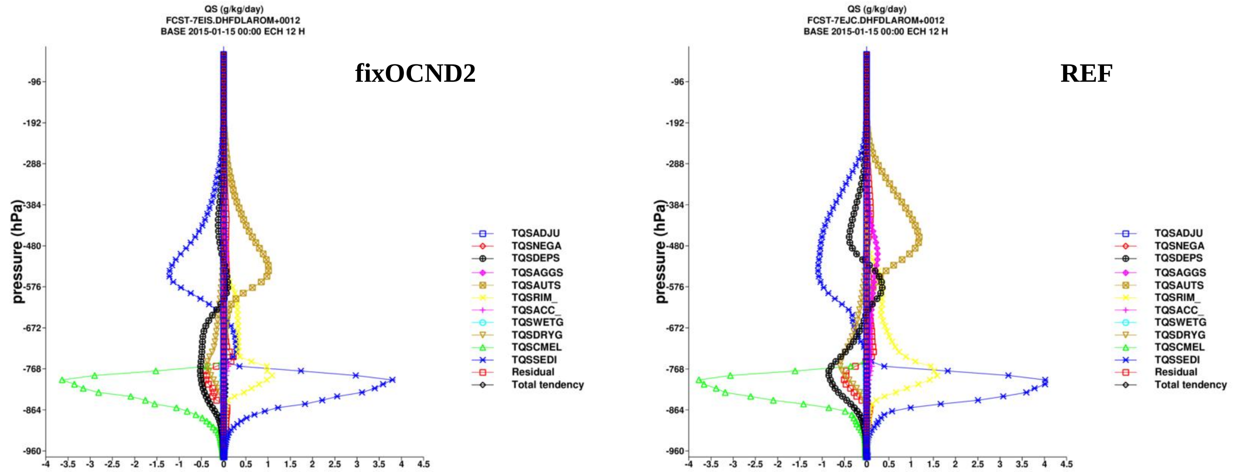

Figure 10: DDH budget of snow in case of fixed OCND2 and reference.

Comparison of ICE3mod and OCND2

If we plot together the vertical profiles of hydrometeors in case of the two modifications and the reference (Fig 11), we can see better the effect of the modifications. For example in case of snow both modifications increase the mixing ratio. But the impact on liquid water and graupel is not so consistent. OCND2 increases the cloud water at each level, especially in the mix-phased middle layers. In contrast, ICE3mod effects only around the location of maximum, it decreases the largest values. With ICE3mod the mixing ratio of graupel decreases, while OCND2 produces more graupel. ICE3mod does not change the ice crystal, only OCND2 has a substantial effect on it.

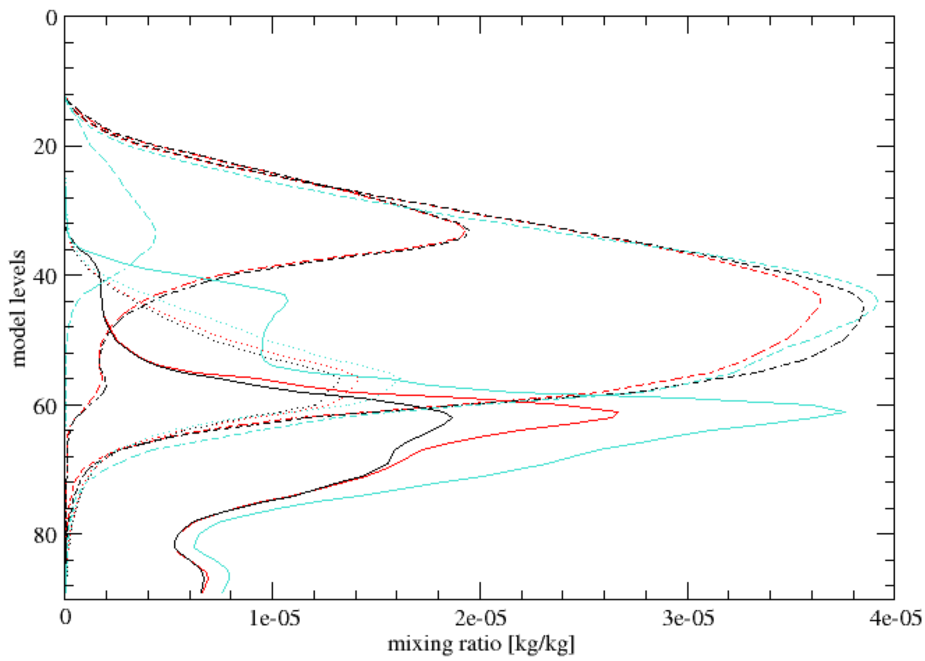

Figure 11: Vertical profiles of hydrometeors in case of OCND2 (turquoise), ICE3mod (black) and REF (red) on 15/01/2015 at 06UTC over the whole domain. See the legend on Fig 3 for the identification of hydrometeor types.

Radiation comparison

As it difficult to compare 3D mixing ratios with observations because of the limited availabilities of data, we compare model results with surface radiation observations. For the radiation comparison see Figure 12-15. Daily mean shortwave and longwave radiation was verified at two sites: at SIRTA (not so far from Paris) and Cabauw station (in Netherlands). Two longer periods were studied: a winter period (7th January–31st January 2015) and a summer period (1st August–31st August 2015). The 2m-temperature at 12 UTC is also plotted, as the daily mean cloud fraction from the models too. Generally it can be said at both sites winter scores show more agreement with the observations. At SIRTA station longwave radiation is slightly underestimated by the models and between 19th January and 23rd January shortwave radiation is overestimated, accordingly there is a little overestimation of the temperature. Between the model variations there are not too much difference in the winter period, only in the cloud fraction can be seen less cloud predicted with OCND2 option.

During summer period longwave radiation values seem correct in the models but shortwave radiation shows overestimation, especially at SIRTA station. Here the different model runs also give different shortwave radiation values but these discrepancies can not be seen in the 2m-temperature values.

Some modifications proposed by HIRLAM radiation group concerning cloud optical properties for instance are not included in the studied experiments, and may also have a significant impact on radiation comparison.

Summary

During the stay two modifications in the microphysics were studied. The aim of ICE3mod is to reduce the sensitivity to time step in the microphysics scheme. Results show more liquid water and snow and a little less graupel in the studied winter case. From the DDH budgets it is clearly seen that the wet growth process was completely switched off before because of a bug which has been fixed.

The other modification called OCND2 carried out a lot of changes around the ice processes, so we saw large impact in the vertical profiles and DDH budgets as well. The biggest impact of OCND2 is the decrease of ice crystals at high levels and the increase of liquid water in the mixed phase area.

As the impacts are sometimes different for some species, it would be interesting to merge the two modifications in the same source code version in order to examine the combined effects.

Acknowledgment

I would like to thank Yann Seity for all his help and guidance during my stay. I found the discussions really useful. Technical assistance provided by his colleagues at CNRM was greatly appreciated.

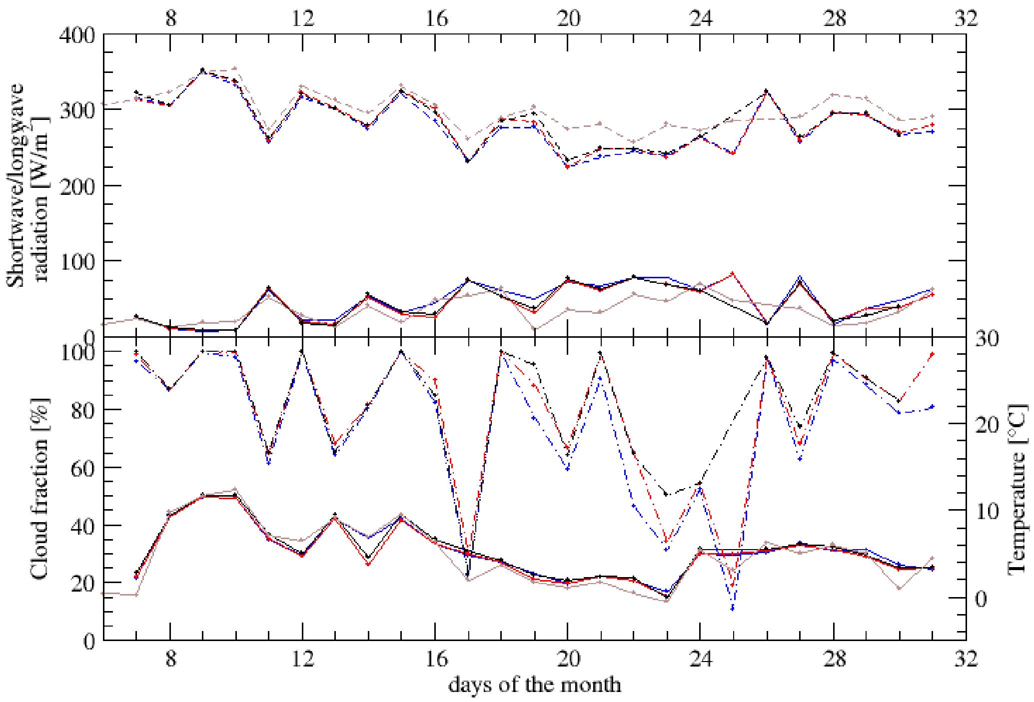

Figure 12: Shortwave (solid line) and longwave (dashed line) radiation, 2m-temperature (solid line) and cloud fraction (dash-dot line) in case of REF (red), ICE3mod (black), OCND2 (blue) and observations (brown) at SIRTA station during January 2015. Dots indicate the exact values.

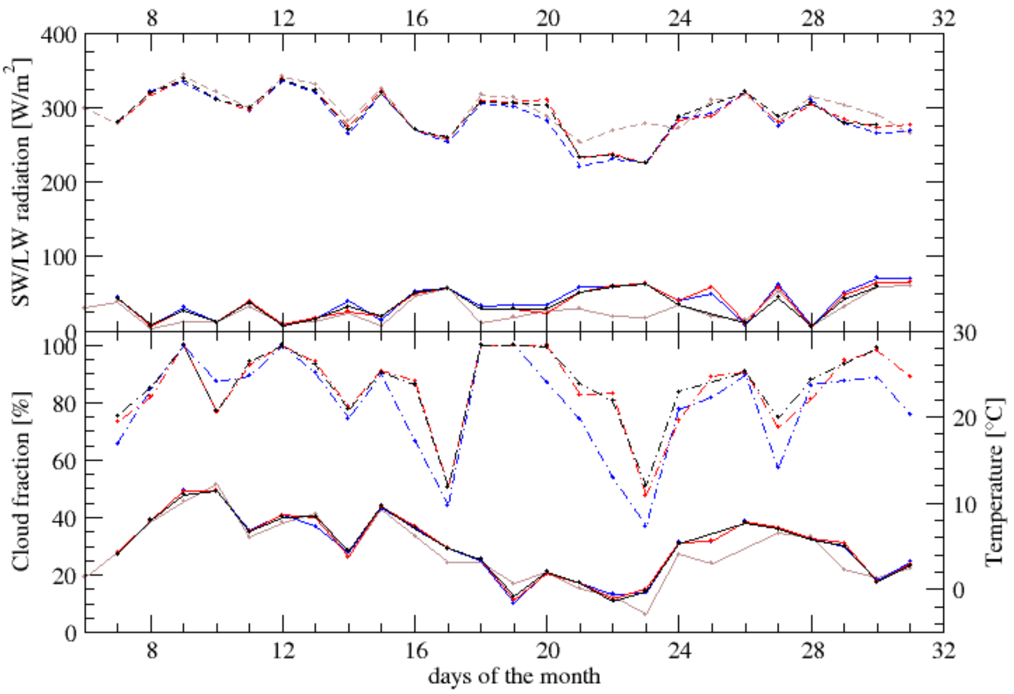

Figure 13: Shortwave (solid line) and longwave (dashed line) radiation, 2m-temperature (solid line) and cloud fraction (dash-dot line) in case of REF (red), ICE3mod (black), OCND2 (blue) and observations (brown) at Cabauw station during January 2015. Dots indicate the exact values.

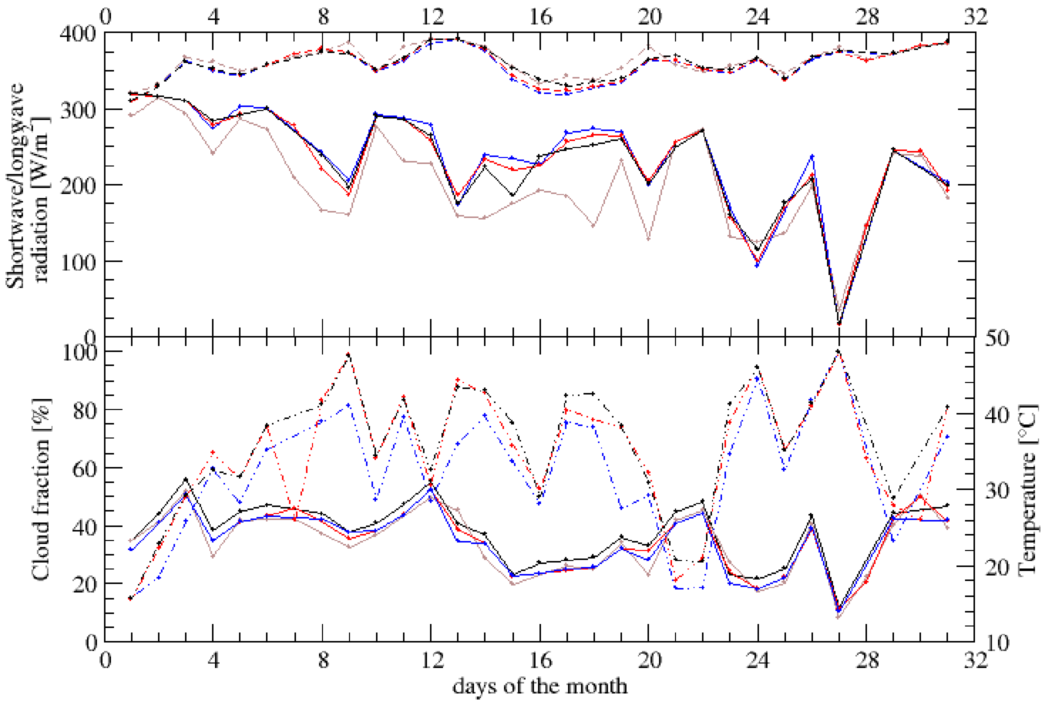

Figure 14: Shortwave (solid line) and longwave (dashed line) radiation, 2m-temperature (solid line) and cloud fraction (dash-dot line) in case of REF (red), ICE3mod (black), OCND2 (blue) and observations (brown) at SIRTA station during August 2015. Dots indicate the exact values.

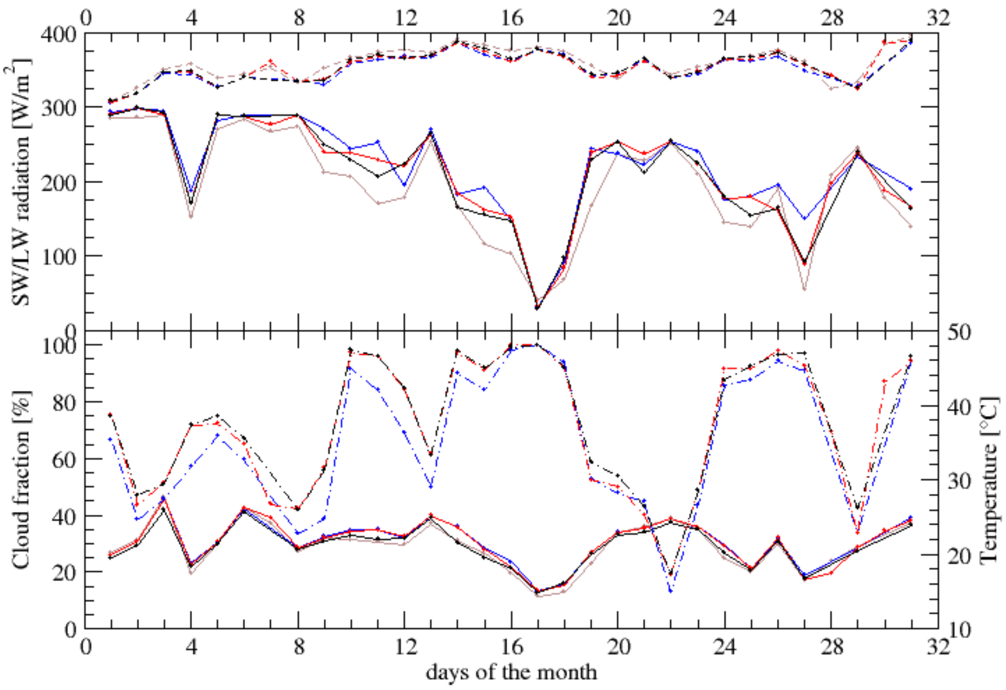

Figure 15: Shortwave (solid line) and longwave (dashed line) radiation, 2m-temperature (solid line) and cloud fraction (dash-dot line) in case of REF (red), ICE3mod (black), OCND2 (blue) and observations (brown) at Cabauw station during August 2015. Dots indicate the exact values.