Examination of dependency of precipitation on time step length in ALARO 10

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1. Introduction

ALARO 10 is a numerical model consisting of dynamical part, which is taken from hydrostatic version of ALADIN and physical parameterisations taken from Meso-NH; a no hydrostatic, unelastic mesoscale model. First tests of ALARO 10 has showen a problem with forecasting precipitation. Much smaller amounts of surface precipitation where forecasted than by ALADIN in the same case. Further more, the amounts of precipitation are dependent on time step length. As time step is longer less precipitation is forecasted.

Two main processes produce precipitation in the model, these are: convection and resolved scale rain. For resolved scale rain an explicit microphysical scheme is used, including five spieces of hydrometeors, *viz.* cloud water and ice, rainwater, snow and graupel. A detailed description of scheme can be found in Book 1 of Meso-NH documentation. It is believed that this microphysical scheme is the main reason for lake of precipitation in ALARO 10 forecasts.

Dependency of precipitation on time scale length was examined on two cases. The first one is the great flood in Gard department on 8.9.2002. Characteristic for this case is a strong convection. The second case is a could front approaching Czech republic on 8.7.2004. For both cases more 12 hours runs were done, each with different time step, to see the effect of time step length on predicting precipitation.

Afther that, the iteration of microphysical scheme during one time step of the model or time splitting was introduced in the model. Several combinations of dynamical and microphysical time steps were tested on both cases.

2. Dependency of precipitation on time step length

2.1. Introduction

In microphysical schemes there is no adjustment for time step length. Microphysical processes represented in it are mainly on shortest time scale than operational time step of ALADIN. When to lomg time step is used truncation error in microphysical scheme is to high. As shortet time step is used as smaller truncation error will be. The consequence is the dependency of precipitation amount on time step of the model. We can expect that when certain short enough short time step is used truncation error will not change significantly change if even shotter time step is used. Otherwords, results of modwel integrations for time steps shorter than critical one will not differ significantly. At the same time it is assumed that possible differences in results of integration of dynamical part of the model with different time steps are minor compared to those caused by microphysical scheme.

It was noticed that shorter time step means more precipitation and vice versa. This finding will be investigated more thoroughly here.

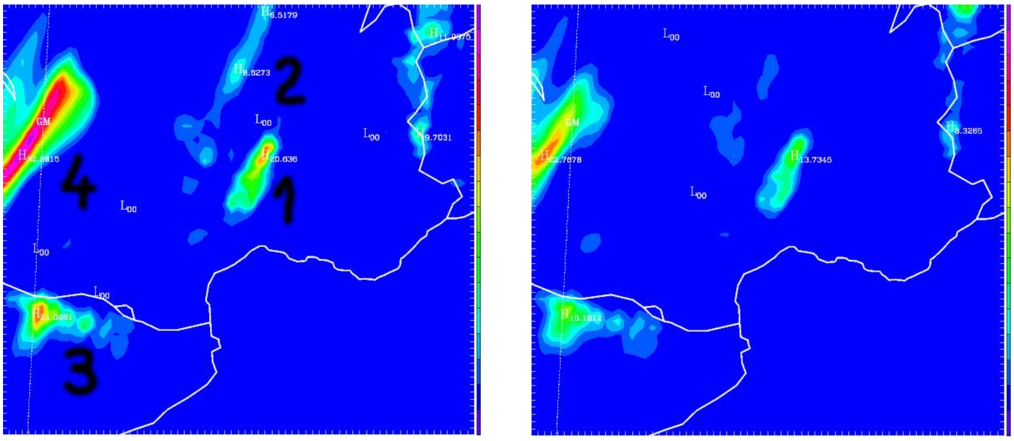
2.2. Method

To investigate precipitation dependency on time step length, model was run for the same initial and boundary values with several time teps, *viz.* 60, 120, 180, 240, 300, 360, 400, 450 and 514 s. Outputs from model were daone for evry hour of forecast time. Twelve hours runs of ALARO 10 were done for two before mantioned cases. To study dependancy of precirpitation on time step, outputs of surface precipitation intensities and accumulated precipitation since the start time where used. Outputs were visualised by coloured nivaeaus on geographic maps, e.g. Fig. 1. On maps distinct areas of precipitation were defined. For each area a maximum value of precipitation intensity and accumulated precipitation were read uot. Values for one area at same output time coming from runs with different time steps were used to plot a curve of dependency of precipitation intensity or accumulated precipitation on time step at that particular output time. These curves were then fitted with the second-degree polynomials. Assuming that calculations of precipitation intensity are more accurate at shorter time steps, the value of the fitting polynomial for time step 0 should be the “true” value of the precipitation intensity. For those precipitation maximums that could be traced through several hours more curves could be extracted and their time changes could be seen.

2.3. GARD case

As mentioned before the GARD case is from 8 September 2002 when there were floods in Gard department in south of France. Great amounts of precipitation were measured, reaching 700 mm in twelve hours. Accumulated precipitation after 12 hours of model run starting at 8 September 2002 12 UTC is shown in Fig. 1 for two time steps 60 and 360 s. The separated areas of precipitation are marked with numbers, and this numbers are used to denote corresponding maximums.

Figure 1: Accumulated precipitation for 12 h run of ALARO 10 for GARD case, starting on 8th September 2003 12 h. a) time step 60 s. b) time step 300 s.



Dependency of precipitation intensity on time step for two maximums, those from area 1 (M1) and 2 (M2), two hours after model’s start is shown in Fig 2a and the same but for maximums 1 and 3 (M3) eight hours after model’s start is shown in Fig 2b. Common characteristics of all curves is that precipitation intensity is

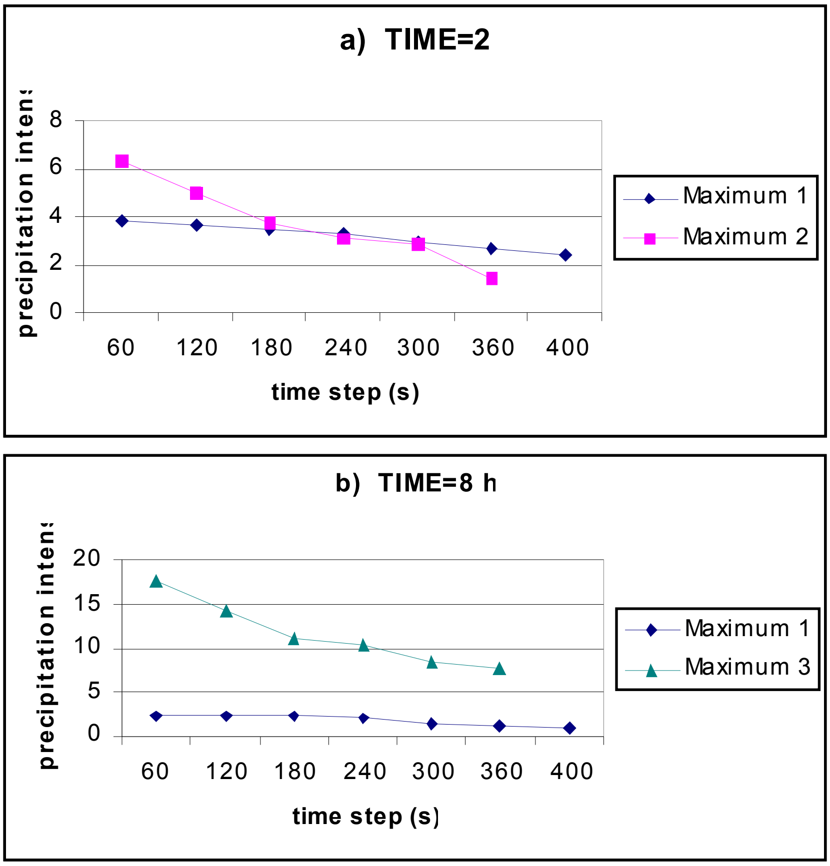


Figure 2: GARD case. Dependency of precipitation intensity on time step, a) two and b) eight hours after the model’s start. Curves for maximums 1,2 and 3 from Fig 1. are shown.

increasing with diminishing time step. The curves for M2 and M3 have some common features. Both curves increase more rapidly for time steps shorter than 180 s, and have a part where intensity changes slower with time step (around 240). It seams that for time steps shorter than 180 s some new process (or processes) is turned on. Curve for M1 at both output times shown at Fig 2. doesn’t have such behaviour; intensity doesn’t change a lot with time step. There are no sudden changes on it.

It must be mentioned that maximum intensity was not at the exactly the same geographical position for each time step, but they always belong to the same area of precipitation. In Fig. 3. dependency curve for intensity at M1 six hours after the start of the model is shown. Irregular shape of this curve is thought to be consequence of the fact that precipitation intensity changes with the time, and that this changes may be different at different time steps.

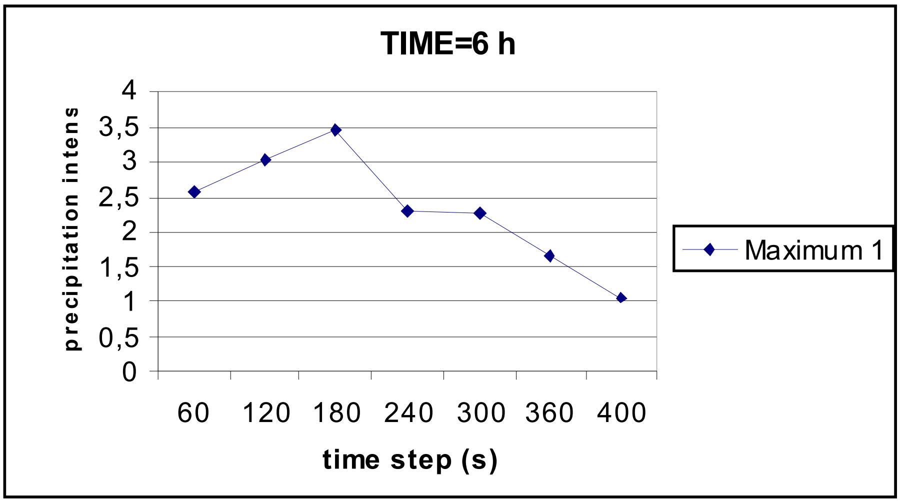


Figure 3: GARD case. Irregular shape of the dependency of precipitation intensity on time step curve.

In Fig 4. intensity of precipitation dependency on time step curves for M4 are shown at the time of three outputs of model ALARO 10. All curves have common characteristic of decreasing intensity of precipitation with increasing time step, which is seen before. As is seen by M2 and M3 for time steps shorter thean 180 s intensity changes faster with time step than for shorter timesteps. This feature is not so pronounced as for M2 and M3.

It is interesting to note that there is almost no difference between three curves for time steps longer than 240 s and that curve for the12th hour of model integration has for all time steps longer than 120 s smaller values of precipitation intensity than values on curve for the 11th hour of integration. The greatest difference between three curves can be seen for time step of 60s. The intensities for this time step shows that precipitation system was growing in intensity. For longer time steps it seems that system was decaying at the 12th hour of model integration. This means that 12th hour curve is composed of two curves, one for decaying cloud, for longer time steps, and the other for growing cloud for shorter time steps. This is the irrgularity caused by changing of intensity during the time, as explained before.

All intensity depandancy curves were fitted with quadratic polynopials, which are the best fitting functions. An example is geven in Fig. 5. If it is true that by running the model with shorter and shorter time step we will reach a time step for which no shortening of time step will cause any changes in precipitation, than chabnges of intensity with time step should be smaller and smaller when time step aproaches zero. There should be an value of time step at which the dependency curve statrs to bend down in direction of shorter timesteps. This is not the case with our curves, except for M1. It must be mentoned that run for time step of 120 s was not successful and values at 120 s were achieved by lineart interpolation. If bending of the curves takes place betweeb time steps of 60 and 120 s it cann't be seen on our curves, it cann't be seen if it happends for time step shoter than 60 s, as well. In the zero limit of the time step our fitting curves are owershooting the value which dependency curves should approach. According to formulas of the fitting curves for M4, in the zero limit of time step the values of precipitation intensities are 41.223, 53.495 and 66.368 for the 10th, 11th and 12th hour of integration respectively.

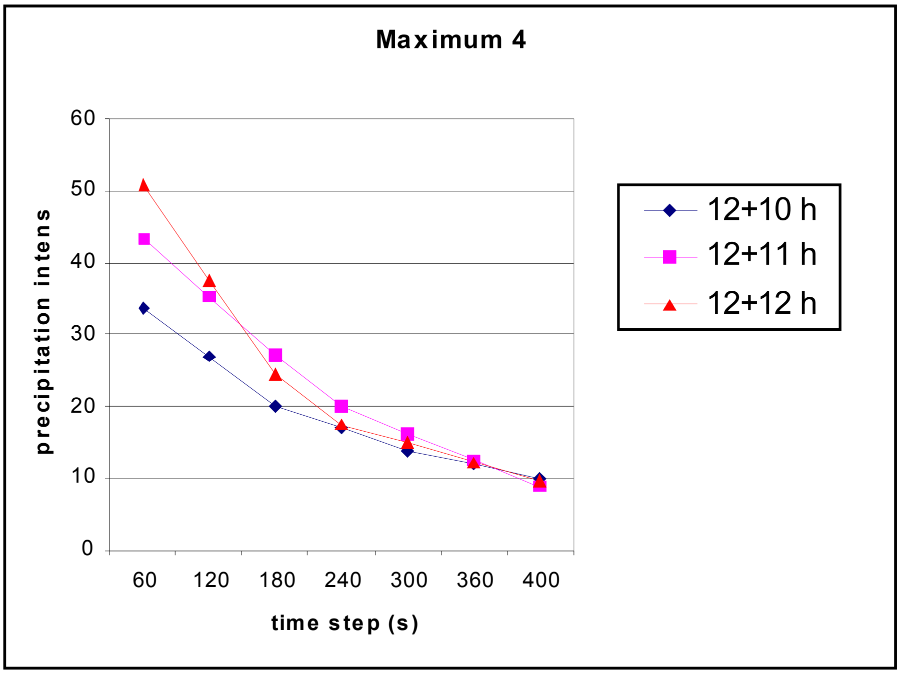


Figure 4: Intensity of precipitation at 12+10, 12+11 and 12+12 hours for western area of precipitation. On x-axe are time steps and on y axe are precipitation intensities

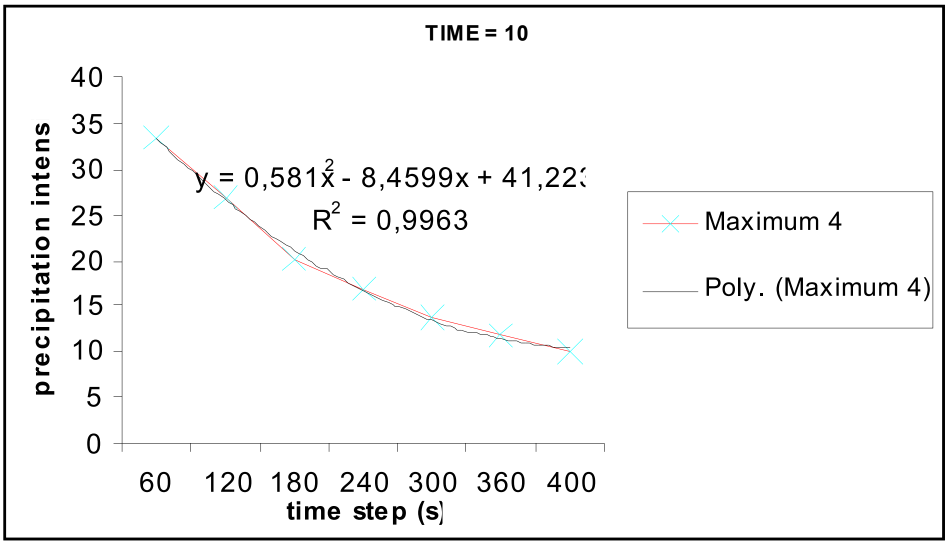


Figure 5 : Intensity of precipitation at 00+10 for western area of precipitation and corresponding fitting curve. On x axe are time steps and on y axe are precipitation intensities.

The acccumulated precipitation dependancy on time step curves for all four maximums are shown in Fig. 6. We can see on it that there are two types of curves. First type is the curve reaching asimptoticaly an limiting value when time step goes to zero. Other type is a curve with inflexion point and at the time step 60 s, the smallest value used, it still doesn't show any changes of sloap. Both curves are decaing.

Curves for M1 and M3 belong to the first type of curves. They have even similar values, except for longest time steps, where differences are somewath greater. For shorter time steps both curves are gradualy approching almoast equal value. There is a difference between these two curves, the precipitation for M1 is of longer duration than for M2. If we take in to account this and that shape of intensity dependency

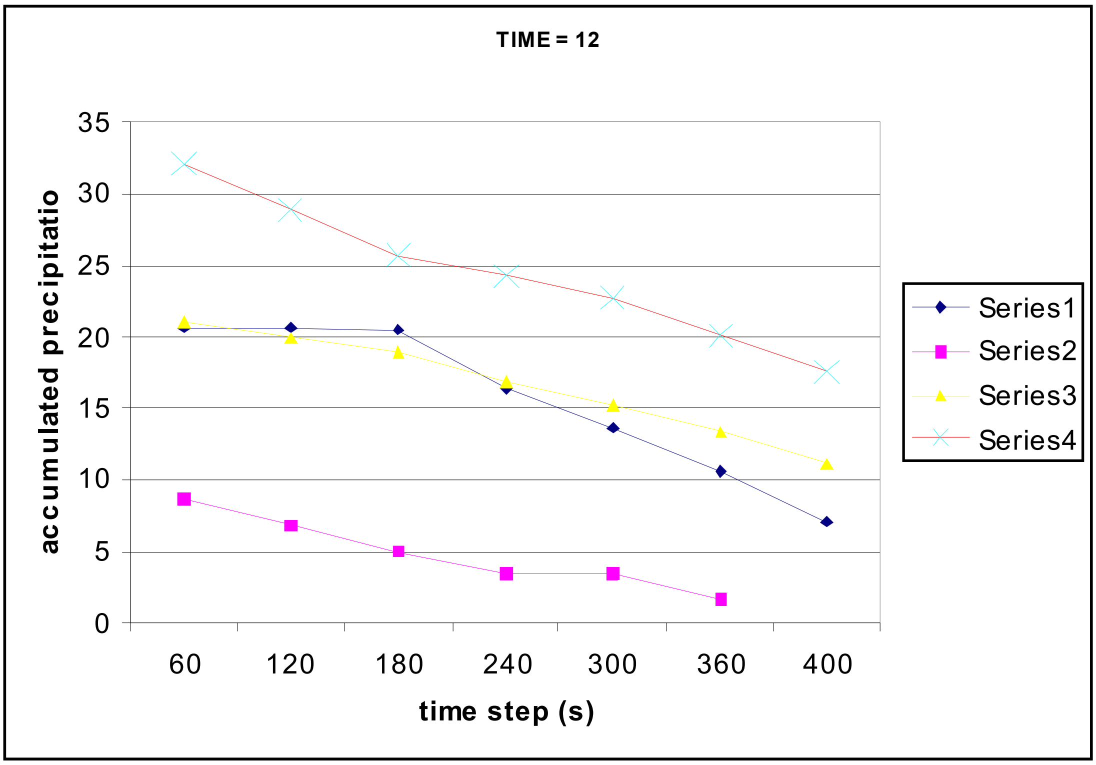


Figure 6. Accumulated precipitation at 00+12 hours.

curves, Fig. 2, are different, it seems that similarity of acccumulated precipitation values is accidentaly. Obviously the time step is not the only factor influencing precipitation amount. The curves for M2 and M4 belong to second type. If we move down the curve for M2 or M4 from longer to shorter time steps the value of accumulated precipitation is grawing until the certain time step value, TS1, when it starts to graw slowlier, or stays constant. Going further to the smaller values of time step we come to the point, at time step TS2, where curve starts to graw faster, again. At this level of investigation it is not possible to give an axact explanation for such behaviour, but let’s propose an explanation for such behaviour. Firs, changes of sloap at TS2 could be caused by turning on some more efficiend precipitation production process, which can be activated at time steps shortet than TS2, but still is not completly resolved by time step of 60 s. Explanation for changes of soap at TS1 could be that some precipitation production process are completely resolved at time step TS1, and usage of shorter time steps will make no improtand difference in precipitation amount. If this is true, we could say that curves of type two are the curves of type one, just with some process actevated at TS2, while for curves of type one this doesn’t hapened. The exact explanation of curves shapes could be get from outputs of microphysical variables sources, which we don’t have at this stage of model code development. It could be only checked up when and where is convection scheme turned on and how this is influenced by time step length.

2.4. Czech (CZ07) case

Another case is a severe cold front with huge rainfalls over Czech republic on 9th July 2004. Erliar comparations showed ALADIN model gave beter forecast than ALARO 10 for the same domain and grid mash.

Precipitation intesity dependency on time step curves had characteristics similar to those observed at GARD case. An example is shown in Fig. 7. This curve has some characteristics of both types of curves for accumulated precipitation, described abov. We can see an asimptotic behaviour vhen time step is approaching zero, like by curves of type one, but there is an part of curve, between time steps 180 and 120 s, with steap slope. This feature is charachteristicsof type two curves at time steps shorter than TS2.

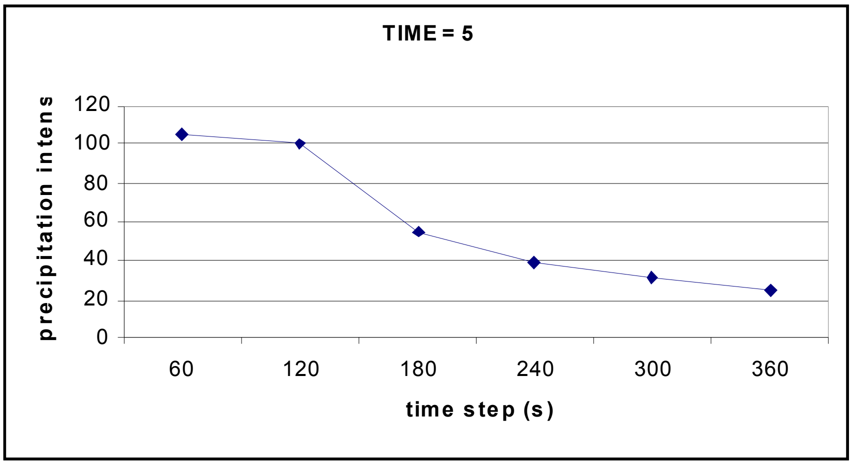
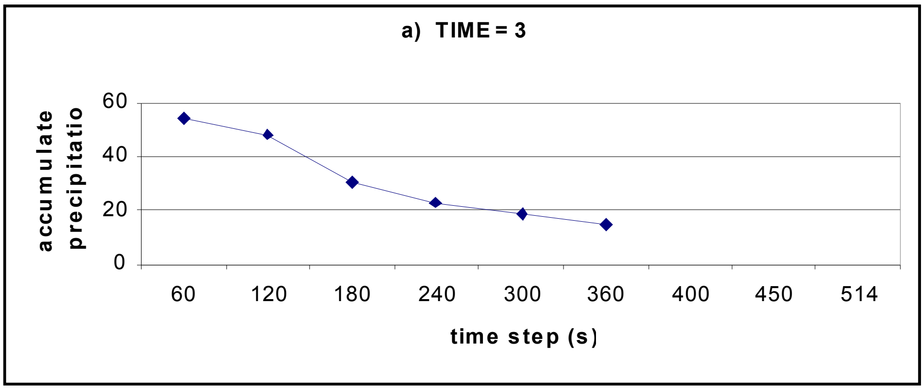


Figure 7: CZ07 case. Dependency of precipitation intensity on time step.

Dependency of accumulated precipitation on time step length is shown in Fig. 8. Curves at three utput times are shown. Curve for accumulated precipitation in first three hours, Fig. 8a, has characteristics similar to those of curve for intensity in Fig. 7. Curve after eight hours, Fig. 8c, has belongs to the type two, and curve after five hours, Fig. 8b has intermediate characteristics between curves on Fig. 8a and Fig. 8c. If we keep the same explanation for shape of curves as in the GARD case, we could say that in CZ07 case there is a process that is resolved on shorter time scales. After three hours of model of forecasted time this process was almost completely resolved at time step of 120 s, but as time went on it was less and less well resolved, and after eight hours it is not completely resolved with time step of 60 s. Here as well, outputs of source terms are needed to get exact explanation of curves.



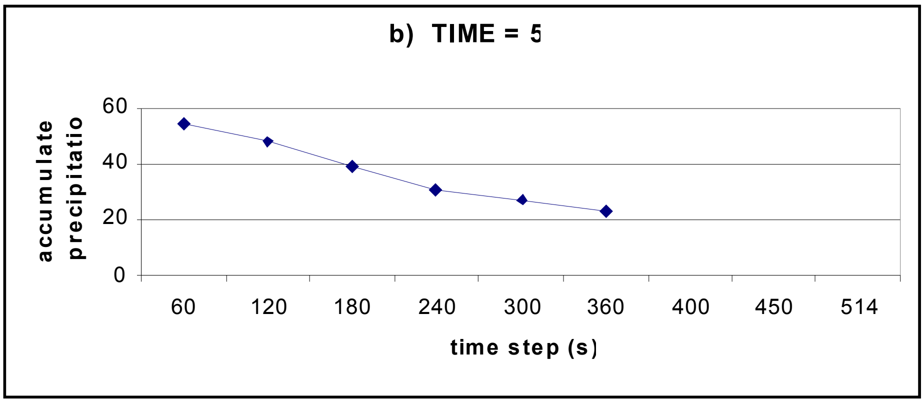
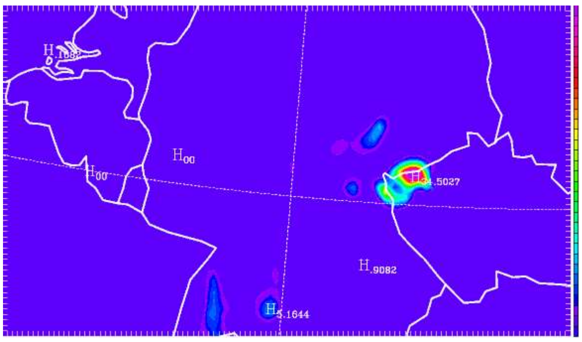


Figure 8. CZ07 case. Accumulated precipitation dependency on time step length for run of ALARO 10 starting on 8th July 2004 12 h, for outputs after a) 3, b) 5 and c) 8 hours.

On this case another feature of dependency on time step can be shown, this is a dependency of position of precipitation are on time step. This is demonstrated in Fig. 9 and 10, showing intensity and accumulated precipitation for seven hours of forecasted time with two time steps. In Fig. 9a precipitation intensity is shown at seventh hour of forecast when model is run with 60 s time steps and Fig. 9b shows the same except for time step which is 360 s. From these two pictures it is clear that precipitation area when time step is 60 s is shifted to the east to the precipitation area when time step is 360 s, and it is more localized compared to area of 360 s time step.

a)



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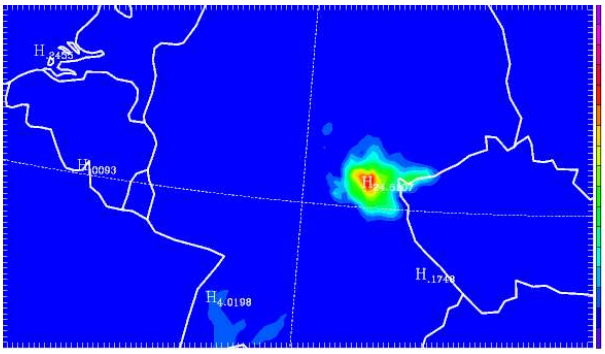
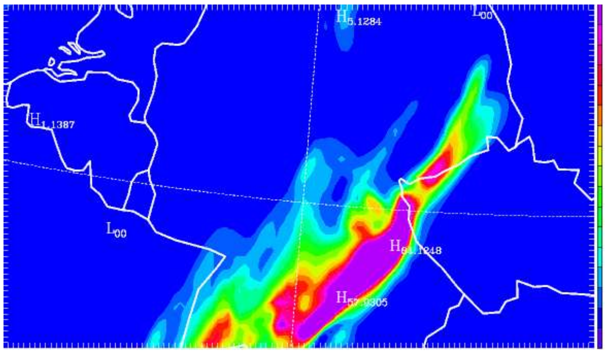


Figure 9. Precipitation intensity 7 hours after the start time for time steps, a) 60 s and b) 360 s.

a)



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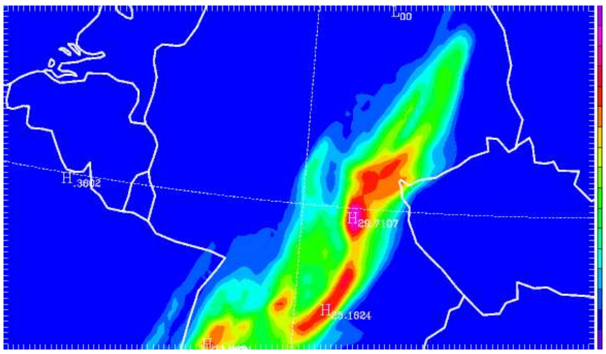

Figure 10. Accumulated precipitation 12 hours after the start time for time steps, a) 60 s and b) 360 s.

Accumulated precipitation at the same time for 60 s and 360 time steps is shown in Fig. 10a and Fig. 10b, respectively. While shape of instantaneous precipitation area, Fig 9., is circular, the shape of accumulated precipitation areas is extended along the trajectory of individual, instantaneous rain areas. As for precipitation intensity, area from 60 s time steps is shifted eastward to area from 360 s time step. This a consequence of shifting of trajectories of all individual precipitation areas eastward, hat can be seen from consecutive one hour outputs, that are not shown here. The result for 60 s time steps gives precipitation in Czech republic; while for 360 s time step there is no rain in Czech republic. As in reality there was rain in Czech republic, the second result is better. One possible explanation for shift of precipitation area could be that as for the shorter time steps intensity of precipitation is greater and it will reach ground earlier than less intensive precipitation in the same case but for the longer time step, for which precipitation can be advected more downstream before reaching the ground. Even in case of convective precipitation, conditions for deep convection can be advected more downstream. To get correct explanation of precipitation area shifting, other variables fields, not just precipitation, should be investigated.

3. Conclusion on dependency of precipitation on time step

1. The overall rule is that when shorter time step is used in model integrations there will be more precipitation within the same precipitation area.
2. Exact shape of the dependency of precipitation on time step curve changes from case to case. Two major shapes, for accumulated precipitation and intensity of precipitation, where recognised, see Fig 6. Type one is descending curve asymptotically approaching constant value when time step is going to zero. Type two is a descending curve with inflexion point within the interval of used time steps. A speculative explanation of these shapes is given. Asymptotic behaviour should have a meaning that at certain time step microphysical processes are completely resolved and shortening of the time step will not change results of microphysical scheme calculations. Abrupt steeping of dependency curves is speculated to be a consequence of activating of certain precipitation production process at certain, short enough, time step.
3. Changing the time step, see Fig. 9 and 10 could change the geographical position of precipitation area. An explanation for this effect could be that less intensive precipitation achieved for longer time steps is advected more downstream than more intensive precipitation get for shorter time steps.
4. On this level of investigation, only maximum values of precipitation intensity and accumulated precipitation were used, it is not possible to get explanation of dependency of precipitation on time step length. Fields of other variables should be investigated, and especially tendencies of water species coming from each of processes defined in microphysical scheme.