Case Studies with the 2-Timelevel Scheme and Prognostic Precipitation

Almut Gassman

Deutscher Wetterdienst, P.O.Box 100465, 63004 Offenbach a.M., Germany

Joining the last developments presented in the COMSO Newsletter 2, that is the 2-timelevel scheme (pp. 97-100) with the prognostic precipitation scheme (pp. 113-117), overcomes the inconsistencies due to different time-level use for moisture variables in the prognostic precipitation scheme. Case studies should reveal the change and hopefully the improvements gained by combining these methods.

While performing first tests it turned out that some changes were necessary to the code due to different reasons. First, the presented sedimenting method was to slow in the performance and second, instabilities occurred because of the slightly unstable vertical advection scheme. Both schemes where replaced by alternatives.

The sedimentation algorithm which was an explicit one is substituted by an implicit Crank-Nicolson scheme. Because the sedimentation velocity for the future time step is not known a priori it is estimated from the future value of the previous level and the present value of the actual level. Flux correction for sedimentation fluxes prevents negative values. Spatial differences are first order upstream.

Vertical advection is now formulated in an implicit manner so that the same algorithm as for the Klemp-Wilhelmson scheme can be used. The arguments of the implicit scheme are now the values ϕ^* representing the model state after the integration of the fast-waves terms alone until the center of the timestep. The contravariant vertical velocity is computed from the Runge-Kutta second order tendencies with third order upstream differences for the metric terms to achieve consistency with horizontal advection discretization.

The case studies covered a period of ten days in summer 2002 (9.-18.8.2002) and 2 days in autumn and winter 2001 when fronts reached Switzerland from northwest (8.11.2001 and 29.12.2001). Model configuration of MeteoSwiss with LM-version 2.18 was used in all cases. The performance of the new version was quite bad, it needed 30% more computing time than the compared reference run with the Klemp-Wilhelmson scheme and the standard gridscale precipitation scheme. Therefore the code was optimized in later versions, even though not enough. Advection of additional variables and the two advection operations in the RK2-scheme cost a lot of resources.

Main results of the runs revealed in comparison to the reference runs that

- more small scale structure was captured,
- unrealistic extrema in moisture variables disappeared,
- precipitation was transported to the lee side of the mountain ranges and was not longer confined to individual mountain slopes,
- spurious $2\Delta t$ noise disappeared,
- the overall precipitation amount diminished and
- convective activity was reduced.

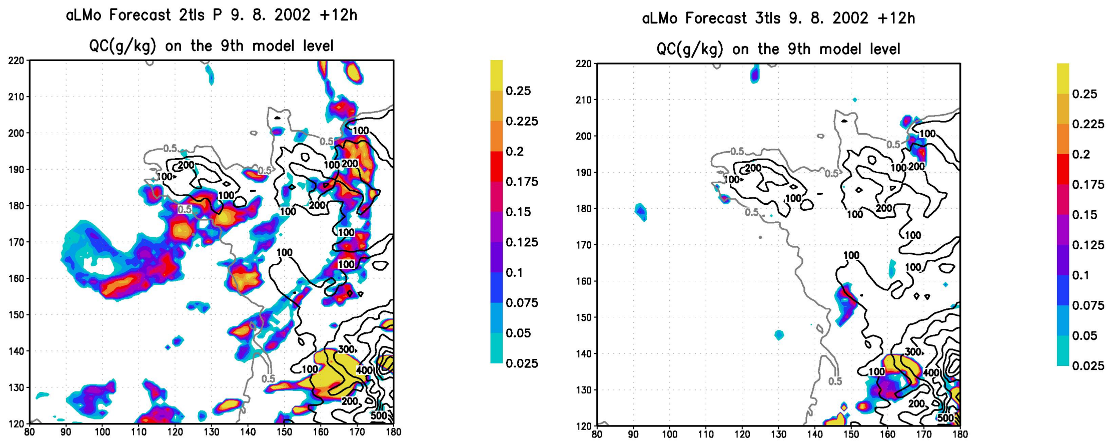

Figure 1: Cloud water content (g/kg) on the 9th model layer over the surface for 9.8.2002 at 12 UTC. Left: new version, right: reference run

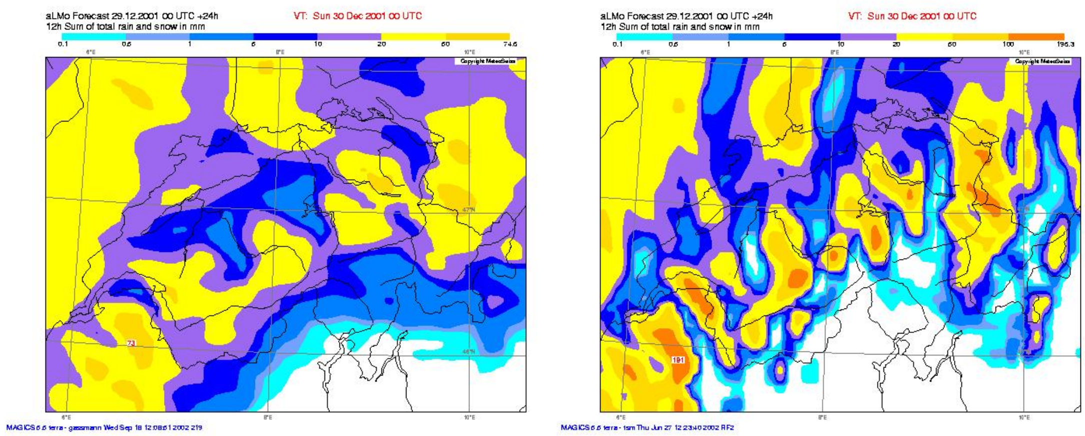

Figure 2: 12-h precipitation amount over Switzerland for 29.12.2001. Left: new version, right: reference run

The reasons for these changes are the increased order of approximation of the advection terms, less diffusivity and consistent treatment of all tendencies, in particular no bag-lagging of physical tendencies. Asselin-filtering is not needed anymore. Detailed results will be shown in the next sections.

Clouds as discrete structure elements occur more often but the cloud water content is generally lower. In turn, these effects affect cloud cover and radiation. Improved advection schemes for moisture variables prevent unrealistic extrema and variablity which is diffused very rapidly. A case example is 9th August 2002 when a trough was situated over western France and the Channel. A lot of convective activity emerges behind the frontal passage. In connection with convection, explicit clouds are produced with the new version whereas almost no clouds are produced with the reference run (Figure 1).

Significant improvements were found in the autumn and winter cases, when frontal precipitation hitted Switzerland from northwest. Lets consider the case of the 29.12.2001 when most of the precipitation was observed as snow (Figure 2). The precipitation pattern of the

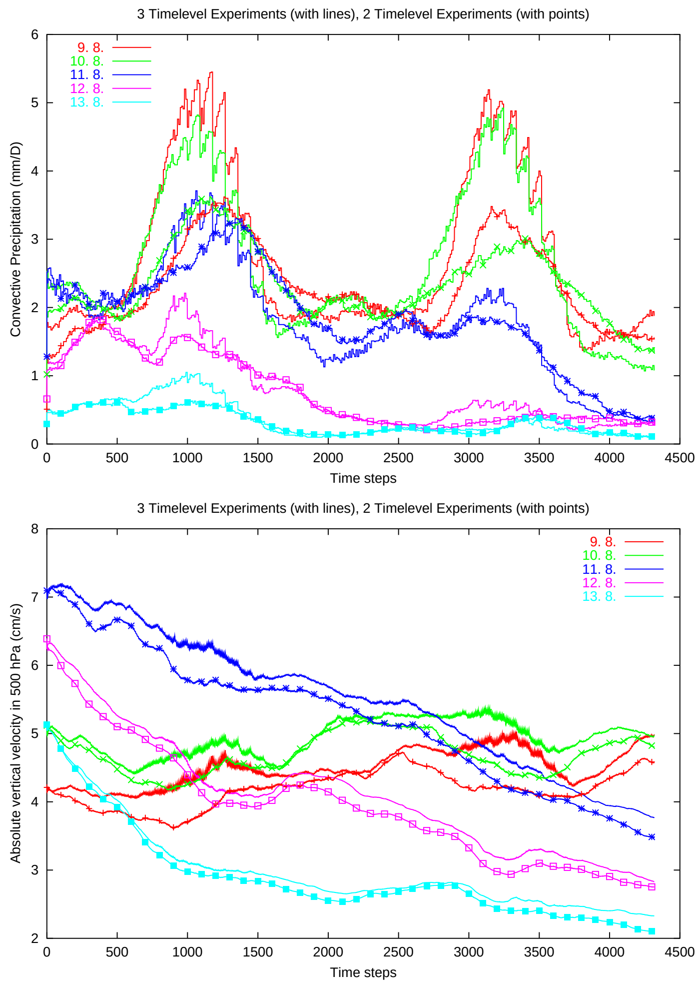

Figure 3: Left: Convective precipitation rates (top) and absolute vertical velocity (bottom) during the first 5 days of the period in August, for the reference runs (lines without symbols) and the new version run (lines with symbols).

reference run revealed maxima at every upwind slope of the Alps and minima next to them so that the field was very variable. Precipitation was not predicted for the southern parts of the Alps (Graubünden), where it was observed. The maximum values were considerably to high (196.3 mm in 12 hours) and regions are found where no precipitation was predicted at all. The forecast with the new version produced a precipitation field which was more smooth, had lower maxima and covered areas that received no snow in the reference run. Comparison with observations suggested that this pattern was closer to reality. The advection of precipitation particles improved forecast skill in a large number of forecasts.

Another positive change was present in almost all cases. Questionable mean values over the whole model domain were corrected. These spurious values appeared as radiation feedback in the convective precipitation rate (Figure 3, top), so that discontinuities appeared every hour. The reason for that feed-back is not known but the 2-timelevel scheme removes it. Also, mean absolute values of the vertical velocity in several heights oscillated with a $2\Delta t$ period (Figure 3, bottom), especially while enhanced convective activity during the day. That is a known drawback of Leapfrog schemes and the bag-lagging of physical tendencies in them. Consequently, runs with the 2-timelevel scheme overcome the problem.

Verification results for the new scheme show somewhat better scores than for the old scheme. Unfortunately, 10 days of parallel run do not reveal a reliable source for such statistics. But from the results it can be concluded that the 2-timelevel scheme alone (without prognostic precipitation scheme) verifies inferior than the reference scheme. Then, the precipitation pattern in mountainous regions varies even more than with the Klemp-Wilhelmson scheme. That is not astonishing, because some of the diffusive and damping mechanisms are no longer present, the approximation order of advection terms increases and sedimenting particles are not advected.

The combination of the 2-timelevel scheme and the prognostic precipitation scheme leads to encouraging results, in particular in cases when frontal precipitation passes a mountain range. Lee side precipitation becomes possible, overestimated extrema disappear and at a first glance the precipitation pattern seems to be much more reliable than before. An eye should kept on side effects like the enhanced cloud cover induced by more explicit cloud representation. Still there is potential to optimize the code. When the LM is used on a finer scale, care must be taken when convective clouds are simulated. Then, the prognostic precipitation scheme will fail because no fast sedimenting ice particles (graupel or hail) can be simulated with the effect that almost no precipitation reaches the surface. But on the scales, the LM is used at the moment it seems unlikely that difficulties occur due to that problem. Nevertheless, the next step will be to introduce graupel in the gridscale precipitation scheme.

References

Wicker, L.J. and W.C. Skamarock, 1998: A time-splitting scheme for the elastic equations incorporating second-order Runge-Kutta time differencing. Mon. Wea. Rev., 126, 1992-1999

Ferrier, B., 2002: A new grid-scale cloud and precipitation scheme in the NCEP Eta model. Lecture notes, Spring colloquium on the physics of weather and climate: Regional weather prediction modelling and predictability, Trieste.