Hungarian Meteorological Service

Improving wintertime low cloud forecasts over Hungary: First experiments

Balázs Szintai[1], Eric Bazile[2], Yann Seity[2], François Bouyssel[2]

[1]Hungarian Meteorological Service, Budapest, Hungary (szintai.b@met.hu)

[2]Météo-France, CNRM/GMAP, Toulouse, France

Background

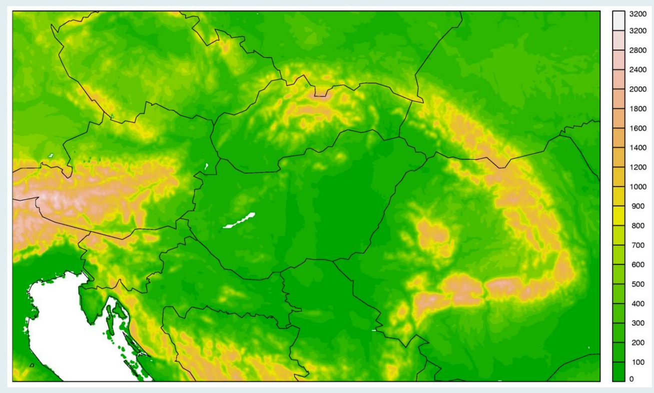
In this study wintertime stratus events are investigated, which are frequent in Central Europe. This weather situation is observed by anticyclonic situations, when cold air resides near the surface and no significant fronts occur which could sweep out the cold air from the Pannonian Basin. As solar irradiation is quite low in this season the morning fog is not dissolved, it is only elevated to about 300-500 m above ground level and a stratus layer is formed which stays constant during daytime. This kind of situation can typically last for 7-10 days. Due to low wind speeds and constant cloudiness the mixing height of pollutants is relatively low and the concentration of air pollutants can rise significantly. Generally, the AROME model – similarly to other NWP models – is not very successful in simulating this weather phenomenon. The stratus layer tends to be dissolved by the model by early afternoon and consequently afternoon temperatures are overestimated and night temperatures are underestimated by the model. The difficulty of this situation from the modelling point of view is that several processes (radiation, turbulence, microphysics) are interacting to form the constant stratus layer.

In 2012, a two-year long bilateral French – Hungarian research project started, which aims at the understanding of model deficiencies in AROME during these stratus events.

Model setup

The following AROME configuration was used for the experiments:

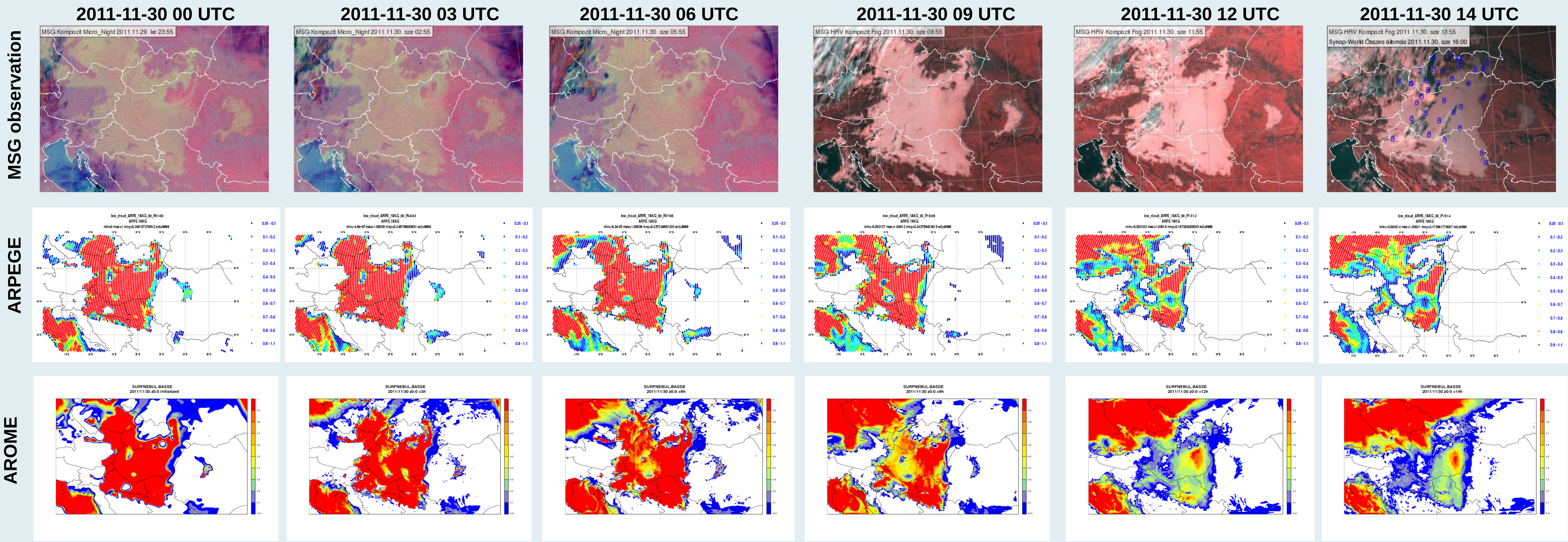
- AROME cycle 36
- 2.5 km horizontal resolution
- 60 vertical levels
- Initial conditions (including hydrometeors) and lateral boundary conditions interpolated from ARPEGE
- SLHD is applied on all dynamical fields but not on falling hydrometeors
- Diagnostic formulation for the variance of saturation deficit (LOSIGMAS=.FALSE.)



The AROME domain used for the experiments.

Performance of ARPEGE and AROME for a wintertime stratus event

On 30th November 2011 a stable anticyclone stretched over the Pannonian Basin. Due to the relatively humid air near the ground and low wind speeds fog during the night hours radiation fog started to develop near the surface. After sunrise the fog could not be dissipated, but it was elevated to about 300 m to form a stratus layer, which remained the whole day. The operational ARPEGE model captured the night time fog evolution well. During the afternoon the low cloud cover dissolved in ARPEGE over the western part of Hungary, while it partly remained over the eastern part of the country. The bad model performance over the western part was due to the bad timing of an approaching cold front from the west. For this case the AROME model performed worse than ARPEGE. Although night time fog was well reproduced, AROME could not retain the 100% low cloud cover in the eastern part of the country during the afternoon hours.



MSG observations of low cloud cover (microwave for night time, visible for daytime) for 30th november 2011 (first row). Forecasts of low cloud cover from ARPEGE (second row) and AROME (third row), initialized at 00 UTC on 30th november 2011.

Sensitivity tests with AROME

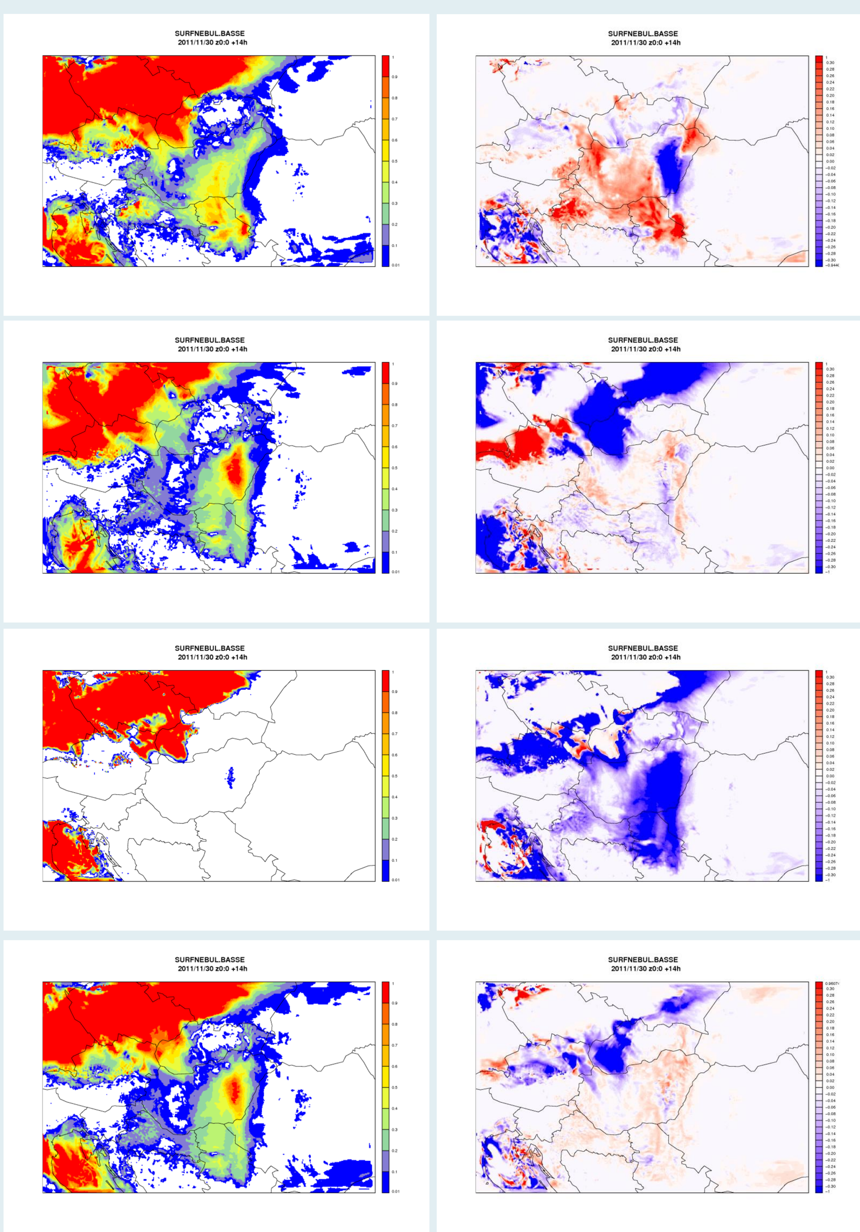
Different sensitivity tests were carried out in order to understand the deficiencies in the cloud cover simulation of AROME. In the following plots always the +14h forecasts are shown for the case study presented above (30th November 2011).

<u>**Data assimilation:**</u>
In this experiment a five day DA spin-up was used before the start time of the experiment. The DA configuration was identical to that of the operational settings at the Hungarian Meteorological Service (3DVAR + OI_MAIN). The DA has a mixed impact on the stratus, over the southern areas it increases low cloud cover, over the eastern part of Hungary it decreases the stratus.

<u>**Lateral boundary conditions:**</u>
LBCs from the IFS model run at ECMWF were used instead of ARPEGE coupling. This has a significant impact on the frontal cloud cover (north from Hungary), but not on the stratus over Hungary.

<u>**Statistical cloud scheme:**</u>
In the reference version a diagnostic formulation was used for the variance of saturation deficit (LOSIGMAS=.FALSE.), while in this test a prognostic formulation (LOSIGMAS=.TRUE.) is applied. This decreases significantly the low cloud cover over Hungary, thus deteriorates the forecast.

<u>**Turbulence scheme:**</u>
In this experiment the turbulent kinetic energy (TKE) was increased by decreasing the coefficient for the dissipation rate of TKE (XCED=0.2, in the reference it is 0.85). This results in a slight increase of stratus over the eastern part of Hungary.



Low cloud cover (left) and low cloud cover difference (exp-ref) for the selected case at 14 UTC.

Conclusions and further work

The performance of two operational numerical weather prediction models was investigated during an anticyclonic winter case when low cloud cover is present the whole day. The AROME model tends to dissolve the stratus clouds too early, while ARPEGE is more successful in retaining the clouds. From the sensitivity test presented above, the following conclusions can be drawn:

- The AROME simulation is not really sensitive to the choice of lateral boundary conditions
- The tuning of the turbulence scheme has a small positive impact
- The diagnostic formulation for saturation deficit variance is more successful than the prognostic one
- By increasing the optical thickness of clouds (heterogeneity factor) the simulation of stratus improves

In the following it is planned to investigate the selected case with the one-dimensional model MUSC.

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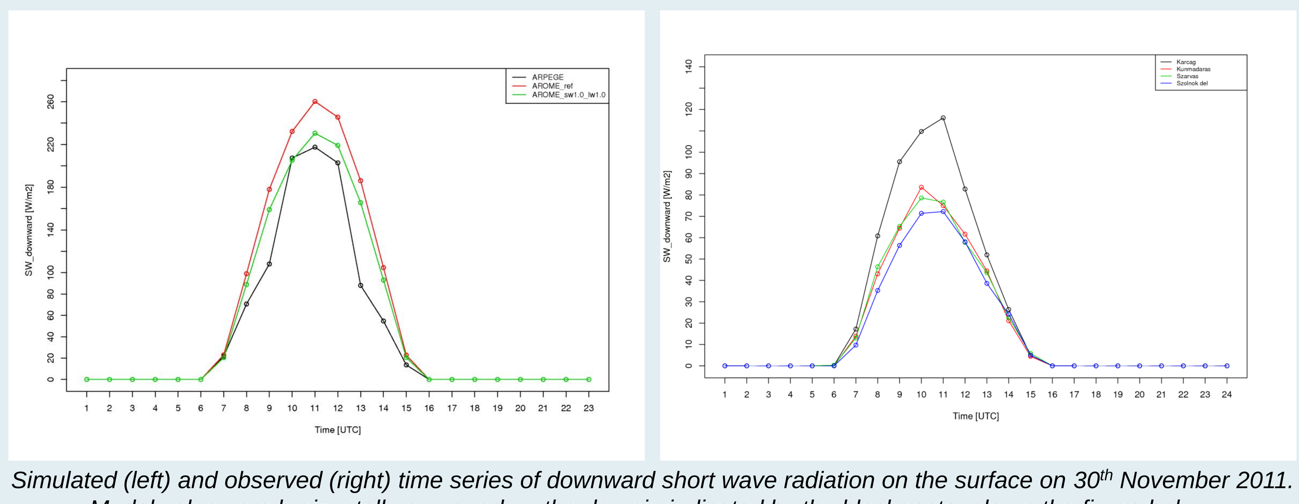
Radiation transfer experiments

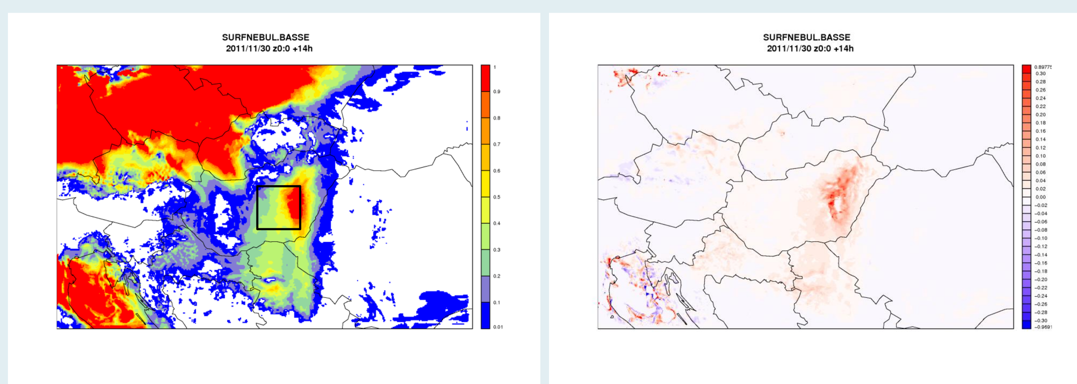
It is assumed that one reason for the dissipation of stratus in AROME could be that after sunrise more short wave radiation is transmitted through the fog layer in the model than in reality. Consequently, surface downward short wave radiation simulations were verified with the radiation measurement network of the Hungarian Meteorological service, which consists of 39 stations. For the present case study, only four stations were selected in the eastern part of Hungary, where stratus was present the whole day both in reality and in ARPEGE, but not in AROME (black rectangle on figure below).

Time series show that ARPEGE slightly overestimates the short wave radiation after sunrise, and the reference version of AROME simulates even higher values than ARPEGE. One of the main differences in the radiation settings of the two models is the value of the long wave inhomogeneity factor, which accounts for an increased radiation transfer in clouds. This parameter is set to 0.9 in ARPEGE and 0.7 in AROME. To test the impact of this parameter both the short wave (RSWINHF) and long wave (RLWINHF) inhomogeneity factors were set to 1.0 in AROME (experiment "AROME_sw1.0_lw1.0"). These settings result in a lower downward short wave radiation flux at the surface in AROME.



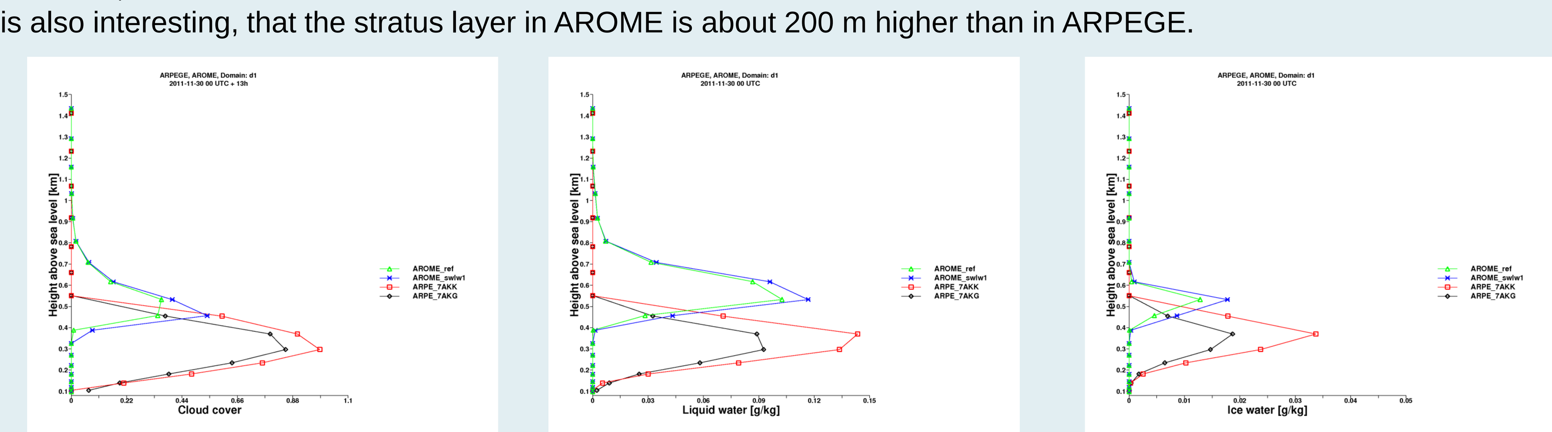
Simulated (left) and observed (right) time series of downward short wave radiation on the surface on 30th November 2011. Model values are horizontally averaged on the domain indicated by the black rectangle on the figure below.

In increased optical thickness of clouds (RSWINHF=LSWINHF=1.0) and the consequently slower heating of the boundary layer slightly increases low cloud cover over the eastern part of Hungary. On areas of frontal activity (north of Hungary) the modification has no impact on cloud cover.



Low cloud cover (left) and low cloud cover difference (exp-ref) for the selected case at 14 UTC.

The impact of this modification can also be seen on the horizontally averaged vertical profiles (domain of averaging is the black rectangle on the figure above). The new AROME run has higher values of cloud condensates than the reference one. However, even the new AROME run simulates lower values of cloud condensates than the reference ARPEGE simulation. It is also interesting, that the stratus layer in AROME is about 200 m higher than in ARPEGE.



Horizontally averaged vertical profiles of cloud cover (right), liquid water content (middle) and ice water content (right) for the selected day at 12 UTC. Next to the reference ARPEGE run („ARPE_7AKG"), a second run is shown which uses the same cloud pdf as AROME („ARPE_7AKK").