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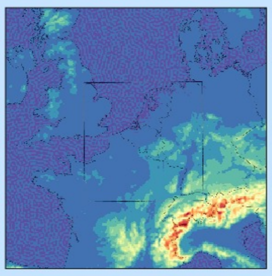
The operational ALADIN-Belgium model

1. Main features

- Model version: AL35t1 + ALARO-0 + 3MT
- 60 hour production forecasts four times a day (0, 6, 12 and 18 UTC).
- Lateral boundary conditions from Arpège global model.

2. The computer system



- SGI Altix 4700.
- 196 Itanium2 CPUs.

3. Model geometry

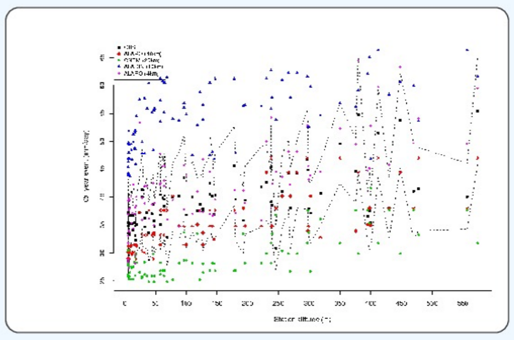
- 7 km horizontal resolution (240*240 points), 4 km resolution (192*192).
- 46 vertical levels.
- Linear spectral truncation.
- Lambert projection.

4. Forecast settings

- Digital filter initialization (DFI with LSPRT=.FALSE.).
- two time level semi-implicit semi-Lagrangian - SISL - advection scheme.
- Time step: 300s (7 km), 180s (4 km)
- Lateral boundary condition coupling at every 3 hours.
- Hourly post-processing (latitude-longitude and Lambert).

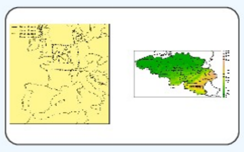
5. Operational suite/technical aspects

- Transfer of coupling file from Météo-France via Internet (primary channel) and the Regional Meteorological Data Communication Network (RMDCN, backup).
- Model integration on 40 processors (7 km), 20 processors (4 km).
- Post-processing on 8*1 processors.
- Continuous monitoring supported by a home-made Kornshell/Web interface.
- Monitoring with SMS (Supervisor Monitor Scheduler).



Multi-scale behavior of ALARO-0 for extreme summer precipitation over Belgium

The model skill to simulate realistic extreme daily precipitation strongly depends on the models spatial resolution and its convective parameterization (Randall et al., 2007). The aim of the study is to elaborate on this relative importance of resolution versus parameterization formulation by tests with the ALARO-0 model, including a new physics parameterization, that was specifically designed to be used from the mesoscale to the convection permitting scales.



The relative importance of resolution versus parameterization formulation is examined by comparing ALARO-0 runs at various resolutions to the ALADIN model which includes the precedent parameterization. Three different model runs are considered: (i) ERA-40 reanalysis for the recent past climate (1961-1990) are dynamically downscaled using ALARO-0 at 40km horizontal resolution (ALR40) on a domain encompassing most of Western Europe (Fig. 1, left); (ii) ALADIN at 10 km resolution (ALD10) and (iii) ALARO-0 at 4 km resolution. The runs (ii) and (iii) are both performed on a nested domain centered on Belgium (Fig. 1, left). In order to investigate how well the ALARO-0 model is performing within the context of ENSEMBLES (http://www.ensembles-eu.org/), ALADIN-Climate/CNRM simulations are also included within our analysis. However, the model setup of CNRM and our simulations is different. Therefore, it is emphasized that CNRM is added to put our model results into a larger perspective, rather than providing a direct comparison between both.
All model runs are compared w.r.t. a observational dataset (OBS) including 93 climatological stations with daily accumulated precipitation, selected from the climatological network of the Royal Meteorological Institute of Belgium (Fig. 1, right: Topography (m) of Belgium showing the location of the 93 selected climatological stations).

Fig. 2 shows the quantiles (2.5, 10, 20, 25, 30, 40, 50, 60, 70, 75, 80, 90, 95, 97.5, 99, 99.9) of observations and models. Quantiles are computed with the 30-year (1961-1990) daily cumulated summer precipitation given for each station separately. The frequency distribution gives an understanding of the trend of frequency and intensity of extreme summer precipitation. ALD10 clearly rains too often, both with very small and very high quantities of rainfall. On the other hand, CNRM demonstrates an underestimation of summer precipitation in particular for the higher quantiles. ALARO-0 shows a clear improvement and is able to reproduce extreme rainfall rates quite well. ALR04 and ALR40 respectively over- and underpredict only slightly the highest 99.9 quantile (i.e. strongest events).

To explore further the ability of the models to reproduce extreme precipitation events, a peak-over-threshold (POT) approach has been applied (Coles, 2001). The excesses or POT events of the observations and models are described by the Generalized Pareto Distribution (GPD), from which return levels for a certain return period can be computed. The threshold that is used to define a POT event is set on the 0.95th quantile of the observations or resp. model. Fig. 3 shows the 5-year return levels of the POT models for the observations and model simulations as a function of station altitude (m). The return levels are generally larger at the higher elevations. The 95% confidence levels of the observed return levels are indicated by the dotted black lines. It appears that for most stations the return levels of ALARO-0, both at 4 and 40 km resolution, lie within the 95% confidence range of the observed return levels. In contrast to ALARO-0, are ALD10 and CNRM not able to produce the observed 5-year return events. Its estimated return levels lie for a great number of stations outside the observed confidence interval (resp. 89 and 74 stations).

Conclusions
(i) The results show an improvement in the representation of extreme summer precipitation by ALARO-0 w.r.t. to the observations;
(ii) The results suggest that the new parameterization scheme of ALARO-0 contributes to the amelioration in the modeling of extreme summer precipitation events, rather than the increase in spatial resolution;
(iii) These findings confirm the multi-scale behavior of ALARO-0, as found by Gerard et al. (2009), but now for a longer study period of 30 years.

References

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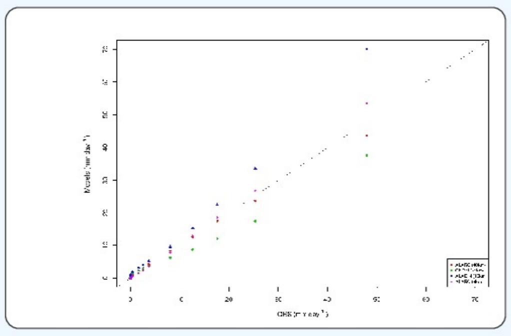


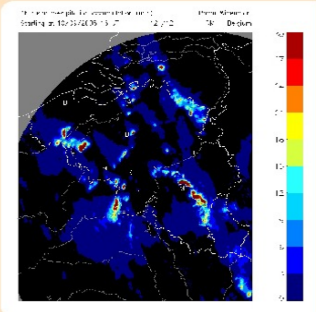
Perturbation approach for the deep convection parameterization scheme

The CSU (complementary subgrid updraft) approach of deep convection parameterization integrates a set of high resolution-specific features, as described below.
1) Perturbation approach where the subgrid scheme does not represent a real updraft but a complementary contribution to the resolved scheme. Analytical relations were developed to compute the perturbation-updraft profile; in these, the mesh fraction as well as the environmental lapse rate play a role. The entrainment is applied continuously along the ascent, unlike in the earlier 3MT scheme where isobar entrainment alternated with pseudo-adiabatic ascent segments.
2) CAPE closure expressed for the steady state of the absolute updraft, and based on the larger scale environment.
3) Evolution over several time steps of the updraft velocity.
4) Evolution of mesh fraction using a relaxation relation towards the steady-state value.
5) Gradual elevation of the cloud top, over several time steps.
6) Initial conditions and triggering computed with the Updraft Source Layer (Kain-Fritsch) technique, but with a specific expression of the buoyancy kick in the spirit of the CSU.

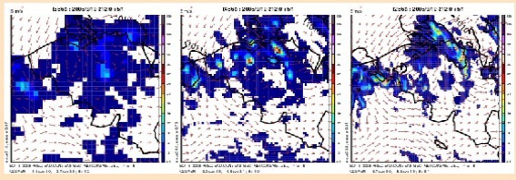
The routines include various switches that allow testing the relative impact of the different features, as well as running in a configuration mimicking mostly the earlier 3MT scheme. The scheme has now been widely tested using an academic setup (Weisman & Klemp, MWR 110, 1982). Further tests will be done for the inclusion into Alaro-1 together with the other new schemes (turbulence, radiation). The first tests on a real case, compared to the 3MT scheme can be seen on Fig. (1). The subgrid part is reduced and diminishes with increasing resolution. The averaging over large grid-boxes produces much smaller amounts at coarse resolution.

Figures: Thunderstorms over Belgium on 2005-09-10.
1-hour accumulated surface precipitation.

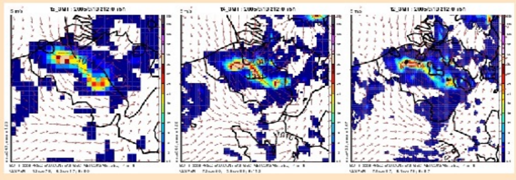
(a) Radar image.
(b) Alaro with CSU-scheme forecast at 8km, 4km, 2km.
(d) idem subgrid part of precipitation.
(c) Alaro-0 3MT forecast at 8km, 4km, 2km.
(e) idem subgrid part of precipitaiton.



(a) Radar image



(b) Alaro with CSU-scheme forecast at 8km, 4km, 2km.



(c) Alaro-0 3MT forecast at 8km, 4km, 2km.

Surface Assimilation with SURFEX EKF

Inroduction:
The equation for the Extended Kalman Filter (EKF):

$$x^a_t = x^b_t + BH^T(\, HBH^T + R\,)^{-1}\, [y^o_t - \mathcal{H}(x_b^o)\,]$$

H is the jacobian matrix of the observation operator $\mathcal{H}$ and is calculated with a finite difference approach:

$$H_{ij} = (\, y_i\,(x + \delta x_j\,) - y_i\,(x)\,)\,/\,(\delta x_j\,)$$

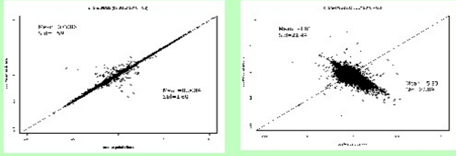
For the calculation of $y_i(x + \delta x_j)$ a run with a perturbed surface field is performed for each of the control variables. This run can be done in two ways:

- *coupled mode*: coupled to the atmospheric model
- *offline mode*: decoupled from the atmospheric model with atmospheric forcing from the lowest model level

We have examined the differences in jacobians, increments and scores between these two options. The EKF assimilates screenlevel observations (RH2m and T2m). The four prognostic variables are superficial water content W_{g1}, surface temperature T_{g1}, root zone water content W_{g2} and deep soil temperature T_{g2}).

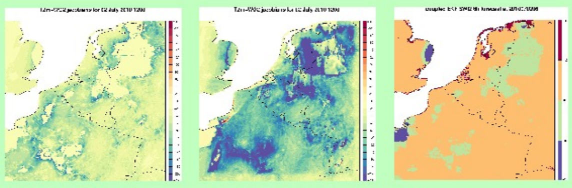
Results:
In Figure 1 the linearity of the observation operator is investigated, by looking at the difference between jacobians calculated with positive and with negative perturbations. The jacobians of the offline EKF better meet the linearity assumption than the the coupled EKF, because the offline EKF can use a smaller perturbation size compared to the coupled EKF. Figure 2 shows the spatial structure of the jacobians for l T2m/l W_{g2}. In the areas where the SWI is slightly below zero, the coupled and offine EKF have very different values. This is due to the fact that the zone around zero SWI is highly non-linear and the offline and coupled runs react differently to this.

In general the spatial structures for the jacobians and increments are the same for the offline and coupled EKF. Only for W_{g2} there are some differences but with limited effects on the forecast scores.



Offline EKF, pert. size 10^{-4} Coupled EKF, pert. size 10^{-1}

Figure 1: Scatterplots of l T_{2m}/l W_{g2} obtained from finite differences with negative and positive perturbations



Offline EKF, l T2m/l W_{g2} Coupled EKF, l T2m/l W_{g2} SWI

Figure 2: Spatial structure of the jacobians and comparison with the SWI-values

Combining SURFEX EKF with 3dVar atmospheric assimilation

The SURFEX EKF (offline mode) has been tested in combination with a 3dVar atmospheric assimilation. The EKF assimilates screenlevel temperature and relative humidity observations. The 3dVar configurations uses only conventional observations. Figure 3 shows the forecast scores (RMSE and bias) for relative humidity. The combination of EKF and 3dVar (green dashed line) improves the RSME in the first 18 hours, compared to running EKF or 3dVar seperately or using optimum interpolation (OI) instead of the EKF.

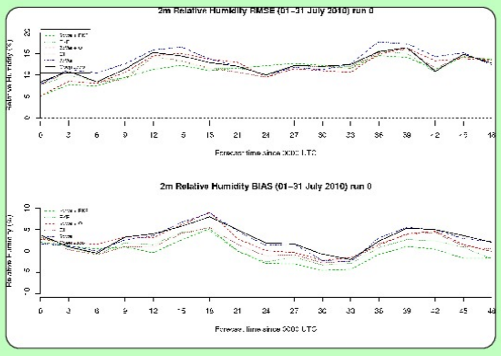
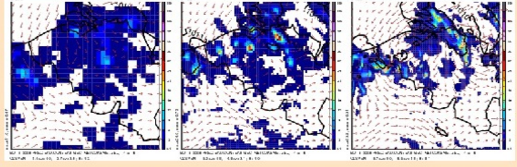
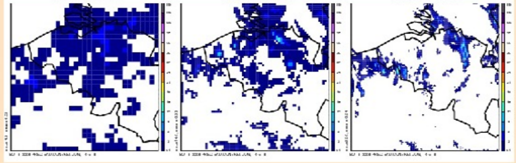


Figure 3: Spatial structure of the jacobians and comparison with the SWI-values



(d) Alaro with CSU-scheme forecast at 8km, 4km, 2km. Subgrid part of precipitation.



(e) Alaro-0 3MT forecast at 8km, 4km, 2km. Subgrid part of precipitation.