Report on stay at ZAMG

06/10/2014 – 31/10/2014, Vienna, Austria

Stochastically Perturbed Parameterized Tendencies in ALARO and AROME

Stochastically Perturbed Parameterized Tendencies (SPPT) is a scheme which has been operationally and successfully used in global IFS model by ECMWF (Buizza et al., 1999, Palmer et al., 2009). In the previous years there was a growing interest around model error representation also in limited area ensemble systems, especially in convection-permitting ensembles. That was a motivation inside ALADIN community to implement the scheme in the limited area version of ARPEGE-IFS code which was done by Francois Bouttier, Météo France, and tested in an AROME-EPS framework (Bouttier et al., 2012).

The author of this paper has also done some preliminar tests with AROME-EPS on the Hungarian domain, without noticing the sufficient impact of the scheme. These results motivated to start some deeper research to understand how SPPT modifies processes inside the model. Additionally Austrian and Hungarian Meteorological Services are both interested in the implementation of this scheme also in ALARO model, while current operational ensemble systems use this model. The above-mentioned reasons motivated the work during my LACE stay, which was the extension of SPPT to ALARO model. Some diagnostic tool were also developed which can help to understand processes in case-studies with ALARO and AROME.

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In the following document the first part explains the technical background of SPPT extension for ALARO. Part 2. is addressed to the running environment of the tests. Part 3. focuses on the representation of the results. Finally there are some words about further possibilities in part 4.

1. SPPT in ALARO

The original SPPT scheme (Buizza et al., 1999) generates independent random numbers (picked from uniform distribution with 0 mean) for columns in space and perturbs tendencies with that. These numbers are constant for a given time, while the size of columns is also flexible (referred also as BMP shceme). In the revised version of SPPT (Palmer et al., 2009) a spectral pattern generator is introduced. This tool generates a pattern which is smooth in space and changing slowly and fluently in time.
From coding point of view spectral pattern generator is a special part of ARPEGE-IFS code, because it is driven by control levels of the model and evolve the pattern in spectral space step by step. The pattern is transformed into gridpoint space in every timestep and used deep inside the physics, if scheme is active.
Francois Bouttier's extension had two main parts:

- Spectral pattern generation was made available also for limited area models on the higher control levels of the code.
- A gridpoint version of pattern was made available in mf_phys routine and passed to apl_arome. On that level (under a switch) it was made possible to call for sppten (part of phys_ec), with the total tendency of temperature, wind components, specific humidity (which are already available at the end of apl_arome) and of course with the pattern itself.

This modification became part of cycle 38.
As SPPT scheme was needed in ALARO, code had to be modified again to call sppten somewhere else. Normally aplpar is the counterpart of apl_arome in ALARO, but this routine does not have total tendencies of the prognostic variables, but tendencies and fluxes of different parameterized processes. In ALARO case total tendencies are ready just later (after calling cptend_new, and after some calculation of cputqy), at the end of cputqy. That is the reason why we decided to call sppten there.
For that purpose not only the spectral pattern, but full level pressure has to be also passed from mf_phys to cputqy, because it is needed for sppten's tapering function. Tapering function helps to make perturbations zero on the top and bottom part of the atmosphere.

- mf_phys
    - apl_arome
        - sppten
    - cputqy_arome
	- mf_phys
	    - aplpar
	    - cptend_new
	    - cputqy
	        - sppten

Very schematic figure about **SPPT's position in AROME**	Very schematic figure about **SPPT's postion in ALARO**

Code modification touches the following routines:
algor/module/spectral_arp_mod.F90
arpifs/phys_ec/sppten.F90
arpifs/adiab/cputqy.F90
arpifs/phys_dmn/mf_phys.F90

Code modification can be found on ecgate here:
/home/ms/hu/hu7/SPPTFLEX/AlaroSppt.tar

A short reminder has to be dedicated to a bugfix in a function of spectral_arp_mod, which is already part of official cycle 40, but which made a lot of investigation for more people working under cycle 38.

It has to be noted that calling sppten from so isolated parts of the model physics is not absolutely ideal. However it was also proposed in ALADIN community to make a common flexible physics interface (Catry et al., 2006) which can be adjust fluxes and tendencies on the same way in AROME and in ALARO case. This flexible interface was implemented by Daan Degrauwe, RMI and became part of the code from cycle 40. As this interface is active cputqy is always used (not cputqy_arome), so sppten were possible to be always called from that routine. It were a logical question to ask if results would be the same or not for AROME, if SPPT would be moved for different place. To decide that question an additional test was done, and SPPT was called from cputqy_arome in AROME case. With this modification AROME results stayed identical which suggests that probably in long-term cputqy would be a good place for both of the models to call for sppten.

2. Test environment

Basic test environment was installed on ECMWF's cca machine. Writing scripts take quite a long time from my stay as I have just started to use the relatively new machine of the center, where running multi-processor jobs needed quite a different settings than on the previous machine. Script system has the following steps:

- it copies IC, LBC and climate files from ECMWF's storage,
- it runs the necessary interpolations (ee927),
- it sets the namelists and copies the proper binary in accordance with the with a special code of the test, and it runs the model itself,
- it saves the results to ECMWF's storage and/or transfer them to OMSZ's computer.

On OMSZ's side mainly two groups of programs support the tests:

- there is a script which collect the necessary IC and LBC files from OMSZ's storage and transfer them to cca,
- there is a small group of simple programs which can make plots to help diagnostic.

ALARO and AROME model configuration were identical with Hungarian operational ones:

- ALARO: 8km horizontal resolution, 49 vertical level, 300s timestep, 3h-coupling to ECMWF, ICs from operational data assimilation cycle
- AROME: 2.5km horizontal resolution, 60 vertical level, 60s timestep, 1h-coupling to ECMWF, ICs from operational data assimilation cycle

3. Results

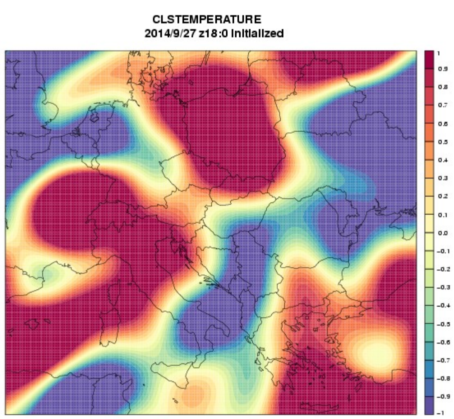
As it was mentioned in the previous part, some plotting tool has been already developed and used to see SPPT's effect inside the model. In this session these tools are presented with some results which can help to see differences and similarities in ALARO and AROME case.
Most of the plots are generated on a case of 18UTC run from 27th of September, 2014. The night after the start of the model integrations was quite clear and stable in Carpathian Basin. It is very usual in such cases that after a relatively warm day, temperature can drop really fast and it closes 0 degree at dawn. In such cases there could be very strong inversion in the lowest part of the atmosphere and there could be a shallow but thick fog layer near the surface. That was the case in some areas of Hungary that night, especially in closed valleys.
Another case was also examined but not that detailed, and only spread results are presented in this session. This case was a 00UTC run from 22nd of October, 2014, which was definitely the stormiest night of my LACE stay, when a very strong cold front went through Austria and Hungary. The front caused strong wind gust events even late in the night.

Spectral pattern

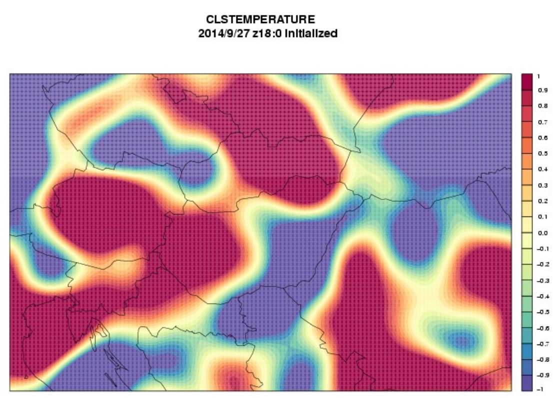
It was important to see how the spectral pattern looks like. For this pattern the three main namelist settings are:

Definition	Name in NAMSPSDT	Used value
Standard deviation	SDEV_SDT	0.5
Horizontal correlation length scale	XLCOR_SDT	4000000
Correlation time scale	TAU_SDT	7200

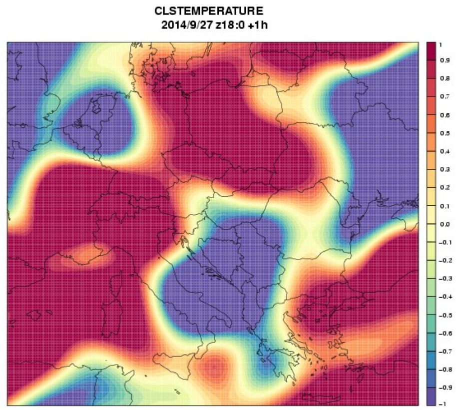
As references suggest the same standard deviation value (0.5) to reach the sufficient spread, we think it as a fix setting now and for the next round of tests as well. Ideal horizontal and time correlation can be very domain and model dependent, so these values are probably worth to tune.



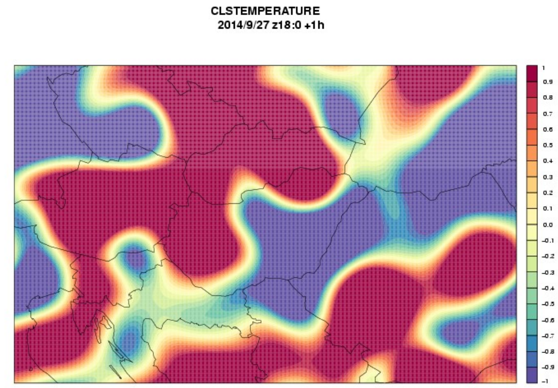
Spectral pattern in ALARO at +0hour



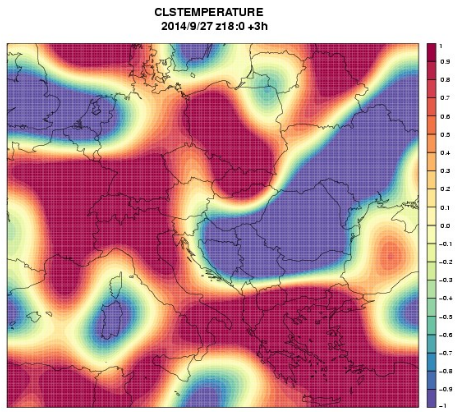
Spectral pattern in AROME at +0hour



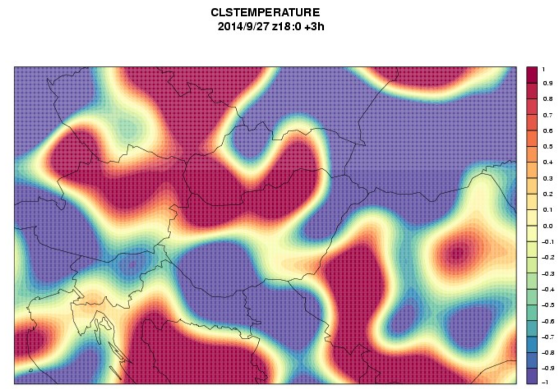
Spectral pattern in ALARO at +1hour



Spectral pattern in AROME at +1hour



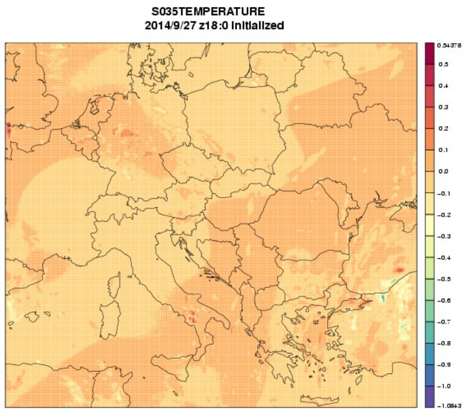
Spectral pattern in ALARO at +3hour



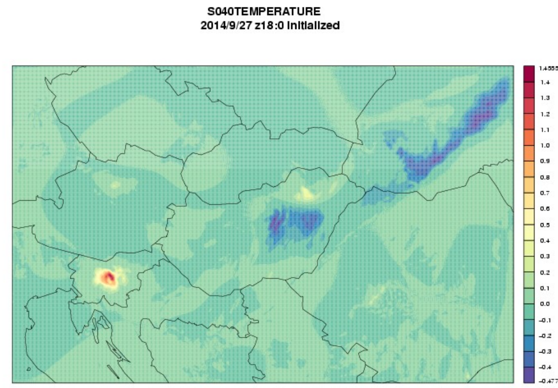
Spectral pattern in AROME at +3hour

Maps of perturbations

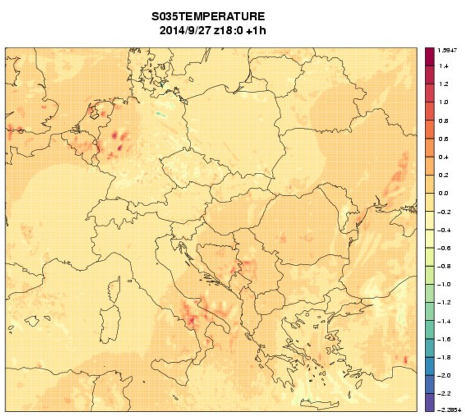
It is interesting to see, how SPPT perturbations evolve inside the model. As they came from the pattern and parameterized tendencies, it is not surprising that their structure is much smaller and finer than what we have seen before at spectral pattern. Even after three hours there are small peaks with high values and there are hardly touched areas.



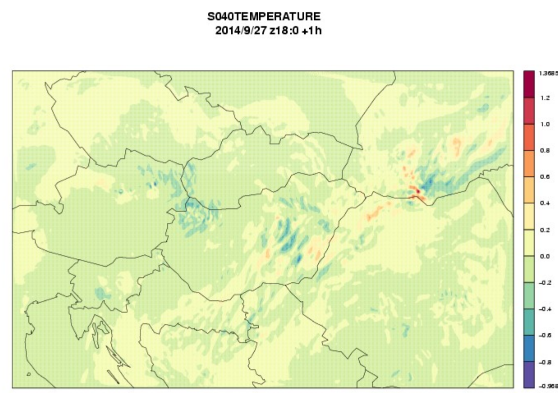
Temperature perturbation in ALARO on 35th model level after just 1 timestep



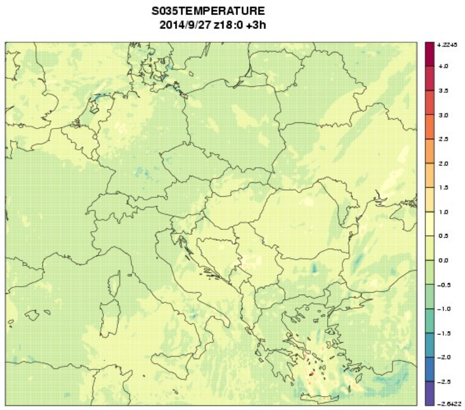
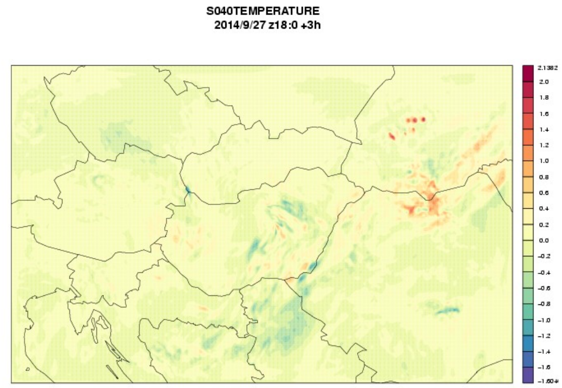
Temperature perturbation in AROME on 40th model level after just 1 timestep



Temperature perturbation in ALARO on 35th model level at +1hour



Temperature perturbation in AROME on 40th model level at +1hour

	
Temperature perturbation in ALARO on 35th model level at +3hour	Temperature perturbation in AROME on 40th model level at +3hour

Vertical profile of perturbations in a mini-ensemble

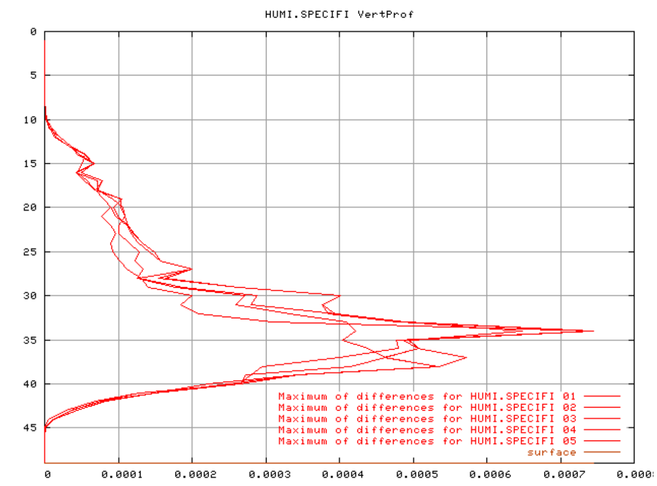
There are vertical profiles for some variables and timesteps. For all the levels two types of plots were made:

- perturbations were averaged for the whole domain,
- maximum absolute values of the perturbations were searched on the whole domain,

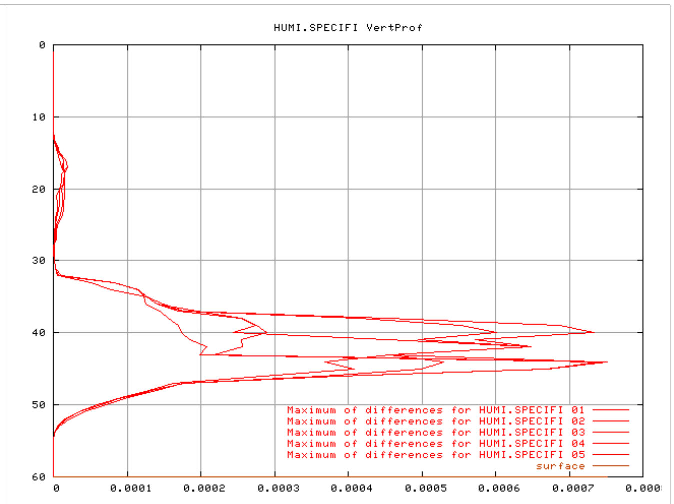
and they were visualized separately as a function of model levels. This diagnostic checked not only one model integration but a 5-member ensemble.

Maximum values look quite different in ALARO and AROME case and usually they are bigger for ALARO. It can be also explained by the fact that ALARO domain is much bigger and it probably contained physically more active areas, because in this case (18UTC, 27th of September, 2014) atmosphere was not that active in Carpathian-Basin, how it was mentioned before.
After just one timestep it can be easily realized where the SPPT scheme was active and where (lowest and highest levels) its effect was limited by the tapering function. After 3 hours the situation is really different as model interacts with injected perturbations. It looks that in AROME more perturbation penetrates in the lowest levels than in ALARO. The explanation is not clear but it can be caused by:

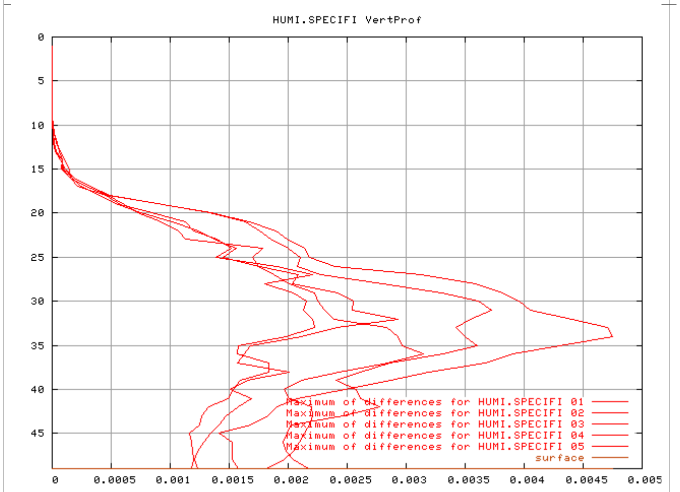
- Different size of domain: In AROME probably perturbations are killed faster by LBC's, which effect is bigger on higher levels than near the surface.
- Weather situation: In AROME domain, the strong cooling of the surface made probably the biggest impact in the examined 3 hours, while in ALARO many other effect can exist in its bigger domain.
- Model physics differences.



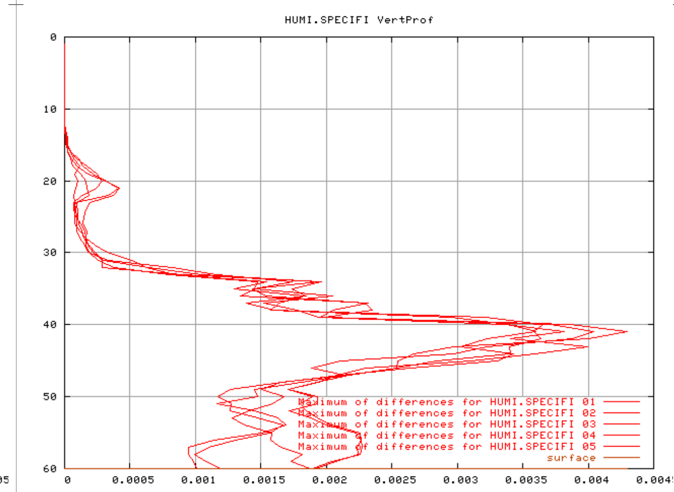
Vertical profile of maximum perturbations in **ALARO** for **spec. humidity** just after **1 timestep**



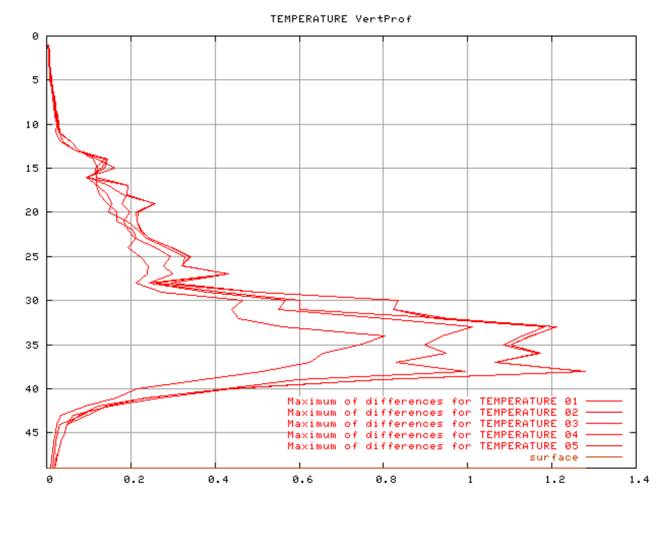
Vertical profile of maximum perturbations in **AROME** for **spec. humidity** just after **1 timestep**



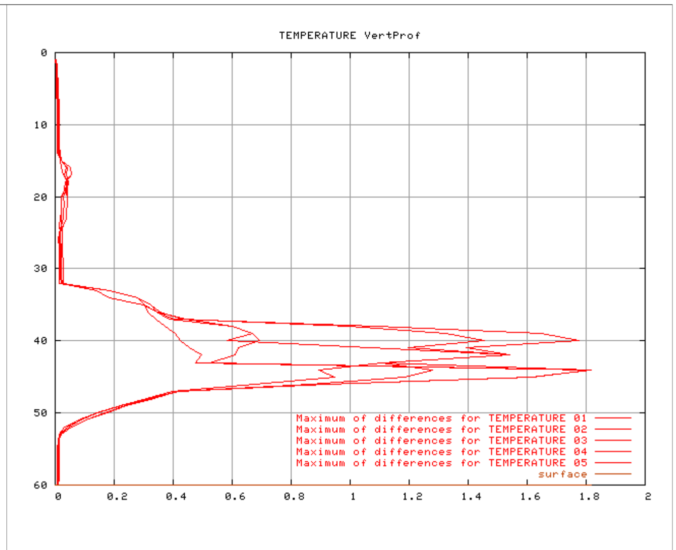
Vertical profile of maximum perturbations in **ALARO** for **spec. humidity** at **+3hours**



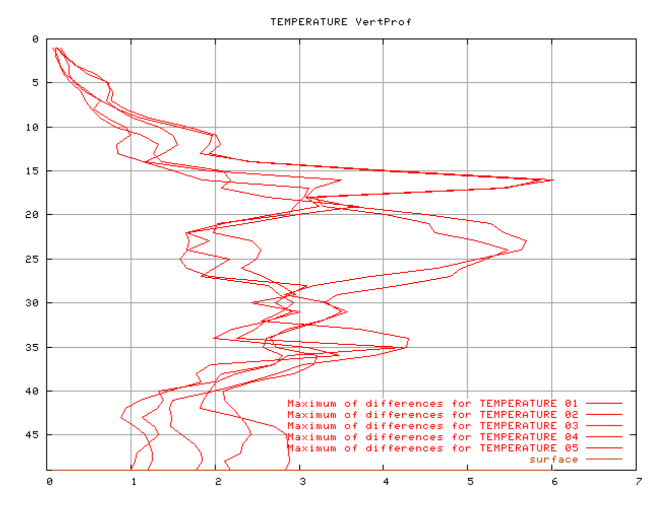
Vertical profile of maximum perturbations in **AROME** for **spec. humidity** at **+3hours**



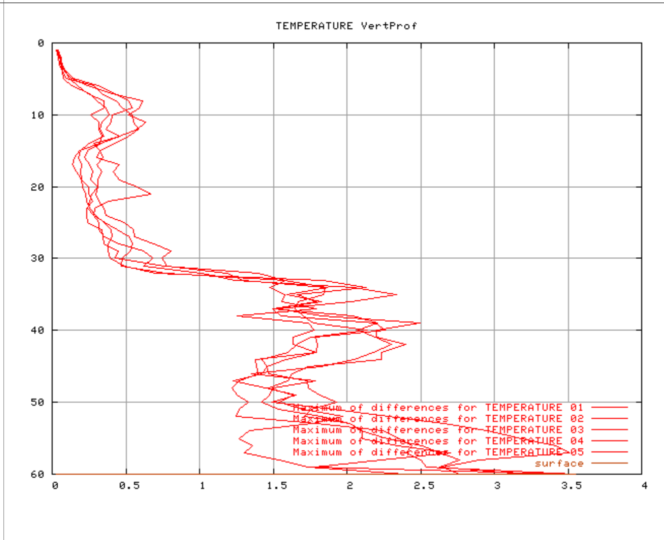
Vertical profile of maximum perturbations in **ALARO** for **temperature** just after **1 timestep**



Vertical profile of maximum perturbations in **AROME** for **temperature** just after **1 timestep**



Vertical profile of maximum perturbations in **ALARO** for **temperature** at **+3hours**

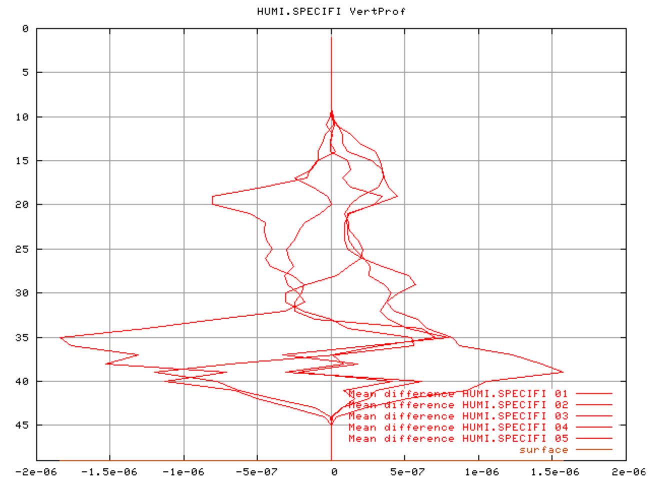


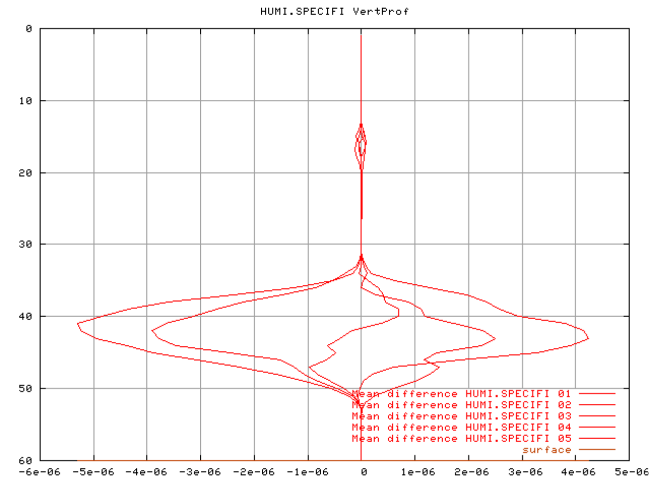
Vertical profile of maximum perturbations in **AROME** for **temperature** at **+3hours**

Average values prove what was already seen on the plots of maximum values: SPPT's effect is bigger on higher levels in ALARO than in AROME. Another interesting detail is, that temperature perturbations in AROME look like going to negative direction more often than positive (the opposite looks true for spec.humidity). Of course a 5-member EPS can give just a small sample, but it take a question about the interaction of SPPT scheme and model physics:

- Can SPPT cause BIAS in specific cases?

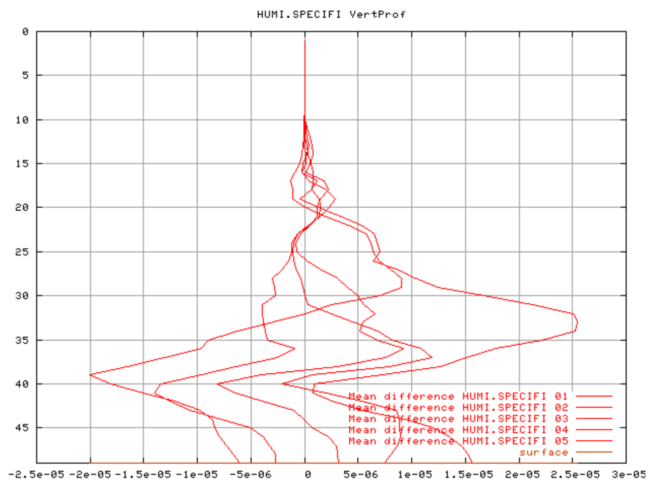
Answering the question and understanding this phenomena needs definitely more tests and diagnostics.

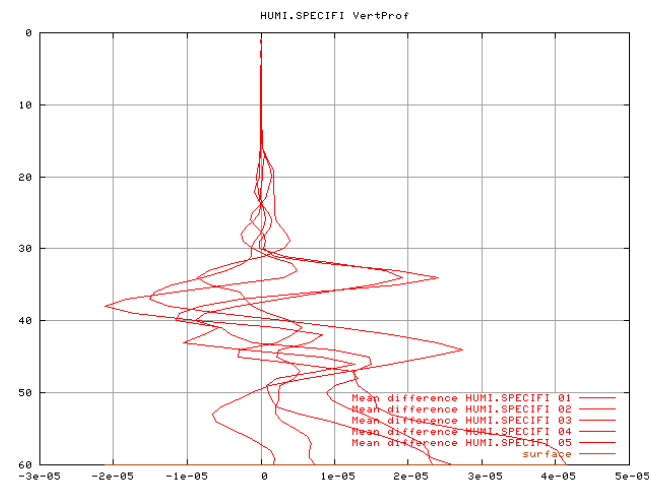




Vertical profile of average perturbations in **ALARO** for **spec. humidity** just after **1 timestep**

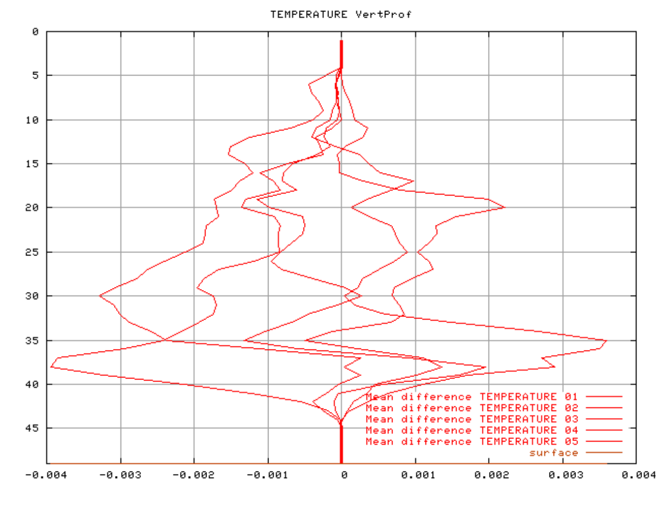
Vertical profile of average perturbations in **AROME** for **spec. humidity** just after **1 timestep**



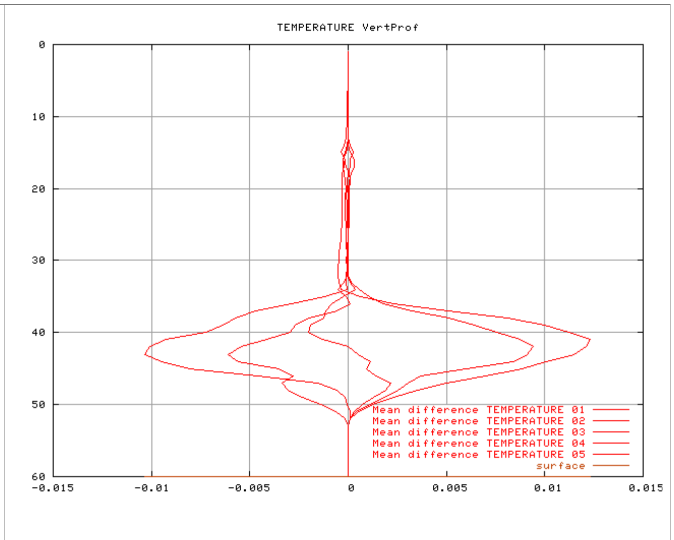


Vertical profile of average perturbations in **ALARO** for **spec. humidity** at **+3hours**

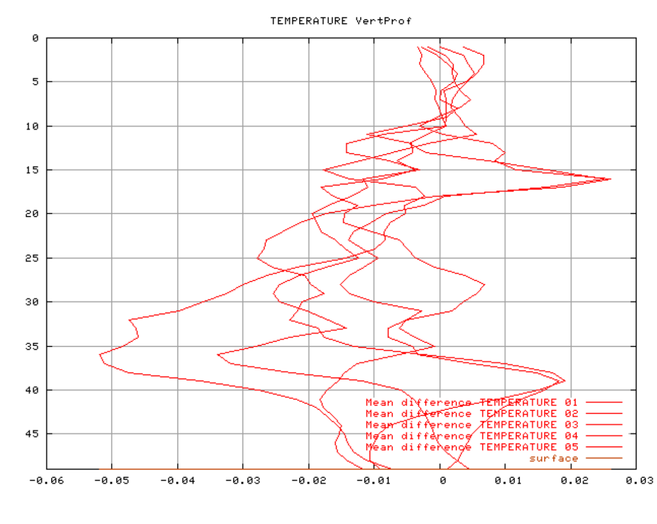
Vertical profile of average perturbations in **AROME** for **spec. humidity** at **+3hours**



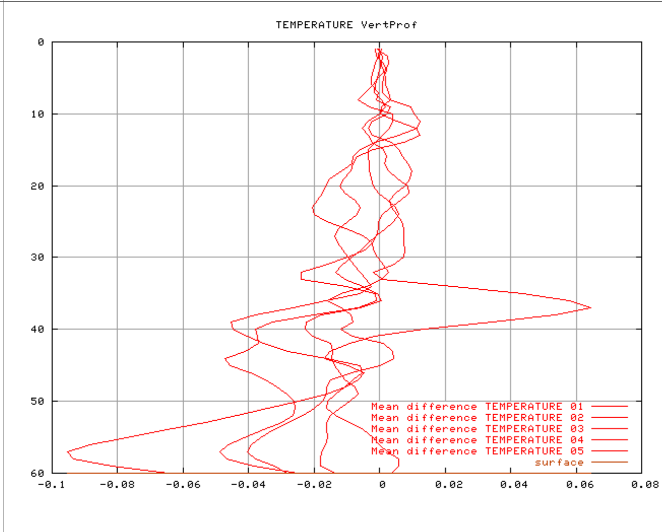
Vertical profile of average perturbations in **ALARO** for **temperature** just after **1 timestep**



Vertical profile of average perturbations in **AROME** for **temperature** just after **1 timestep**



Vertical profile of average perturbations in **ALARO** for **temperature** at **+3hours**



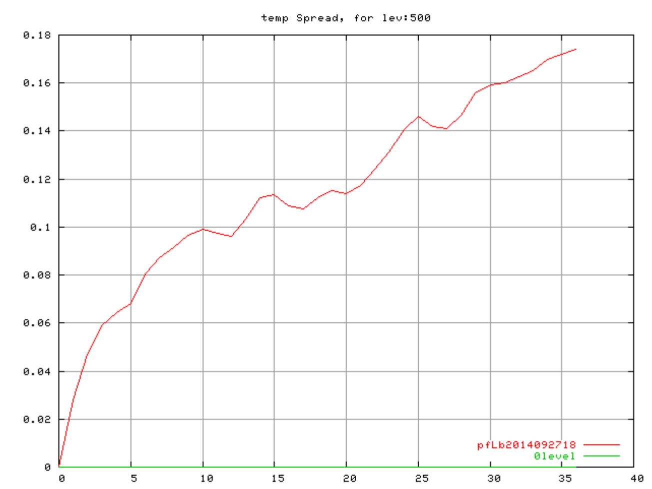
Vertical profile of average perturbations in **AROME** for **temperature** at **+3hours**

Spread evolution in a mini-ensemble

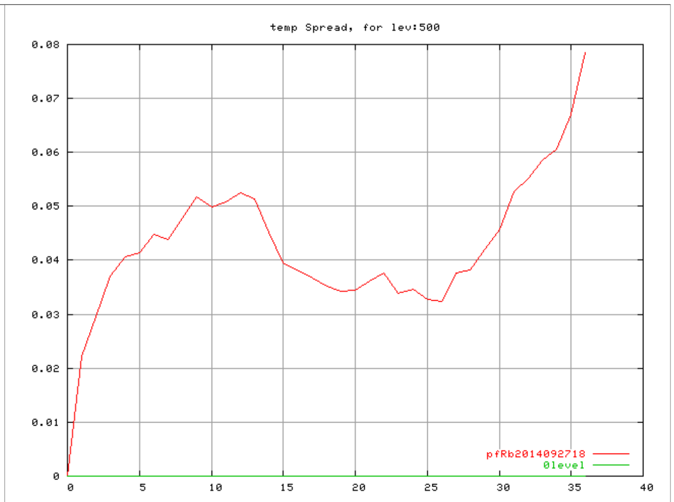
In simple non-linear systems and toy models the typical growth of perturbations can be divided into two main parts:

- a fast growing early part, which looks exponential,
- a slower growing later stage, when size of perturbation converge to a model climate value.

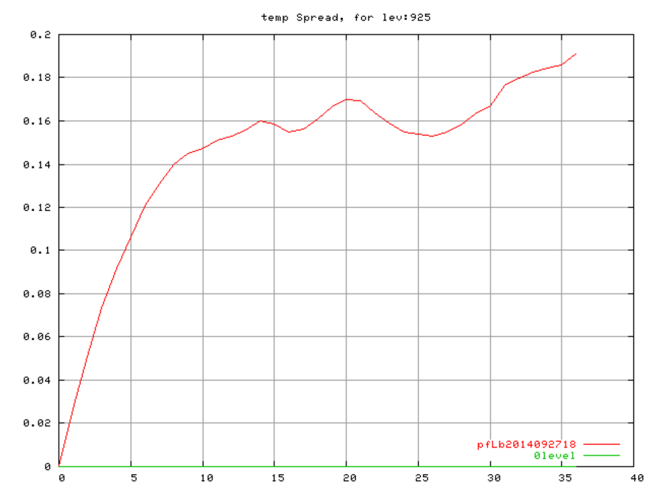
Of course in big NWP systems we can not expect exactly the same picture, especially in single-case-studies and on limited area, where the effect of LBCs can overwrite many things. However ALARO case can show something similar than expectations, but AROME can not. After a very short, very fast perturbation growth, spread can decrease in AROME many times, and also daily-cycle appears. This is more valid on higher-levels, which can be probably explained again with the bigger influence of LBCs on smaller domain.



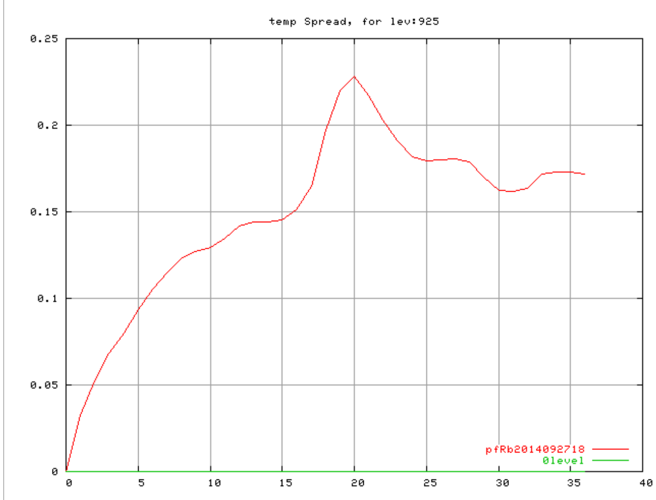
Spread evolution of **temperature** on **500hPa** in **ALARO** (18UTC, 27th of Sep, 2014)



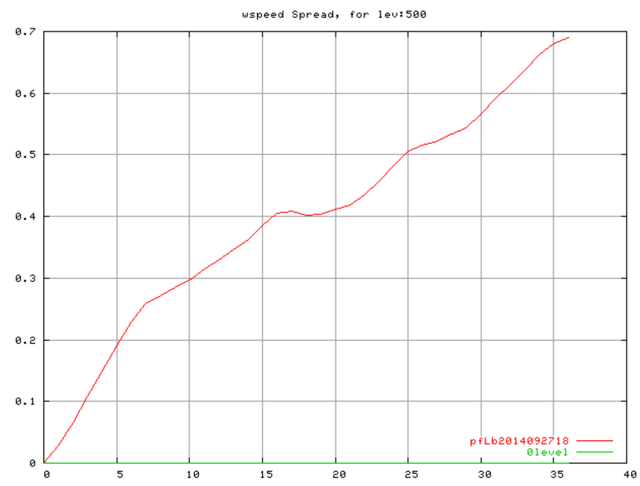
Spread evolution of **temperature** on **500hPa** in **AROME** (18UTC, 27th of Sep, 2014)



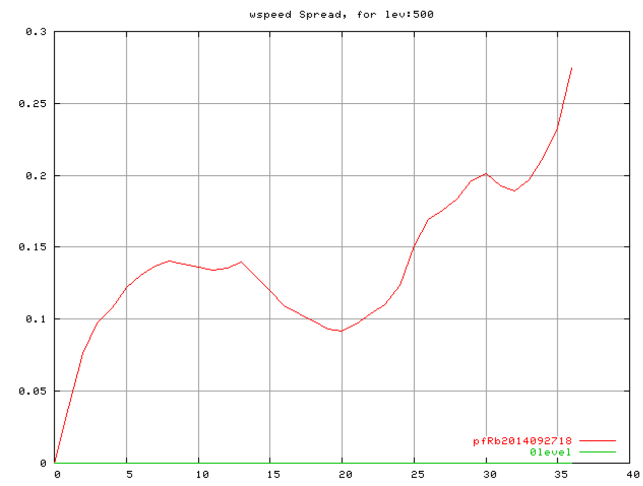
Spread evolution of **temperature** on **925hPa** in **ALARO** (18UTC, 27th of Sep, 2014)



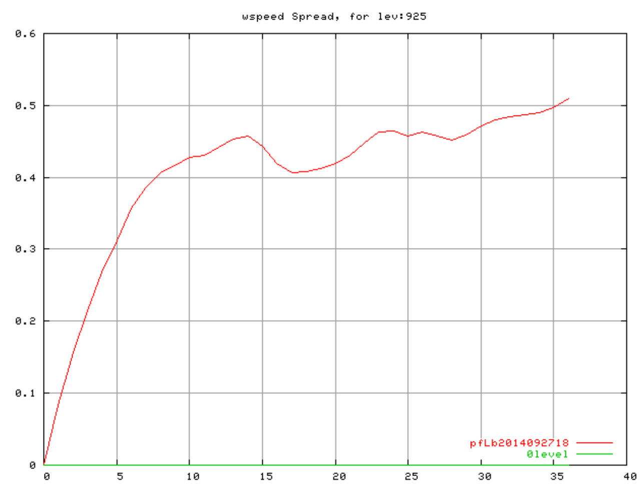
Spread evolution of **temperature** on **925hPa** in **AROME** (18UTC, 27th of Sep, 2014)



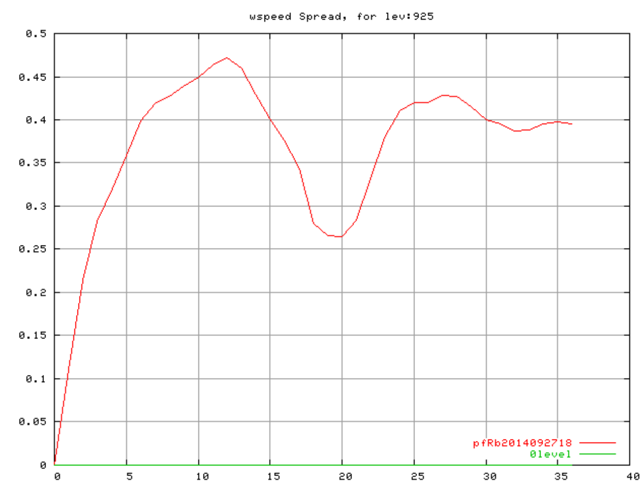
Spread evolution of **wind speed** on **500hPa** in **ALARO** (18UTC, 27th of Sep, 2014)



Spread evolution of **wind speed** on **500hPa** in **AROME** (18UTC, 27th of Sep, 2014)

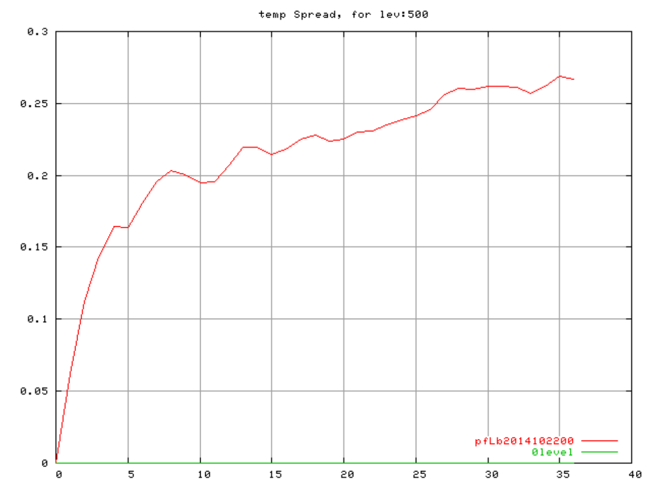


Spread evolution of **wind speed** on **925hPa** in **ALARO** (18UTC, 27th of Sep, 2014)

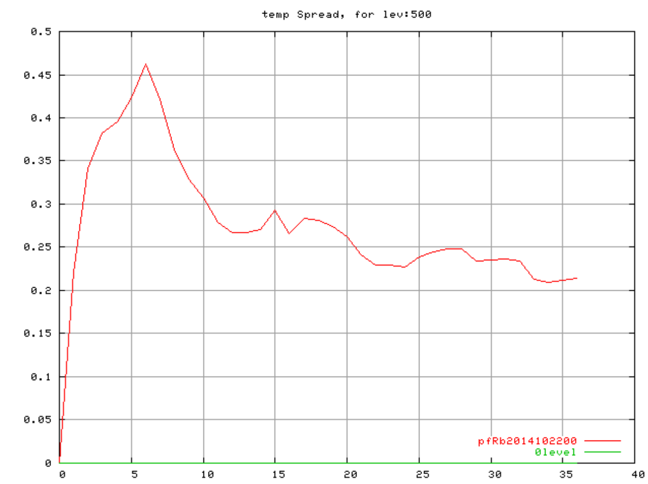


Spread evolution of **wind speed** on **925hPa** in **AROME** (18UTC, 27th of Sep, 2014)

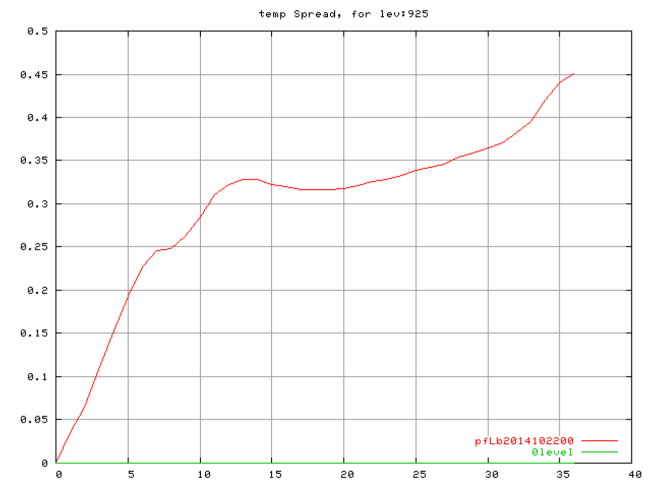
This effect is more surprising in the second case-study (00UTC, 22nd of October, 2014), when in the first hours atmosphere was extremely active because of a strong cold front.



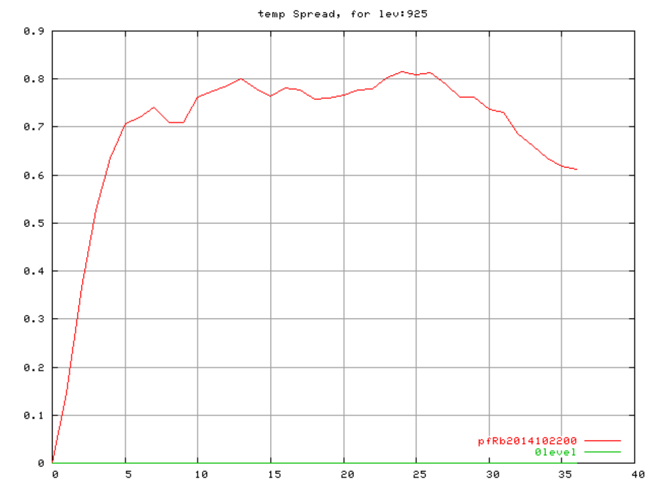
Spread evolution of **temperature** on **500hPa** in **ALARO** (00UTC, 22nd of Oct, 2014)



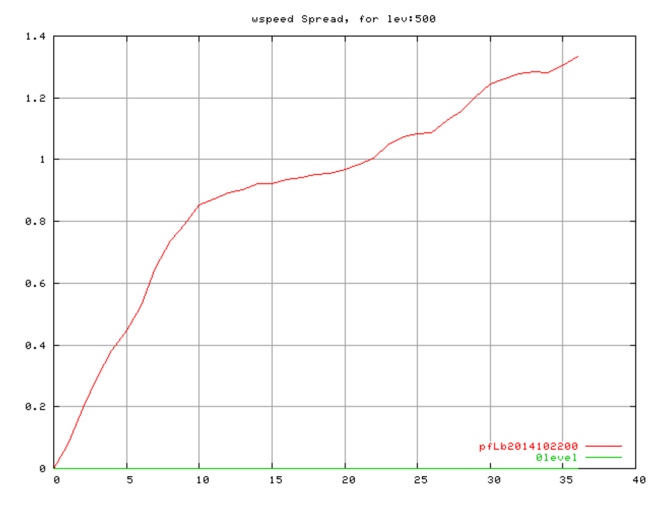
Spread evolution of **temperature** on **500hPa** in **AROME** (00UTC, 22nd of Oct, 2014)



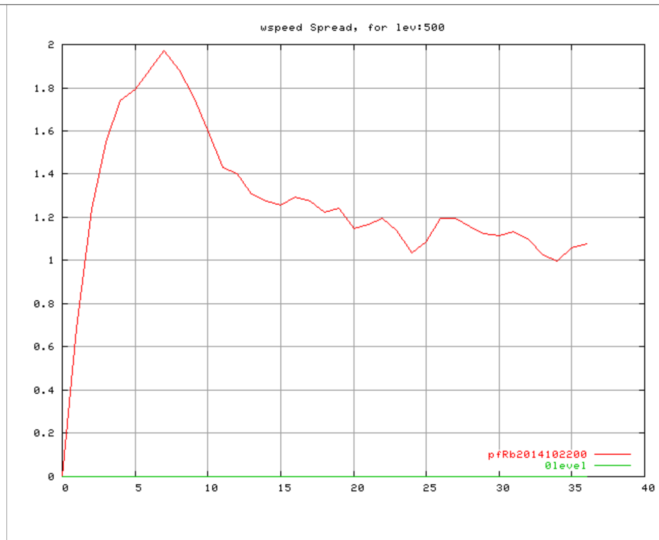
Spread evolution of **temperature** on **925hPa** in **ALARO** (00UTC, 22nd of Oct, 2014)



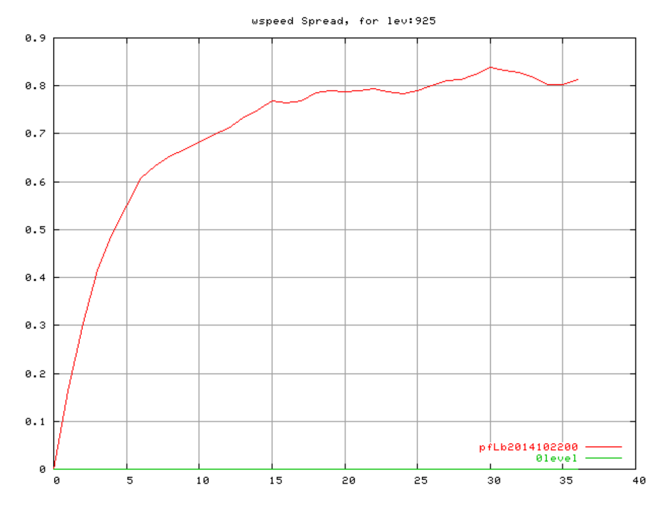
Spread evolution of **temperature** on **925hPa** in **AROME** (00UTC, 22nd of Oct, 2014)



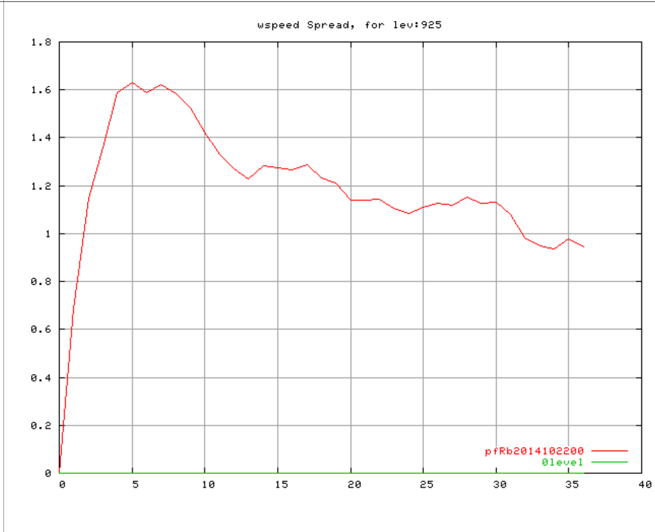
Spread evolution of **wind speed** on **500hPa** in **ALARO** (00UTC, 22nd of Oct, 2014)



Spread evolution of **wind speed** on **500hPa** in **AROME** (00UTC, 22nd of Oct, 2014)



Spread evolution of **wind speed** on **925hPa** in **ALARO** (00UTC, 22nd of Oct, 2014)



Spread evolution of **wind speed** on **925hPa** in **AROME** (00UTC, 22nd of Oct, 2014)

4. Further plans

At the end of my stay three different ways was identified to go on with tests:

- 27th of Sep case-study or tests with other foggy situations, to see clear if there is really a cooling effect inside the AROME, and what can cause that.
- Running more ALARO test to decide if model is sensible on changes in horizontal or time correlation length settings, and how can we effectively increase the spread of an ensemble.
- Running longer test periods with active SPPT scheme in ALARO based ensemble systems, if the ideal settings are found.

5. Acknowledgment

Finally I would like to say thank you for the whole modeling group of ZAMG, for their supportive attitude. They helped me in all my scientific, technical and personal troubles which made my work really smooth during my stay.
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