Report on stay at ZAMG

04-15/06/2018

Phasing and 3D-extension of SPG

In the previous years there were several stochastic physics related LACE stays and this one is kind of continuation of the work which has been started many years ago. It was only a two-week-long stay so the goals were not that ambitious and focused mainly to two topics.

Stay report is structured into four parts: The first one is a short overview with references about the background of SPPT scheme in general and SPPT related LACE stays executed in the previous years. Second part gives information about the phasing of SPG based SPPT code into cycle40. Third part is about a simplified test of possible extension of SPG into 3 dimensions. The fourth part contains conclusions and ideas for the future.

Author:
Mihály Szűcs (OMSZ)
szucs.m@met.hu

Supervisor:
Martin Belluš (SHMU)
martin.bellus@shmu.sk

Christoph Wittmann (ZAMG)
christoph.wittmann@zamg.ac.at

1. Background information

The global version of the scheme was successfully used by ECMWF (Buizza et al., 1999) and tuned with a spectral pattern generator during a main revision (Palmer et al., 2009). The limited area version and AROME extension was implemented by Francois Bouttier from Météo France (Bouttier et al., 2012).
Inside LACE several tests has taken place since 2014 and also many possible direction of developments was identified:

- The first tests were realized in AROME-EPS by implementing French settings. Results were quite mixed and not really positive (Szintai, 2015).
- In 2014 the positive impact of using the scheme for surface fluxes instead of upper-air fluxes was found in LAEF framework (Bellus, 2014, 2017).
- In the same year the extension of the scheme to ALARO physics was done (Szucs, 2014).
- After a careful investigation it was pointed out that stochastic pattern generator does not work in a proper way in LAM version (Szucs, 2015, Szucs, 2016b, Szucs, 2016c). It was suggested to make tricks with the current pattern generator or implement a better one.
- It was decided to implement the so-called SPG to create better and more reliable random fields (Tsyrulnikov and Gayfulin, 2017). This implementation was realized in two steps under cycle38 (Szucs, 2016a, Szucs, 2017).
- It became clear that not only the pattern generation is an important question regarding the scheme but the way how point-wise perturbations are used for tendencies. The default SPPT contains vertical and humidity-dependent filters which can be switched-off (Szucs, 2016d) for having less biased and more consistent perturbations.
- It was also investigated that the scheme can be applied for partial tendencies or modified on the same way how ECMWF do in SPP framework (Wastl et al., 2018).

2. SPG based SPPT under cycle40

How it was detailed in the previous session the tests and developments has already had a quite long history inside LACE. Myself started the first related stay in 2014 and have been worked under cy38 since then. Meantime this cycle became a bit old and most of the partners moved to cy40. AROME is operationally running under cy40 both in Austria and Hungary and additionally latest version of LAEF is using cy40, as well. This is the reason why it became important to phase all the pattern generator related changes to cy40.

The modifications were detailed in the last year's report (Szucs, 2017). It contained only 7 routines but some of them were really rewritten:
algor/module/spectral_arp_mod.F90
arpifs/control/stepo.F90
arpifs/module/yomspsdt.F90
arpifs/namelist/namspsdt.nam.h
arpifs/phys_ec/sppten.F90
arpifs/setup/suspsdt.F90
arpifs/utility/dealmod.F90

These routines were phased under cy40 based on one of Florian Weidle's pack on cca:
/perm/ms/at/kmw/PACKS//40t1_bf.05.MPI631INTEL150.x/

The cy40 based SPG pack can be found here on cca:
/perm/ms/hu/hu7/pack/spg2

Clemens Wastl made also a binary from that modified pack and this binary was further tested:
/home/ms/at/kmcw/PACKS/cwastl_sppt/bin/MASTERODB

It was realized that the pack is working properly and it can give back all the features of pattern generator which was detailed in last year's report (Szucs, 2017).

3. Test of 3-dmiensionality

One practical advantage of SPG in comparison with the current pattern generator is that its statistical features (standard deviation, temporal and spatial correlation) can be set in a more exact and proper way. Moreover it was written many times (Tsyrulnikov and Gayfulin, 2017, Szucs, 2016a, Szucs, 2017) that it has even theoretically better properties (proportionality of scales, homogeneous and isotropic). Although the external program of SPG can produce 3-dimensional patterns where the ratio of vertical and horizontal spatial correlation can be set by namelist. In the previous interpretation of the scheme only 2-dimensional patterns were available in ALADIN code and it seemed as an obvious idea to extend it to 3-dimensional version.
Looking into the details it became clear that this is not a simple code modification because in external program fields are represented in 3-dimensional Fourier-space and Fourier and inverse-Fourier transformations are realized in accordance with that. The usual process inside ALADIN code is quite different so it would need a deeper reorganization of the code. That work was beyond the possibility of my stay so I decided to check the effect of 3-dimensionality on a more simple way.
Code was modified to allow to define more (1-5) patterns at the same time:

- The point-wise random number coming from the first pattern is valid on every single level. Its properties can be set from namelist, as before.
- Depending on the number of the other patterns the whole column is divided into subparts. On the bottom and top level of a subparts only one additional pattern is valid so the final random number is a sum of the random number coming from the main pattern (first one) and the random number coming from the other valid random pattern.
- Inside a subpart, the mixture of the top and bottom random numbers are added to the main random number (coming from the first pattern). One example for this mixture can be seen on Fig.1 where 5 patterns are defined in total and there are 60 model levels.

This kind of pattern mixture takes place under apl_arome before calling sppten. Only few modifications were necessary in other routines just to allow the increase of the number of patterns.
Modified pack's binary can be found here:
/perm/ms/hu/hu7/pack/38t1_new_spg.06.MPI631INTEL150.x/bin/MASTERODB

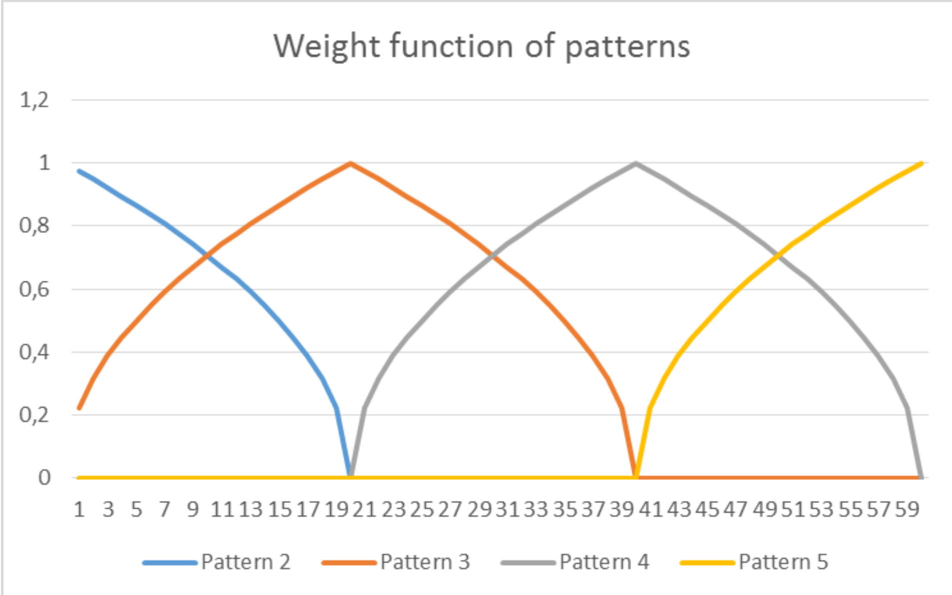

Fig. 1.: There is one dominant pattern which is active on all level. The roles of the additional four patterns are driven by level-dependent weight-functions as it is shown on the figure.

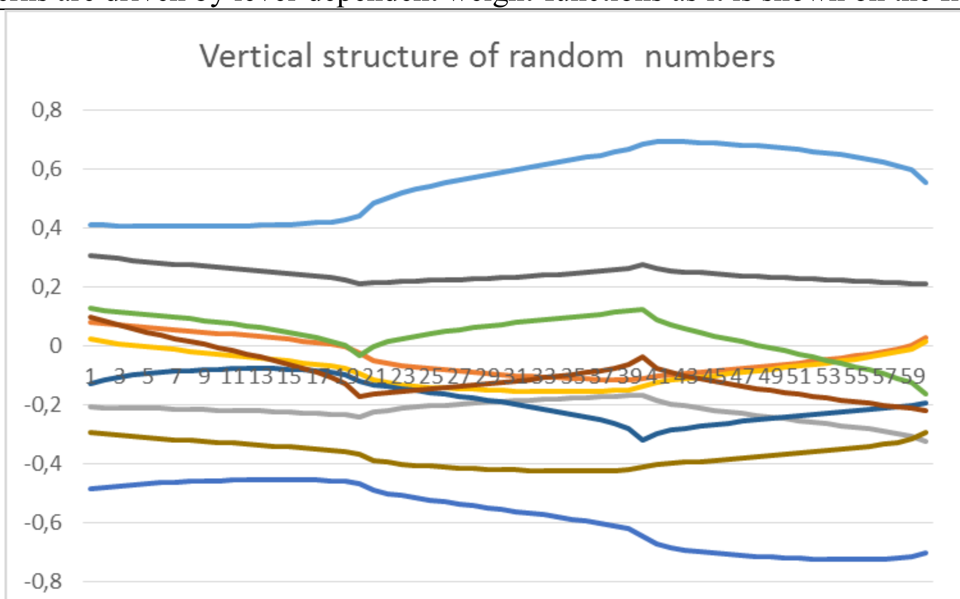

Fig. 2.: It is an example how random numbers are realized as function of level in the test experiment. Values are coming from 10 members at a randomly chosen timestep and column.

After the code modification a test was executed to see the effect of 3-dimensionality. For such test Austrian quota was used with user 'kmek' so all the scripts, namelists were moved to the following directory:
/home/ms/at/kmek/SPG

For test purpose the 'usual' days were running:
2015042718 2015050518 2015051318 2015053018 2015061418 2015070718 2015072518 2015080118 2015081618 2015081818
These 10 days are from the convective season of 2015 which were found as interesting cases by Hungarian forecasters. This is not a long and complete verification but can help to see the effect of

different settings. Almost all the Hungarian SPPT related results which were shown in different reports and workshops were based on the same days' verification. Test system contains 10+1 members integrated for 36hours over the Hungarian AROME domain.
In the comparisons five lines can be seen which belong to the following experiments (Fig. 3-6.):

- 'LBC' (purple) which is the simple downscaling without any stochastic scheme. This is a kind of reference.
- 'SPPT+SPG' (green) where SPPT is activated with the new SPG (σ=0.5 ; L0.5=100km and T0.5=3hours). Here the default tapering function and the default supersaturation check were used. In that case 'drying effect' can be visible even with the consolidated SPG.
- 'LBC+SpgSppt+SymIte' (blue) – Same as the previous one but a new supersaturation check part was introduced (Szucs, 2016d). BIAS values are quite close to the reference but meanwhile scheme does not look very effective (not much additional spread) with these settings.
- 'LBC+SpgSppt+noSnoT2' (orange) – SPPT with SPG but tapering function and supersaturation check were switched-off. At the same time σ=0.35 was set. The idea behind that setting is that I wanted to use a moderate but well-behaving random pattern and neglect additional artificial filters. This version can be more effective and make more spread but it can further increase already existing BIAS especially near the surface, like in case of wind.
- 'LBC+SpgSppt3d' (yellow) – Same as the previous one but σ=0.35 is not from one pattern but 5 independent ones. The dominant one was active on all the levels with σ=0.32 and others were mixed to that with smaller σ values. At the end total standard deviation was constant and height-independent. For better understanding of how the four smaller random number was combined Fig.1. shows their weight as a function of level. Fig.2. shows an example how random number was varying as a function of level in a given cell in a given timestep in case of 10 perturbed members.

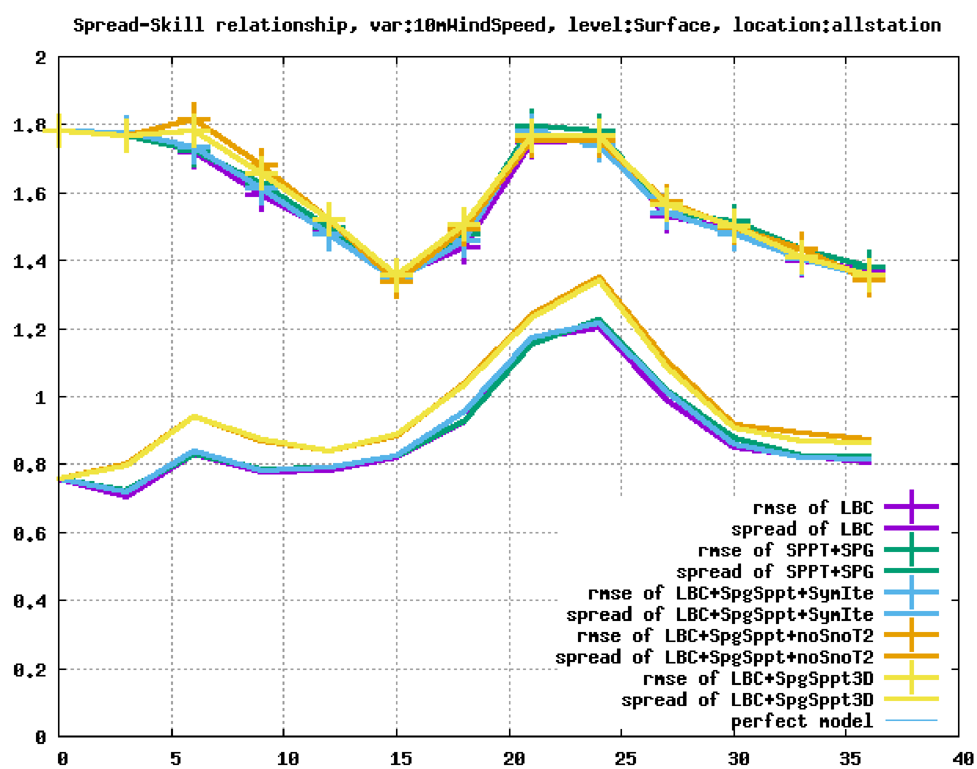

Fig. 3.: Spread-Skill relationship for 10meter wind speed. See the detailed description of the experiments in the text.

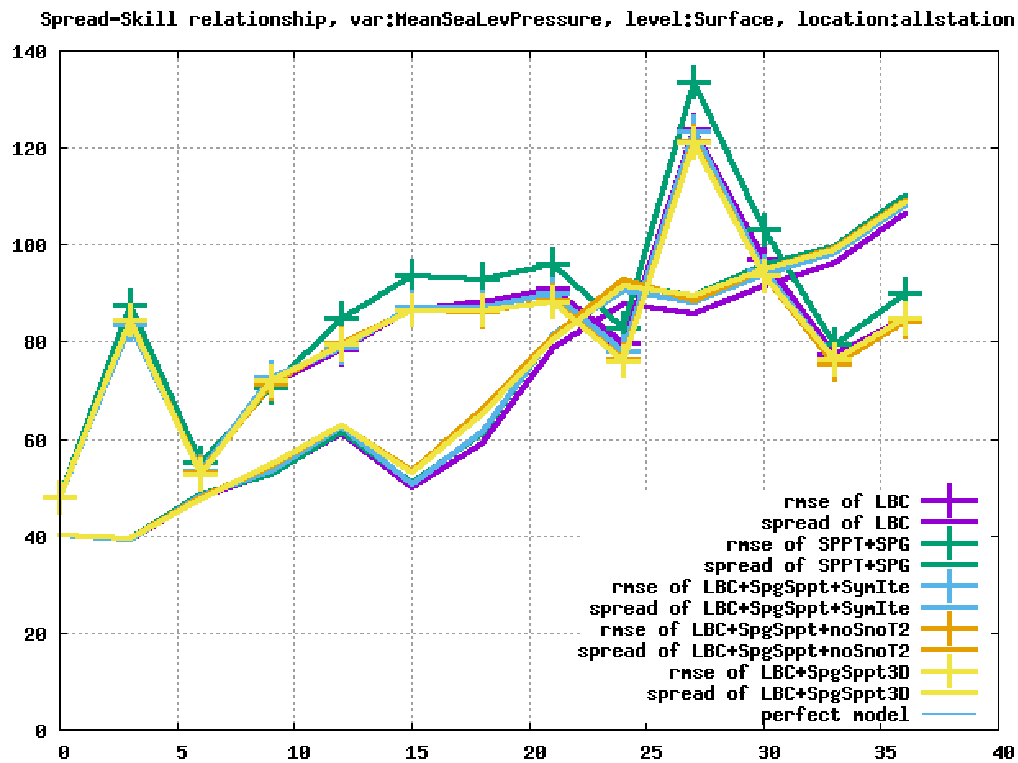

Fig. 4.: Spread-Skill relationship for mean sea level pressure. See the detailed description of the experiments in the text.

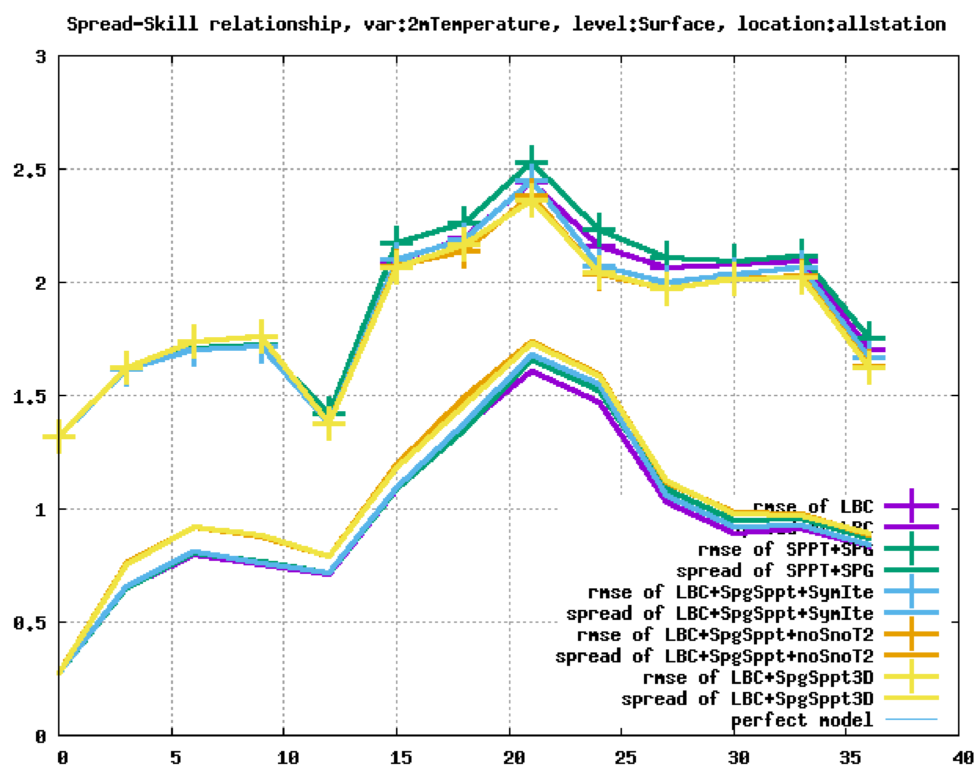

Fig. 5.: Spread-Skill relationship for 2meter temperature. See the detailed description of the experiments in the text.

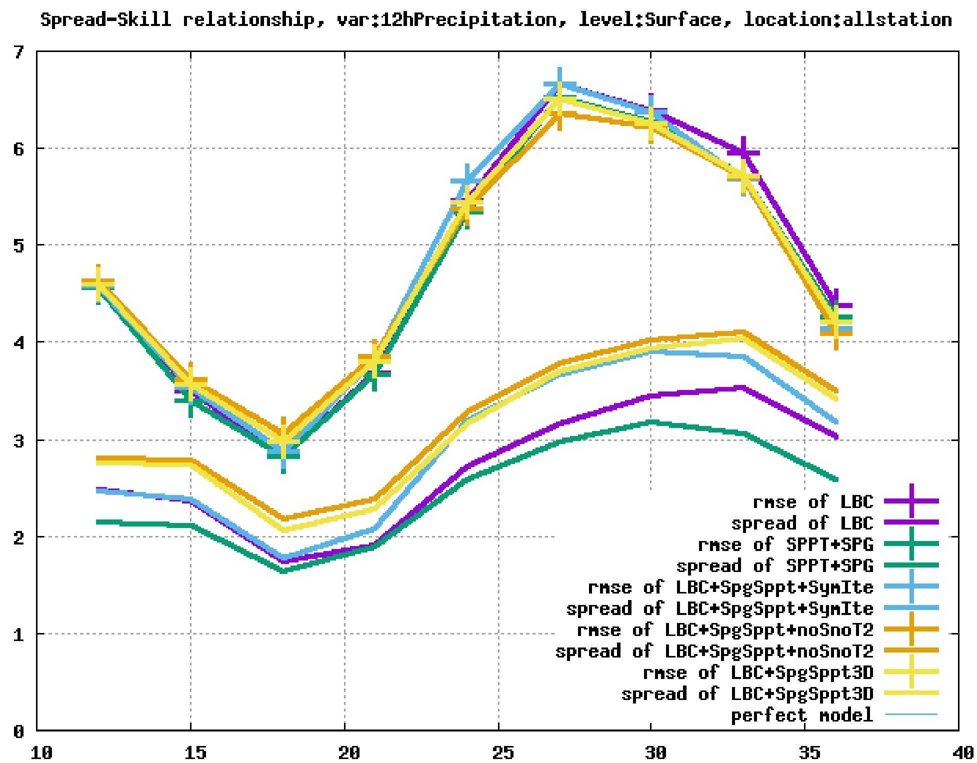

Fig. 6.: Spread-Skill relationship for 12-hourly accumulated precipitation. See the detailed description of the experiments in the text.

Taking into account the results it looks that such moderate 3-dimensionality does not cause too much difference on the results (yellow and orange lines are always close to each other). Probably a more intensive setting (convergence of dominant pattern's standard deviation to the other ones) can change conclusions and also it would be worth to check case-studies.

4. Conclusions

During the stay Austrian quota was used to execute test runs. After the stay it has not been comfortable to go on with testing other settings. It can be interesting to try out the 3-dimensional version with a bit stronger vertical variability.
However my opinion is that even 2-dimensional SPG is a far better and more reliable solution than original pattern generator. Probably this is good enough and it would be better to focus on point-wise usage of random numbers and invest more to the comparison of:

- original SPPT concept (perturbing total tendencies and using tapering function and supersaturation check);
- original SPPT concept without additional filters (how it is represented with orange lines here);
- partial tendency concept (how it was explained by Clemens Wastl);
- SPP concept

We should consider that not only the effectivity of the scheme is important but also the way how it changes model behave. So not only big and long tests are important to check its effect on spread but also case-studies to check realization of perturbed members and the caused BIAS.

Acknowledgement

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.
I am also grateful to Martin Belluš for the inspiring discussions and mailings and for the patience what he showed as LACE Area Leader.

References

Belluš, M., 2014: Stochastically perturbed physics tendencies of surface fields in ALADIN-LAEF system, Report on stay at ZAMG 12/05 - 20/06/2014, Vienna, Austria

Martin Belluš, 2017: IC and model perturbations for new ALADIN-LAEF, Report on stay at ZAMG, 24/04~19/05, 2017, Vienna, Austria

Bouttier, F., Vié, B., Nuissier, O., Raynaud, L., 2012: Impact of Stochastic Physics in a Convection-Permitting Ensemble. Mon. Wea. Rev., **140**, 3706–3721.

Buizza, R., Miller, M., Palmer, T.N., 1999, Stochastic representation of model uncertainties in the ECMWF Ensemble Prediction System, Quart. J. Roy. Meteorol. Soc., **125**, 2887–2908.

Palmer, T., Buizza, R., Doblas-Reyes, F., Jung, T., Leutbecher, M., Shutts, G., Steinheimer, M., Weisheimer, A., 2009: Stochastic parametrization and model uncertainty. Tech. Rep., ECMWF Tech. Memo. **598**, 42 pp. [Available online at http://www.ecmwf.int/publications/.]

Szintai, B., Szűcs, M., Randriamampianina, R., Kullmann, L., 2015: Application of the AROME non-hydrostatic model at the Hungarian Meteorological Service: physical parameterizations and ensemble forecasting. Időjárás 119, 241-266

Szűcs, M., 2014: Stochastically Perturbed Parameterized Tendencies in ALARO and AROME , Report on stay at ZAMG 06/10/2014 - 31/10/2014, Vienna, Austria

Szűcs, M., 2015: Tests of possible SPPT developments , Report on stay at ZAMG 28/09/2015 - 06/11/2015, Vienna, Austria

Szűcs, M., 2016a: Stochastic pattern generators , Report on stay at ZAMG 23/05/2016 - 17/06/2016

Szűcs, M., 2016b: Test of the SPPT scheme, Joint 26th ALADIN Workshop & HIRLAM All Staff Meeting 2016, 4-8/04/2016, Lisbon, Portugal

Szűcs, M., 2016c: The convection- permitting ensemble system of the Hungarian Meteorological Service, SRNWP- EPS II Workshop “Probabilistic prediction of severe weather phenomena” 17- 19 May 2016, Bologna, Italy

Szűcs, M., 2016d: SPPT in AROME and ALARO: test reuslts and open questions, HIRLAM EPS Working Week 2016-2 https://hirlam.org/trac/attachment/wiki/Meetings/EPS/EPS2016-2/SPPT_SzucsMihaly.pdf

Szűcs, M., 2017: Implementation of Stochastic Pattern Generator (SPG) in ALADIN code, Report on stay at ZAMG, 12/06~21/07, 2017, Vienna, Austria

Tsyrulnikov M. and Gayfulin D., 2017: A limited-area spatio-temporal stochastic pattern generator for simulation of uncertainties in ensemble applications. – Meteorol. Zeitschrift, 2017, doi: 10.1127/metz/2017/0815, in press.

Wastl, C., Wang, Y., Wittmann, C., Keresturi, E., 2018: C-LAEF: Convection permitting Limited Area Ensemble Forecasting, 40[th] EWGLAM and 25[th] SRNWP Workshop