Report on stay at ZAMG

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Stochastic Perturbation of Physics Tendencies in new CY40T1 with ALARO-1 physics

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::Acknowledgement

I would like to express my big thanks to Christoph Wittmann and Mihály Szűcs for their valuable help with the debugging of CY40T1 and for localising the problem inside CPG.

::Foreword

This stay was split into two parts mainly because of the logistics. The offices at ZAMG were fully occupied in September-October by the other stagiaires and also there were LSC and EWGLAM meetings (with my participation) in between. Thus the first 2 weeks (14-25 Sept) were mostly dedicated to the finalization of the paper for MWR dealing with the two different methods of surface IC perturbation in a regional EPS. Then the next 3 weeks (12-30 Oct) were spent by more technical work. The Stochastic Perturbation of Physics Tendencies (SPPT) for the surface parameters (ISBA) was ported into the new cycle CY40T1 and validated against CY38T1.

::I. Final work on NCSB vs ESDA paper

The verification plots have been recreated for better readability and to suit well B&W printing. Also new daily scores for outliers and ensemble spread valid at the initial time have been included to demonstrate the impact of NCSB and ESDA perturbation methods. Finally, the manuscript with the title “Perturbing surface initial conditions in a regional ensemble prediction system” (Bellus, Wang, Meier) was submitted to Monthly Weather Review in January 2016. Currently the paper is in peer-review.

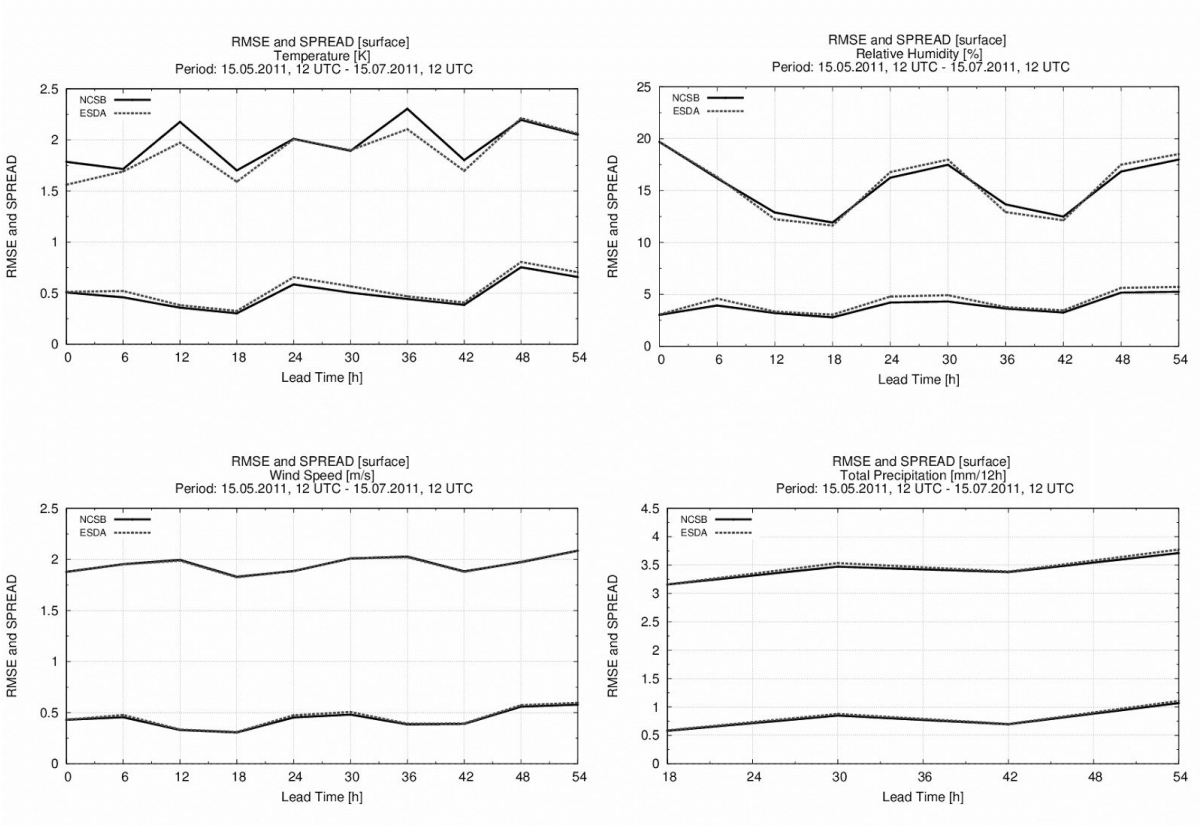

Fig.1: RMSE (upper lines) and spread (bottom lines) of the ensemble for the

screen-level variables: NCSB (solid) and ESDA (dashed) experiments as function of lead time. Displayed parameters are 2 m temperature (upper left), 2 m relative humidity (upper right), 10 m wind speed (bottom left) and 12 hourly precipitation (bottom right), averaged over the verification domain and over the verification period from 15 May 2011 to 15 July 2011.

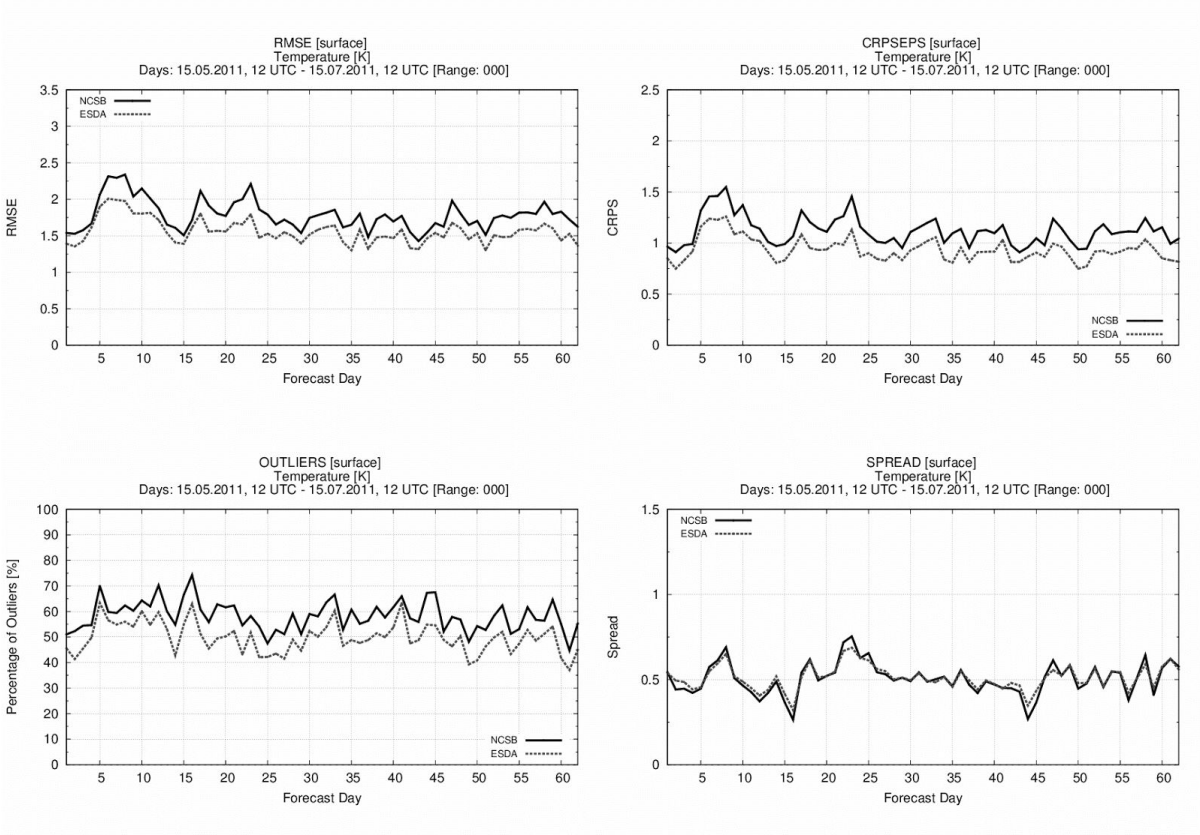

Fig.2: Statistical skill scores for the ensemble of 2 m temperature analysis (+0h) for the whole 62 days of the validation period, averaged over the verification domain: RMSE (upper left), CRPS (upper right), outliers (bottom left) and spread (bottom right) for NCSB (solid) and ESDA (dashed) experiments.

::II. Porting the SPPT into new CY40T1

The implementation of SPPT in the new export version of CY40T1 was not that straightforward as expected. First experiments were spoiled and quite a time was spent by tracking down the source of the error. For a clean test, we have compiled and run CY40T1 without the local development of surface SPPT, but with the diagnostics containing a slice of PGPSDT2D array with the stochastic pattern. The wrong data were present already there as one can see on the following figure (Fig.3 - bottom). Another test on a different platform (SGI cluster at ZAMG) confirmed exactly the same problem.

With the great help of Christoph Wittmann and Mihály Szűcs, the bug was eventually found in CPG routine and reported to the ALADIN community. The stochastic pattern passed to MF_PHYS was declared in CPG but never correctly filled with the random numbers, i.e. the content of PGPSDT2D was unpredictable chunk of memory (see Fig.3 - bottom).

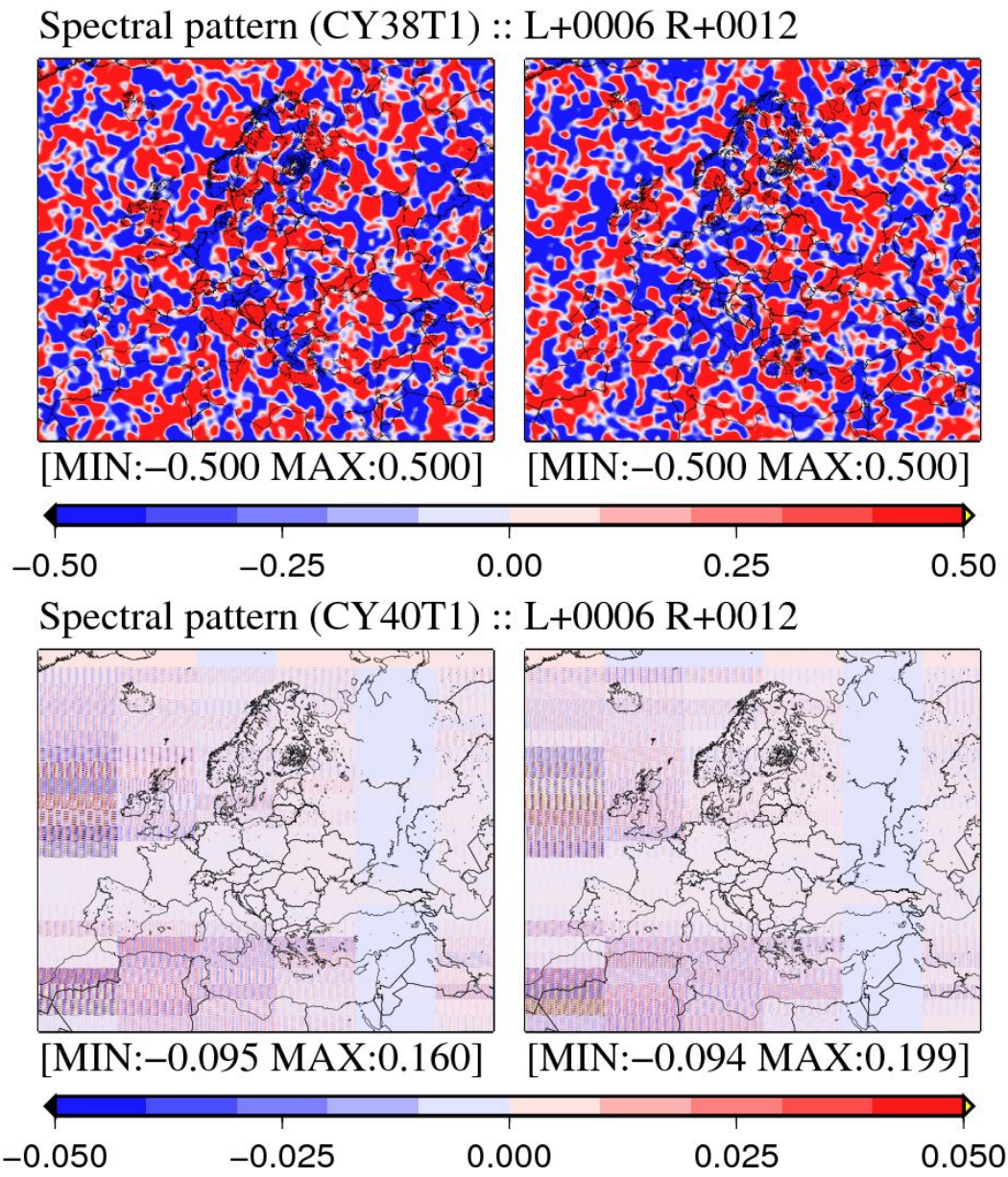

Fig.3: Stochastic spectral pattern in CY38T1 (up) and wrong pattern in CY40T1 (bottom) for sigma=0.25, tau=2 h, L=500 km and for the ranges +06 (left) and +12 (right).

As a result, model was instantly crashing after the several timesteps. A clear disruption of the forecast had been visible for instance on the 2D temperature maps

as well. In the following picture (Fig.4) there is side by side comparison of spoiled and reference 12 h temperature forecast on CY40T1.

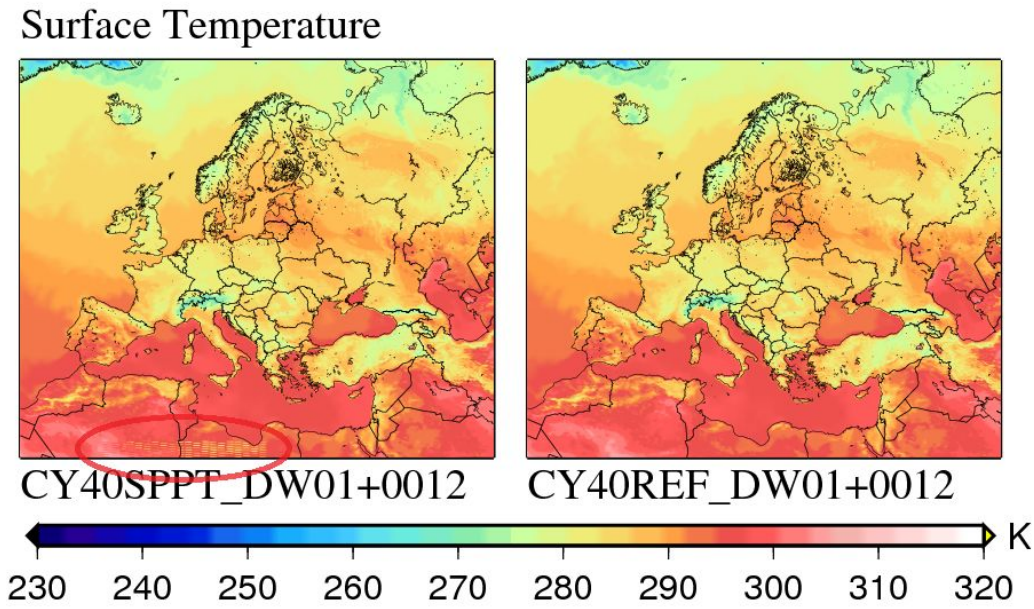

Fig.4: Surface temperature 12 h forecast for the experiment (left) and the reference with switched off SPPT (right) using CY40T1 - bugged version.

The correction of CPG routine is indeed small. The declaration of a local array ZGPSDT2D (which was holding the stochastic pattern in previous cycle) on line 395 has to be removed, it is not needed anymore:

```
~~REAL(KIND=JPRB) :: ZGPSDT2D(NPROMA,YGPSDT%NG2D)~~
```

And then within the call sequence to MF_PHYS on line 693 this obsolete ZGPSDT2D array has to be replaced symmetrically by PGPSDT2D:

```
CALL MF_PHYS (IBL,KGPCOMP,IST,IEND, …, PGPSDT2D, …)
```

Following experiments with the fixed CPG routine in CY40T1 including the surface SPPT development (SPPTEN_ISBA, MF_PHYS) on CRAY cluster at ECMWF gave already expected results and the model became stable. (For more information about the surface SPPT implementation in ALADIN-LAEF please see the RC LACE report of M. Belluš, 2014: “Stochastically perturbed physics tendencies of surface fields in ALADIN-LAEF system”.) The diagnosis of physics tendencies confirmed that the technical implementation of SPPT is now correct. In the picture (Fig.5) one can see the mostly positive (in the morning) and mostly negative (at noon) physics tendencies of surface temperature including the local perturbations by SPPT.

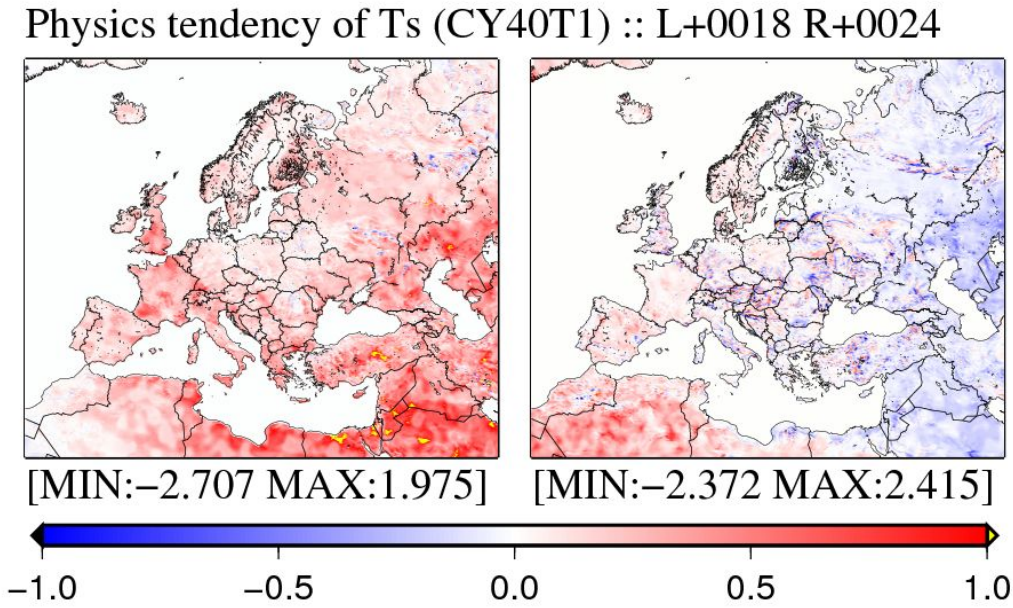

Fig.5: Perturbed physics tendency of surface temperature in bugfixed CY40T1 for range +18 (06 h in the morning, left) and +24 (12 h at noon, right).

::III. Verification of SPPT (CY38T1 vs CY40T1 vs REF)

To test the overall stability of SPPT introduced in CY40T1 together with the new ALARO-1 physics package, the evaluation experiments were conducted for one month verification period. We have coupled ALADIN-LAEF with the ECMWF EPS dataset from 2011 (May-June) just because it was already used many times and it makes the results inter-comparable. Therefore, we needed to run only the two experiments utilizing CY40T1. The first one with the implemented SPPT for the surface parameters. The second one without the SPPT (as for the reference). The grib files for the third experiment containing the surface SPPT on CY38T1 were already available from our previous work.

All the experiments were driven by the first 16 ECMWF EPS members in dynamical adaptation, i.e. without the local assimilation cycle. The uncertainty of the initial condition comes therefore just from the interpolation of the global ensemble perturbation (ECMWF EPS). However, the model uncertainty is simulated by the stochastic perturbation of physics tendencies of the surface prognostic variables (in case of SPPT experiments for both CY40T1 and CY38T1) while the reference run on CY40T1 is pure downscaling of ECMWF EPS forecast.

The verification scores shown in the figures (Fig.6-12) as a function of forecast lead time are averaged over the one month verification period (15.05.~15.06.2011) and over the central European verification domain.

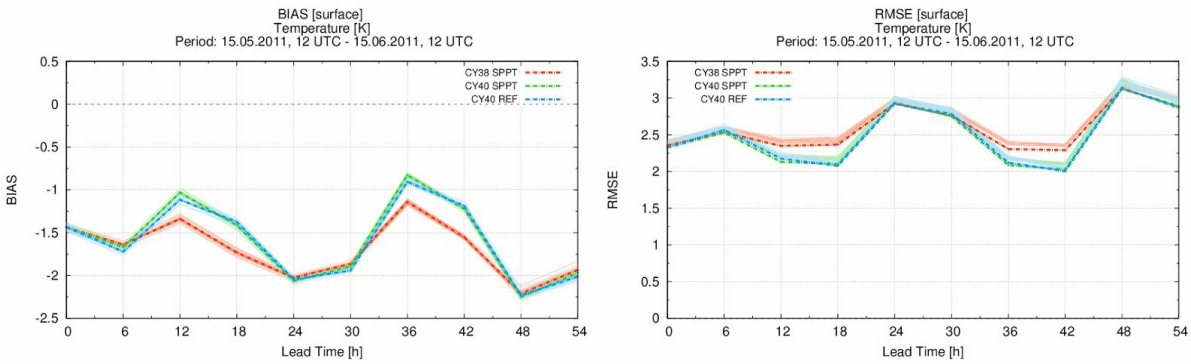

Fig.6: BIAS (left) and RMSE (right) for temperature at 2 m for SPPT experiments on CY38T1 (red) vs CY40T1 (green) and the reference without SPPT on CY40T1 (blue).

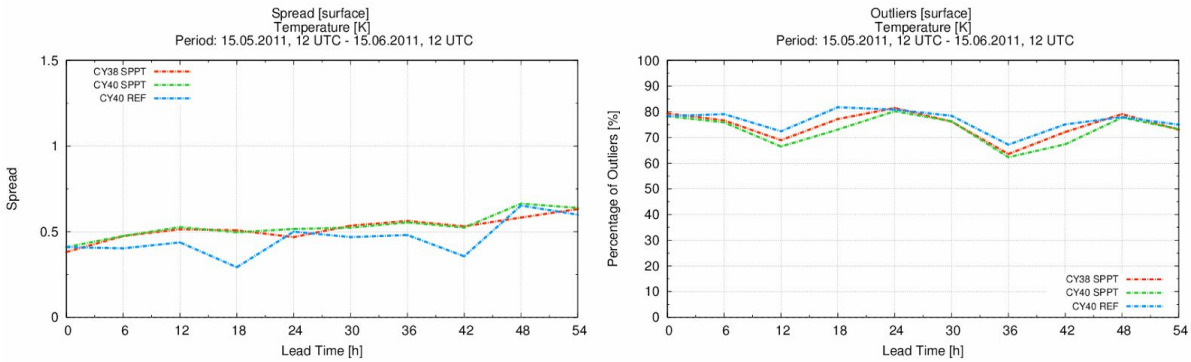

Fig.7: Ensemble SPREAD (left) and OUTLIERS (right) for temperature at 2 m for SPPT experiments on CY38T1 (red) vs CY40T1 (green) and the reference without SPPT on CY40T1 (blue).

From the above statistical scores it is obvious that SPPT works better within the new version of the code. This is clearly demonstrated by the difference between the red and green lines for BIAS and RMSE scores (CY40T1 vs CY38T1 with SPPT). Such improvement is caused mainly due to the more sophisticated ALARO-1 physics in CY40T1, because the observed difference between green and blue lines is to the contrary rather small for BIAS and RMSE scores (CY40T1 with vs without SPPT). The error of temperature at 2 m forecast is significantly reduced during the night and morning hours, while the afternoon values are not affected. On the other hand the ensemble spread is enlarged and the percentage of outliers is reduced for the SPPT experiment on CY40T1 (green vs blue lines for SPREAD and OUTLIERS scores), which is indeed the benefit of stochastic physics.

For the other screen-level parameters like wind speed at 10 m (Fig.8-9) or relative humidity at 2 m (Fig.10-11) the differences between both model versions including SPPT to perturb the surface prognostic variables are too small to be significant.

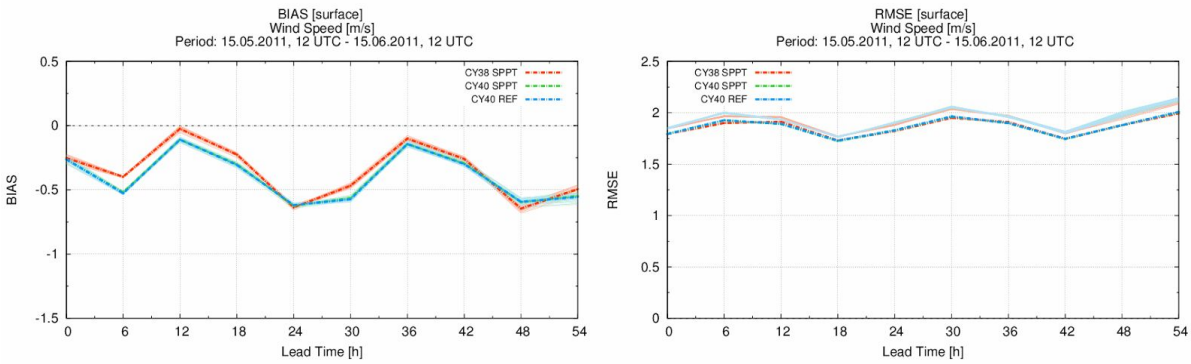

Fig.8: BIAS (left) and RMSE (right) for wind speed at 10 m for SPPT experiments on CY38T1 (red) vs CY40T1 (green) and the reference without SPPT on CY40T1 (blue).

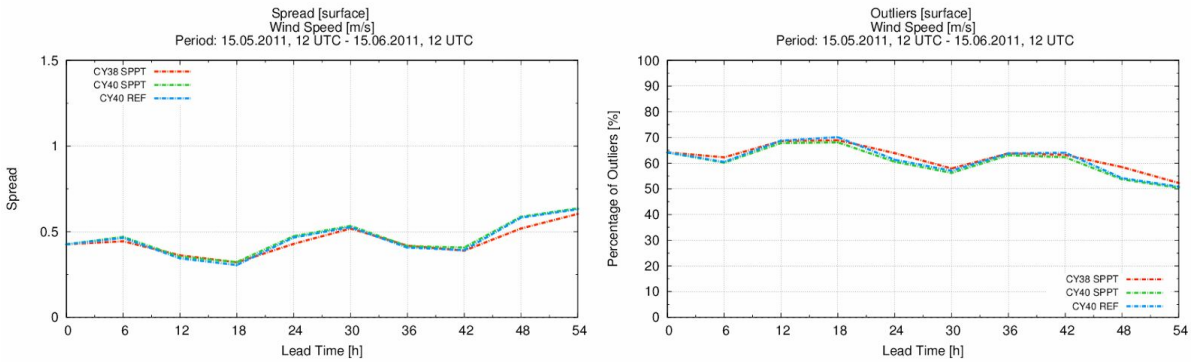

Fig.9: Ensemble SPREAD (left) and OUTLIERS (right) for wind speed at 10 m for SPPT experiments on CY38T1 (red) vs CY40T1 (green) and the reference without SPPT on CY40T1 (blue).

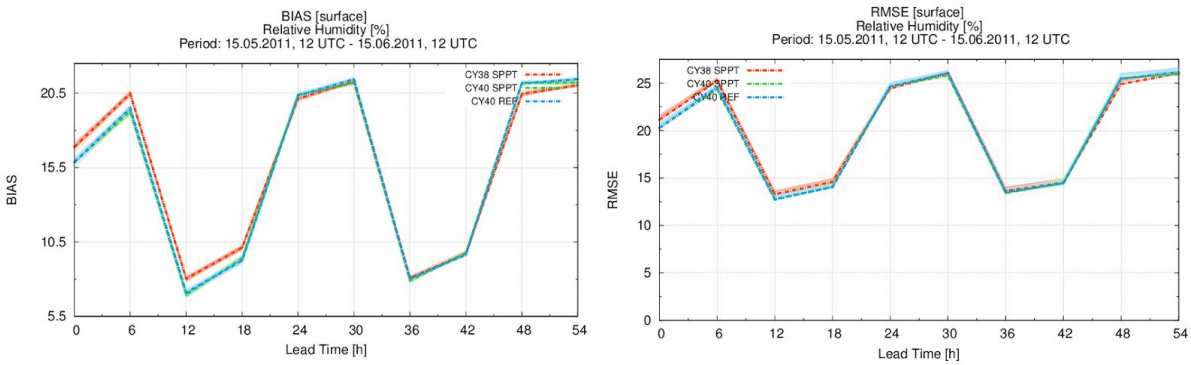

Fig.10: BIAS (left) and RMSE (right) for relative humidity at 2 m for SPPT experiments on CY38T1 (red) vs CY40T1 (green) and the reference without SPPT on CY40T1 (blue).

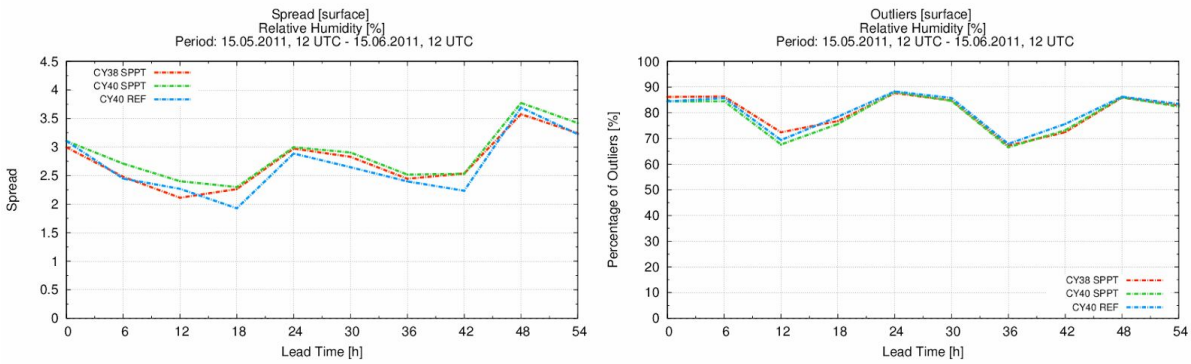

Fig.11: Ensemble SPREAD (left) and OUTLIERS (right) for relative humidity at 2 m for SPPT experiments on CY38T1 (red) vs CY40T1 (green) and the reference without SPPT on CY40T1 (blue).

The different situation is in case of mean sea level pressure (MSLP). There we can observe slight deterioration of the verification scores, both for the BIAS and RMSE (Fig.12). The scores valid for previous cycle CY38T1 with ALARO-0 physics are better (red lines). However, this is in agreement with already observed MSLP issue, where rather the scores of ALARO-0 vs ALARO-1 have been evaluated. According to the deterministic model verification regarding ALARO-0 vs ALARO-1 packages at Slovak Hydrometeorological Institute (SHMU), the bigger MSLP errors have been observed for ALARO-1 especially during the summer period (personal communication with Mária Derková). Therefore, we can conclude that such worsening of the scores in our experiment is caused by the ALARO-1 parameterization itself, particularly when the SPPT impact on the MSLP scores on CY40T1 is rather negligible (green vs blue lines on Fig.12).

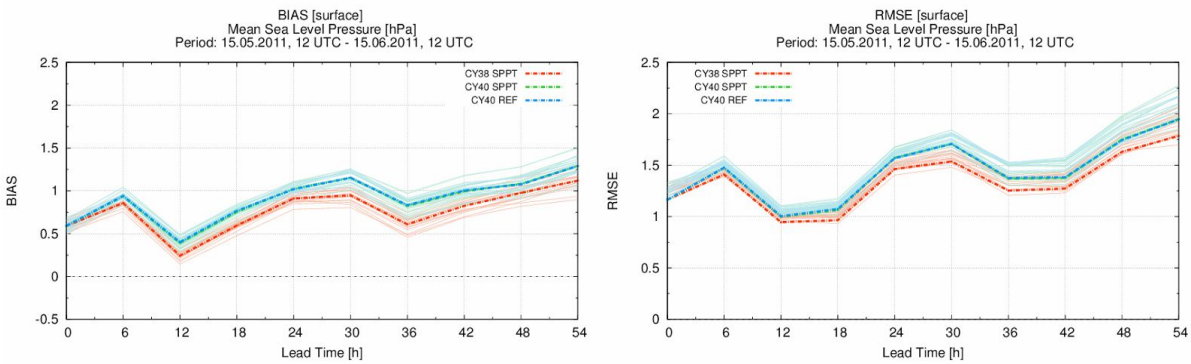

Fig.12: BIAS (left) and RMSE (right) for mean sea level pressure for SPPT experiments on CY38T1 (red) vs CY40T1 (green) and the reference without SPPT on CY40T1 (blue).

::Conclusions

We have discovered an important issue in the export version of CY40T1 (bf5) related to the PGPSDT2D array holding the random number values. Luckily, the implementation of SPPT was successful in the end. What is more, the statistical verification results have shown a significant improvement regarding the surface SPPT in CY40T1 over CY38T1 for screen-level temperature forecast during the night and morning hours, which is most likely due to the improved physics in ALARO-1 package. Nevertheless, some slight enhancement of the scores obviously came from SPPT as well, since the ensemble spread for our experiment was enlarged and the percentage of outliers was decreased at the same time. This can be clearly assigned to the stochastic perturbation, because it is an improvement over the reference run on CY40T1 without SPPT. For the other screen-level parameters (e.g. wind speed at 10 m and relative humidity at 2 m) the scores are neutral or marginally better. The opposite is valid for MSLP, but that seems to be an issue of ALARO-1 package rather than its combination with SPPT.

::Appendix

Some technical notes - output data location:

(**ZAMG archive**)
GRIB data for the verification domain (2011-05-15 ~ 2011-06-15, 12 UTC):
/ment_arch2/bellus/CY40_SPPT
CY40_SPPT: run with stochastically perturbed phys.tend. of surface fields: Ts, Ws, Wsi, Wr, Sn, An, Rn (TCC, SPPT sigma=0.25, L=500 km, t=2 h, DADA) on CY40T1 with ALARO-1 physics
CY40_REF: reference run without SPPT on CY40T1 with ALARO-1 physics
SPPT_025: run with stochastically perturbed phys.tend. of surface fields: Ts, Ws, Wsi, Wr, Sn, An, Rn (TCC, SPPT sigma=0.25, L=500 km, t=2 h, DADA) on CY38T1 with ALARO-0 physics

Verification period:
15.05.2011 ~ 15.06.2011, 12 UTC run - 1 month: CY40_SPPT, CY40_REF, SPPT_025 (CY38T1 with SPPT)