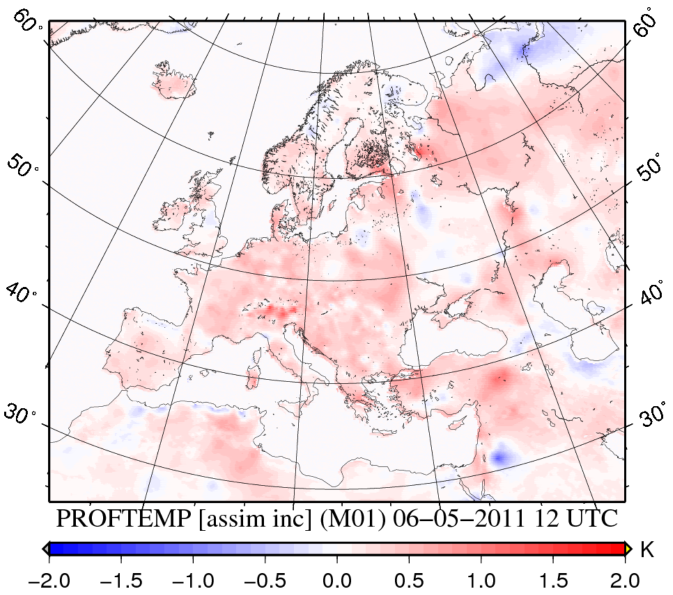
Report on stay at ZAMG

11/04 – 20/05/2011, Vienna, Austria

The assimilation and perturbation of surface/soil fields in ALADIN-LAEF system



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::Content

::Acknowledgement

I am very grateful for the opportunity to work again on a fresh new and very interesting LAM EPS topic. Many thanks also to the whole local team for their hospitality and friendly atmosphere as usual.

::Foreword

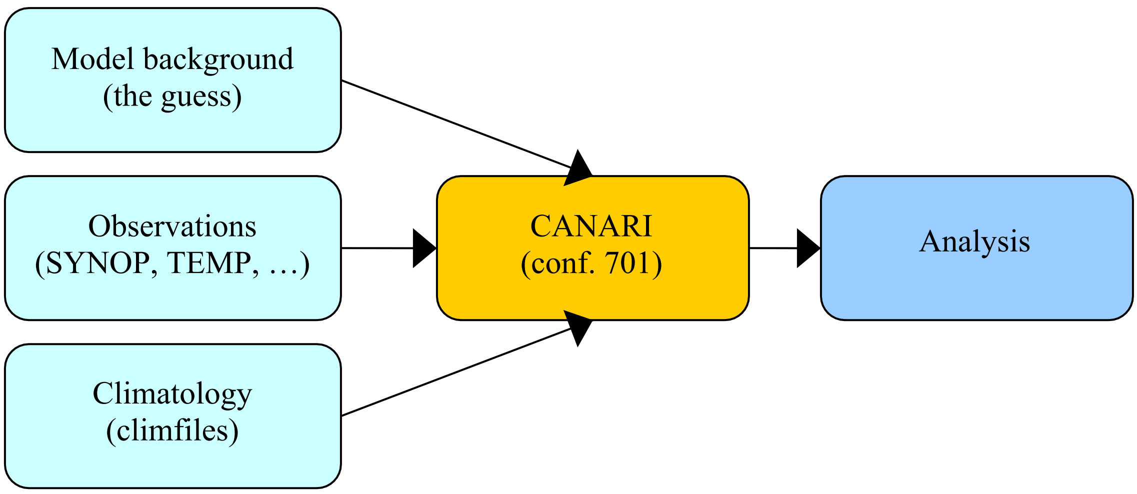
The quality of surface initial-conditions is indeed very important for the competitive deterministic forecast but it is crucial for the ensemble prediction system as well. The known problem of ALADIN-LAEF system coupled with ECMWF EPS lies in the different surface and soil parameterizations used in the two models. Hence the idea of our own ALADIN-LAEF surface assimilation cycle was the main motivation for this work. What is more, such assimilation tool can be used not only to reduce the system bias (due to the different surface schemes) but at the same time it can be applied as a LAM source of initial-time surface perturbation. This can be achieved for instance by the appropriate perturbation of used observations in the assimilation procedure.

::I Brief introduction to CANARI configuration

CANARI (Code for the Analysis Necessary for ARPEGE for its Rejects and its Initialisation) is just one of the many model configurations. It does the global analysis based on Optimal Interpolation method.

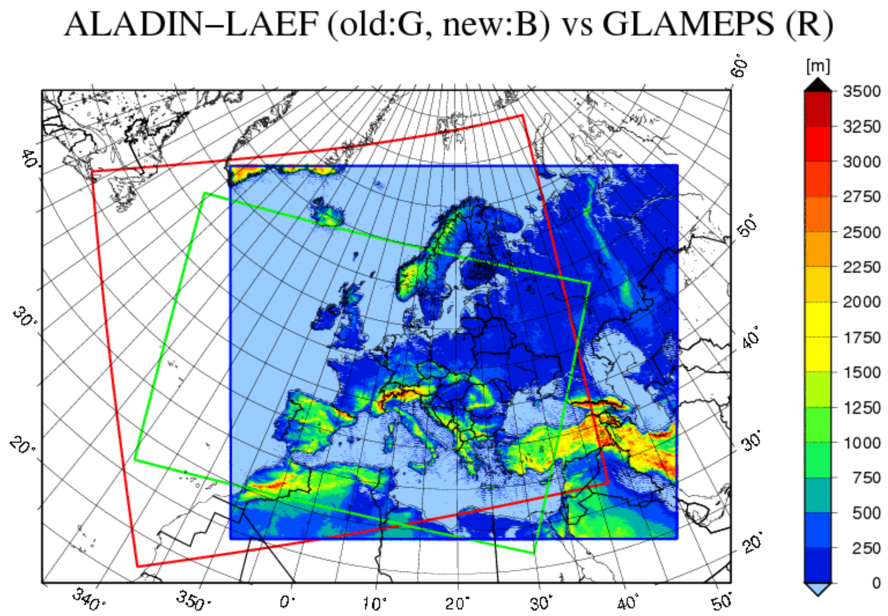
CANARI was naturally developed at Meteo-France in ARPEGE code back in 1988 and operationally used since 1992. In 1993 it was adapted to the ALADIN code as well. In 1997 CANARI was replaced by more sophisticated 3D-VAR assimilation system at Meteo-France, but CANARI was further kept for quality control and the analysis of surface fields. Since 1998 ISBA (Interaction Soil-Biosphere-Atmosphere) is used operationally in ARPEGE and ALADIN. It is a land-surface parameterization model scheme describing soil-vegetation-atmosphere interactions. Since 2001 the ODB (Observation Data Base) is used in CANARI.

The general idea behind CANARI is to create an atmospheric state as close to the reality as possible and at the same time dynamically consistent. This is done taking into account all available information such as the observations, numerical model itself, physical constrains and the climatology.

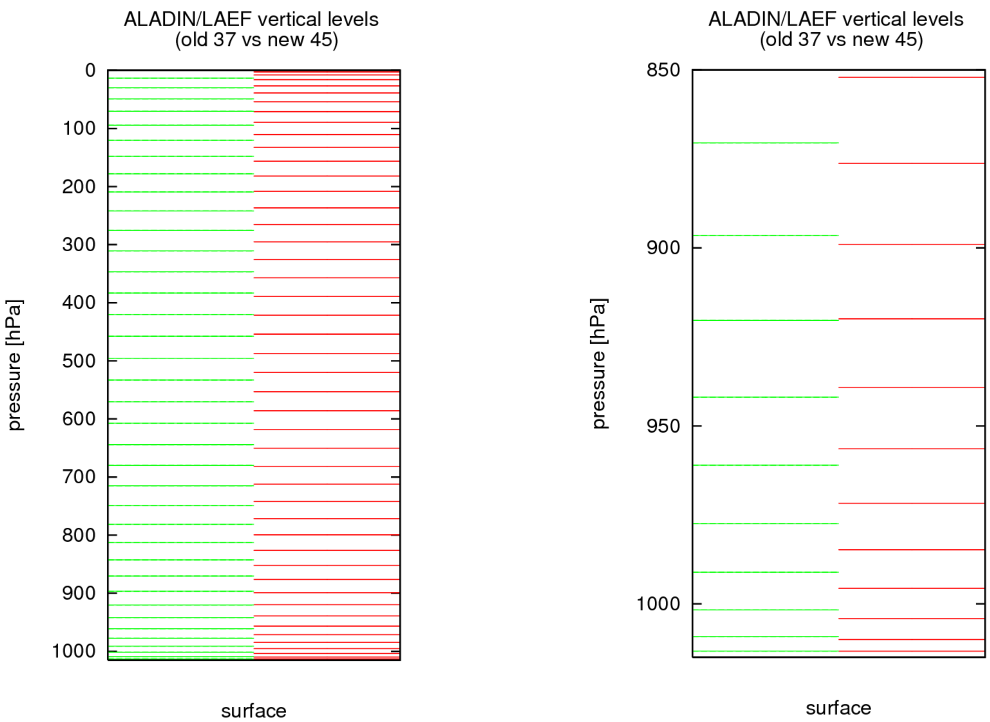


::II New ALADIN-LAEF perturbation/assimilation cycle

The implementation of surface assimilation cycle and the control experiments were carried out already on the new ALADIN-LAEF domain (see Fig.1). Together with enlarged domain size and the finer horizontal resolution, also the number of vertical levels was increased (see Fig.2).



::Fig.1 Comparison of the old (green) and new (blue) ALADIN-LAEF domains. The red borders are representing GLAMEPS domain. New ALADIN-LAEF domain has spatial resolution of 10.9 km while the resolution of old domain was 18 km.



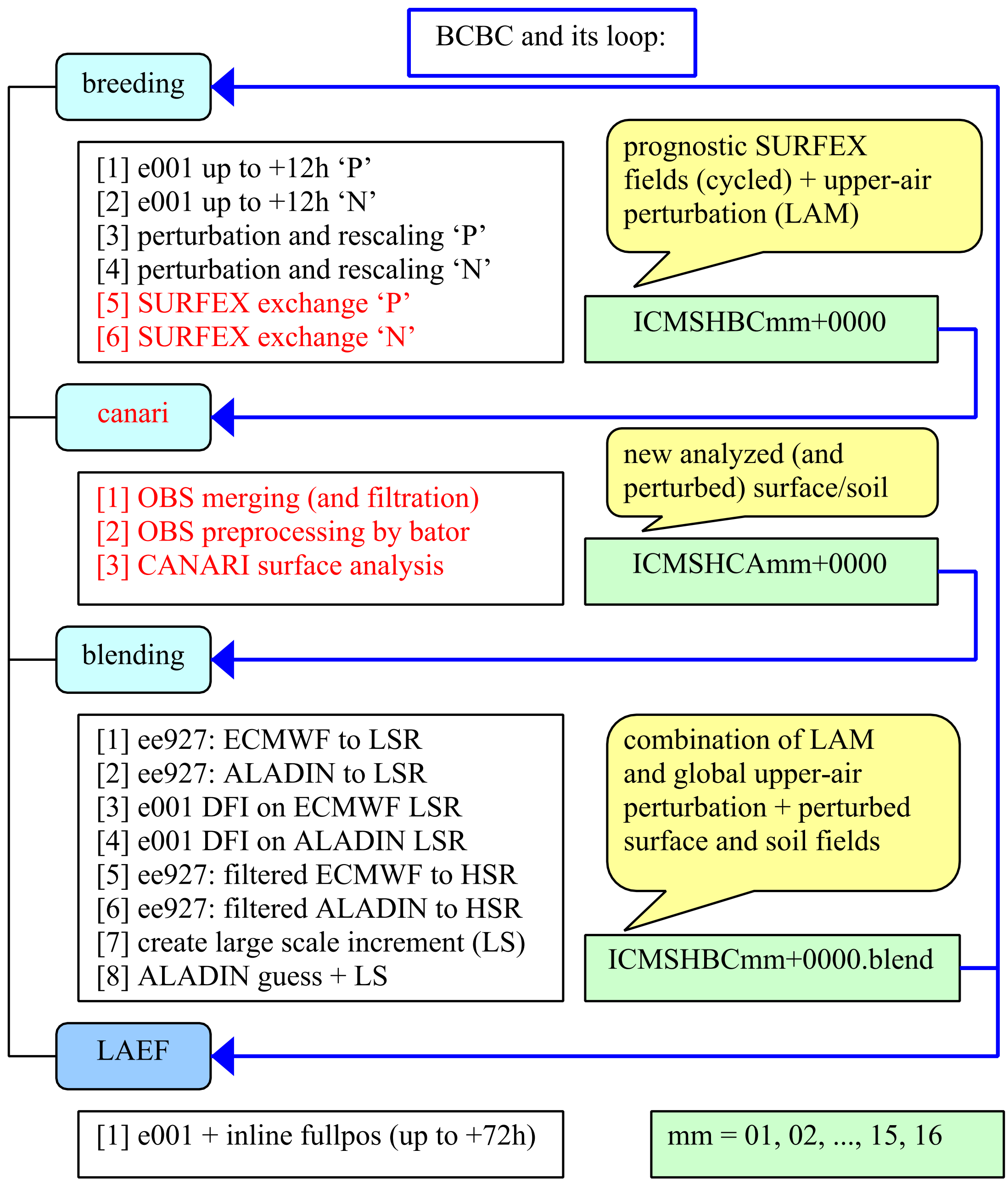
::Fig.2 Comparison of model vertical levels distribution for the old domain (37 levels, green) and the new domain (45 levels, red). The whole vertical profile is shown on the left side while zoom over the model levels up to 850 hPa is to the right.

CANARI surface assimilation procedure has been implemented into the ALADIN-LAEF system as a new building brick (similarly to the existing blending and breeding bricks). This means, it can be eventually used in different LAEF configurations.

The main functions of new ALADIN-LAEF surface assimilation building brick are following:

- Merging of the observations
- Observations pre-processing by *bator*
- CANARI surface assimilation

To create a surface assimilation cycle within the existing upper-air breeding-blending cycle, we decided for the following scheme – the breeding-canari-blending cycle (BCBC). The steps denoted by red color are completely new:



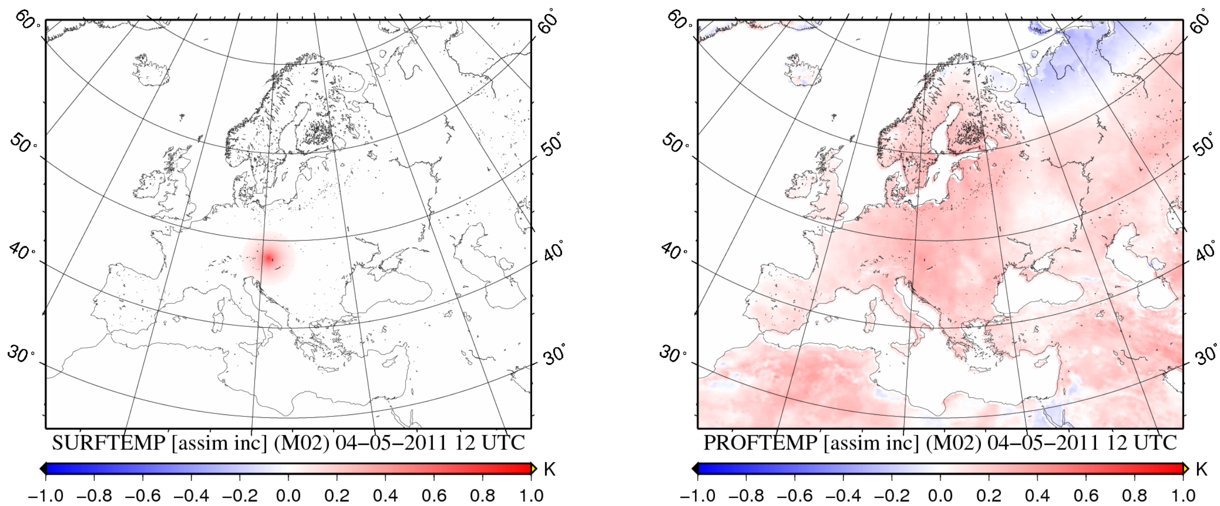
The above is the configuration used for the ALADIN-LAEF development at ZMAG. The operational ALADIN-LAEF configuration at ECMWF is slightly different. It is not using a separately running breeding-blending cycle (which is very useful in the development), but the guess used in the breeding perturbation procedure is taken directly from the +12h LAEF forecast. This means, that the breeding in the operational suite at ECMWF is reduced just to the steps [3] and [4]. After the implementation of new surface assimilation, the steps [5] and [6] will be mandatory as well (for breeding).

The new breeding-canari-blending cycle (BCBC) is capable to replace the actual non-cycled surface breeding (NCSB) which is now used to perturb the surface fields. The advantage of BCBC over NCSB method leans on the fact, that surface fields are in addition cycled and pushed towards the new observations. At the same time they are perturbed in the same way as for the NCSB – which is done by the interaction with perturbed atmospheric fields during the short 12h integration. (What is more, that separated 12h integration dependent on the actual ARPEGE analysis used for NCSB can be skipped afterwards, because instead the +12h LAEF guess will be used in BCBC with the similar physical effect.)

::III The first ALADIN-LAEF assimilation experiments

III.1 Single observation experiment

Single observation experiment is usually performed to verify the correct functionality of the assimilation procedure. It does exactly what it says – only a single observation is assimilated into the background model fields. For the verification of our surface assimilation procedure we chose the measurement of Vienna SYNOP station (11035, Hohe Warte) valid at 04-05-2011 12 UTC. The model background (the guess) used in this experiment came from 12h breeding integration started at 04-05-2011 00 UTC.

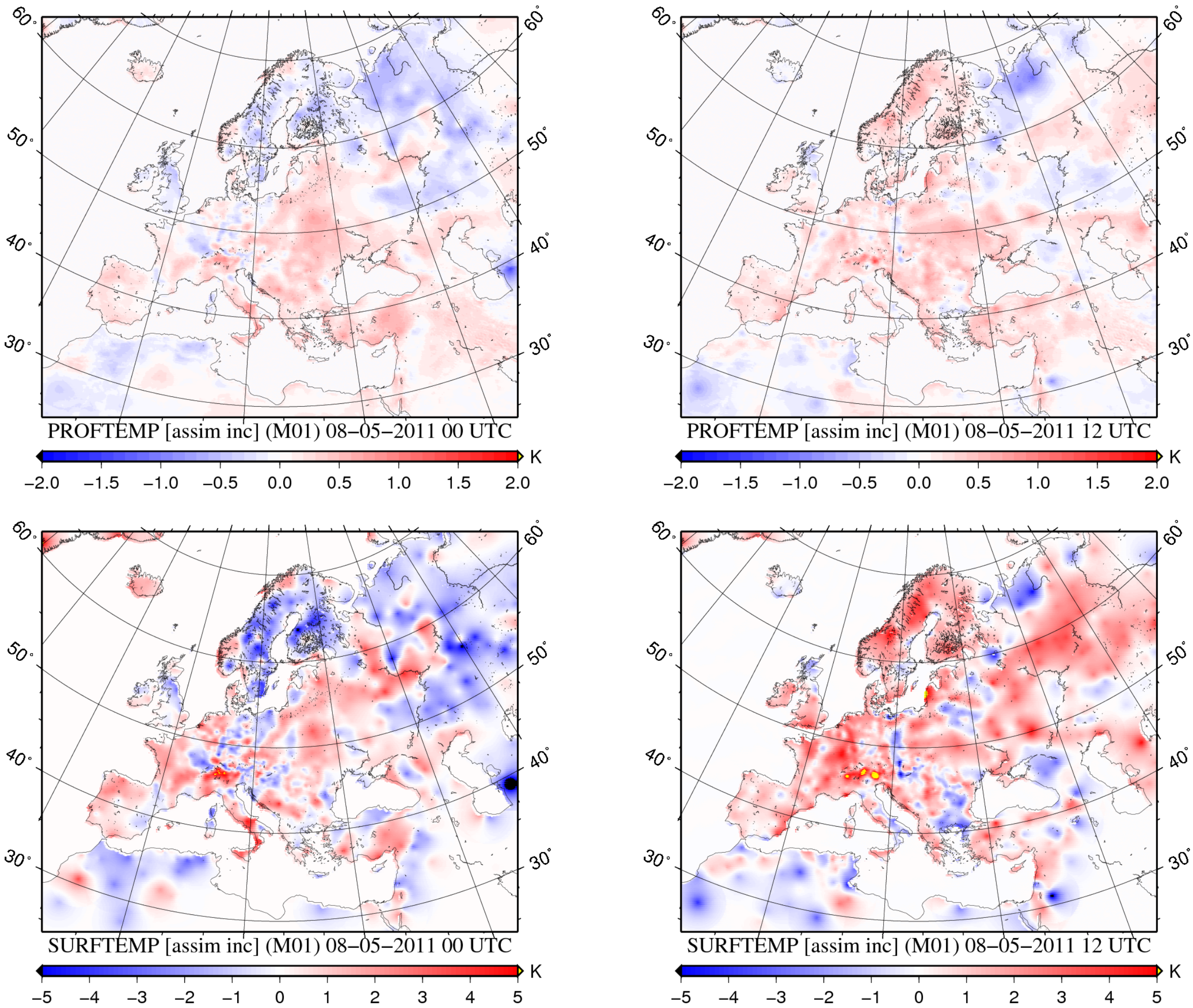


::Fig.3 Assimilated surface temperature field (left) is affected by the point observation from Vienna station exactly as we have expected. Assimilated deep-soil temperature (right) is affected not only by the one observation but there is some relaxation towards the climatology as well (which is perfectly OK, since it was set in the namelist).

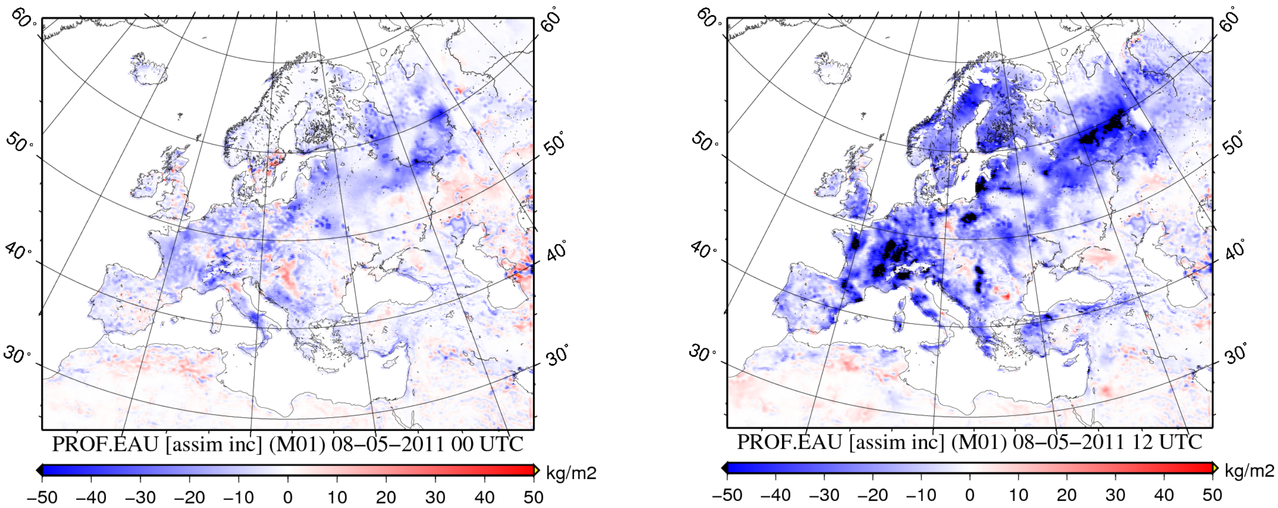
III.2 Full assimilation experiment

In the next experiment we were running full breeding-canari-blending Cycle (BCBC) for several consecutive days using the all available SYNOP observations from OPLACE archive and also the data from local Austrian automatic stations (altogether about 2500 measurements per run). The cycle was initialized by the ECMWF analysis valid at 06-05-2011 00 UTC. We ran the cycle till 10-05-2011 12 UTC and only for two ensemble members (to save the computer CPU, time necessary for fetching the boundary conditions from ECMWF and also the large amount of disk-space :). Two members are the minimum possible set, because breeding works with ensemble pairs. Anyhow, for showing technically the functionality of this perturbation/assimilation cycle and also its basic features – two members are absolutely enough. The results are presented on the following plots.

The assimilation increments from BCBC show the effect of surface assimilation procedure on the surface initial-conditions used in the ALADIN-LAEF system.

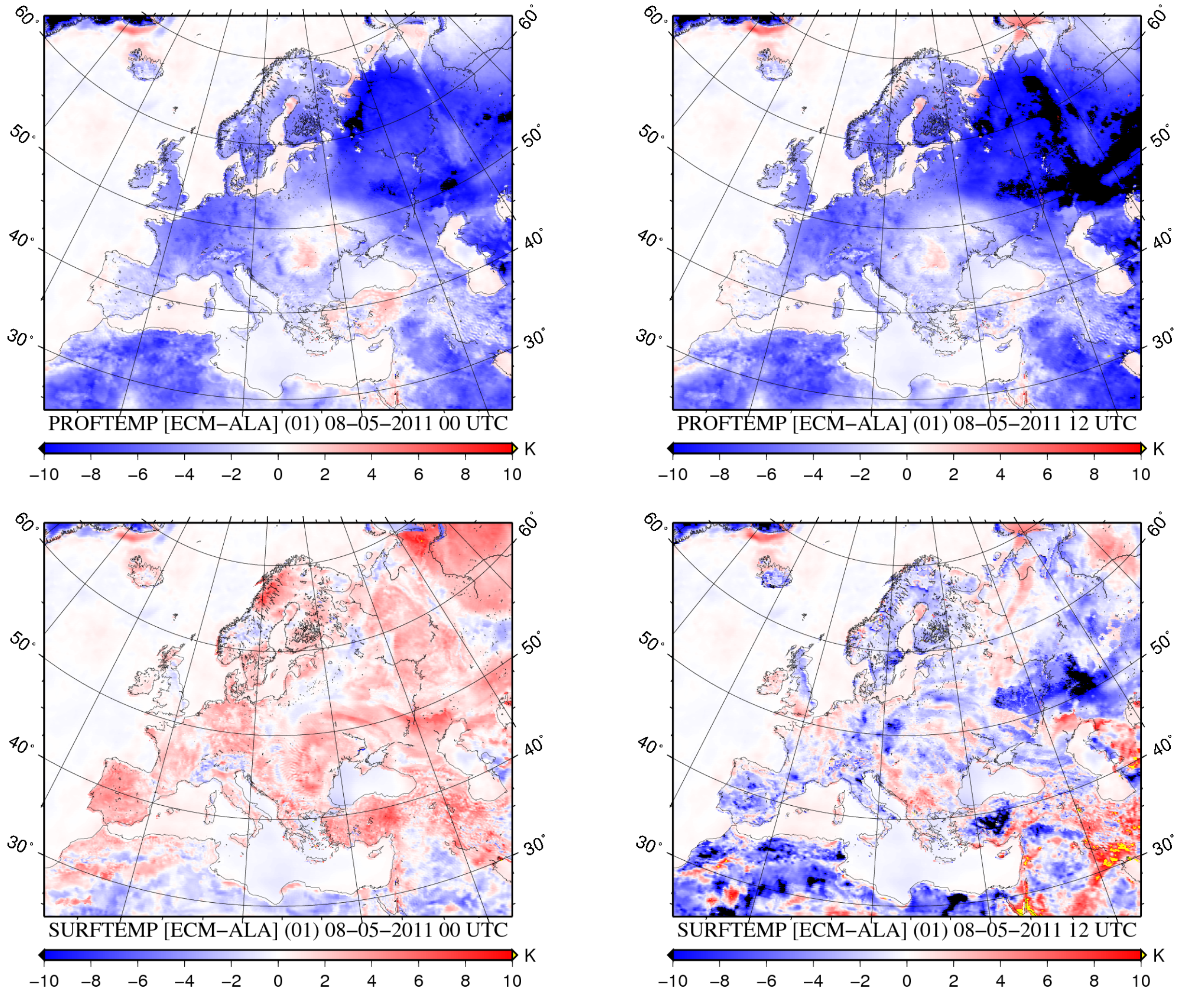


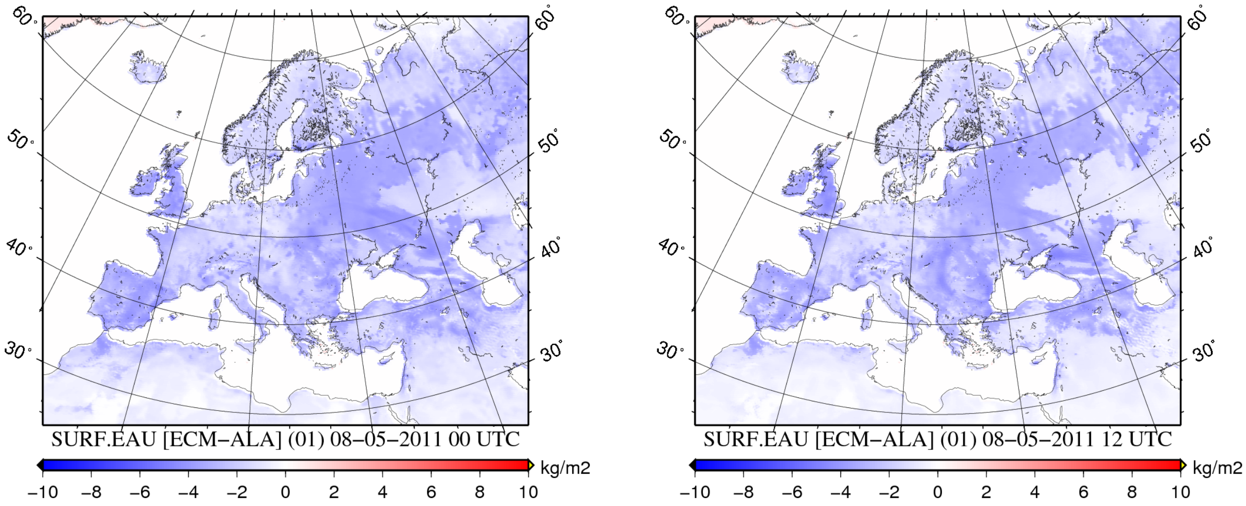
::Fig.4 Assimilation increments for deep-soil temperature at 00 and 12 UTC (up) and for surface temperature at 00 and 12 UTC (bottom).



::Fig.5 Assimilation increments for deep-soil moisture at 00 and 12 UTC.

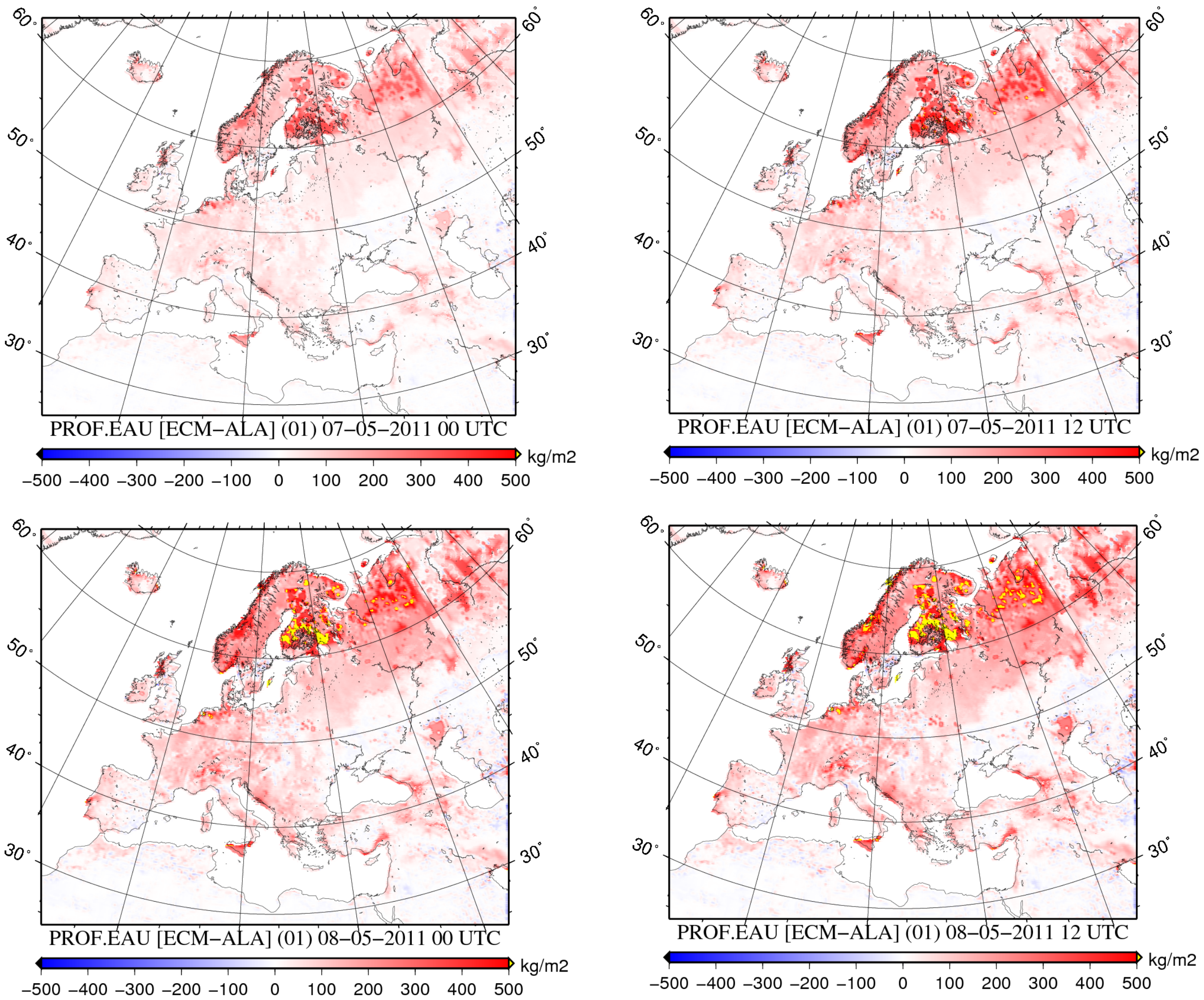
The differences between surface initial-conditions generated by the breeding-canari-blending cycle in ALADIN-LAEF system and the corresponding ECMWF fields demonstrate how the "original" ECMWF surface and soil fields are modified in order to reduce the temperature cold bias and deep-soil moisture.

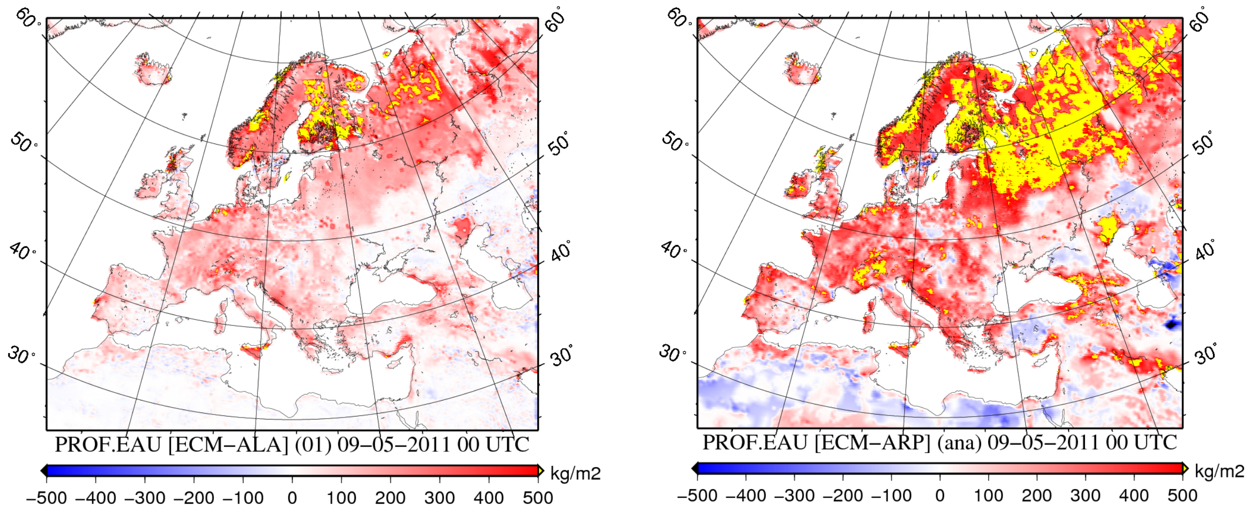




::Fig.6 Differences between initial ECMWF and ALADIN-LAEF fields for deep-soil temperature at 00 and 12 UTC (up), for surface temperature at 00 and 12 UTC (middle) and for surface moisture at 00 and 12 UTC (bottom).

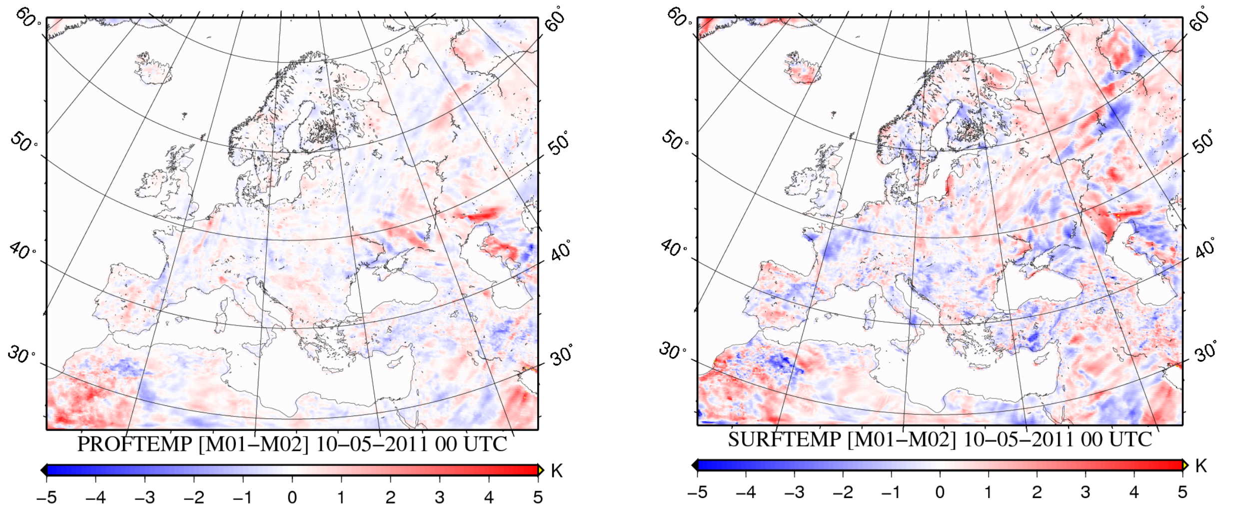
Convergence to the "ALADIN surface" due to the surface assimilation cycle in ALADIN-LAEF coupled by ECMWF EPS can be demonstrated with the time evolution of deep-soil moisture within the BCBC loop.



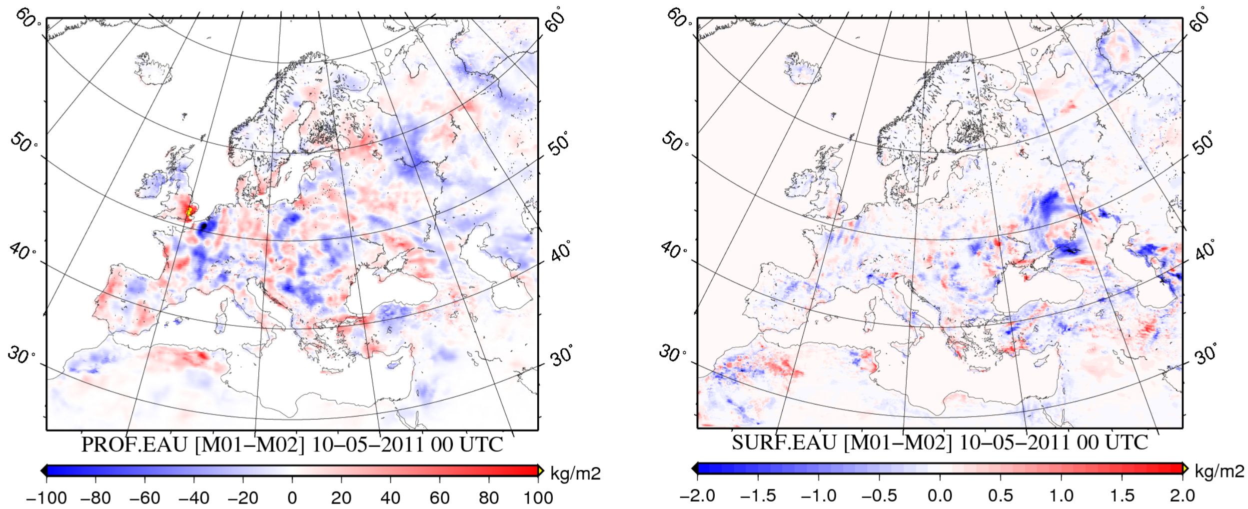


::Fig.7 Time evolution of the deep-soil moisture differences between ECMWF and ALADIN-LAEF from the beginning of the assimilation cycle up to 5 loops (from upper left to the bottom) in comparison with the same difference but between the ECMWF and ARPEGE analyses representing the real discrepancy between the two model surfaces (bottom right).

Finally, to show the potential spread (at least partially) of initial-time perturbation for surface and soil fields generated by new breeding-canari-blending cycle in ALADIN-LAEF system, the following maps present the difference between the two ensemble members (that's why it is not representing the spread of full ensemble which consists of 16 members).



::Fig.8 Uncertainty of surface initial conditions computed as a difference between two ensemble members for deep-soil temperature (left) and surface temperature (right).



::Fig.9 Uncertainty of surface initial conditions computed as a difference between two ensemble members for deep-soil moisture (left) and surface moisture (right).

The observed initial-time perturbation of surface and soil fields is evoked by the fact that the fields are integrated for 12 hours under the ECMWF EPS coupling. This is very similar to the NCSB approach, but instead of using always a fresh ARPEGE analysis the fields are initialized by the breeding-canari-blending cycle. The surface assimilation is mandatory here, because it ensures the consistency of surface fields with the actual observations. The biggest advantage of BCBC is that the ensemble spread of surface fields is not re-set to zero at the beginning of each forecast.

::IV Important technical notes

SW changelog (modifications, upgrades, bug-fixing):

Breeding:

- *breed.pl* (main application script)
  - added cycling of SURFEX prognostic fields (*)
- *Pptbini.F90*, *Nptbini.F90* (upper-air perturbations)
  - read input file date (KDATEF) and write it to the output FA-file header (**)
  - alpha coefficient in vertical scale profile is now function of NFLEVG (***)
  - model level corresponding to 850 hPa was changed according new A, B
- *ptbPSini.F90*
  - corrected allocation for the array storing the scaling factor (was crashing on IBM architecture)

Blending:

- *blend.pl* (main application script)
  - namelist modified according to the new domain with 45 vertical levels

Canari:

- *canari.pl* (main application script)
  - new "LAEF brick" to perform the surface assimilation
  - new script for merging the OBSOULS (filtration of duplicated records)

(*) For correct and safe cycling of surface and soil prognostic fields in ALADIN-LAEF system the following conditions are mandatory:

- All the SURFEX prognostic fields must be copied from 12h breeding integration (or 12h LAEF forecast) into the FA files after the breeding perturbation is performed by *Pptbini*, *Nptbini* and *ptbPSini* programs (otherwise just the surface fields from the actual ECMWF analysis will be used). This is done using the ALADIN *blendsur* tool (in *breed* application on NEC two additional steps [5] and [6] are added to do this job via Perl *exsurf* subroutine).
- It is necessary to select the option "*keep the surface from breeding member*" in the last blending step [8]. Originally the option "*keep the surface from ECMWF member*" was chosen to avoid drifting of surface fields far from the model climatology. By implementing the surface assimilation into the ALADIN-LAEF system this is not any more the case and cycling of the surface fields is desirable.
- New surface assimilation by CANARI must be enabled via BCBC in ALADIN-LAEF system. This kind of cycle (BCBC) then works as a surface and soil perturbation tool while pushing the fields towards the actual observations in every loop.

(**) It is necessary to have a background guess for CANARI surface assimilation which is the forecast and not the analysis. The perturbation programs originally modify the 3D-fields just inside the ECMWF input file (which is the actual analysis). That's why the CANARI configuration was crashing in the code in subroutine *cacsts* (while there is no real reason for that, just the definition of base and validity date in FA-file header and how it is used in that subroutine). To solve this problem, we modified the perturbation programs *Pptbini* and *Nptbini* to keep the base and validity date information from the input files (+12h breeding integration or +12h ALADIN-LAEF forecast).

(***) Now the formula for computation of the vertical profile of scaling factor need not to be retuned in case of changed number of model vertical levels. However, if some different scaling strength is required, there is still β coefficient to play with (it prescribes the minimum scaling factor at the model top).

::Conclusion

During this stay (my first on the ALADIN-LAEF surface assimilation subject) mostly the technical work was done and the new perturbation/assimilation cycle for ALADIN-LAEF system was designed.

A new Perl script for merging the observations was created in order to carry out some sophisticated filtration of duplicated station records. There were usually about 5 hundred duplicated records for given date within common OPLACE archive and the local observation database. The problem could arise later in the assimilation procedure due to the fact that most of the duplicated records were referred to a slightly different lat/lon positions (un-consistent station meta-data used). To prevent this and to disburden CANARI from a possible useless CPU burning, we implemented the filtration based on the measurement type. At the same time we also discovered, that in OPLACE obsouls there were duplicated station-IDs corresponding to some stations within LACE domain but at the same time to some local Hungarian stations too. This was soon fixed by Hungarian team giving their local automatic stations the prefix "HU".

The Fortran programs for breeding perturbation and rescaling were modified in order to pass the input file date (KDATEF) into the output file. This was necessary because originally the output FA file inherited the date of used analysis which was not accepted by the ALADIN configuration 701 (CANARI). The output FA file header is perfectly consistent, since the data validity time is unchanged and the base time corresponds to the source of LAM perturbation from the breeding integration.

The breeding application was updated with the new feature. It is now possible to “copy” selected surface and deep-soil fields from the end of breeding integration into the output file. The output file normally consists of LAM perturbed and rescaled upper-air fields and of the global model unperturbed surface. The new feature enables perturbed LAM surface and soil fields to be further used as the input into the surface assimilation procedure, LAEF forecast and next perturbation/assimilation cycle.

Most importantly, the surface assimilation LAEF building brick was created. It is a Perl script application (similar to the breeding and blending one) which enables the implementation of surface and soil-fields assimilation within the breeding-blending cycle. The proposed breeding-canari-blending cycle (BCBC) does both upper-air (T, u, v, q) and surface (deep-soil and surface temperature) fields perturbations. The necessary relaxation towards the actual atmospheric state and climatology is ensured by the upper-air spectral blending with the analysed ECMWF 3D-fields and by the surface assimilation process.

The first results from the ALADIN-LAEF perturbation/assimilation cycle (BCBC) are very promising. It is indeed the way how to reduce unwanted system bias, which comes from the discrepancy between ALADIN and ECMWF surface parameterizations. Furthermore, it can be used as a favourable tool for a LAM surface-fields perturbation. This perturbation is done via 12h model integration coupled with ECMWF EPS boundary conditions. Another possibility for perturbing the surface and soil fields even further requires for example some randomly modified observations on input. This option will be tested probably in the near future.

When the present determines the future BUT the approximate
present does not approximately determine the future.
(Lorenz about the Chaos)

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