The joint HIRLAM All Staff Meeting 2012 and ALADIN 22st Workshop took place in Marrakech from May 7th till 10th 2012.
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Annex A Programme and participant list of the ASM 2012/ALADIN 22th Wk
Introduction

Tilly Driesenaar

This Newsletter is devoted to presentations made by HIRLAM staff in the joint HIRLAM/ALADIN Workshop/All Staff Meeting (ASM) that was held on 7-10 May 2012 in Marrakech, hosted by the Moroccan Meteorological Service (DMN). We thank the staff of DMN for providing such wonderful meeting facilities in the fairy-tale environment of Marrakech.

I'm sure no-one will forget the hospitality of the Moroccan host, in the glamorous environment of the Palais the Congres with on the background the mannequins preparing for the big Marrakech fashion event Kaftan 2012. Also the inspiring speeches of the director of DMN, Mr. Abdellah Mokssit, made a deep impression. For the participants from most HIRLAM countries Marrakech provided experiences with a very different culture. We had to learn how to bargain the price for the taxi rides and souvenirs and how to cross the crowded streets without traffic lights. And the image of Aladin with his girlfriend Hirlam next to him flying over the desert on his carpet at the end of the conference diner is certainly a beautiful view to keep in mind.

As has become usual the last few meetings the scientific part of the programme took place in fully plenary sessions. After a warm welcome by Mr. Mokssit, there was a short opening session on Tuesday morning, in which overviews were given of the progress and status of the ALADIN, HIRLAM, LACE programmes. This was followed by five thematic sessions, on data assimilation and use of observations, probabilistic forecasting and LAMEPS, dynamics, model physics, dynamics, and system aspects and verification. The programme is listed in Appendix A and the presentations can be found at http://www.hirlam.org and http://www.cnrm.meteo.fr/aladin. The number of HIRLAM contributions from the meeting for this newsletter is relatively small, because many results are being published in literature. This trend is visible in the last years and is of course a very good development.

The newsletter also contains a number of contributions which are not related to the ASM. The first one is an article by Nils Gustafsson and Sigurdur Thorsteinsson about a comparison study between HIRLAM 7.2 and HIRLAM 7.4 within the EUCOS experimentation framework. The article of Magnus Lindskog et.al. describes the improvements of the handling of ATOVS processing and usage in the HARMONIE reference system. Xiaohua Yang contributed with two articles. One about a new cycling strategy using different base times than the synoptic times we're used to, in order to find a way to deliver experimental HARMONIE forecasts earlier than is often the case now due to limited computing capacity. The other article contains a report about the consortium wide concerted work that was done on the technical and meteorological evaluation during the pre-release of HARMONIE 37h1. The newsletter is concluded by the customary overview of the status of, and plans for, the HIRLAM and HARMONIE reference Systems by Ulf Andrae.

Enjoy!

Tilly Driesenaar
Scientific secretary HIRLAM-B
Using $J_k$ In AROME 3DVAR
Some Initial Tests

Per Dahlgren

1 Introduction

$J_k$ refers to the method of adding an extra source of information to a limited area variational data-assimilation system containing the large scales from the host model that provides lateral boundaries. In HARMONIE, $J_k$ was first implemented and tested in ALADIN, (Guidard and Fischer, 2008), but here it has been activated in an AROME setup with 2.5 km horizontal resolution.

The experiments presented here were made within the MetCoOp project which aims at preparing operational joint NWP production between SMHI (Sweden) and met.no (Norway). At the beginning of the project it was decided that the focus should be on the HARMONIE system on the 2km horizontal scale with AROME. One of the many tasks is to choose which method of blending\(^1\) to use. There are two options for this that will be compared, one is $J_k$ and the other is called LSMIXBC. The LSMIXBC method combines the large scale spectral components from the host model with the short scale spectral components from the regional model, producing a modified first guess for the upper air analysis. The experiments presented here are an excerpt from the work on activating $J_k$ in AROME with ECMWF as the lateral boundary model.

This text will first present the formulation of $J_k$ in HARMONIE and describe how the code was modified to make it work with AROME. Then a section on the calculation of error covariances from ECMWF data will follow. Thereafter, the behavior of the data assimilation system with $J_k$ activated for some cases will be presented. This part will focus on the analysis fit towards the host model large scales in $J_k$ versus the fit towards observations. Also, the increments produced by $J_k$ and so called wrap around effects will be investigated.

2 $J_k$ In HARMONIE

The model state vector in HARMONIE, here denoted $x$, is:

$$
x = \begin{pmatrix} 
\zeta \\
\eta \\
T \\
q \\
\ln(p_s)
\end{pmatrix}
$$

where $\zeta$=vorticity, $\eta$=divergence, $T$=temperature, $q$=specific humidity and $p_s$=surface pressure. If the host model information vector is denoted $x_{ls}$, then $J_k$, an extra term in the cost-function that measure the distance between the model state and the host model, can be written:

\(^1\)The word blending in this text refers to the general problem of mixing the large scale information of the host model into a limited area NWP.
\[ J(x) = J_b + J_o + \left( x - x_{ls} \right)^T V^{-1} (x - x_{ls}) \] (2)

\( V \) is a matrix with the error covariances of the host model, \( x_{ls} \). In HARMONIE, \( V \) is considered diagonal and contains the error variances of the host model calculated in the regional model geometry.

In ALADIN, where \( J_k \) was first used, (Guidard and Fischer, 2008), all model-state variables are in spectral space while \( q \) is in grid-point space in AROME. This means that some code modifications were necessary to be able to use \( J_k \) in AROME. For simplicity, the parts of the \( J_k \) code that handles specific humidity were commented out, thus disabling the usage of \( q \) in \( J_k \). This may also be justified by assuming that specific humidity is probably not the most important descriptor of the large scale flow compared to vorticity and divergence.

3 Error Covariances

The domain on which these experiments were conducted was the first setup within the MetCoOp project for the very first, mainly technical, tests. It has 540 grid-points in the zonal direction, 900 in the meridional and 65 vertical levels. The distance between grid-points is 2.5km. To be able to use \( J_k \), the covariances in the \( V \) matrix (equation 2) need to be calculated. ECMWF is used at the boundaries and therefore the ECMWF error-covariances need to be calculated over the domain shown in figure 1. This is done in three steps:

1. Extract +24h and +48h ECMWF forecasts, valid at the same time, from the MARS archive at ECMWF. Use the HARMONIE system boundary interpolation routines to interpolate these fields to the domain in figure 1. The ECMWF fields are interpolated to the AROME domain, but the original horizontal resolution, 16km, is maintained.

2. Calculate the differences between the interpolated +24h and +48h fields. The HARMONIE master binary, MASTERODB, is used for this with the namelist setting LFEMARSD=.true. The FEMARS option did not work with the HARMONIE code version used, so modifications to primarily the cnt3.F90 routine were needed, provided by KNMI. On top of that, the code needed some changes to prevent it from trying to read a number of fields not present (and not needed) in the interpolated ECMWF data-files.

3. The difference-files can then be used by the same program that calculates the background error covariances, festat. Since only the error variances are needed, the calculation of the statistical balance regressions can be switched off by setting LSTABAL=.false.

ECMWF data was extracted for 8 weeks spread out over the year, 2 weeks in January 2011, 2 weeks in April, July and October respectively.

An example of the outcome from festat is shown in figure 2. It shows the variance spectrum for vorticity on 6 different vertical levels compared to the background errors of AROME used in the \( J_b \)-term. The difference in resolution makes AROME resolve scales to wave-number 449 while the ECMWF data resolves scales to wave-number 79. Also, especially on the vertical levels 50 and 60, AROME has a lot of activity on scales not resolved by ECMWF. This plot is also helpful to determine which scales to use in \( J_k \), i.e. where to truncate the large-scale data.
Figure 1: The domain used in these experiments

Figure 2: Variance spectrum for Vorticity. Solid line is ECMWF ($J_k$) and dotted line is the AROME background errors
3.1 Truncation Of The Large Scale Data

Figure 3 shows vertical level 30 magnified for wave-numbers up to 80 on the x-axis. The background and large-scale errors are of the same order of magnitude up to wave-number 20, thereafter the large-scale errors decrease rapidly and they differ by several orders of magnitude. In the experiments shown in this report, the $J_k$-data was truncated at wave-number 20. This ensures that the errors $J_b$ and $J_k$ are of the same order of magnitude which will make it easier to tune the weight of the $J_k$-term.

![Vorticity variance at level 30](image)

Figure 3: Variance spectrum for Vorticity at model level 30. Solid line is ECMWF ($J_k$) and dotted line is the AROME background errors

4 Experiment 1: Minimization and Observation fit

In this first experiment, $J_k$ is activated in 3DVAR and the behavior of the minimization studied. Only conventional observations were used in the analysis, i.e. SYNOP, SHIP, BUOY, TEMP, PILOT and AIRCRAFT. The weight of the $J_k$-term is adjusted by applying a scaling to the ECMWF variances. Each variable has its own scaling factor, and the variables active in $J_k$ is vorticity, divergence, temperature and surface pressure, not specific humidity due to reasons explained in section 2.

First, an analysis was calculated with $J_k$ switched off and the observation term $J_o$ is plotted as the red line in left hand plot in figure 4. $J_o$ measure the distance between observations and the model state and thus describes the analysis observation fit. The observation term minimize smoothly and converges in 52 iterations. Next, $J_k$ is activated with a low impact (high error) and the $J_o$ term for this case is shown as the black curve in the left hand plot in figure 4. Now the $J_o$ term minimizes smoothly, but it takes 61 iterations to converge. The final value of the $J_o$-term is almost the same as in the former case, the red curve. This means that we have activated $J_k$ without losing observation fit. It has been checked that the same number of observations are used in all the cases. Finally, $J_k$ is activated with a high impact (low error), the blue curve in left hand plot in figure 4. The $J_k$-value for the same case is plotted in the right hand plot. Now the $J_o$ term minimizes, but with a lot more spikes which could mean that it is now a bit more problematic for the minimization method to handle all the information. The final value of the $J_o$-term is also higher which means that we have lost observation fit. The right hand plot of figure 4 shows that the $J_k$ term converges smoothly, and quite fast.
Figure 4: Cost-function values during the minimization for some cases. Left plot, red curve: The observation term $J_o$, when $J_k$ is not used. Left plot, black curve: Behavior of $J_o$, when $J_k$ is active, but with low impact (high error). Left plot, blue curve: Behavior of $J_o$ when $J_k$ is active with high impact (low error). Right plot: minimization of the $J_k$-term.

5 Experiment 2: Increments and Wrap-around Effects

In this experiment, an analysis was performed with $J_k$ active and all upper air observations switched off, keeping only the SYNOPs. The increments in the upper atmosphere can then be assumed to come from $J_k$. Figure 5 shows synoptic scale and smooth temperature increments at model level 5, which is what we would expect. At the same time, the increments near the lateral boundaries are clearly reflected over to the other side which is called wrap-around effects.

![Temperature increments at model level 5 when $J_k$ is active and only SYNOP observations used. These increments can then be assumed to come from $J_k$ only.]

The next step is to test how the wrap-around effects can be remedied. To do that, a rather crude experiment was made: Zero out the $J_k$ information in a zone between the lateral boundaries and 100 grid-points into the domain. If the large-scale field is denoted $x_{ls}$ and the LAM model background $x_b$, the $J_k$ information vector
is \((x_{ls} - x_b)\). Setting the \(J_k\) information to zero thus means to set \((x_{ls} - x_b)\) to zero. Since the information vector in the analysis is in spectral space, we need to transform the fields to grid-point space, zero out the information at the selected points, and then transform back to spectral space. Figure 6 shows the zone were the information is put to zero and it is quite large, but this is just a test and the width of the zone will have to be investigated further if this method is to be used in forecast performance experiments. Now we perform a new analysis and look at the temperature increments at model level 5, shown in figure 7. The wrap-around effects are gone so the method seems to work.

**Figure 6:** The \(J_k\) information was set to zero in the zone between the inner and outer rectangles.

**Figure 7:** Temperature increments at model level 5 when \(J_k\) is active and set to zero in the zone showed in figure 6
6 Summary

The $J_k$-feature in the HARMONIE system has been activated in an AROME setup with 3DVAR. Error covariances of the ECMWF model in the AROME geometry were calculated with the same software used for the background errors, \textit{festat} and the statistics were based on the NMC-method, i.e. differences between +24h and +48h forecasts valid at the same time.

To be able to use $J_k$ in AROME, the $J_k$ code that handles specific humidity was commented out because it is stored in grid-point space, while the $J_k$ code assumes all variables are in spectral space. With $J_k$ activated, some minimizations were carried out to highlight the tuning problem of losing observation fit if we draw too much to the large scales in $J_k$.

Thereafter the temperature increments at model level 5 were studied and there turned out to be a lot of wrap-around problems associated with the $J_k$ increments. Setting the $J_k$ information to zero near the boundaries turned out to be a possible remedy for this.

References

Assimilation of Radar Reflectivity Data using the Field Alignment Technique

Carlos Geijo, AEMET.

1 Summary

Radar reflectivity images offer a good opportunity to test the Field Alignment (FA) technique for correction of position errors (Ravela et al. 2007). This method was already tested with model fields used as pseudo-observations in a previous work with encouraging results (Geijo, 2011). The question of how the FA technique performs with real data remained however open. In this communication, reflectivity data from one C-radar of the AEMET radar network have been employed successfully to correct position errors of rain structures in HARMONIE-AROME short-range mesoscale forecasts, within a circular domain of 240 Km in diameter around the radar site.

The impact of this correction on the 3D-Var analyses and on the subsequent short-range forecasts has been determined using radar reflectivity images as verification data together with a cluster based verification method that provides a straightforward and objective measure of the difference in location between radar echoes and model rain structures. The experiments presented in this communication, where only radar data (Z, DOW) were assimilated, have comprised two different strategies for assimilating the reflectivity data. The reason for these several essays lies in the rather involved problem of the assimilation of this kind of data. Precipitating hydrometeors, responsible for the signal detected by the radar, are not included in the set of analysed variables in the current HARMONIE-AROME 3D-Var scheme. Moreover, the connection between these Z observations and the analysis variables (i.e., air humidity) is only very indirect. Using a Bayesian approach, Caumont et al. (2010) have overcome these difficulties by developing an algorithm that infers air humidity content from the Z observations. The method retrieves relative humidity pseudo-observations by sampling the model fields of Z and rh in the vicinity of each radar bin entering in the analysis.

The first strategy tested comes from the observation that, by correcting the phase errors of Z and rh model fields coherently during the alignment process, the FA technique can also generate rh pseudo-observations, and one may also expect better results because of the removal of the locality constraint in the method developed by Caumont et al. (2010). The other alternative, more in the spirit of the FA method, is to align the Z and rh fields as a previous step to the assimilation with the Bayesian algorithm.

The results obtained from a winter in-land rainy episode about 30 hours long, with an analysis cycle of 3 hours, allow us to draw some conclusions, but always keeping in mind the need for further experimentation. First, it is confirmed that the assimilation of radar data (Z and DOW) improves the quality of the forecasts. The novelty of this conclusion is maybe in the employment of the location verification method and the use of radar data as verification data. Second, this improvement is limited to the first few hours of the forecast. Here some comments are necessary: the experiments were carried out in “broken-loop” configuration (no feedback from previous analyses), the initialization of the hydrometeor fields is still not well understood and these fields show very little sensitivity to the initial conditions, and only the two lowest elevations of the radar polar volume were utilized in this work. In the third place, of the two strategies tried for the assimilation of Z data, the one using FA as a previous step to the Bayessian 1D-Var method gives better results than that in which the latter method is bypassed completely. This conclusion cannot be considered firm either because the rh pseudo-
observations obtained from the alignment were not presented to the analysis via ODB, which would have meant a cleaner comparison, but used instead to generate (T, q) increments passed over directly to the initial conditions via field blending. In these experiments the FA+1D-Var method gives neutral to slightly positive impact with respect to the experiment where only the Bayesian 1D-Var method is employed.

2 Description of the Experiments

2.1 Radar Data

The radar data used in this work comes from an AEMET network C–band radar situated near to Madrid (3.713W, 40.177N; emitter altitude 717m a.m.s.l). Between November 4th 11 UTC and 5th 20 UTC several rain bands associated to an average winter frontal instability crossed the radar domain from West to East. At that time the radar was operated with a 10-minutes cycle producing polar volumes with 21 elevations. Thirteen of these elevations were produced in dual-PRF (1200Hz-900Hz) short-pulse (0.5 μs) mode. This configuration allows the generation of Doppler radial winds (DOW, ambiguity threshold around 45 m/s) as well as reflectivity (Z) observations. These elevations go from 7 degrees up to 23 degrees over the horizontal as the radar antenna elevation increases and then two last elevations at 1.4 and 0.5 degrees when the radar antenna descends to return to the scanning cycle initial position. In this study only these two last elevations have been used because for more slant beams the horizontal range within the Troposphere is short (these other elevations are mainly intended for deep convection situations and VAD retrievals) and because the coordinates employed have been the original radar polar coordinates. Had been used rectangular coordinates instead, these vertical elevations would have been useful to interpolate in the shorter ranges. The maximum range for the data considered here is 120 Km with a resolution of 0.5 Km (240 range bins per ray) and an angular resolution of 0.8 degrees (450 rays per scan).

The radar data processor (IRIS RVP8) carries out a series of quality control checks that remove data with low S/N ratios and, by using spectral methods, also filter out ground echoes. These QC checks require thresholds that are calibrated manually by radar experts. Visual inspection of much of the data used in this work did not indicate any serious problem with the quality of the data. Radar calibration parameters were useful to determine the “threshold of detection curves” as functions of distance to the radar. These curves are a convenient way of filling in “Z data gaps”, or more precisely, to create continuous reflectivity fields comprising both, areas with precipitation and areas without precipitation. The availability of these continuous fields is a big advantage to the application of the FA method.

Last but not least, the necessary format conversions were handled with an “α version” of the CONRAD package, developed at met.no (Norway). This package is useful for the homogenization in the radar data pre-processing from local formats to the ODB required format.
2.2 Alignment of Model Fields

Geometry transformations and interpolations play an important role in the application of this FA technique. We decided to work on the radar slant beam cones, but at model spatial resolution, because in this way the alignment process is simpler if only two elevations are considered. With this limited number of elevations, projection onto model coordinates or horizontal planes make the numerical treatment more complicated. The operator to transform between model and radar geometry is constructed from a gaussian antenna pattern with a 3dBZ aperture of 0.9 degrees. A 4/3 effective radius approximation is used to navigate the data. The reflectivity simulator to compute the model pseudo-images is the one integrated in HARMONIE-AROME (Caumont et al, 2006).

The alignment equation is then solved for each elevation. The algorithm employed (Geijo, 2011) diagonalizes the equation by transforming to k-space. However, this alone is not enough because the
Figure 2: The deformation fields obtained from the alignment of the reflectivity data are used to rearrange spatially in a coherent way with this alignment other parameters like hydro species concentration (upper row) and relative humidity (middle row). These plots display the initial situation on the left and the final situation on the right. The lower row shows the initial and final 2D-histograms for the \((Z, rh)\) data, with \(Z\) on the y-axis and \(rh\) on the x-axis. See text for more details.

The set of resulting equations is not invertible for all \(k\) and the harmonic eigenvectors do not satisfy the required boundary conditions. Both difficulties are overcome by working in a \(2^2\) extended domain. Another problem is that this algorithm utilizes rectangular coordinates and therefore some adaptation
is necessary for the polar geometry used in this work. A convenient solution is found by means of a ring-shaped transition zone where the radar images splice smoothly together with the model fields. Beyond this ring the radar data is taken equal to the model fields and therefore easily continued until an outer rectangular frame. Also, it is found that the process performs better if the reflectivity data is previously filtered to remove very small scale structures, as was done also in Geijo (2011).

Figures 1b, 1c and 1d show a typical example of how the method performs. The top right figure (1b) shows a pseudo reflectivity image after the filtering just mentioned. It corresponds to a 3-hour forecast valid for 4 November 21 UTC. The square is 128 model points wide (about 320 Km) and the elevation is 1.4 degrees above the horizontal. This elevation corresponds to the upper beam depicted in blue on figure 1a (top left). Actually, the radar beam does not reach so far as displayed on this figure; the maximum range falls approximately on the point 112 on the x-axis. The prolongation is necessary for the treatment of the boundary conditions also just described. The bottom left figure (1c) shows the real reflectivity data for the same time. The scattered structures closer to the borders (y-coordinate > 112 on top or x-coordinate < 16 on the left) are in reality features taken from the model fields but seamlessly integrated in the data following the procedure outlined above. The precipitation scenes from the model and from the radar differ clearly. The former is more compact and more intense, as in a more mature stage than that detected by the radar, which is relatively retarded (rain band motion from left to right) by about 30 Km. Also, one can distinguish on the radar image a weak pre-frontal instability area which is not present in the model forecast. The bottom right figure (1c) shows the result of the alignment. The FA algorithm has managed to deform the model field in such a way that it now reproduces quite well all the relevant features. It is clear that the method does not simply shift structures from one place to another; it can also smear out or enhance maxima or minima. We can also notice that the precipitation structures closer to the borders have not changed because the forcing over these areas has been kept small all along the alignment process.

Because of the geometry selected for this work, the displacements during the alignment process are not truly horizontal, in fact they can take place between vertical levels significantly different (figure 1a). This observation is relevant because the displacements are used to drag model fields of relative humidity and hydrometeors, parameters that do have a vertical variability structure that is not taken into account during the alignment. For instance, radar echoes from an upper level are produced mainly by hydrometeors in solid phase (graupel, snow), while those coming from lower levels are reflected back usually by liquid water. Consequently, after hydrometeors have been re-arranged spatially, a final redistribution in thermodynamical phases is still necessary. This is achieved in the following way. The relative amounts of the different hydro-species at each grid point are initially determined as function of (e, T) at that grid point. As expected, these two parameters allow to discriminate fairly well the hydrometeor type. When the alignment process of these \{q_i\} fields is finished, the relative amount among them is brought in agreement with the (e, T) values at the final position using these tables. For the relative humidity, we have to rely on the compensation effect of T and q both decreasing with height and expect that this compensation will decrease the error introduced by not accounting for this vertical variation effect.

Figure 2 shows the result of this dragging for the total amount of hydrometeors (upper row) and for the relative humidity (middle row) for the same case as in figure 1. The concentration of scatterers has been rearranged in a manner that is clearly consistent with the deformation of the reflectivity field: the main precipitation area is stretched in south-north direction and displaced backwards and another instability area is formed ahead of it. High concentrations responsible for the strong echoes to the north inside the radar domain are removed and those still further away in the buffer area are left untouched, as they should. For the relative humidity (lower row) the vertical variability effect mentioned above is apparent, but seems to be pronounced only in the outer part of the domain, outside of the area where the alignment takes place. The deformation of the relative humidity field also looks consistent with the deformation applied to the reflectivity field.
The lower row in figure 2 shows 2D histogram for Z and rh before the alignment (left) and after the alignment (right). Pixels in yellow or orange colours indicate pairs of Z and rh values that are the most frequent, while blue or purple colours correspond to the least frequent combinations of Z and rh values. One would expect that histograms of this kind before and after the alignment were similar if both fields Z and rh are rearranged spatially in a consistent way. It is clear that this is the case. Note in particular that over-saturated pixels (\(rh > 1\)) are preserved after the dragging. Some high reflectivity values have been “chopped off” and this is in agreement with what is shown in figure 1. Two main structures are visible in these histograms. The first, nearly horizontal and slightly sloping down from left to right, correspond to low reflectivity values and is the signature of the “threshold of detection curves” embedded in the radar images to get continuous fields, that is, most of these (Z,rh) pairs correspond to non-precipitating locations. The other prominent feature is a vertical cluster of points parallel and near to the saturation line. These correspond to precipitating locations. We see that the rh values in these cases are above 0.9 but also note that there are rh values below 0.9 and with high Z values, a situation that is also physically meaningful, precipitation falling through unsaturated air.

2.3 Specification of the Hydrological Initial Conditions

The assimilation of radar reflectivity data in the HARMONIE-AROME system (v36h1.4) (Caumont et al., 2010) is a rather complex procedure that comprises the generation of relative humidity pseudo-observations as a first step. As explained in the summary of this communication, the FA method can be utilized to generate these relative humidity pseudo-observations also, with the advantage of removing the locality constraint. In the example used to illustrate this communication, this can be achieved by simply taking the difference between the right and left fields shown on the middle row in figure 2. Some posterior QC may be necessary at this point. It was found that the joint analysis of rh and Z increments at a given location usually allows to identify easily the wrong cases.

The straightest way of using these rh pseudo-observations would be to present them to the 3D-Var analysis via the ODB database. However, due to technical reasons, this was not done in this work. Instead a more winding route had to be taken. The rh increments at each grid point were first converted to (T, q) increments by using the rh observation adjoint operator, also available in the HARMONIE-AROME system.

Together with the aligned hydro-species fields \(\{q_i\}\) we have now finally a set of position error corrected fields \((T, q, \{q_i\})\) that can be used to specify the initial conditions for a forecast run in two different ways: a) directly start a forecast run from them; b) input these fields in the 3D-Var analysis. Note that the conversion from rh increments to \((T, q)\) increments mentioned above is also necessary in this second assimilation alternative. By construction, the 1D+3D-Var Bayesian approach computes the rh fields from other model fields as a previous step to the generation of the rh pseudo-observations, it does not search on the list of available fields in the input files for the rh parameter. For the same reason, it also computes the Z field from the \(\{q_i\}\) fields available in the guess. Therefore one has to expect some differences between the aligned Z field and the Z field actually used for the retrieval of rh pseudo-observations. This “b” alternative looks more promising not only because it is more faithful to the spirit of the FA technique, which relies on conventional methods for assimilating the amplitude component of the increment, but also because it will filter out noise introduced by all the previous processing, and because it will in general return better balanced initial conditions. This expectation is confirmed by the results presented in section 2.6.

2.4 Experiments Settings

In order to have a first test on the performance of these ideas several experiments were conducted. The period chosen was between 4 November 12 UTC and 5 November 18 UTC with a +18H forecast
every 3 hours. The experiments were run in non-cycling mode, that is, all the necessary guess fields for each cycle were taken from downscaled ECMWF fields with the exception of the \( \{q_i\} \) fields which were provided by +3H forecast from the control run for all the experiments (and for the own control run). This setting aims at isolating as much as possible the impact on the results of the different data assimilation methods tested in this exercise. For the same reason, only radar data (Z and DOW) were utilized, and as explained above, just one radar site was considered. The assimilation of DOW data \textit{in all experiments} follows the procedure described in Thibaut and Faccani (2009).

The \textbf{control run (CNTL)} initial conditions are simply a downscaling from ECMWF forecasts plus “the blending” of the +3H \( \{q_i\} \) from the previous CNTL cycle. All the experiments were performed with HARMONIEv36h1.4 at 2.5Km and 60L resolution. CNTL includes one more forecast with initial time 4\(^{th}\) November 09 UTC which provides 3H spun-up \( \{q_i\} \) fields for the first cycle (4\(^{th}\) November 12 UTC) of the rest of the experiments.

The \textbf{first experiment (RDR)} initial conditions are produced by adding the information from the radar data to the fields used to initialize CNTL. The assimilation of these radar data is done in this RDR experiment as is done by default in HARMONIE 36h1.4. In particular, RDR and CNTL share the same precipitation fields at +0H.

The \textbf{second experiment (RDRFA1)} initial conditions correspond to the “a” alternative explained in the previous section “specification of the initial conditions”. This means that the 3D-Var algorithm actually only processes the DOW data. The reflectivity data enters in the IC through the processing of the \((T, q, \{q_i\})\) fields that has been explained in section 2.3. These fields overwrite the equivalent fields in the downscaling files before the analysis step. Because the 3D-Var algorithm is multivariate, there will be some minor corrections to the \((T, q)\) fields via B–coupling with the wind field. In this RDRFA1 experiment, the precipitation fields at +0H are position corrected by the FA method.

The \textbf{third and last experiment (RDRFA2)} initial conditions correspond to the “b” alternative explained in section 2.3 “Specification of the IC”. The 3D-Var algorithm processes both the Z and DOW data, but different from the RDR experiment the \((T, q, \{q_i\})\) have all been position-corrected by the FA method plus a posterior inversion of \(r_h\) to \((T,q)\) at each grid point. Therefore RDRFA1 and RDRFA2 share the same precipitation fields at +0H.

### 2.5 Verification Data and Method

Before the presentation of the results, a few words regarding verification are necessary. First, it was decided to use the radar data as the verification source. The reason for this is that the study is confined to an area around the selected radar site. The availability of radar images every ten minutes covering an area of 240 km in diameter around this place makes that most of the relevant conclusions can be drawn from verification with these data. Second, the focus is on position errors because the FA method targets specifically this kind of errors. Z images (DOW data not used for verification) offer a good resource to characterize and measure these errors.
An obvious candidate method for position error verification is the SAL method (Wernli et al. 2008). This is so because SAL is already included in the HARMONIE utilities package. However, SAL does not give the precision wanted in this study. The characterization of position errors by SAL takes into account only the distance between centre of masses in model and data scenes and the difference in the respective average dispersions of clusters around these centres.

This characterization can be made more precise by pairing data and model clusters. There are of course many different ways of doing these pairs, but it is possible to get a unique result by imposing the additional conditions that the total length of the distances between the data-model pairs be a minimum and that no cluster can be left unpaired. We can call the parameter that results in this way “position disparity (PD)”. It is clear that this parameter characterizes better the position errors in a given scene because it is able to discriminate many situations where the bulk SAL formula would give the same result.

It turns out that, even considering just points instead of clusters of finite size, the problem stated above is computationally costly when the number of clusters-points increases. But it is also not hard to find an algorithm that gets to an approximate solution of acceptable accuracy (within 10% according to numerical tests) (López and Geijo, 2012) if the numbers of clusters-points in each set (data and model)
are not very different. This “quick-algorithm” can then be used to determine the PDs that result from random simulations in which the model clusters are given random positions within the verification domain. Analysing the empirical distribution of PDs so obtained, we can express the departure of the actual PD from mere randomness by means of a “P-value” which measures the probability [0,100] of producing such a PD by random sampling: the lower this P-value is, the more unlikely that the observed PD can result by chance and the higher skill in predicting position the model shows. Also high P-values will indicate a significant departure from randomness, but in this case the model would have little or no skill at all.

At the time of implementing this verification method several issues required a careful consideration. One is the difficulties that arise from working, not with clusters-points, but with clusters of finite size. It is convenient to subdivide big clusters in smaller ones to capture better shape and size effects. Also the disparity in sizes between data and model clusters, which may reflect a bias between data and model, hamper the application of the method. It was then decided to use adaptable contouring thresholds at the time of extracting the clusters. This means that for each scene and each source (model or Z radar data) only a proportion of the pixels within the scene are grouped in clusters. This solution is acceptable in this case because these pixels correspond to the areas of more intense precipitation which are the ones more interesting in this context.

Figure 3 shows an example of the method. In blue colour we have the radar reflectivity clusters and in green the model pseudo-reflectivity clusters. The actual situation is the one on the top left of the panel. The PD parameter value is 240 (in grid point units). Using a random number generator we can shift the model clusters around in such a way that they all are totally within the verification domain and that they do not overlap with each other. These conditions are required because they are realized in the actual situation. It would not be difficult to add the possibility of changing the orientation of the clusters as they are moved about, but for simplicity this possibility has not been implemented. Therefore we can see that the clusters are parallelly translated. The top right panel shows the scene with the lowest PD (166) in a sample of 1000 cases. On the bottom left panel we have a case in the median bin of the sample (PD=364, P-value=50) and on the bottom right panel one case corresponding to the P-value=90 bin of the sample (PD=532). The actual case (top left) gets a P-value of 12.4, which means that in about 10% of the cases the random sampling gets better clusters location agreement than HARMONIE.
2.6 Results

The results of the different experiments were verified and compared as explained in section 2.5. Figure 4 synthesizes the outcome. The mean values for the PD “position disparity” and P-value parameters are shown on the left and right plots respectively as a function of forecast range. The number of cases that enter in the computation of each mean value is indicated by the boxes and the scale on the right vertical axis (actually the same values on both plots, note the change of scale). The cases better sampled are the analyses and the forecasts up to +2H with 16 cases each. Then the sample size decreases and becomes 10 for +6H forecasts. The P-value parameter displays higher sensitivity (the curves show bigger differences among them) than the PD parameter, also note that both measures are consistent.

The first feature is the effectiveness of the position correction method. We see that the cyan and purple curves (RDRFA1 and RDRFA2 respectively) display at +0H (analysis) much smaller position errors than the red and green curves (CNTL and RDR respectively). There is still some amount of position error in RDRFA1 and RDRFA2 at +0H, which can be explained by the fact that the Z fields used in the verification have been re-computed from the aligned \( \{q_1\} \) fields as explained in section 2.3 and also by residual errors introduced by the interpolations and changes in resolution (the alignment is done on low band pass filtered fields). However, the correction is clearly working and these position errors have virtually being removed. We also see that, as explained in section 2.4, CNTL and RDR on one hand and RDRFA1 and RDRFA2 on the other share identical initial precipitation fields.

Also prominent is the steep raise of the error curves in the RDRFA1 and RDRFA2 experiments. This leads to very small differences with respect to the methods not using the FA technique only after 1 hour. In fact, most of the difference is dismissed in the first few minutes (not shown). This has clearly to do with the short lifetime of hydrometeors in the atmosphere and also with the specifics of the initialization of these hydrometeor fields. Also the “broken cycle” scheme followed in these experiments, which impedes propagation of information from one cycle to the next, and the use of only a limited number of radar elevations may have aggravated this problem. More investigation is needed here.

As far as the comparative performance for the different tests, we see that at +1H, RDRFA2 and RDR are clearly superior to the other two tests. Afterwards the results are mixed. This conclusion is a bit disappointing because it points that the FA method has not succeeded in this case in improving the short-range forecast skill. As mentioned before, that RDRFA2 improves over RDRFA1 is quite natural because the 3D-Var analysis of the rh fields helps to filter out some of the noise introduced in all the previous processing of the fields and also because eventually can produce better balanced initial conditions.

3 Conclusions

In this study we have proofed that the FA technique can be applied with success to radar reflectivity images, and also that it is possible to correct the position errors of other related variables coherently. As a by-product of this work, a position error verification method has been developed and implemented.

However, the results are to some extent degraded by the intrinsic difficulty in assimilating reflectivity data, which bears only an indirect relation with the analysis variables for the initialization of AROME, and also with the specifics of the initialization of the very short lived hydro-species variables which do not seem to feedback strongly in the dynamics of the model. As a result, the beneficial impact is gone in a short time.
The results of this study are therefore mixed. Further investigation is required. Some of the ideas to be checked have already been mentioned along this paper. This includes also the application of the method to other variables like radar winds whose impact is expected to be bigger because of its clearer connection to the analysis variables.

4 References


Winter-time convection – a heavy snowfall case in Southern Finland

Sami Niemelä

1 Introduction

Due to Finland's northern location between the latitudes 60N and 70N one might expect that winter-time convection is not really a problem. However, more than a third of the population in Finland live in the vicinity and under the influence of the Baltic Sea. In the winter-time, before the freezing period, the relatively warm sea acts as a constant source of moisture. Moreover, in some conditions sensible heat flux from the sea surface may be enhanced resulting in vigorous convective activity with large amount of snow (Markowski and Richardson, 2010). Such events are called lake effect snow episodes.

The purpose of this study is to present 5-day lake effect snow episode, which took place over Gulf of Finland and Southern Finland in 1 – 5 Feb 2012. The main emphasize is given to the 3rd day of the episode, which caused a major snowfall case in Helsinki region. Up to 300 cars were involved in multiple pile-ups in all major entrance roads of Helsinki. In total, 43 persons were injured, however, fortunately no lives were lost. The second aim is to explore how well the mesoscale NWP model Harmonie is able to reproduce the characteristics and different phases of the episode.

2 Lake effect snow case, 1 – 5 Feb 2012

Figure 1 shows both surface and atmospheric conditions preceding and during the lake-effect snow episode. Before the episode, 31 Jan 2012, the Gulf of Finland was almost completely ice free. Only the most eastern part of the Gulf was ice covered. At the same time, the persistent low pressure over the Baltic countries started to push very cold continental air mass towards the eastern areas of the Baltic Sea. On the 3rd of Feb the 850 hPa temperature over the Gulf was as low as -25°C resulting in a temperature difference between sea surface and 850 hPa as large as 26°C. According to Markowski and Richardson (2010), temperature difference about 13°C can be considered as a “rule of thumb” threshold value for suitable conditions for lake-effect convection. In this case the threshold is largely exceeded.

The key ingredients for the strong lake-effect convective episode were in place: i) ice free sea surface, ii) very cold air mass over the sea and iii) suitable mean flow direction over sea. Figure 2 shows the radar reflectivity composites over the Gulf of Finland from the different phases of the episode. During the first two days (1-2 Feb) the mean flow direction was from the east. As a consequence, a very long convective snow band formed parallel to the Gulf (Fig. 2a). This convective band slowly moved back and forth between the Finnish and Estonian coastlines while still maintaining it's single band characteristics. In this flow pattern, the convective band was strengthened due to the convergence of land breeze type flow structures originating from cold land areas on both sides of the Gulf (not shown). This effect favoured and supported the formation of a single convective band. During 3-4 Feb the mean flow started to turn south-easterly. The type of convection changed accordingly. Firstly, the main convective band drifted over the coast of Finland (Fig. 2b) and, secondly, the single convective band disintegrated into multiple narrow convective lines (Fig. 2c) when the convergent land breeze flow was not supporting the system anymore. Finally, on the 5th of Feb, the winds were
getting weaker, which did not support the banded convective structures. However, the remaining instability was removed as a form of local mesoscale vortex (Fig. 2d).

![Figure 1: Left: Hirlam SST and sea ice cover analysis on 31 Jan 2012. Right: Hirlam 850 hPa temperature and geopotential height analysis on 3 Feb 2012.](image)

The most intense snowfall in Helsinki occurred on day 3 of the episode (Fig. 2b), during the transition phase between parallel and perpendicular convective modes. In the morning of the 3rd of February, the visibility in the snowfall was very low (~100 m) and road surfaces became extremely slippery due to snow compression. These were the main factors leading to multiple car pile-ups within few hours of each other. From the driver point of view, the third element of surprise was the locality of the snowfall. Only 30-40 km inland the skies were clear and remained to be clear during the whole 5 day period.

![Figure 2: Composite of radar reflectivity from Finnish radar network (Saltikoff et al. 2010). a) 2 Feb 2012, 00 UTC. b) 3 Feb 2012, 09 UTC. c) 3 Feb 2012, 21 UTC. d) 5 Feb 2012, 06 UTC.](image)
3 Model configuration

One of the aims is to study the performance of FMI’s operational mesoscale NWP model Harmonie in this case. Harmonie is a non-hydrostatic model based on fully compressible Euler equations. The FMI configuration includes Arome-physics package with the single-moment 6-class microphysics scheme (Pinty and Jabouille, 1998), a shallow convection scheme for non-precipitating shallow cumuli (Siebesma et al. 2007), the TKE-l based turbulence scheme (Cuxart et al., 2000), multi-band radiation schemes for both the longwave (Mlawer et al., 1997) and shortwave (Morcrette and Fouquart, 1986) part of spectrum and the Surfex surface parameterization (Le Moigne, 2009) module.

FMI is running Harmonie cy36h1.4 operationally, with 2.5 km horizontal grid size and with 65 levels in vertical (20 levels in lowest 1km). With such a grid size, deep convection parameterization is not activated. Upper air data assimilation is handled by 3D-Var, whereas optimum interpolation is used for surface variables. An one and a half day (+36h) forecast is made with 6-hourly assimilation cycles.

4 Results

Figure 3 shows the Harmonie 1h-accumulated precipitation and mean sea level pressure during the third day of the episode. Harmonie is able to generate the main snow band parallel to the coastline (Fig. 3a and 2b). The snow band is moving realistically over the Gulf (not shown) and in the beginning of the transition phase the convective line is touching the Finnish coast at the right time. However, when the convective mode is shifted to the perpendicular phase, the model is not able to perform as well any more. The strongest and largest convective line is qualitatively well represented by the model, but the multiple narrow snow bands are not (Fig. 3b and 2c).

![Figure 3: Harmonie 1h-accumulated precipitation and mean sea level pressure. Blue colors indicate total amount of snow and graupel. Analysis time 3 Feb 2012, 00 UTC. a) +9h forecast and b) +21h forecast.](image)

Figure 4 shows the simulated cloud reflectivity and observed satellite picture (MODIS) in the afternoon of 3 Feb 2012. In addition to the precipitating convective bands, several narrow cloud streets (perpendicular the coastline) were formed over Gulf of Finland (Fig. 4b). In the model forecast, some structures of perpendicular cloud streets are visible. However, due to lack of resolution in the model, the cloud bands are not as narrow as observed.
Figure 4: a) Harmonie-based simulated cloud reflectivity valid at 3 Feb 2012, 15 UTC (+15h forecast) b) MODIS satellite picture, afternoon 3 Feb 2012.

Figure 5: Vertical cross sections along the red line in Fig. 4b. Land (sea) on the left (right) side of the figure. a) Radar reflectivity from Vantaa radar at 3 Feb 2012, 9:30 UTC. b) Harmonie (3 Feb 2012, 09 UTC) hyrometeors in color (rain+snow+graupel, g/m³), cloud water and ice in grey scale and potential temperature as isolines.

Figure 5 shows vertical cross sections of radar reflectivity and Harmonie hyrometeors perpendicular to the coastline in the morning of 3 Feb 2012. The vertical structure produced by the model agrees very well with the observed structure. Although the system produced a significant amount of snow, the vertical extent was rather shallow. The top of the clouds were only in between 1.5 – 2 km in both model and observations. Moreover, the largest amount of hydrometeors and maximum radar echoes
coincide in vertical (below 500m). The horizontal location of the strongest snow band was well captured by the Harmonie model.

Figure 6 shows the simulated cloud reflectivity and observed satellite picture (MODIS) in the morning of 5 February 2012. The mean flow structure has already weakened and the 5 day episode is at its final stage. When the winds are weak and do not support the formation of the cloud bands, the remaining convective activity is organized as mesoscale convective vortex (Fig. 6b). The diameter of the system is approximately 30-40 km. The Harmonie model is able to reproduce the similar vortex with a good accuracy in terms of location and size (Fig. 6a).

![Figure 6](image.png)

**Figure 6**: a) Harmonie based simulated cloud reflectivity valid at 5 Feb 2012, 06 UTC (+12h forecast). b) MODIS satellite picture, morning 5 Feb 2012

5 Conclusions

This paper presented the case study of winter-time convective event (lake effect snow) over the Gulf of Finland. The whole episode lasted 5 days in total and caused severe traffic accidents in all major entrance roads in Helsinki on the 3rd of February. In addition, the performance of the operational mesoscale NWP model Harmonie was studied. The main findings are following:

Harmonie was able form a realistic convective snow band parallel to the Gulf of Finland

- Harmonie was able to reproduce the structure of the mesoscale vortex over the Gulf of Finland
- The vertical structure of the main convective band was well captured by the model.
- The model struggled in forming the narrow precipitating convective lines perpendicular the coastline. One of the most likely reason for this behaviour is the lack of resolution in the model.
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References


Numerical Stability and Kinetic Energy Spectra in High-Resolution HARMONIE

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1 Introduction

Operational demand exists for a “usable, high-resolution HARMONIE”, but naively refining the horizontal resolution of the NWP model HARMONIE to a grid-size of, say, 0.5 km (and reducing the time-step proportionately) frequently leads to numerical instability and model failure.

These instabilities in high-resolution HARMONIE with “standard” dissipation were investigated from the perspective of spectral kinetic-energy (KE) profiles. The classical concepts are summarized schematically in Fig. 1 (from Skamarock, 2008). In the real atmosphere, kinetic energy is injected into the system through baroclinic instability, convection, or other means. This kinetic energy is then transferred both up-scale (e.g., into zonal jets) and down-scale through nonlinear wave-wave interactions in an inertial “cascade” that proceeds all the way down to scales that are orders of magnitude smaller than anything that can be resolved by even the highest-resolution mesoscale model. This cascade results in the “correct spectrum” curves shown in both panels.

Schematic of some typical atmospheric spectra

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**Figure 1**: Schematic showing the possible behavior of spectral tails derived from model forecasts. Model spectra on the left panel are stable and “correct” down to the “effective resolution” wavenumber. There is some spread among models at wavenumbers between “effective resolution” and the short-wave cut-off at 2 Dx wavelength. The model spectrum on the right panel is unstable and incorrect, with physically spurious energy at high wavenumbers.

All atmospheric models, however, have a short-wave cutoff at some point, represented by the ends of the model spectra (the thick curves in Fig. 1), at wavelengths corresponding to twice the grid-spacing.
(the 2Dx wavelength values of k in Fig. 1). This short-wave cutoff represents an artificial “dead-end” for the natural downscale energy cascade. Without smaller scales available to transfer into, energy either “piles up” at the short-wave cutoff or is spuriously aliased to longer wavelengths.

To restore numerical stability, therefore, models typically introduce a scale-selective dissipation term, which operates preferentially at the shortest scales to compensate for the missing “sink” of energy represented by even smaller unresolved scales. As shown on the left side of Fig. 1, that scale-selective dissipation typically over-compensates for the unresolved small scales, and reduces the model spectrum below the “correct” one of the real atmosphere. The point on the left panel of Fig. 1 where the model and “correct” spectra separate is referred to as the “effective resolution” (since model energy is unrealistically low at scales smaller than this, with the difference sometimes referred to as “missing energy”).

This paper describes how high-resolution HARMONIE can be stabilized by changing its kinetic energy spectra from shapes like that on the right panel of Fig. 1 (with the characteristic up-turned tail) to shapes more like those on the left panel (with either no up-turned tail, or else just the hint of one at a much reduced energy level). The stabilization is accomplished essentially by changing the 4th order scale-selective dissipation term to a much more selective 6th order, and also strengthening it somewhat – at least at the short-wave end of the spectrum.

## Results

### 2.1 HARMONIE Configuration

The configuration currently used by Met Éireann was taken as the starting point for development of the “high-resolution” version. The operational configuration uses a 2.5km grid-size, with 540 points in the x-direction and 500 points in the y-direction. Time-step is 60s. The 500 hPa field forecast for 23 hrs after a “cold start” at 18Z on 7th May 2011 (a relatively normal day) is shown in Fig. 2a, with the usual contour interval of 6 dam.

The simplest way to run a first “high-resolution” HARMONIE test was to reduce the grid-size to 0.5km, reduce the time-step proportionately to 12s, but to keep roughly the same problem size by using 600 points on both x and y-directions. The high-resolution domain is thus approx. 19 times smaller than the operational (2.5km resolution) domain. Fig. 2b shows this domain (most of the island of Ireland but excluding the northern and eastern parts), along with the 500 hPa field forecast for 23 hours for the same initial and verifying time as in Fig. 2a. Since the domain in Fig. 2b is so small, contour interval is now 1 dam. Initial and boundary conditions for both standard 2.5km and high-resolution 0.5km HARMONIE are taken from both observations and from a larger regional HIRLAM model in which HARMONIE is essentially “nested”. Boundary conditions from HIRLAM are updated every hour, just as is done operationally. The only difference between the runs shown here and operational forecasts is that all integrations for this paper have “cold starts”.

The reason that the 23-hr forecast from 18Z on 7th May 2011 is shown in Fig. 2 is that this is the last snapshot saved from the high-resolution run, before it “blew up” with unphysical large winds and a CFL instability before it completed the 24th hour. Overall, the contours in Fig. 2b are a lot more variable and noisier than the relatively smooth contours of the 2.5km run in Fig. 2a. Much of that variability is physically plausible, and simply reflects the smaller gravity wave and topographically induced structures that exist in the real atmosphere and can be resolved with a 0.5km grid. However, the dense contouring just to the west and north of centre in Fig. 2b is most likely unphysical, and probably represents the seeds of the spurious structures that cause model failure within the following forecast hour.
Evidence for this interpretation is the field in Fig. 2c, which is identical to Fig. 2b (i.e., a 23-hr forecast from a cold start at 18Z on 7th May 2011) but from a 0.5km HARMONIE run with “enhanced scale selective damping” (as described in section 3 below). The run from which Fig. 2c is taken is numerically stable, and continues to normal completion after 48hrs. Many of the contours in Fig. 2c are almost identical to those in Fig. 2b, but the extreme noisy and dense contours to the west and north of centre in Fig. 2b are absent from the “stabilized” run of Fig. 2c. The enhanced small-scale dissipation of the run shown in Fig. 2c has removed those spurious structures, while leaving the other physical features almost unchanged.

Figure 2:  (A) 2.5km resolution    (B)  0.5 km res. (default damping);     (C) 0.5 km (enhanced damping)

HARMONIE was also configured to run over the open ocean (by simply moving the domain 7 degrees west). Tests with this domain showed that large-amplitude gravity waves were also excited at all scales, and the 0.5km HARMONIE proved just as unstable over the open ocean as over Ireland.

2.2 Enhanced Scale-Selective Damping

The small-scale features in the fields generated by the high-resolution 0.5km HARMONIE runs just prior to failure suggested that excessive small-scale energy was building up near the short-wave cutoff scale, i.e., that there was a turn-up in the spectral tail as shown on the right panel of Fig. 1. To test this, the linear, spectral scale-selective dissipation scheme in HARMONIE was adjusted to make it (a) more scale selective, and (b) stronger, at least at the shorter scales.

The main horizontal diffusion scheme in HARMONIE is outlined by Bengtsson et al. (2012). In greatly simplified form, a variable X is diffused according to the equation:

$$\frac{\partial X}{\partial t} = -K_X |\nabla^r X|$$

Here X is one of the main prognostic variables, $K_X$ is the damping coefficient (RRDXTAU), and $r$ is an even positive integer exponent (REXPDH). Eqn. (1) is applied in spectral (wave) space, so the $\nabla^r X$ operator is “scale selective”, i.e., generates larger dissipation for larger wavenumbers (smaller scales). This “scale selectivity” is enhanced by larger values of the exponent $r$. In HARMONIE, $r=4$ by default.

Since the problem with the “naïve” 0.5km HARMONIE appears to be too much small-scale energy, a simple, natural adjustment is to increase the exponent $r$ from 4 to 6. In practice, the exponent $r$ operates on a normalized wavenumber, with values between 0 and 1. Taking a higher power of such values makes them smaller, so changing $r$ from 4 to 6 by itself actually weakens dissipation in HARMONIE, even if it is made more scale-selective. To compensate for this general weakening, the coefficient $K_X$ in (1) also needs to be increased.

Changing just those two parameters: i.e., the exponent $r$ (from 4 to 6) and the coefficient $K_X$ (from 123 to 12,300), seems to be a way to stabilize the 0.5km HARMONIE with the lightest possible touch and the least intrusive number of changes. E.g., the field shown in Fig. 2c is from a 0.5km HARMONIE
run stabilized in this way. Those results look quite acceptable, in that the dense, noisy, cluster of contours to the west and north of centre in Fig. 2b (from the equivalent run with default damping) has vanished, while the contours elsewhere are hardly changed at all. With this evidence, then, it is possible to attribute the densely contoured features in Fig. 2b to spurious short-wave energy accumulation that has been suppressed by the enhanced scale-selective dissipation of Fig. 2c.

2.3 Kinetic Energy Spectra from HARMONIE

While the enhanced scale-selective dissipation effectively stabilizes HARMONIE, a full explanation of why this works requires spectral energetics analysis.

To this end, KE densities in spectral space were calculated from the horizontal \((u,v)\) wind fields saved by HARMONIE every simulated hour. Fig. 3 plots the KE for each individual wave as a function of total wavenumber, from a run with standard dissipation (Fig. 3a) and with enhanced dissipation (Fig. 3b). Since there are approximately 300 wavenumbers in both zonal and meridional directions, each panel in Fig. 3 has about 90,000 points. Fig. 3a (from run with standard dissipation) shows the distinctive turn-up in the tail (as on the right panel of Fig. 1), while Fig. 3b (with enhanced dissipation) has very efficiently (maybe even too efficiently) suppressed energy at the shortest scales.

![Figure 3: Vertically-averaged kinetic energy spectra showing each individual wave as a function of total wavenumber, from (a) run with standard dissipation (left panel) and (b) run with enhanced scale-selective dissipation (right panel). Note the energy density on the y-axis spans a larger range in (b) than in (a). The straight purple line has a reference slope of \(k^{-3}\) in both panels. Blue dots are from the one-third highest meridional wavenumbers; red dots from the middle third, and green dots from the lowest one-third.](image)

At large to medium-scales (i.e., to the left side of each panel in Fig. 3), the spectra closely approximate a slope of \(k^{-3}\). This represents an average slope down the 2-d spectrum. If all the points within each unit-wavenumber bin are summed, and the sum is plotted as a function of wavenumber, this produces an “integrated” or total KE spectrum that has a slope closer to \(k^{-2}\) (or even \(k^{-5/3}\)), since the number of waves in each wavenumber band (i.e., between \(k\) and \(k+1\)) is roughly proportional to \(k\).

Total KE can be further decomposed into contributions from each model level, and from the “rotational” and “divergent” components of the wind separately. Not surprisingly, KE increases with height, and the spectral shapes change subtly as well, with the “turn-up in the tail” appearing most prominently at the top-most level. Moreover, that turn-up in the tail, or pile-up of KE at the shortest scales, is quite prominent in the divergent component of the wind, but not at all in the rotational component (which is dominated by larger quasi-geostrophic circulations).

Figure 4 shows the divergent KE at the top-most level in the model (approx. 10 hPa) at the same 23-hr moment into the forecast as in Figs. 2 and 3. The scatter diagram of contributions from each individual wave is shown (as in Fig. 3) with the blue dots representing the one-third shortest
meridional scales, the red dots the middle third, and the green dots the one-third longest meridional scales. Integrated or accumulated energy from all waves within each unit wavenumber band is shown as the orange curve, while the straight blue line is simply proportional to $k^{-5/3}$.

Figure 4: Scatter diagram of divergent KE from every wave at the top model level (approx. 10hPa) 23 hrs into the HARMONIE 0.5km forecast (using standard dissipation). The highest one-third meridional wavenumbers are in blue; middle one-third in red, while lowest one-third are in green. Also shown is the sum over the scatter (i.e., integrated divergent KE) for each wavenumber band (orange curve), along with a curve proportional to $k^{-5/3}$ for reference.

The turn-up in the tail is again evident in Fig. 4, even in the integrated divergent KE curve. The spectral slope only weakly follows any particular slope over any broad range, but the -5/3 slope is nevertheless reasonably representative.

It is likely that any enhanced spectral dissipation that reduces the turn-up in the spectral tails shown in Fig. 4 and allows the spectrum to drop off monotonically with wavenumber will permit HARMONIE to run in a numerically stable way.

3 Discussion

Decompositions of HARMONIE kinetic energy spectra (from both 2.5km and 0.5km resolutions) into “rotational” and “divergent” components, as well as over time and the vertical dimension, reveal that the numerical instabilities are associated with:

- Initial spin-up (not surprisingly, since the model variables are typically unbalanced when spun up from a cold start);
- Upper levels in the model atmosphere, and
- The divergent component of the wind.
Those last two characteristics suggest that the numerical instability is ultimately due to HARMONIE’s inability to adequately resolve gravity wave-breaking in the model stratosphere or upper troposphere. In that sense, the extra scale-selective dissipation introduced to stabilize the 0.5km HARMONIE could be regarded as a “poor-man’s gravity-wave drag”. As the HARMONIE documentation states, the model has no separate parameterization for gravity wave drag. For the configurations that have been tested and used operationally so far, there has been no need for such a scheme, but for higher resolutions, perhaps there is.

A more physical solution might be to increase the vertical resolution at high levels in conjunction with the increased horizontal resolution, but that has not been done because the counter-attraction is to keep the same vertical resolution as the nesting HIRLAM model.

Barkmeijer (2010) also ran experiments with Harmonie at 0.5km resolution, and similarly found that his runs “blew up” unless he too strengthened certain damping parameters.

While the motivation and focus of this work has been to simply stabilize high-resolution HARMONIE, a spin-off benefit has been a deconstruction or decomposition of the kinetic energy spectra. Experience from observations and other models (as well as from dimensional scaling theory), as documented e.g., by Skamarock (2008) suggests that the HARMONIE kinetic energy spectra should follow a $k^{-5/3}$ profile, at least over well-resolved intermediate scales that best approximate an inertial range. In the case of the HARMONIE runs shown here, however, updated as they were every hour with boundary conditions from HIRLAM, perhaps no true inertial range is permitted to develop. The horizontal KE spectra followed more of a $k^{-2}$ profile than a $k^{-5/3}$ one. However, that was mainly because the winds were dominated at larger scales by the vortical or rotational component (which has a spectral slope of -2) rather than the divergent component (which indeed does have a slope very close to the classical -5/3). It should be no surprise whatsoever that the rotational (more quasigeostrophic or 2-dimensional) component of the winds should have a steeper slope than the divergent (more 3-dimensional) component, since conservation of potential vorticity in quasigeostrophic dynamics require an up-scale energy cascade along with a down-scale enstrophy one. Overall, this pattern is consistent with the results and analyses presented by Erler et al. (2012).

4 References


ATOVS PROCESSING AND USAGE IN THE HARMONIE REFERENCE SYSTEM

Magnus Lindskog*, Mats Dahlbom, Sigurdur Thorsteinsson, Per Dahlgren,
Roger Randriamampianina, Jelena Bojarova

1 Introduction
Handling of ATOVS data in the HARMONIE reference system has recently been subject to an overhaul. The aim is to have a proper handling of ATOVS data in a co-ordinated impact study and to have the possibility to include ATOVS data as a default option in the HARMONIE reference system. Several problems and weaknesses have been identified and taken care of. The problems were related to bugs residing from major ATOVS handling modifications in cycle 36, issues due to differences in ATOVS input BUFR format from different ATOVS pre-processing chains and missing adaptions needed due to the relatively low model top in the HARMONIE reference set-up. The handling of these problems is described as well as the procedure for data selection, bias correction and monitoring.

The improved system is suitable for extended ATOVS data assimilation and forecast impact studies, but experiments should be carried out before activating assimilation of ATOVS as the default in the HARMONIE reference system.

The characteristics of ATOVS instruments and channels are presented in Section 2. Thereafter, in Section 3, the ATOVS BUFR data from different streams are described. Sections 4, 5 and 6 are devoted to data selection, evaluation and tuning of variational bias correction (VARBC) and extended observation monitoring, respectively. Finally some concluding remarks are presented in Section 7.

2 ATOVS instruments and channels

ATOVS is the acronym for Advanced Tiros Operational Vertical Sounder. For older systems it is comprised of the AMSU-A and the AMSU-B instruments while for newer systems AMSU-B has been replaced by the MHS instrument. The AMSU-B and the MHS instruments have similar characteristics. There are several polar orbiting satellites, such as: NOAA 15, NOAA 16, NOAA 17, NOAA 18, NOAA 19 and METOP. All of the satellites mentioned above are equipped with an AMSU-A instrument. Furthermore, NOAA 15, NOAA 16 and NOAA 17 are equipped with an AMSU-B instrument while NOAA 18, NOAA 19 and METOP are instead equipped with a MHS instrument. In the HARMONIE system however, following Mété-France procedure, NOAA 18 MHS is treated as AMSU-B.

The AMSU-A instrument measures the radiance that reaches the top of the atmosphere in 15 channels, associated with different wavelengths. Eleven of these channels are atmospheric sounding channels that are sensitive mainly to atmospheric temperature in different vertical layers. These are characterized by their weighting functions. There are also four window channels (for quality control and surface and cloud characterization). Figure 1 shows the AMSU-A weighting functions for channels 3-10. These were derived using RTTOV version 7 in HIRLAM 3D-Var (Gustafsson et al., 2001; Lindskog et al. 2001). In HARMONIE

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cycle 37 RTTOV version 9 is used. These differences in modelling systems and RTTOV versions are not
expected to influence the main characteristics of the weighting functions for different channels, neither for
AMSU-A (as described here) or for AMSU-B/MHS (as described below).

The AMSU-B/MHS instruments measure the radiance that reaches the top of the atmosphere in 5 channels
associated with different wavelengths. Channels 1 and 2 are surface sensitive channels while channels 3 to 5
are atmospheric sounding channels, sensitive to atmospheric humidity profiles. Channel 5 is the lowest
peaking of the atmospheric sounding channel while channel 3 is the highest peaking one. The weighting
functions for channels 3-5 are illustrated in Figure 2 for different atmospheric conditions. Also the AMSU-B
weighting functions were derived using RTTOV in HIRLAM 3D-Var.

All of the instruments (AMSU-A, AMSU-B, MHS) sweep from side to side in both directions (left and right,
relative to the direction of movement of the satellite) with an instrument (AMSU-A, AMSU-B, MHS)
dependent scan angle ($\theta$) relative to the nadir. This scanning procedure is illustrated in Figure 3. For AMSU-A
the maximum scan angle is 58 degrees and the angular resolution ($\Delta\theta$) is 3.8 degrees at the nadir and 4.6
degrees at the edges of the scan line. For AMSU-B the maximum scan angle is 58.7 degrees and the angular
resolution is 1.25 degrees at the nadir and 1.55 degrees at the edges of the scan line. For MHS the maximum
scan angle is 59.4 with an angular resolution of 1.26 degrees at the nadir and 1.6 degrees at the edges of the
scan line.

Figure 1: Weighting functions for AMSU-A channels 3-10.
Figure 2: Atmospheric water vapour content (wv) for wet and dry atmospheric conditions (left) and associated weighting functions for AMSU-B channels 3-5 (middle and right).

Figure 3: Illustration of scanning procedure for ATOVS instruments along a scan line, including scan angle (θ) and angular resolution (∆θ).
3 ATOVS BUFR data from different streams

There might be some minor but crucial differences in the contents of an ATOVS BUFR report, depending on whether the report originates from the ECMWF MARS archive or is generated by local pre-processing software at the HIRLAM member state institutes.

- **ECMWF MARS archive:** Here the instrument codes for AMSU-A, AMSU-B and MHS are 3, 4 and 15 respectively. Furthermore, for each scan line (see Figure 3) the scan angles ($\theta_1$ to $\theta_N$) are always positive, regardless of whether the satellite looks to the right or to the left (relative to the movement of the satellite). It is implicitly assumed that data following each other from the same scan line are stored from left to right. All this is exactly what is expected in the HARMONIE/IFS code.

- **Local pre-processing software:** The instrument codes for AMSU-A, AMSU-B are 3 and 4, respectively. For MHS data that originate from the EUMETSAT EARS retransmission service (and probably also for those data received by local antennas, followed by local processing) the instrument code is 11 (if not explicitly modified by the local processing software). Furthermore, for AMSU-A, AMSU-B and MHS data from many of the local processing centres half of the scan angles along a scan line have negative values. The ones with negative values are from when the satellite is looking to the left (relative to the movement of the satellite). Referring to Figure 3 this means that $\theta_1$ is negative and equal to $-\theta_N$. The reason for introducing these negative values in the pre-processing is that they are needed in order to match the definitions in HIRLAM variational data assimilation system.

The BATOR part (actually FORTRAN routine bator_decodbufr_mod.F90) of HARMONIE cycle 37 has now been adapted to handle ATOVS data in both of the formats, as described above. Also a FORTRAN code part that originally caused a crash when the originating centre was missing in the ATOVS BUFR message has been taken care of. The updated system has at present been tested and seems to be properly working with ATOVS data originating from MARS, SMHI and DMI. To confirm its functionality and possibly add more adaptations it should in the future be tested also for data originating from local processing systems of other HIRLAM institutes. It is likely that there are other local modifications that are still unknown to us.

When it comes to maintenance of the local updates in consecutive HARMONIE cycles we foresee potential problems and a considerable amount of work and co-ordination. All modifications necessary for handling data from one particular local data assimilation system should not be restricted to a local branch but be incorporated into the reference so that there is one single HARMONIE system (in particular bator_decodbufr_mod.F90) working for ATOVS data from all different data streams. Such a system needs careful phasing in between different HARMONIE cycles. A preferred procedure would be to modify the format of the locally processed ATOVS data to match the format of the ATOVS data from the MARS archive. Such a modified system is under development within the MetCoOp co-operation between Sweden and Norway.

4 Data selection

As mentioned in the introduction there are ATOVS instruments on-board a large number of different satellites. Some of the instruments and some of the channels on some instruments are not properly working. For the NOAA satellites some quality information can be found on the website:
http://www.oso.noaa.gov/poesstatus/

In addition one can gain knowledge of quality from the experiences of different data assimilation centres. One should keep in mind that the quality may change. The HARMONIE ATOVS usage default settings introduced here are based on the current quality of different instruments. To start with data from the following instruments will enter the data assimilation:

- AMSU-A from NOAA-15, NOAA-16, NOAA-18, NOAA-19, METOP
• AMSU-B from NOAA-18 (actually MHS but treated as AMSU-B)
• MHS from METOP

An important issue is that in the reference HARMONIE set-up the uppermost model level is at 10 hPa. Due to this relatively low model top we cannot assimilate channels with weighting functions having a significant contribution from vertical layers above 10 hPa. Our choice, like in the HIRLAM variational data assimilation, was therefore to exclude AMSU-A channels 11-15 in the HARMONIE reference system. It may even be questioned whether AMSU-A channel 10 should be used, since a part of the weighting function is above 10 hPa. On the other hand channels with weighting functions close to the surface are affected by surface emissivity and model biases at the surface. Therefore we do not want to utilize AMSU-A channels 1-5. To summarize, as default we are utilizing channels 6-10 from the AMSU-A instruments on-board the satellites mentioned above. The exceptions are AMSU-A NOAA 19 channel 8 and AMSU-A METOP channel 7. These are excluded since they are known to be of poor quality. For AMSU-B and MHS channels 3-5 are used from the satellites mentioned above.

This static selection of satellites/instruments/channels is done within mf_blacklist.b. This is an important part of the ATOV S data assimilation. Utilisation of ATOV S channels with weighting functions peaking above the model top will degrade the quality of the analysis. The ATOV S data as described above are used both over sea and land areas. In future one should also consider to use the relatively low peaking ATOV S AMSU-A channel 5, at least over sea.

This first ATOV S data selection is our present choice and needs to be revised every now and then. In future, for example, it should be possible to try to utilize NOAA 19 MHS data from some channel or to stop utilizing data from the old NOAA satellites (15 and 16). However, we have at this stage chosen not to have a data selection system that automatically takes time into account.

In addition to this static data selection within mf_blacklist.b a data selection could be made through a file LISTE_LOC_HH, where HH means hour in assimilation cycle. In the co-ordinated impact study we apply such a selection to prevent utilisation of satellite data from paths that just touch the model domain. This selection involves some manual inspection of data coverage and is meant to provide bias correction based on a sample size of observations that is not too small. Too small sample size may create unstable statistical properties (for ex. bias) due to for example satellite data residing from paths at the edge of the model domain not being completely representative for the area (see for ex. Randriamanampianina et al., 2011).

The satellite data are subject to a horizontal thinning. There are two characteristic thinning distances: RMIND_RAD1C and RFIND_RAD1C. RMIND_RAD1C is the minimum horizontal distance allowed between two observations of the same type. RFIND_RAD1C is the resulting average horizontal thinning distance between two observations after thinning. The thinning distances applied for ATOV S AMSU-A, AMSU-B and MHS data are presented in Table 1. These thinning distances are considered appropriate for the HARMONIE system. The some what shorter minimum thinning distances for AMSU-B/MHS as compared to AMSU-B might be motivated by differences in instrument characteristics, as was shown i Section 2. In addition one may argue that horizontal observation error correlations due to representativity error are shorter for sensors mainly sensitive to humidity (AMSU-B/MHS) than for sensors mainly sensitive to temperature (AMSU-A). Thus a shorter minimum thinning distance is needed for humidity sensitive sensors than for temperature sensitive sensors to account for horizontal observation error correlations. These thinning distances are part of the result of observing system experiments.

5 Evaluation and tuning of VARBC

One of the attractive things with the HARMONIE data assimilation system is the VARBC (Dee, 2005; Auligné et al. 2007) adaptive bias correction. Until now the default settings for VARBC have been appropriate
for a global model with a high model top rather than for the default HARMONIE limited area system, with its relatively low model top.

VARBC utilises a selection of pre-designed predictors. Each of these predictors will contribute to a smaller or to a larger extent to explain and account for the bias in the satellite observations. We want the predictors to be adaptive on an appropriate timescale. It should not be too long, then the system would be impractical and sudden changes in instrument quality might not be represented. On the other hand, neither should it be too short, then we risk interpret the model bias as instrument bias. The predictors applied as default up to now for ATOVS AMSU-A channels 6-10 and AMSU-B/MHS channels 3-5 are listed in Table 2. These are defined in the FORTRAN routines varbc_pred.F90 and varbc_rad.F90. How adaptive the VARBC predictors in general are for the respective instruments might be tuned by the parameters nbg_AMSU-A, nbg_AMSUB and nbg_MHS. The default values for all of these three parameters are at present 5000 and these are defined in the FORTRAN routine varbc_rad.F90. Decreasing the nbg values will lead to more quickly adaptive VARBC coefficients and increasing the values will lead to more slowly varying VARBC coefficients.

Table 1: Minimum and average thinning distances for different ATOVS instruments.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>RMIND_RAD1C (km)</th>
<th>RFIND_RAD1C (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMSU-A</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>AMSU-B</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>MHS</td>
<td>40</td>
<td>80</td>
</tr>
</tbody>
</table>

Table 2: VARBC original default predictors for ATOVS channels 6-10 and AMSU-B/MHS channels 3-5.

<table>
<thead>
<tr>
<th>Predictor no.</th>
<th>Predictor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>constant</td>
</tr>
<tr>
<td>1</td>
<td>1000-300hPa thickness</td>
</tr>
<tr>
<td>2</td>
<td>200-50hPa thickness</td>
</tr>
<tr>
<td>5</td>
<td>10-1hPa thickness</td>
</tr>
<tr>
<td>6</td>
<td>50-5hPa thickness</td>
</tr>
<tr>
<td>8</td>
<td>nadir view angle</td>
</tr>
<tr>
<td>9</td>
<td>nadir view angle **2</td>
</tr>
<tr>
<td>10</td>
<td>nadir view angle **3</td>
</tr>
</tbody>
</table>

Before starting a data assimilation experiment a spin-up of VARBC coefficients is needed. This is achieved by running data assimilation with satellite data in passive mode only. This prevents the still potentially biased satellite data from influencing the resulting analysis and potentially degrading it. This degradation would then influence the spin-up of the VARBC coefficients.

The co-ordinated impact study will cover the period 20100807 to 20100824. For that, we will spin up VARBC coefficients in a data assimilation experiment starting at 20100615 and ending approximately a month later. In this spin-up experiment satellite data will be assimilated in passive mode only. Figure 4 shows the time evolution of normalised VARBC predictors for NOAA 19 AMSU-A, channel 9 at 03 UTC, during the first six days when applying the original default predictors and nbg values. It can be seen that the normalised predictor 5 value dominates and its absolute value is growing. After two or three more days of data assimilation this will cause a crash with associated error message 'non-positive Hessian in in VARBC'. This has been experienced by several researchers working with ATOVS data assimilation in HARMONIE cycle 37.

One solution to the problem is to remove predictors 5 and 6, with contributions from above the model top, in particular predictor 5. Figure 5 shows the predictor evolution for the remaining 6 predictors, for NOAA 19
AMSU-A, channels 6 and 9 at 03 UTC, for different values of nbg for the instruments AMSU-A, AMSU-B and MHS. In the upper part of the Figure the original default value 5000 was used for the three instruments, while in the middle a value of 2500 was used and in the lower part of the Figure an nbg value of 500 was used for the three instruments. It can be seen that with this choice of predictors and nbg values of 5000 it takes more than 120 days for the predictors to spin-up. On the other hand with nbg values of 500 the feeling is that the predictors are too adaptive and the risk might be that VARBC adjusts to model error. Values slightly smaller than 2500 for nbg seem to be a proper choice, leading to a spin-up time of approximately one month.

One evident feature of Figure 5 is that there appears to be a strong correlation between predictors 0 and 2. It might be that they should not be used together. To investigate that, an additional experiment was carried out. The additional experiment was identical to the one with nbg value of 2500, except for that now also predictor 2 was removed. Figure 6 shows the predictor evolution for NOAA 19 AMSU-A, channels 6 and 9 at 03 UTC, for the experiments with and without predictor 2 and using a nbg value of 2500. By comparing the upper and the lower panel in Figure 6 one can see that when predictor 2 is removed the value of the (normalised) predictor 0 is almost doubled, as was expected from the parallel evolution of predictors 0 and 2. The conclusion is that it is sufficient to use predictor 0, and not both 0 and 2, as the default for the HARMONIE system and the co-ordinated impact study.

The sensitivity studies with VARBC has led us to the conclusion that application of the five predictors 0, 1, 8, 9 and 10 as defined in Table 1, is an appropriate choice for the HARMONIE impact study and as the default values for the HARMONIE reference system. When it comes to the nbg values of ATOVS AMSU-A, AMSU-B and MHS it seems that 2000 is a good compromise in adaptivity and stiffness of the system. This value will be used in the co-ordinated impact study and would also be suitable as the default value in the HARMONIE reference system.

6 Extended observation diagnostics

To assure proper observation handling a monitoring system is needed. In HARMONIE cycle 37 so far monitoring of satellite observation usage and bias correction include ATOVS AMSU-A data only. Since also ATOVS AMSU-B/MHS will be used in the co-ordinated impact study the monitoring system needs to be extended to handle also these data. Such enhancements have been carried out. An example is given in Figures 7 and 8. Figure 7 shows NOAA-18 AMSU-B channel 4 observations minus first guess departures for 2010071512 before bias correction was applied. Figure 8 shows NOAA-18 AMSU-B channel 4 area averaged
Figure 5: Time-evolution of normalised VARBC predictors for NOAA 19 AMSU-A channel 6 (left column) and 9 (right column) at 00 UTC from 20100615 and a number of following days. Upper part when nbg values of 5000 are used, middle part when nbg values of 2500 are used and lower part when nbg values of 500 are used.

10 day time-series for 2010071512 and 10 days back in time. The time-series are for (1) observations minus first guess departures before VARBC, (2) observations minus first guess departures after VARBC and (3) observations minus analysis departures. For this particular case the satellite data were assimilated in passive mode and did not influence the analysis.
Figure 6: Time-evolution of normalised VARBC predictors for NOAA 19 AMSU-A channel 6 (left) and 9 (right) at 00 UTC from 20100615 and a number of following days. Values for nbg were set to 2500. Upper part is when predictor 2 used and lower part when predictor 2 is not used.

It should be mentioned that there is a longer term action outside the co-ordinated impact study to improve the observation diagnostics system by making it more extensive, flexible and informative.
Figure 7: Observations minus first guess departures for NOAA 18 AMSU-B channel 4, before variational bias correction (upper), at 2010071512 (unit: K).

Figure 8: Time series of observations minus first guess departures before VARBC (red line), observations minus first guess departures after VARBC (green line) and observations minus analysis departures (blue line). The time-series ends at 2010071512 and starts 10 days before.
7 Concluding Remarks

Preparation for the co-ordinated impact study revealed several deficiencies in the handling of ATOVS data in HARMONIE cycle 37. These were mainly related to the handling of differences in the ATOVS BUFR format from different streams and to data selection and VARBC settings, bearing the characteristics of the HARMONIE reference set-up in mind. Several of the weaknesses have been identified and the system has been improved in many aspects. The enhancements will be used in the co-ordinated impact studies. It is also proposed to incorporate the enhancements in future versions of the HARMONIE system.

A next natural step would be to carry out full scale data assimilation impact studies with ATOVS data. In particular it would be interesting to investigate the influence of the relatively newly (HARMONIE cycle 36) introduced spectral nudging, in which HARMONIE upper level fields are gradually replaced with host model (usually ECMWF) fields (see FORTRAN routine elbc0a_mod.F90). This will probably hamper the impact of ATOVS channels with higher peaking weighting functions on forecast quality.

8 Acknowledgements

The authors are grateful to Dick Dee for his input regarding ATOVS AMSU-A channel selection and VARBC predictor selection. We also acknowledge Bjarne Amstrup and Vincent Guidard for sharing their expertise on ATOVS data handling.

References


Note on a comparison between HIRLAM 7.2 and HIRLAM 7.4 within EUCOS experimentation

Nils Gustafsson and Sigurdur Thorsteinsson

1 Introduction

A group of HIRLAM staff members (Nils Gustafsson, Sigurdur Thorsteinsson, Roger Randriamampianina and John de Vries) participated in an EUMETSAT EUCOS observing system experiment to study the effects of a reduced network of upper-air observations (radiosondes and AMDAR) over Europe. The experiments with HIRLAM were affected by a dry model bias of the order of 10% in tropospheric relative humidity forecast profiles as verified against radiosonde observations. With every assimilation cycle, the assimilation model state adapted to radiosonde observations of moisture and in the subsequent model integration the model state adjusted back to the drier model atmosphere. This 6-12 hour oscillation in the model water vapour profiles also affected precipitation forecasts simply since the adjustment of the water vapour profiles back to the drier model climate caused extra precipitation during the early phase of the forecast (moisture spindown). The denser the radiosonde observations that were utilized in the assimilation process, the stronger this moisture spindown was experienced in the subsequent forecast. The embarrassing result was that a denser network of radiosonde observations resulted in worse precipitation forecast verification scores as compared to a less dense radiosonde network.

The HIRLAM EUCOS experiments were done with the HIRLAM 7.3 system with the exception of the forecast model, which was taken from the HIRLAM 7.2 system. The reason for using the HIRLAM 7.2 forecast model, was the experience of (another) cold bias of the HIRLAM 7.3 forecast model in low tropospheric temperature forecasts. Since the HIRLAM 7.4 forecast model (the trunk version) has been reported to be improved over the HIRLAM 7.3 forecast model, we thought that it would be interesting to re-run some of the EUCOS experiments with the HIRLAM 7.4 system, under the assumption that the dry model bias would be reduced.

Indeed, the EUCOS experiments with HIRLAM 7.4 now indicate a less severe dry bias in water vapour profiles as compared to HIRLAM 7.2 and we also see a neutral impact from using a denser network of radiosonde observations on precipitation verification scores. On the other hand, we see a general degradation of forecast verifications scores in moving from the HIRLAM 7.2 system to the HIRLAM 7.4 system. These forecast score differences are summarized below, more just for documentation purposes without any intention to push for developments and tuning to improve the HIRLAM 7.4 system (at this late hour in the lifetime of the HIRLAM system).

2 Experiments

We compared the following set of experiments: EUS2, EUCOS Scenario 2 (operational network) with HIRLAM 7.2; EUS1_1, EUCOS Scenario 1 (strongly reduced network) with HIRLAM 7.2; EUS2t, EUCOS Scenario 2 with HIRLAM 7.4 and EUS1t, EUCOS Scenario 1 with HIRLAM 7.4. All experiments were run with the same setup of HIRLAM 4D-Var, using conventional observations, AMSU-A and AMSU-B radiances,
geostationary satellite AMVs and SEAWINDS scatterometer winds. The experiments were run over a domain covering Europe in a 10 km grid resolution and with 60 vertical levels. The experiments were run for the summer period 1 June - 15 July 2007. Verification was carried out for the period 7 June - 15 July 2007.

3 Results

Forecast verification scores for relative humidity profiles are presented in Figure 3 for validation time 00 UTC. We may notice a dry forecast bias that is reduced in moving from version 7.2 to version 7.4 (from -12% to -8% at 700 hPa). We may also notice that HIRLAM 7.4 provided improved 700 hPa relative humidity RMSE verification scores as compared to HIRLAM 7.2 and that a denser radiosonde network (Scenario 2) provided better 700 hPa relative humidity RMSE verification scores than a less dense radiosonde network (Scenario 1).

![Figure 1: Verification of relative humidity forecast profiles against radiosonde observations. Valid time of the day is 00UTC. Average verification scores over +12, +24, +36 and +48 h forecasts.](image)

The moisture spin-down problem is illustrated in Figure 3, which shows verification of 700 hPa relative humidity forecasts against radiosonde observations as a function of forecast length. First we may notice that the two experiments based on the denser radiosonde network drew much closer to the radiosonde observations at analysis time simply because the same observations were used for the analysis and for the verification and this was more or less independent of which version of the forecast model was applied. Then in the subsequent forecast model integration we may notice a moisture spindown such that an asymptotic model moisture bias level of -10% was established for the two HIRLAM 7.2 experiments, while this asymptotic bias level was reduced to -7% for the two HIRLAM 7.4 experiments. Concerning the standard deviation verification scores for 700 hPa relative humidity after the initial period of moisture spindown, we may possibly observe slightly better scores for the two experiments based on the denser network of radiosonde observations, most likely (but...
here we only guess) due to the information content of radiosonde temperature and wind information that is easier for the model assimilation to "digest".

![Figure 2: Verification of 700 hPa relative humidity forecasts against radiosonde observations as a function of forecast length.](image)

The moisture spindown process so clearly seen in the vertical relative humidity profiles is visible also in the precipitation verification scores (Figure 3) since the "rejected" atmospheric moisture content will fall out as precipitation. The experiment with the most intensive moisture spindown process, experiment EUS2 with the denser radiosonde network and with HIRLAM 7.2, also had the largest positive-valued precipitation bias. Furthermore, with HIRLAM 7.2, precipitation standard deviation verification scores remained worse for the forecasts based on the dense radiosonde network throughout the +48 h model integration, as compared to forecasts based on the sparse radiosonde network. What is more noticeable from Figure 3 is the fact that precipitation verification scores for HIRLAM 7.4 were significantly worse than precipitation verification scores for HIRLAM 7.2 at all forecast lengths.

To complete the picture on the comparison between the HIRLAM 7.2 and HIRLAM 7.4 forecast verification scores we have included forecast verification scores for mean sea level pressure, 2 meter temperature and total cloudiness in Figures 3 - 3, as well as for profiles of temperature, wind speed and geopotential height in Figures 3 - 3. The remarkable results as shown in these figures, is that all standard deviation/RMSE verification scores were worse (more or less) for HIRLAM 7.4 than for HIRLAM 7.2.
4 Concluding remarks

Some EUCOS observing system experiments, originally carried out with the HIRLAM 7.2 forecast model (and HIRLAM 7.3 for other parts of the HIRLAM system), have been re-run with the HIRLAM 7.4 system. A dry model bias that hampered the observing system experiment with HIRLAM 7.2 has been reduced in HIRLAM 7.4 but remains significant.

Forecast verification scores for other model variables are in general worse with HIRLAM 7.4 as compared to HIRLAM 7.2 for the period of the experiments. Since the HIRLAM 7.4 physics is more advanced than the HIRLAM 7.2 physics from a process/algorithic point of view, it is likely that the HIRLAM 7.4 physics lacks tuning.

Figure 3: Verification of precipitation forecast against SYNOP observations as a function of forecast length.
Figure 4: Verification of mean sea level pressure forecast against SYNOP observations as a function of forecast length.
Figure 5: Verification of 2 meter temperature forecasts against SYNOP observations as a function of forecast length.
Figure 6: Verification of total cloudiness forecasts against SYNOP observations as a function of forecast length.
Figure 7: Verification of temperature forecast profiles against radiosonde observations. Valid time of the day is 00UTC. Average verification scores over +12, +24, +36 and +48 h forecasts.
Figure 8: Verification of wind speed forecast profiles against radiosonde observations. Valid time of the day is 00UTC. Average verification scores over +12, +24, +36 and +48 h forecasts.
Figure 9: Verification of geopotential forecast profiles against radiosonde observations. Valid time of the day is 00UTC. Average verification scores over +12, +24, +36 and +48 h forecasts.
Configuration of HARMONIE cycling with asynoptic base time

Xiaohua Yang, Danish Meteorological Institute

Introduction

For many operational NWP services, the need to accommodate several time critical, computational intensive NWP suites is a major challenge due to the competitive needs on limited computational resources. This is especially the case in the coming years for the HIRLAM services, of which many face a transition period where forecast systems based on both HIRLAM and HARMONIE are likely to be maintained side by side, and some of these also to be run on ensemble mode. In this study, we examine the feasibility of a proposed strategy for a 6-hourly or 3-hourly mesoscale HARMONIE forecast cycling, in which the data assimilation is configured to be centred around a “base hour” (i.e., the nominal analysis time) that is “asynoptic” instead of “synoptic”. The "synoptic" base hour refers to regular points in time, i.e. 00, 06, 12 and 18 UTC. The construction of an "asynoptic" cycling structure is believed to be effective to secure the HIRLAM member services with a frequent and timely delivery of the operational HARMONIE forecast while maintaining operational cycling of the synoptic-scale HIRLAM system. Hopefully, this will speed up the operationalization of the HARMONIE system at the member services.

Challenges with operationalization of mesoscale HARMONIE

Operational Numerical Weather Prediction (NWP) systems usually run with intermittent data assimilation, in which the basic model states are updated using observation data at regular time intervals, typically every 3, 6 or 12 hours. After the data assimilation, time integration is initiated to obtain forecasts about future atmospheric states. For limited area NWP, apart from observation data, the forecast suites also depend on the availability of lateral boundary data, which is usually the latest available forecast by the "host" model covering a larger domain. For the HIRLAM and HARMONIE systems, the lateral boundary is normally the ECMWF global forecast with ca. 6 h delay.

Traditionally, NWP cycles are configured around “synoptic base time” (00, 06, 12, 18 UTC), with assimilation of observation data collected 3 h before and 3 h after the synoptic base times. This has been natural in the past, in view of the availability of observation data, which consisted mainly of in-situ synoptic (conventional) data available at 6 to 12 h intervals, many of them made manually. Among the conventional observation types, the radiosonde (TEMP) has been shown to be most dominant information source for synoptic-scale NWP and hence crucial for high quality data assimilation. In recent decades, the availability of automatic and often continuous observations for most of the conventional types, especially remote sensing data from satellite, radar and GPS, enabled operational NWP with a more frequent cycling. Presently, for a Rapid Update Cycling (RUC) of 8 cycles per day, additional cycles are typically put evenly around the base hours 03, 09, 15 and 21 UTC in addition to the cycles around the synoptic times, with a synoptic observation data time window of 3 h centred around base time.

Associated with the intermittent data assimilation cycling, the computational load on the High Performance Computer (HPC) facilities at NWP services is often characterised by a strong imbalance. This is especially obvious for operational centres with dedicated operational clusters, on which the
Load tends to peak during the period with operational sessions, while during rest of the time, the load level becomes minimal. To illustrate this, Figure 1 shows the load status for the Cray-XT5 operational cluster at Danish Meteorological Institute (DMI) during a recent 2-day period. The green colour in the plot shows the nodes that are active and the greyish blue the idle. The figure depicts a rather regular 6-hourly pattern, with about half of the time little load, the other half showing a structure of double load peaks that follows each other. The first of such peak starts approximately 1h45m after synoptic time (i.e., 0745, 1345, 1945 and 0145 UTC). After about one and half hour, the second load peak appears, which then terminates about 4-h after synoptic time (06, 12, 18 and 00 UTC). After this, the cluster appears to be rather idle until the next 6-h cycle.

**Figure 1:** An example of load situation on DMI’s operational cluster (Cray XT5) during 23 and 24 Oct 2012. (Source: DMI internal monitoring web page on Cray XT5).

It is worth noting that, in the above actual example, the activities behind those shown in the Fig 1 in form of double peaks that accompany one another, are forecast suites with same base hour, the first for operational HIRLAM forecasts (SKA-3 km deterministic and S05 5-km ensemble), the second for HARMONIE (DKA, 2.5 km with a mesh of 800x600x65). By the nature of the routine NWP forecast, all these model suites are expected to provide time critical forecast information for end users, and as such, need to deliver in time. Clearly, the current arrangement to place the HARMONIE-suites after that of the HIRLAM-ones is an ad hoc choice in lack of sufficient HPC resources, taking into account the assumed top priority for the HIRLAM-forecast suites. As a result, while the HIRLAM forecast results are secured with timely delivery to duty forecasters and other downstream applications, the HARMONIE forecasts could only reach end users with a delay of up to two hours compared to those for HIRLAM.

No doubt, the late delivery of the HARMONIE forecast is a major disadvantage for the development and operationalization of the HARMONIE forecast system at operational HIRLAM services, as this limits strongly the access, hence the use and evaluation by duty forecasters. Indeed, one can often read from the log messages by duty forecasters in DMI that they had to skip the HARMONIE forecast products due to the delay. This is a bit ironic because for the end users of a mesoscale forecast system like HARMONIE, a frequent and timely availability is especially important considering the type of weather phenomena such a system brings into focus, namely the high impact weather that typically features smaller spatial and temporal scales. Such targeted phenomena are also often associated with reduced predictability.
Clearly, the co-existence of HIRLAM and HARMONIE forecast system is one of the main reasons for the delayed availability of HARMONIE forecast, like in the current example. The competitive needs for computation resources add to the constraints for the feasible resolution and domain size for the operational HARMONIE system. Presumably, the need to maintain both computationally intensive HIRLAM and HARMONIE systems for deterministic forecasts may disappear in some years, when the HARMONIE suite completely replaces HIRLAM in operational use. However, it is likely that at many operational services, numerous valid arguments remain to maintain an operational HIRLAM forecast suite for some time to come.

As an alternative to deal with the resource constraints as shown in Figure 1, one may consider to schedule a 4-cycle/day HARMONIE suite using different base hours, such as 03, 09, 15, and 21 h UTC. This will allow a reasonable HARMONIE cycling while having minimal strain on the HPC resources at operational services. Such a cycling setup may be especially suitable for the real time test suite of HARMONIE, (e.g., for testing new cycles or domain configuration changes). The drawback of this alternative, however, is that it does not accommodate conveniently for the comparison between the runs due to the use of different base hours. In addition, this option may also require some extra adaptation at operational services, where the forecast production system and duty forecasters normally are organised along a regular 6-hour shift. Furthermore, a 3-hour shift in cycling base hours does not solve the problem when the HARMONIE system migrates to a 3-hourly RUC, which is the near term target for the reference HARMONIE system.

To summarise, it appears to be a major challenge for operational centres to ensure a timely delivery of the computationally intensive HARMONIE forecasts, especially for the centres that need to maintain production of both HIRLAM and HARMONIE systems during the transition period.

**HARMONIE cycling with asynoptic base time**

Based on the above analysis, we consider here an alternative cycling strategy for the operational HARMONIE implementation, in which the nominal analysis time of the data assimilation is shifted from the conventional synoptic base hours to other, asynoptic ones. Essentially, for the 6-h cycle, the base hour is chosen to be 23, 05, 11 and 17 h UTC instead of the synoptic times at 00, 06, 12 and 18 h UTC. Accordingly, the data assimilation time window for the new base hour is also shifted. E.g., for the cycle with base hour 11 h, observation data between 0800 and 1400 h is used. Accordingly, for the 3-h cycle, additional base hours at 02, 08, 14 and 20 h UTC are added, each with a 3-h time window for observation data.

The selection of a 1-h shift ahead of synoptic time is motivated by the fact that at most HIRLAM services like DMI, both operational HARMONIE and HIRLAM cycling use the ECMWF global model as host to provide the Lateral Boundary Conditions (LBCs), with a 6-h cycle delay. Experiences at DMI show that the first 60-h forecast from ECMWF is typically delivered between +5h40m and +6h20m after the nominal analysis time (base hour).

**Table 1: Operational scenario with a 6-hourly HARMONIE cycling at member services. (time in UTC)**

<table>
<thead>
<tr>
<th>Base hour</th>
<th>Observation Data window</th>
<th>Observation cut-off time</th>
<th>Cycle origin of ECMWF boundary</th>
<th>Launch</th>
<th>Estimated delivery time of 37h forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>05</td>
<td>02:00 - 08:00</td>
<td>06:15</td>
<td>00</td>
<td>06:15</td>
<td>07:30</td>
</tr>
<tr>
<td>11</td>
<td>08:00 - 14:00</td>
<td>12:15</td>
<td>06</td>
<td>12:15</td>
<td>13:30</td>
</tr>
<tr>
<td>17</td>
<td>14:00 - 20:00</td>
<td>18:15</td>
<td>12</td>
<td>18:15</td>
<td>19:30</td>
</tr>
<tr>
<td>23</td>
<td>20:00 - 02:00</td>
<td>00:15</td>
<td>18</td>
<td>00:15</td>
<td>01:30</td>
</tr>
</tbody>
</table>
Taking into account the availability of ECMWF LBCs for HARMONIE, it is feasible to construct a HARMONIE suite that is launched immediately after the arrival of the LBC. Table 1 gives an example of such a schedule of a 6-hourly HARMONIE-cycle. The configuration details for the observation time window, LBC, launch time and estimated forecast delivery time are given for each cycle. Please note that we assume the total production time to be equal to the production time of DMI-DKA at the local platform, i.e. 1h15m.

In Table 2, the corresponding scenario with a 3-hourly cycle is presented. It is probably worth to comment that 3-h cycling may not be very meaningful without data assimilation. In the example given on the table, a 3DVAR cycling is assumed, with the time information based on example that is valid for the DMI platform.

### Table 2: Operational scenario with a 3-hourly HARMONIE-3DVAR at member service

<table>
<thead>
<tr>
<th>Base hour</th>
<th>Observation Data window</th>
<th>Observation cut-off</th>
<th>Cycle origin of ECMWF LBC</th>
<th>Launch</th>
<th>Estimated delivery time of 37h forecast</th>
</tr>
</thead>
<tbody>
<tr>
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<td>00:30 – 03:30</td>
<td>03:15</td>
<td>18</td>
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<td>03:30 – 06:30</td>
<td>06:15</td>
<td>00</td>
<td>06:15</td>
<td>07:30</td>
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<tr>
<td>08</td>
<td>06:30 – 09:30</td>
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<td>00</td>
<td>09:15</td>
<td>10:30</td>
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<td>09:30 – 12:30</td>
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<td>12</td>
<td>18:15</td>
<td>19:30</td>
</tr>
<tr>
<td>23</td>
<td>21:30 – 00:30</td>
<td>00:15</td>
<td>18</td>
<td>00:15</td>
<td>01:30</td>
</tr>
</tbody>
</table>

As is suggested in Table 1 and 2, shifting the base time of the HARMONIE cycling implies a much earlier launch time. For a load scenario as shown in Figure 1, the proposed cycling enables an HARMONIE forecast production well ahead of the regular HIRLAM suites, which are typically organized around synoptic time. As a result, the HARMONIE forecasts can be delivered much earlier than the regular HIRLAM forecasts. Arranging the HARMONIE suites at “asynoptic” times helps to balance the computational load on a HPC system, and it also makes implementation of 3-hourly HARMONIE RUC easier, since it does not directly compete against existing synoptic-scale suites that run at regular 6-hour interval.

### Feasibility experiments and results

To examine the feasibility of running an HARMONIE cycling with asynoptic base time, two 40-day data assimilation cycling experiments for the period of Aug 20 to Sept 30 2012 have been configured on the ECMWF HPC platform:

- a) DKA05C, 6-h cycling of the HARMONIE 37h1 branch with upper air blending, basically following the configuration as specified in Table 1;
- b) DKA05A, 3-h cycling of the HARMONIE 37h1 branch with 3DVAR, with a cycling structure as in Table 2.

These experiments are compared to the real time HARMONIE 36h1.4 run with upper air blending (DMI-DKA). The comparisons concern observation verification, use of observation data and performance diagnosis of the data assimilation and forecast components.

**Configuration.** The blending experiment DKA05C is to a large degree the same as for the present DMI-DKA, with the main deviations as follows:
- these are run at different HPC platforms;
- these are based on different versions of HARMONIE (36h1.4 for DKA and 37h1 for DKA05C); and
• there is a minus 1-h shift in base time of DKA05C w.r.t. DMI-DKA.

The differences between the DKA05A and the DKA05C suite are that DKA05A runs 3-h 3DVAR data assimilation and uses the large-scale background blending option (LSMIXBC). The main idea of the LSMIXBC is similar to the reforecast procedure in the reference HIRLAM system, in which the large-scale information from the “host” model (which provides the lateral boundary) is blended with that of the corresponding native HIRLAM fields. In HARMONIE, such blending is done through spectral nudging of the ECMWF forecast and the HARMONIE background (Ole Vignes, met.no, personal communication).

Use of observations. For the HARMONIE cycling using the blending scheme (DKA and DKA05C), only surface observation data over land (T2m, RH2m) and water (SST) are used in data assimilation. In addition, these systems also use the SST and ice analysis from ECMWF as pseudo observations, which are available for the HARMONIE cycles with a 6-h delay. Thus, essentially only the SYNOP, SHIP and DRIBU type observations are used in these cycling schemes. Since most of these observation data in Europe are available to the NMS’s with rather short delivery time (less than 1 h), and the data are delivered at least in 3-h intervals, in most cases, the 1-h shifted observation time window has in practice no negative consequences on the amount of data entering the assimilation system. For the 3-h 3DVAR cycling with asynoptic base hours (DKA05A), the 1-h window shift also showed little impact, except for the use of radiosonde data. This is due to the fact that most data types are currently either delivered continuously (most conventional data such as SYNOP, SHIP, DRIBU, AIREP/AIRCRAFT, WINDPROFILER, RADAR, GPS), or at other time points which are unrelated to synoptic time (ATOVS, ASCAT etc.). However, few of the radiosonde TEMP data is available at the observation data cut-off time that is more than 1 h earlier than the usual cut-off time at HIRLAM member services. The consequence of leaving out most of radiosonde data in the HARMONIE data assimilation is discussed hereafter.

Observation verification. In Figure 2 and 3 we show the score comparison between the three cycling schemes described above. To facilitate the inter-comparison of the schemes, we have converted the model data from the two “asynoptic” cycling experiments to the forecast initiated 1h later, in order to make them comparable to the results from DKA. In this way, for instance, both the 25-h forecasts of the 11 UTC cycle of DKA05C and DKA05A, and the 24-h forecast from the 12 UTC cycle of DKA, are verified with the same observations valid at 12 UTC on day 2.

By inter-comparing the relative scores of the observation verification results, we hope to get an indication of the consequences of the differences of the tested configurations, such as the difference in HARMONIE system version (DKA – 36h1.4 vs. DKA05C and DKA05A – 37h1); the difference in computation platform (DKA – DMI Cray XT vs. DKA05C and DKA05A – ECMWF IBM); the difference in cycling base hour (DKA – synoptic, 6 hourly, DKA05C – asynoptic, 6 hourly), and the difference in assimilation scheme (DKA05C – 6-hourly blending and DKA05A – 3-hourly 3DVAR).

From the observation verification results shown in Figures 2 and 3, one can see that the mean sea level pressure (MSLP) scores are quite similar for all runs, with the exception that the STD score of MSLP in the asynoptic suites (DKA05A, DKA05C) is slightly worse than in the synoptic suite, at short forecast length. This is presumably associated with the fact that the MSLP score tends to be sensitive to the forecast length at the initial forecast. While at analysis time the DKA run has a fit immediately after blending of ECMWF data, for the converted results of the asynoptic suites the model includes already a 1-h forecast at this “analysis time” and consequently some additional error growth. For the upper air wind, temperature and surface temperature, both the experiment suites outperform the DKA suite, presumably mostly due to the improvement from CY36h1.4 to Cy37h1. For cloud cover, the 3DVAR suite shows a quite stable error growth during the short forecast range. This confirms our previous experience that with 3DVAR and frequent cycling, the HARMONIE system appears to be able to improve on moisture spin-up in general. To further demonstrate this, we show in Figure 4 the averaged time series for the domain averaged rain rate for each model step of the forecast integration.
in all three models, for the entire September month 2012. As is shown in the figure, the spin-up in the 3DVAR suite appears to be clearly better than that in the runs without upper air analysis.

To summarise, the inter-comparison of observation verification scores reveals no major drawbacks. Some differences are obviously due to differences between model versions (T2m and W10m), some are due to the assimilation scheme (cloud), but there is generally little indication of differences due to the shift of base hours. In other words, shifting the cycling start time by 1h does not show indications of score degradation.

**Delivery time.** The data flow of the blending scenario DKA05C is essentially the same as that of DKA and the time for forecast delivery depends mainly on launch time of the suite. As described in section 1, the DMI-DKA runs are launched 2h45m after synoptic base time due to constraints in computational resource, and finish around 4 h after base time. With the shift of the launch time to 0h15m in the new scenario, DKA05C can be finished at about 1h30m, which is two and half hour earlier than the current typical delivery time. The delivery scenario for DKA05A is quite similar to that of DKA05C. Compared to DKA05C, DKA05A includes in addition a 3DVAR step, which typically consume less than 5 min execution time on both ECMWF and DKA platforms. Thus, considering the meteorologically comparable forecast skill of the asynoptic test scenarios and the regular cycling, the most significant benefit of the asynoptic time based cycling schemes is its earlier delivery time.

**Summary and discussion**

Compared to traditional ‘synoptic scale’ NWP, the mesoscale HARMONIE forecast system has its main focus on improved forecast for high impact weather, which often is associated with small scale, rapid evolving weather phenomena with a short life time. Such systems also feature a limited predictability. As such, a frequent data assimilation cycling and timely delivery of forecast products is crucial. This study is motivated from the observation that, in a multi-year transition period, many HIRLAM member services face a dilemma with the need to accommodate two time critical NWP systems, HIRLAM and HARMONIE. While HIRLAM is an operational, computationally intensive NWP system, HARMONIE is often even more demanding. With a conventional data assimilation cycling strategy using synoptic base time, the competitive needs on a limited HPC resource inevitably slow down the pace of HARMONIE development, at least on its operationalization.

Two near real-time numerical experiments have been configured to examine the feasibility of the proposed HARMONIE cycling strategy using asynoptic base times, one with 6-h cycling using a blending scheme, and another with additional 3DVAR cycling. Due to time constraints and other practical reasons, the experiments have not been as thorough as desirable. E.g., the experiment period, which is relatively short, does not contain major severe weather, and no remote sensing data has been included in the data assimilation. Furthermore, the reference model run used in the comparison is based on an earlier HARMONIE version and has been run at a different computer platform. In spite of all that, one may still argue that from the results of the numerical experiments, the relatively insignificant difference in the performance between the asynoptic-time based suites and the operational, synoptic-time based suite DKA, suggests that the proposed alternative cycling scheme may work sufficiently satisfactory, with the bonus of a forecast product delivery several hour earlier than in the current scheme. The new option also enables a rather easy operational implementation of 3-h 3DVAR cycling at operational platforms such as DMI's, thus opening opportunity for future intensified work to assimilate more remote sensing data.

Admittedly, in a configuration with data assimilation cycling with asynoptic base hour, the most important potential flaw lies in the handling of radiosonde TEMP data. Due to a relatively short observation cut-off time in such strategy, most TEMP data with nominal observation times of 00 and 12 will not enter the assimilation cycle centred at 23 and 11 UTC. Thus, an asynoptic time based cycling implies a major deviation from the traditional data assimilation strategy in synoptic-scale
NWP systems, in which the use of radiosonde data is considered crucial. On the other hand, the verification results from this study as shown in Fig 2 and 3 show little indication of negative impact on the usual forecast parameters that represent large scale properties, such as surface pressure, upper air wind, temperature and geopotential height. Presumably, this may partly be attributed to the contribution of the high quality ECMWF forecast that is used both for the lateral boundary and for the first guess blending with large scale mixing. In the latter the large scale background from ECMWF forecast is blended with native model to constrain initial model states. One may thus argue that, some of the information that radiosondes could potentially contribute, may have entered the HARMONIE system via the ECMWF fields. On the other hand, according to a recent study at Meteo-France using 3-hourly AROME data assimilation, (Pierre Brousseu, 2012, HIRLAM-ALADIN All Staff Meeting in Marrakesh), there is no longer dominance of the radiosonde data in the overall HARMONIE data assimilation, which is characterised by a frequent update and use of a wide range of remote sensing data (satellite, radar, ground-based GPS). The same study also concluded that radiosonde data is not one of the data sources that deliver smaller scale observation information. We therefore assume that it is appropriate for future HARMONIE systems to move away from the traditional cycling strategy, where the data assimilation system heavily relies on the availability of intermittent observation data like radiosonde, to a new cycling strategy that fully exploit the new features of HARMONIE like frequent updates and intensified use of remote sensing data.
Figure 2: Observation verification for HARMONIE-DKA (800x600x65) with different configuration: DKA (in red, with 6-h blending with regular base hour, 36h1.4, launch time 2h45m after base hour, on DMI-Cray XT5), DKA05C (in green, 6-h blending with base hour shifted ahead by 1h, 37h1, launched time 0h15m after base hour, on ECMWF IBM), DKA05A (in blue, 3-h 3DVAR with asynoptic base time, 37h1, launch time 0h15m after base hour, on ECMWF IBM). Experiment period Aug 24 to Sept 30 2012. Parameters verified are mean sea level pressure (upper left), T2m (upper right), W10m (lower left), cloud cover (lower right).
Figure 3: Same as in Figure 2 but for vertical profile of observation verification for geopotential height (left), temperature (middle) and wind speed (left).
Figure 4: Averaged time series of domain averaged rain rate along forecast integration, for DKA (6-h cycled upper air blending, 36h1.4, upper), DKA05C (6-h cycled upper air blending, 37h1, middle) and DKA05a (3-h cycled 3DVAR cycling, 37h1, lower), for Sept 2012. The red lines in the middle and low plots are averages for cycles with short forecast length, the green lines for those with normal forecast lengths.
Report on pre-release meteorological evaluation
for HARMONIE 37h1 in HIRLAM-B

Xiaohua Yang

Introduction

During late 2011 and early 2012, a series of extensive and coordinated validation studies of HARMONIE-37h1 has been organised in HIRLAM-B to enable the release of the quality assured HARMONIE forecast system, 37h1.1. Based on the good experiences from the validation of HARMONIE-36h1.3 one year earlier, the validation of 37h1 involves an even wider participation from the HIRLAM community, with an added focus on the determination of the relative performance of cycle CY37h1 in comparison with the tagged version based on the previous cycle, 36h1.4. Staff members from all of the HIRLAM member services and affiliates contributed to the concerted and extensive exercise. The validation involved a number of iterations with various corrections and improvements, which ultimately enabled the official release of 37h1.1 in mid-2012. This note recalls briefly the evolution and tests done for the various tagged CY37h1 versions, outlines the main tested configurations for the evaluation of 37h1 code series, reports the whereabouts of the online materials, and summarizes the main findings.

Who have been involved

The evaluation and testing of 37h1 involved a large number of colleagues in HIRLAM, and it is appropriate to declare right from start that the credits of this coordinated work goes to the whole HIRLAM-B program, especially the following colleagues that have been directly involved in performing data assimilation cycling runs for at least two months:

AEMET: Javier Calvo, Estrella Gutierrez
DMI: Bjarne Stig Andersen, Shuyu Zhuang, Xiaohua Yang
FMI: Sami Niemela
KNMI: Wim de Rooy, Toon Moene
LHMS: Martynas Kazlauskas
Met Eirean: Eoin Whelan, Enda O’Brien
Met.no: Ole Vignes, Mariken Holmleid, Trygve Aspelien
SMHI: Ulf Andre, Lisa Bengtsson, Magnus Lindskog
VI: Sigurdu Jonsson

In addition, some colleagues have also actively contributed to the coordinated work in other ways: Sander Tijm (KNMI), Yann Seity (Meteo France).

Harmonie code series 37h1 and validation experiments

A series of version tags has been made in the reference HARMONIE with a source code based on CY37T1, which ultimately leads to the official release of 37h1.1. In connection with these tags,
numerical experiments with both technical and meteorological nature have been conducted. In the following, we recall briefly the history of the version tagging, and the evaluation work organized behind these tags.

HARMONIE versions tagged prior to the official release of 37h1

**37h1.alpha**, tagged in Oct 2011. This followed some hard work by the HIRLAM system core group on the technical adaptation of the source code based on CY37T1. The tested settings include those for the AROME/surfex physics on the ‘denmark’ domain and ALARO/surfex physics on "scandinavia-5.5" domain. Starting from this version, the ALADIN physics are no longer tested. For AROME, the EDKF option became temporarily the default due to an adaptation problem with EDMFM.

**37h1.beta1**, tagged in Dec 2011. This tag is followed by a major validation phase in which model runs for most of the relevant configuration scenarios and domains for the HIRLAM member services are tested for selected periods, in most case for both winter and summer months. Tests in this phase include comparisons between the EDMFM vs. the EDKF option, upper air blending vs. 3DVAR and 60 vertical levels vs. 65 levels. In addition, experiments are done to find out the impact of a higher LBC update frequency and the impact of surface assimilation vs. surface downscaling. To overcome various encountered scripts problems and stability issues during the validation of 37h1.beta1, different tunings and corrections are made, such as the bug correction in the spectral nudging in the forecast model, and hence the correction in the LSMIXBC option (Ole Vignes, met.no) and a crucial improvement in the algorithm to convert the surface moisture field from the external model (ECMWF and HIRLAM) to that of HARMONIE related to soil ice (Sander Tijm, KNMI).

The tuning of the strength of the surfex drag in SSO and CANOPY-DRAG is done for several domains. The outcome of these runs resulted tagging in 37h1beta2.

**37h1.beta2**, tagged in March 2012.

**37h1rc1 and 37h1**, release candidate (May 2012) and official release of HARMONIE 37h1.1 (June 2012). Prior to the final tagging of 37h1, two monthly-long runs are carried through to confirm sanity of all the bug corrections and modifications, on the “denmark” domain, including use of default the options EDMFM and LSMIXBC.

Validation experiments of HARMONIE 37h1

**Baseline configuration.** The baseline run throughout the evolution of cycle 37h1 uses the default settings as defined in the reference code. The main features include non-hydrostatic, AROME and surfex physics, 6-h 3DVAR and surface data assimilation with conventional data, no-initialization, coupled to ECMWF forecast with a 1-h interval for lateral boundary, and on the "denmark" domain.

In addition, non-hydrostatic ALARO with surfex physics, 6-h 3DVAR with incremental DFI initialisation for the 5.5-km domain of "scandinavia"-5.5, is regularly tested for some of the intermediate versions of 37h1.

**Coordinated validation runs.** For the main validation using system versions 37h1.beta1 and 37h1.beta2, a large variety of model configurations have been run for periods of one month for both winter and summer episodes. If no reference runs from CY36h1 were available, additional runs are made in order to find the relative performance between versions. These experiment configurations use mainly AROME physics with surfex, some ALARO physics, and they are coupled to ECMWF forecasts as lateral boundaries. A large number of model domains used for operational purposes have been selected. Tests are configured for different vertical levels, different LBC update frequencies, the assimilation setup (dynamic downscaling, upper air blending, 3DVAR with or without LSMIXBC).
Furthermore the physics tuning of soil moisture conversion during initial cycling, the EDMFM vs. EDKH condensation and the SURFEX canopy-drag and subgrid scale orographic drag are tested.

Common to all the validation experiments is a desire to get insight in the general technical and meteorological quality of the new system, and possible corrections or remedies in case of deficiencies. As comparison, models are compared to other quality benchmarks such as of ECMWF, HIRLAM and 36h1-based HARMONIE, both in extreme as well as average weather conditions. Validation on many different domains also provides a rare insight on how the HARMONIE model behaves for different domains with different climatological conditions for various situations. For the present cycle, additional attention has been put on the learning sensitivity and tuning potential about AROME condensation scheme (EDMFM vs EDKH), initialisation of soil properties in connection with the conversion of the soil water index from external models, the strength of the canopy drag, the schemes and strengths in subgrid scale orographic drag (SSO) parameterization, the use of background blending with ECMWF data by LSMIXBC, the vertical coordinate and the update frequency of the lateral boundary. The validation experiments also offer an opportunity to examine various technical aspects of the system, such as the computational efficiency for various configurations w.r.t. domain, analysis and forecast options, time steps, the handling of observations, run-time stability, etc.

As a summary, Table 1 lists some of the main validation experiments conducted during the period.

<table>
<thead>
<tr>
<th>Responsible</th>
<th>Domain</th>
<th>Model version</th>
<th>Physics</th>
<th>Assimilation</th>
<th>Episode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andrae, Yang</td>
<td>DENMARK</td>
<td>37h1alpha</td>
<td>AROME</td>
<td>DA with 3DVAR</td>
<td>201008 201001</td>
</tr>
<tr>
<td>Yang, de Rooy, Andersen</td>
<td>SCANDINAVIA A_5.5</td>
<td>37h1beta1</td>
<td>AROME, edkf and edmfm</td>
<td>DA with 3DVAR, LSMIXBC(yes/no)</td>
<td>201008 201001</td>
</tr>
<tr>
<td>Niemela</td>
<td>FINLAND</td>
<td>37h1beta1</td>
<td>AROME</td>
<td>DA with 3DVAR</td>
<td>201008 201001</td>
</tr>
<tr>
<td>Whelan</td>
<td>IRELAND, L65</td>
<td>37h1beta1</td>
<td>AROME, edkf</td>
<td>Blending, 3h/1h LBC</td>
<td>201112</td>
</tr>
<tr>
<td>Andrae</td>
<td>IRELAND, L60</td>
<td>37h1beta2</td>
<td>AROME, edmfm</td>
<td>DA with 3DVAR</td>
<td>201112</td>
</tr>
<tr>
<td>Kazlauskas</td>
<td>LITHUANIA</td>
<td>37h1beta1</td>
<td>AROME</td>
<td>Blending &amp; surface DA</td>
<td>201001</td>
</tr>
<tr>
<td>Calvo, Gutierrez</td>
<td>IBERIA</td>
<td>37h1beta1</td>
<td>AROME</td>
<td>Blending &amp; surface DA</td>
<td>201107 201108 201112</td>
</tr>
<tr>
<td>Jonsson, Yang</td>
<td>ICELAND</td>
<td>37h1beta1</td>
<td>AROME, edkf</td>
<td>Blending &amp; surface DA</td>
<td>201107 201108 201112</td>
</tr>
<tr>
<td>Andersen, Yang</td>
<td>NUUK</td>
<td>37h1beta1</td>
<td>AROME, edkf</td>
<td>Blending &amp; surface da</td>
<td>201107 201112</td>
</tr>
<tr>
<td>Andrae, Bengtsson, Homeleid, Moene, Vignes</td>
<td>SCANDINAVIA A_5.5</td>
<td>37h1beta1</td>
<td>ALARO</td>
<td>DA with 3DVAR, LSMIXBC (yes/no)</td>
<td>201008 201001</td>
</tr>
<tr>
<td>Andrae, Lindskog</td>
<td>FINLAND</td>
<td>37h1.1rc1</td>
<td>AROME, edmfm</td>
<td>DA with 3DVAR, test of soil temperature response</td>
<td>201008 201001</td>
</tr>
<tr>
<td>Andrae, Yang</td>
<td>DENMARK</td>
<td>37h1.1rc1</td>
<td>AROME, edmfm</td>
<td>DA with 3DVAR, LSMIXBC (yes/no)</td>
<td>201001 201008</td>
</tr>
</tbody>
</table>

Table 1: Validation experiments prior to release of 37h1.1
Web-portal with the evaluation results

On the wiki of HIRLAM-B, a summary portal is established to publish the detailed information of the validation experiments, including the information about the configuration of each experiment, the main topic to examine, and the link to the verification results. The web-link for the page is https://hirlam.org/trac/wiki/Harmonie_37h1/ValidationTests which is accessible for everyone in the HARMONIE community. On the HIRLAM forum special sessions/topics have been setup for discussion and exchange of information connected to the joint evaluation. The HIRLAM forum is open to all interested (registered) users to contribute.

Main outcome and future perspectives

As for the previous cycle, the coordinated validation study during the preparation stage of the reference HARMONIE system offers a good opportunity for the large research community in the HIRLAM programme to get directly involved in the preparation of the new HARMONIE system release. An intensive use of the system by a large community helps by itself to familiarize a wider user community with the HARMONIE system. In general it makes easier to detect deficiencies and to improve user friendliness.

The adaptation process of 37T1 to HARMONIE started with usual initial difficulties due to the need to adjust data flow and name-lists. To our satisfaction, many problems detected during the initial phase of the 37h1 development got resolved during the process, to list some examples of these:

- The slow soil spin-up as seen in the previous version, and relatedly, a strong hockey-stick phenomenon associated with the warm bias for the cold winter time in the scatter plots for T2m observation verification, is mostly gone starting from 37h1.beta2, following the implementation of the correction for the conversion scheme of the soil wetness index from the external model to HARMONIE.
- A generally increased surface wind bias has been found to be associated with removal of the surfex canopy-drag option in the default settings for 37T1. Activating this option again reduces effectively the increased wind bias.
- The much increased cloud fraction bias in AROME has been found to be much improved in the tested episodes at the release of 37h1.1.
- EDMFM. This option was initially disabled in 37h1.beta1 due to an adaptation problem. It is put back to default since 37h1.beta2.
- The B-level parallelization and code reproducibility have been solved for EDKDF scheme. For EDMFM scheme, the problem appears to have gone for most cases, but some problems may remain for a very large problem size.
- Stability of running the AROME model. Many crashes have been encountered with 37h1.beta1, but this problem appears to have disappeared with 37h1.beta2 following the bug correction of the spectral nudging.
- LSMIXBC. This initially didn't work, but has become default after a bug correction.
- Numerous other problems and deficiencies in scripts and utilities. Most of reported problems have been corrected.

At the time of the release of 37h1.1, the validation results for the final tested reference settings indicate an overall improvement of meteorological scores, with indications of improvement on surface wind with the exception of mountain areas, cloudiness and precipitation. For large scale quantities such as PMSL and upper air scores, LSMIXBC together with 3DVAR is found to have improved slightly.
Meanwhile, the evaluation also brought forward some interesting findings, such as:

- In general a very small sensitivity between the EDMFM and EDKF schemes for the tested episodes.
- The HARMONIE model, especially with 3DVAR, shows in general very little moisture spin-up, even in the absence of initialisation.
- Over Greenland, Iceland and some Scandinavian mountain areas, the wind speed from 37h1.1 tends to be too weak.
- A quite substantial surface wind bias over some part of Eastern Europe (e.g. Belarus), which seem to be a common feature from ECMWF and HIRLAM.
- It appears to be difficult for the models to predict extreme cold conditions during calm and clear nights.
- Noisy PMSL pattern have sometimes been seen over sea and mountain area. The noisy pattern over sea is often associated with strong wind conditions.

Admittedly, the above summary only reflects some of the personal observations from extensive work done by a large community. Interested readers are suggested to access directly the above mentioned web portal in the HIRLAM wiki and look for more information and inspiration there.

For the future it is envisaged that the practice of a joint validation campaign during the preparation stage of a new HARMONIE cycle will continue. In such a coordinated effort, it is vital to involve as many as possible researchers at each member service, from different expertise areas. In this way a wide range of scenarios that are relevant to the operational implementation at member services are dealt with at an early stage, and various deficiencies, either technical or meteorological, can be identified and eventually solved. Such a wide involvement of the whole community is considered to be a unique potential of the HIRLAM collaboration. Based on the practical experiences from validation of this and the previous cycle, it may be desirable to target the next exercise to be extended as much as possible to the local computational platforms at member services, which shall further speed up the operational implementation of the HARMONIE system at member services and bring a harmonisation in operational systems.
Status of the HIRLAM/HARMONIE systems

Ulf Andræ

Status of HIRLAM

Status of the reference system

The last version of HIRLAM, version 7.4, was released on the 9th of March 2012. The main features of this version is the increased horizontal and vertical resolution of the RCR domain and the introduction of the fresh water lake parametrization Flake. It also includes tuning for surface parameters for improved performance over e.g. the Baltic Sea. Increased precision in the semi-lagrangian calculations removed problems seen e.g. at DMI. In addition 7.4 also includes some interesting non default options such as large scale constraint in data assimilation (Jk), an introduction of the Lie-Penner cloud parametrization and improvements to the alternative cloud scheme STRACO.

After the release of HIRLAM 7.4 hybrid assimilation methods like ETKF and EnsDA have been introduced in the repository. These changes have also brought updates to the EPS version of HIRLAM. These contributions are important for the future versions of GLAMEPS. ECMWF has been on its way to introduce 137 vertical levels operationally for a while. Technically it means that upper air model data can no longer be encoded in GRIB1. GRIB2 has been disseminated by ECMWF for a while now, but with the introduction of 137 levels we have to filter the data before converting them back to GRIB1 and using them as boundary conditions for HIRLAM. The gribconv tool takes care of this and have been successfully tested on real data. For up to date information read more on https://hirlam.org/trac/wiki/ECMWF-137lvl.

Figure 1. Long term evolution of T2M scores for HIRLAM
Operational experiences with HIRLAM

HIRLAM continues to be acknowledged for the good technical stability. On the meteorological side it has been seen that problematic lake temperatures are corrected by Flake in 7.4. In general forecasters continue to be happy with the performance of HIRLAM. It is particularly noted for its rain/sleet/snow mix diagnoses during winter precipitation. The long term performance of T2M can be seen in figure 1.

Status of Harmonie

Almost all HIRLAM countries have one or more semi-operational HARMONIE suites running. The different domains can be seen in figure 2 and the corresponding configurations in table 1. The Lithuanian Hydrometeorological Service is new for this year. MetCoOp, the operational cooperation between met.no and SMHI, is also a newcomer. The benefit of using surface assimilation is well documented and all services but IMO now runs in cycled mode. More institutes also couples HARMONIE directly to ECMWF.

It is clear that HARMONIE is starting to find its place in the production line at the different weather services. From forecasters it is reported a good description of details in cases of strong dynamical forcing and good precipitation structure in cases of convection. The impression of temperature forecasts is mixed with problems of forecasting very cold temperatures on one hand and to warm temperatures over water bodies on the other hands. Both aspects will be treated better in the future releases with an improved surface energy balance scheme and the introduction of Flake in SURFEX. For the screen level wind there are several reports of to low winds, but also good mountain wind forecasts. In general the wind behaviour is very dependent on the surface type and there is more work to be done in this area to harmonize the behaviour.

On the technical side the poor I/O scalability is still an issue for many services. We have also had some reports on the need to reduce the time step of the forecast model to overcome strong upper air wind speed cases. Scalability problems with CANARI and the memory requirements of FULLPOS are other problems reported on the technical side. Some of these problems may be pure configuration problems that we have to deal with in future versions. Problems with large number of boundary interpolation tasks in mSMS as well as problems with the GRIB generating tasks, the listener, have also been reported and will be addressed in 37h1.2.

Table 1: Basic model characteristics of real-time HARMONIE suites in April 2012. All suites runs with AROME at 2.5km using surface assimilation with CANARI and OIMAIN unless nothing else is noted.

<table>
<thead>
<tr>
<th>Domain</th>
<th>Cycle</th>
<th>Size</th>
<th>Levels</th>
<th>DA</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEMET</td>
<td>36h1.4</td>
<td>384 x 400</td>
<td>65</td>
<td>3DVAR</td>
<td>3h ECMWF LBC</td>
</tr>
<tr>
<td>DMI</td>
<td>36h1.4bf1</td>
<td>384 x 400</td>
<td>65</td>
<td>3DVAR</td>
<td>3h ECMWF LBC</td>
</tr>
<tr>
<td>FMI</td>
<td>36h1.4</td>
<td>300 x 600</td>
<td>HIRLAM 60</td>
<td>3DVAR</td>
<td>3h ECMWF LBC</td>
</tr>
<tr>
<td>KNMI</td>
<td>36h1.4</td>
<td>800 x 800</td>
<td>MF_60</td>
<td>3DVAR</td>
<td>3h cycling, HIRLAM (H11) LBC</td>
</tr>
<tr>
<td>Met.Eirann</td>
<td>36h1.3</td>
<td>540 x 500</td>
<td>HIRLAM 60</td>
<td>Blending</td>
<td>HIRLAM 10km LBC</td>
</tr>
<tr>
<td>Met.no</td>
<td>36h1.3</td>
<td>360 x 800</td>
<td>HIRLAM 60</td>
<td>Blending</td>
<td>HIRLAM 8km LBC</td>
</tr>
<tr>
<td>IMO</td>
<td>36h1.3</td>
<td>360 x 288</td>
<td>HIRLAM 60</td>
<td>Downscaling</td>
<td>3h ECMWF LBC</td>
</tr>
<tr>
<td>LHMS</td>
<td>36h1.4</td>
<td>384 x 400</td>
<td>65</td>
<td>Blending</td>
<td>3h ECMWF LBC</td>
</tr>
<tr>
<td>SMHI</td>
<td>36h14.bf1</td>
<td>506x574</td>
<td>HIRLAM 60</td>
<td>3DVAR</td>
<td>3h ECMWF LBC</td>
</tr>
<tr>
<td>MetCoOp</td>
<td>36h1.4</td>
<td>540 x 900</td>
<td>65</td>
<td>3DVAR</td>
<td>3h ECMWF LBC</td>
</tr>
</tbody>
</table>

hydrostatic ALARO 5km
**Harmonie 37h1 status**

After a long period of evaluation and debugging Harmonie-37h1.1 was released on the 13th of June 2012. The main aspects are summarized in table 2. Some services have now updated their operational suites to cy37h1.1. From the user perspective it's worth mentioning the new GRIB1 tables in 37h1.1. Due to several inconsistencies and problems in earlier versions of Harmonie an attempt has been done to clean the parameter definitions. A full description of output parameters can be find on https://hirlam.org/trac/wiki/HarmonieSystemDocumentation/Forecast/Outputlist/37h1.1.

Table 2: Overview of harmonie-37h1.1 updates compared to cy36h1.4.

<table>
<thead>
<tr>
<th>Physics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SURFEX 6.1</td>
<td>Diagnostics of cloud heights according to WMO definitions is now default for AROME.</td>
</tr>
<tr>
<td>Updated EDMFM scheme for shallow convection</td>
<td>Cellular automata in ALARO</td>
</tr>
<tr>
<td>Improved spinup of surface variables through a corrected handling of frozen soil moisture when starting with ECMWF/HIRLAM data.</td>
<td>MUSC, the single column model in HARMONIE</td>
</tr>
<tr>
<td>Optional usage of ECOCLIMAP2 (experimental) through the ECOCLIMAP_VERSION flag</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assimilation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple single obs experiment through the SINGLEOBS flag</td>
<td>Allow for assimilation cycles shorter than 6h (RUC).</td>
</tr>
<tr>
<td>Experimental EKF setup for surface assimilation with SURFEX</td>
<td>Use deep soil temperatures as a proxy for lake temperatures in assimilation.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technical</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Open-MP adaptations and other I/O optimizations</td>
<td>Stand alone code norm checker</td>
</tr>
<tr>
<td>Internal optional build of grib_api</td>
<td>Several mSMS updates</td>
</tr>
<tr>
<td>Reproducibility checks in testbed</td>
<td>More efficient MARS retrievals at ECMWF</td>
</tr>
<tr>
<td>Introduce RUNNING_MODE=operational</td>
<td>research for different behaviour in error treatment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Verification</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Extended station list for verification</td>
<td>New and corrected skill scores.</td>
</tr>
<tr>
<td>New generalized input format for larger flexibility</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diagnostics and postprocessing</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rewritten listener with fewer tasks.</td>
<td>A completely new FA2GRIB conversion table</td>
</tr>
<tr>
<td>Extended list of postprocessing</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HARMONEPS (experimental)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Towards multi model ensemble capabilities</td>
<td>Several technical updates for better performance.</td>
</tr>
</tbody>
</table>
Harmonie-37h1.2

At the time of writing we are about to conclude the 37h1 series with a release of 37h1.2. It collects large parts of the work done on the development of HarmonEPS, radar assimilation, recent corrections in assimilation of ATOVS radiances and usage if VARBC just to mention a few things. It also integrates the adaptation of Harmonie to run climate simulations done at SMHI and KNMI. From the meteorological point of view there are a few corrections in assimilation and surface physics which should help to improve the scores. The overall impact is though still under evaluation. The most interesting technical change for an operational environment is the possibility to run FULLPOS in-line and thus to do very fine grained selection of output during the forecast. For more details on the content of 37h1.2 read more on https://hirlam.org/trac/wiki/Harmonie_37h1/37h1.2_changes.

Coming Harmonie cycles
The preparation for cycle 38t1 was started already in early 2012 and the latest bugfix release from Meteo France was issued at the end November 2012. We are still working hard to get all parts to work well together in our environment. A final release date is difficult to predict but we hope to be able to release an evaluated version in late spring 2013. The latest common cycle between ECMWF and Meteo France, cycle 39, was released in November 2012. For us it means that we have started to collect and evaluate contributions to cy39t1. The joint cy39t1 phasing in Toulouse will start in January 2013 and is quickly followed by a common cycle 40 later in the spring. The main reasons for this very tight schedule for new cycles is the OOPS re-factoring of the IFS code and the introduction of new super computers at Meteo France and ECMWF.

General system aspects

Training and documentation

In September 2012 the third Harmonie system training course was held in Norrköping. The course gathered about 20 participants and lecturers that spent the week learning everything on how to master the Harmonie system. This year some more focus was spent on MUSC, the single column model of Harmonie, and it turned out to be a good educational tool. For more details on the material please have a look at https://hirlam.org/trac/wiki/HarmonieSystemTraining2012. In early 2013 we will do a survey about the need for a repetition of the training during 2013.

A more localized training exercises was performed in Hungary during the spring. During an intensive week a full installation of Harmonie on the Hungarian operational machine was completed. The installation was a good porting exercise and also brought some good changes back into the Harmonie system.

Repository changes

Today Meteo France, ECMWF and HIRLAM have three different systems to manage almost the same source code. With the introduction of cy39t1 Meteo France will change from ClearCase to git. Git is an open source system which is already used by HIRLAM for GLAMEPS and for OOPS at ECMWF. It will also be used to manage the future verification development with our ALADIN partners. Since there is much to gain by using the same system we will start preparing for a shift from subversion to git during 2013.
Acknowledgements

All the above mentioned work is the result of the joint effort of the system group and various researchers in different areas both in the HIRLAM and the ALADIN consortia.

Figure 1: Operational Harmonie domains for the different HIRLAM member countries. Yellow AEMET, cyan DMI, dark green DMI-Greenland, light green FMI, black Met Eirann, light blue met.no, grey KNMI, red MetCoOp, magenta IMO, dark blue LHMS.
# AGENDA (version 10/05/12)

## ALADIN / HIRLAM

### 22\textsuperscript{th} Workshop / All-Staff Meeting 2012

**Palais des Congrés**, Marrakesh, 7-11 May, 2012

<table>
<thead>
<tr>
<th>Sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Monday 7</strong></td>
</tr>
</tbody>
</table>
| *Main room* ~90p | Opening : 1h00  
S1 Data assimilation (including discussion): 5h10  
Reception/ice breaker |
| **Tuesday 8** |
| *Main room* ~90p | S2: Probabilistic forecasting and LAMEPS (including discussion) : 1h50  
1\textsuperscript{st} Poster session: 1h30  
Working group Session 1 (use of high-resolution observations): 1h30  
ALADIN LTM meeting 2h  
2\textsuperscript{nd} Poster session : 2h  
ALADIN CSSI preparation meeting : 1h30 |
| **Wednesday 9** |
| *Main room* ~90p | S3: Dynamics (including discussion): 1h30  
S4: Model physics (including discussion) : 4h10  
visit and Dinner |
| **Thursday 10** |
| *Main room* ~90p | S5: System aspects and verification: 3h30  
Closing session: 0h20  
Working group Session 2 (system aspects): 1h30 |
| **Friday 11** |
| ~20p | HMG-CSSI :9h-18h |

** Talks (including questions) : normally 20' each (10' for Pms during the opening)  
30' for general discussion  
20' for closing session**
Monday, 7 May

08:30-09:00  Registration

09:00-09:50  Plenary opening session. Chair: Jan Barkmeijer
  Opening of the Meeting
  Welcome
  Practical arrangements for the meeting
09:10-09:20  Piet Termonia: ALADIN organizational relevant aspects
09:20-09:30  Jeanette Onvlee: HIRLAM organizational relevant aspects
09:30-09:40  Dijana Klaric: LACE program future
09:40-10:00  Gergely Boloni: C-SRNWP and the new EUMETNET programme phase (2013-2017)

10:00-10:30  Coffee break

10:30 – 12:10 Plenary session 1: Data assimilation and use of observations. Chair: Claude Fischer
10:30-10:50  Fatima Zahra Hdidou & Zahra Sahlaoui: Data assimilation in ALADIN-MOROCCO: State of art
10:50-11:10  Pierre Brousseau: Recent research on AROME-France data assimilation
11:10-11:30  Tomislav Kovacic: Data assimilation at RC LACE
11:30-11:50  Jan Barkmeijer: Harmonie suite at KNMI and future plans
11:50-12:10  Roger Randriampianina: The use of High-resolution winds in ALADIN/Hu

12:10-14:00  Lunch

14:00 – 15:20 Plenary session 1 (...): Data assimilation and use of observations. Chair: Ole Vignes
14:00-14:20  Loïk Berre: Variational ensemble data assimilation
14:20-14:40  Per Dahlgren: Using Jk in AROME 3DVAR, some initial test
14:40-15:00  Jelena Borajova: Flow-dependent data assimilation in HIRLAM/Harmonie
15:00-15:20  Geijo Carlos: Assimilation of AEMET Radar Reflectivity Data in HARMONIE using the Field Alignment technique

15:20-15:50  Coffee break

15:50 – 18:00 Plenary session 1 (...): Data assimilation and use of observations. Chair: Gergely Boloni
15:50-16:10  Claude Fischer: Progress and plans on Observations in MF
16:10-16:30  Roger Randriampianina: On the use of satellite radiances in ALADIN/HARMONIE
16:30-16:50  Sibbo van der Veen: MSG cloud mask initialisation in the Rapid Update Cycle of Hirlam
16:50-17:10  Ekaterina Kurzeneva: Data Assimilation over lakes: introduction and first results
17:10-17:30  Cornel Soci: Improvements to the surface analysis in EURO4M project
17:30-18:00  General discussion

18:30 –20:00 : Reception/ice breaker

Tuesday, 8 May

09:00-10:50  Plenary session 2: Probabilistic forecasting and LAMEPS. Chair: Roger Randriamampianina
09:00-09:20  Yong Wang: R&D status of ALADIN-LAEF
09:20-09:40  Mihaly Szucs: Latest developments around the LAMEPS in Hungary
09:40-10:00  Alex Deckmyn: GLAMEPS setup and verification
10:00-10:20  Inger-Lise Frogner: Plans for GLAMEPS, HarmonEPS and FROST-14
10:20-10:50  General Discussion
Coffee break

11:20 – 12:50: Poster session 1
11:20 – 12:50: Working group 1: use of high-resolution observations

Lunch

14:30-16:30: ALADIN LTM meeting
14:30-16:30: LTM meeting, CSSI members welcome
14:30-16:30: Poster session 2

Coffee break

ALADIN CSSI preparation meeting to HMG/CSSI

Wednesday, 9 May

09:00–10:30: Plenary session 3: Dynamics. Chair: Mariano Hortal
09:00-09:20: Pierre Bénard: Recent developments in AROME dynamics
09:20-09:40: Daan Degrauwe: The implementation of Boyd's proposal in the HARMONIE system
09:40-10:00: Steven Caluwaerts: Potential innovations for the ALADIN-dynamical core? The future of the ALADIN dynamical core
10:00-10:30: General discussion

Coffee break

10:30-11:00: Plenary session 4: Model physics. Chair: Neva Pristov
11:00-11:20: Piet Termonia: ALARO-1: an overview
11:20-11:40: Joris Van den Bergh: Prognostic graupel and new cloud overlap scheme in ALARO
11:40-12:00: Eric Bazile: Evolution of the ARPEGE physics
12:00-12:20: Yann Seity: Status and plans on AROME-France configuration (model part)
12:10-12:40: Javier Calvo: Representation of deep convection in HARMONIE/AROME model

Lunch

14:00-15:20: Plenary session 4: (...): Model physics. Chair: Sander Tijm
14:00-14:20: Laura Rontu: Le Monde Physique de l'HARMONIE
14:20-14:40: Rafiq Hamdi: Coupling SURFEX/TEB to the high-resolution (4km) ALARO: Which benefits for a highly urbanized area, Belgium
14:40-15:00: Patrick Samuelsson: Status of multi-energy balance in SURFEX
15:00-15:20: Margarita Choulga: Estimations of mean lake depth for boreal lakes

Coffee break

15:20-15:50: Eric Martin: Recent advances in the SURFEX governance, scientific and technical aspects
16:10-16:30: Sami Niemelä: Winter-time convection in Harmonie - a heavy snowfall case in Southern Finland
16:30-17:00: General discussion

17:00-: visit and official dinner
Thursday 10 May

09:00-10:20 Plenary session 5: System aspects and verification. Chair: Sami Niemela
09:00-09:20 : Ryad el Khatib : Optimization of CANARI
09:20-09:40 : Enda Obrien : Stabilizing high-resolution HARMONIE
09:40-10:00 : Claude Fischer : A tentatively brilliant overview of cycles and objects
10:00-10:20 : Theresa Gorgas : On the uncertainty of verification measures by reference data

10:20-10:50 Coffee break

10:50-12:20 Plenary session 5: System aspects and verification. Chair: Alex Deckmyn
10:50-11:10 : Ulf Andrae : Status of the HIRLAM/HARMONIE reference systems
11:10-11:30 : Xiaohua Yang: Evaluation of Harmonie Cy37h1
11:30-11:50 : Xiaohua Yang: Verification methods
11:50-12:10 : Tijm Sander : Experiences and user requirements for HARMONIE
12:10-12:40 : Christoph Zingerle : Verification activities in ALADIN
12:40-13:00 : General discussion

13:00-13:15 : Plenary closing session. Chair:Jeanette Onvlee and Piet Termonia
13:00-13:15 : Closing discussions

13:15- 14:30 Lunch

14:30-16:00 Working Group 2 : system aspects

Friday 11 May (9:00-18:00) : HMG-CSSI meeting

09:00-10:30 HMG-CSSI

10:30-10:45 Coffee break

10:45-12:15 HMG-CSSI (...)

12:15- 13:45 Lunch

13:45-15:15 HMG-CSSI (...)

15:15-15:45 Coffee break

15:45-18:00 HMG-CSSI (...)

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<td>Banciu Doina</td>
<td>ALADIN Operational activities in Romania</td>
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<td>Bogatchev Andrey</td>
<td>Status of the operational application in BULGARIA</td>
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<td>Bucanek Antonin</td>
<td>The Evolution of Dispersion Spectra in Blending cycle</td>
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<td>El Ouarini Rachida</td>
<td>Sensitivity of ensemble-based variances to initial background perturbations</td>
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<td>Hamadache Bachir</td>
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<td>Hamdi Rafiq</td>
<td>Regional climate of summer maximum surface air temperature over Belgium through high-resolution dynamical downscaling</td>
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<td>Lindskog Magnus</td>
<td>Correction of phase errors. Warping and balancing</td>
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<td>Meier Florian</td>
<td>Austrian National Poster - activities in the framework of ALADIN/ALARO at ZAMG</td>
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<td>Implementation of and experiments with AROME 2.5km over Austria</td>
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<td>Monteiro Maria</td>
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<td>Pristov Neva</td>
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<td>Sbii Siham</td>
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<td>Stanesic Antonio</td>
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<td>A diagnostic study of the background error statistics in ALADIN/HR data assimilation system</td>
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<td>Szucs Mihaly</td>
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<td>Trojakova Alena</td>
<td>ALADIN@CHMI - operational status in Czech Republic</td>
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<td>Vignes Ole</td>
<td>MetCoOp - Swedish/Norwegian Operational Cooperation</td>
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<td>Whelan Eoin</td>
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<td>Assimilation of new radiosonde observations in Harmonie</td>
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<td>Zaaboul Rashyd</td>
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<td>Bachir Hamadache (dep LTM)</td>
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<td>Theresa Gorgas Florian Meier Yong Wang (dep LTM) Christoph Zingerle (CSSI)</td>
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<td>Steven Caluwerts Alex Deckmyn (LTM, CSSI) Annelies Duerinckx Daan Degrauwe (CSSI) Rafiq Hamdi Piet Termonia (PM) Joris Van den Bergh Rozemien De Troch Geert Smet</td>
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SRNWP : Gergely Boloni