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ACCORD A Consortium for COnvection-scale modelling Research and Development

# LACE/HIRLAM Algorithmic Data Assimilation Developments

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and

LACE/HIRLAM DA Staff

# Outline

- Introduction
- Handling of background errors
- Including host model information
- Flow-dependent data-assimilation algorithms
- Nowcasting
- Conclusions

A Consortium for COnvection-scale modelling
Research and Development

# Introduction

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Hirlam

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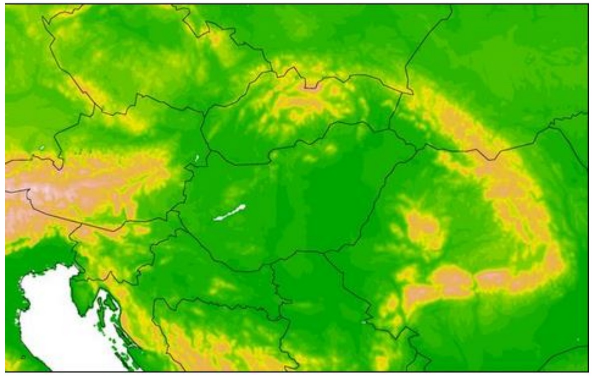
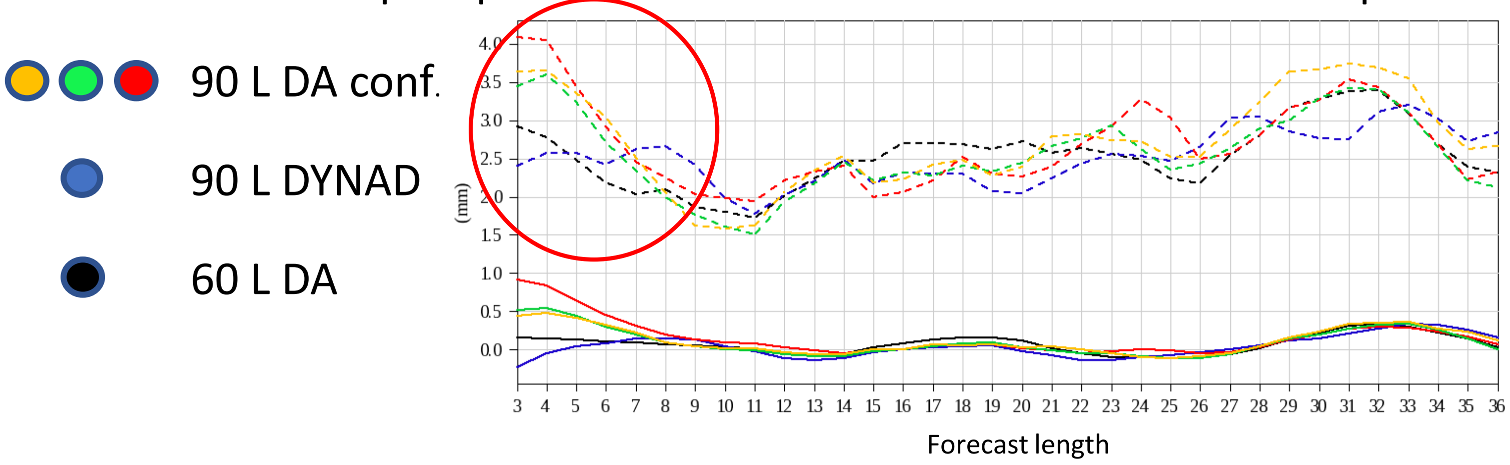
# Tuning of error representation for new vertical geometry

- New vertical geometry for AROME/Hungary (90 instead of 60 levels, but still 2.5 km horizontal resolution).
- Tuning of observation- and background-errors has been carried out by applying the Desroziers‘ method.
- The sensitivity to the tuning was explored by comparing runs with different error tunings for the 90-level configuration (**orange**, **green**, **red**) with each other and comparing also with a 90 level configuration dynamical adaptation run (**blue**) and a run from the operational 60 level configuration (**black**).
- Tuning of the 90-level error characteristics has a clear impact on precipitation spin-up. However, there is still larger **spin-up when data assimilation is applied in the 90-level configuration** as compared with both dynamical adaptation in the 90 level configuration and data assimilation with the old operational 60 level configuration.



Modelling domain and orography.

3-hour precipitation RMSE and bias for a 3 week summer period

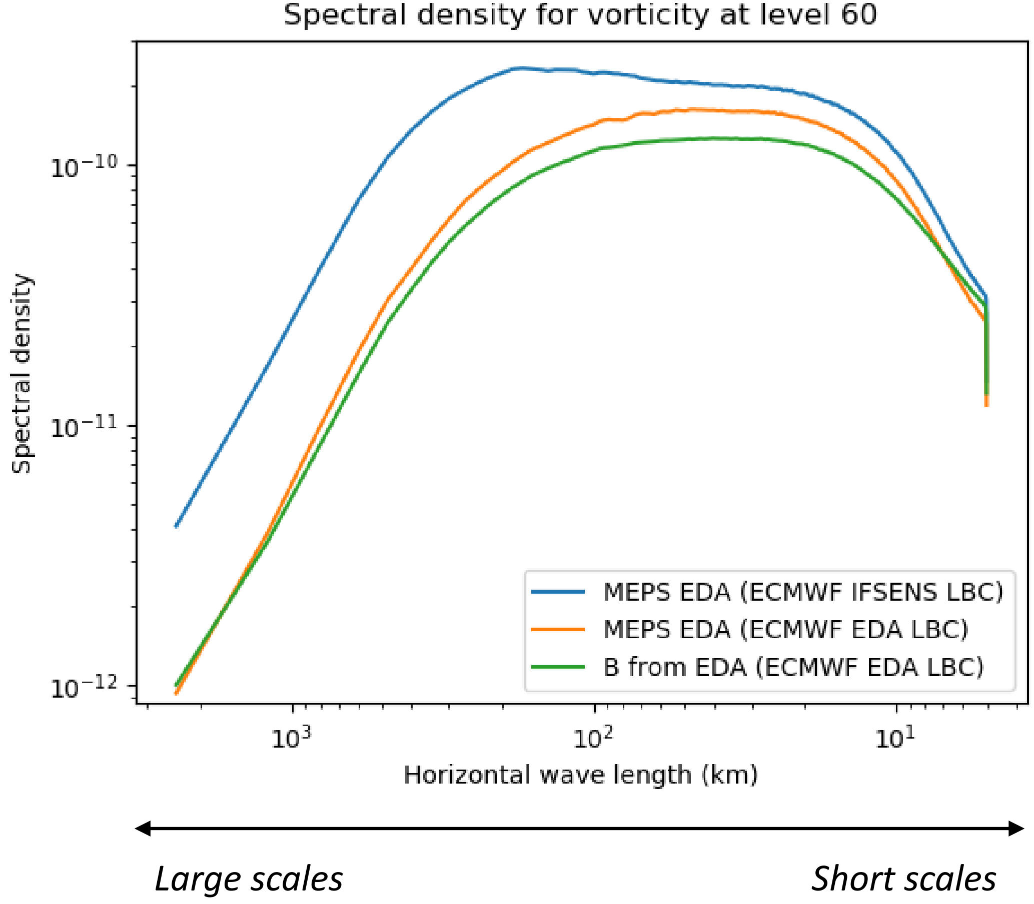



*V. Homonnai et al. (OMSZ)*

# Exploiting the use of an operational ensemble for calculating a B-matrix for potential use in data assimilation

- Operational-like MEPS LAM EDA ensembles have been run for a one-month period to generate background error statistics.
- Operational-like MEPS LAM EDA ensemble uses ECMWF IFS ENS as LBC, which results in too much energy in large horizontal scales in the B-matrix.
- Modifying MEPS LAM EDA to use ECMWF EDA as LBC and modifying the way of using the LBC information in the LAM ensemble has a clear effect. It results in a horizonal background error spectra in better agreement with the operationally used B-matrix.
- The operationally used B-matrix derived applying LAM-EDA, but for a different period than the MEPS LAM EDA.

*(slightly above 1000 hPa)*




*U. Andrae, I.-L. Frogner, M. Lindskog (SMHI, met)*

# Evaluating the effect of introducing host model information through a $J_k$ – term in cost function and of hydrometeor cycling

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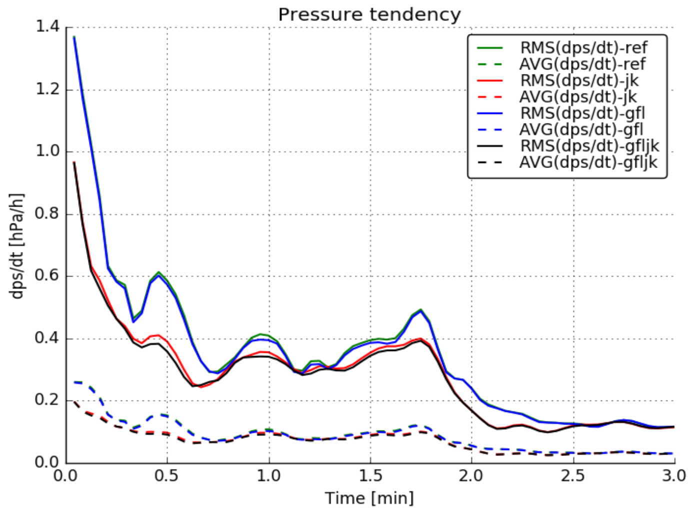
HIRLAM High Resolution Limited Area Model

- A 17-day winter period parallel experiment with significant weather (precipitation, freezing rain).
- Taking host model information into account by introducing a Jk- term in the cost function has a clear impact on reduced spin-up (Figure to the right).

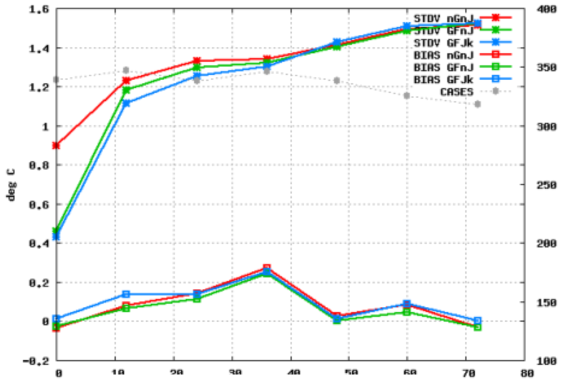
$$\begin{aligned}\min_{x} J(x) &= J_b + J_o + J_k \\ &= \frac{1}{2}(x - x_b)^{\mathrm{T}}\mathbf{B}^{-1}(x - x_b) + \frac{1}{2}(y - \mathbf{H}x)^{\mathrm{T}}\mathbf{R}^{-1}(y - \mathbf{H}x) + \frac{1}{2}(x - x_c)^{\mathrm{T}}\mathbf{C}^{-1}(x - x_c)\end{aligned}$$

- Cycling of hydrometeors has a positive impact on upper-air forecast scores up to 20 h (Figures below).



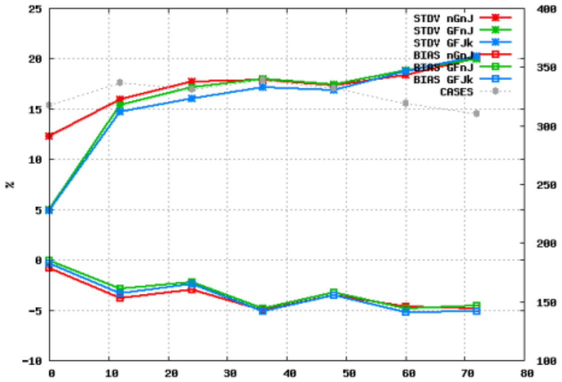

REF
GFL cycling
Jk
Jk + GFL

*STD and Bias for T at 850 hPa*



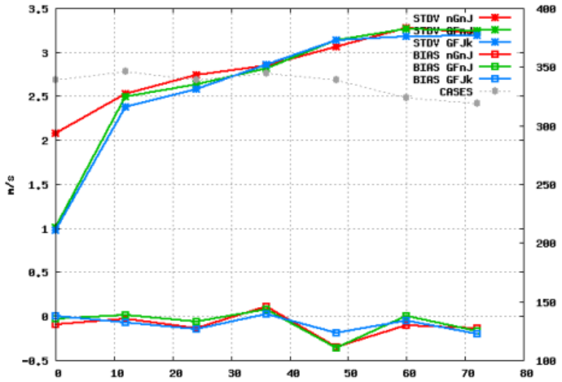

Forecast length (h)

*STD and Bias for RH at 850 hPa*




Forecast length (h)

*STD and Bias for WSPD at 850 hPa*




Forecast length (h)

REF
GFL cycling
Jk and GFL

*E. Keresturi, A. Stanešić et al. (DHMZ)*

# Taking large scale host model information into account

Traditional $J_k$ – formulation with additional term in cost function:

$$\begin{aligned}\min_x J(x) &= J_b + J_o + J_k \\ &= \frac{1}{2}(x - x_b)^{\mathrm{T}}\mathbf{B}^{-1}(x - x_b) + \frac{1}{2}(y - \mathbf{H}x)^{\mathrm{T}}\mathbf{R}^{-1}(y - \mathbf{H}x) + \frac{1}{2}(x - x_c)^{\mathrm{T}}\mathbf{C}^{-1}(x - x_c)\end{aligned}$$

New approach under development and testing:

## *Method*

we define

$$\widetilde{x_b} = \mathbf{C}(\mathbf{B} + \mathbf{C})^{-1}x_b + \mathbf{B}(\mathbf{B} + \mathbf{C})^{-1}x_c$$

and

$$\widetilde{\mathbf{B}} = \mathbf{B}(\mathbf{B} + \mathbf{C})^{-1}\mathbf{C} = \mathbf{C}(\mathbf{B} + \mathbf{C})^{-1}\mathbf{B}, \qquad \widetilde{\mathbf{B}}^{-1} = \mathbf{B}^{-1} + \mathbf{C}^{-1}$$

then

$$J(x) = \frac{1}{2}(x - \widetilde{x_b})^{\mathrm{T}}\widetilde{\mathbf{B}}^{-1}(x - \widetilde{x_b}) + \frac{1}{2}(y - \mathbf{H}x)^{\mathrm{T}}\mathbf{R}^{-1}(y - \mathbf{H}x)$$

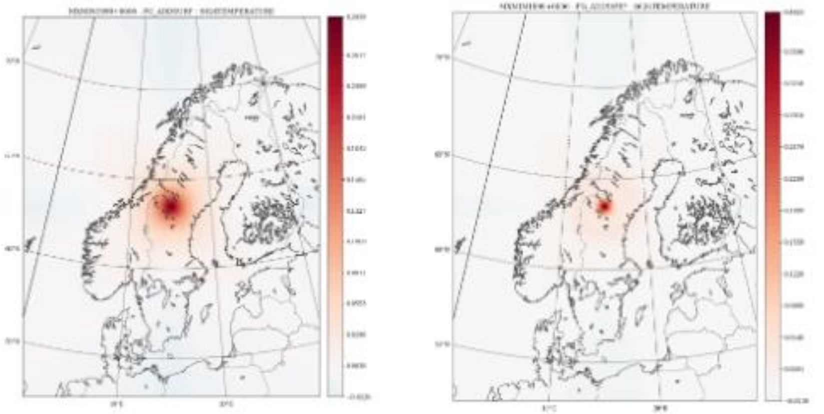
meaning that (at least theoretically) the minimization can be performed without the extra $J_k$ term explicitly present, provided

- we pre-mix $x_b$ and $x_c$ into a new background term $\widetilde{x_b}$
- we use a modified background error covariance matrix $\widetilde{\mathbf{B}}$

Not necessarily any simpler for a completely general $\mathbf{C}$.

## *Example of functionality*

One single temperature observation +1K at 500 hPa, L24, $\rho(0) = 0.4$, $\rho(K-1) = 3$.

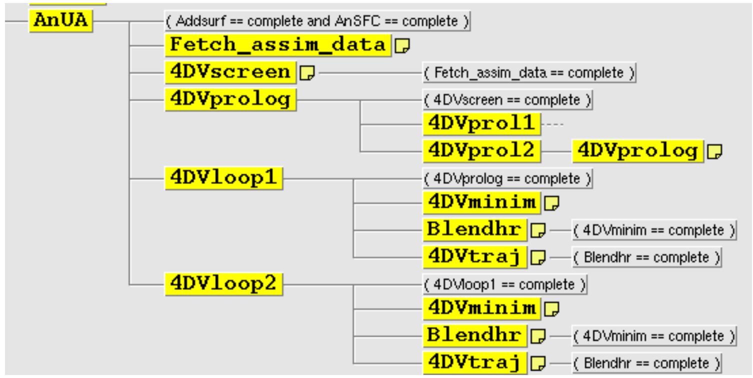


Left with original $\mathbf{B}$, right with spectrally mixed $\widetilde{\mathbf{B}}$.

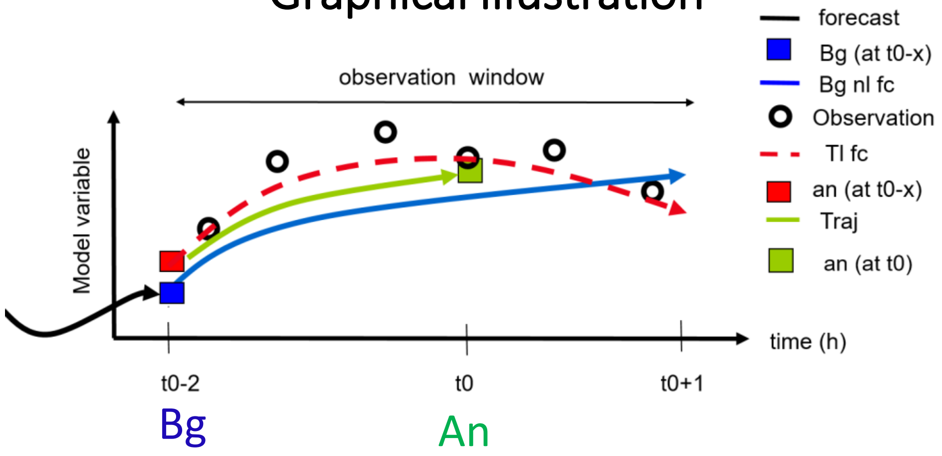
*O. Vignes (met)*

# 4D-VAR

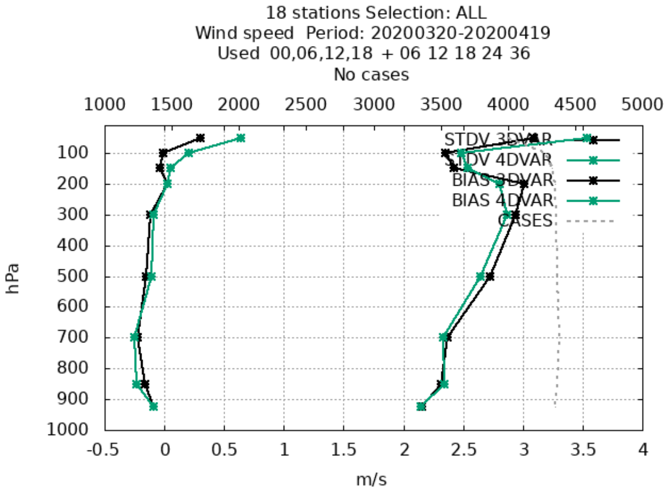
## Multi-incremental formulation

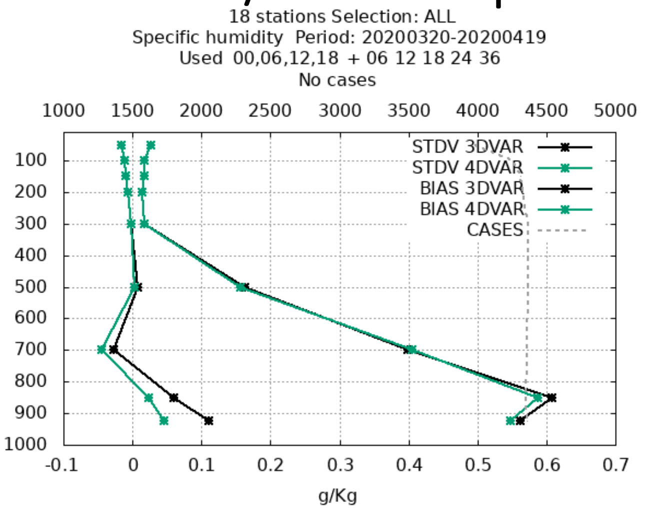



## Graphical illustration




## Verification scores for a one-month 3D-/4DVar comparison




## Conclusions and Outlook

- An operationally feasible 4D-Var available (different parts in single precision)
- Daily runs in operational environment
- Explore use in nowcasting
- Further enhancements planned

J. Barkmeijer et al. (KNMI)

# HYBRID EN-VAR

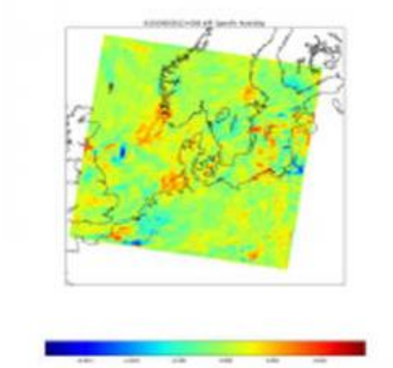
Introducing ensemble information into the variational data assimilation through an α control variable

$$J\left(\delta \boldsymbol{x}_{\text{var}}, \boldsymbol{\alpha}\right) = \beta_{\text{var}} J_{\text{var}}\left(\delta \boldsymbol{x}_{\text{var}}\right) + \beta_{\text{ens}} J_{\text{ens}}(\boldsymbol{\alpha}) + J_{\text{o}}$$

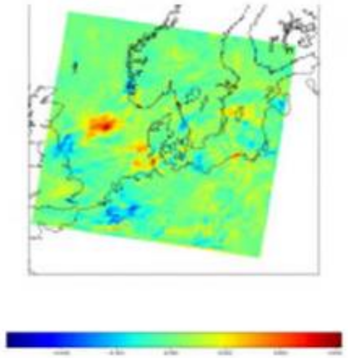
- 20+1 ensemble members
- Compare HYBRID EN-(3D)VAR using ensembles generated with different techniques on EDA, BRAND, BREND
- Different localisation scales
- Visualisation of structures

*Humidity-increments at 700 hPa*

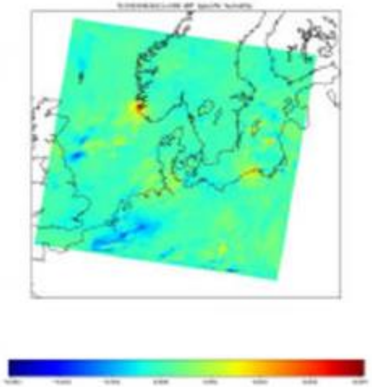
*BREND (500 km)*



*BREND (100 km)*



*EDA (100 km)*



*Jelena B. (SMHI)*

# 1h RUC (1.3 km) compared to operational 3h cycling (4.4 km)

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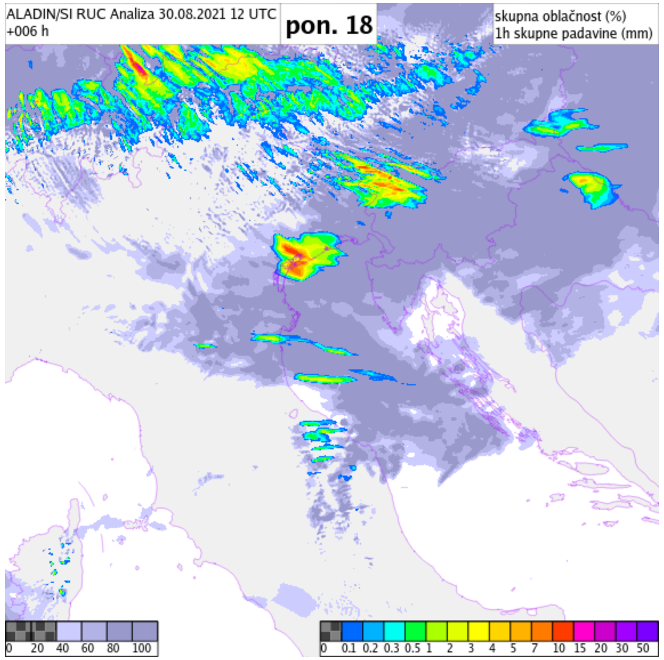
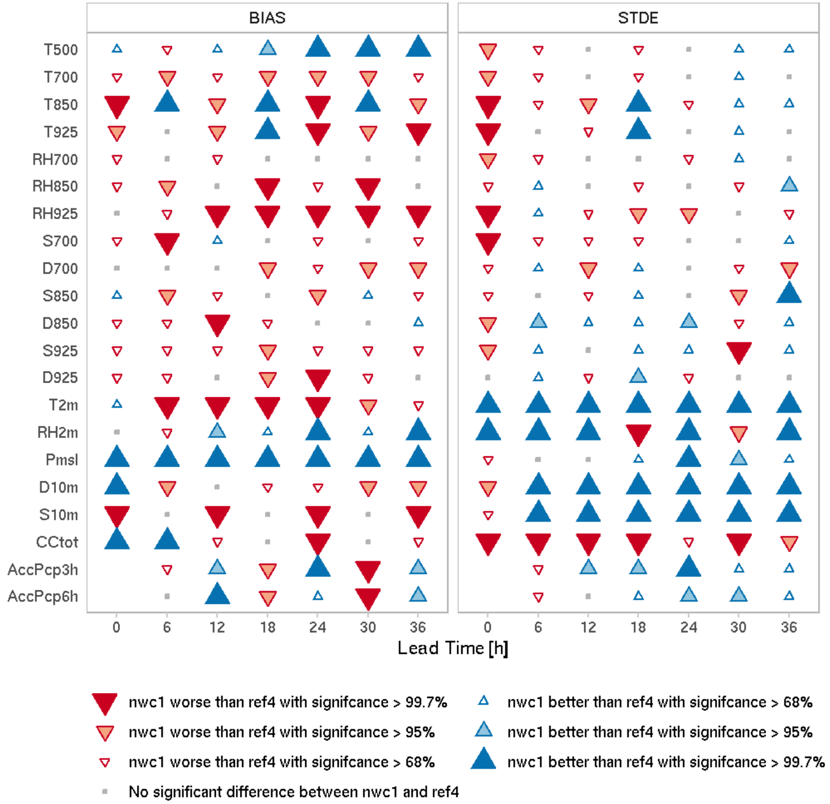
**Results from a one-month winter-period parallel run**

Modelling domain and 1h accumulated precipitation for one particular case




*Scorecard*

***blue – improvement** of hourly vs. 3h cycle - winter*

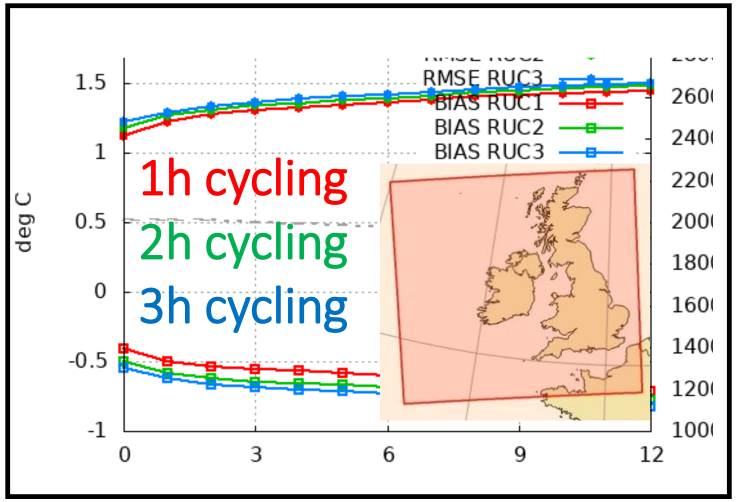


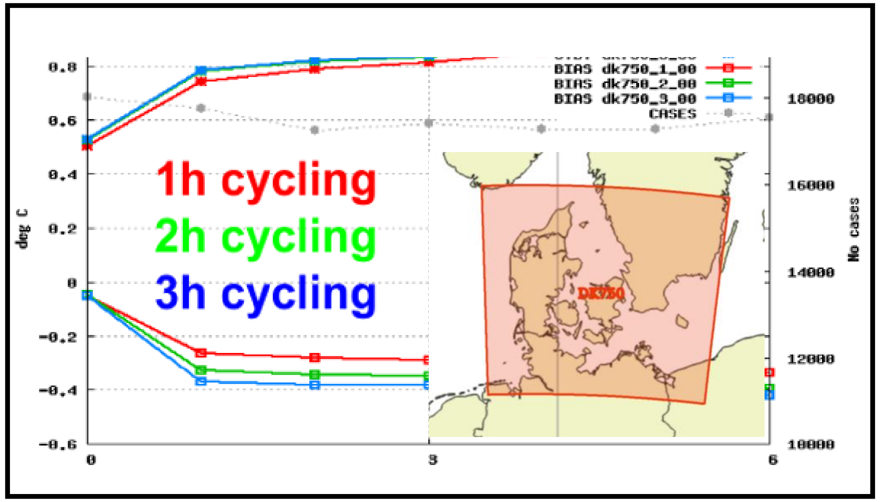

*B. Strajnar (ARSO)*

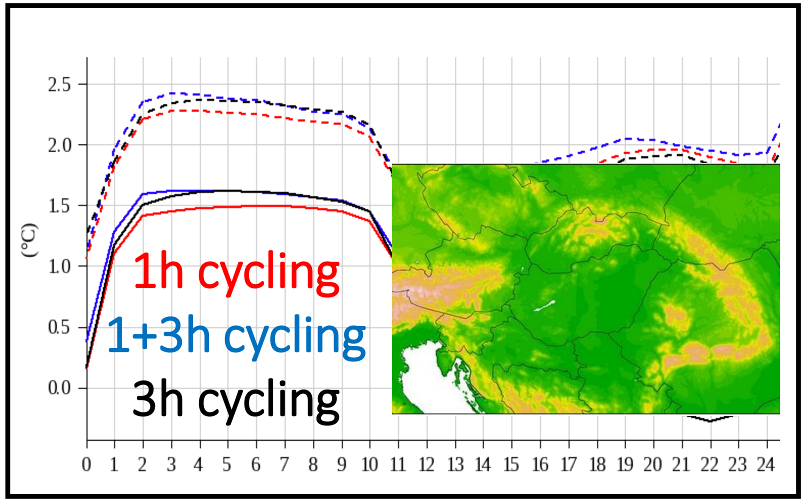
Significantly better at screen level, slightly worse for cloudiness/upper air fields

# Comparing 1h/2h/3h DA-cycles at same model resolution

| Spring<br>std and bias | Autumn<br>std and bias | Summer<br>rmse and bias |
| --- | --- | --- |




Forecast length (h) | Forecast length (h) | Forecast length (h)

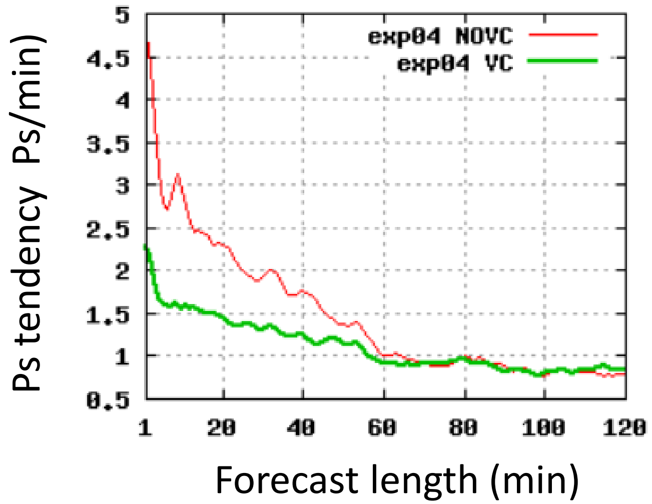
Short range two-meter temperature scores in general better with 1h cycling
(not the same for short range forecasts of moisture variables)

No benefit for this summer period of 1 upper-air DA and 3h surface DA cycle

*E. Harney, X. Yang,* K. Szanyi et al. *(Met Eireann, DMI, OMSZ)*

# On-going work and plans

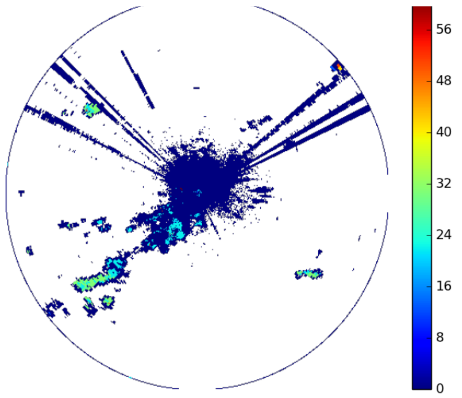
- Exploiting and optimizing time-filtering through initialisation approaches.
- Assimilation procedures adopted to nowcasting.
- Improved use of cloud products (machine learning, optical thickness).
- Methods for handling/initialisation of hydrometeors.
- Various studies of spin-up and sensitivity to observation usage etc.
- A framework for sub-hourly data assimilation cycles is being set-up.




Without filtering

Application of VC

Variational Constraint (VC)
work by C Ceigo, AEMET




*3D hydrometeor classification in a radar scan work by ZAMG*

C. Ceigo, F. Meier., K. Szanyi et al. (ZAMG), S. v. Veen, E. Gregow, T. Landelius, C. Pederssen, A. Stanešić , O. Vignes, M. Dahlbom, J. Bojarova, J. Barkmeijer, B. Stranjar, X. Yang, U. Andrae et al.

# Conclusions

- An operationally feasible 4D-Var has been developed.
- There is on-going work towards bringing data-assimilation and operational ensemble system closer together.
- Taking host model information into account in data assimilation procedure can lead to more balanced initial states and shorter scale analysis increments.
- Encouraging results were obtained with 1h-RUC, although there are remaining challenges.
- LACE and HIRLAM are working increasingly closer together with upper air data assimilation developments within the newly formed ACCORD consortium.

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