CARLOS GEIJO GUERRERO, AEMET (Spanish Meteorological Agency)
cgeijog@aemet.es

Initialization Experiments with Sub-Hourly DA of Radar Wind Data in H-AROME

Intialization methods are relevant to DA for NWC-NWP. In the experiments here presented Doppler-shift LOV winds generated by a C-band weather radar are used to study the impact of an intialization algorithm on the quality of NWC forecasts. The algorithm employed is based on a variational problem that uses the semi-implicit formulation of the fully elastic EE equations in H-AROME as weak constraints to filter the observations induced departures from a well-balanced model state. By construction this "Variational Constraints (VC)" algorithm is effective only on the initialization of the model dynamics (i.e it does not consider the model physics). The experiments verification is done using the own radar reflectivity and wind data.

To be more specific, let Δx be (conveniently non-dimensionalized) departures of the solution from the reference model state; d the departures of the observations from the same reference state ; C_1 ,C_2 ,C_3 ,C_4 the constraints derived form the SI dynamics and expressed in terms of local and non-local vertical operators (ξ coordinate) ; w the free parameter that gives the relative weight between forcing term and constraints, the variational problem to solve is

$$2\,J\,(\Delta x) = \int_0^{\bar{\xi}} d\xi \left(w(\Delta x - d)^2 + C_1(\xi)^2 + C_2(\xi)^2 + C_3(\xi)^2 + C_4\,(\xi)^2\right)$$

The four constraints arise from the vertical and horizontal momentum equations (C_1 and C_2), the full elastic T equation (C_3) and the tendency equation (C_4). When the SI is solved in favour of the vertical velocity these constraints take the form below. The κ stands for horizontal wavenumber, ϰ and ϒ have the usual meaning and H and N are the height-scale and buoyancy frequency of the SI baseline vertical profile respectively

$$C_1(\xi) = L_\xi[\Delta gw] = \left(-\lambda + \partial_\xi(\partial_\xi + 1)\right)\Delta gw(\xi) \;\; ; \lambda = {1 + K^2\gamma(1 + N^2\varkappa)}\big/{N^2\gamma} \;\; ; K = \kappa H N^2 \,;\, H = \frac{RT^*}{g} \,;\;\, N^2 = \frac{g(timestep)^2}{H}$$

$$C_2(\xi) = -K^2\left(1 + \gamma\partial_\xi\right)\Delta gw(\xi) + \,(1 + \gamma K^2)\Delta D(\xi)$$

$$C_3(\xi) = \Delta T(\xi) + (\gamma - 1)\left(\Delta D(\xi) - \partial_\xi \Delta gw(\xi)\right)$$

$$C_4(\xi) = \Delta\pi_s(\xi) + e^{-\xi}\int_0^{\bar{\xi}} d\eta\, e^{\eta}\,\Delta D(\eta)$$

It is noteworthy that this problem can be solved by numerical quadratures using GF kernels and a vertical discretization scheme based on interpolation by cubic splines. These GF kernels are calculated for the following self-adjoint fourth-order differential operator in the vertical downwards running coordinate ξ

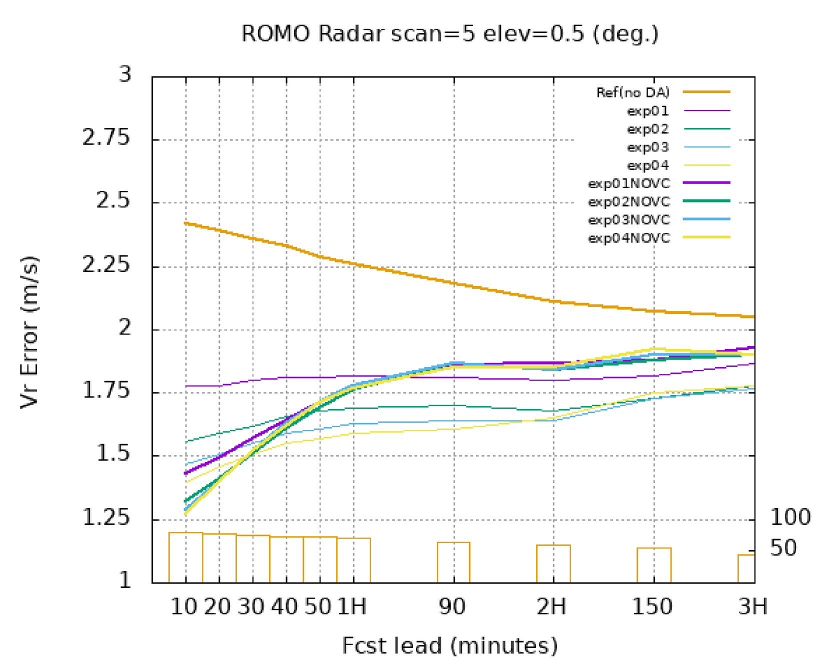
$$O_\xi = b - a\,\partial_\xi^2 + \partial_\xi^4 \;\; ; a, b\; real\; > 0\,;\;\; \Delta gw(0) = \Delta gw(\bar{\xi}) = \partial\Delta gw(0) = \partial\Delta gw(\bar{\xi}) = 0$$

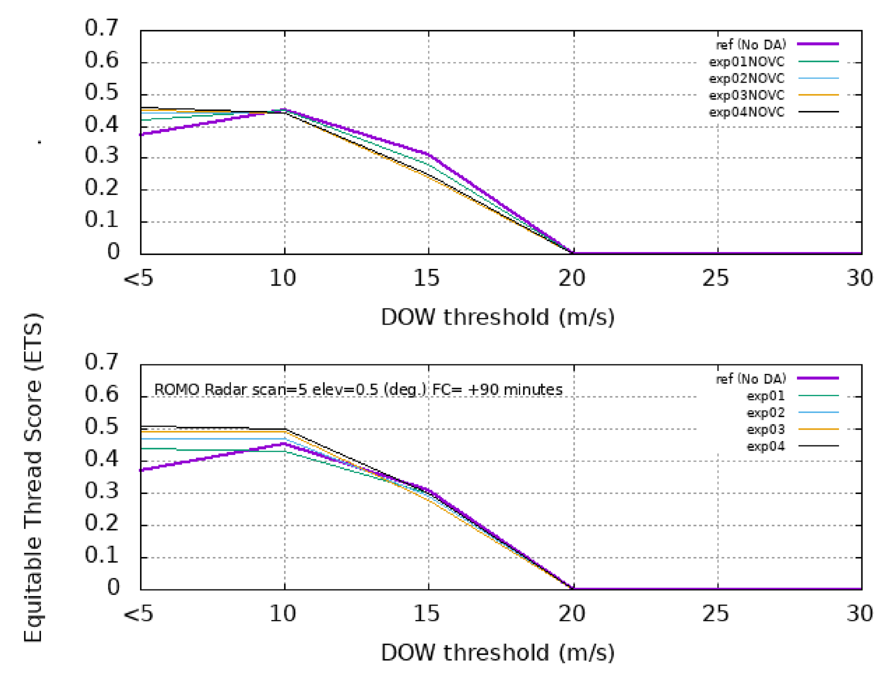
Experiments Set-Up

10-minutes volumes of (quality controlled) wind data from the Danish Römö weather radar collected during the early hours of 23rd May 2023 are used in the initialization of H-AROME by running 10-minutes DA cycles. The LOV Doppler data are processed with the Field Alignment (FA) algorithm to obtain pseudo-observations wind fields which are then presented to the 3D-Var algorithm. An important parameter in this experiments set-up is the number of consecutive 10-minutes cycles or "model wind-up interval" employed. Configurations with up to four consecutive cycles, i.e. time intervals up to 30 minutes before the initialization time, are tested. The 3D-Var multivariate increments are submitted to the VC filter in order to supress remaining noise, and is precisely the impact of this last processing step the main aspect to be analysed in these experiments. NWC forecasts up to 3 hours are considered. The sample size is determined by the availability of enough rainy radar data and turned out to be 22 cases.

Experiments Results (Wind field)

The verification for LOV wind parameter is satisfactory. On the (near) right the error-growth curves are shown. In the NOVC experiments the error increases fast and levels-off after about one hour, while in the VC experiments the departure from observations augments at a clearly slower rate. In the NOVC experiments the initial state draws closer towards the observations but the subsequent evolution of the forecast indicates that the fit contained much noise. Also, the curves for the different experiments (0,10,20 and 30 minutes wind-up interval) are almost indistinguishable in the NOVC case, while they are well separated and monotonous decreasing for the VC case, which means that successive assimilations acted coherently, not so in the NOVC case. There is as well indication of saturation suggesting that 30 minutes wind-up interval, or 4 consecutive assimilations, was not far from the optimal value in these experiments.

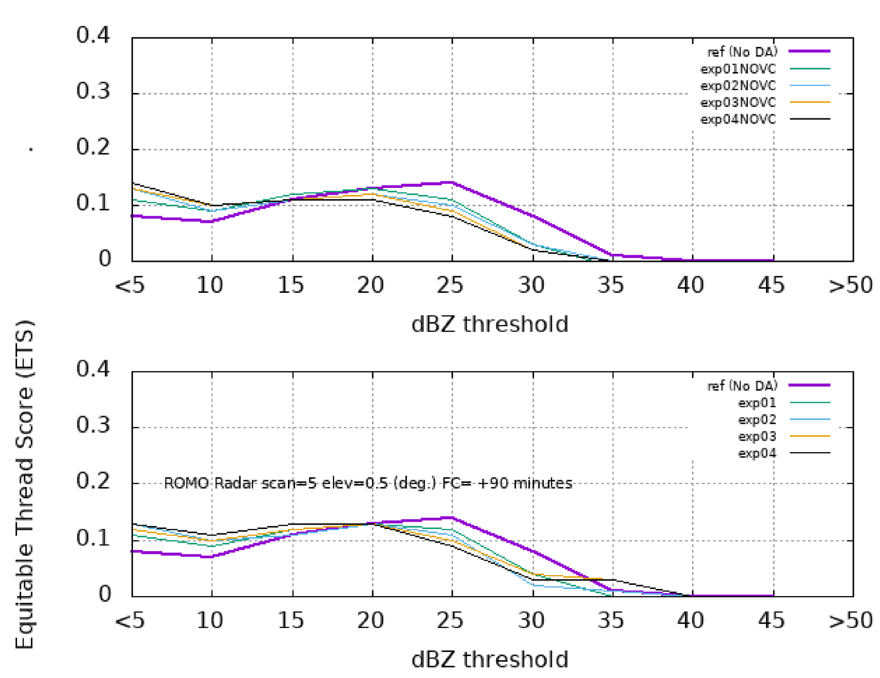


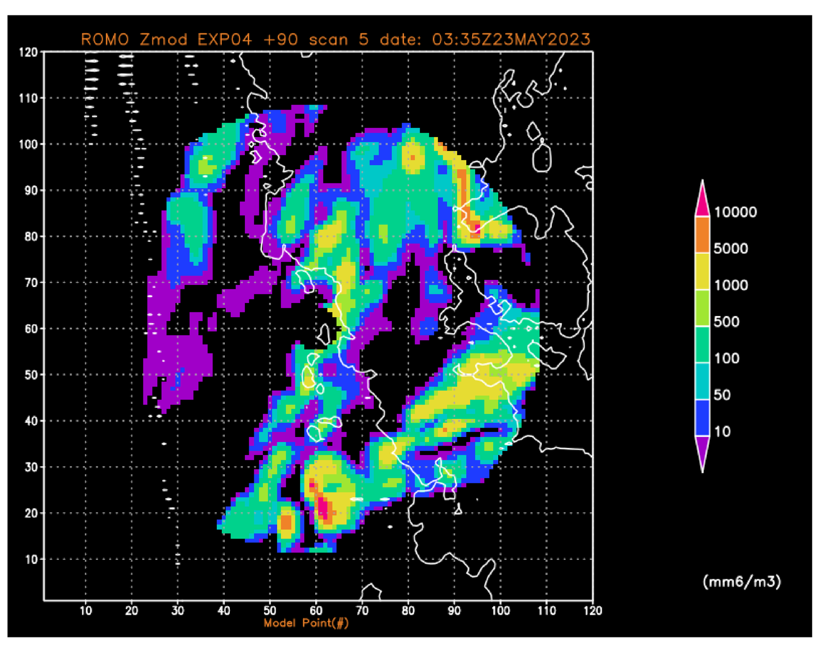


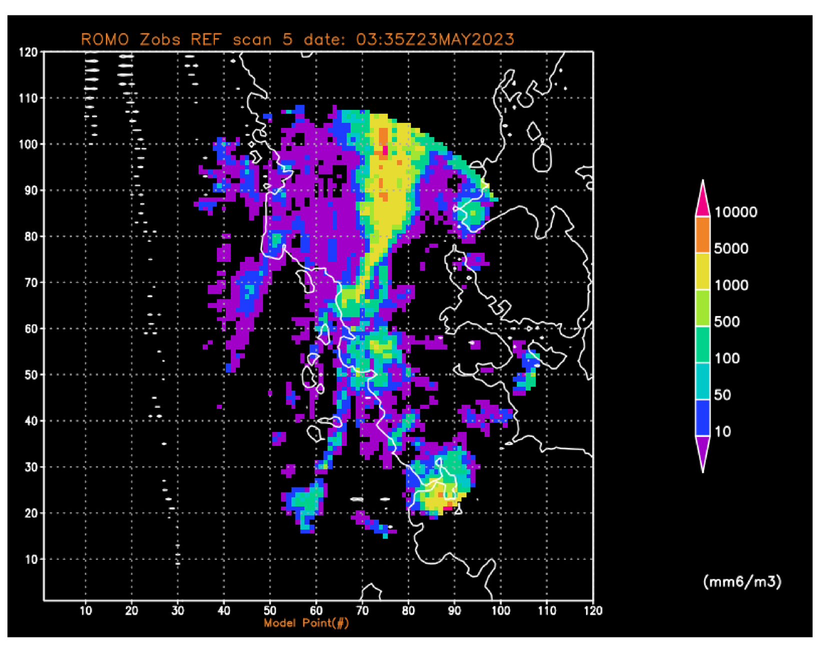
On the (far) right ETS curves for the 90-minutes forecasts at lowest radar scan elevation are shown. Other forecast lead times and radar scan elevations give similar results.

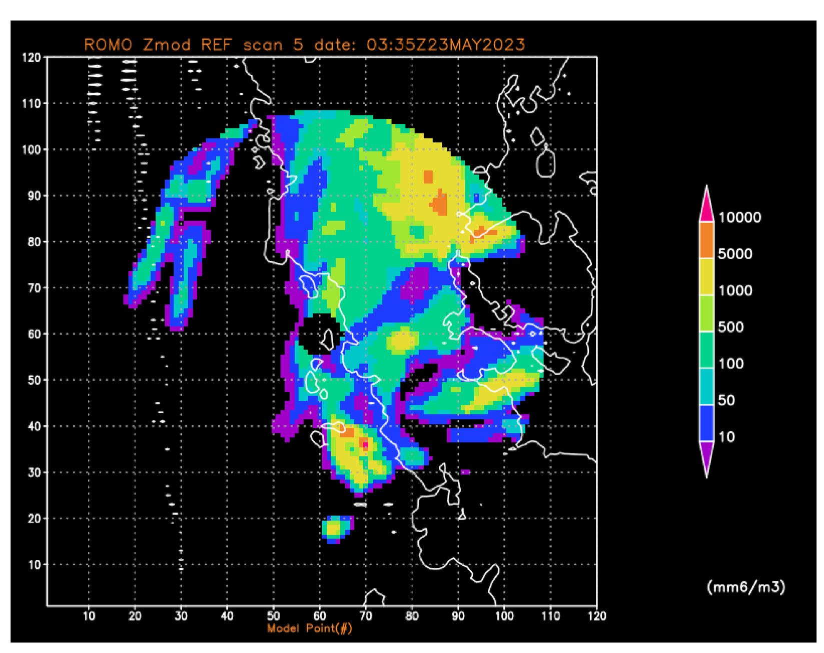
Experiments Results (Reflectivity field)

In these experiments only LOV wind data were assimilated, the VC initialization algorithm does not consider the model physics, but nonetheless verification of rain data is in order. Radar pseudo-images are readily generated with the FA software, a 90-minutes NWC forecast example (IT 02:05 UTC, VT 03:35 UTC) is displayed below. It corresponds also to the lowest Römö elevation operating with ambiguous velocity above 40 m/s, and again other forecasts in the experiment sample and radar scan elevations lead to similar conclusions. The assimilation of the wind data has improved the NWC rain forecast (left) by giving to it a band-like spatial organization more alike to the radar image (centre) than in the reference forecast without wind data assimilated (right). However, prominent (erroneous) features of the original forecast persist or even are aggravated , like local maxima in the pre and post-band areas. At bare eye, differences between NOVC and VC forecasts (not shown) are not significant. More quantitative evaluation of the impact is provided by ETS curves (far left below). These curves compare worse with their counterparts for the wind shown above, there seems to be a slight improvement when VC is applied.









References:
C. Geijo "Exploring Sub-Hour DA in H-AROME". AccordNewsLetters #4 6/2023
C. Geijo, P. Escribá "Variational Constraints for DA in ALADIN-NH Dynamics". HirlamNewsLetters #11 7/2018

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