Radar data assimilation in AROME-France
1st ACCORD All Staff Workshop

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Radar data assimilation in AROME-France

Modifications in the cy46_t1 cycle
  Correction of the observation operator
  Thinning modification
  Tuning of the Bayesian inversion
  Performances

Direct assimilation of reflectivity in a 3d-Envar (with OOPS)
  Context
  How it works?
  Single-obs assimilation
  Impact on forecast
  Perspectives

Bourges radar
Modifications in the cy46_t1 cycle
Correction of the observation operator

Bug corrections:

▶ Calculation of air density in the transformation specific quantity to mass concentration (instead of 1.2)

▶ Add ice content (in the GOM-2d and in the screening namelist)

⇒ Improvement of the AROME-France simulated reflectivities

2d histogram of observed (left) and simulated (right) reflectivities (solid line = obs median, dashed line = model median)
Modifications in the cy46_t1 cycle
Thinning modification

Assimilated wind profiles (27/11/2019 0h UTC)

Comparison of the configurations:

- Configuration cy43:
  - BATOR filtering 5km
  - thinning RMIND=4km, RFIND=8km

- Configuration cy46:
  - BATOR filtering 4km (more coherent with thinning boxes)
  - thinning RMIND=RFIND=8km
  - shifting of the second box (RMIND/2 in both directions)

Impacts:

- number of observations decreases of about 20%
- better geographic distribution
- no more observations closer than 4km
- no impact on the monitoring
Modifications in the Bayesian inversion:

- tuning of the $\sigma_z$ value: 0.2 instead of 5 (now in namelist)
  ⇒ pseudo-observations of humidity more variable but more realistic (see figure)

Bayesian method scheme

\[
\begin{align*}
   &\text{Observations} \\
   &\text{Model first guess} \\
   y_2 &\leftarrow x_U^2 \\
   &H_z(x_i)
\end{align*}
\]

with

\[
y_{\text{po}}^U = \frac{\sum_i x_i^U \exp \left( -\frac{1}{2} J_{\text{po}}(x_i) \right)}{\sum_j \exp \left( -\frac{1}{2} J_{\text{po}}(x_j) \right)}
\]

and $\sigma_z$ is used in the calculation of $J_{\text{po}}(x)$

PPI of retrieved humidity, Blaisy radar elevation 0.5°, 15/10/2019 3h UTC.

cy43 : $\sigma_z$=5
cy46 : $\sigma_z$=0.2
Modifications in the cy46_t1 cycle
Tuning of the Bayesian inversion

Modifications in the Bayesian inversion:

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Changes in the selection of data especially below 3600m:

▶ cy43: reflectivity below 15 dBZ are not taken into account but non-rainy observation are
  ⇒ unbalance between drying and moistening

▶ cy46: reflectivity below 15 dBZ are taken into account

PPI of retrieved humidity, Blaisy radar elevation 0.5°, 15/10/2019 3h UTC.
Experiments have been conducted over few months (three 2-month periods in 2018 and 2019, a 1-month period in 2020). Conclusions are coherent between all the periods:

- obstat show improvements (specially decrease of the bias vs radar humidity and AMSU-B, ATMS and SEVIRI)
- scores vs ground stations (SYNOP, see figures) are quite neutral for temperature and wind but improved for humidity and precipitation rates over 6 hours.
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Context

Mayeul Destouches PhD

Hydrometeors in the control variable of a 3d-Envar assimilation system with OOPS

Guillaume Thomas PhD

Direct assimilation of radar observations (reflectivity and dual-pol variables)

Possibility to act directly on hydrometeors in assimilation system

Indirectly with crossed covariances

Directly with reflectivity observations

What about direct assimilation of reflectivity in a 3d-Envar with OOPS?

Need of TL and AD versions of observation operator...

TL and AD versions of observation operator coded and included in an OOPS version of AROME minimisation code
Direct assimilation of reflectivity in a 3d-Envar (with OOPS)

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How it works?

- Assimilation of relative humidity
- Increment of specific humidity
- Assimilation of reflectivity
- Increment of rain content
- Crossed correlations
Direct assimilation of reflectivity in a 3d-Envar (with OOPS)

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Direct assimilation of reflectivity in a 3d-Envar (with OOPS)
Single-obs assimilation

Direct assimilation of reflectivity in a 3d-Envar (with OOPS)

Specific humidity increment

Assimilation of relative humidity pseudo-observation

Assimilation of reflectivity

Warning, scales are different!
Direct assimilation of reflectivity in a 3d-Envar (with OOPS)

Single-obs assimilation

Rain content increment

Assimilation of relative humidity
pseudo-observation

Assimilation of reflectivity

Warning, scales are different!
Direct assimilation of reflectivity in a 3d-Envar (with OOPS)

Single-obs assimilation

These single-obs experiments show that:

- technically, direct assimilation of reflectivity in a 3d-Envar assimilation system with OOPS is OK
- direct assimilation of a single-obs of reflectivity gives coherent results with assimilation of the pseudo-observation of relative humidity from Bayesian inversion at the same point.

But differences are observed between the two methods (not shown here)...
- is it linked with the assimilation method (direct vs Bayesian inversion)?
- is it linked to the 3d-Envar?

More studies are needed.
Direct assimilation of reflectivity in a 3d-Envar (with OOPS)
Impact on forecast

Experiment to evaluate the impact on forecasts

Description of the experiment

- 17/10/2019 situation
- 1h assimilation cycle over 24 cycles
- Assimilation system: 3d-Envar with OOPS with hydrometeors in the control variable
- Only reflectivity observations are considered
- Two configurations:
  - assimilation of relative humidity calculated from Bayesian inversion
  - direct assimilation of reflectivity

Expectations

- Does the direct assimilation of reflectivity work?
- Do the results are coherent using the two different assimilation methods?
- Do the hydrometeors increments is persistent enough?
Direct assimilation of reflectivity in a 3d-Envar (with OOPS)

Impact on forecast

Specific humidity increment

Assimilation of relative humidity

Assimilation of reflectivity

Specific humidity increments are of the same order of magnitude (tuning of reflectivity sigma-o) and structures are coherent between the two methods.

Scales are the same!
Direct assimilation of reflectivity in a 3d-Envar (with OOPS)  
Impact on forecast

17/10/2019 1h UTC

1h accumulated precipitations (ANTILOPE)

RR1 assimilation HU

RR1 assimilation Z

A better geographic repartition of the precipitations is observed when assimilating directly reflectivity, but some over-estimations.
Direct assimilation of reflectivity in a 3d-Envar (with OOPS)
Impact on forecast

18/10/2019 0h UTC

1h accumulated precipitations (ANTILOPE)

RR1 assimilation HU

RR1 assimilation Z

After 24 cycles, no "explosion" of the rain accumulations when using direct assimilation.
Direct assimilation of reflectivity in a 3d-Envar (with OOPS)

**Impact on forecast**

Direct assimilation of reflectivity has a positive impact on 1h accumulated precipitations:

- visually, impacted areas are better described.
- objective scores show an improvement of the assimilation cycle forecasts performances: strong improvement of Detection rate, no change for False alarm rate.
Direct assimilation of reflectivity in a 3d-Envar (with OOPS)

Perspectives

These results are very encouraging but many topics are under investigation:

▶ more studies on the non-linearity of the TL observation operator
▶ properly modify the screening to separate both assimilation methods for radar reflectivity
▶ study observation error correlations (and tune thinning distance?)
▶ improve non-rainy assimilation
▶ study solutions for zero-gradient for hydrometeor contents

And all the questions that can remain in the 3d-Envar data assimilation method (cf P. Brousseau presentation yesterday).
Thank you for your attention.