Radar data assimilation at convective scale in AROME France: current status, challenges and international cooperations

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6th WMO Symposium on Data Assimilation
1. Main features of radar assimilation within AROME
   • Radar network
   • Raw data: current strategy for quality of radar data
   • Observation operators

2. Assimilation of radar data
   • Strength of the assimilation algorithm of reflectivity (1D+3DVar)
   • Impact on forecast performance, scores

3. Some challenges
   • Specification of spatial error characteristics
   • International cooperations

4. Conclusion
Outline

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French ARAMIS network
- 25 Doppler radars, 13 Polarimetric, between 3 and 11 PPIs in 15’. 1km *1km

Within AROME:
- Radial wind (25)
- Reflectivity (24)

All elevations (cartesian/polar) in BUFR gathered for each radar

Radar observations considered as profiles in the model
• Current strategy: distinction between pixels. Instead of signal filters. Only use of reliable quantitative value of reflectivity (or wind).

• Removal of pixels identified as ground clutter (pulse-to-pulse reflectivity fluctuation), clear air echoes (insects, birds,…), sea clutter, anomalous propagation, strong rain-induced attenuation,…)

Raw data: adopted strategy for preprocessing
Need for some added filtering of the radial winds

Use of a staggered triple-PRT scheme to unfold radial velocity (Tabary, et al. 2006)

Unfolding not perfect: spectral width, level of SNR...

High non-ambiguous velocity needed ~ 50 m/s

Histo against reference with median filter

Obs. minus First-Guess of AROME
After sensibilities studies (Caumont, 2006 and Caumont et Ducrocq, 2007):

⇒ Same radar beam geometry (Z and DOW) considering the Earth’s effective radius model. No horizontal integration along the radar beam.

⇒ Hypothesis fundamental for operational NWP to take into account parallelisation of the code (fast code).

1. For DOW: particule fall speed and weighing by reflectivities not considered, but beam broadening modellized by a gaussian function, Montmerle and Faccani 2009, MWR

2. For Z: Rayleigh retrodiffusion, anaprop and attenuation not simulated, but Z non homogeneous through the beam broadening, Caumont et al. 2011, Wattrelot et al. 2013, under review
Ze only depends upon the relative permittivity of the hydrometeor scatterers and the beam width but not upon the radar wavelength

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Strength of the 1D+3DVar method: use of « no-rain » signal
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- Production of rain by moistening

Saturation in rainy areas
Production of rain by moistening
Symmetrically, use of « no-rain » information to remove rain by drying

Drying thanks to the observed valid non-rainy pixels
Strength of the 1D+3DVar method: use of « no-rain » signal

- Production of rain by moistening
- Symmetrically, use of « no-rain » information to remove rain by drying

☞ A good characterization of the « no-rain » signal is required

☞ Resulting in no humidity bias in the model. *Wattrelot et al. 2013, under review*
Forecast scores for wind field (over one month)

**RMS and bias for 700 hpa wind against own analyses at 24h forecast term**

- **rms référence**
- **rms radar**
- **bias référence**
- **bias radar**

**Simultaneous assimilation of Vr and Z against only Vr:**
Positive impact on wind field

⇒ Coherence between humidity structures and low level wind circulation (better assimilation of radial wind / weakness cross-correlations of B-matrix)

**RMS and bias of wind at 925 hpa against radiosondes, at 12 h forecast term**
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Role of the observation error and impact of the error specification

• B but also R determine the weight and spreading of the observation in the analysis: \( x_a - x_b = B H^T (H B H^T + R)^{-1} (y - H x_b) \)

For B: Talk 8.3 Montmerle and poster B-p13 Ménétrier

• Spatial error correlations (induced by observation operator, quality control, representativeness error...) to be included in R matrix

• But in practice, R diagonal

• To reduce observation density to avoid correlations

❓ Is it possible to revisit the current horizontal thinning?

❓ Do we need to specify spatial observation-error correlations?
• It depends on the ratio between the length-scales of the background-error (in observation space) and the observation-error correlation (Liu and Rabier, 2002)

\[
L_{\text{model}} \sim L_{\text{obs}} = 100
\]

\[
L_{\text{model}} \ll L_{\text{obs}} = 200
\]

Corr. not specified
Corr. specified

Poster B-p06 MTG-IRS

\[
\text{Cov}(d_b, d_b^t) = R_{\text{true}} + H B_{\text{true}} H^t
\]

• Need for finding a reliable estimate for B in observation space... to deduce R
Observation error diagnostics: Hollingsworth-Lönnberg method

Main assumption

- **Observation errors are spatially uncorrelated**

\[
\text{Cov}(d_b, d_b^t) = R_{\text{true}} + H B_{\text{true}} H^t
\]

\[
\Rightarrow \text{Cov}(d_b, d_b^t) \sim H B_{\text{true}} H^t
\]

- **Small jump at 0 km separation: not reliable method if observation error spatially correlated**
Observation error diagnostics: Desroziers diagnostic

Main assumption

- **Specified Obs and Background errors consistent with the true values...**

\[
\text{Cov}(d_a, d_b^t) = (I-HK) \text{Cov}(d_b, d_b^t) \
\Rightarrow \text{Cov}(d_a, d_b^t) \sim R_{true}
\]
Observation error diagnostics: Estimation and correlations

<table>
<thead>
<tr>
<th></th>
<th>Obs. error stddev (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>As specified</td>
<td>2</td>
</tr>
<tr>
<td>HL method</td>
<td>1.49</td>
</tr>
<tr>
<td>Desroziers diagnostic</td>
<td>1.29</td>
</tr>
</tbody>
</table>

- **Iterative research of** $\sigma_o$: no convergence in our case.

- **Question:** Misleading results if correlation length scales for background and observation are too close (Desro et al., 2010)

Spatial Correlation

Correlation

Distance (km)

between 10 and 20 km
Observation error diagnostics: Background-error method

- **Use of an ensemble assimilation (90 members) to estimate \( HBH^t \)**

\[
Cov_{ij} = \frac{1}{N-1} \sum_{k=1}^{N} H(x_b^{k,i} - x_b^i) \left( H(x_b^{k,j} - x_b^j) \right)^t
\]

\(~ H \cdot (B_{\text{ens, estimate}}) \cdot H^t ~\)

\(~ H \cdot B_{\text{true}} \cdot H^t ~\)
Observation error diagnostics: Background-error method

• Use of an ensemble assimilation (90 members) to estimate HBH^t

\[ \text{Cov}_{ij} = \frac{1}{N-1} \sum_{k=1}^{N} H(x_b^{k,i} - x_b^i) \left( H(x_b^{k,j} - x_b^j) \right)^t \]

\[ \sim H. (B_{\text{ens, estimate}}). H^t \]

\[ \sim H. B_{\text{true}}. H^t \]
Observation error diagnostics: Background-error method

- Use of an ensemble assimilation (90 members) to estimate $H^t B_H$

$$
C_{ov_{ij}} = \frac{1}{N-1} \sum_{k=1}^{N} H(x^{k,i}_b - x^i_b) (H(x^{k,j}_b - x^j_b))^t
$$

$\sim H. (B_{ens, estimate}). H^t$

$\sim H. B_{true}. H^t$

Vr – Spatial Correlation

Lo = 41.7 km
Other challenge: European Collaborations

• Full code cooperation between ALADIN and HIRLAM consortia
• But…quality information not sufficiently provided for our assimilation requirements in AROME
• Météo-France is strongly involved in the EUMETNET OPERA programme to specify a homogeneous product for assimilation

Assimilation of Z and DOW from spanish radars is currently evaluated in AROME-France in the HyMex framework
Conclusion: results summary

After several years of operational radar assimilation:

• Preprocessing approach essential for assimilation

• Two steps assimilation of reflectivity valuable in context of strong non-linearities

• Systematic improvement of QPF scores of the first 6h-forecasts (case studies and over long periods). *More results in Wattrelot et al. 2013 MWR*

• Mid to low level wind circulation better improved by simultaneous assimilation of Z and Vr.

• *Other impact of the radar on the AROME system found in the Poster l-p03 Brousseau*

Specification of R to improve assimilation impact…

• First estimates *a posteriori* suggest similar length-scales of Background and Observation error correlation: 15 km (~Lo/2) of thinning is indeed a maximum to not degrade the current system (2.5 km)

• *Tests (not shown) have indeed shown that under 15 km of thinning degrade the system*
Conclusion: prospect and challenges

Current contribution of DPOL:

• New algorithms of non-meteorological identification to be evaluated for assimilation (rain-attenuated pixels correction)

• Work is underway to define the best use of hydrometeor identification in the model: direct assimilation of DPOL variables or hydrometeor contents

• X-band radar to be addressed under DPOL radars

Challenges:

• Essential to get a more realistic R (and B) matrix in order to improve the radar assimilation. More work is needed to find more realistic R

• To increase the density of observations becomes important in the context of near future higher resolution of the AROME model

• To assimilate European radar volume data
Thank you for attention...

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