Optimisation and evolution of the assimilation of radar data in the AROME model at Météo-France

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1. 1D+3DVar assimilation method of reflectivity
   • Strength of the method

2. Estimates of spatial observation-error characteristics
   • Context
   • Methods and results
   • Conclusion and prospect

3. Attempts to assimilate X-band radars of the Rhytmme project
   • Rhytmme project context and experimental setup
   • Analysis and forecast impact
   • Prospect
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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
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

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

For assimilation purposes, noise and (removed) clutter have to be differentiated in the quality flag

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_A good characterization of the « no-rain » signal (knowledge of the sensitivity of each individuel radar, signal not attenuated by rain or orography…) is required (Wattrelot, 2010. ERAD2010 - Sibiu)_

\[ MDZ = f(\text{range}) \]
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Resulting in no humidity biais in the model

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Cost function of the 3DVar:

\[ J(x) = \frac{1}{2} (x - x_b)^T B^{-1} (x - x_b) + \frac{1}{2} (y^o - H(x))^T R^{-1} (y^o - H(x)) \]

R to be specified: standard deviation of obs. error and covariances

- Instrumental error, calibration error, representativity error, errors on observation operator, quality control

⇒ Induce spatial correlations a priori to be included in R matrix

But currently R is diagonal in the system!

Thinning to counteract possible spatial error correlations: only 1 obs. per box of 16 km x 16 km

Questions:

- 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).
Methods and Results

First Method:
- Hollingsworth-Lönnberg method: estimate of the observation-error standard deviation by extrapolation of the (o-g) spatial covariances
Main assumptions: ~ linear obs. operator and observation errors are spatially uncorrelated!

Spatial Covariances for each radar separately

Covariances (m²)

Distance (km)
Methods and Results

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\[ \sigma_o^2 \quad \sigma_b^2 \]

\[ \text{Spatial Covariances for each radar separately} \]

\[ \text{Cov}(d_b, d_b^t) \sim R + HBH^t \sim HBH^t \]
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\[
\sigma_o^2 \sim R + HBH^t
\]

\[
\sigma_b^2 \sim HBH^t
\]

<table>
<thead>
<tr>
<th>Obs. error stdev (m/s)</th>
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<tbody>
<tr>
<td>As specified</td>
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<tr>
<td>HL method</td>
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<tr>
<td>Desroziers diagnostic</td>
</tr>
</tbody>
</table>
Methods and Results

Second Method:
- Desroziers’s diagnostic to estimate spatial observation and background covariances

Main assumptions: agreement between specified observation-error and true error covariances, and large differences between FG and Obs. length-scales of correlation structures
Conclusion and prospect

• Both methods give similar values for the estimate of the standard deviation of observation-error
• The spatially uncorrelated part of the observation error dominates for separation greater than 10 km. Current thinning scale (15 km) is close to this interval
• To reduce observation interval need to introduce explicitly observation-error covariances in the observation-error matrix

However, unexpected results on spatial correlations: it suggests possible no separation between FG length scale and Obs. length scale of correlation structures!

Prospect

• Randomized estimates of HBH\textsuperscript{t} to deduce R = E(d_{b} d_{b}^{\dagger}) – HBH\textsuperscript{t} to be compared to DES’s diagnostics
• Similar computations for humidity relative retrievals (from reflectivity) are underway
• ditto to estimate inter-radar correlations: could lead to assimilate more data in areas covered by several radars
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X-band technology and Rhytmme Project Context

- Project to prevent HYdrometeorological Risk in Mediterranean and Mountain areas: **S. Westrelin - 11.5, F. Kabeche – 6.5, J. Beck – 13A.4**
- 4 polarimetric X-band radars to be deployed before 2013
- Improvement of the radar coverage in the Southeast of France
- Complement the S-band radars coverage (less clutter, better in lower rain, but strong rain attenuation, wet radome…)

Experimental setup:

- Separated impact of radial wind, SPOL and DPOL reflectivity (technical problems from the radar production team)
- Evaluation of Mt-Maurel X-band radar added in the assimilation system (10 elevations)
- Evaluation of
  - convective rain assimilation (during Autumn 2011)
  - snow cases (3 weeks January/February 2012)
  - Convective case studies (July 2011)
Doppler Radial Wind

- Triple PRF are needed to get a non-ambiguous velocity around 50 m/s
- Ratio of PRF needed to be close to 1 to get such high velocities (important for assimilation purposes)

- Important noise after unfolding of the wind (low PRF)
- Median filter may be insufficiently reliable (oversmoothing if raw data are too noisy). First-guess QC is enhanced: 15 m/s against 20 m/s
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However, consistent analysis increments can be observed in some cases…
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Results summary:

- Consistent analysis increments
- Neutral to slightly positive impact for short-term precipitation scores and neutral impact for other forecast scores

10 days Oct/Nov 2011

With Maurel
Without Maurel
Reflectivity

- Removal of beam-blocked pixels and correction of rain-attenuation up to 15 db
- DPOL reflectivity meaning: clutter removing algorithms and PIA correction of $Z_h$
- Use of the differential phase $\Phi_{DP}$ to estimate the Path Integrated Attenuation PIA:
  - Pixel identified as “RAIN”: $Z_{corr} (\text{dbZ}) = Z (\text{dbZ}) + \gamma_h \cdot \Phi_{DP}$ : Z corrected!
  - Pixel identified as “NO-RAIN”: $Z_{corr} (\text{dbZ}) \leq M_D (\text{dbZ}) + \gamma_h \cdot \Phi_{DP}$

Extinction : Minimum Detection Reflectivity is enhanced: 40 dbZ!

Extinction : Correction of the $Z_{simulated} > M_D (\text{dbZ}) + \gamma_h \cdot \Phi_{DP}$
Results summary:

=> Degradation of QPFs scores with use of SPOL reflectivities (not shown)
=> Slight degradation of the fit of the FG against the neighbouring radars (neutral for other forecast scores)
Prospect

⇒ X-band polarimetric Mt-Maurel radial wind and reflectivity monitored in AROME parallel E-suite
⇒ Real-time assimilation of radial wind in AROME-WMED SOP1 (Autumn 2012) of the Hymex Project

Limitations:
⇒ Improvement of radial wind quality is required to have a better impact on the model
⇒ Dual-polarisation PIA correction absolutely necessary to assimilate the reflectivity
⇒ No shown added value by DPOL reflectivity assimilation

Questions:
⇒ PIA correction used too far away from the radar?
⇒ Can the high non ambiguous velocity required for assimilation be revisited?

Question: Can X-band radar be propitious for our current assimilation systems?
Thank you for your attention!
• What happens if the model doesn’t contain enough consistent thermodynamic profiles with the observed « radar » reality?
• Artificially saturation (or dryness) unwanted (because of humidity positive bias)
Strength of the 1D+3DVar method: original quality control

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- A 1D convergence checked by an original quality control based on the observed minus analyzed reflectivity departures preferred!
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1D+3D-Var methodology

- **Model background**
- **3D-Var Analysis**
  - \( T, ps, q \ldots \)
- **Model analysis**

1D retrieval

\( Z_{Obs} \)

Obs
Use of model hydrometeors to get a relative humidity retrieval from reflectivity (1D) and modify $T$, $p_s$, $q$, $\text{Div}V$… by 3DVar

Caumont et al. 2010
Use of model hydrometeors to get a relative humidity retrieval from reflectivity (1D) and modify T, ps, q, \( \text{DivV} \)… by 3DVar

Caumont et al. 2010
Convection better analyzed and forecasted in Southwest of France.
Simulated reflectivity
Arome – P3

Reliable ground gusts in agreement with observations

with REFL

without REFL

Composite – 21h

Composite – 00h

Simulated reflectivity
Arome – P3

Simulated reflectivity
Arome – P3

with REFL

without REFL