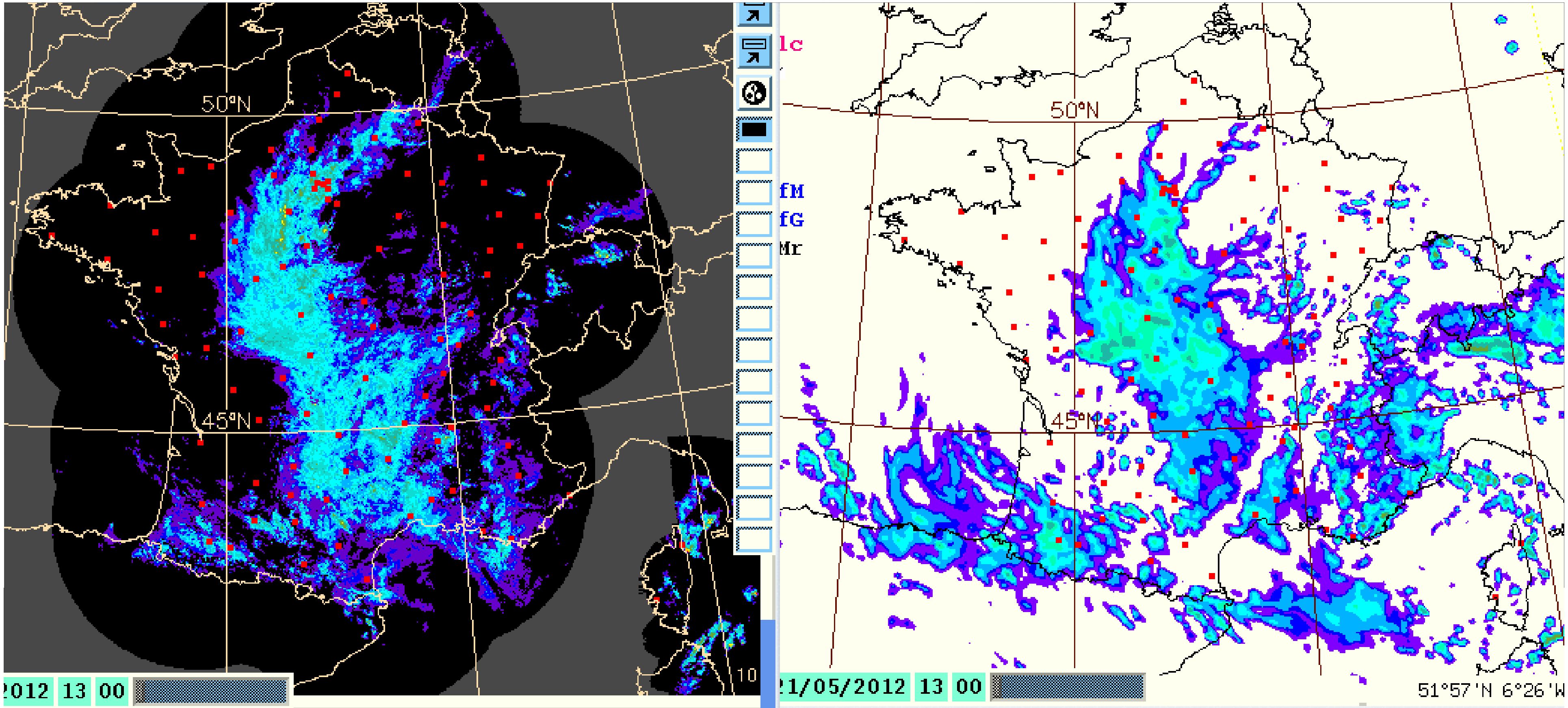


Optimisation and evolution of the assimilation of radar data in the AROME model at Météo-France

Eric Wattrelot

ERAD 2012 – 29/06/2012

METEO FRANCE
Toujours un temps d'avance

Outline

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

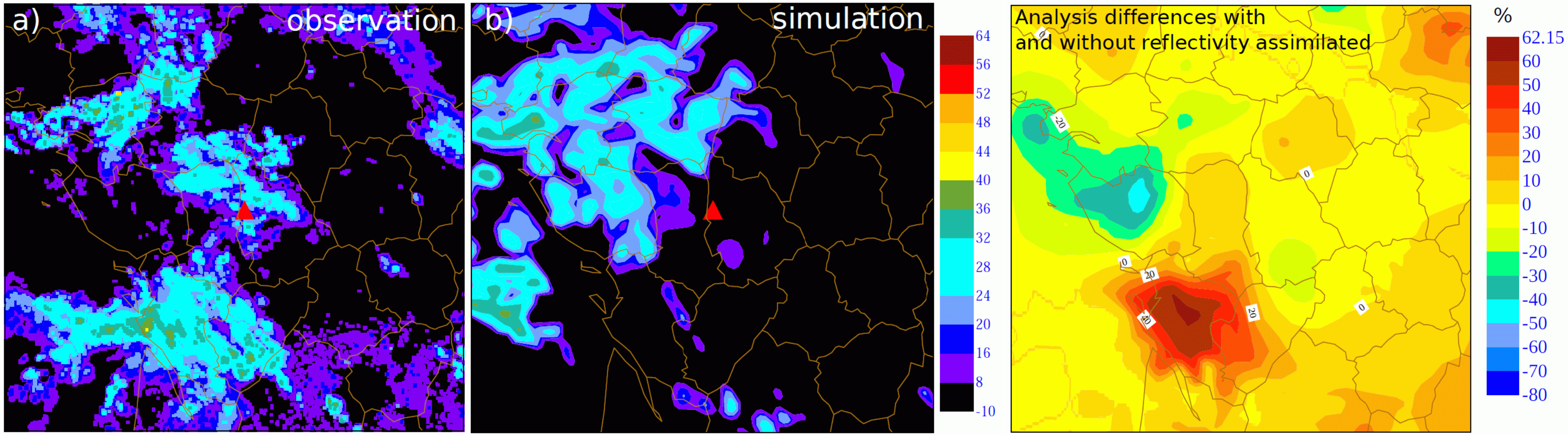
Outline

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

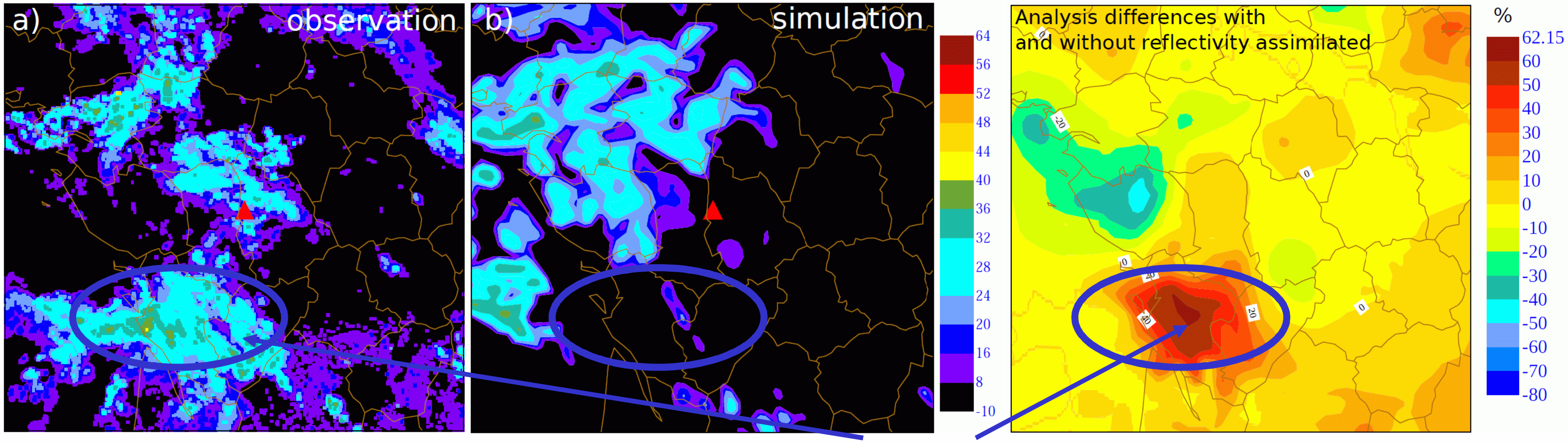
3. Attempts to assimilate X-band radars of the Rhytmme project
   - Rhytmme project context and experimental setup
   - Analysis and forecast impact
   - Prospect

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



METEO FRANCE
Toujours un temps d'avance

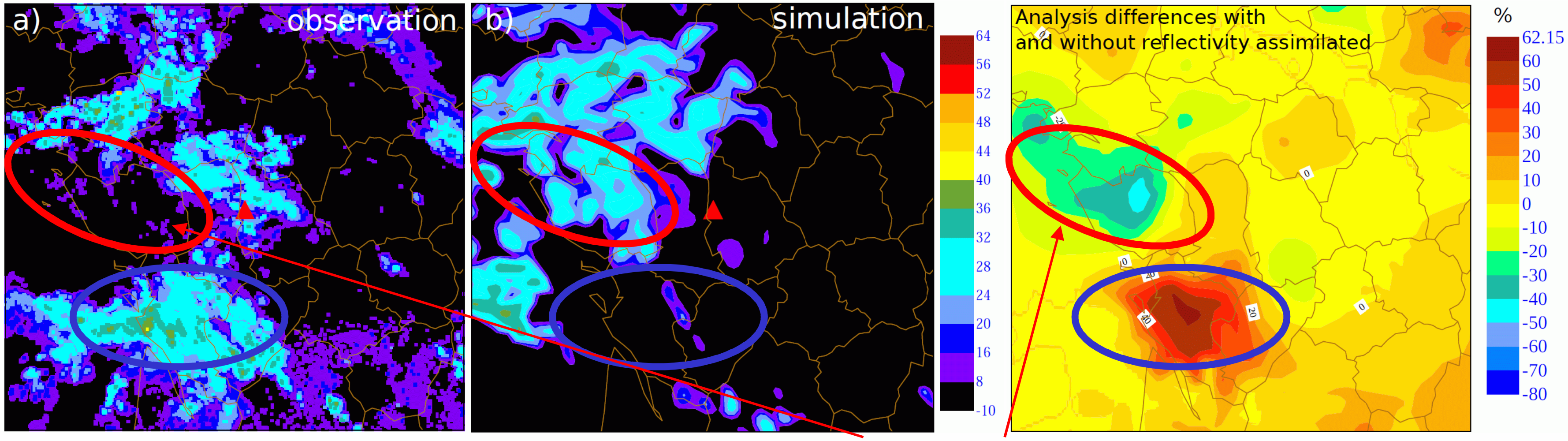
Strength of the 1D+3DVar method: use of « no-rain » signal



Saturation in rainy areas

- Production of rain by moistening

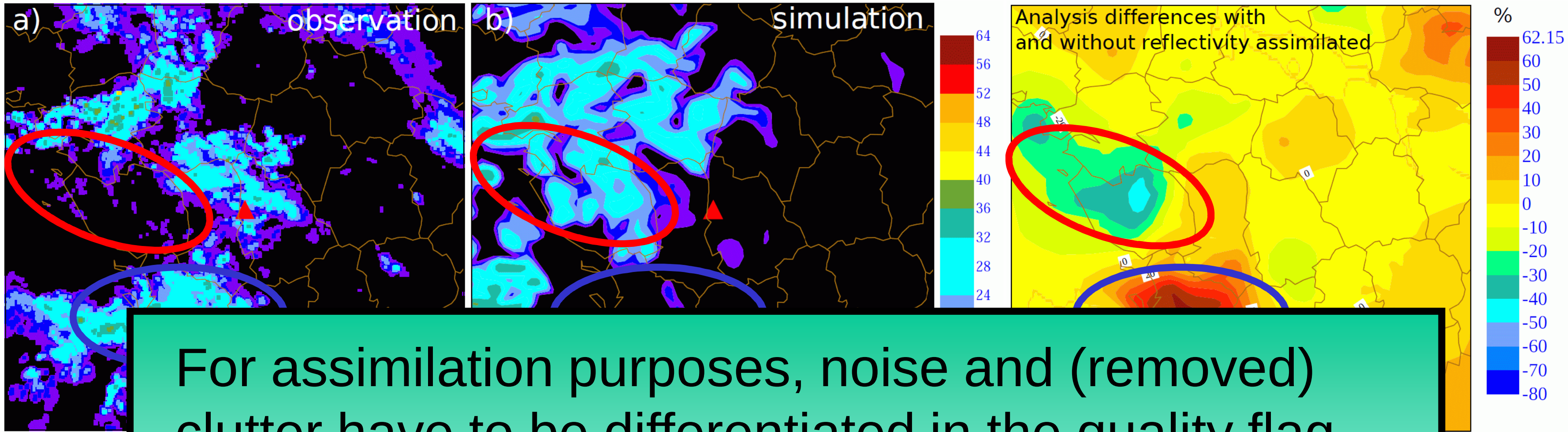
Strength of the 1D+3DVar method: use of « no-rain » signal



Drying thanks to the observed valid non-rainy pixels

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

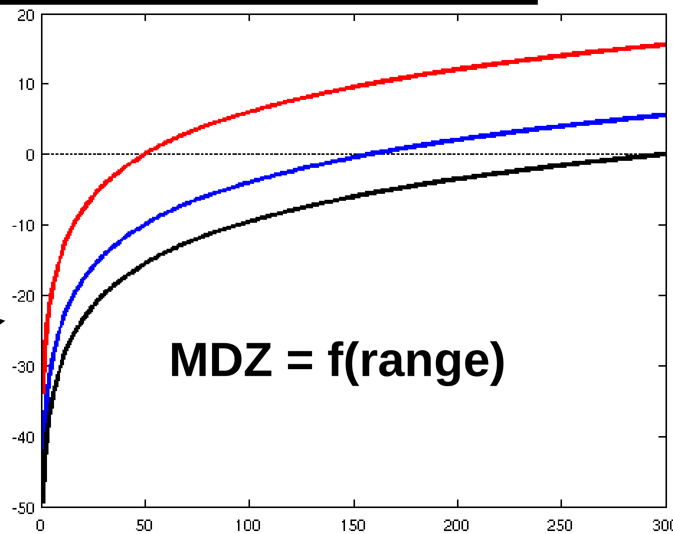
Strength of the 1D+3DVar method: use of « no-rain » signal



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

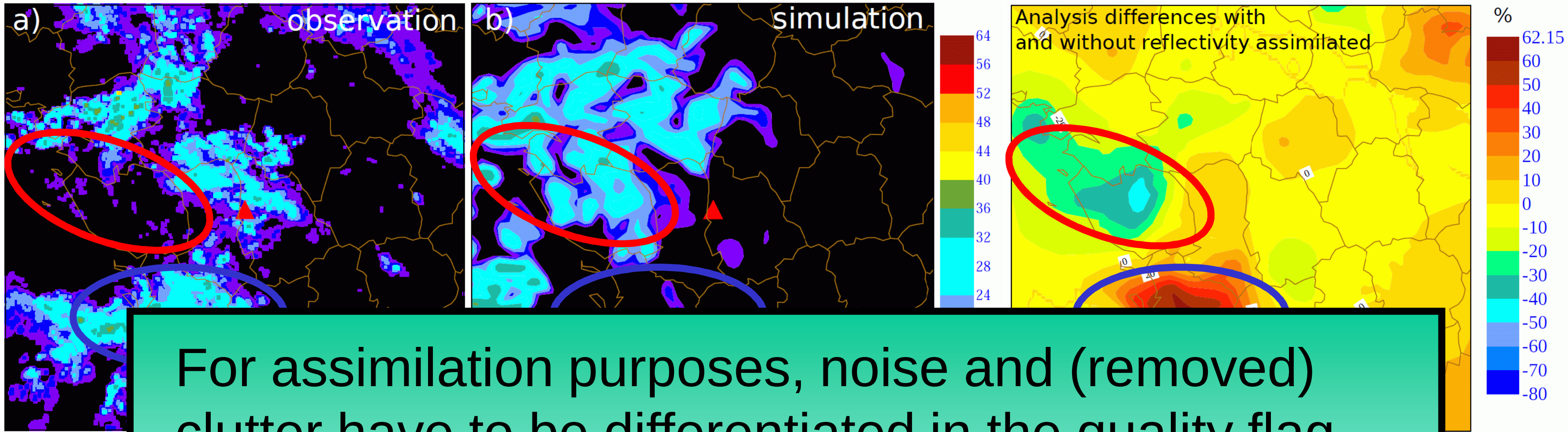
- Production of rain by moistening
- Symetrically, use of « no-rain » information to remove rain by drying

☞ **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*)**



METEO FRANCE
Toujours un temps d'avance

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

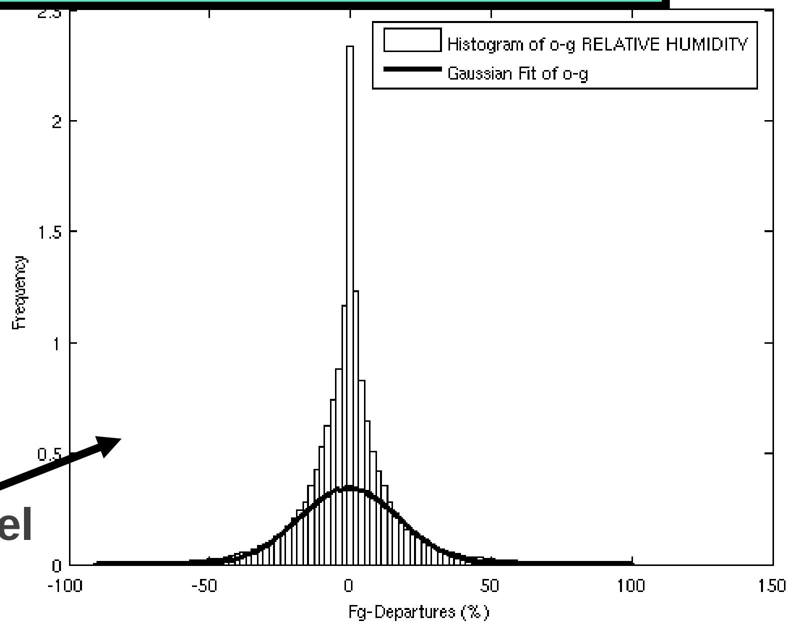


For assimilation purposes, noise and (removed) clutter have to be differentiated in the quality flag

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

☞ **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*)**

☞ **Resulting in no humidity biais in the model**



Outline

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

Context

Cost function of the 3DVar: $$J(x)=\frac{1}{2}(x-x_b)^T\mathbf{B}^{-1}(x-x_b)+\frac{1}{2}(y^o-H(x))^T\mathbf{R}^{-1}(y^o-H(x))$$

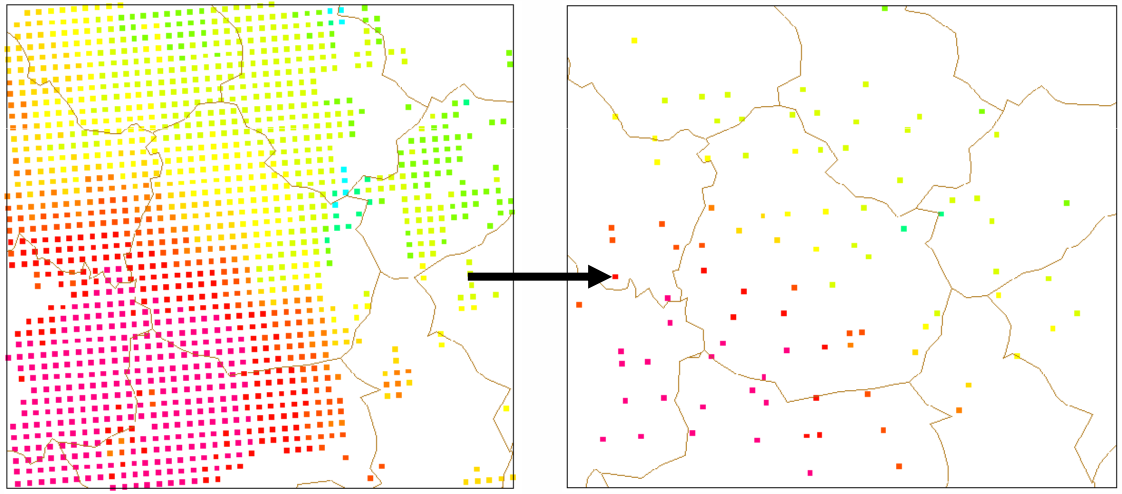
R to be specified: standard deviation of obs. error and covariances

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

$\Rightarrow$ **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

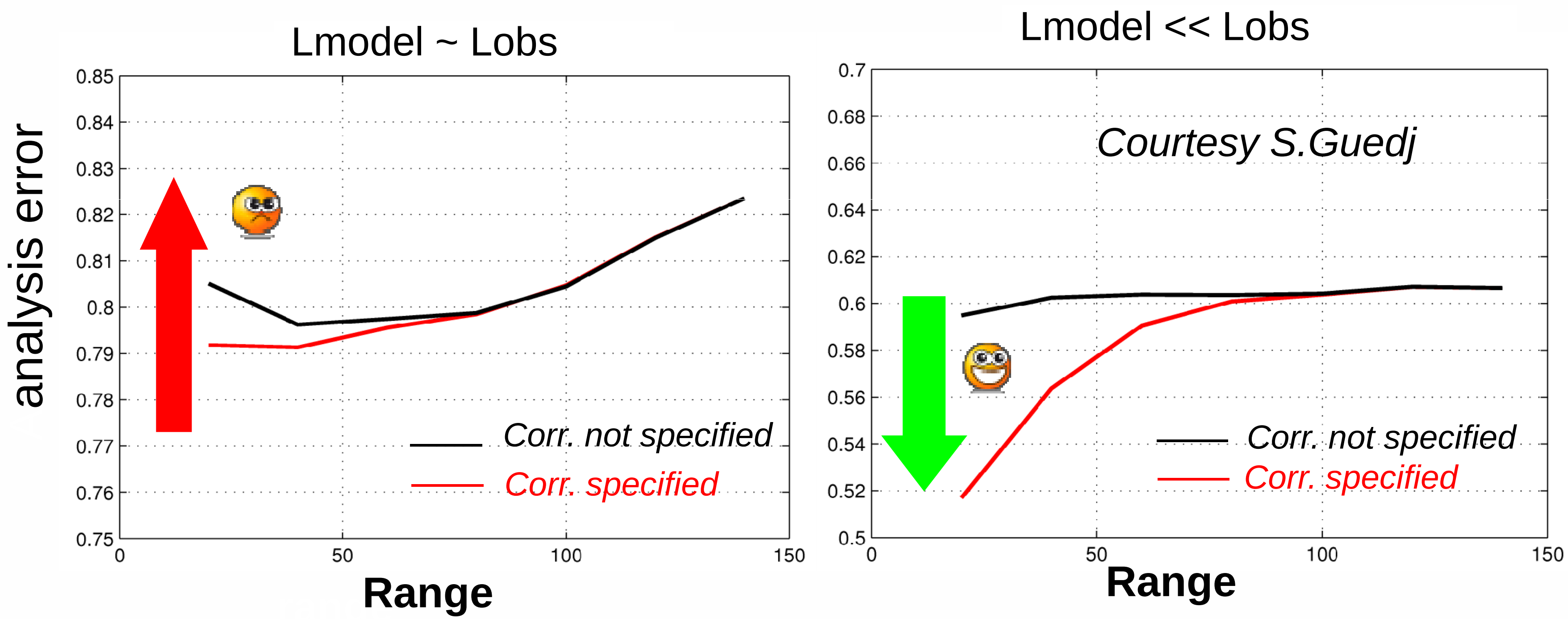


Questions:

- Is it possible to revisit the current horizontal thinning?
- Do we need to specify spatial observation-error correlations?

Context

☞ **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)**

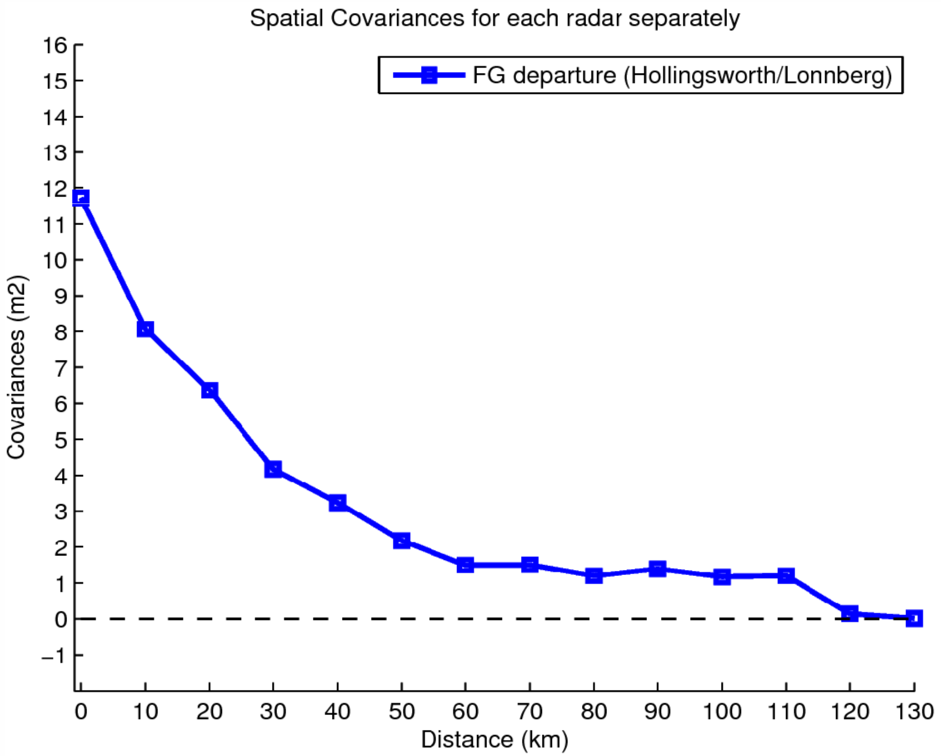


Methods and Results

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!

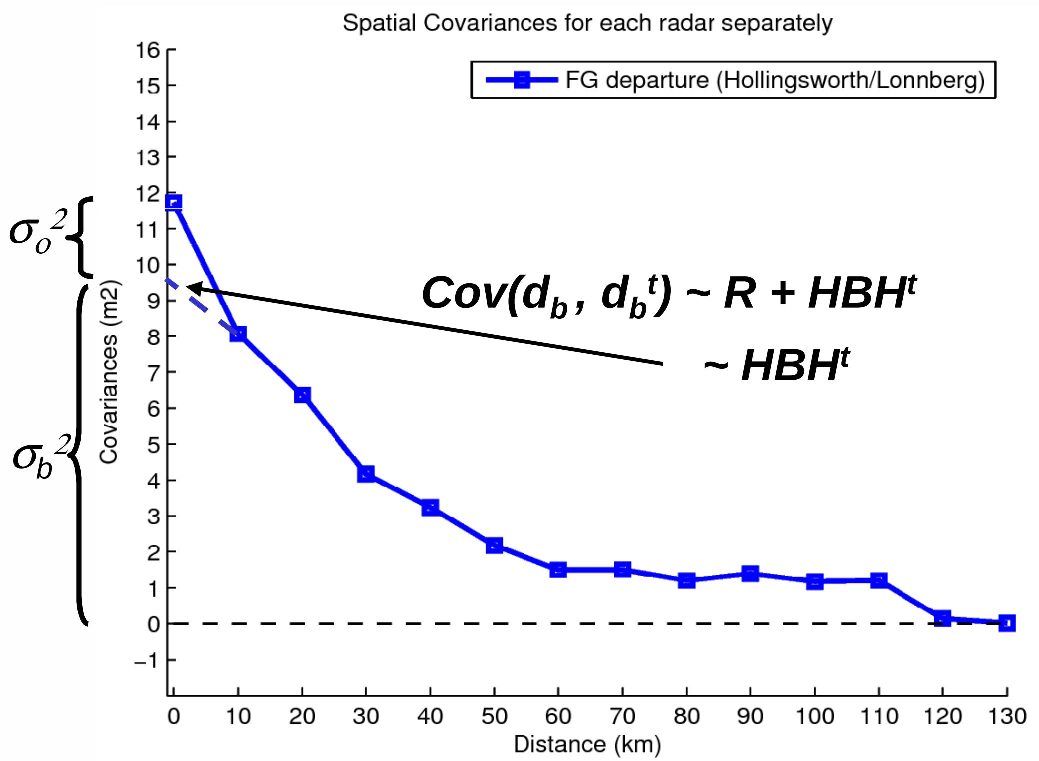


Methods and Results

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!

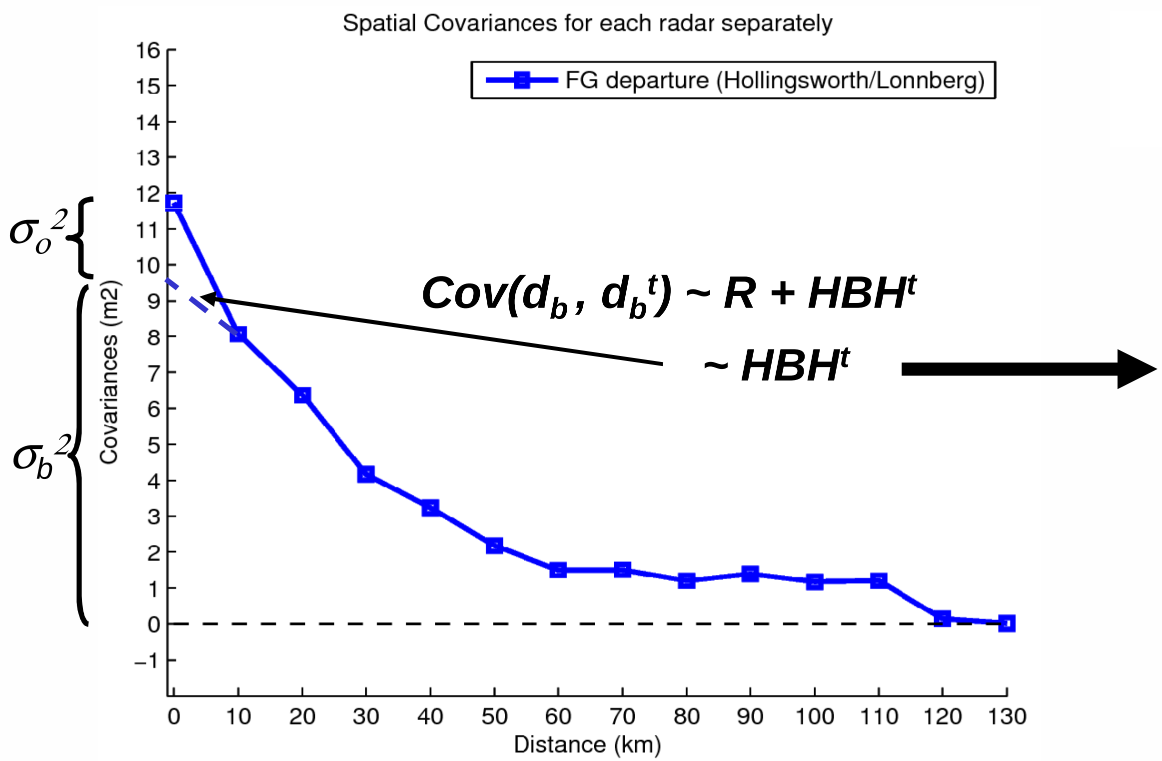


Methods and Results

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!



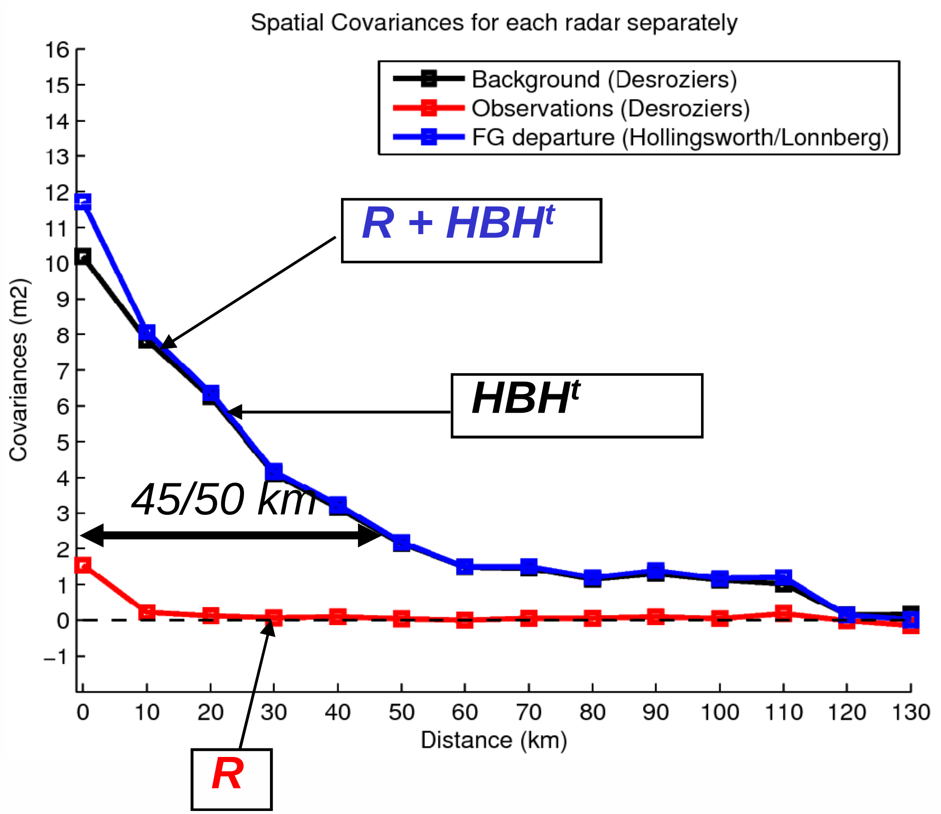
	Obs. error stdev (m/s)
As specified	2
HL method	1.49
Desroziers diagnostic	1.29

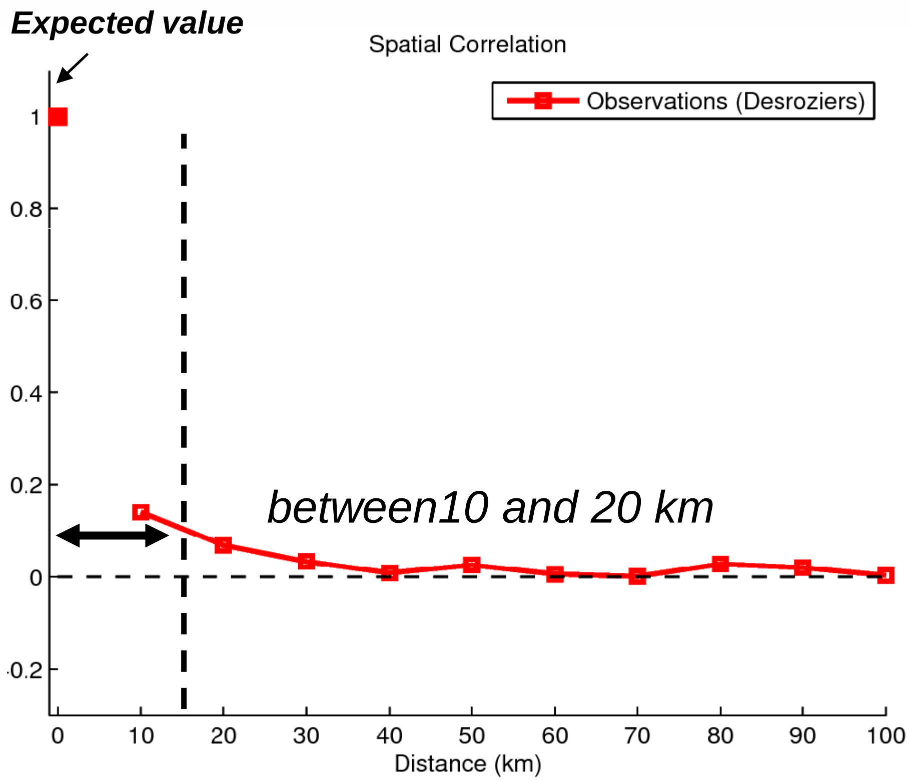
Methods and Results

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. lenght-scales of correlation structures





METEO FRANCE
Toujours un temps d'avance

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 lenght scale and Obs. lenght scale of correlation structures!**

Prospect

- Randomized estimates of HBH^t to deduce $R = E(d_b\ d_b^t) - HBH^t$ 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 coveraged by several radars

Outline

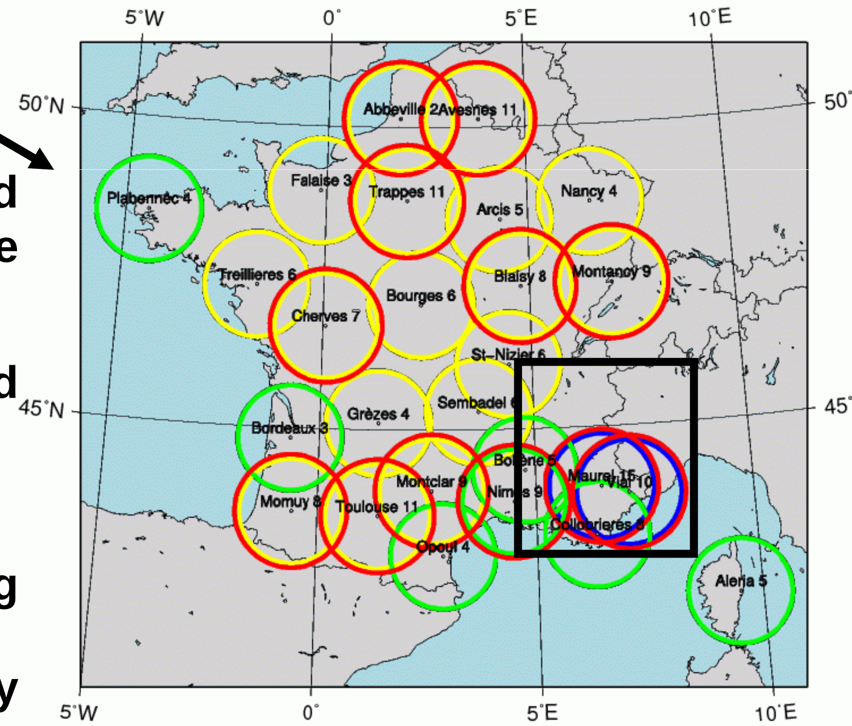
1. 1D+3DVar assimilation method of reflectivity
   - Strength of the method

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

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…)



<u>Experimental setup:</u>

- **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/Febrary 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**

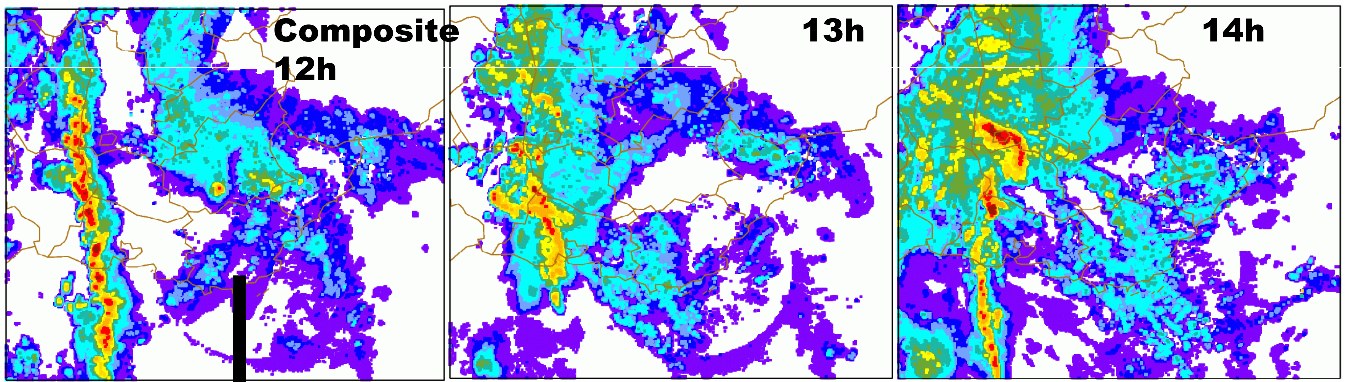
Doppler Radial Wind

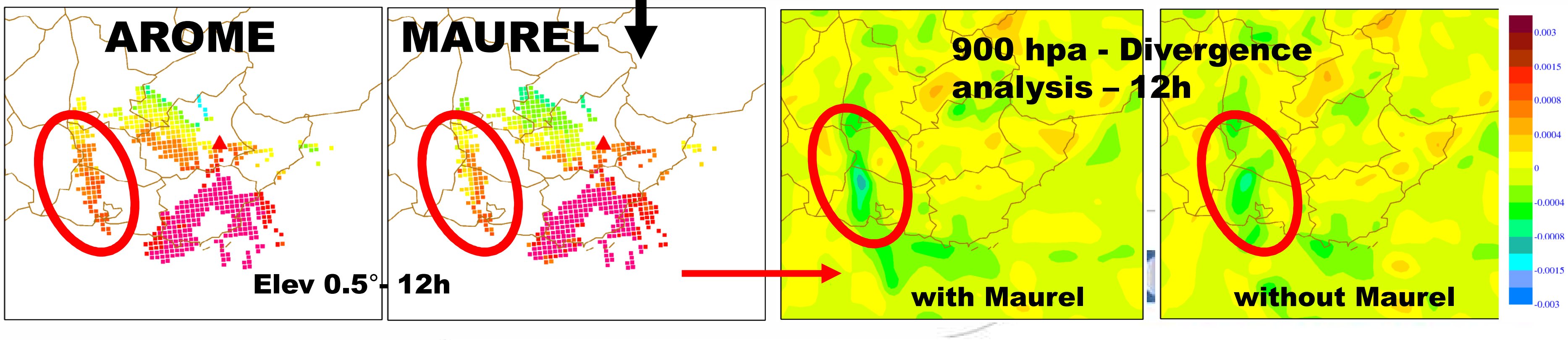
- Triple PRF are needed to get a non-ambiguous velocity around 50 m/s
- Ratio of PRF needed to be close to 1 to get such high velocities (important for assimilation purposes)

☞ **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**

However, consistent analysis increments can be observed in some cases…





Doppler Radial Wind

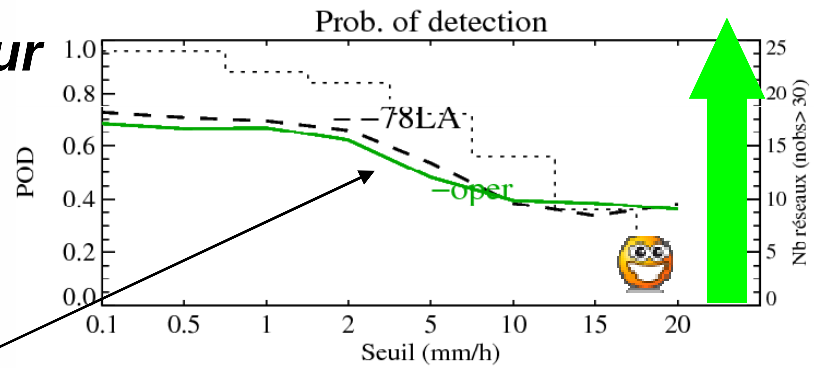
- Triple PRF are needed to get a non-ambiguous velocity around 50 m/s
- Ratio of PRF needed to be close to 1 to get such high velocities (important for assimilation purposes)

☞ **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**

Results summary:

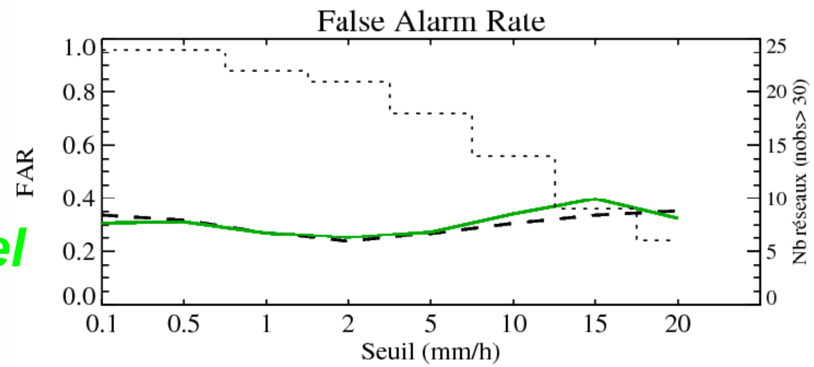
RR6 hour



=> 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



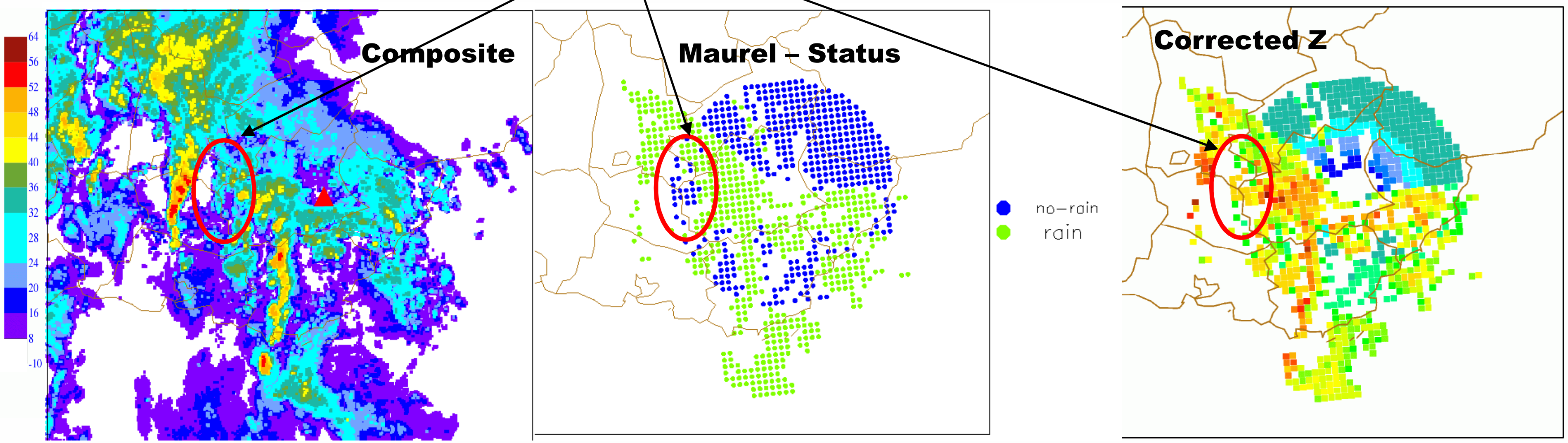
- - - ***With Maurel***

——— ***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 Φ_{DP} to estimate the Path Integrated Attenuation PIA:**
  - **- Pixel identified as "RAIN": Z_{corr} (dbZ) = Z (dbZ) + $\gamma_H . \Phi_{DP}$: Z corrected !**
  - **- Pixel identified as "NO-RAIN": Z_{corr} (dbZ) $\leq$ MDZ (dbZ) + $\gamma_H . \Phi_{DP}$**

Extinction : Minimum Detection Reflectivity is enhanced: 40 dbZ !



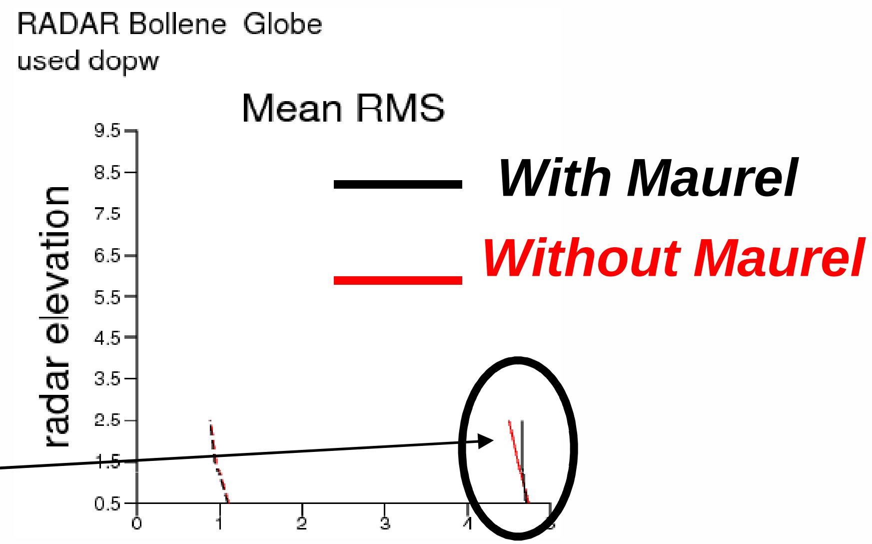
Extinction : Correction of the $Z_{simulated}$ > MDZ (dbZ) + $\gamma_H . \Phi_{DP}$

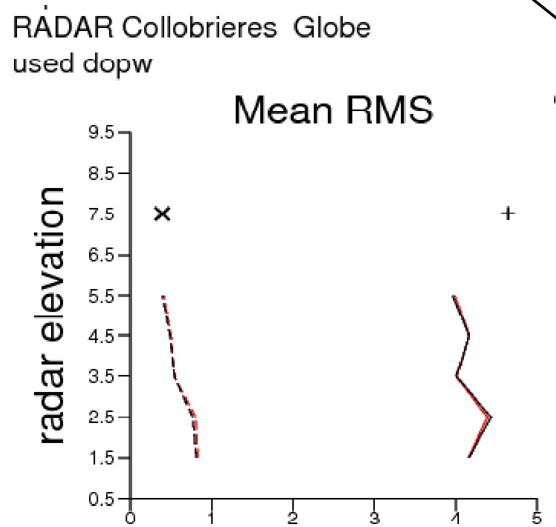
Reflectivity

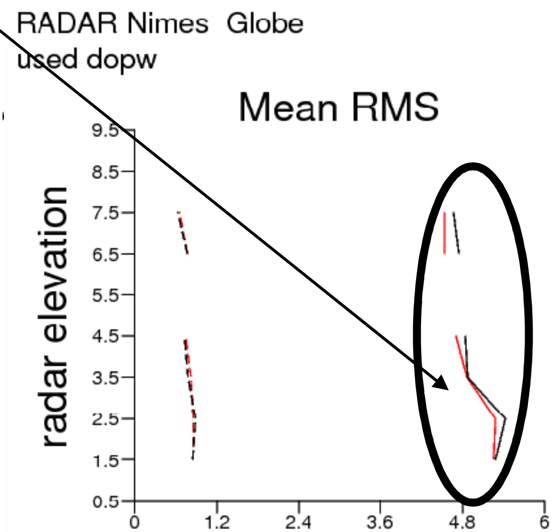
Results summary:

=> 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)







METEO FRANCE
Toujours un temps d'avance

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

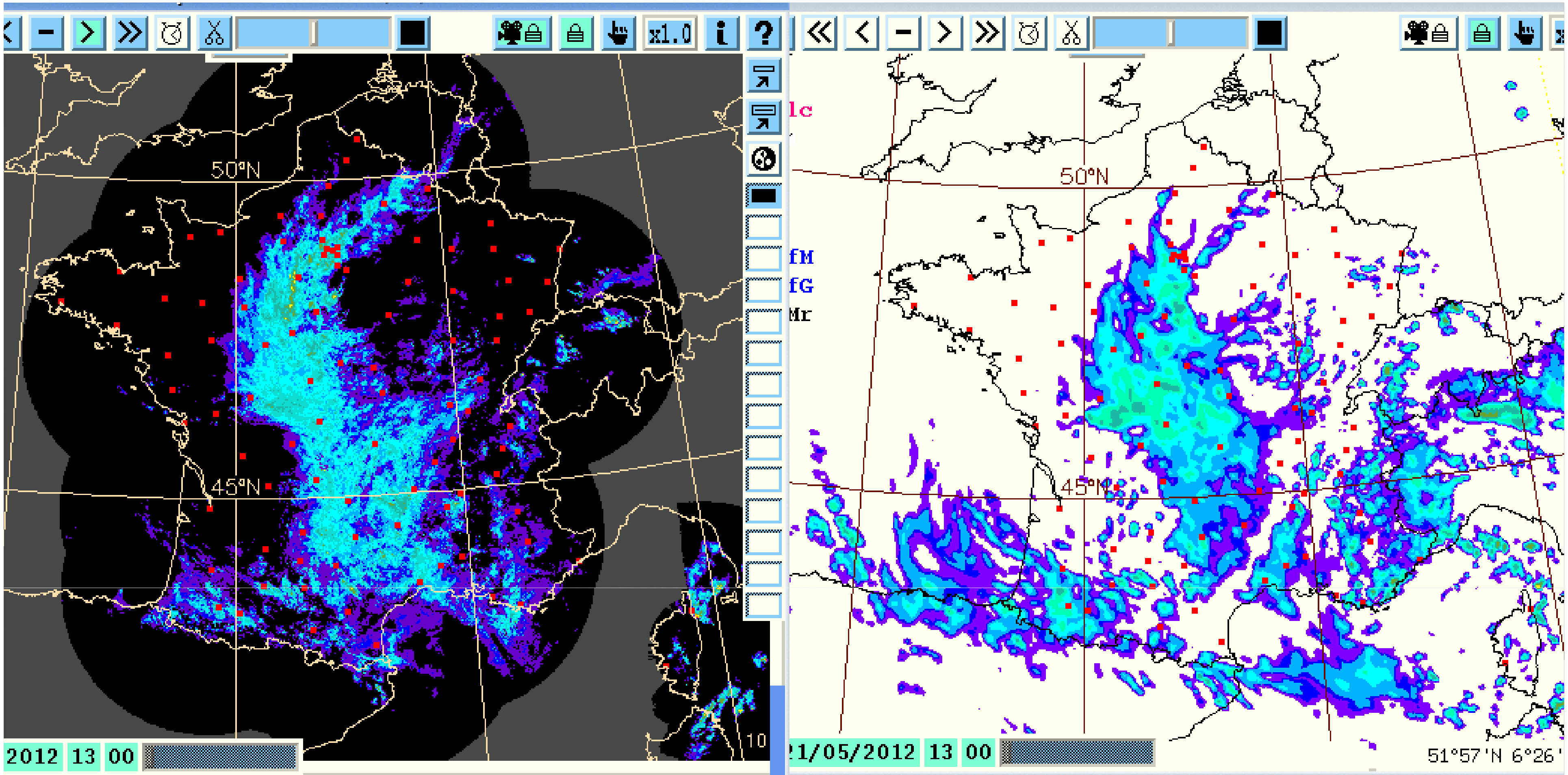
⇒ No shown added value by DPOL reflectivity assimilation

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 !

Strength of the 1D+3DVar method: original quality control

• What happens if the model doesn't contain enough consistent thermodynamic profiles with the observed « radar »reality?

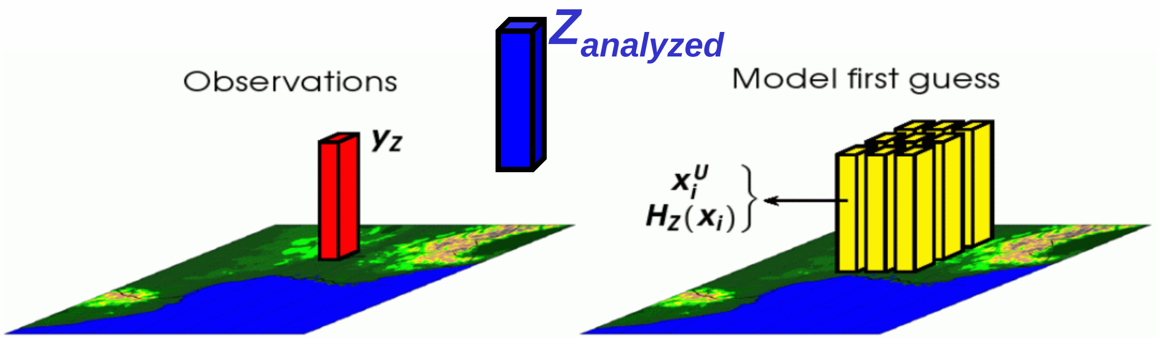
• Artificially saturation (or dryness) unwanted (because of humidity positive biais)

• What happens if the model doesn't contain enough consistent thermodynamic profiles with the observed « radar »reality?

• Artificially saturation (or dryness) unwanted

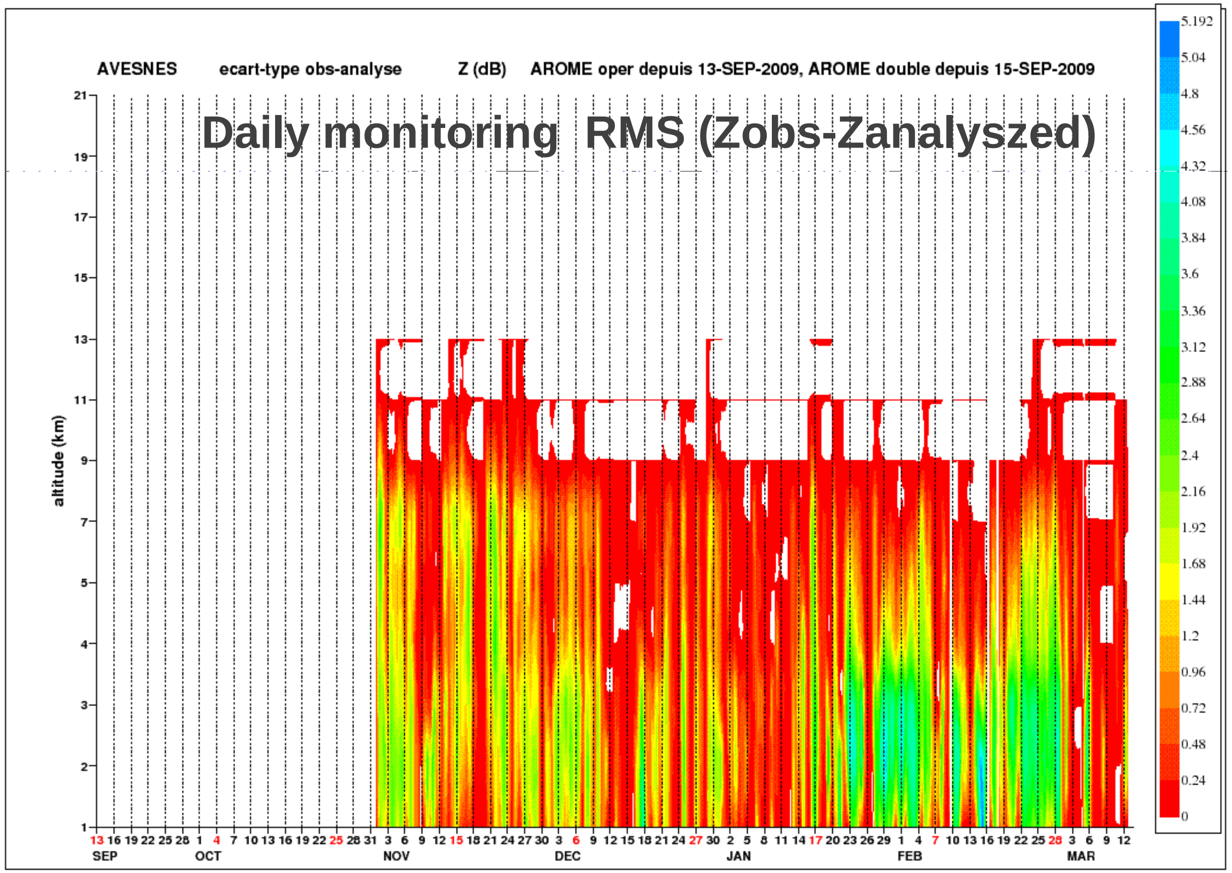
• A 1D convergence checked by an original quality control based on the observed minus analyzed reflectivity departures preferred !

$$Z_{analyzed} = \sum_i Z(\ldots) \times \frac{e^{-\frac{1}{2}(\ldots)}}{\sum_j e^{-\frac{1}{2}(\ldots)}}$$

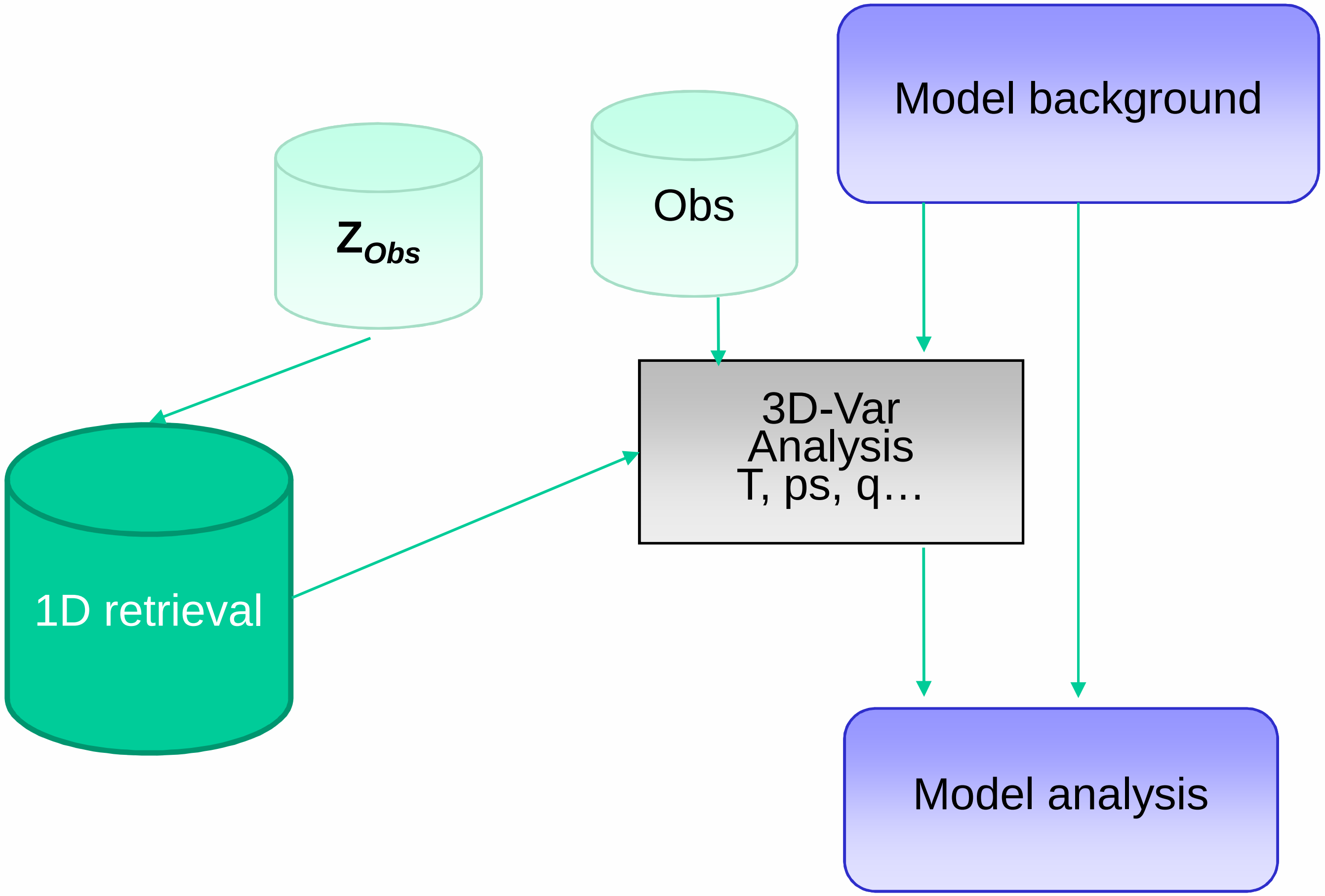


Strength of the 1D+3DVar method: original quality control

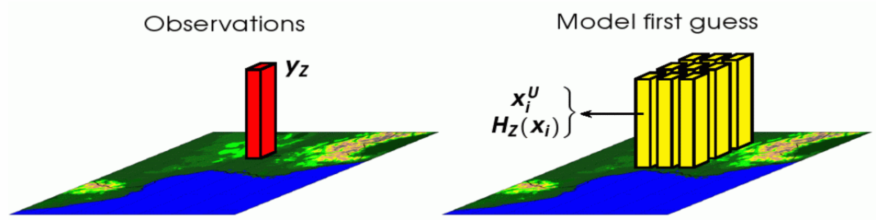
- What happens if the model doesn't contain enough consistent thermodynamic profiles with the observed « radar »reality?
- Artificially saturation (or dryness) unwanted
- A 1D convergence checked by an original quality control based on the observed minus analyzed reflectivity departures preferred !



1D+3D-Var methodology

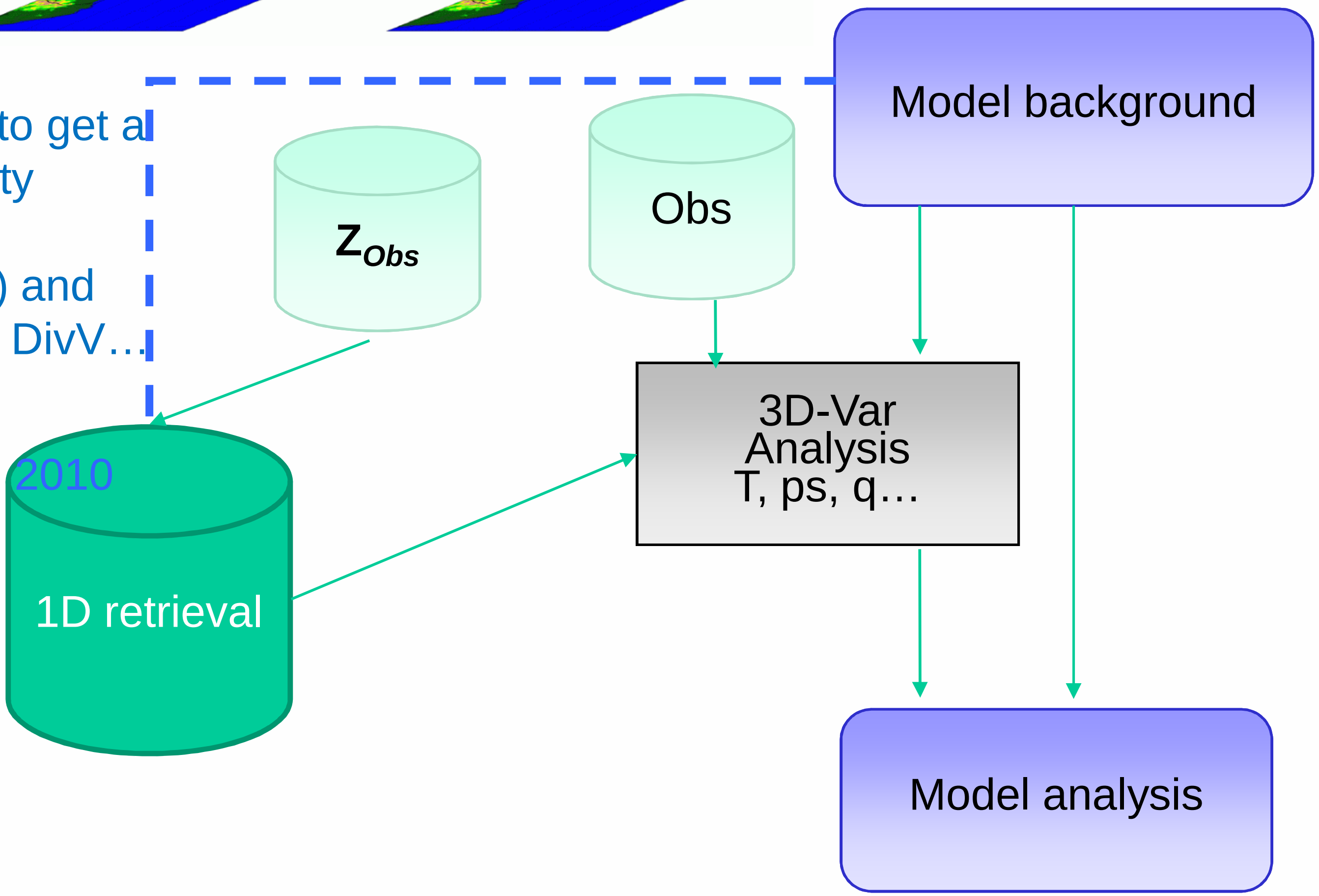


1D+3D-Var methodology

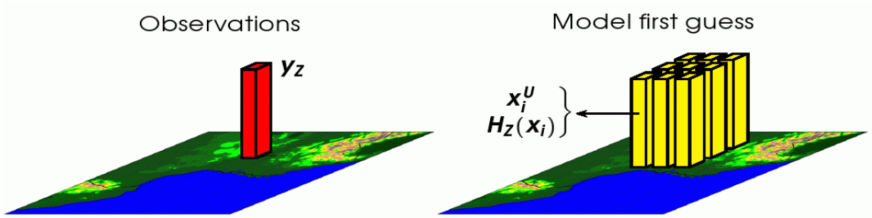


Use of model hydrometeors to get a relative humidity retrieval from reflectivity (1D) and modify T,ps, q, DivV… by 3DVar

Caumont et al. 2010

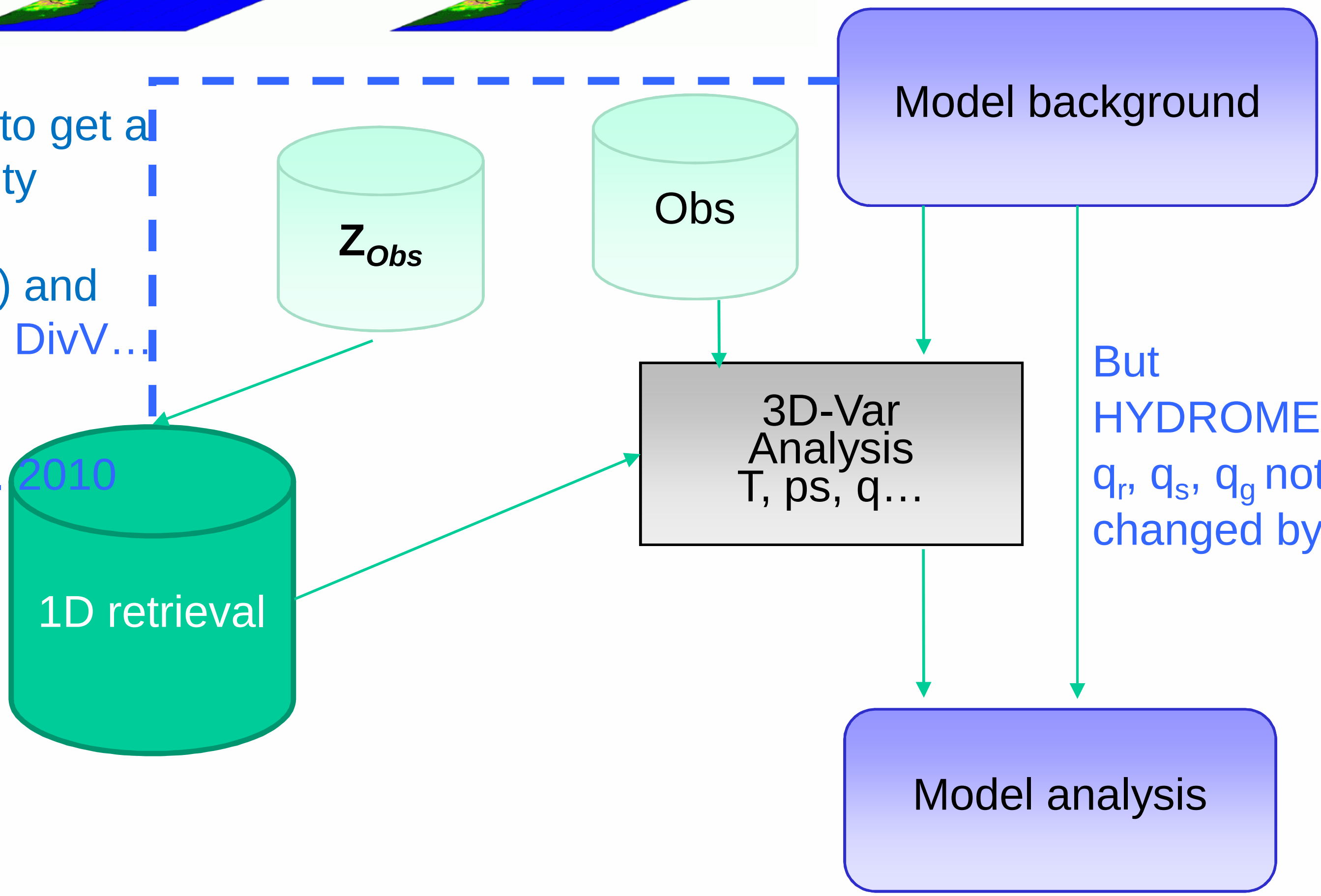


1D+3D-Var methodology

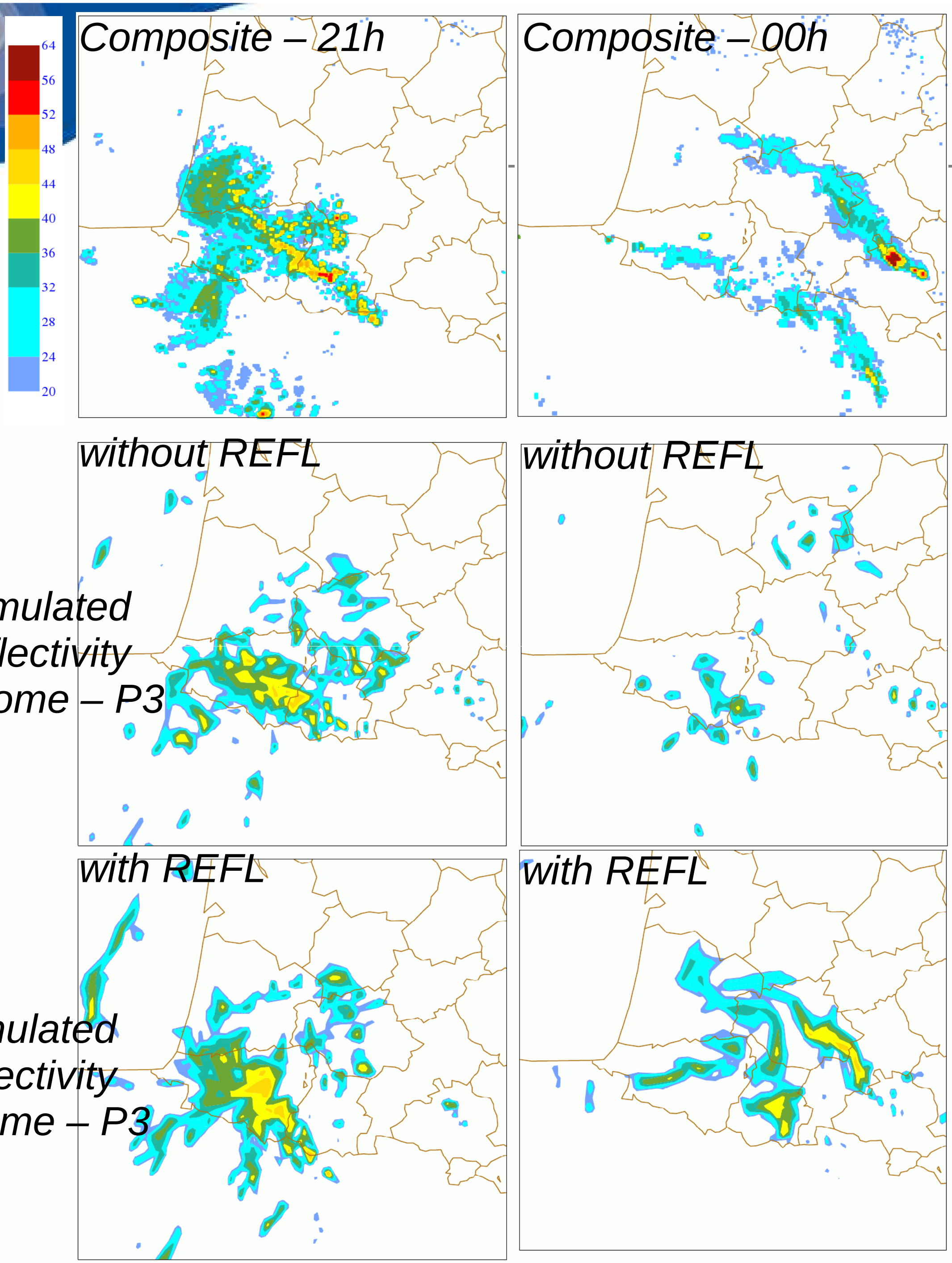


Use of model hydrometeors to get a relative humidity retrieval from reflectivity (1D) and modify T,ps, q, DivV… by 3DVar

Caumont et al. 2010

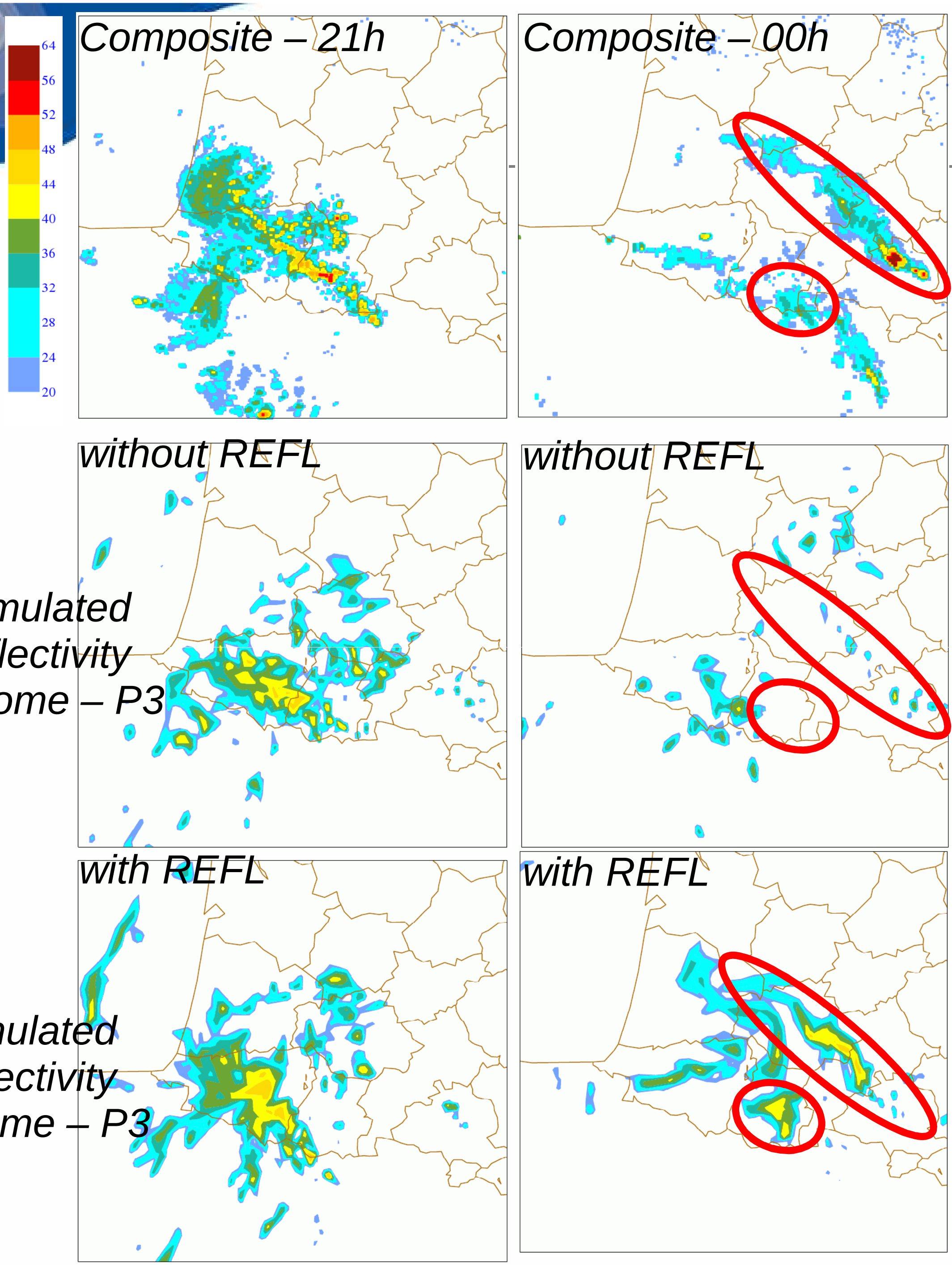


But HYDROMETEORS q_r, q_s, q_g not changed by 3DVar



Simulated reflectivity Arome – P3

Simulated reflectivity Arome – P3

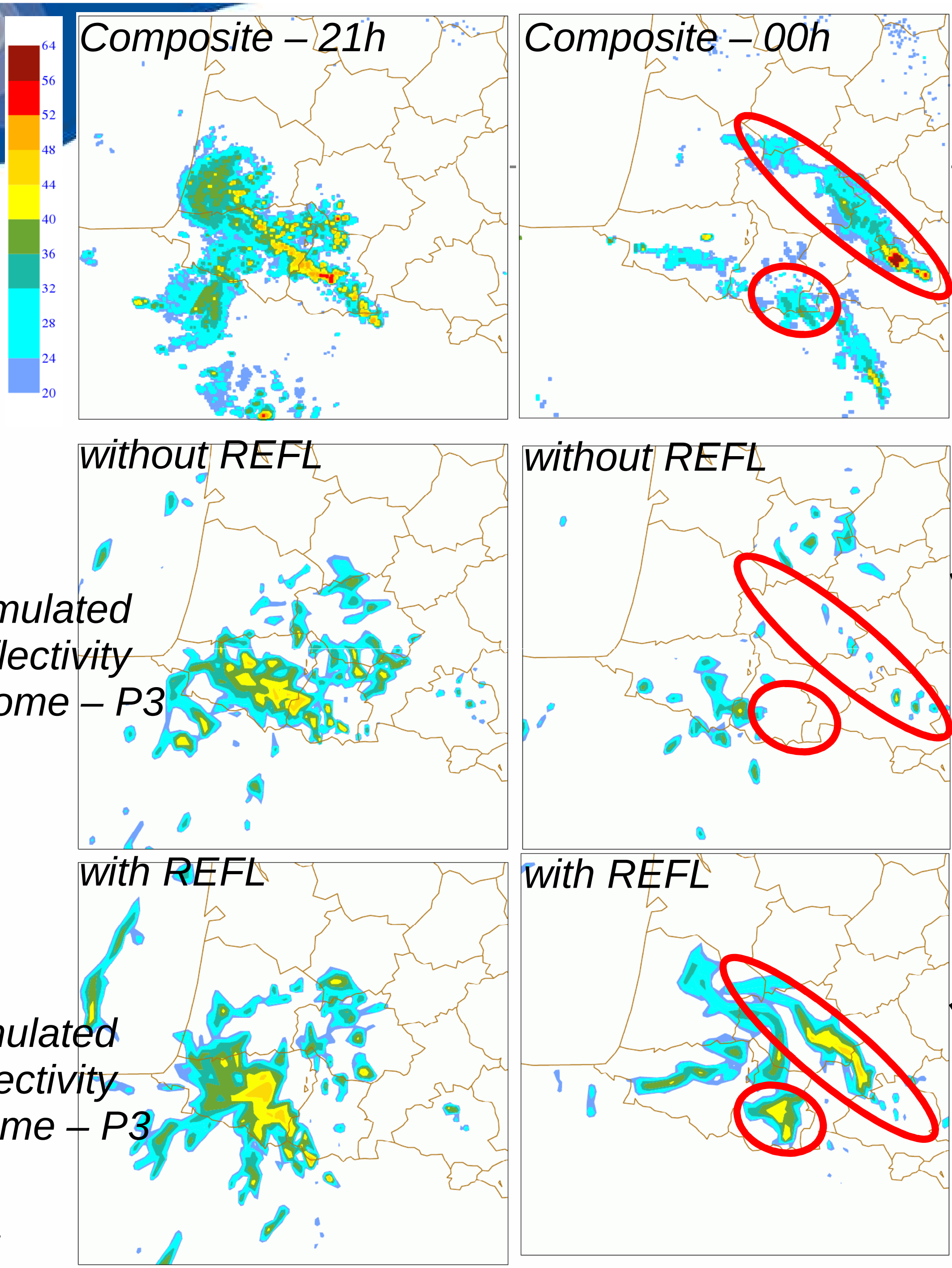


Simulated reflectivity Arome – P3

Simulated reflectivity Arome – P3

Convection better analyzed and forecasted in Soutwest of France

METEO FRANCE
Toujours un temps d'avance



Simulated reflectivity Arome – P3

Simulated reflectivity Arome – P3

Reliable ground gusts in agreement with observations