Ongoing developments on radar data assimilation in AROME

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material provided by

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Outline

1. Main features of radar assimilation within AROME
    - Radar network over France
    - Operational configuration
    - 1D+3D-Var methodology
    - Screening and quality controls

1. Illustrations
    - Importance of « no-rain » assimilation
    - Importance of quality of raw data

1. Planned activities
    - Use of polarimetric measurements
    - Towards the use of European radars (OPERA, HYMEX)
    - Collaborations with HIRLAM

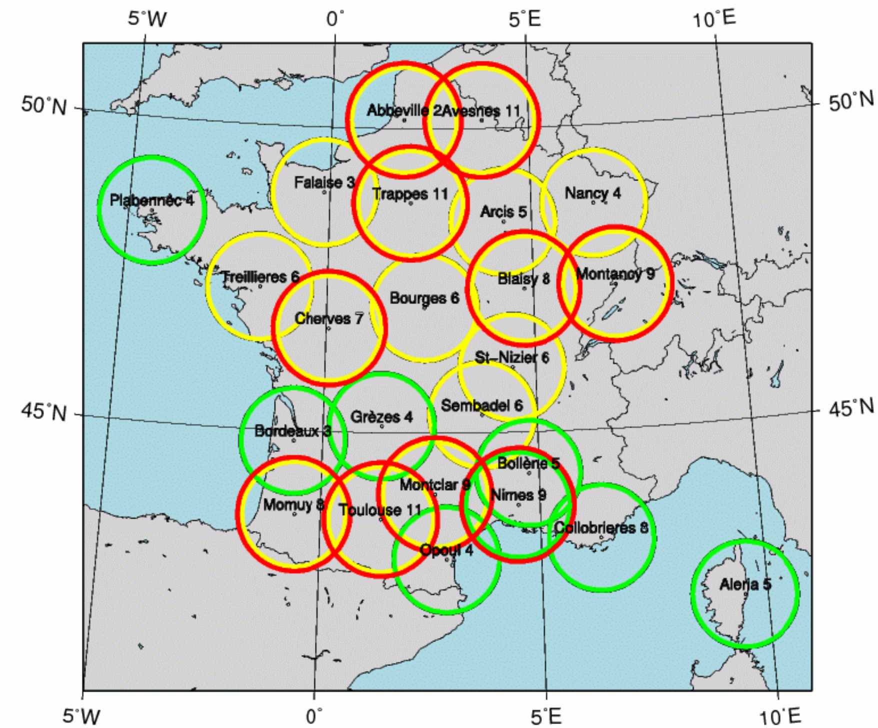
Current operational use of rada data

French ARAMIS network

- 24 Doppler radars (8 S-band and 16 C-band), 10 Polarimetric, between 3 and 11 PPIs in 15’

Within AROME:

- **Radial wind from 15 radars since December 2008; from 22 radars since 24 November 2010 (Grèzes and Plabennec missing)**
- **Reflectivity from 24 radars since 6 April 2010**



Radars : C Band · Polarimetric radar · S Band

Name and number of elevations in circles

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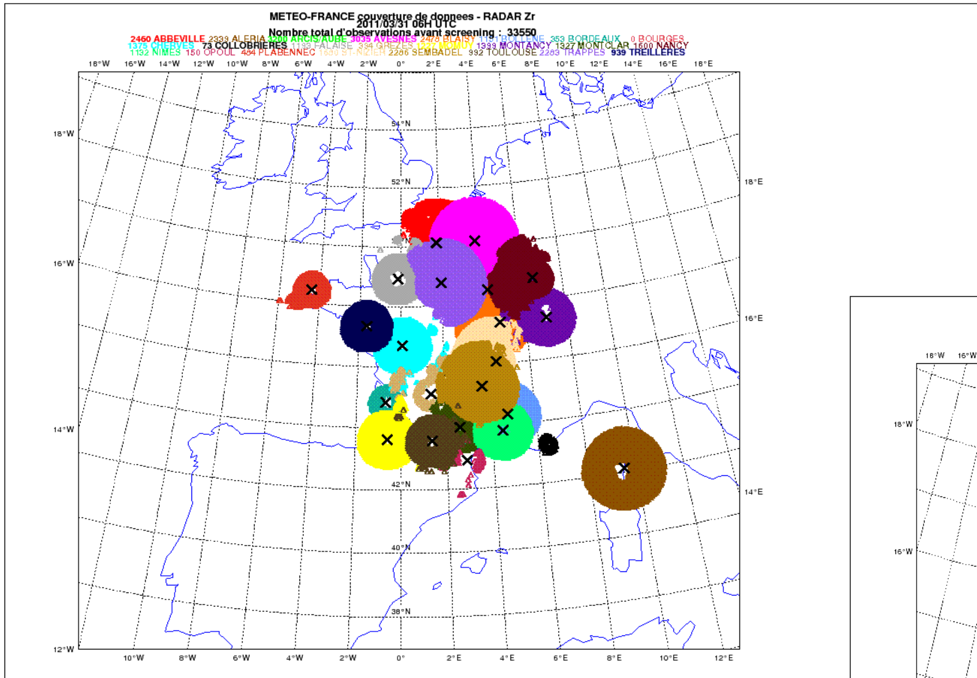
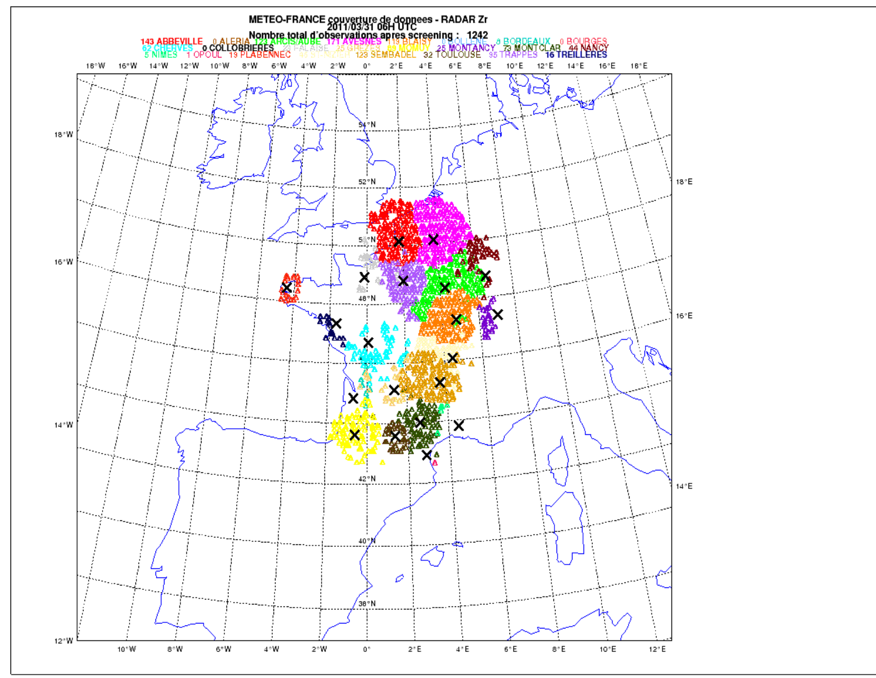
Spatial coverage of reflectivities over the current AROME domain



Before screening
Nobs=33550

After screening
Nobs=1242



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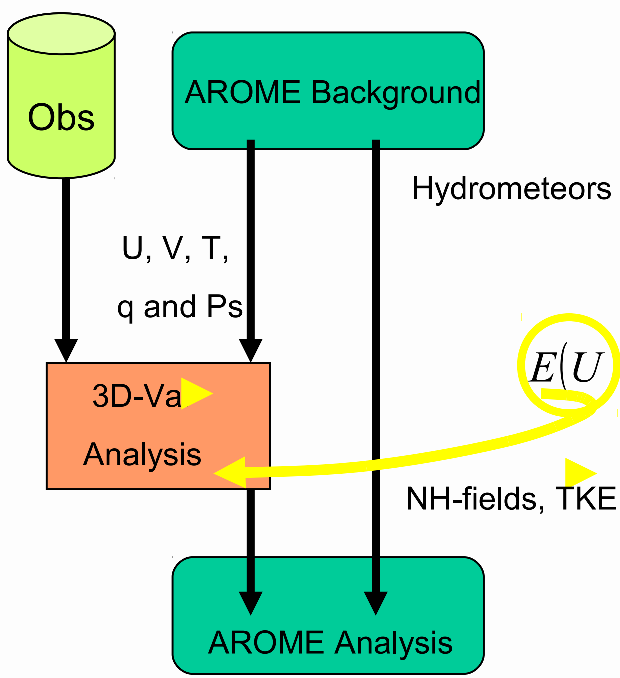
- Choice of retrieving humidity information (~ Marécal and Mahfouf, 2002)
- 1D inversion technique based on GPROF algorithm used to retrieve surface rainfall rates (Kummerow, 2001) or latent heat profiles (Olson et al., 1999) from microwave rainy radiances using a data base from cloud resolving model simulations
- Caumont et al., 2010: Use of background information in the neighbourhood of an observation to create a database of profiles



Use of model hydrometeors to modify humidity (1D), wind, temperature .. (3D-Var) without changing hydrometeors !

$$E(U) = \sum_i U_i \frac{\exp\frac{-1}{2}\cdot\|Y_0 - Y_s(U_i)\|^2}{\sum_j \exp\frac{-1}{2}\cdot\|Y_0 - Y_s(U_j)\|^2}$$

Observation operator of reflectivity

1. Pros:
   - Dependency of retrieved profiles upon the situation of the day
   - Consistency between precipitating clouds created by the inversion and the model microphysics
   - No need to linearize the observation operator nor the AROME microphysics
   - No need to extend the control variable to hydrometeors and to provide associated background error statistics
   - 1D+3DVar: is a robust method (radar calibration, profile data base)

1. Cons:
   - Double use of background profiles : correlation between pseudo-observations and model first-guess
   - Lack of balance in the analysis between hydrometeor fields and the control variable: information could be provided by polarimetric measurements and by modelling covariance statistics ?
   - Technical challenge for operational implementation in AROME (code parallelization)

Screening : pre-processing, quality controls and errors

- Importance of pre-processing :rather restrictive algorithms in order to avoid assimilating artifacts and loosing useful information. It has allowed the use of data from the 24 radars of the French network. How to adapt them when using polarimetric data and data from OPERA ?
- Pre-processing before assimilation:
  - Reflectivity field very heterogeneous : difficult to define a spatial filtering technique
  - Elimination of **anomalous propagation** (important for S-band radars at low levels)
  - **Beam blocking** areas are blacklisted
  - Retrieval errors (**attenuation**, **beam broadening**) accounted for in the specification of observation errors in the 3D-Var

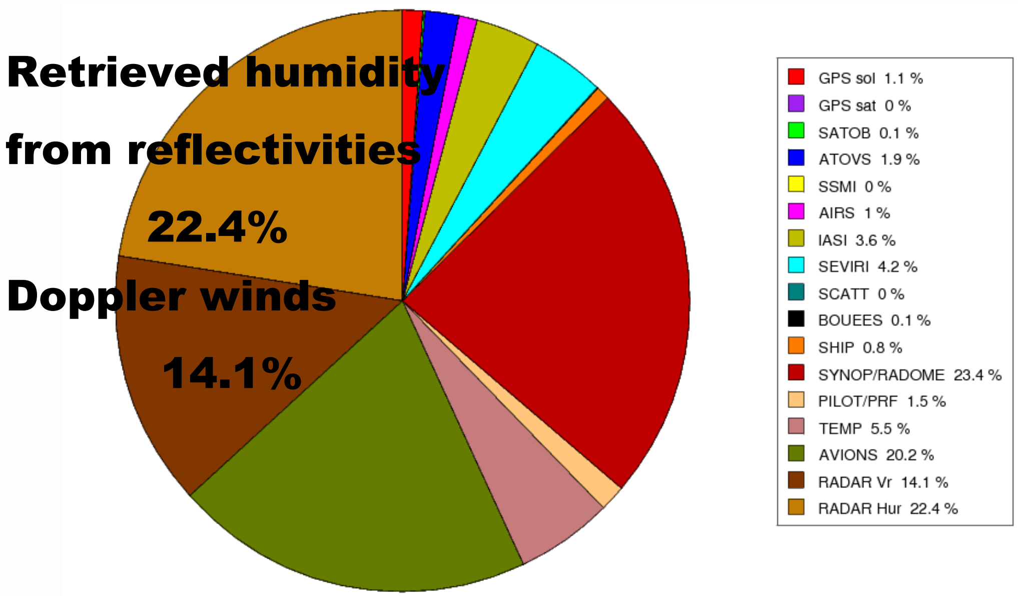
- Quality control vs model :
  - Very small Sigma_o in 1D inversion (0.2 dBZ): no retrieval if the model is too far from the observation (implicit QC: « better doing nothing than doing wrong»)
  - Consistency checks of RH increments vs. reflectivity innovations
  - Relaxed FG check compensated by examining the difference « **analysis of pseudo-reflectivity – observed reflectivity** » (also used for observation monitoring)

Screening decisions : thinning and active data

1. Thinning of reflectivities : **16 *16 km** to avoid correlations of observation errors and representativeness errors in the model – increasing density can degrade the current system.

2. 3DVar: Errors in pseudo-observation for relative humidity depend linearly upon radar distance. A-posteriori diagnostics (Desroziers et al., 2005) show a slight overestimation of these errors

Assimilated observations after screening:



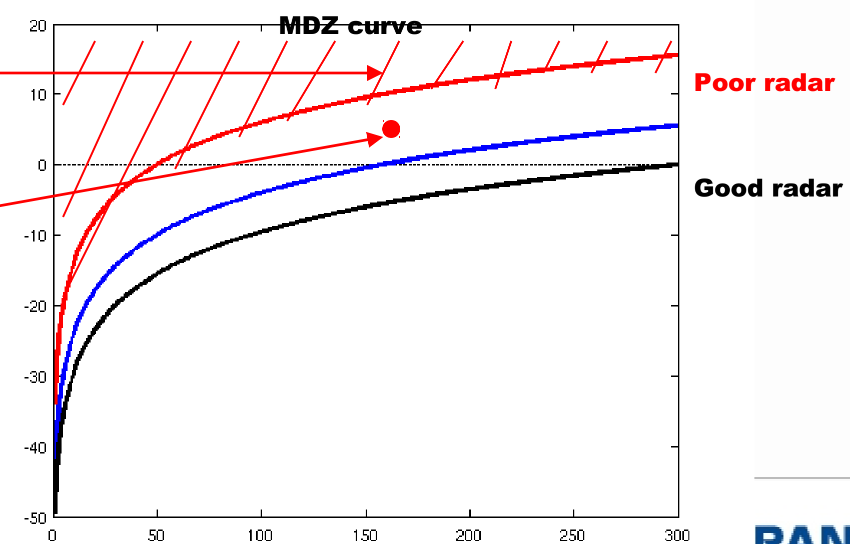
Importance of accounting for the « no-rain » information in the assimilation : better balance between creation and destruction of rainy areas in the model, reduced model humidity bias.

What is a precipitating signal ?

- RADAR: it rains if the SNR ratio is large enough, use of a small SNR value if the minimum detectable reflectivity (**MDZ**) is known for each pixel
- AROME: as soon as precipitating hydrometeors are produced

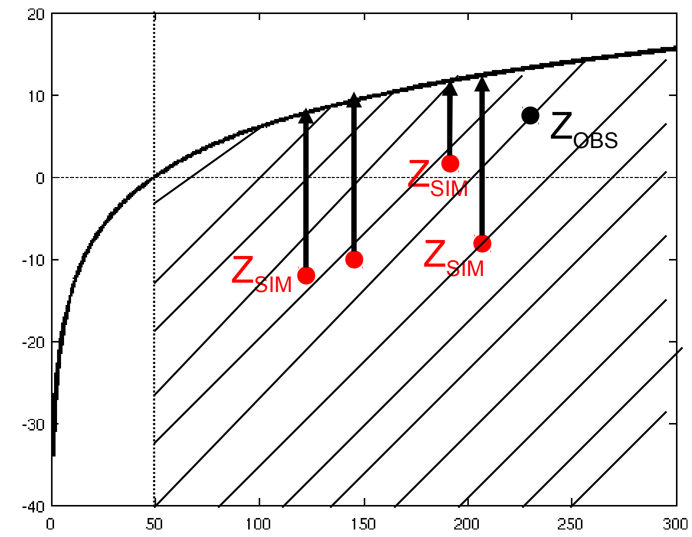
Rain in radar

Sensitive detection in the model

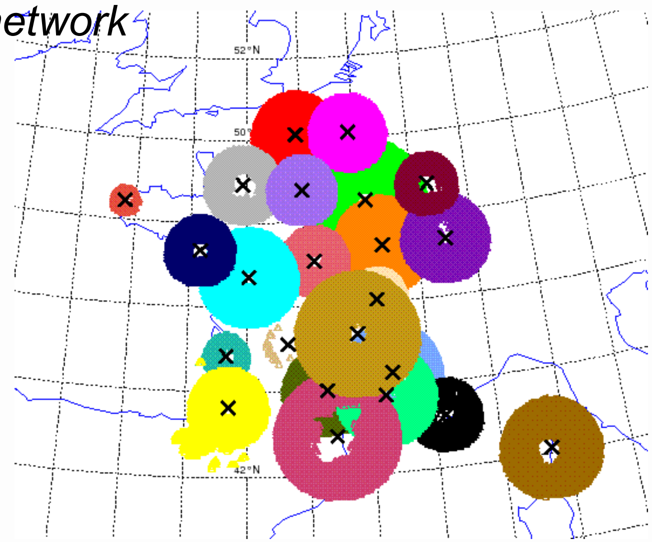


« no-rain » information (2)

- The model threshold is set to the radar value. ($Z_{SIM} < MDZ \Rightarrow Z_{SIM} = MDZ$) but:
- Sensitivity when the noise has large values : possibility of wrongly removing undetected small rainfalls (Wattrelot et al. 2009)



Example of areas of possible model « drying » from the ARAMIS network



Large impact on precipitation scores – 29 April to 12 May 2010

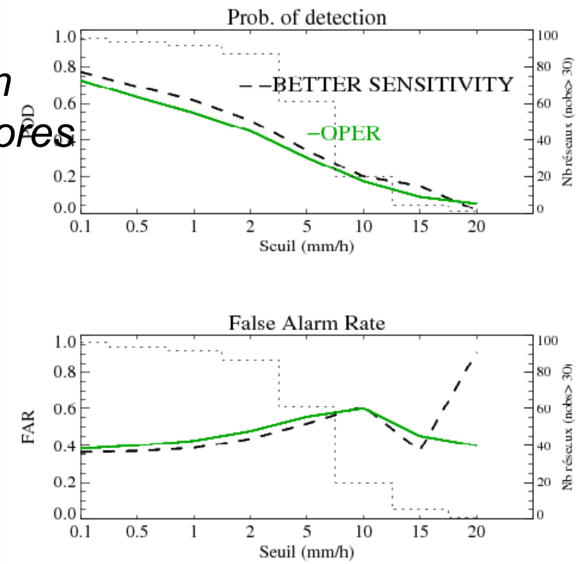


Illustration – reflectivity field – radar and model

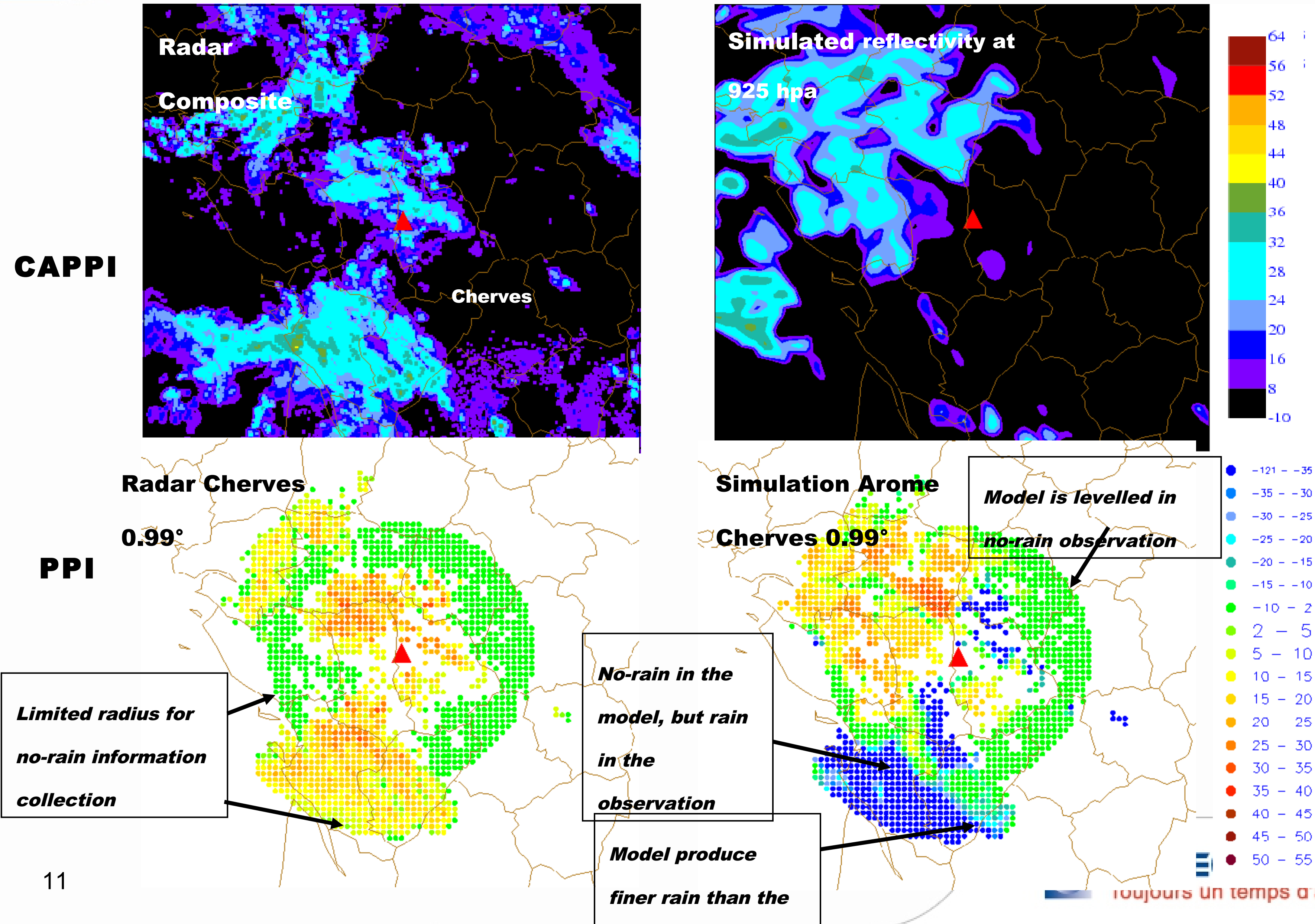
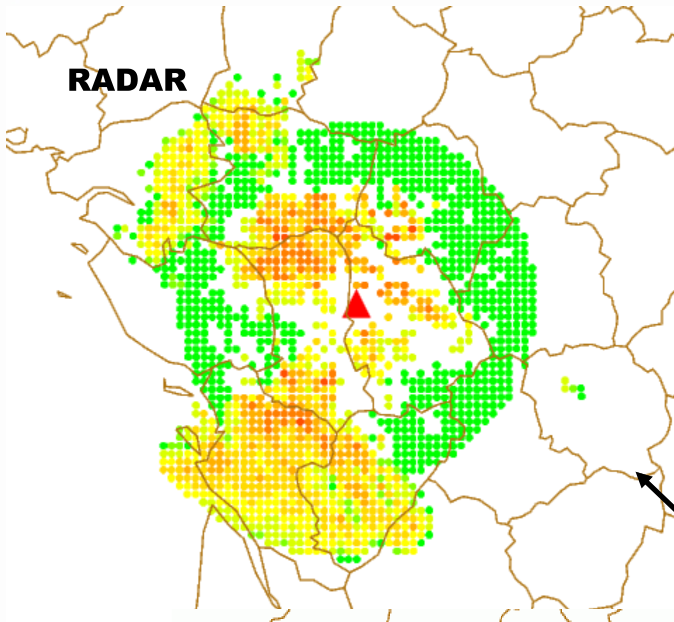
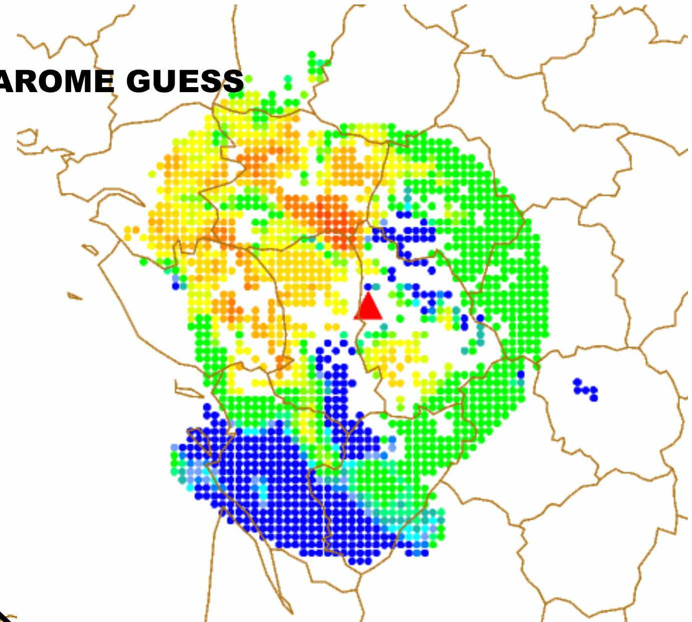
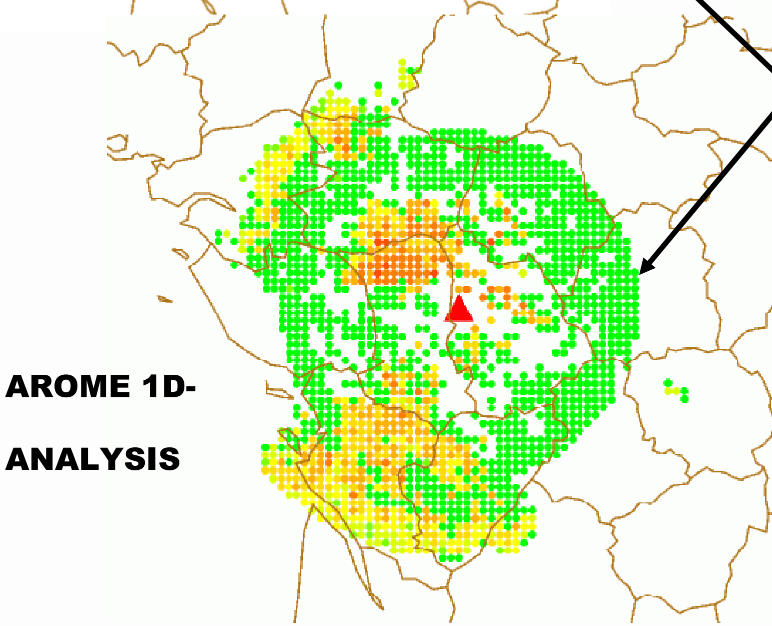


Illustration – comparison between radar reflectivity and reflectivity 1D analysis : 1D convergence and quality control

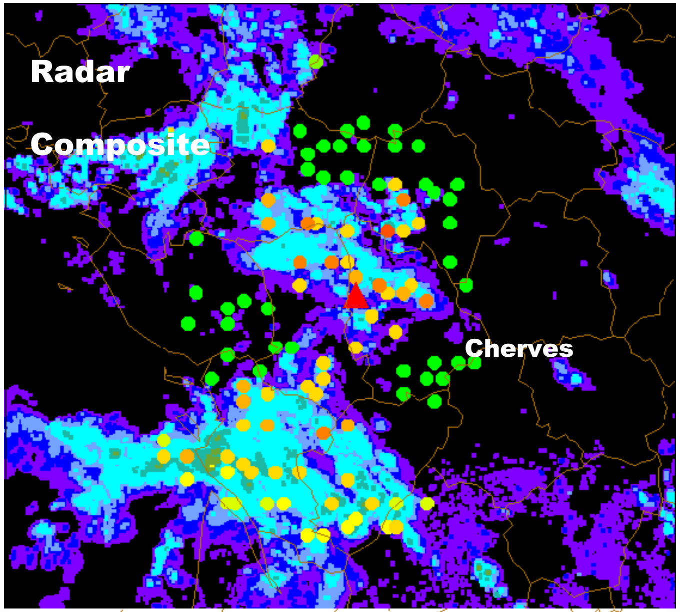


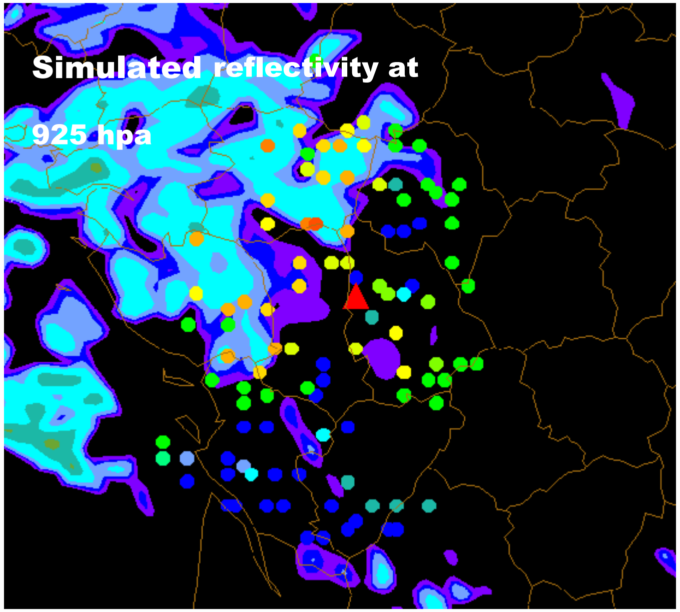




- ***Quality control based on ||radar minus 1D-analysis||***
- ***Thinning of 16 km***

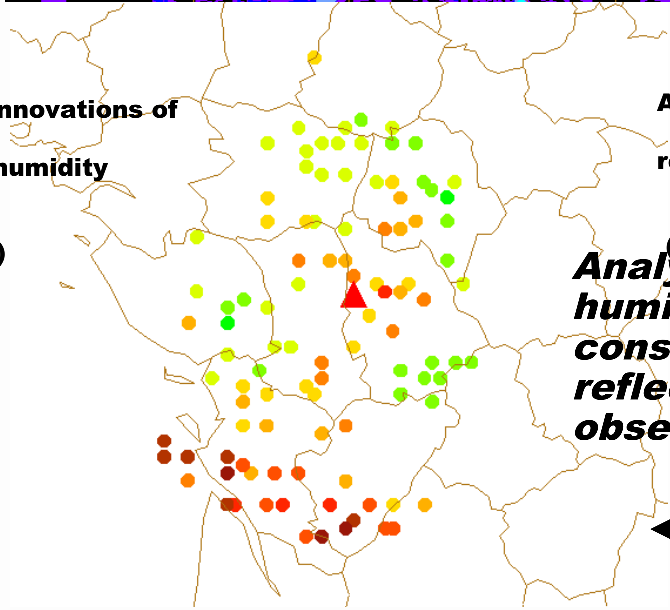
Illustration – Active data of humidity retrievals and 3DVAR analysis increments





Pseudo-innovations of relative humidity

(OBS-BG)



Analysis increments of relative humidity

(ANALYSIS-BG)

Analysis field of humidity strongly constrained by reflectivity observations

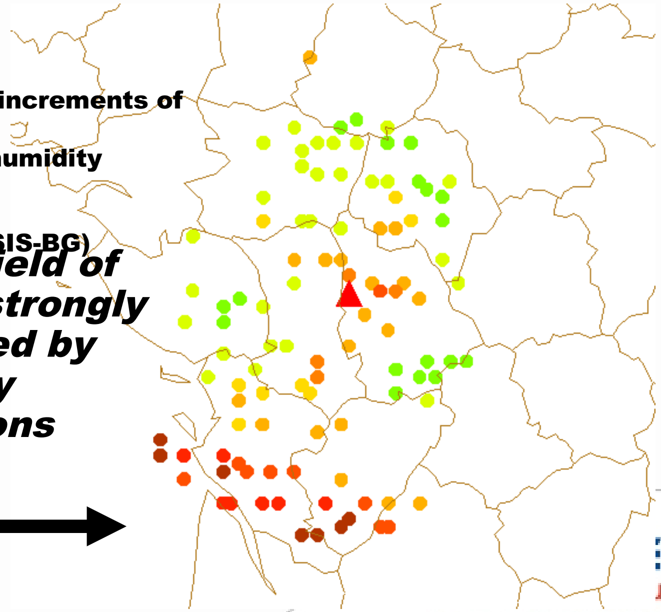
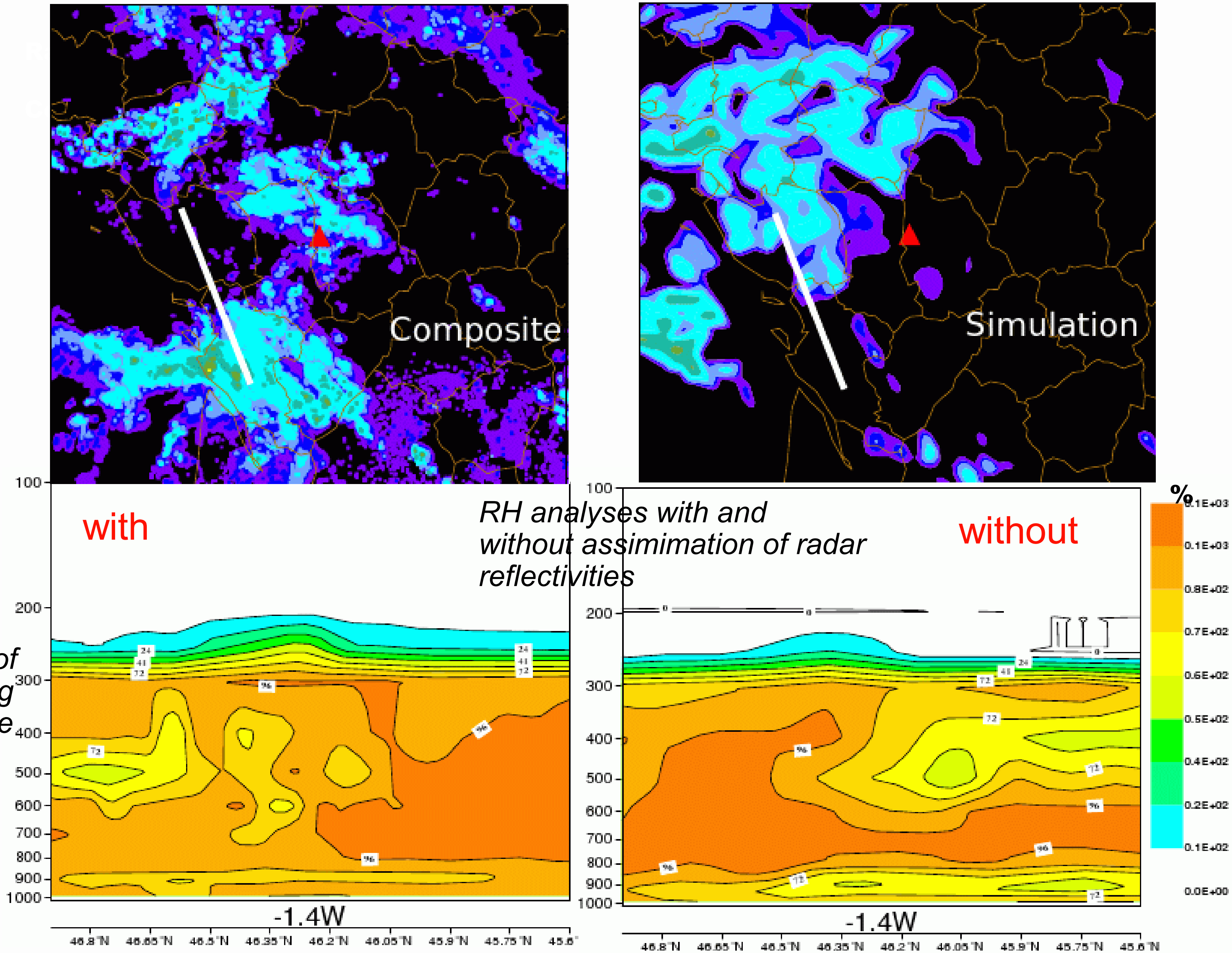
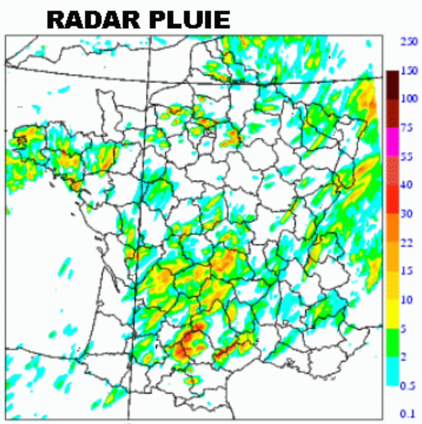


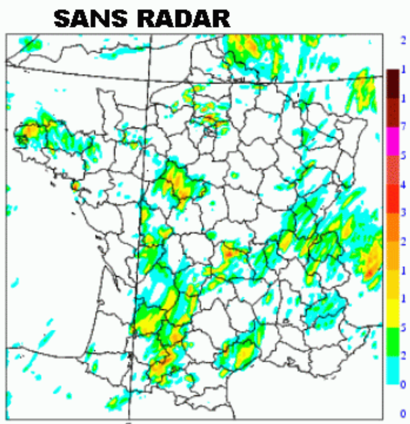
Illustration – Analysis differences with and without radar reflectivity assimilation

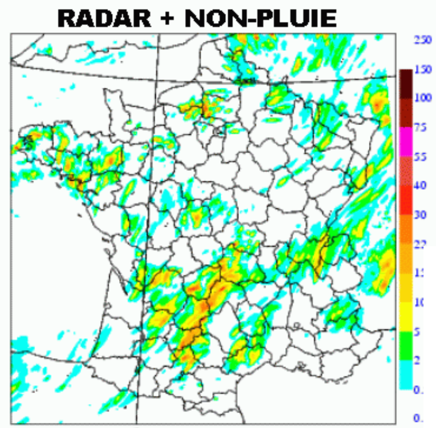


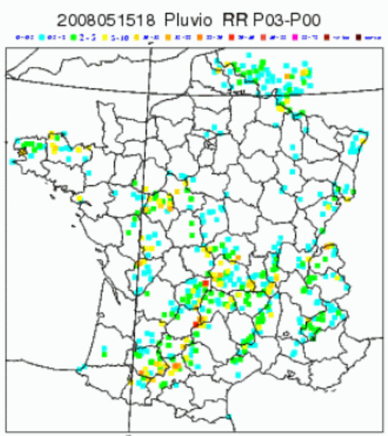
Vertical cross section of RH along white line

First tests with « non-rain » information

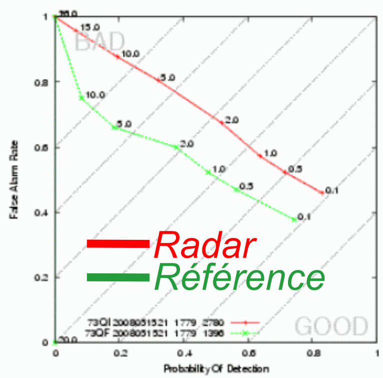


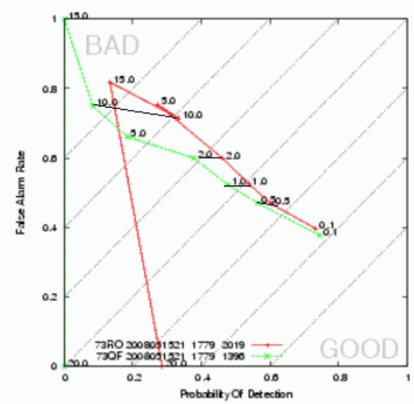






3h accumulated forecasts compared against raingauges



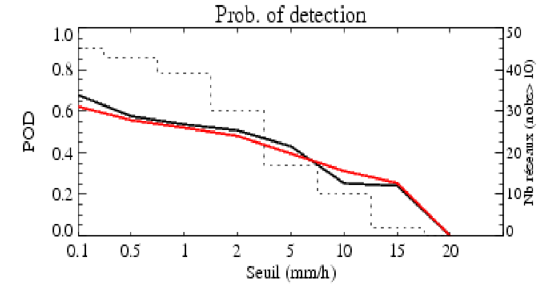


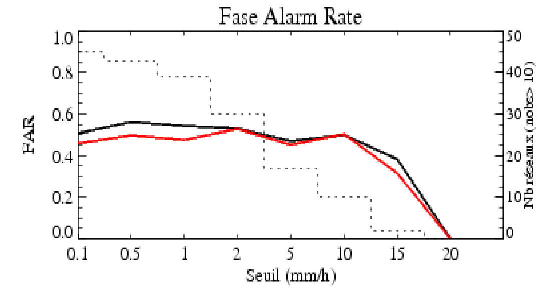
With « no-rain » information : improved the POD without degrading the FAR

April 2008: use of « no-rain » information: improved POD and similar FAR

REFERENCE

RADAR





Categorical precipitation scores

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Precipitation scores (with inclusion of « no rain » information)

Time series of convective events

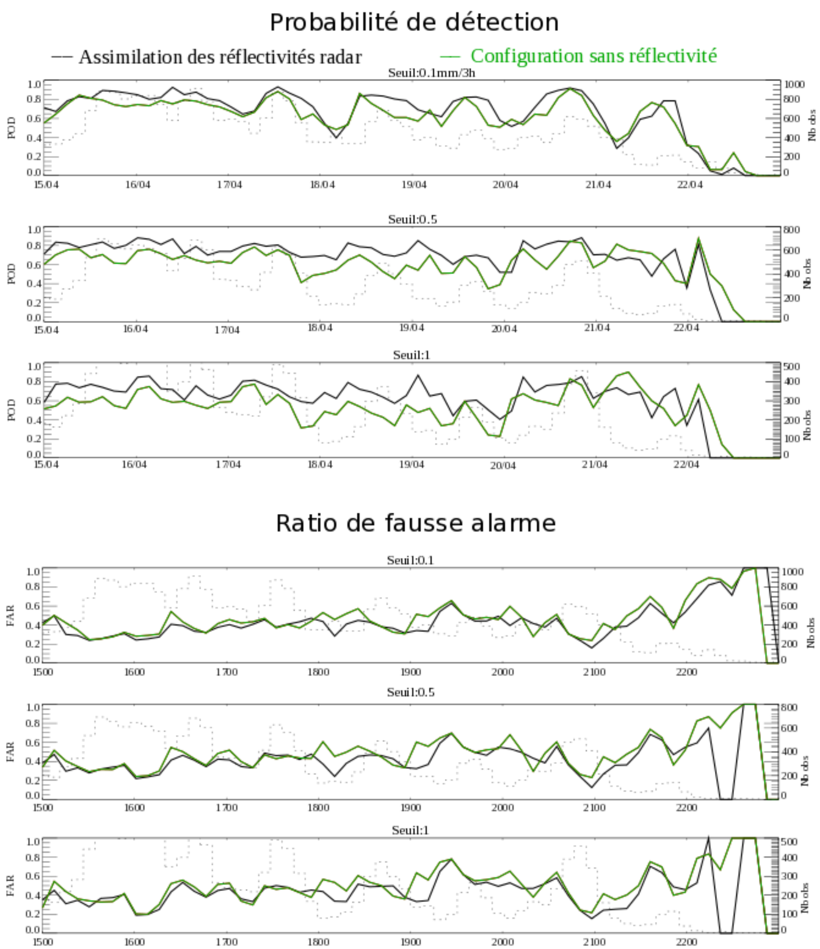


Fig. 2: Séries temporelles de scores probabilistes de cumuls de précipitations pendant les 3 premières heures d'échéance de prévisions pour les seuils 0.1mm, 0,5mm et 1 mm. Sur la période du 15 au 23 avril avril 2009, pour l'expérience sans assimilation des réflectivités radar (vert), avec l'assimilation des réflectivités radar (noir). En haut pour la probabilité de détection, et en bas, pour le ratio de fausses alarmes.

Scores over 36 days in winter

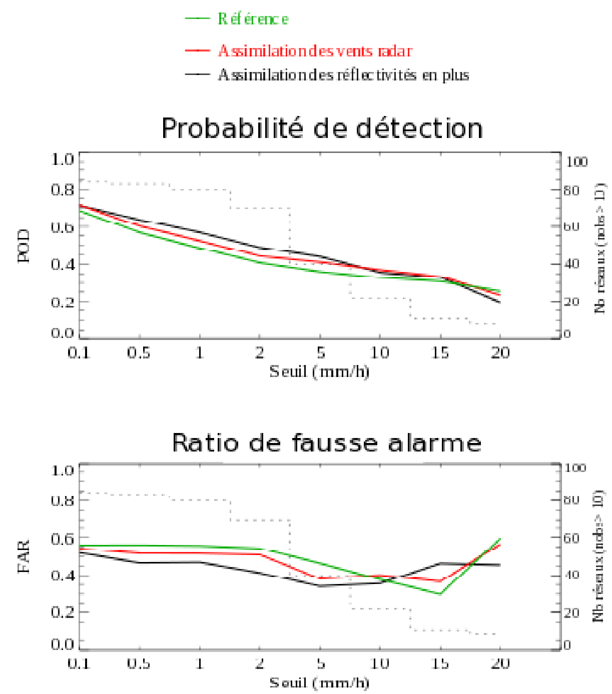
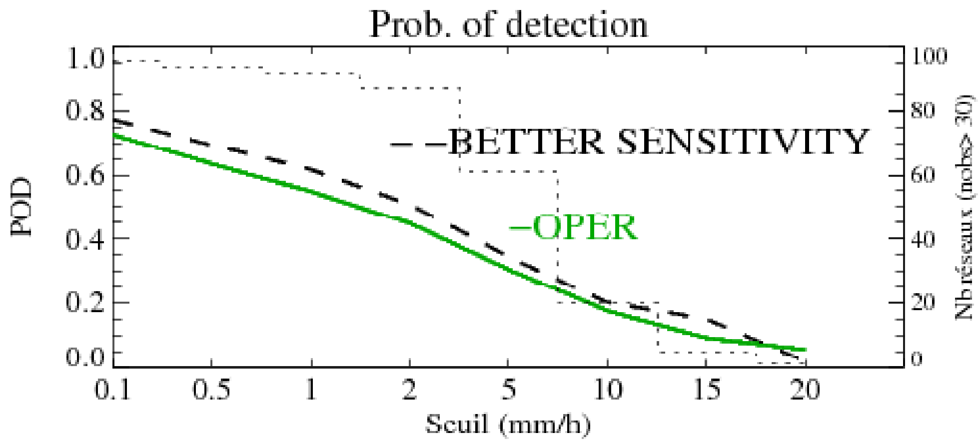
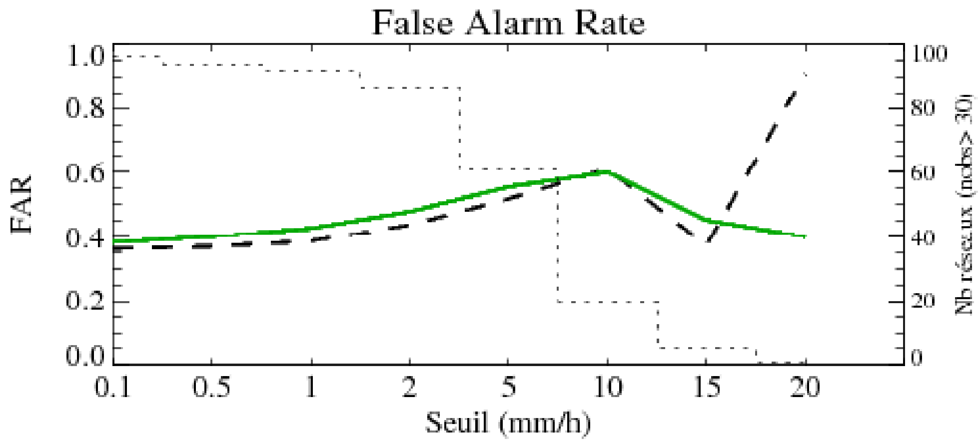


Fig.3: Moyenne de séries temporelles de scores de cumuls de précipitations suivant différents seuils. Nombre de réseaux pris en compte en tireté noir.

Precipitation scores with improved tuning of « no-rain » detection (operational configuration)

- *Example over 15 days in April/may 2010 with significant convective events*





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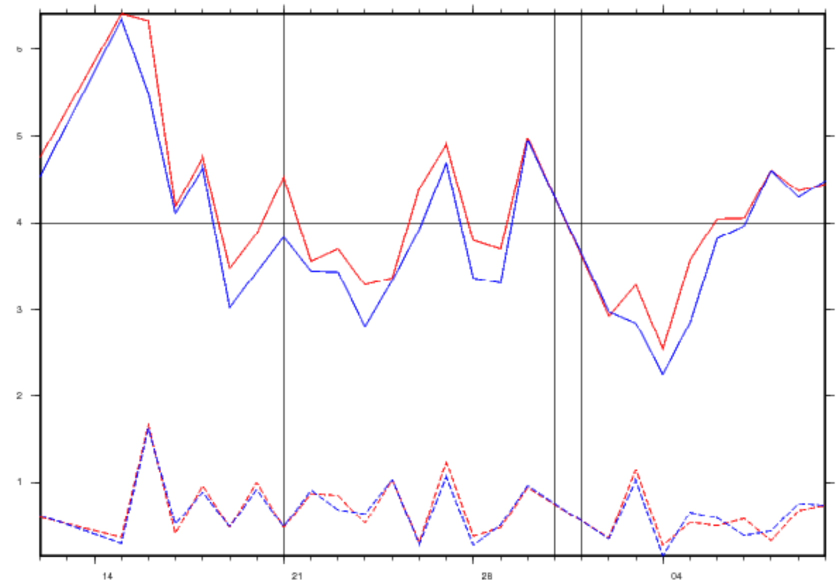
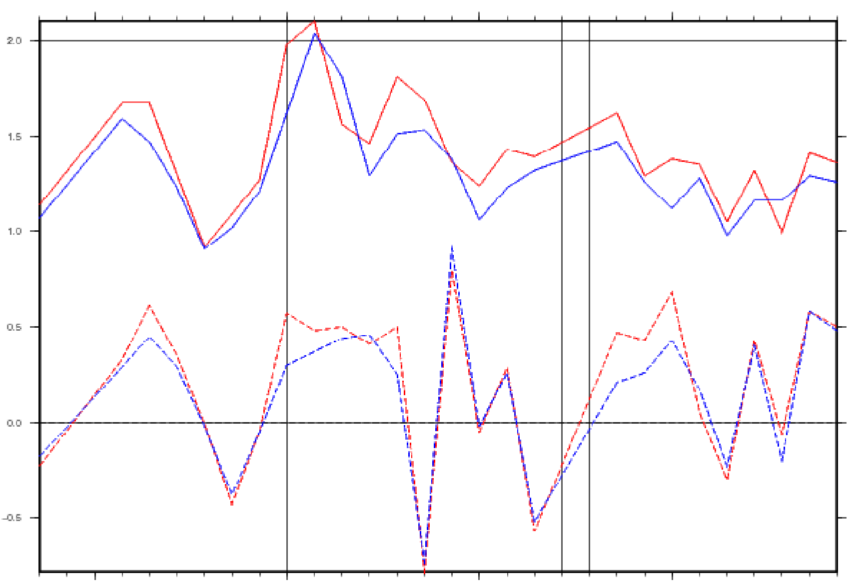
24h forecast scores for wind and temperature (over one month)

rms reference
rms radar

bias reference
bias radar

- *RMS and bias for **700 hPa wind** against own analyses (28 days)*





*RMS and bias for **925 hPa temperature** against own analyses (28 days)*

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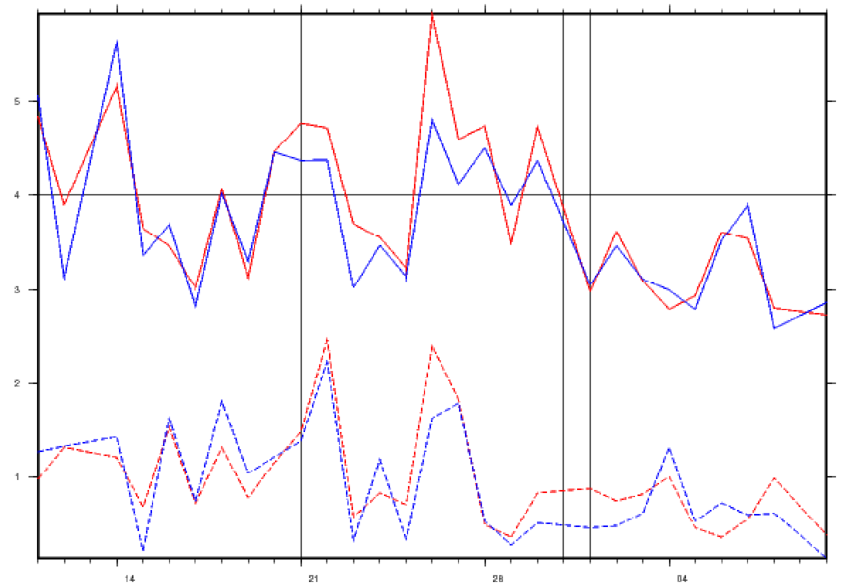
12 forecast scores for wind against radiosoundings

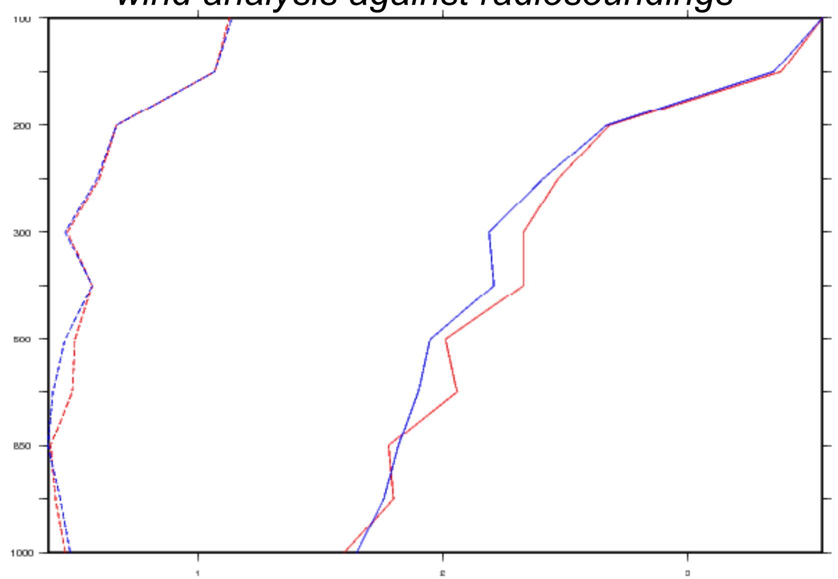
rms reference
rms radar

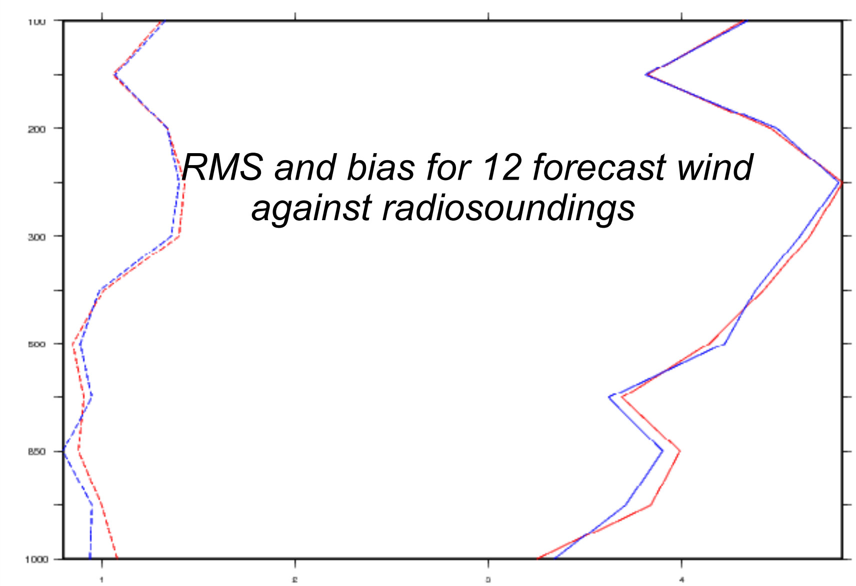
bias reference
bias radar

- *RMS and biais for **925 hpa wind** against radiosoudings*



Better fit to analysis : RMS and bias for wind analysis against radiosoundings

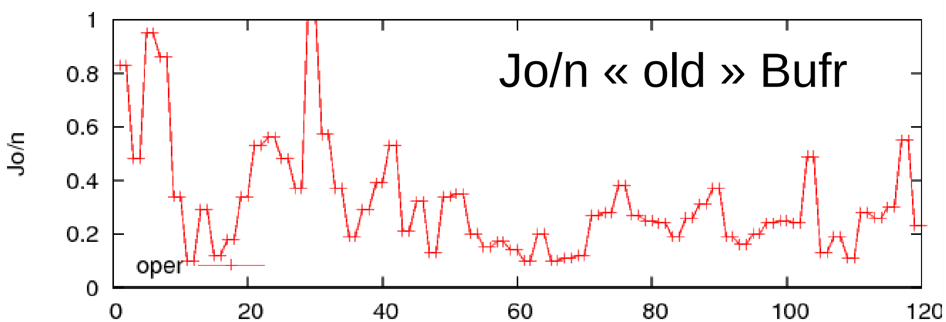


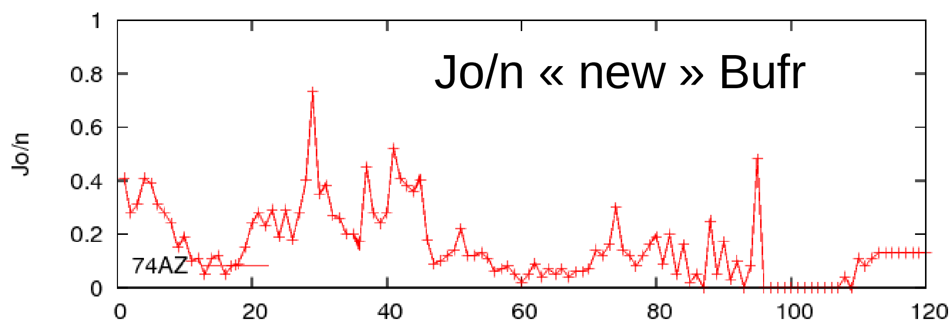


Summer 2009, revised BUFR from CMR : better identification of **ground clutter, clear sky echoes and sea clutter** using various algorithms (fuzzy logic, anaprop, texture analysis, …)

=> Significant impact on scores !

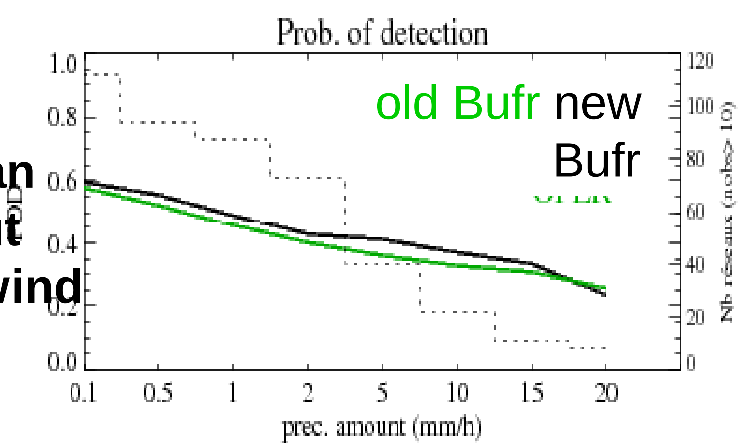
Model background closer to observations :

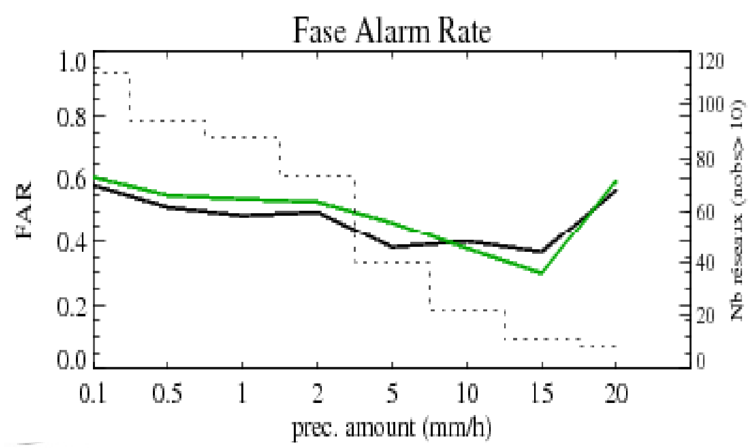




15 day QPF (6h accumulations):

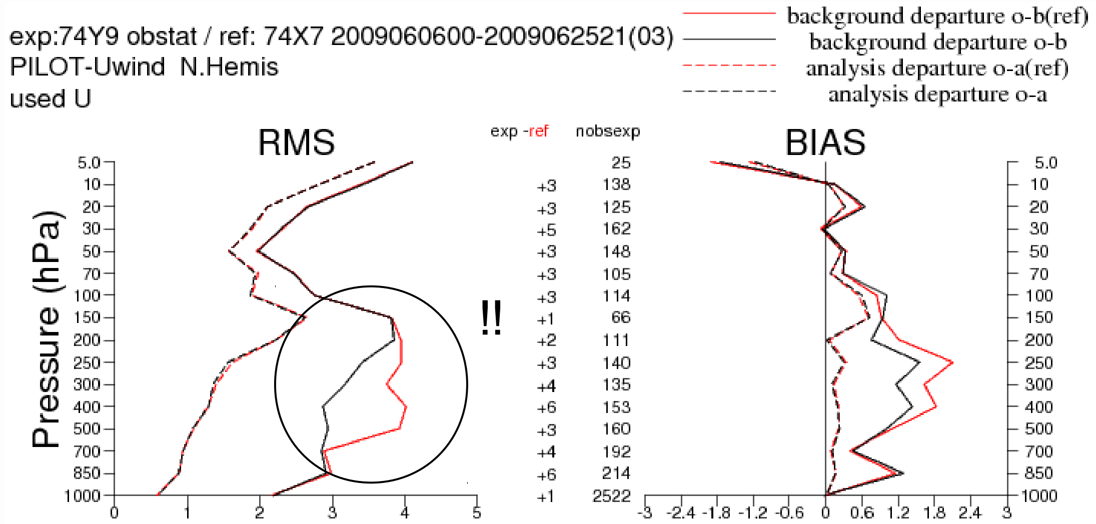
More impact than with and without initial Doppler wind data

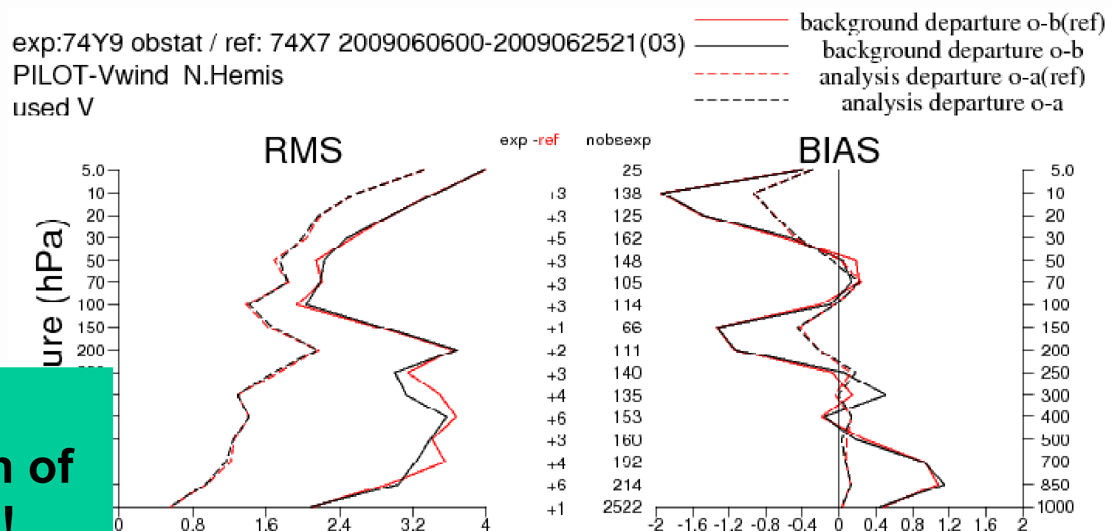




Impact of the assimilation of poor radar wind data

old Bufr
new Bufr





Scores over 19 days against PILOT

Strong impact on 3h forecasts …

Importance of an efficient identification and elimitation of non-meteorological echoes !

Use of polarimetric radar data for data assimilation

- Improved consistency between water vapour and hydrometeors
- Reduced model spin-up
- Improve short-range precipitation model forecasts
- Improvement of the quality of radar images through an improved identification of non-meteorological echoes
- Correction of the reflectivity from attenuation effects.
- Initialisation of identified hydrometeors (rain, snow, graupel, hail) using Z/M relationships according to hydrometeor types (Preliminary studies undertaken by O. Caumont at CNRM/GMME)
- Direct assimilation of K_{DP} et Φ_{DP} with a suitable observation operator (Jung et al. 2007)

Conclusions and perspectives

- Operational assimilation of radar reflectivities from ARAMIS network in the 3D-Var AROME since April 2010 (1D+3D Var methodology)
- Importance of identification of non-meteorological echoes and of non-rainy areas
- Improved usage of polarimetric data (clear air echoes, attenuation)
- Need for an increased usage of European radar data : EUMETNET OPERA project – preparation of HYMEX
- EUMETNET observation roadmap (2013-2020) + shorter term needs for NWP
- Improved specification of « undectected » pixels within ODC : currently mixture between areas affected by clutter and those without rain (for individual radars)
- Collaborations with HIRLAM : conversion from cartesian to polar coordinate system (cartesian is specific to French radars)
- Experimentation with X-band radars in the southeastern part of France (RHYTMME project for hydrology)
- Other developments : assimilation of polarimetric data (hydrometeor initialisation) and radar refractivity (low level humidity)

Thank you for your attention !

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