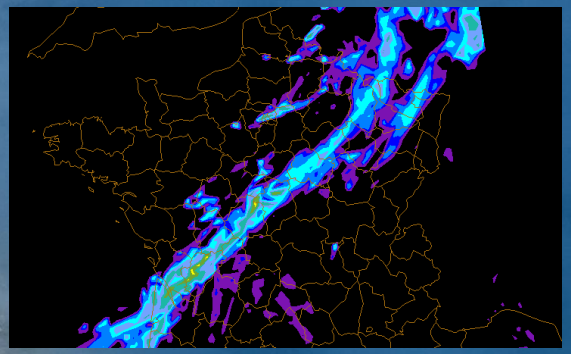

Radar data assimilation at Météo-France

J.-F. Mahfouf, E. Wattrelot,
T. Montmerle (CNRM/GMAP),
O. Caumont (CNRM/GMME),
P. Tabary (DP/CMR)

WGNE meeting, Toulouse

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Outline

1. Main features of radar assimilation at Météo-France
   - Radar network over France
   - The operational mesoscale model AROME
   - 1D+3D-Var methodology
   - Screening and quality controls

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

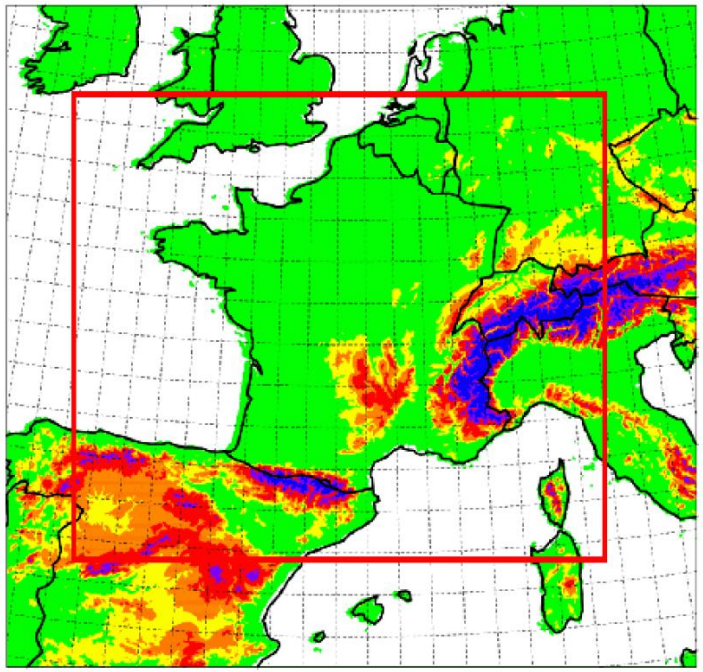
3. Ongoing activities
   - Use of X-band radars
   - Towards the use of European radars (OPERA, HYMEX)

Importance of radar data at mesoscale

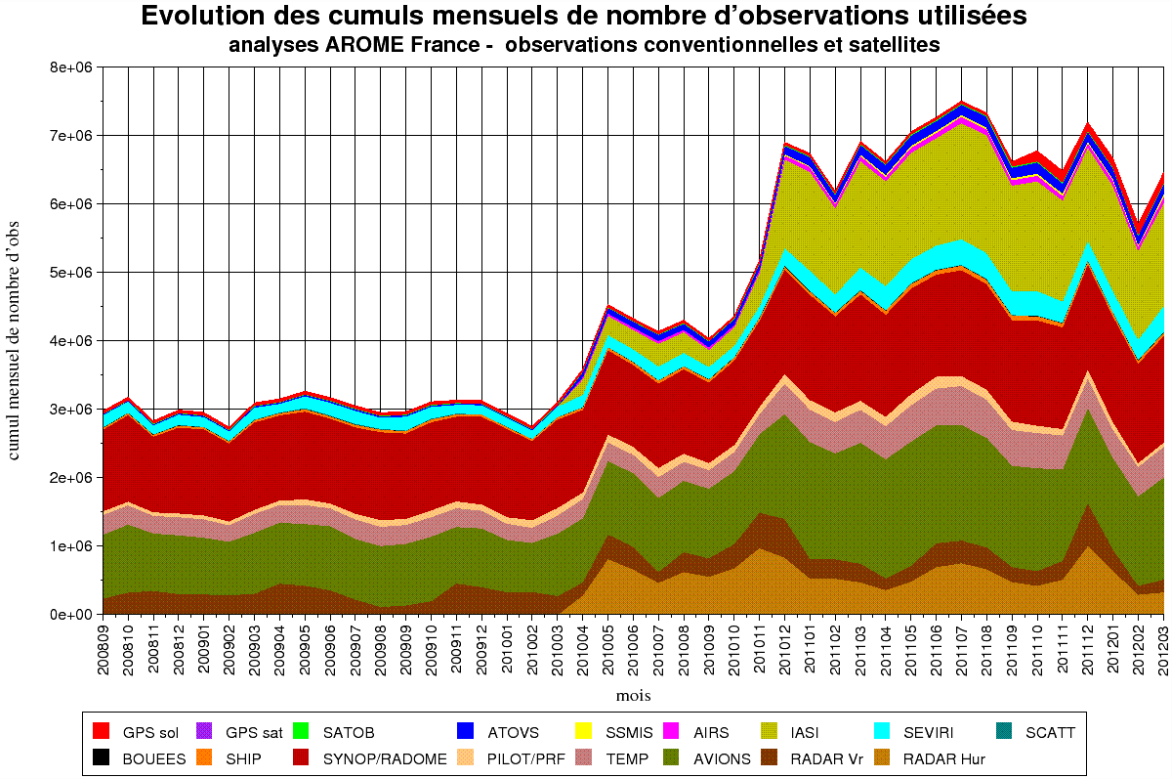
- National Weather Services need to issue accurate forecasts of high impact weather at small scale (severe thunderstorms, wind gusts, fog, ….)
- During the last 10 years many convective permitting models ($\Delta x < 3$ km) have been developed that have recently reached an operational status (JMA, MetOffice, DWD, MSC, Météo-France)
- Most of them have a dedicated data assimilation system
- Many feasibility studies (e.g. Ducrocq et al., 2000, 2002) have shown the importance of the initialisation of pre-storm environment
- Relevant observations : high temporal and spatial resolution informative about the atmosphere in precipitating systems
- Radar data : spatial resolution < 1 km : temporal resolution < 15 min : information on hydrometeors (radial velocity, rainfall rate, type)

Regional model AROME

- Spectral limited area model (non-hydrostatic with explicit moist convection)
- 60 vertical levels
- Δx = 2.5 km
- 3D-Var data assimilation (3h window)
- Coupling files : hourly forecasts from global model ARPEGE
- Forecast range : 30 hours
- Operational since December 2008



Observations in AROME



RADARS
AIRCRAFTS
SYNOP/RADOME
IASI

SEVIRI
TEMP
Ground GPS

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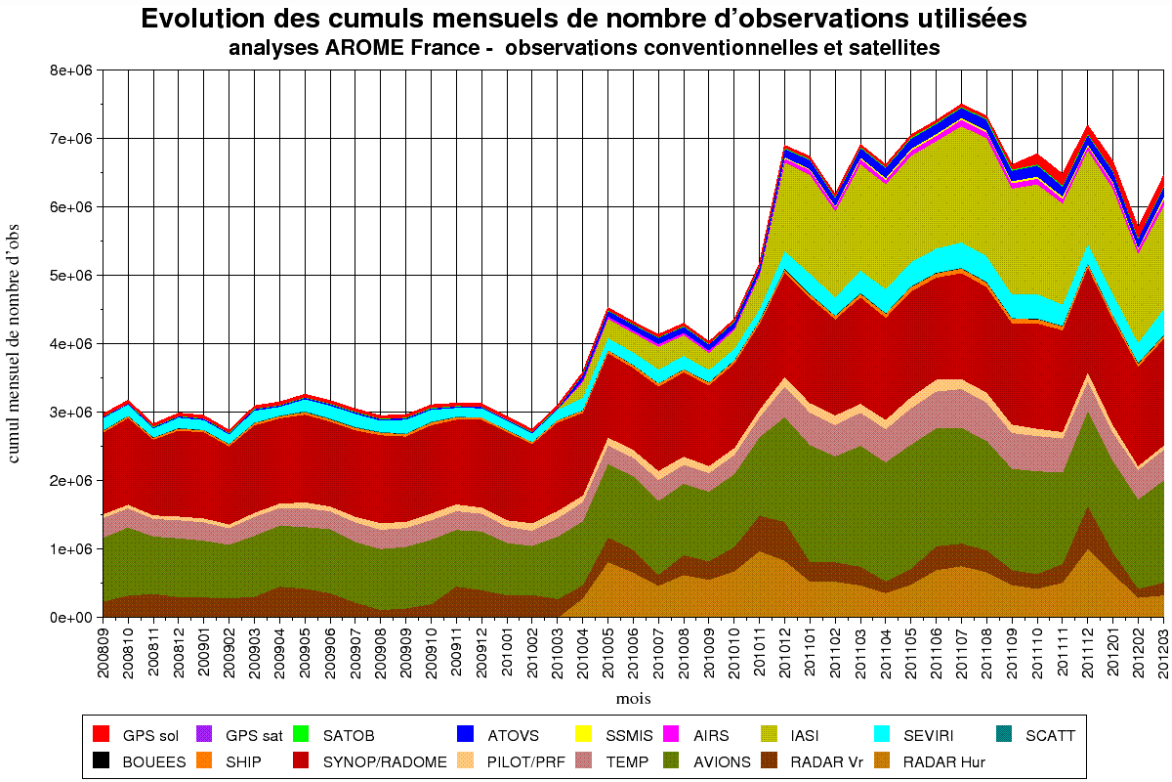
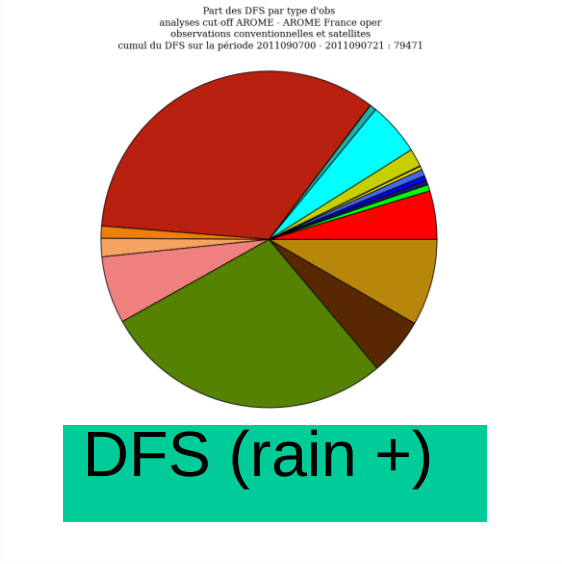
Observations in AROME





DFS (rain +)

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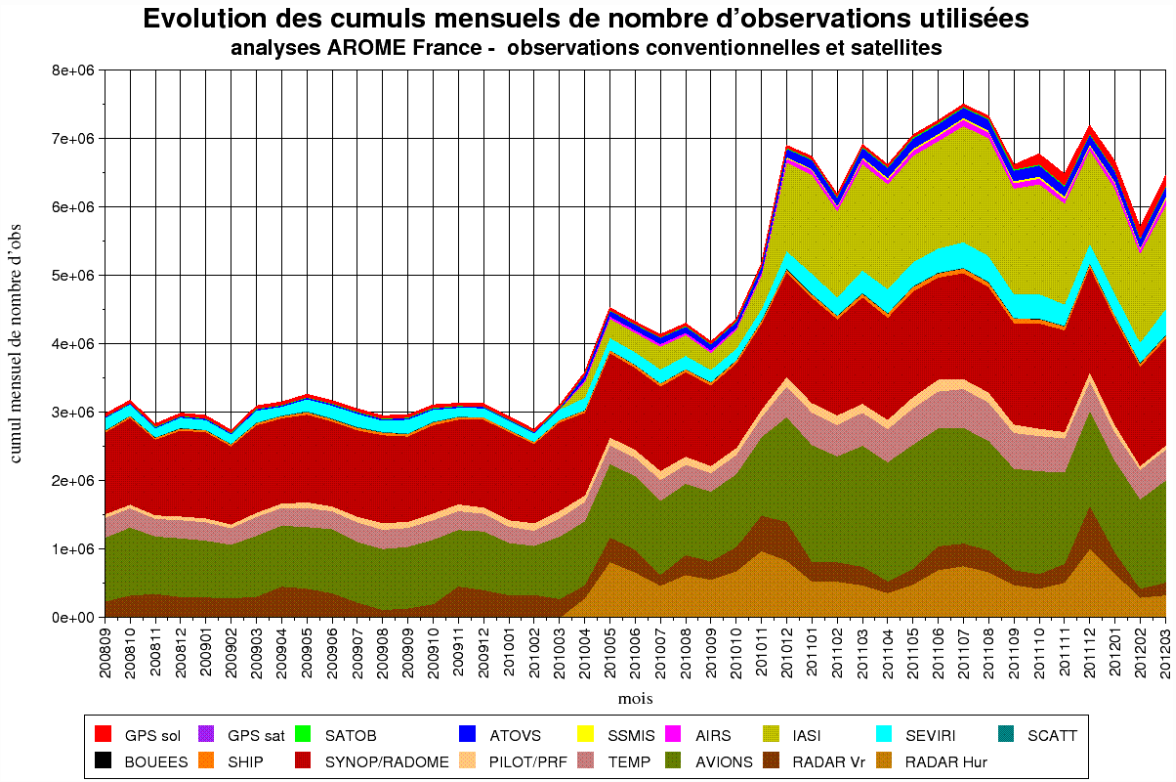
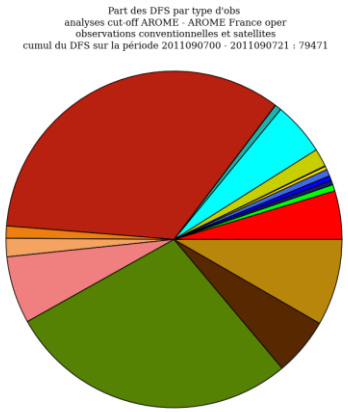
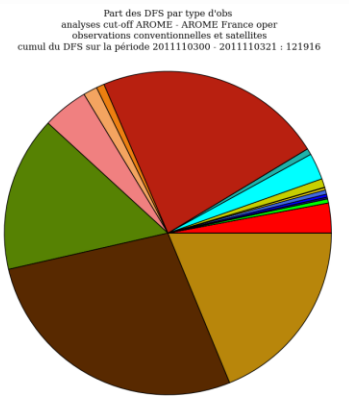
Observations in AROME





DFS (rain +)



DFS (rain +++)

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Current operational use of rada data

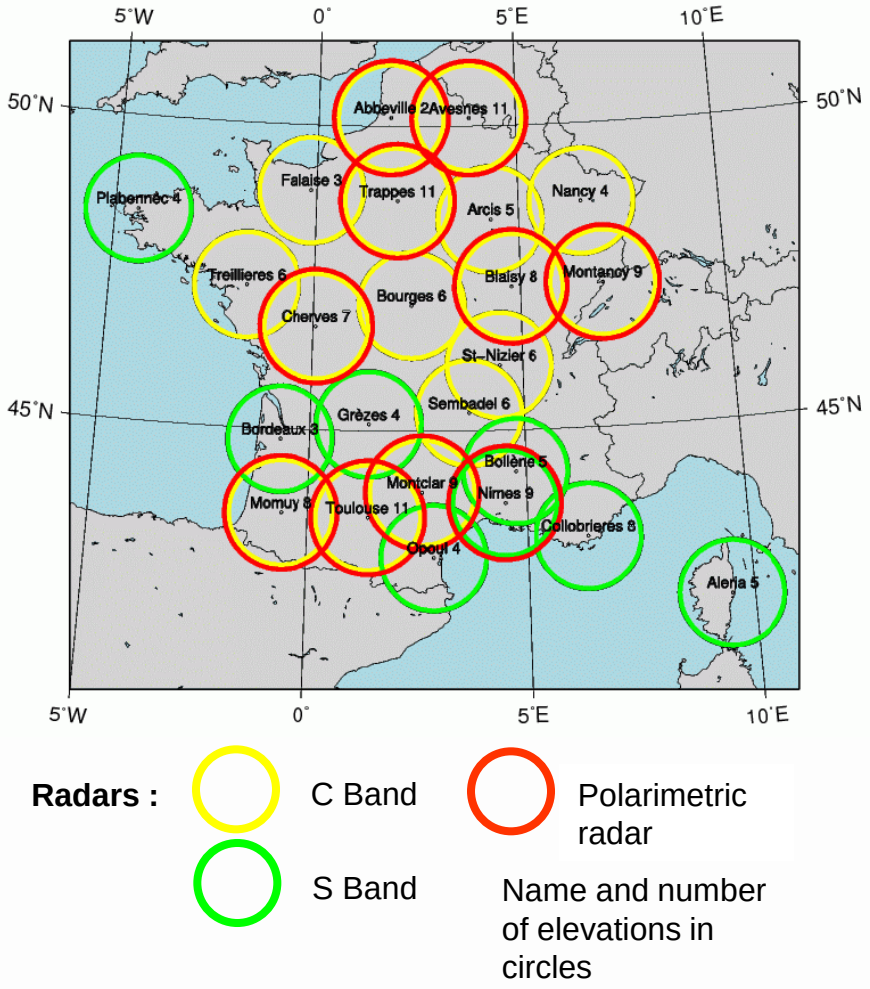
French ARAMIS network

- 24 Doppler radars, 10 Polarimetric, between 3 and 12 PPIs in 15’

Within AROME:

Volumic observations are considered every 3 hours

- **Radial wind** from 15 radars since December 2008; from 22 radars since 24 November 2010 – Triple PRT leading to unambiguous velocity of 60 m/s
- **Reflectivity** from 24 radars since 6 April 2010



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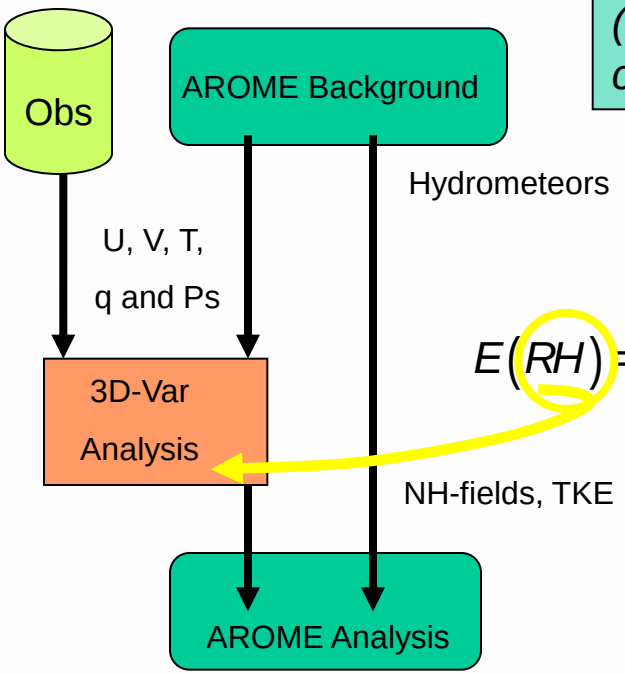
1D+3D-Var method for radar reflectivities

- Choice of retrieving humidity information (~ Marécal and Mahfouf, 2002)
- 1D Bayesian inversion technique (~precipitation retrievals from MW radiances)
- 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 !



$$E(RH) = \sum_i RH_i \frac{\exp\frac{-1}{2}\times\| Z_0 - Z_s(RH_i)\|^2}{\sum_j \exp\frac{-1}{2}\times\| Z_0 - Z_s(RH_j)\|^2}$$

Observation operator of reflectivity

Pros and cons

1. Pros:
   - Dependency of retrieved profiles with 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 corresponding background error statistics
   - 1D+3DVar is a robust method

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

Screening : pre-processing, quality controls and errors

- Importance of pre-processing : restrictive algorithms to avoid assimilating artifacts and loosing useful information.

- Pre-processing before assimilation:
  - Elimination of **anomalous propagation** (height and Z thresholds)
  - **Beam blocking** areas are blacklisted
  - Retrieval errors (**attenuation**, **beam broadening**) accounted for in the specification of observation errors in the 3D-Var (linear increase upon radar distance.)
- Quality control vs model :
  - Very small σ_0 in 1D inversion (0.2 dBZ) => no retrieval if the model is too far from the observation
  - Consistency checks of RH increments vs. reflectivity innovations
  - Relaxed FG check compensated by examining the difference « **analysis of pseudo-reflectivity – observed reflectivity »**
- 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.

« No rain » information

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

Precipitation signal :

- **RADAR**: it rains if the SNR is large enough (Z above the minimum detectable reflectivity (**MDZ**) known for each pixel)
- **AROME:** as soon as precipitating hydrometeors are produced

Rain in radar (SNR>0)

Sensitive detection in the model

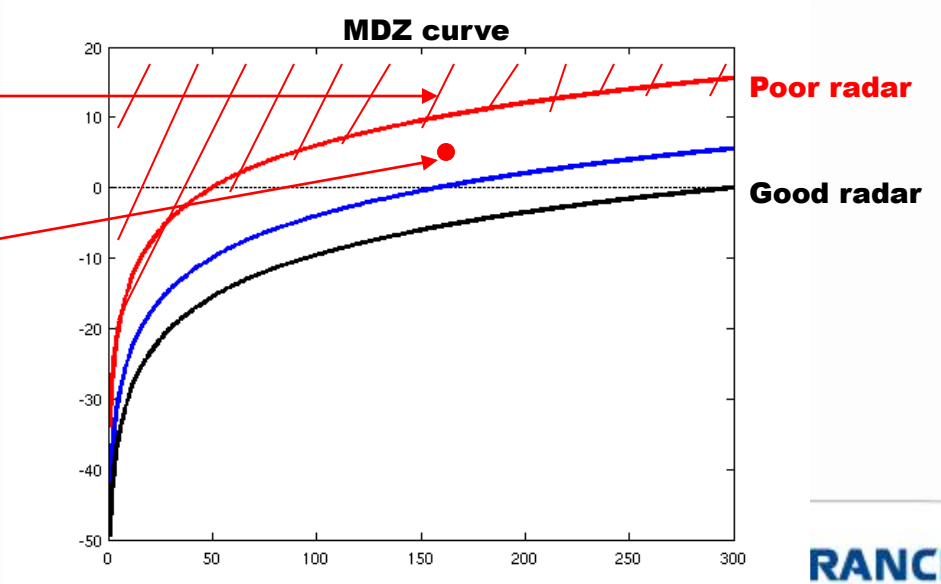
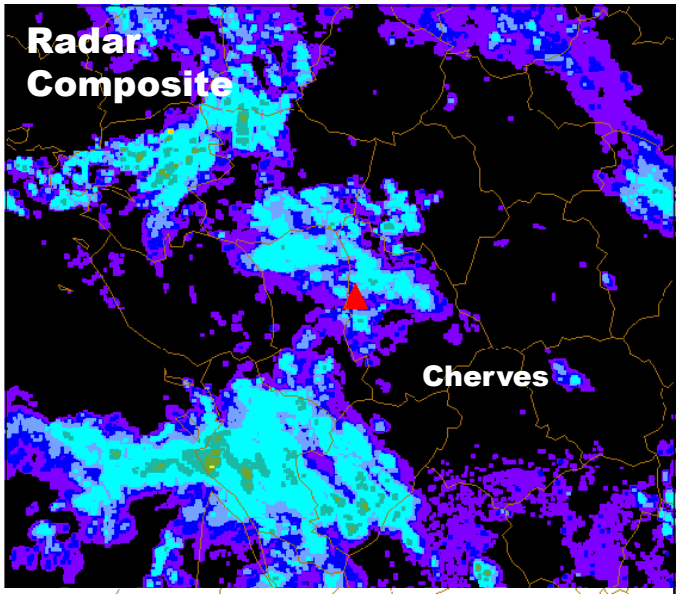
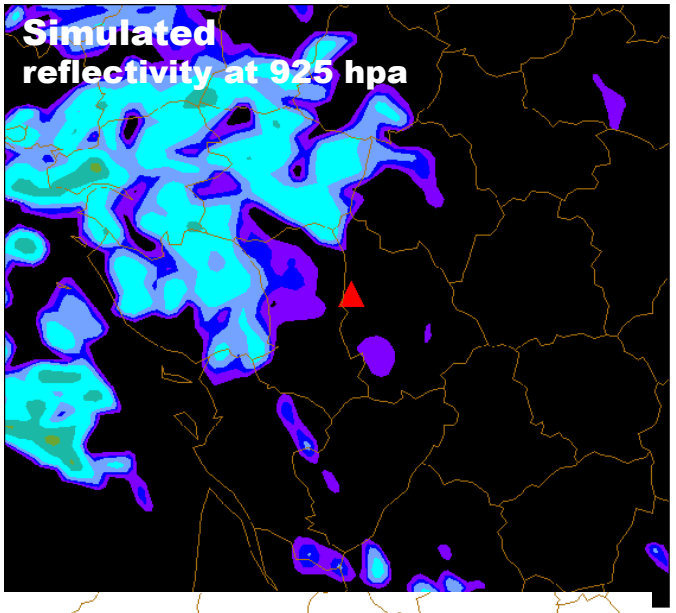


Illustration – reflectivity field – radar and model

CAPPI





PPI

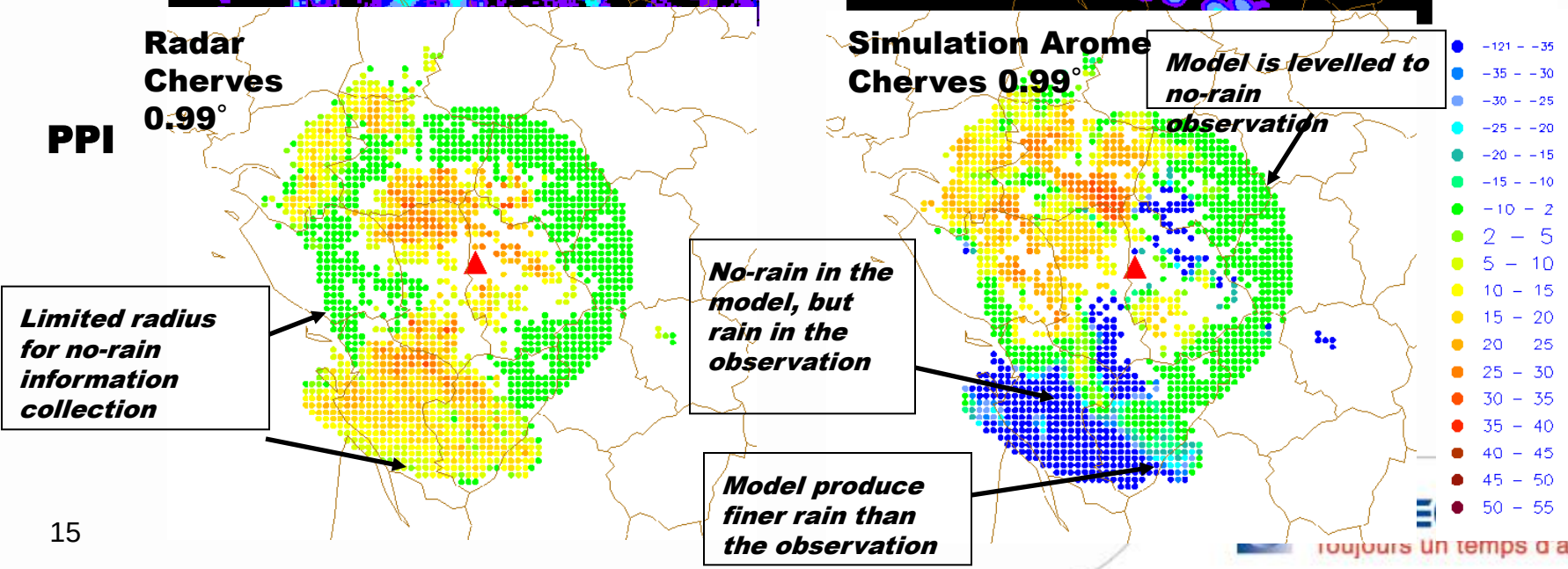
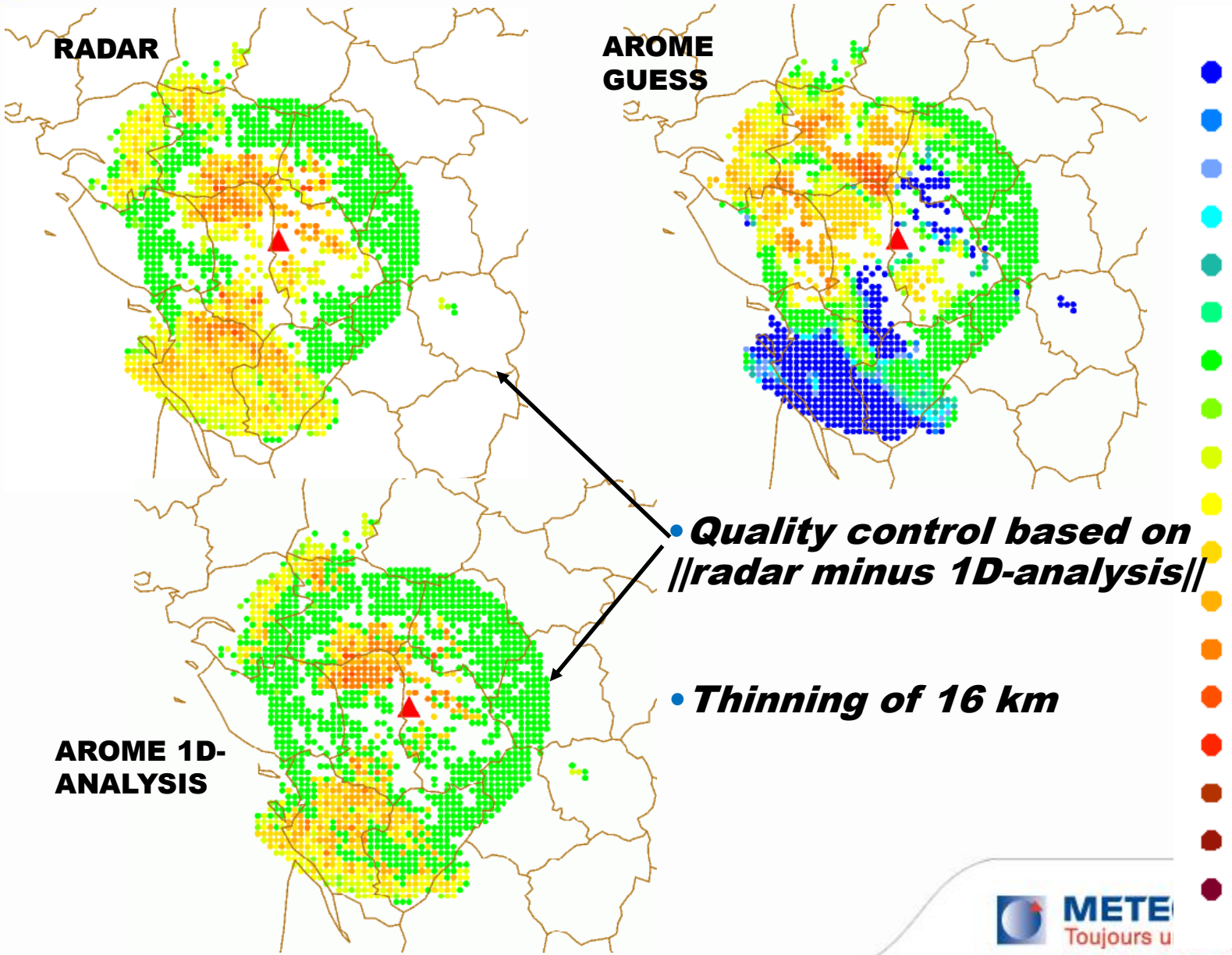
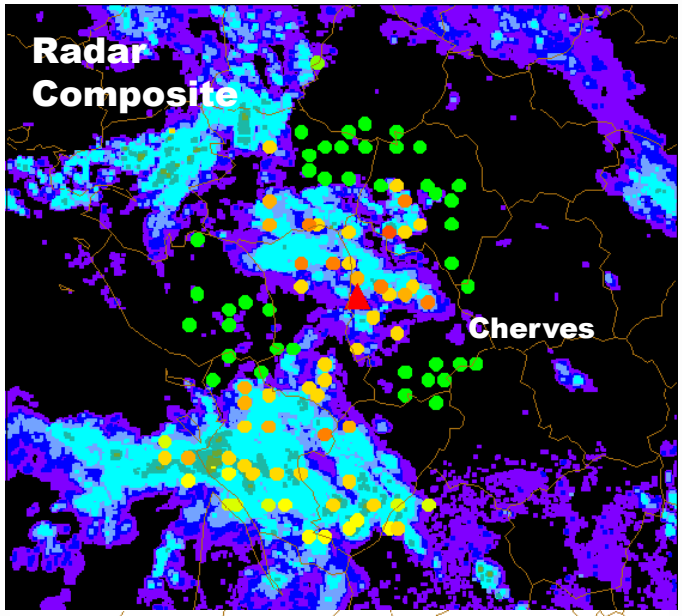


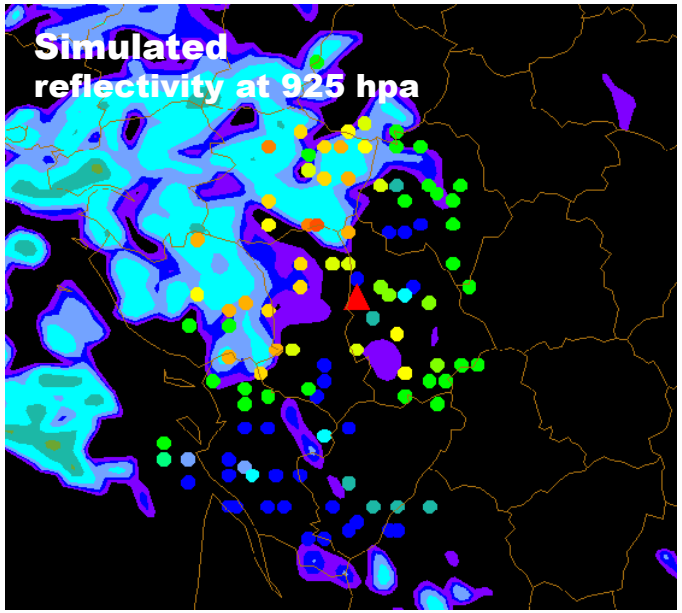
Illustration – comparison between radar reflectivity and reflectivity 1D analysis : 1D convergence and quality control

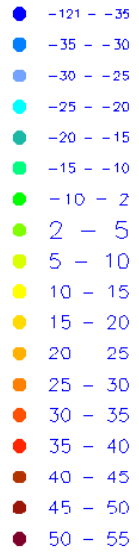


- ***Quality control based on ||radar minus 1D-analysis||***
- ***Thinning of 16 km***

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







Pseudo-innovations of relative humidity

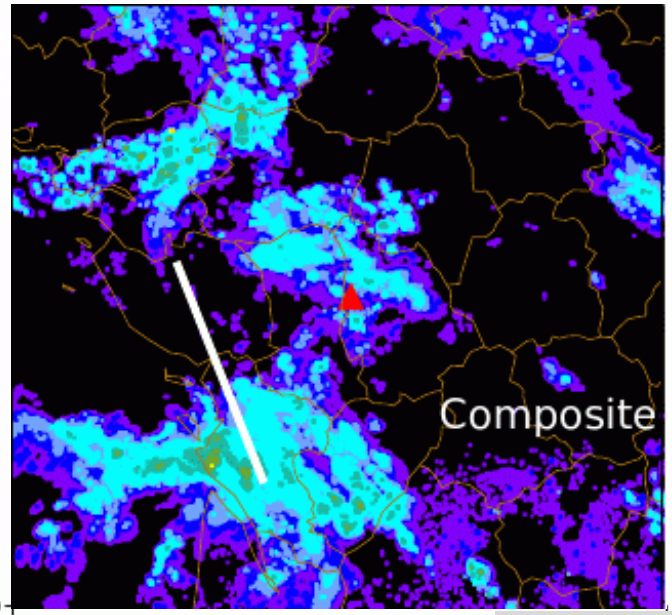
(OBS-BG)

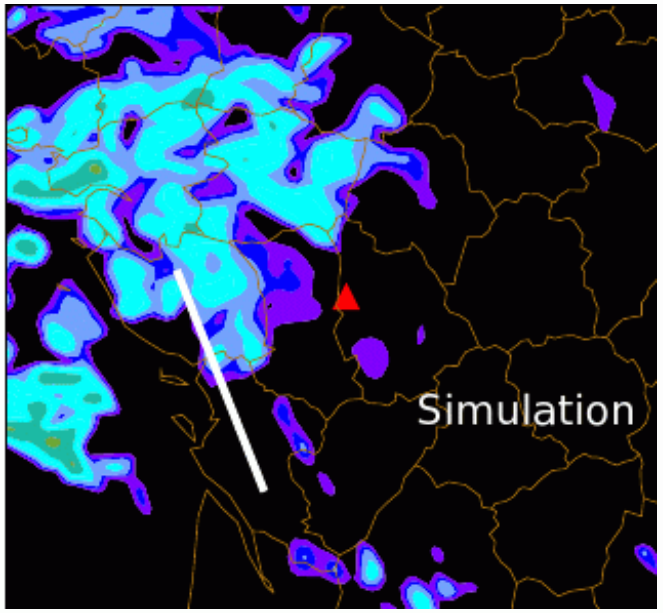
Analysis increments of relative humidity

(ANALYSIS-BG)

Analysis field of humidity strongly constrained by reflectivity observations

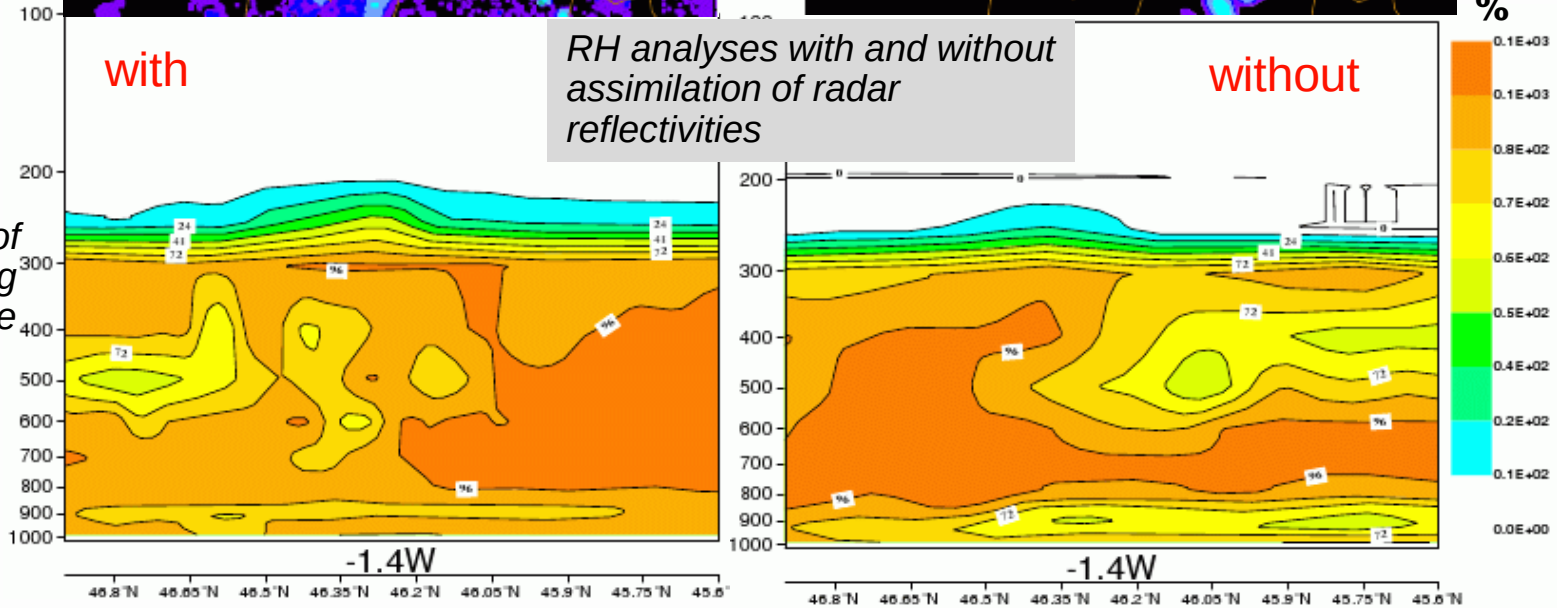
Illustration – Analysis differences with and without radar reflectivity assimilation





RH analyses with and without assimilation of radar reflectivities

Vertical cross section of RH along white line



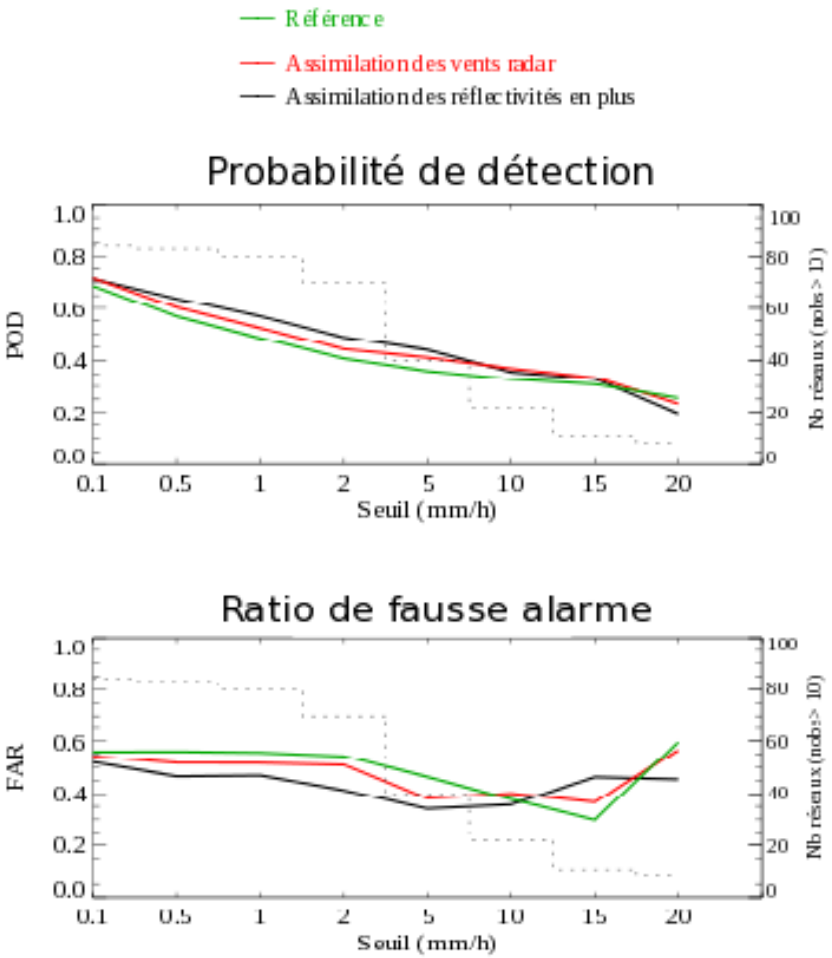
Precipitation scores

Scores over 36 days in winter

Reference

Assimilation Doppler winds

Assimilation of DOW + Z



Probability of detection

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

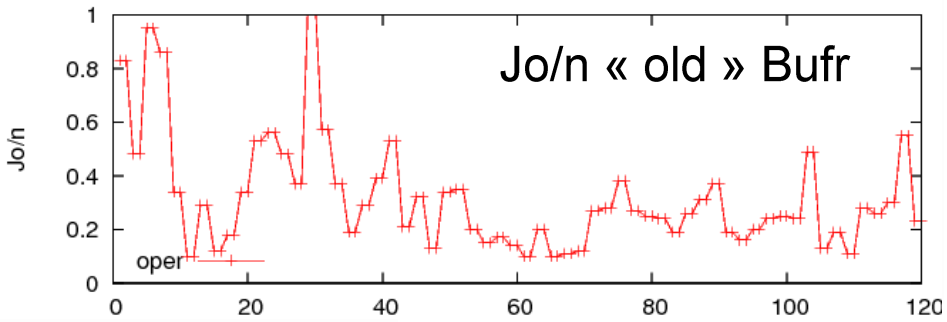
False Alarm Rate

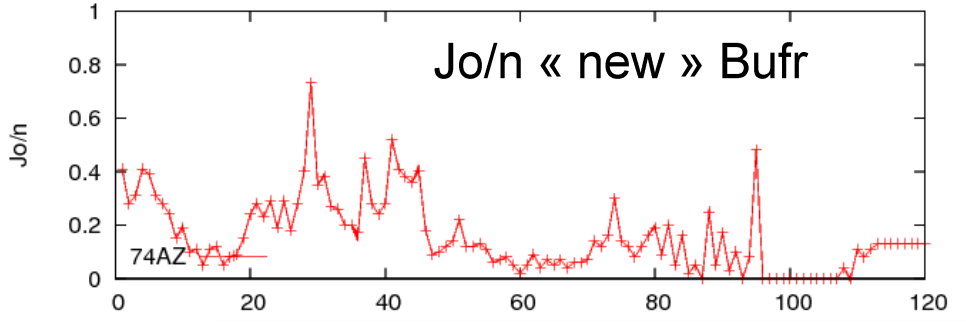
Impact of the assimilation of poor radar wind data

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 !

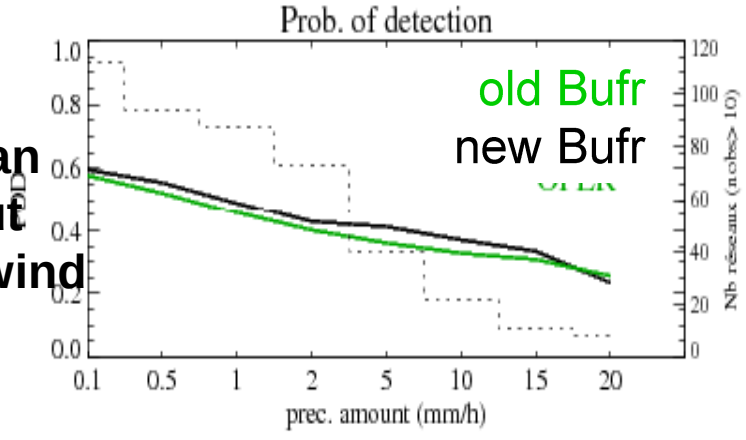
Model background closer to observations :

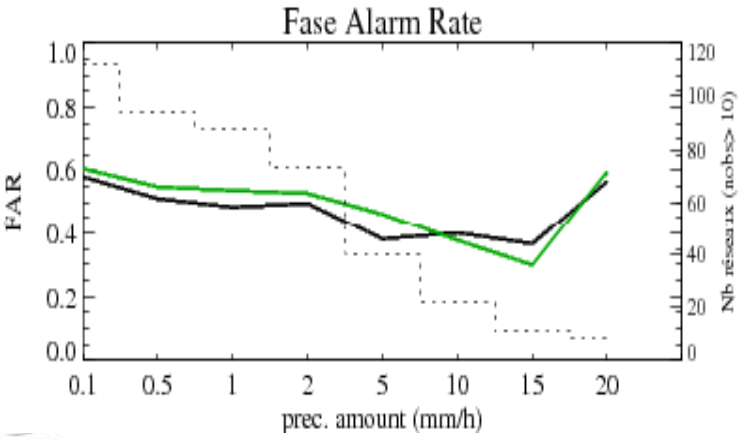




15 day QPF (6h accumulations):

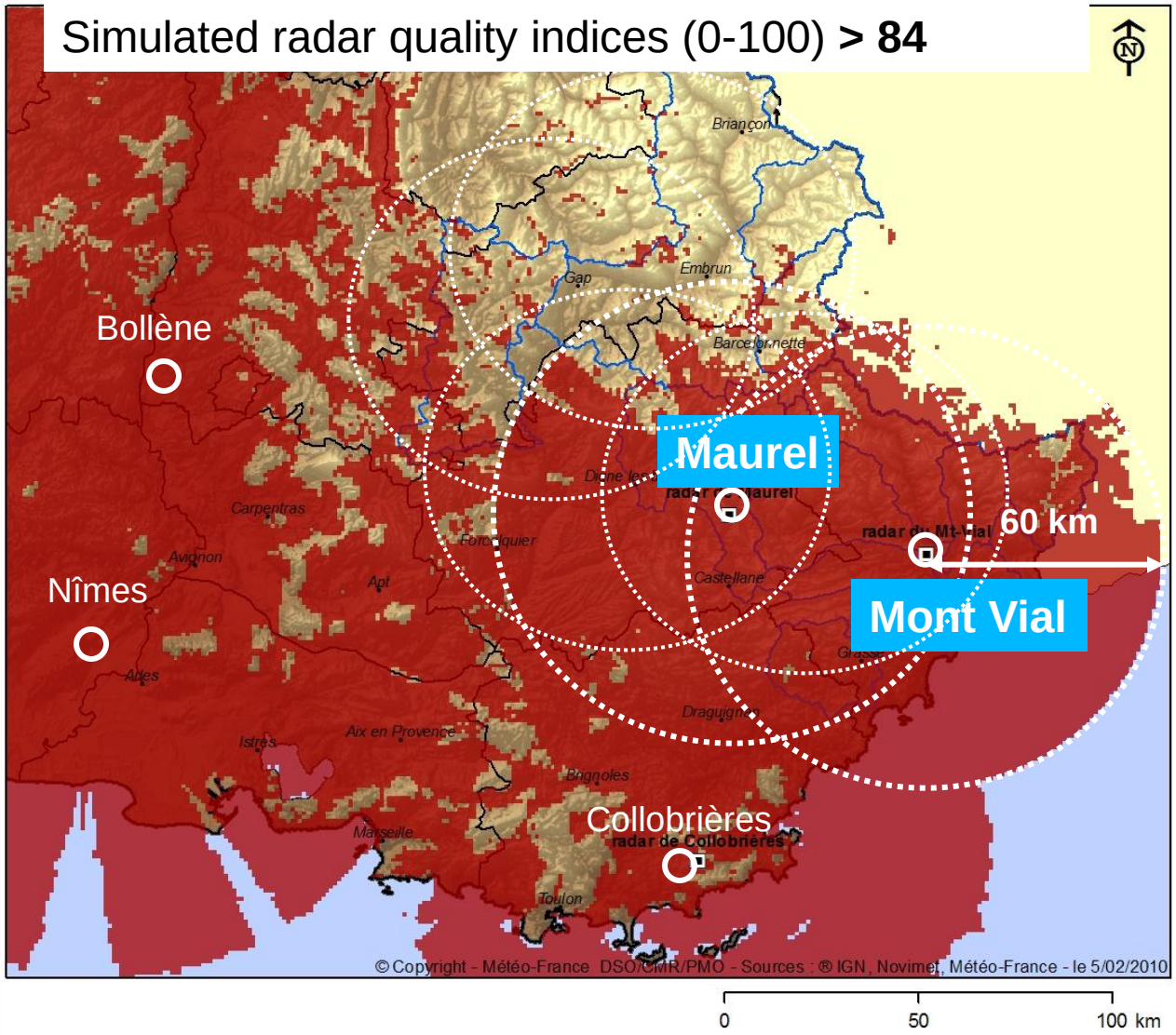
More impact than with and without initial Doppler wind data





A network of X-band radars

Simulated radar quality indices (0-100) **> 84**



Quality index > 84

River basins

\+ radar Hydrix® at **Mont Vial** (1550m)

\+ radar at Mt **Maurel** (1770m)

(Hymex SOP1)

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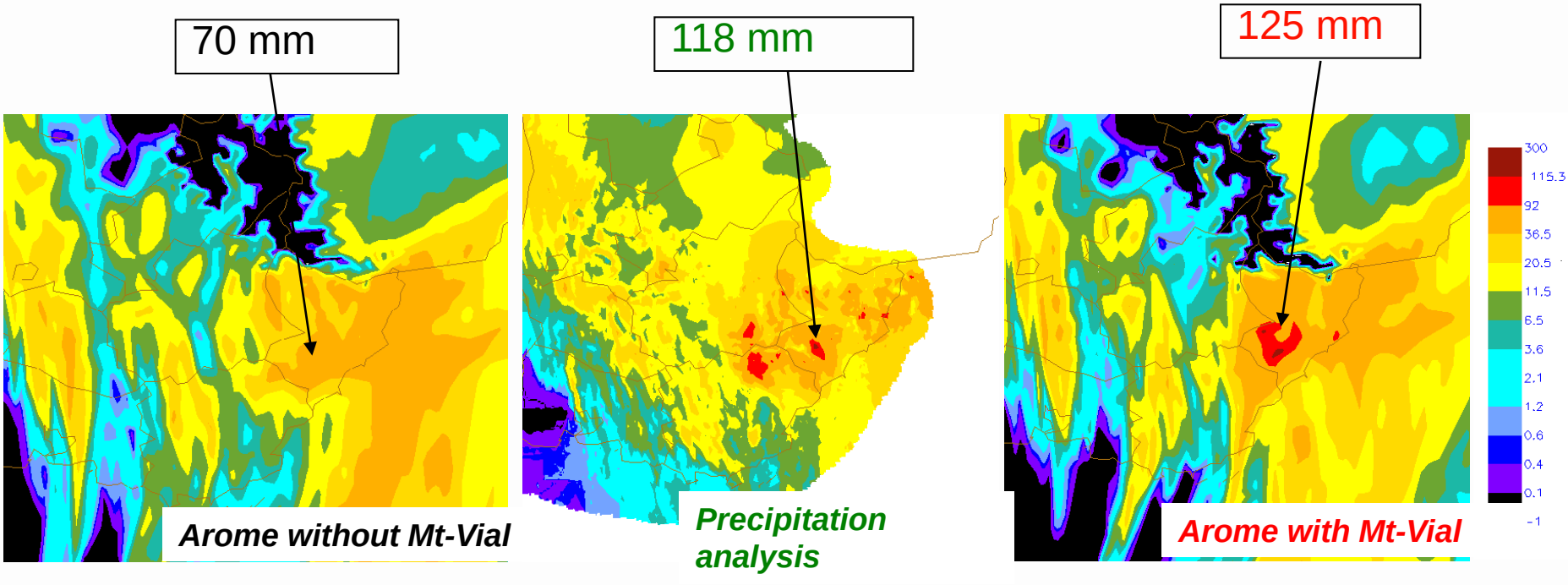
Impact of X-band radar assimilation



Improvement coming from DOW (similar behavior with DOW+Z)

31/10/2011 (12 UTC)

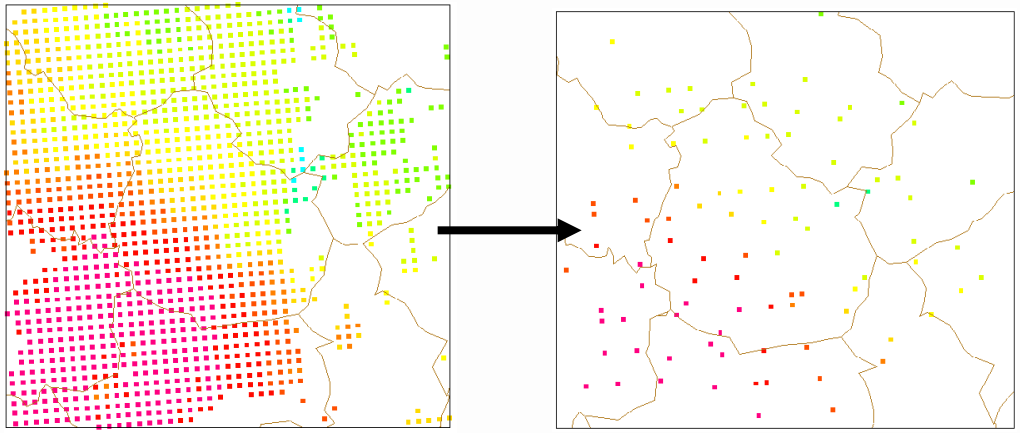
Horizontal correlation of observation errors

Cost function of the 3D-Var:

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

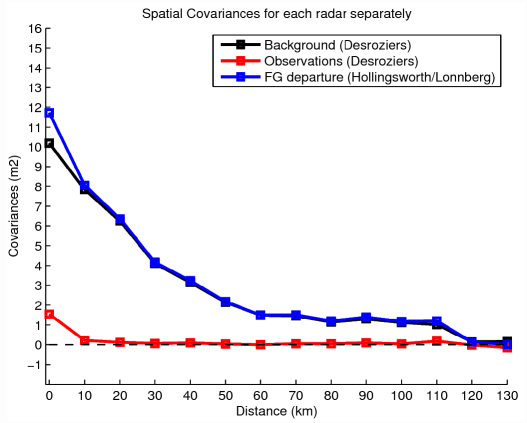
But currently R is diagonal in the system !

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



Diagnosis of correlation of observation errors

- Method of Hollingworth-Lonnberg
- Method of Desroziers
- Use of Assimilation Ensemble results



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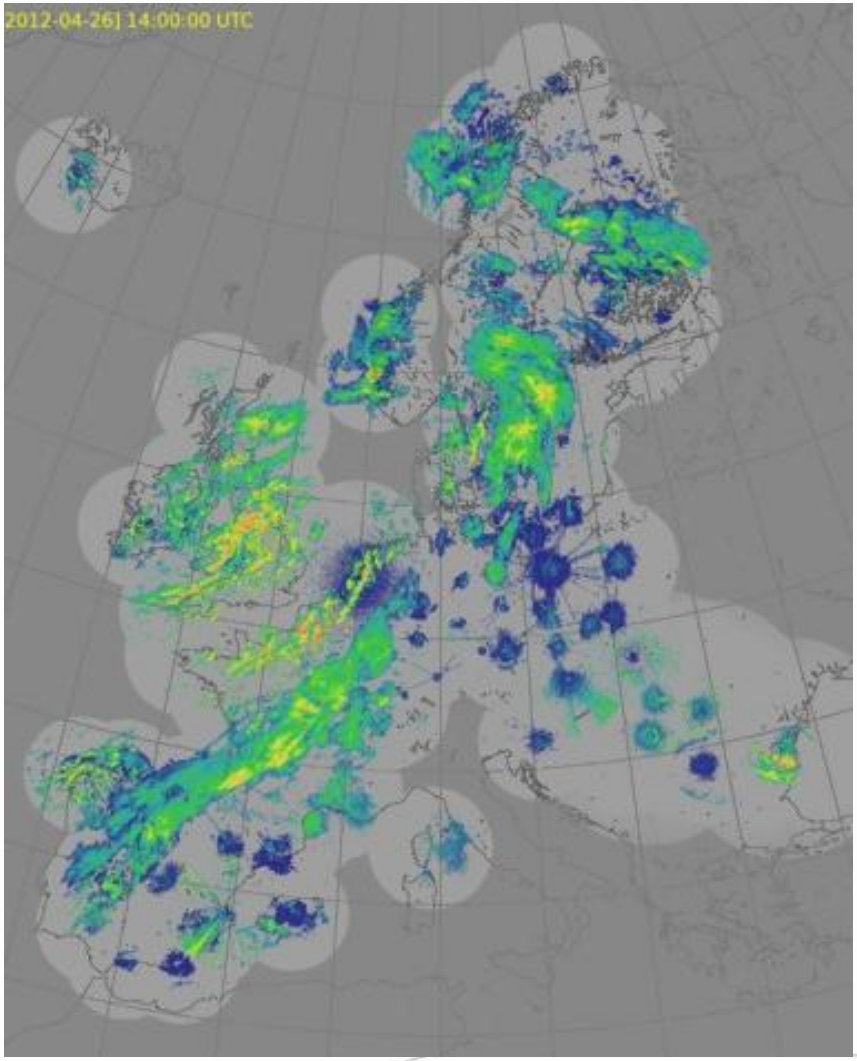
OPERA : Towards a European radar data exchange

- EUMETNET optional programme
- Previous phases :
  - Common Data Format exchange (ODIM)
  - Exchange of radar composites : Z and RR
- **Next phase : 2013 -2017**
  - Better specification of the NWP community needs
  - Improved quality flags and echo types
  - Exchange of 3D volume data (Z and DOW) from individual radars



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Conclusions and perspectives

- Operational assimilation of radar data from the French network ARAMIS in the 3D-Var AROME since :
  - **December 2008** for Doppler winds
  - **March 2010** for reflectivities (1D+3D Var methodology)
- Improved assimilation by a better identification of non-meteorological echoes and of non-rainy areas (importance of polarimetric information)
- Experimentation with X-band radars in the southeastern part of France (RHYTMME project)
- Towards an increased usage of European radar data (HYMEX field campaign + EUMETNET OPERA)
- Need for improved specification of observation errors : horizontal correlations
- Ongoing developments :
  - AROME at 1.3 km with 3D-Var RUC (1h window)
  - Assimilation of polarimetric data (hydrometeors) and radar refractivity (low level humidity)


Thank you for
your attention !
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