Operational assimilation of radar data at convective scale in AROME France

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LACE DA working days, June 2012

METEO FRANCE
Toujours un temps d'avance

Outlines

1. Introduction: impact of radar data in AROME
2. Radar DA components
3. Current studies
4. International cooperations
5. Conclusions

The ARAMIS radar network

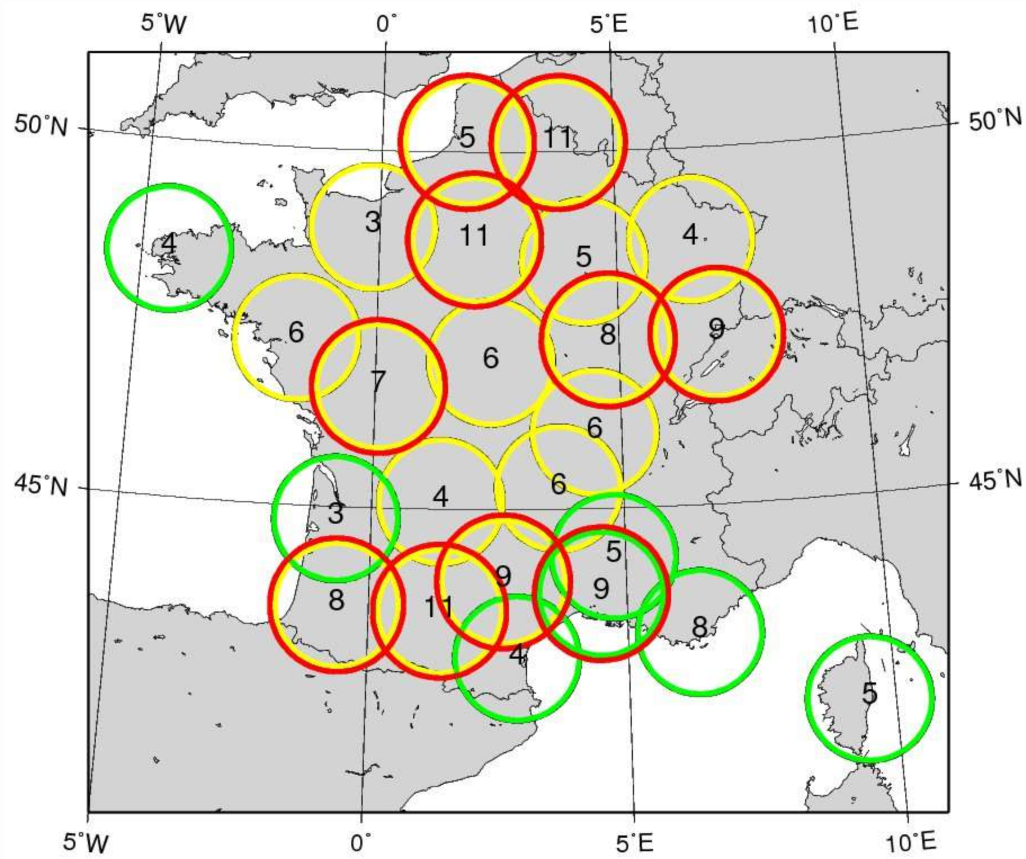
- **24 radars**, performing between 3 and 12 PPIs/15’
- in AROME, volumic observations are considered every 3h so far (hourly assimilation is planned in 2014)
- triple PRF leading to an unambiguous velocity of 60 ms^{-1}
- Data from 3 X-Band radars currently tested

S Band

C Band

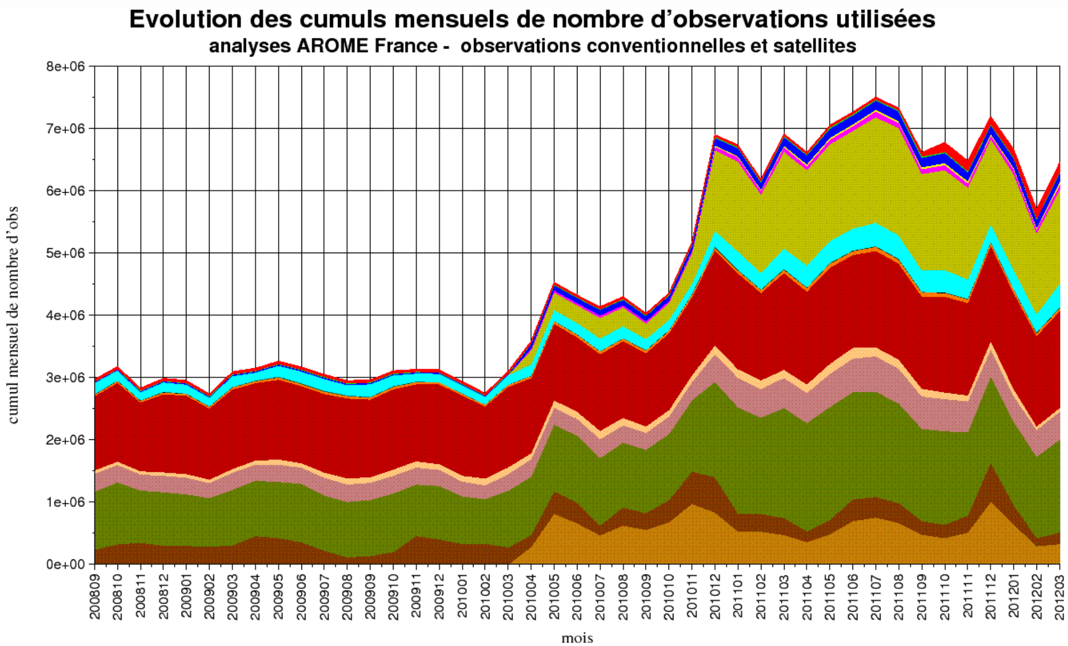
Dual Pol.

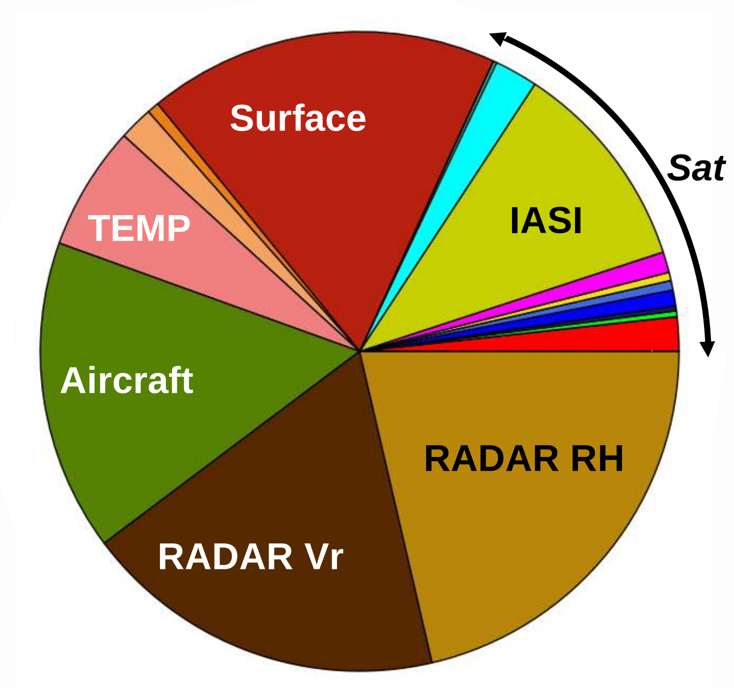
5 : nb of elevations/15’



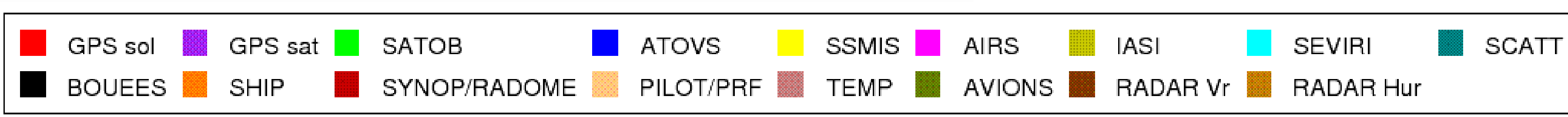
Impact of radar data in AROME

Number of assimilated observations:





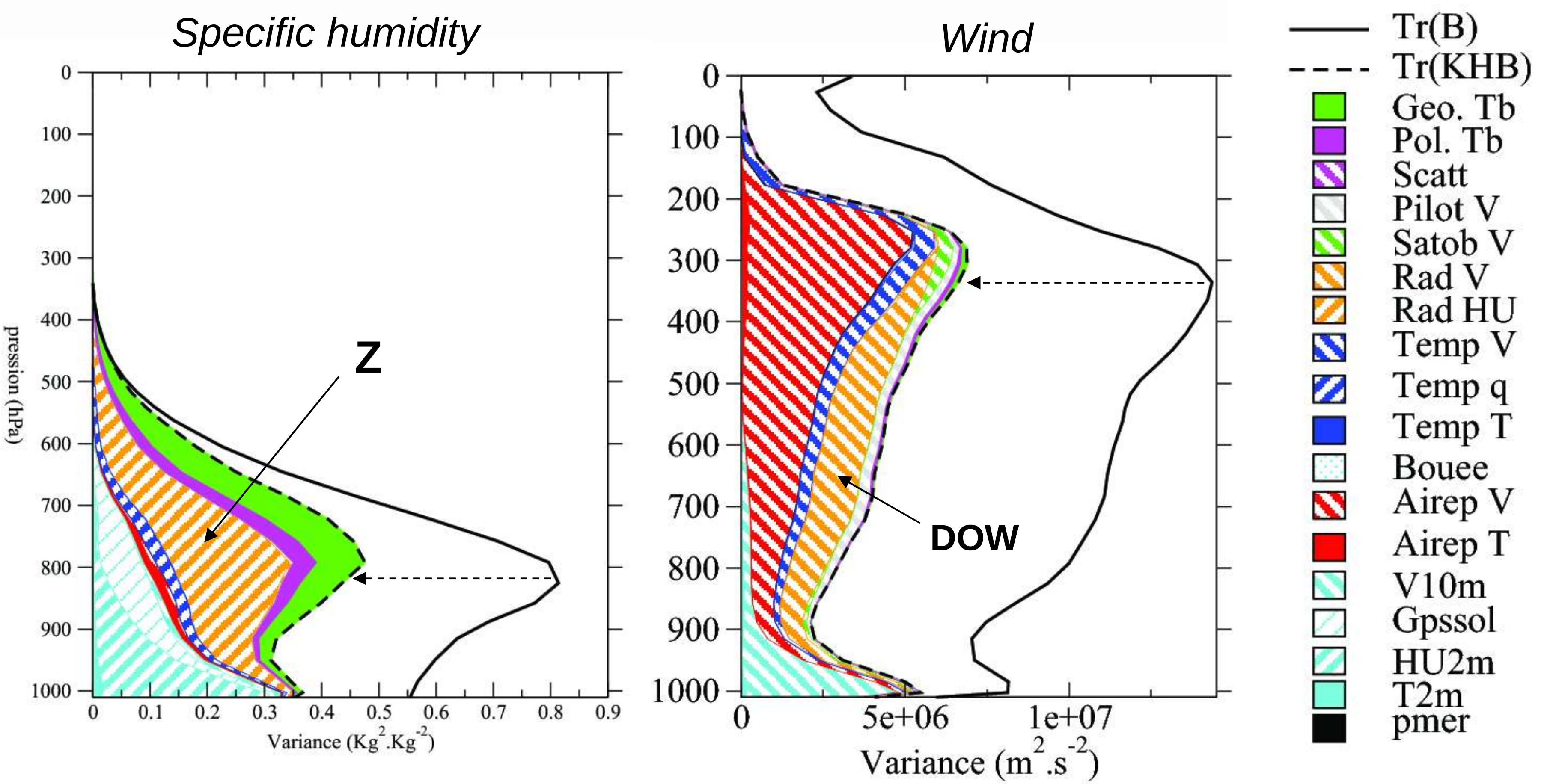
Active obs in AROME for one rainy day (3rd of nov. 2011)



Impact of radar data in AROME

Averaged daily impact on forecast error reduction

$$r = Tr(\mathbf{B}) - Tr(\mathbf{A}) \;\; = Tr(\mathbf{KHB})$$



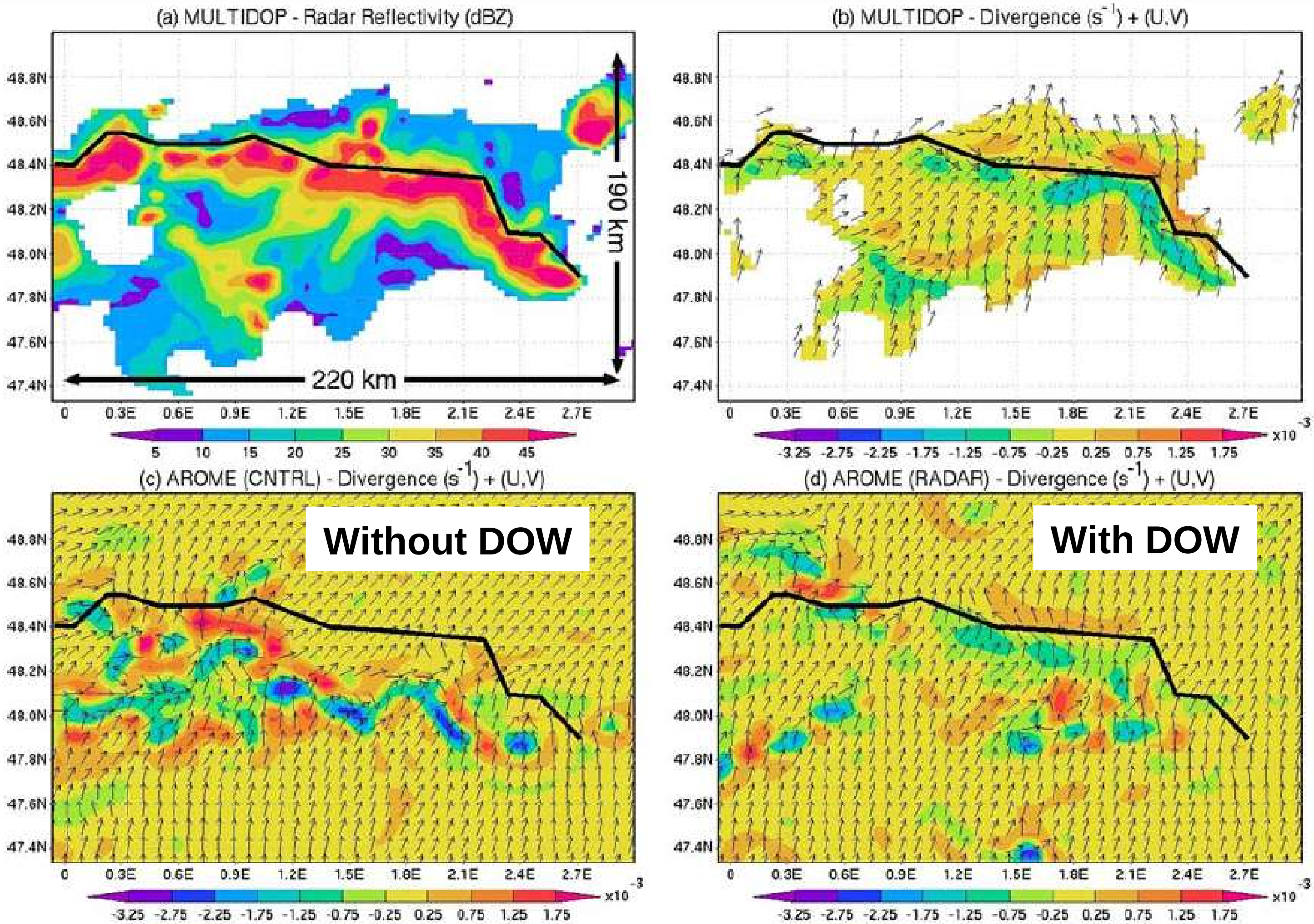
P. Brousseau

Impact of radar data in AROME

Impact on wind analysis

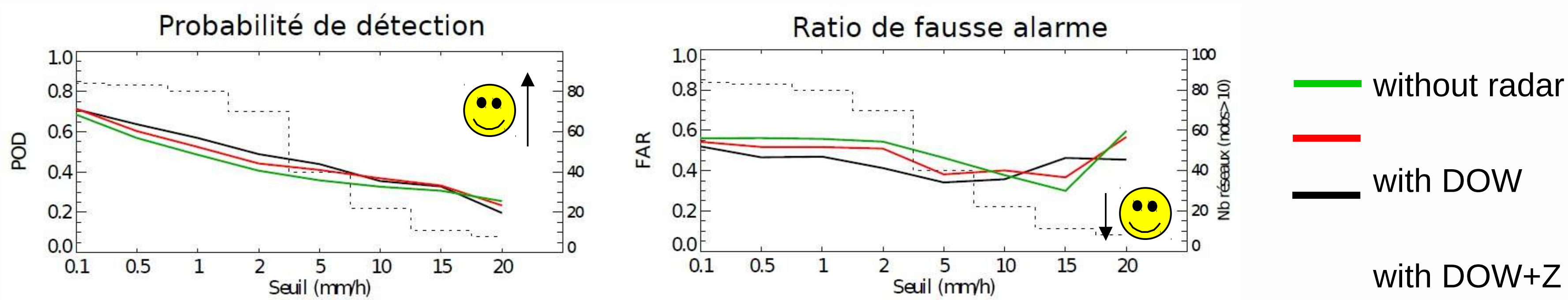
OBS:
Z &
3D wind from
multiDoppler
analysis

AROME:
Analyses at
950hPa of
divergence &
horizontal wind

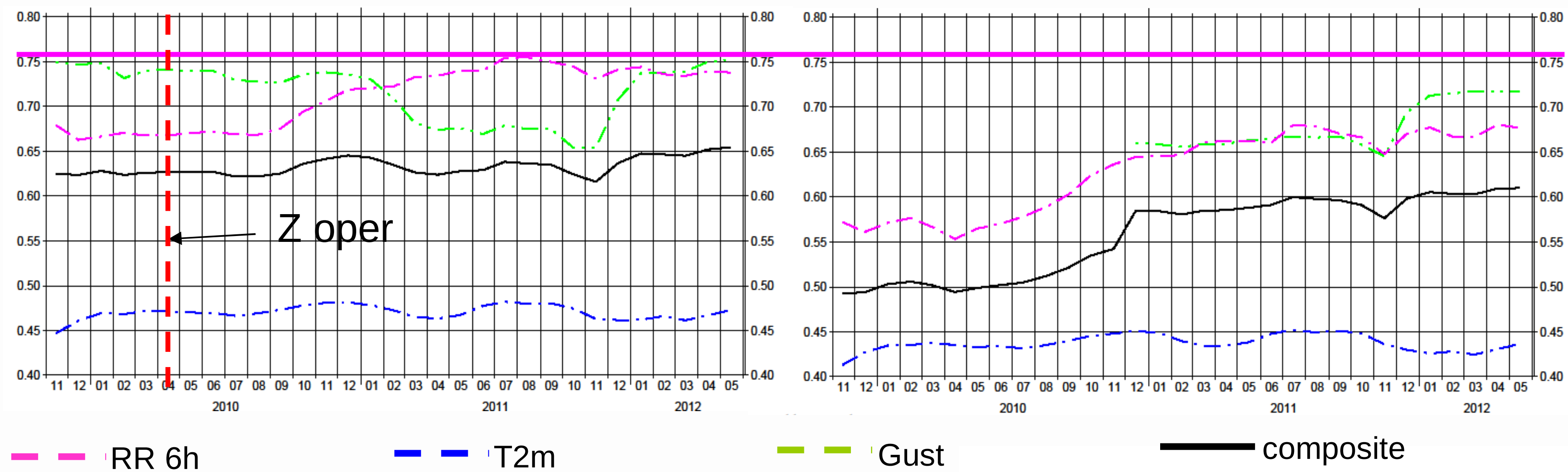


Bousquet, Montmerle and Tabary (GRL, 2008)

Impact of radar data in AROME

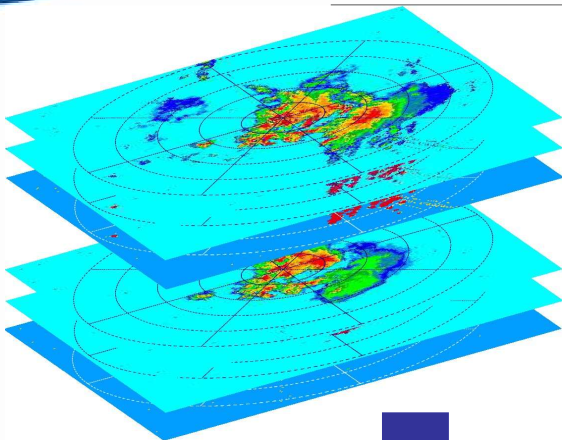


Accumulated rain POD (left) and FAR (right) computed at different thresholds (x axis) for 3-h forecasts, averaged on 15 days



Annual running averages of BSS normalized by the Lagrangian Persistency (6 to 24h forecast ranges)

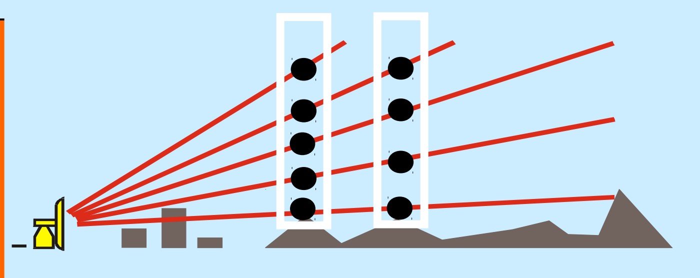
Technical issues: radar data flow



All elevations in BUFR gathered for each radar

BATODB

- Decoding, data quality check
- Calculation of pixel locations
- Filtering of DOW
- Storage as profiles in ODB arrays



AROME

Obs. Operators:

- Simulation of DOW and Z at pixel locations
- Bayesian 1D inversion of Z to retrieve Rel. Humidity profiles

Screening:

- Quality check vs. Guess
- thinning (15 km² boxes)

Minimisation

Guess

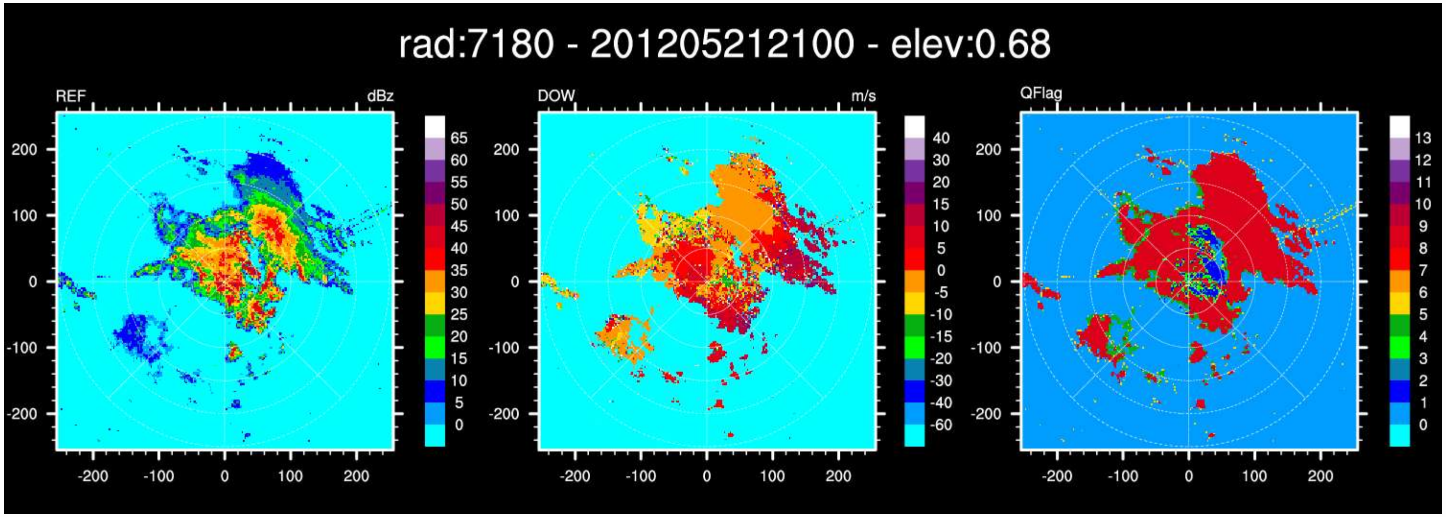
Analysis

Forecast

t_0+3h

Radar BUFR file

BUFR format using a cartesian or a polar grid:
1 header/elevation + (Z, DOW, Quality Flag)



QF coded on 8 bits:

• 4 first bits: **echo types** (types of clutters, specification of **non rainy (but valid) pixels**, precipitation types)

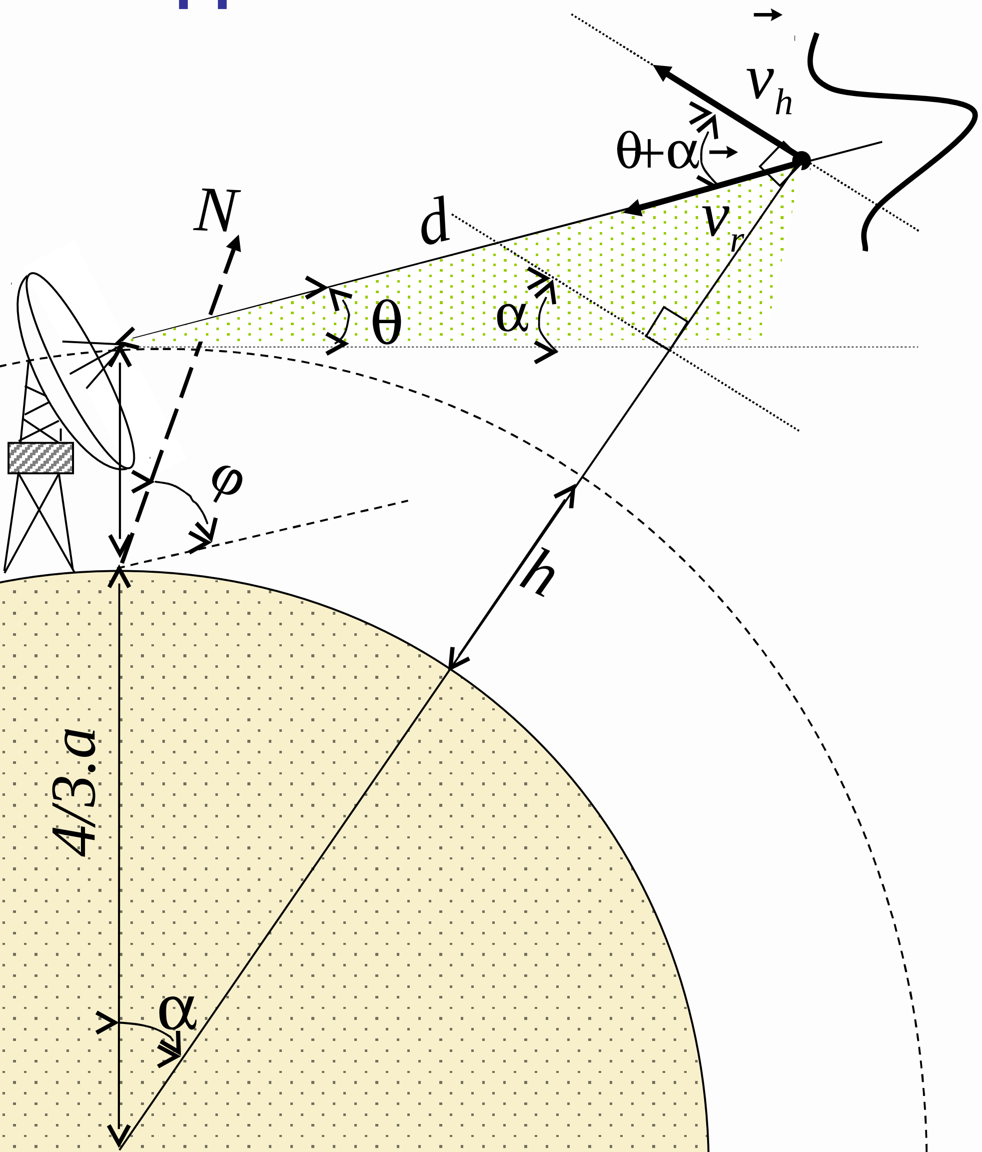
• 4 other bits: **rain attenuation** (exploitable for polarimetric radars, X-band)

• Z are not corrected for beam blockage and for rain attenuation : Corrections are done afterwards in AROME

⇒An efficient characterization of artifacts and of valid non-rainy pixels is essential for a successful assimilation!

Observation operators

Doppler Wind:



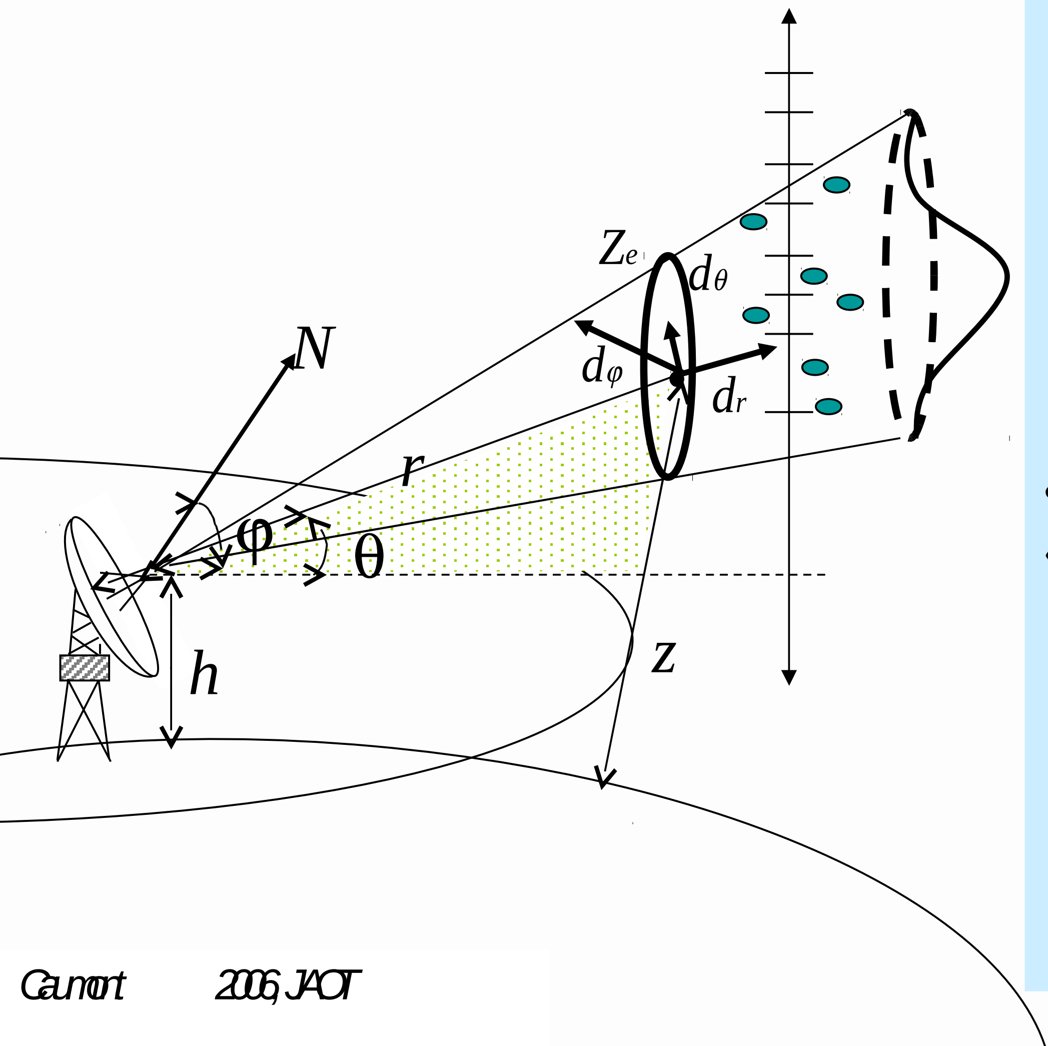
- **Bi-linear interpolation** of the simulated wind
- **Projection on the slanted direction of the radar beam** (using the earth's effective radius model)
- No fall speed correction
- Side lobes contributions neglected
- **Broadening of the radar beam** simulated by a Gaussian function
- **TL/AD**

- $\sigma_o = f(r)$
- 15 km² thinning boxes
- no bias corrections applied in azimuth nor in intensity

⇒More details in Montmerle and Faccani, 2009, MWR

Observation operators

Reflectivity:



Caumont 2006, JAOT

- Bi-linear interpolation of (T, q, q_r, q_s, q_g)
- **Compute radar reflectivity** on each model level

$$\eta(r) = \sum_{j=rain,snow...} \int_0^\infty \sigma_j(D,r).N_j(D,r)dD$$

Backscattering cross section: Rayleigh (attenuation neglected)

Microphysic Scheme in AROME

Diameter of particules

- **Simulated Reflectivity factor in « beam volum *bv*»**

$$Z_e = 10\log\left(\int_{bv} \eta(r).f^4(\theta,\varphi).dr.d\theta.d\varphi\right)$$

Resolution volume, ray path: standard refraction (4/3 Earth's radius)

Gaussian function for main lobe

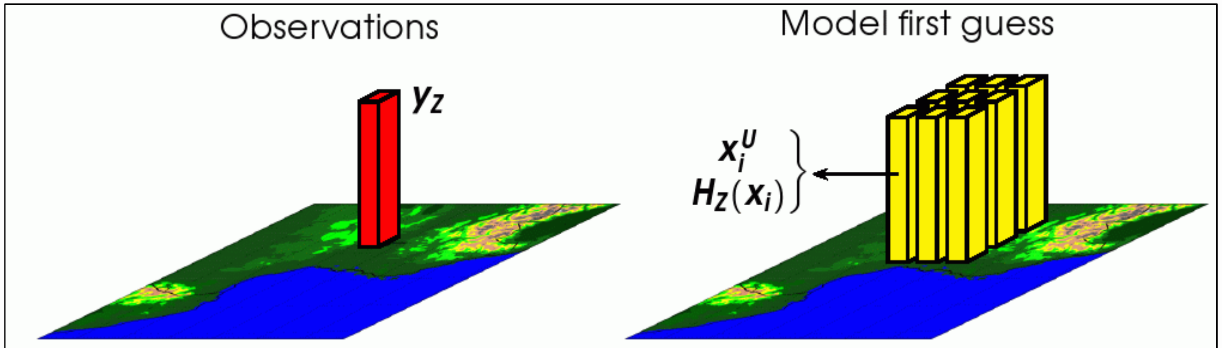
1D+3DVar assimilation of Z

Use of model profiles in the vicinity of the observation as representative database:

Wattrelot et al. 2008, ERAD proceeding

Wattrelot, 2009,joint ALD-HIRLAM Wkshp

Caumont et al., 2010, Tellus



$$y^U_{po} = \sum_{i \in \text{neighbours}} x^U_i \frac{\exp\left(-\frac{1}{2}\|y_Z - H_Z(x_i)\|^2\right)}{\sum_{j \in \text{neighbours}} \exp\left(-\frac{1}{2}\|y_Z - H_Z(x_j)\|^2\right)}$$

y^U_{po}: column of pseudo-observed relative humidity,
y_Z: column of observed reflectivities,
x^U_i: column of relative humidity,
$H_Z(x_i)$: column of simulated reflectivities.

⇒**Retrieved profiles of RH assimilated in the 3DVar as pseudo-obs**

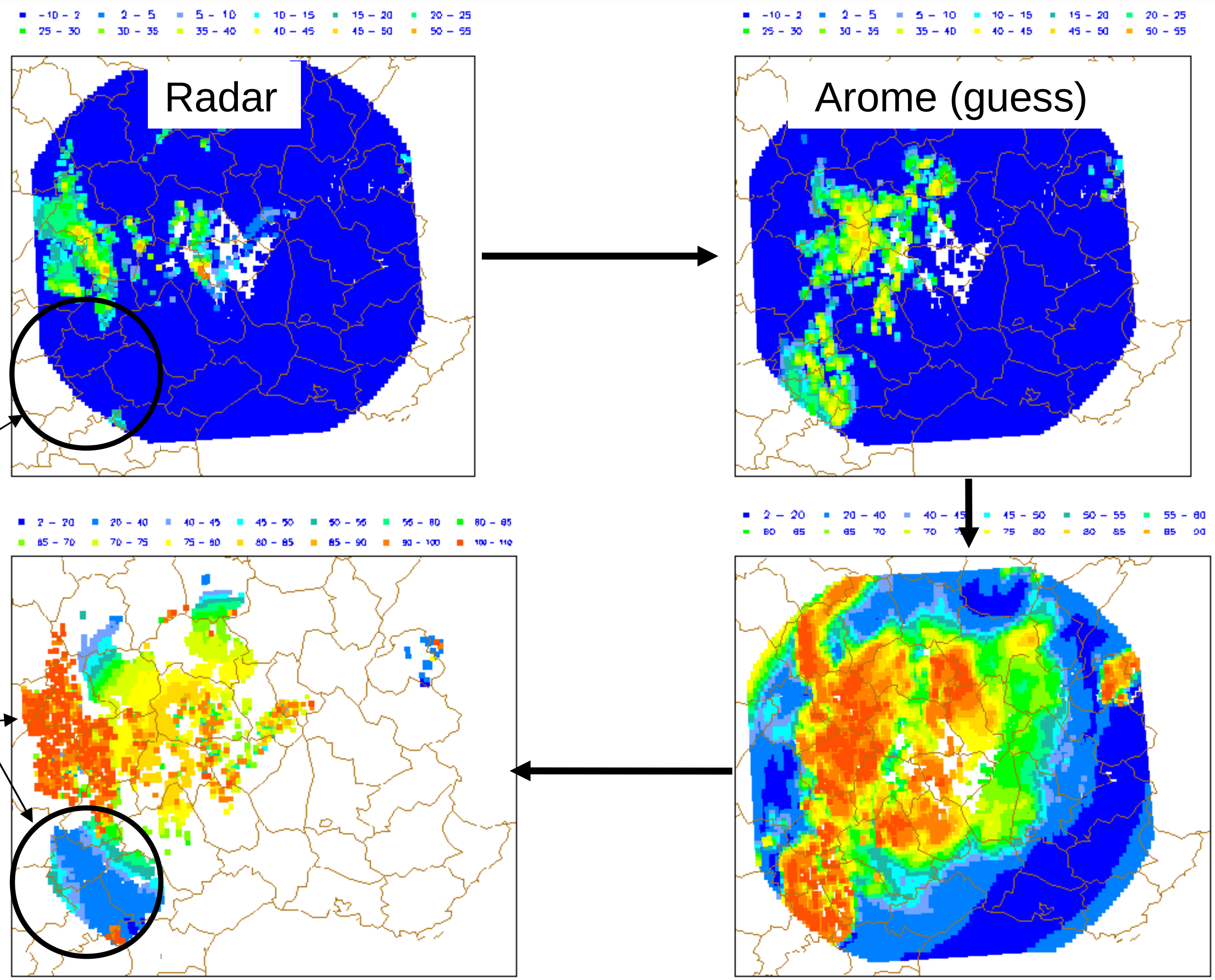
\+ Consistency between the retrieved profile and clouds/precipitations that the model is able to create

\- Unrealistic solution possible if model too far from the reality

1D+3DVar assimilation of Z

Reflectivities

(0.44° Elevation)



Drying thanks to the observed valid non-rainy pixels

Saturation in rainy areas

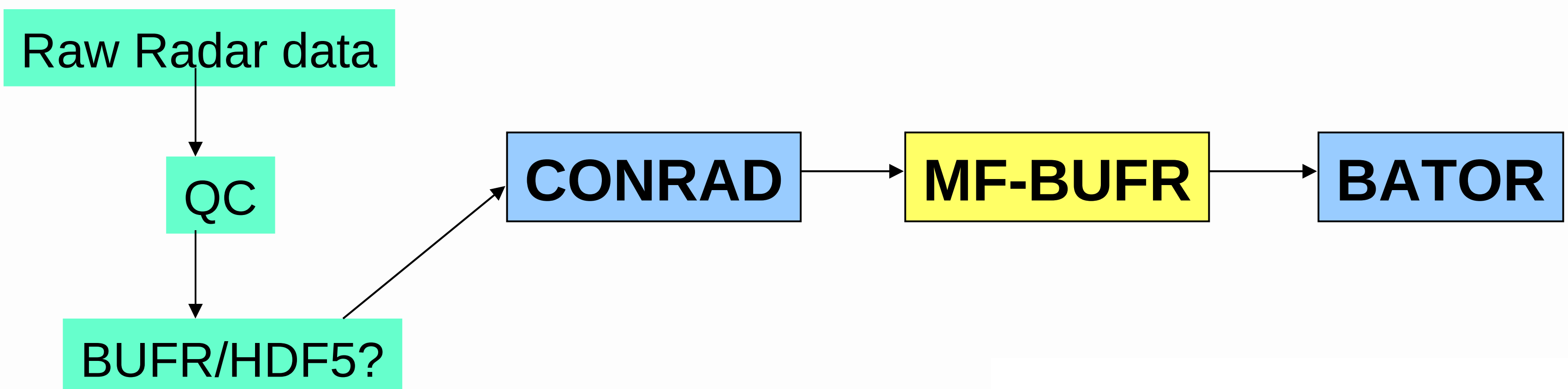
Relative humidity

Pseudo-observation

Arome (guess)

European Collaborations

- **Météo-France is strongly involved in the EUMETNET OPERA programme** (OD1 (QF) and OD3 (Volume distribution to NWP) working packages)
- Quality information proposed in OD1 compatible with assimilation requirements in AROME
- MetNo (Martin Groensleth) has developed a **format converter called CONRAD**, aiming at converting local radar formats in BUFR for AROME (HARMONIE):

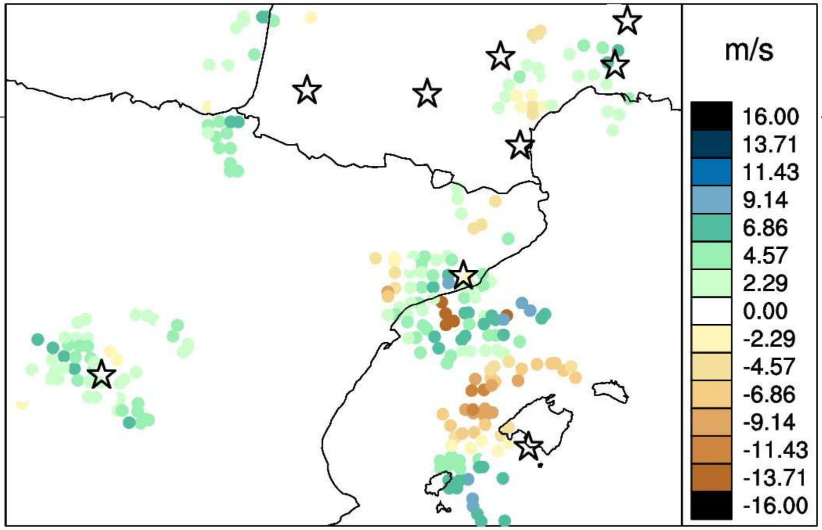


http://lists.met.no/mailman/listinfo/conrad

European Collaborations

Many ongoing studies using CONRAD in different NWP systems:

• Assimilation of Z and DOW from 5 spanish radars is currently evaluated in AROME-France in the HyMex framework

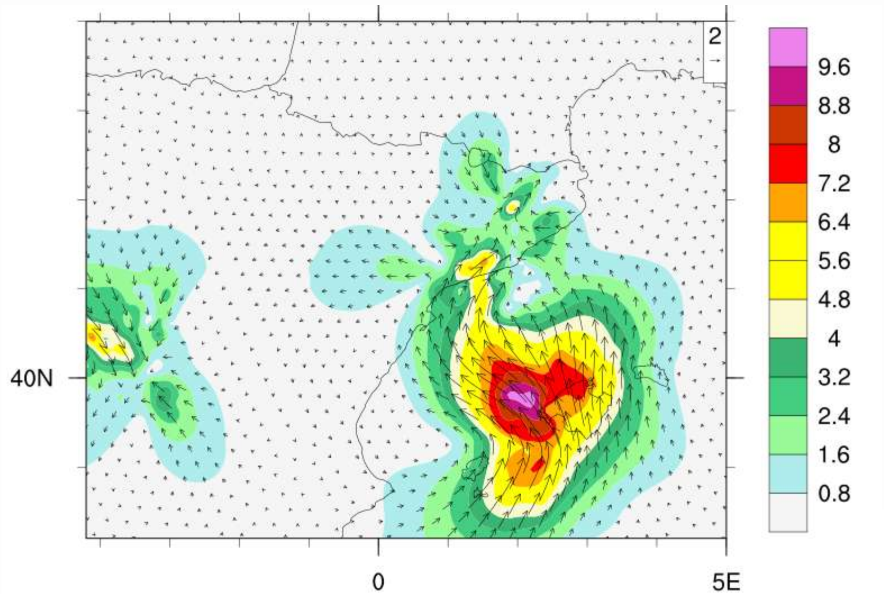


(obs-guess) in observation space (DOW positive towards the radar)

• MetNo is evaluating the assimilation of both Z and DOW

• KNMI is assimilating successfully DOW of 2 radars and has tested the inclusion of some French radars

• works are ongoing in Austria, Croatia, Hungary…

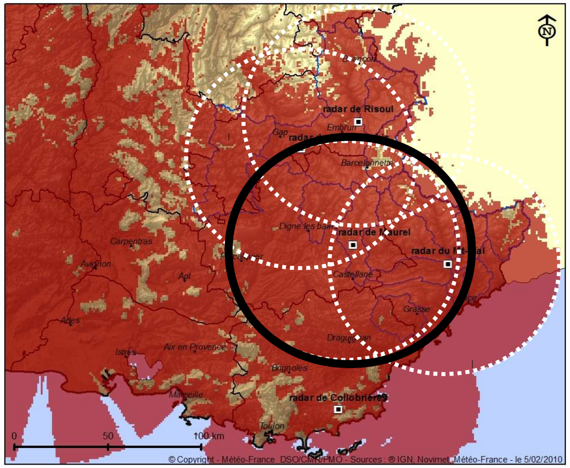


Analysis differences with/without AEMET radars

Current studies

Assimilation of 4 X-Band radars located in SE France over the Alps

Problematic:



- **DOW difficult to unfold** because of the low PRF => requirements for NWP (60 ms^{-1}) need probably to be lowered and/or efficient filtering need to be applied

- **strong attenuation of Z in heavy rain:** attenuation correction based on differencial phase of the dual-pol. measurements ϕ_{dp} is essential

Consistent increments have been however obtained so far

⇒DOW of Mt Maurel monitored in AROME

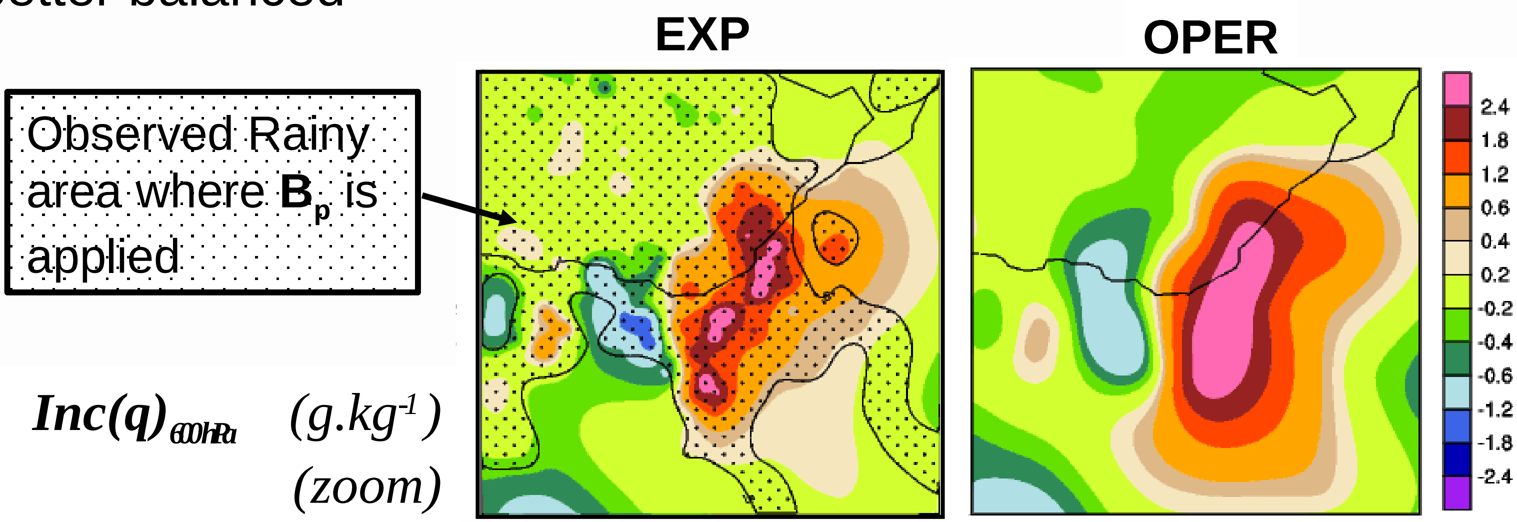
⇒Tests with Z corrected by the Path-Integrated Attenuation underway

⇒**Real time evaluation in AROME WMED in the HyMeX framework**

Current studies

Optimisation of the use of radar data

- **Use of specific background error covariances B in precipitations:** enhancement of the q-div couling, smaller correlation lengths, analyzed fields better balanced



Montmerle and Berre 2010, QJRMS; Montmerle 2012, MWR

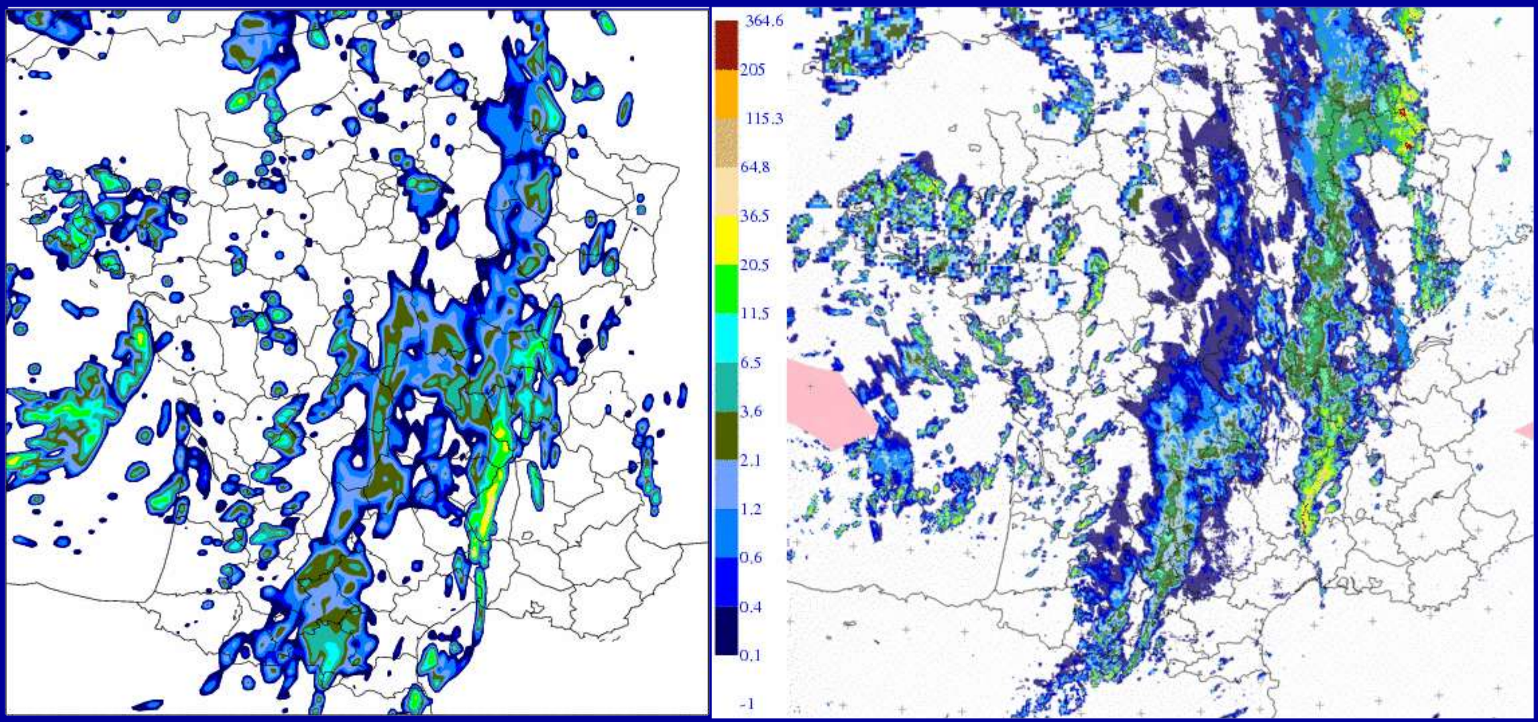
- **Computation of the obs. error covariance matrix R** using a posteriori diagnostics (Hollingsworth-Lönnberg, Desroziers)

- **Revise thinning method** by assimilating more data from different radars which cover the same area (low inter-radar obs. error correlations)

Conclusions

- Radar data has become an important observation type in AROME
- A BUFR format has been thought specifically for the assimilation of radar volume data
- **An efficient pre-processing is essential** to unfold DOW and to identify clutters, especially non-rainy echoes
- **Simultaneous assimilation of DOW and Z gives better result**, allowing to retrieve mid to low level wind circulation that are coherent with RH structures. Assimilating Z alone requires suitable forecast errors
- More work is needed to optimize their use (**B**, **R**)
- The open source CONRAD software allows to generate BUFR files from different local formats
- **Needs for the distribution of European flagged radar volume data** (DOW+Z) : Development packages OD1 and OD3 in OPERA with strong implication of MF

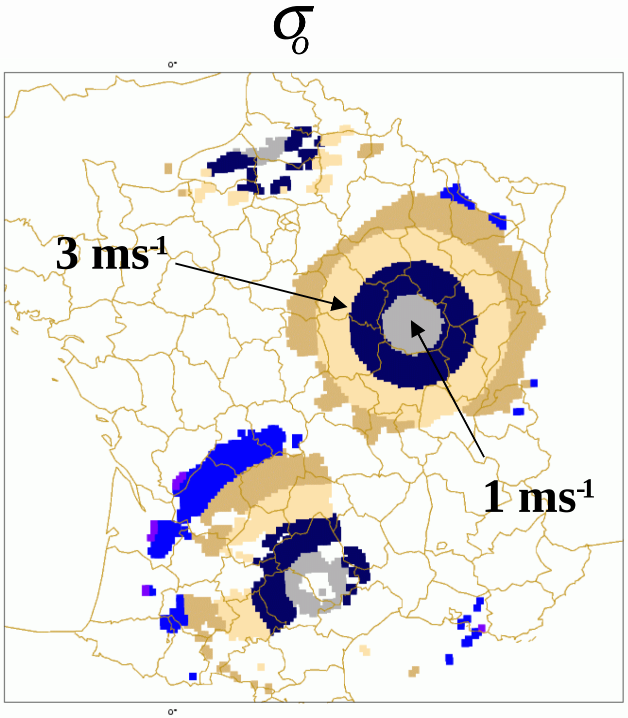
Thanks for your attention!



AROME **OBS**

26th of August 2011 12h, 12h forecast

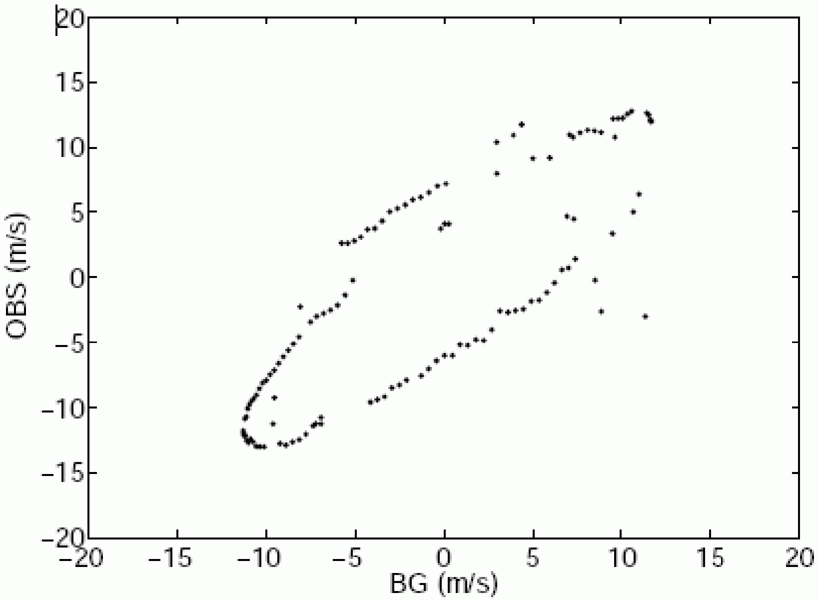
Screening decisions

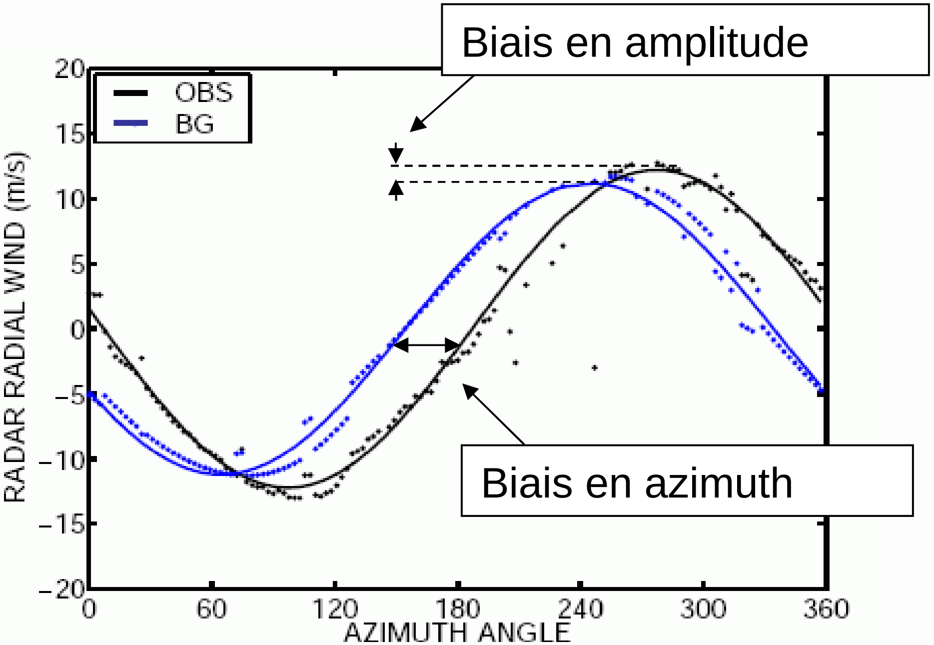


Ex: ABBE, BLAI, MCLA

- **σ_o varies linearly with the distance from the radar** to take into account error due to the beam broadening
- pixels 150 km away from the radar are not considered
- innovations (obs-guess) between +/- 20 ms^{-1} are kept
- thinning within 15x15 km^2 boxes using a sorting criteria based on the distance and on the number of observations per profiles

Biais des vitesses radiales





Salonen et al., 2007

Ici, $< \mathbf{y}^o - H[\mathbf{x}^b] > = 0$

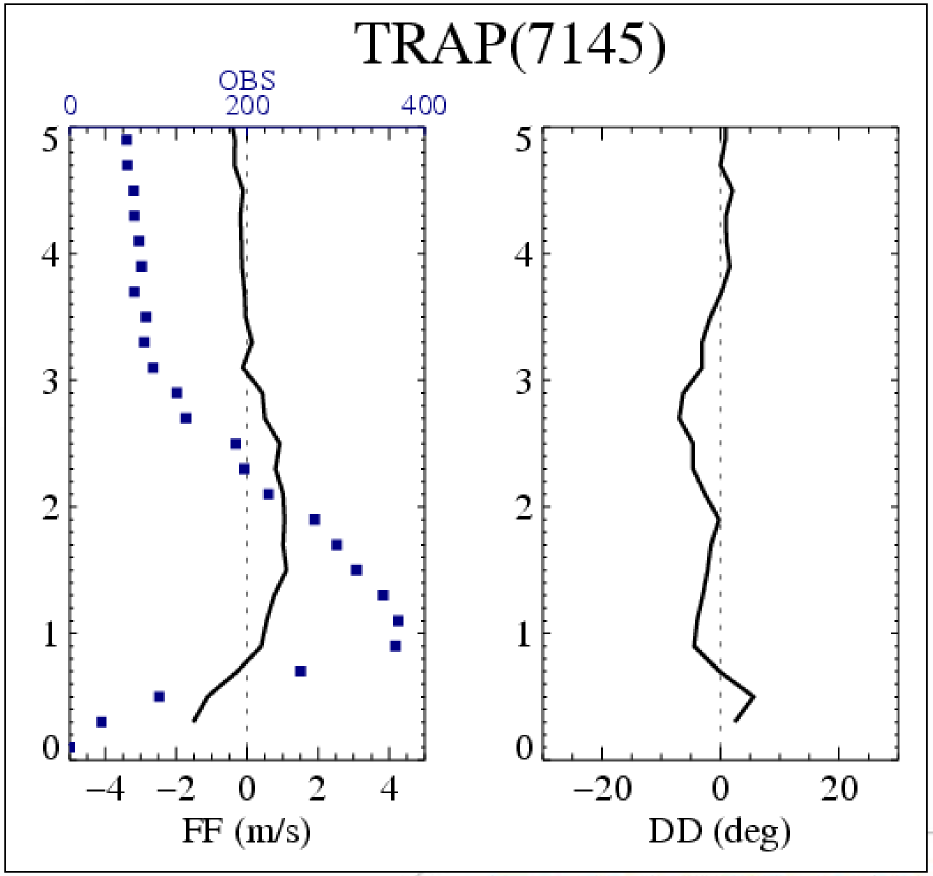
Représentation Vr/Azimuth

Correction de biais

biais en amplitude et en azimuth possibles, même si le biais d'innovation est nul

⇒**Calculs de profils VAD observés et simulés** sur plusieurs mois de données

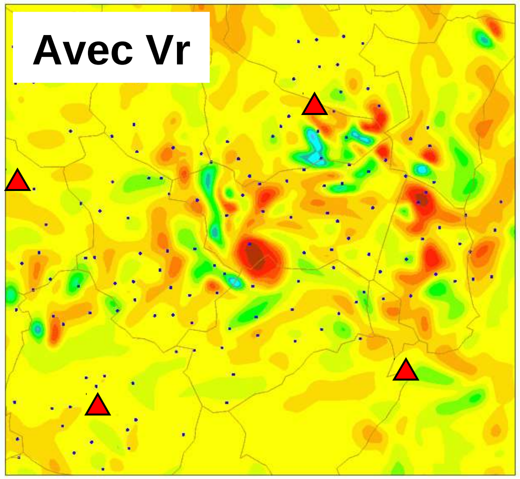
- Biais proches de 0
- Calculs fortement dépendant de la stratégie d'échantillonnage et de la position des systèmes échantillonnés



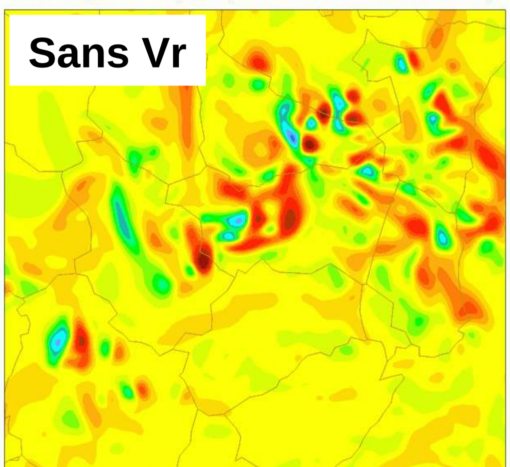
Exemple d'impact sur la prévision d'un méso-cyclone

Analyse de vorticité *(700 hPa)*

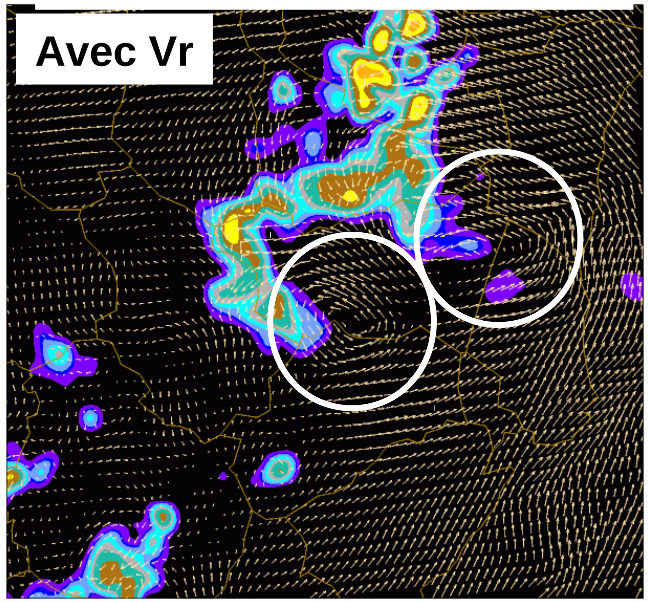
PARIS Analysis VT:Friday 30 May 2008 21UTC 600hPa absolute vorticity

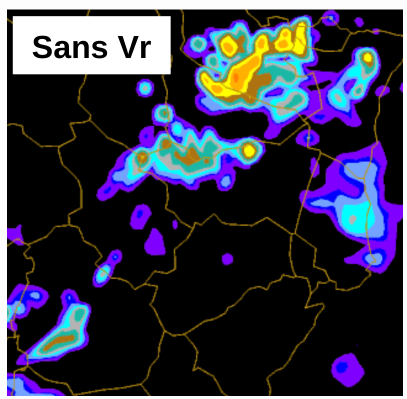


PARIS Analysis VT:Friday 30 May 2008 21UTC 600hPa absolute vorticity

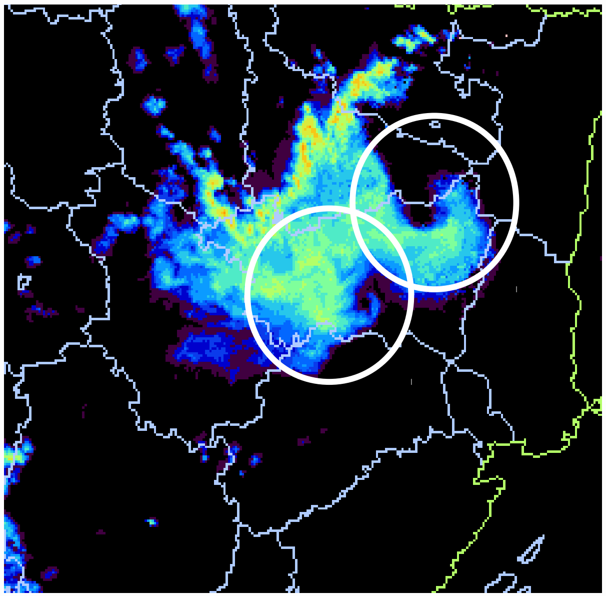


Prévi 3h – Z_{850hPa} et $Vent_{700hPa}$





Z observée

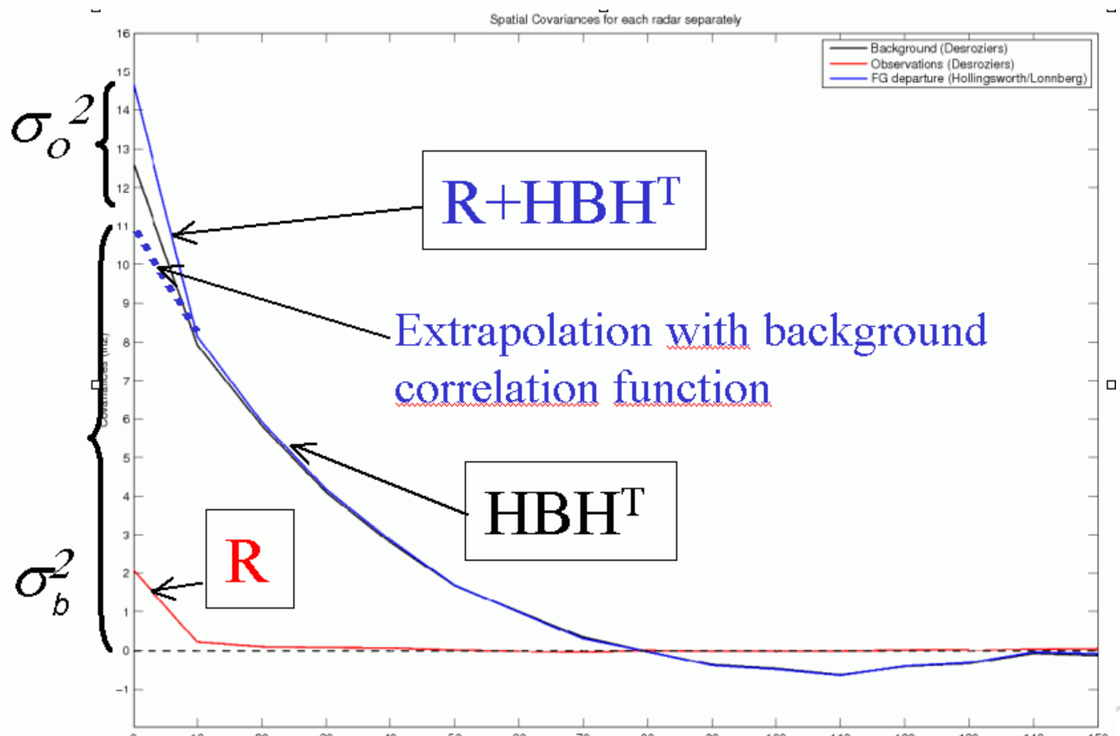


Meilleure représentation du cisaillement vertical du vent horizontal
⇒**Systèmes convectifs mieux structurés**

• Spatial intra-radar covariances

- The both methods used here are based on the first guess FG (Hollingsworth-Lönnberg, 1986, HL) and analysis departures (Desroziers diagnostic 2005, DES) from a database of pairs of radial winds which are binned by separation distance. For these computings, these data are assimilated with a constant observation-error variance. Each pair of observations is taken among each radar and each PPI elevation separately,

at the same time over a time period of sixteen days.



	Obs. error stdev (m/s)
As specified	2
HL method	1.92
Desroziers diagnostic	1.51

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Toujours un temps d'avance