Operational assimilation of radar data at convective scale in AROME France : current status and international cooperations

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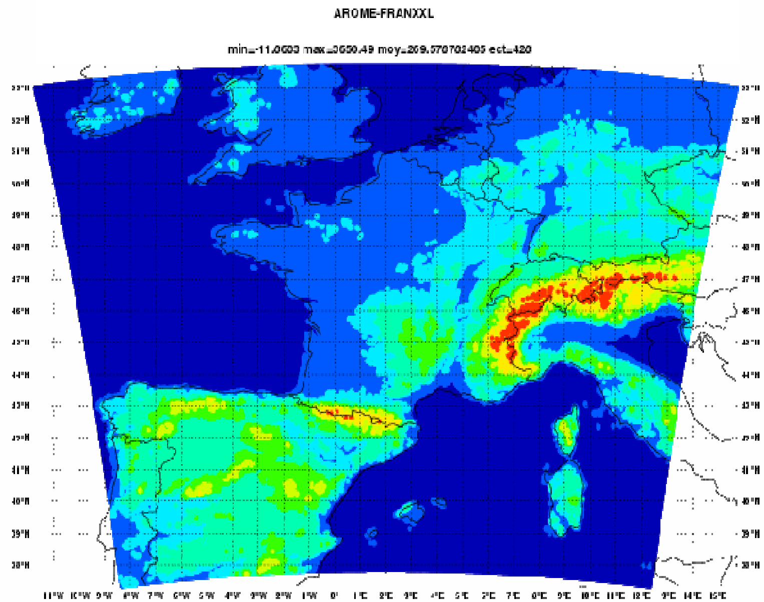
Toujours un temps d'avance

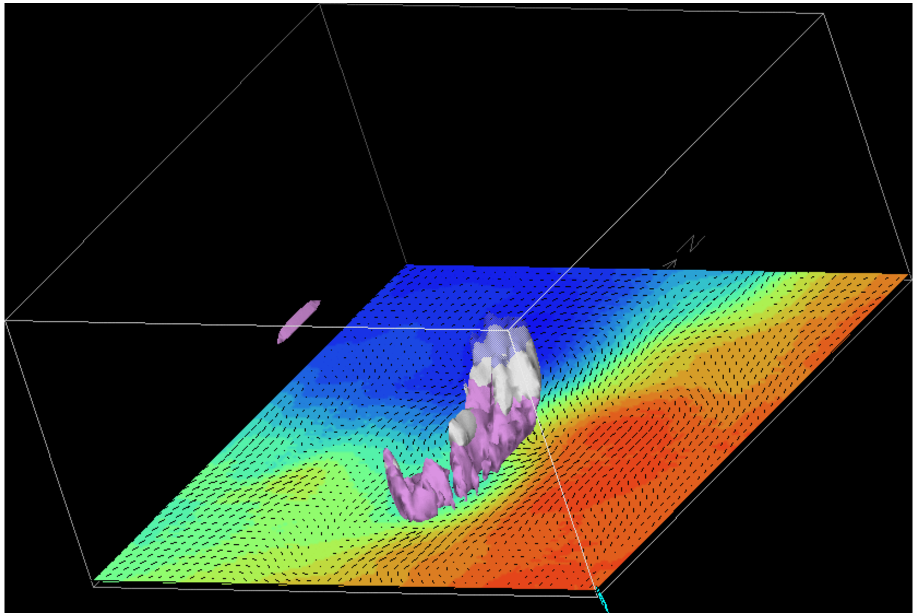
Outlines

1. Introduction: The AROME NWP system
2. Impact of radar data in AROME
3. Radar DA components
4. International cooperations
5. Perspectives

The AROME NWP system

- Operationnal since the end of 2008 (Seity et al. 2011)
- Δx=2,5 km, 60 vertical levels
- Realistic representations of clouds, turbulence, surface interaction…
- Coupled with ARPEGE

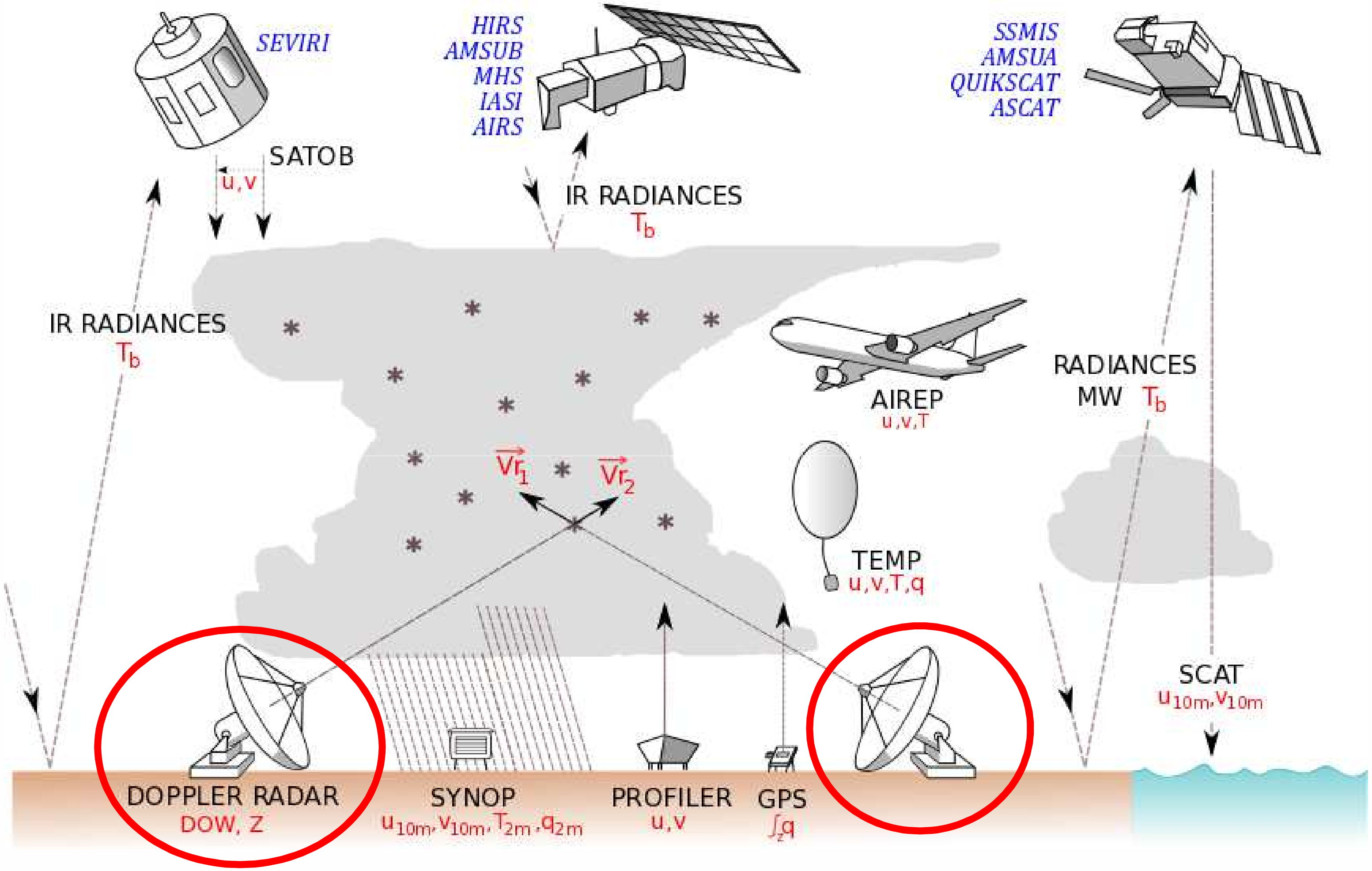




S. Malardel

- Cycled assimilation/forecast steps every 3h
- 3DVar, climatological **B** deduced from an ensemble assimilation
- Own surface analysis
- Comprehensive set of obs. assimilated, including radars

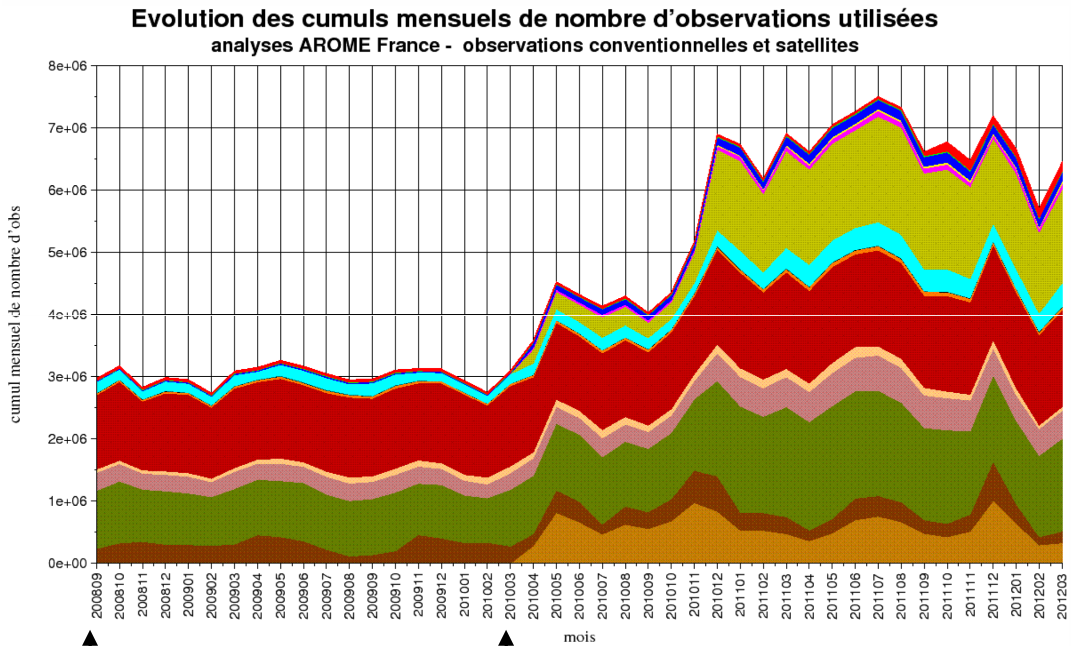
The AROME NWP system



- **24 radars from the ARAMIS network:** between 3 and 12 PPIs/15', unambiguous velocity of 60 ms^{-1}
- 3 X-band radars currently tested (see Eric's talk later)

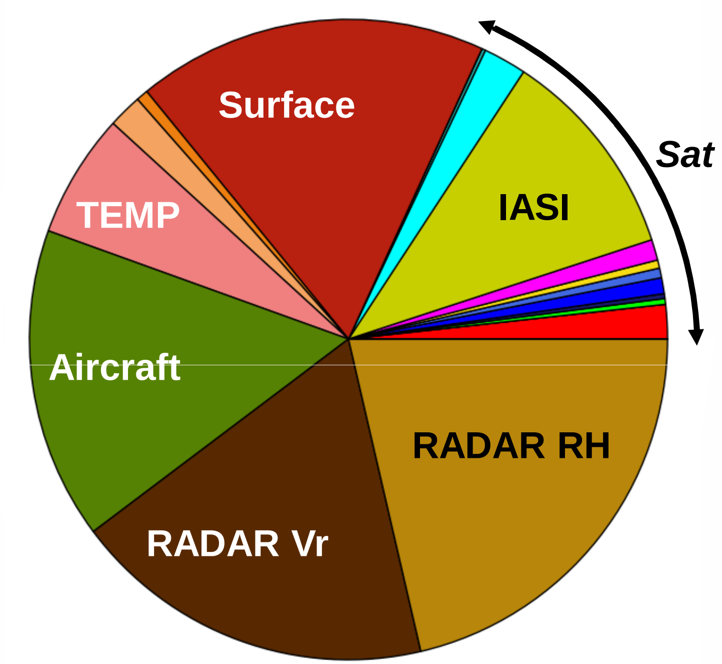
Impact of radar data in AROME

Number of assimilated observations:



Sept 2008
Oper with DOW

April 2010
Z / IASI added



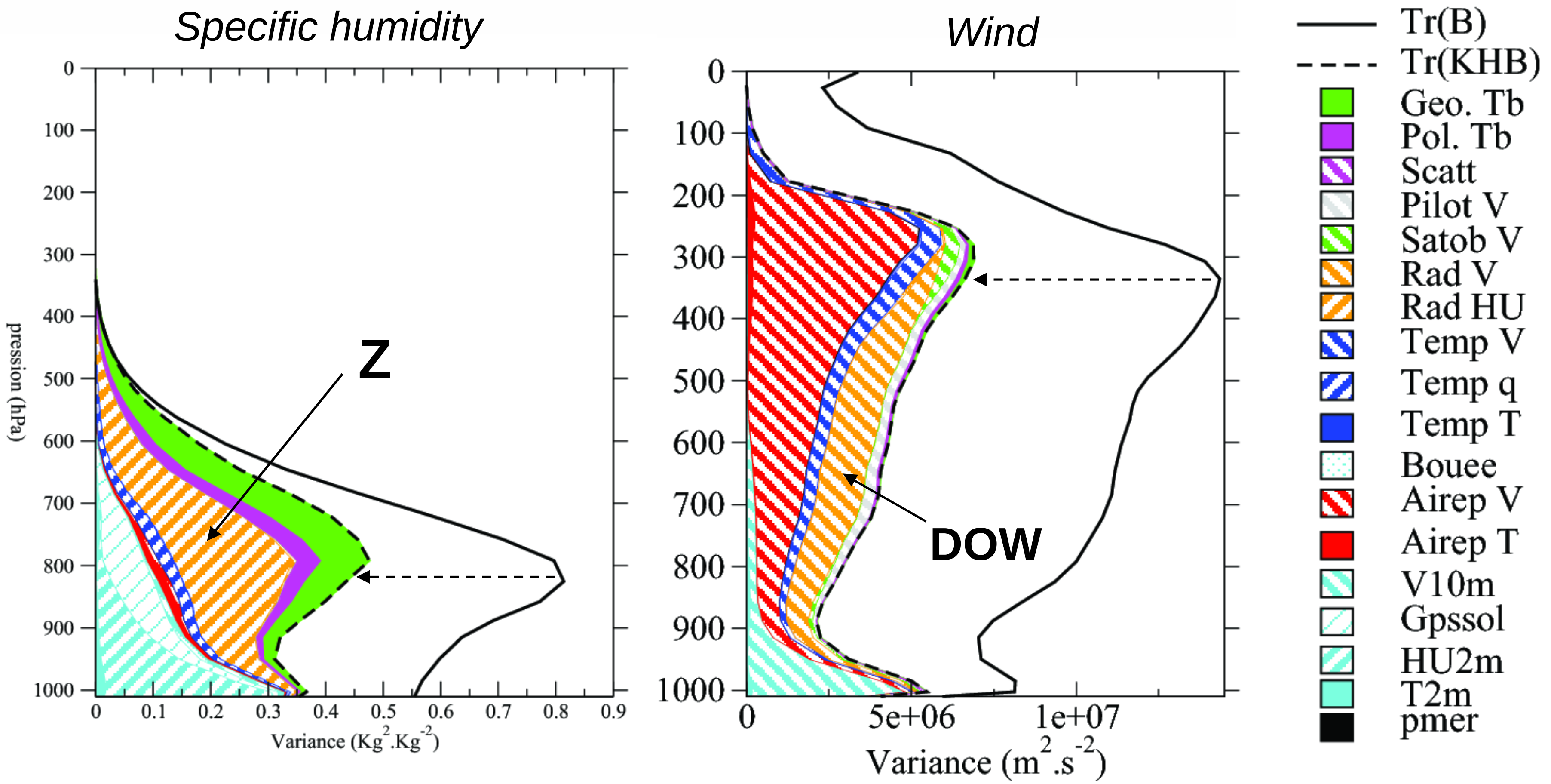
Active obs in AROME for one rainy day (3rd of nov. 2011)

GPS sol | GPS sat | SATOB | ATOVS | SSMIS | AIRS | IASI | SEVIRI | SCATT
BOUEES | SHIP | SYNOP/RADOME | PILOT/PRF | TEMP | AVIONS | RADAR Vr | RADAR Hur

Impact of radar data in AROME

Averaged daily impact on forecast error reduction

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



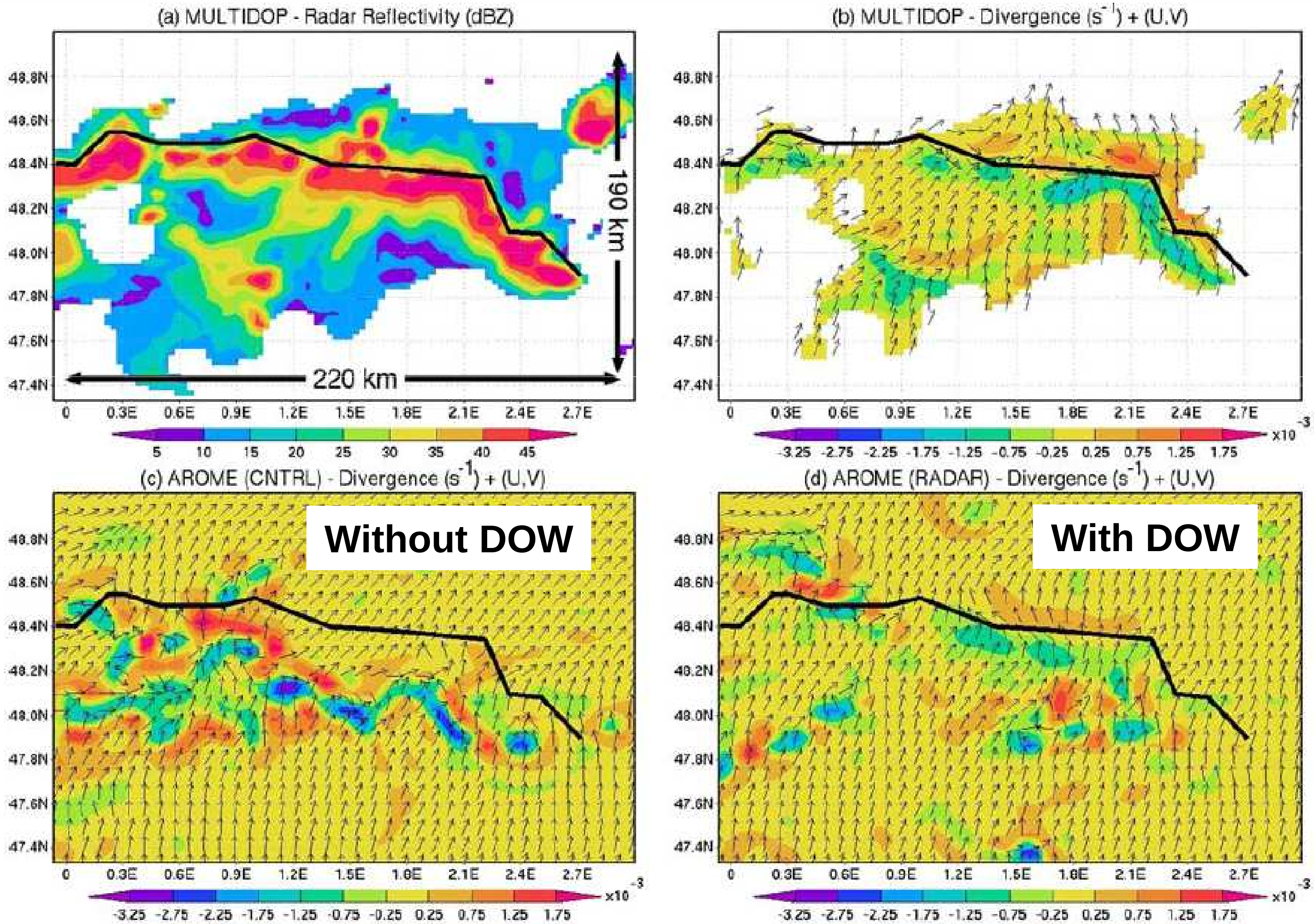
P. Brousseau

Impact of radar data in AROME

Impact on wind analysis

OBS:
Z &
3D wind from
multiDoppler
analysis

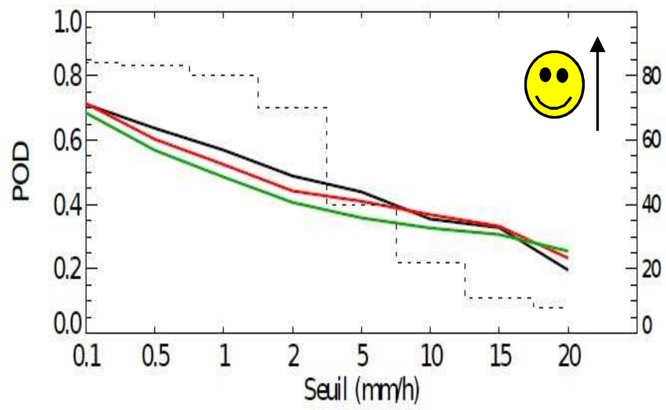
AROME:
Analyses at
950hPa of
divergence &
horizontal wind



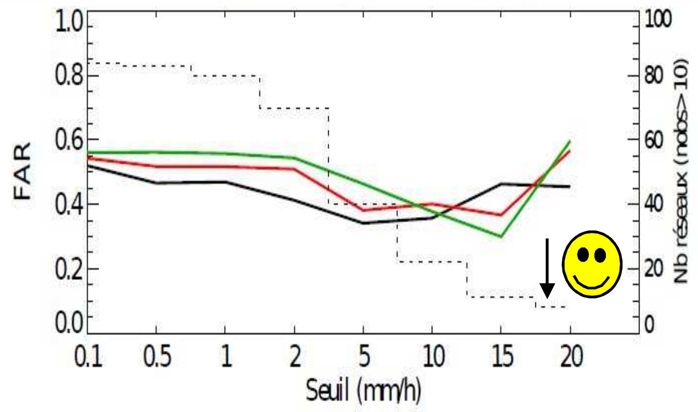
Bousquet, Montmerle and Tabary (2008)

Impact of radar data in AROME

POD

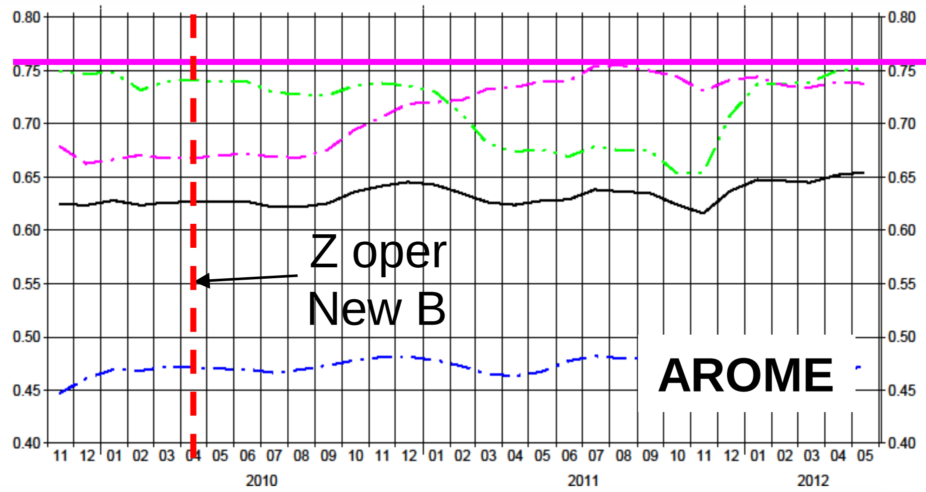


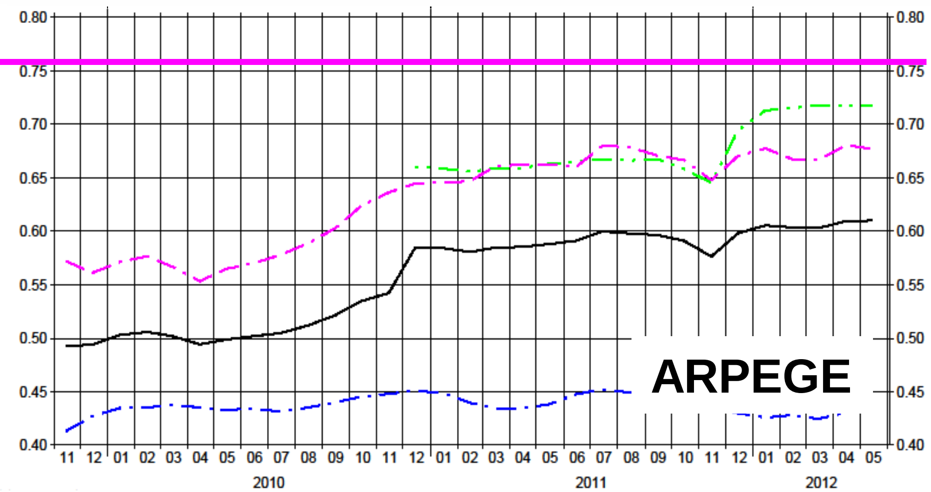
FAR



QPF scores for 3-h forecasts averaged on 15 days

- without radar
- with DOW
- with DOW+Z

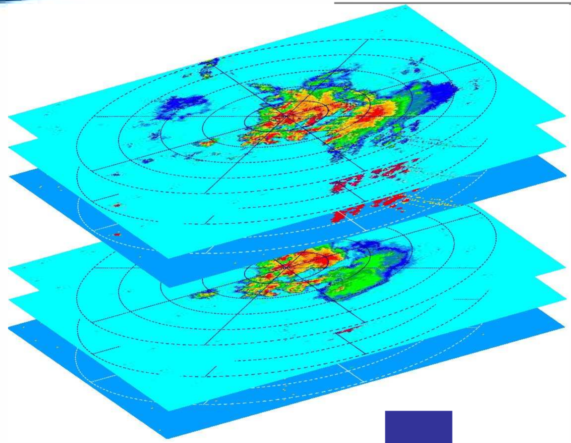




RR 6h T2m Gust composite

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

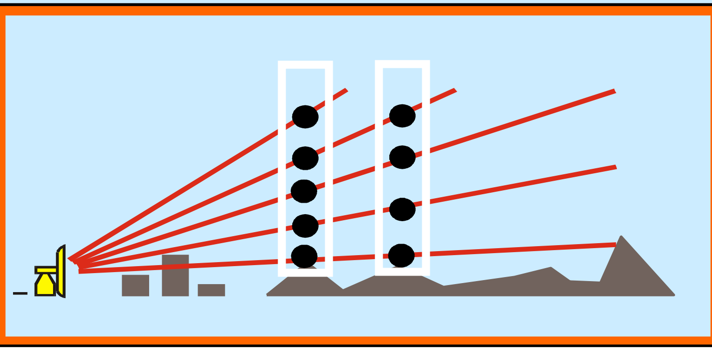
Radar DA components



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 km^2 boxes)

Minimisation

Analysis

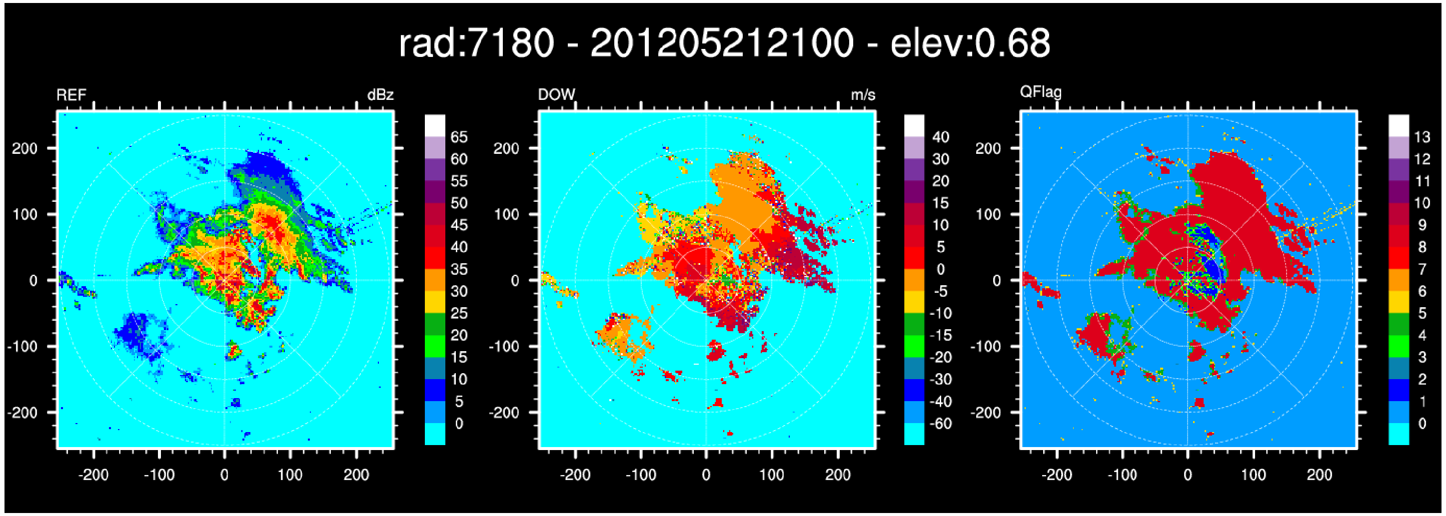
Forecast

Guess

t_0+3h

Radar DA components

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



Quality Flag:

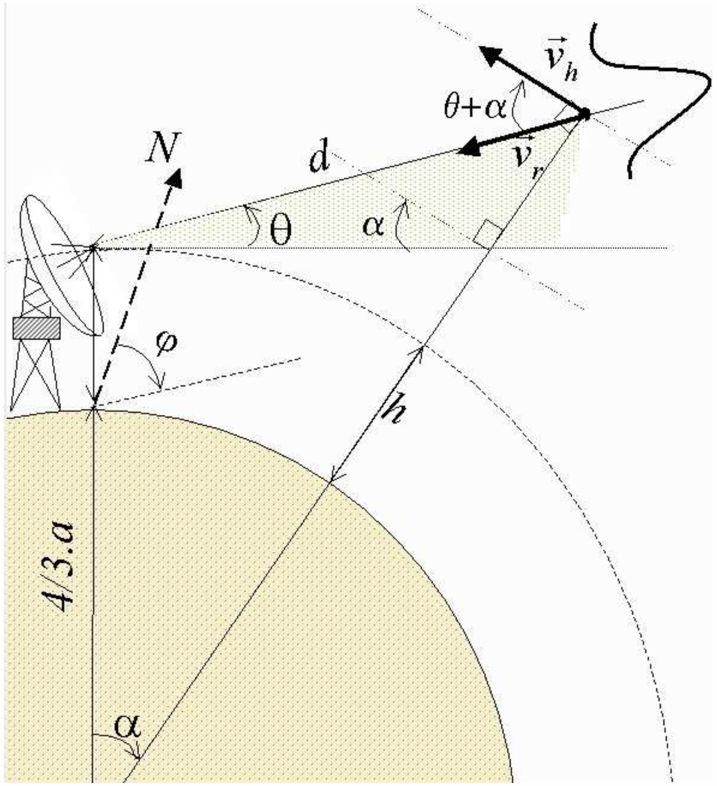
- **Echo types** (types of clutters, specification of **non rainy (but valid) pixels**, precipitation types)
- **Rain attenuation** (exploitable for polarimetric radars, X-band)

Corrections for beam blockage and for rain attenuation are done afterwards in AROME

Radar DA components: Observation operators

For operational NWP, such operators need to be fast and to take into account parallelisation of the code

⇒ **Integration along the path unaffordable:** Radar beam geometry computed considering the Earth's effective radius model, anaprop and attenuation not simulated



⇒ **For DOW:** see Montmerle and Faccani 2009, MWR
⇒ **For Z:** simulated reflectivity integrated within beam volumes (see Wattrelot et al.,2008, ERAD (operator derived from Caumont et al. 2006, JAOT))
⇒ **Profiles of RH** deduced from surrounding simulated profiles of Z using a 1D Bayesian method (Caumont et al., 2010, Tellus)

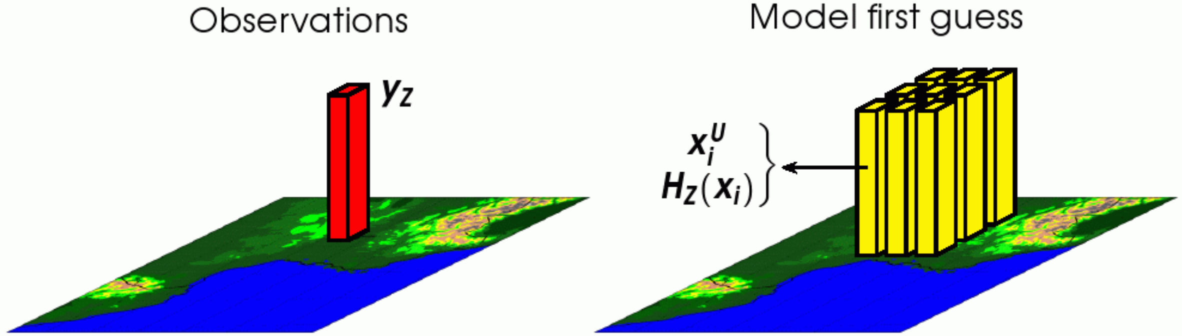
1D+3DVar assimilation of Z

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



$$y_{\mathrm{po}}^{U} = \sum_{i \in \text{neighbours}} x_i^U \frac{\exp\left(-\frac{1}{2}\|y_Z - H_Z(x_i)\|^2\right)}{\sum_{j \in \text{neighbours}} \exp\left(-\frac{1}{2}\|y_Z - H_Z(x_j)\|^2\right)}$$

y_{po}^U: column of pseudo-observed relative humidity,
y_Z: column of observed reflectivities,
x_i^U: 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; avoid TL/AD of diabatic processes

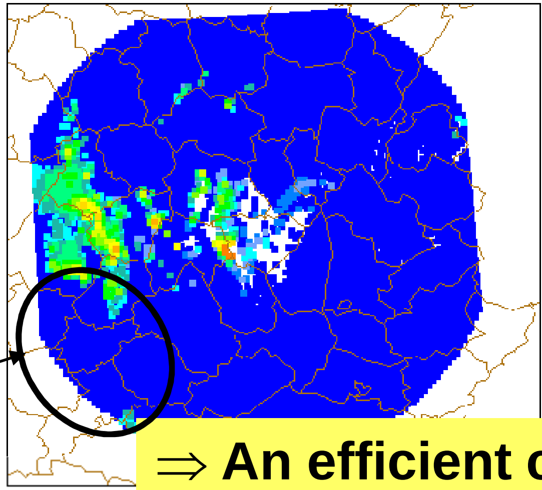
\- Unrealistic solution possible if model too far from the reality

1D+3DVar assimilation of Z

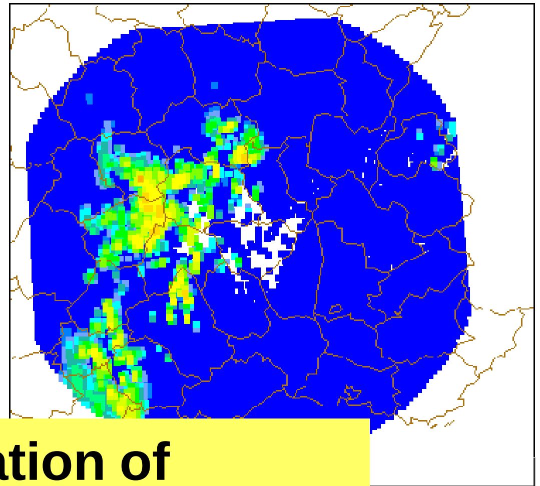
Elevation 0.44°

Z

Observation



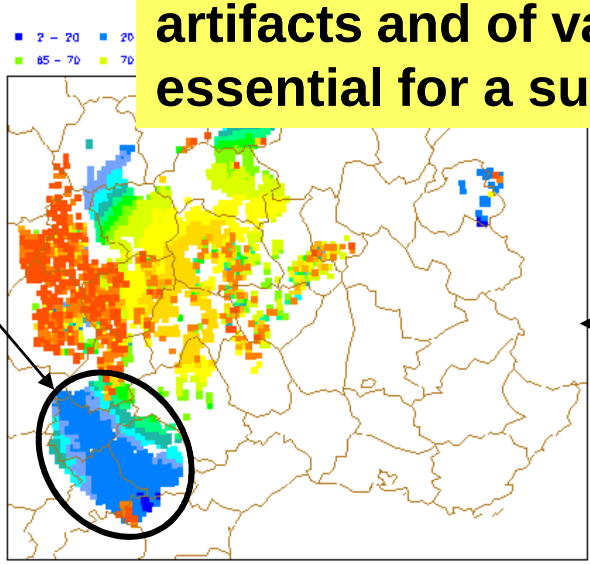
Arome (guess)



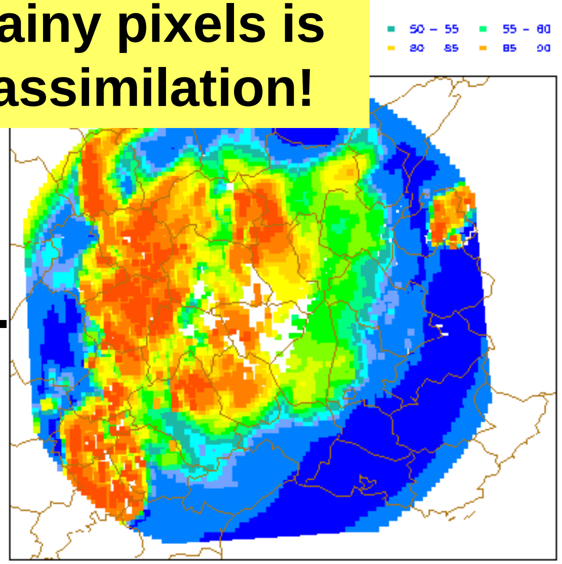
Drying thanks to the characterization of valid non-rainy pixels

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

Relative humidity



Pseudo-observation

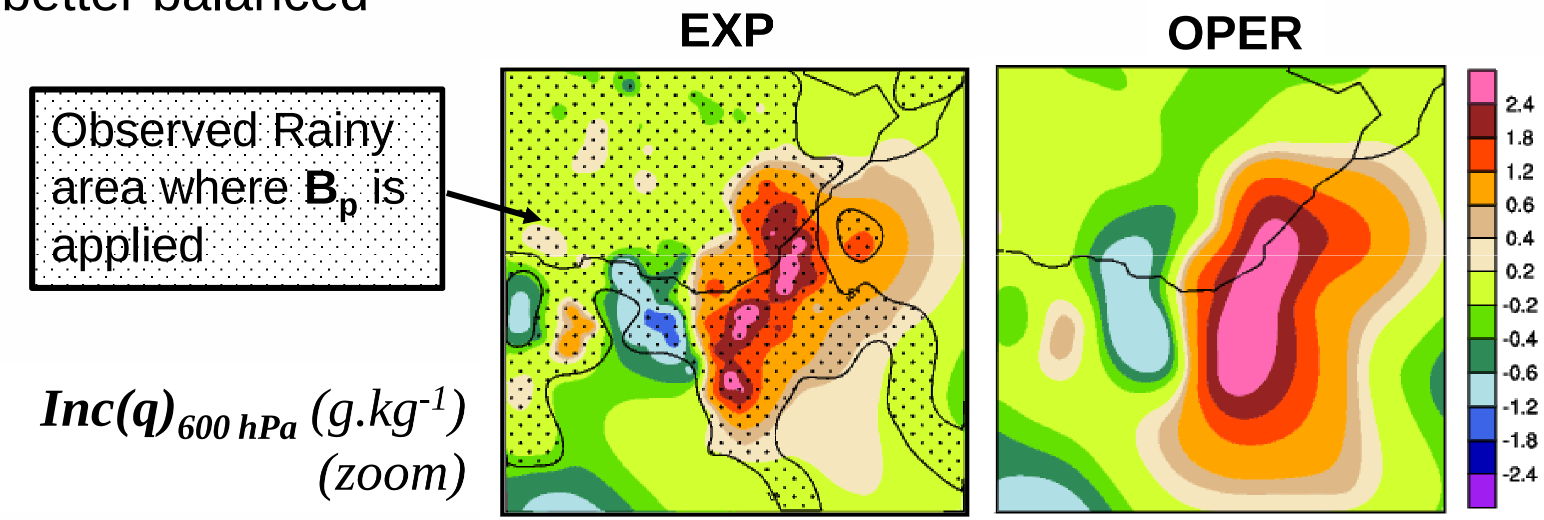


Arome (guess)

Radar DA components: 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

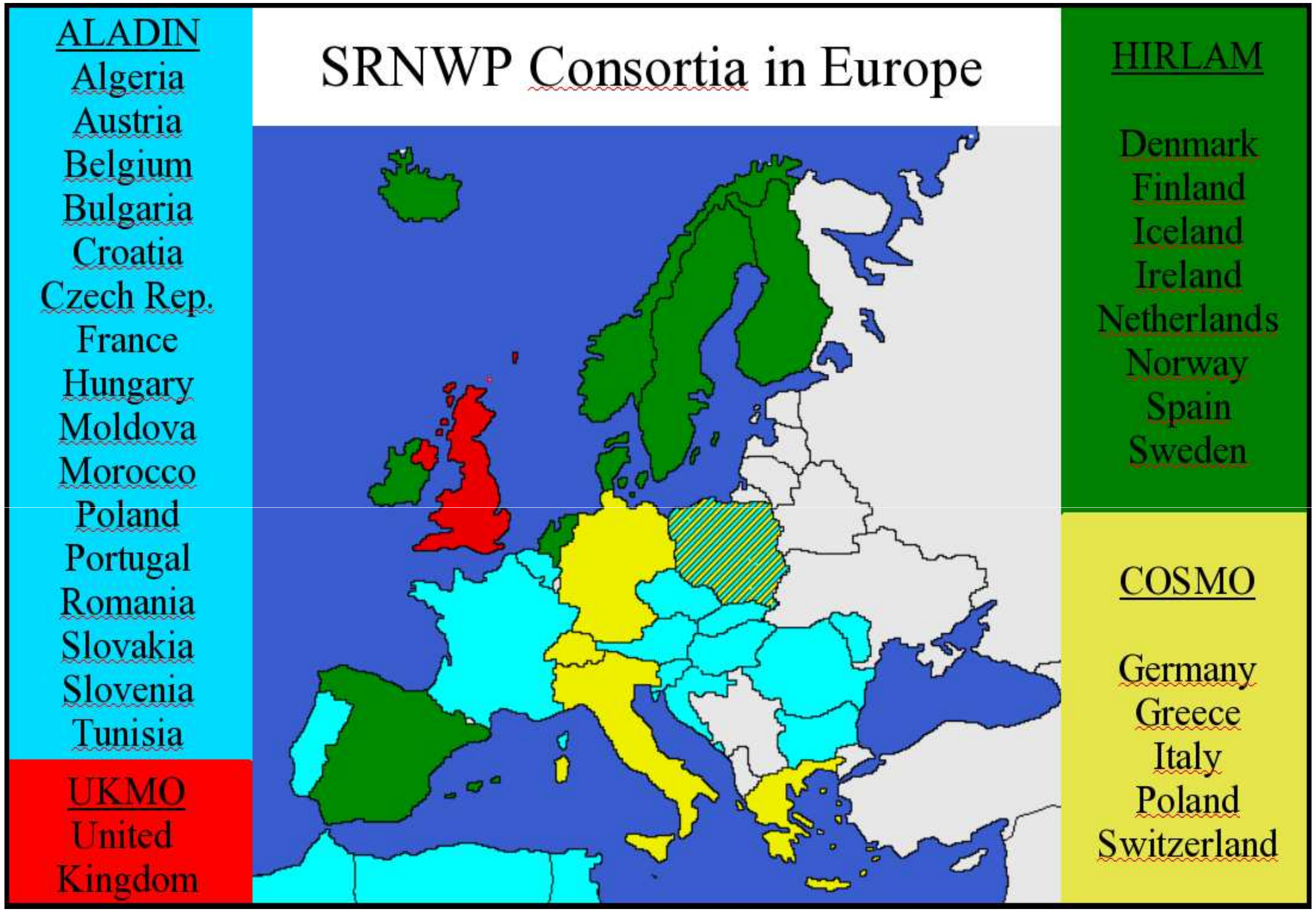


Montmerle and Berre 2010, QJRMS; Montmerle 2012, MWR

• **Computation of the obs. error covariance matrix R** using a posteriori diagnostics (see Eric Wattrelot's presentation later)

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

European Collaborations

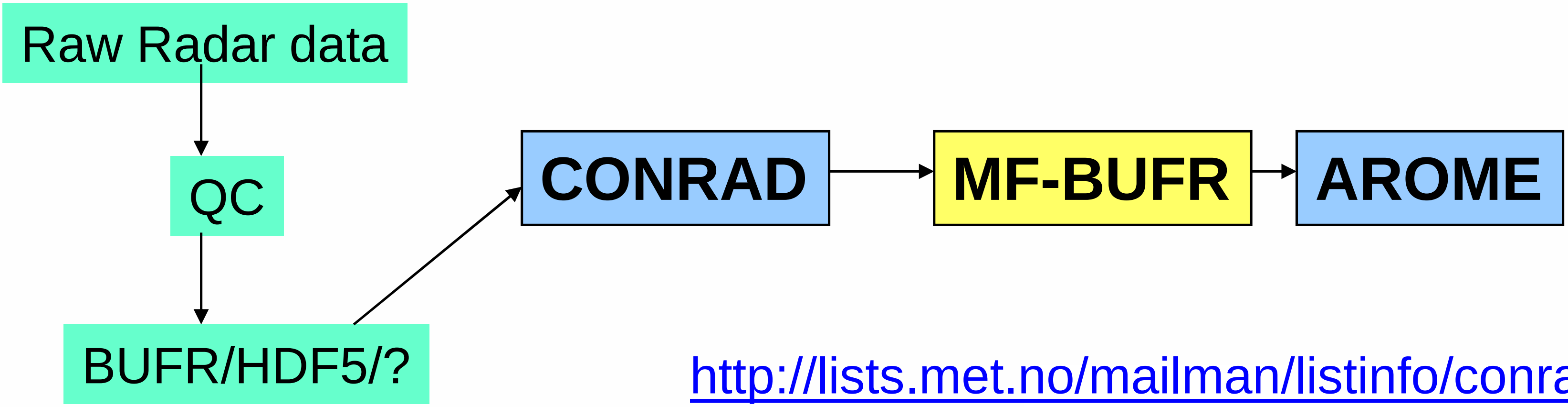


Since 2004: « full code » cooperation between ALADIN and HIRLAM
⇒ some HIRLAM countries use BATODB+AROME (in so called « HARMONIE »)

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 for OPERA IV compatible with assimilation requirements in AROME

- MetNo 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

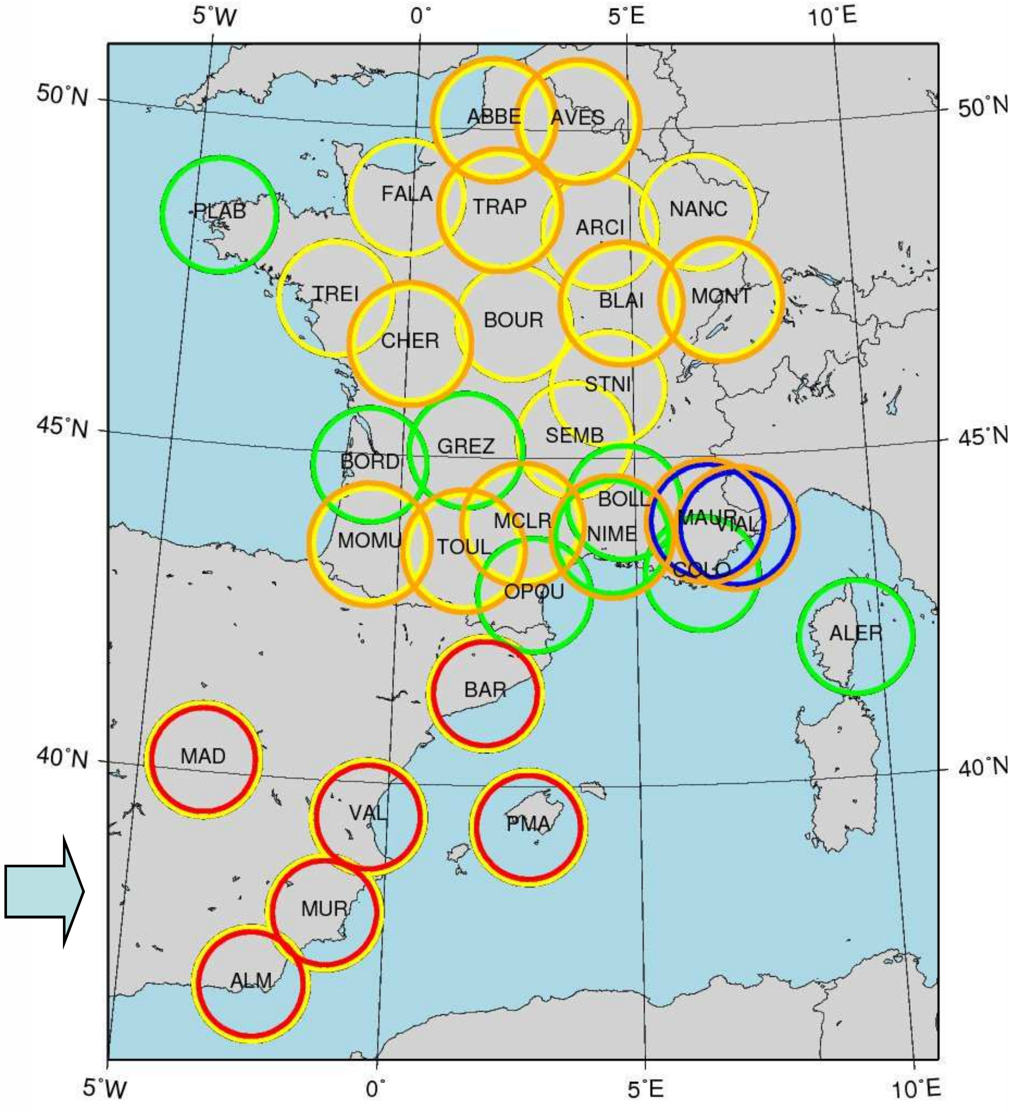
Many ongoing studies using CONRAD in different NWP systems:

• **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…

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

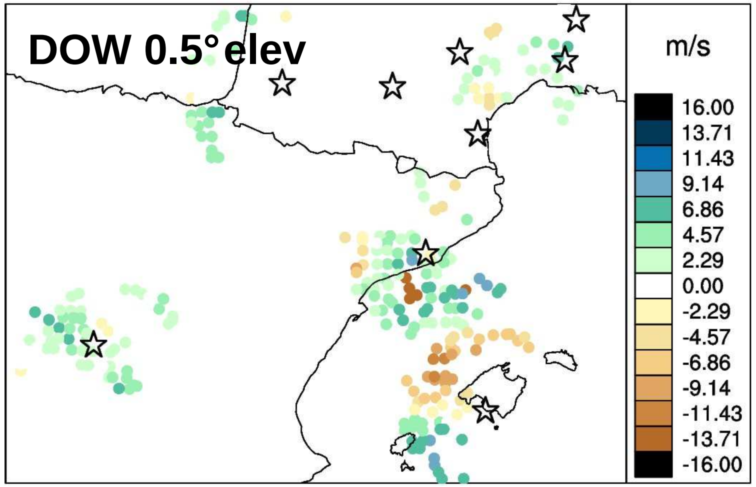


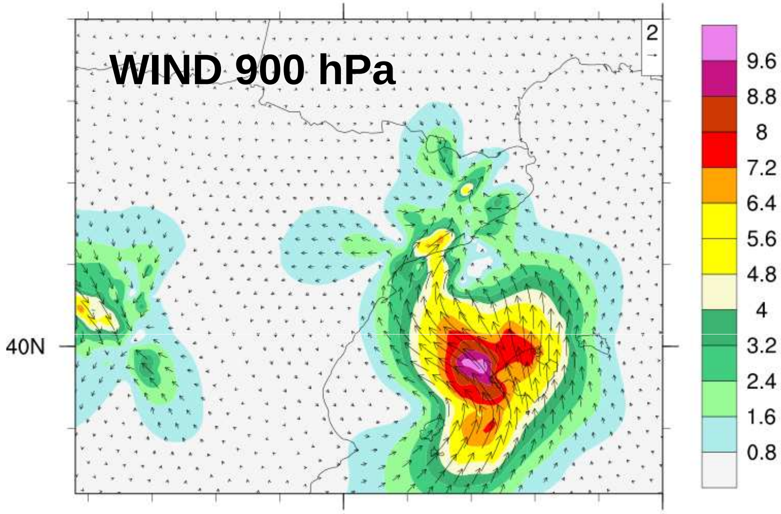
European Collaborations

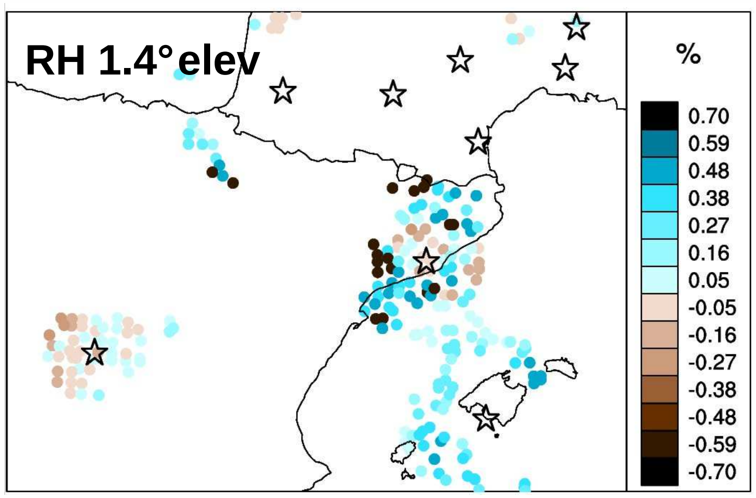
Assimilation of AEMET's radars in AROME

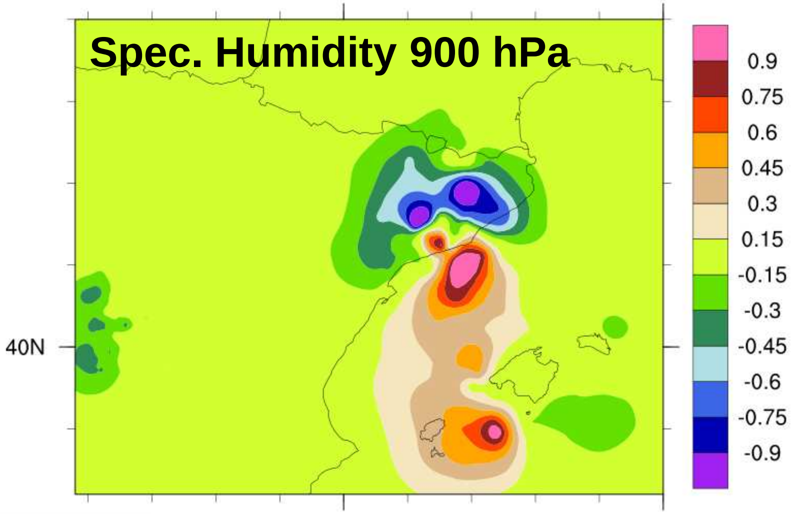
(obs-guess) in observation space
(DOW positive towards the radar)

Analysis differences with/without
AEMET radars at 9 UTC

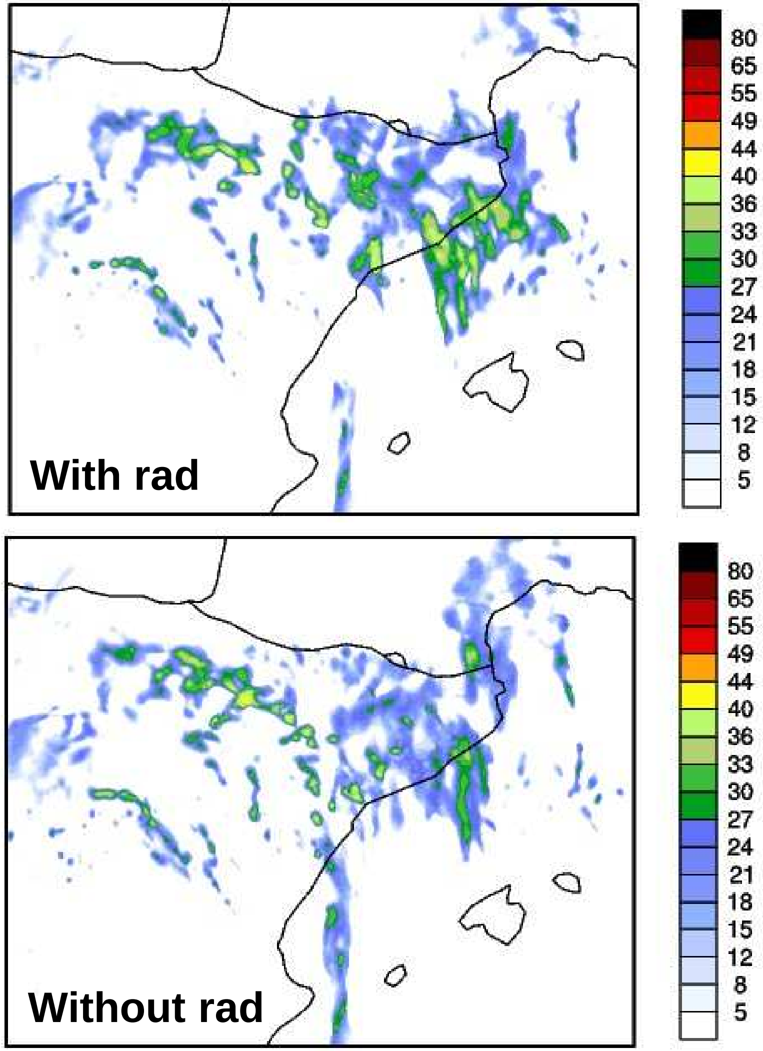








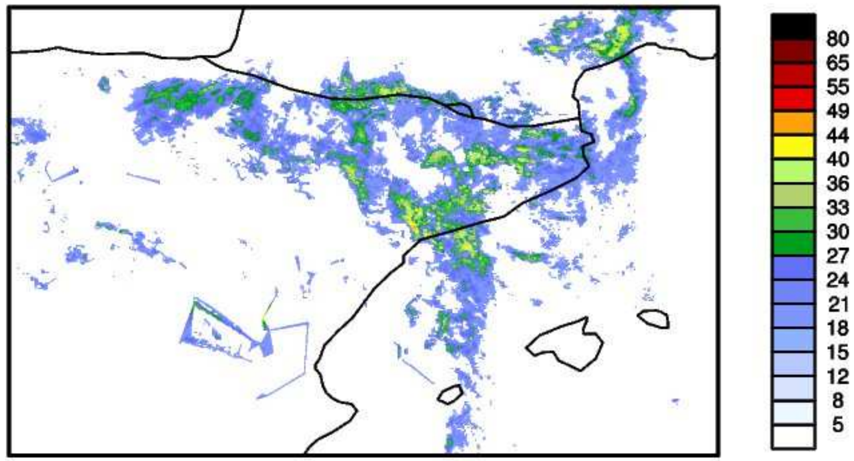
Assimilation of AEMET's radars in AROME: precip. forecast



3h Forecasts of Z (1500m)

⇒ Realistic enhancement of the southerly humid flux, bringing more precipitations over Catalonia

Radar Mosaic (2012032112)



- Technically OK, but more validation is needed
- 6 radars currently tested in quasi real time in AROME-WMED in order to prepare the first SOP this autumn

Conclusions

Assimilating Radar data in AROME allows:

- to improve forecast scores, especially for precipitations
- to capitalize on DOW
- to detect measurement failures through innovation monitoring

After 4 years of operational radar DA we can say that:

- **An efficient pre-processing is essential** to unfold/filter 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 only one of those parameters requires suitable forecast errors in precipitations

$\Rightarrow$ More work is however needed to optimize their use in DA (flow dependent **B**, more realistic **R**)

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Conclusions

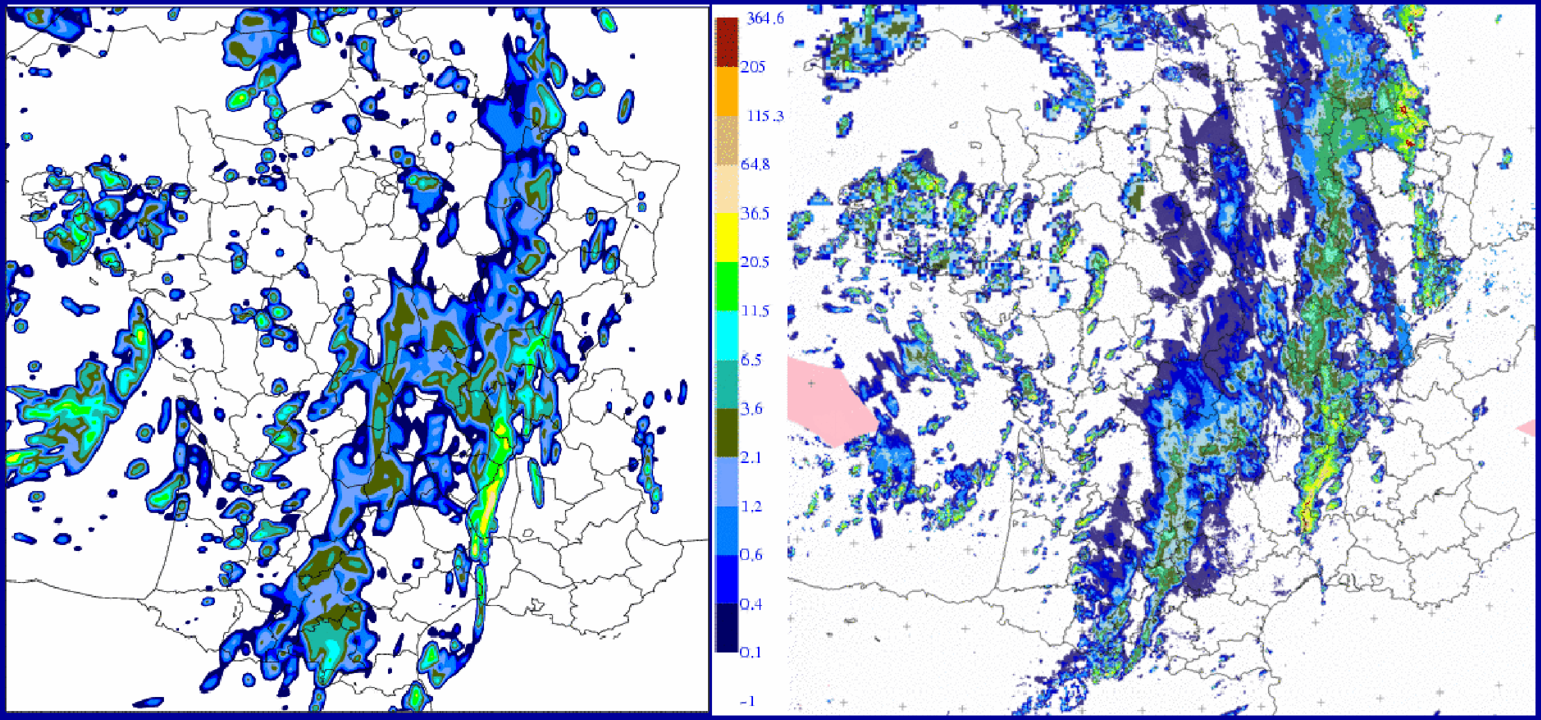
The usefulness of new types of radars, like X-band, need to be addressed in this context

It is now time to look behind our borders:

• Many international collaborations ongoing, thanks to the ALADIN/HIRLAM cooperations and the CONRAD software

$\Rightarrow$ **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

References

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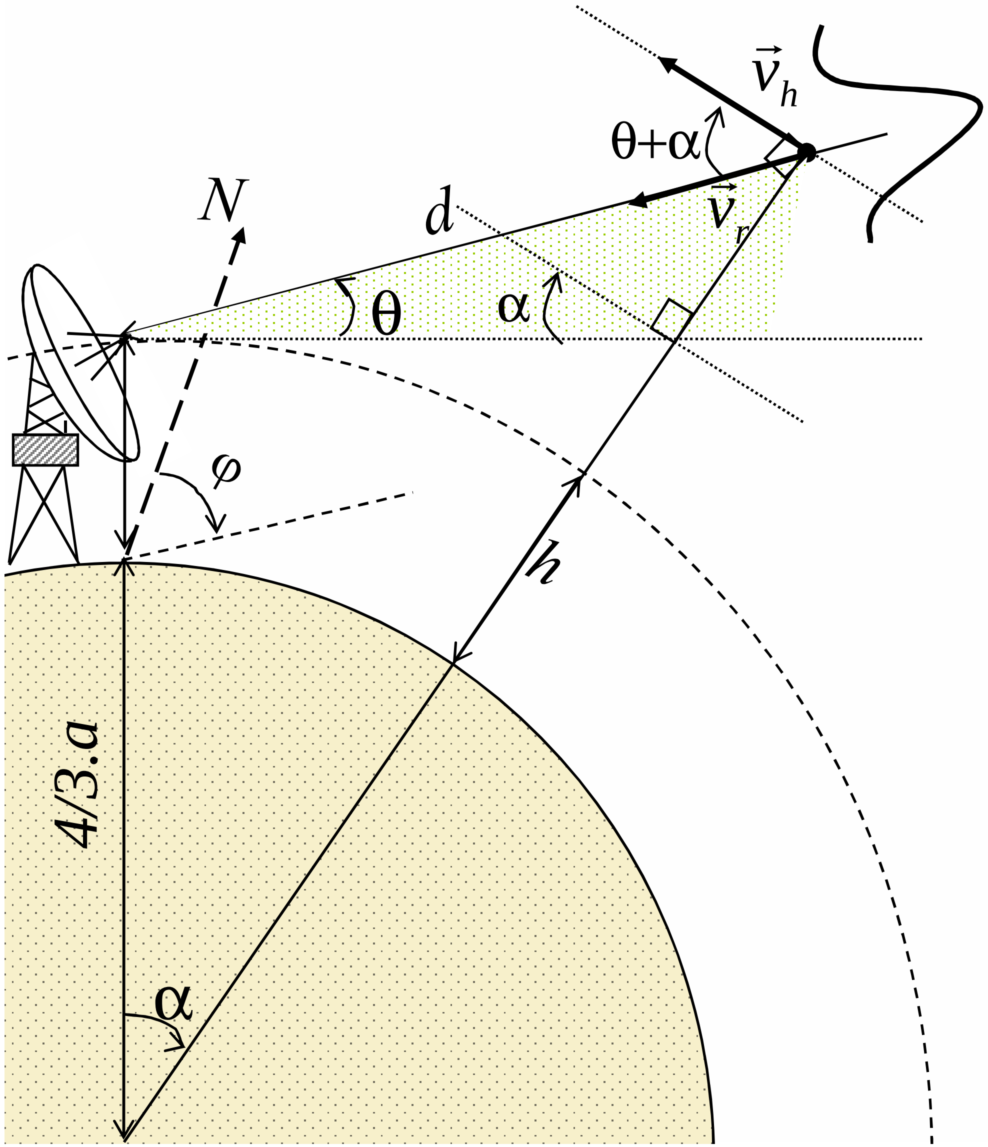
Observation operators

Doppler Wind:



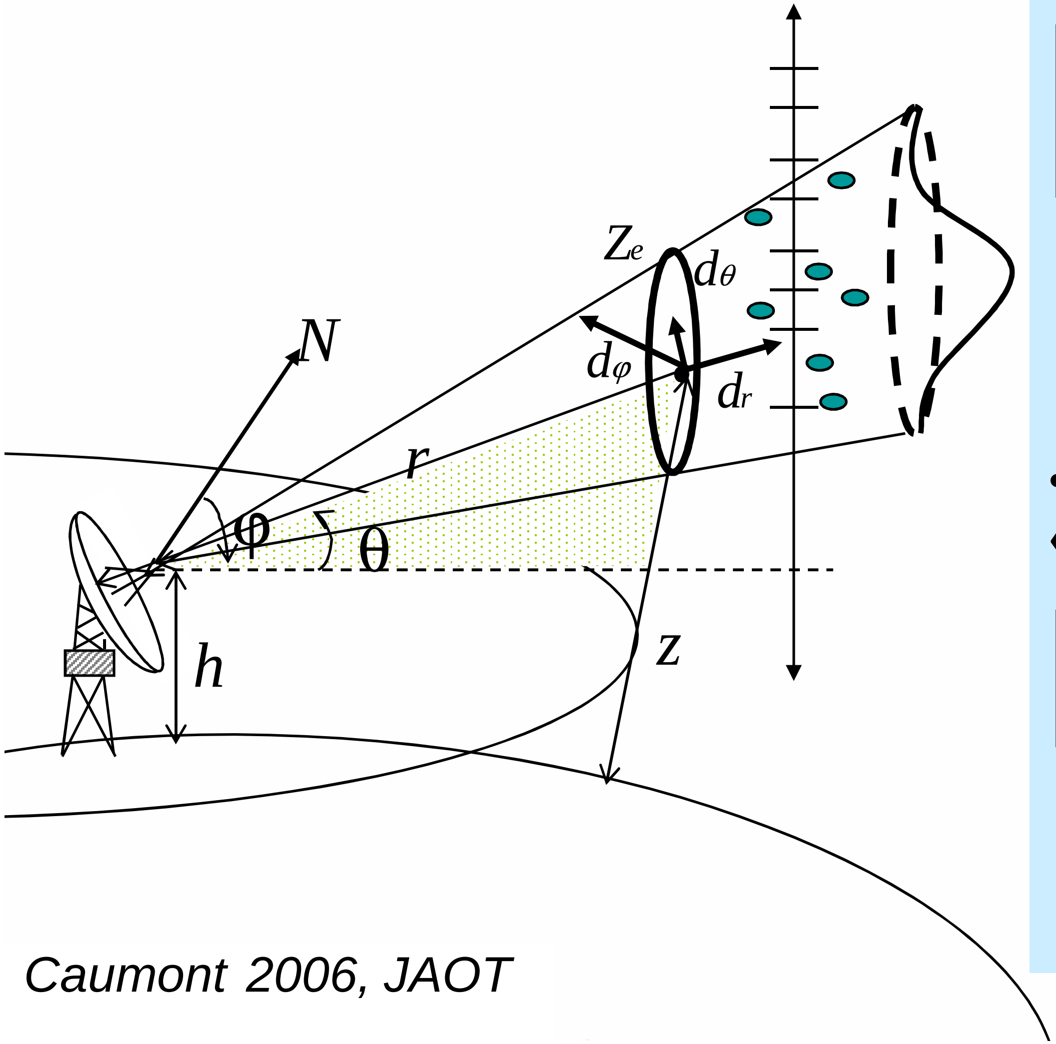
- **Bi-linear interpolation** of the simulated wind
- **Projection on the slanted direction of the radar beam** (using the earth's effective radius model)
- No fall speed correction
- Side lobes contributions neglected
- **Broadening of the radar beam** simulated by a Gaussian function
- **TL/AD**

- $\sigma_o = f(r)$
- 15 km^2 thinning boxes
- no bias corrections applied in azimuth nor in intensity

⇒ More details in Montmerle and Faccani, 2009, MWR

Observation operators

Reflectivity:
Limitations (watt 2008)



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*»**

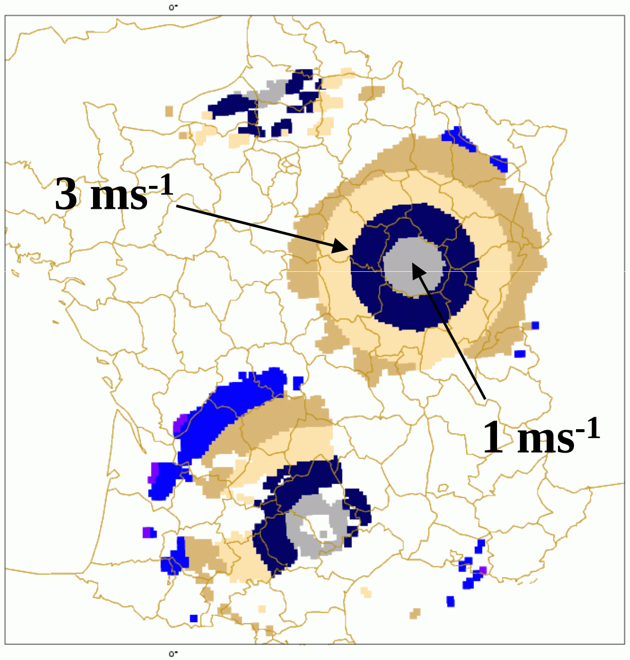
$$Z_e = 10\log(\int_{bv} \eta(r).f^4(\theta,\varphi).dr.d\theta.d\varphi)$$

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

Gaussian function for main lobe

Screening decisions

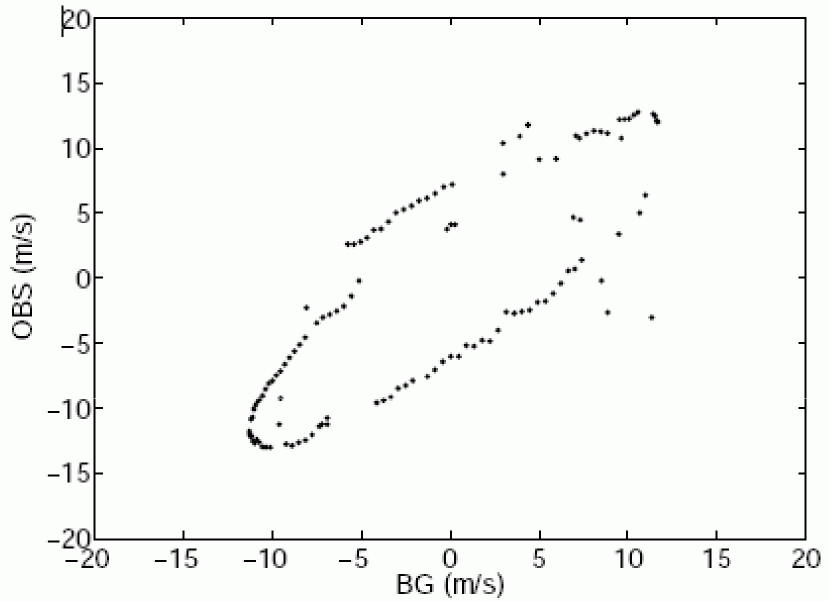
σ_o

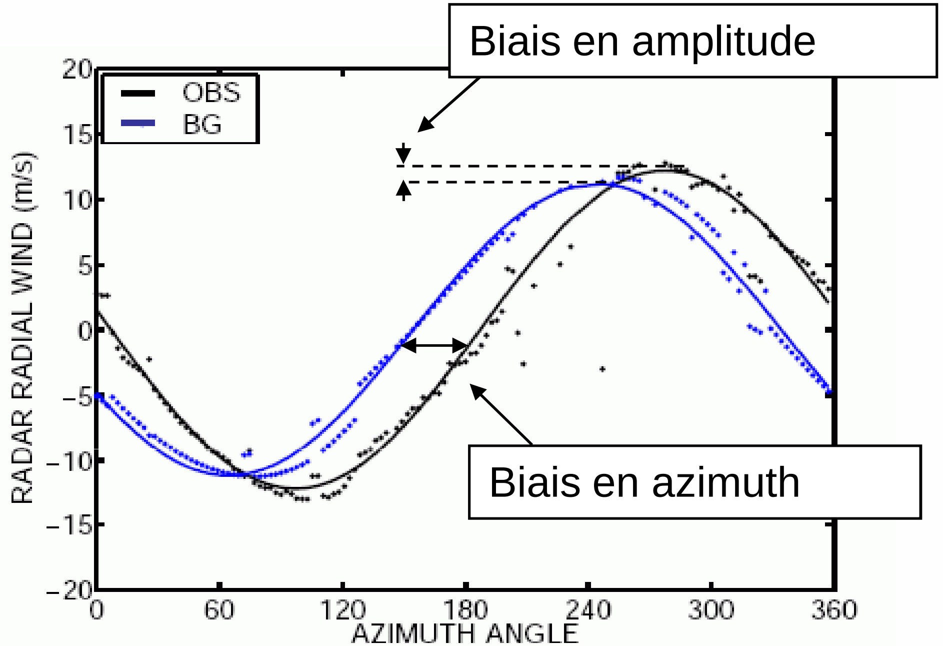


Ex: ABBE, BLAI, MCLA

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

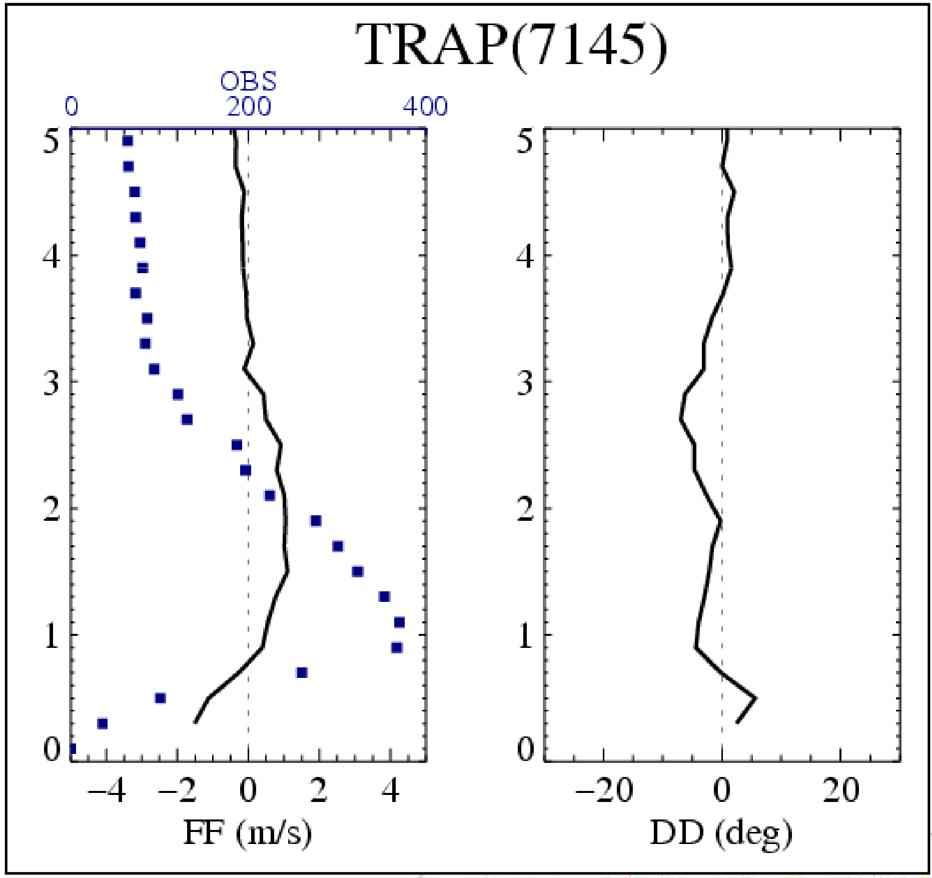
Représentation Vr/Azimuth

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

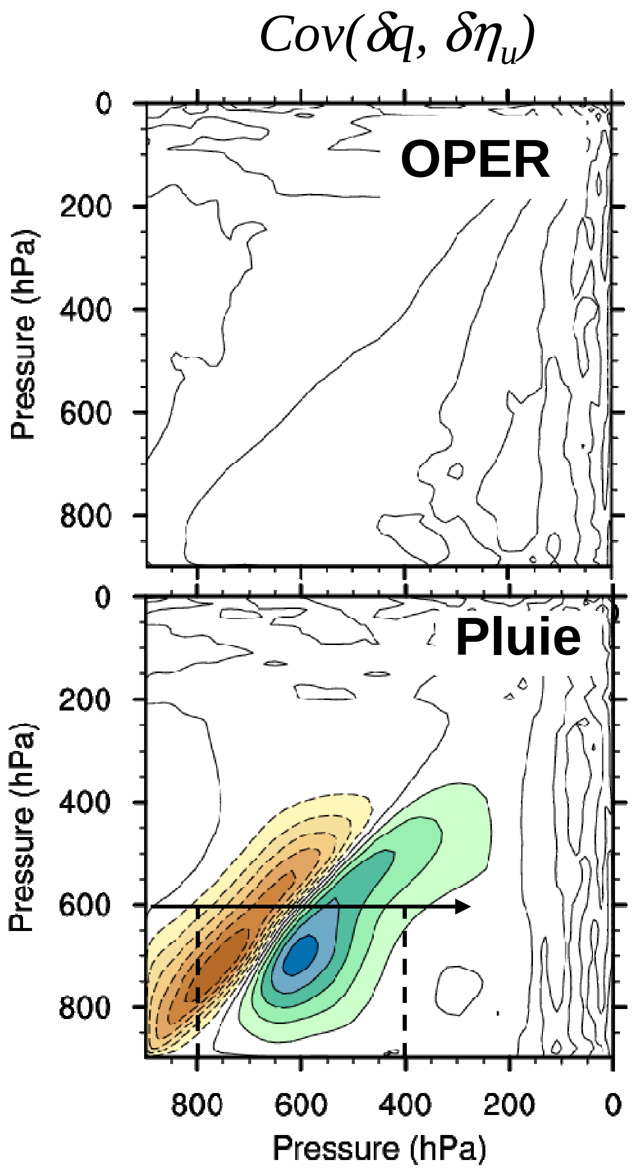
- Biais proches de 0
- Calculs fortement dépendant de la stratégie d'échantillonnage et de la position des systèmes échantillonnés

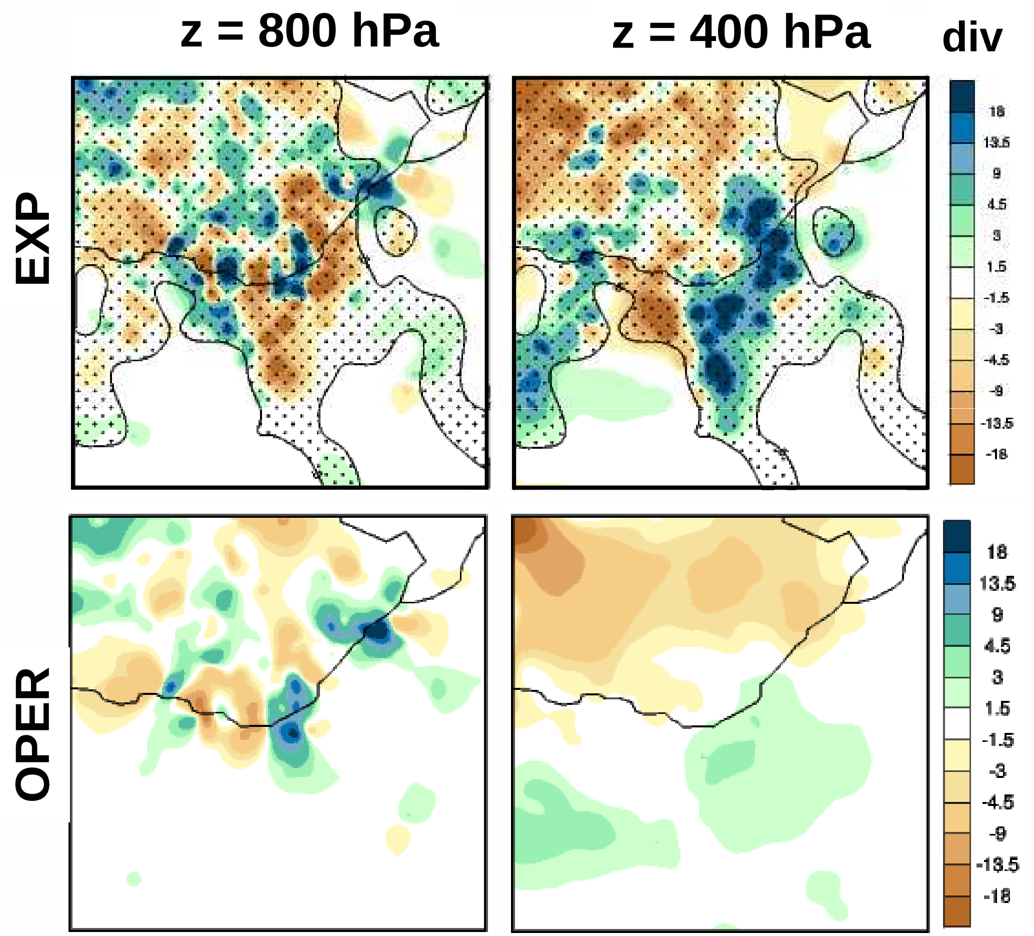


Optimisation de l'utilisation des observations

Prise en compte des erreurs de prévision dans les précipitations

Montmerle, MWR, 2012





Incréments de divergence

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