RAINGAIN Leuwen Workshop

16 April 2012

Topic#1 X-band and C-band radar calibration: methods and experiences

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Questions on calibration / monitoring of dual-pol variables

✓ If well calibrated and processed (Z_{DR}), polarimetric variables improve the quality of all conventional radar products;

✓ If not well calibrated / processed (e.g. large bias on Z_{DR}, remaining ground-clutter impacting Φ_{DP} offset computation), polarimetric variables may lower the quality of all conventional radar products;

⇒ Need to have very robust calibration / correction procedures

⇒ Need to monitor very carefully the quality of the radar (and trigger alerts in case of failure) !

⇒ Can we really achieve the required stability / precision on Z_{DR} for quantitative applications (0.2 dB ⇒ 15% error on retrieved rain rate) ?

Questions relevant at all wavelengths: C / S / X !

Météo France routine monitoring indicators

Mean Z_{DR} at 90° — Expected value $Z_{DR}^{90°} = 0$ dB

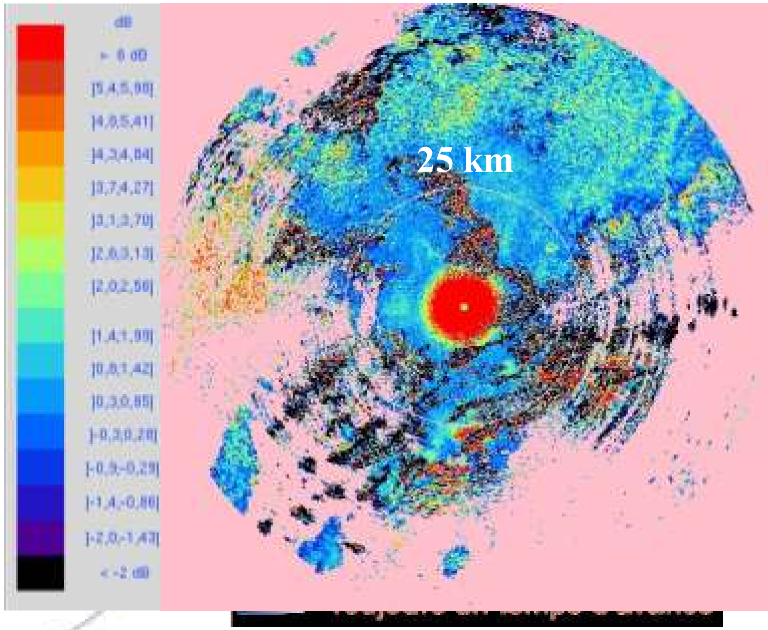
Mean Z_{DR} in rain for Z_H between 20 and 22 dBZ at close-range and high-SNR — Expected value $Z_{DR} = 0.2$ dB

Upper 80% quantile of all ρ_{HV} values in rain at close-range and high-SNR — Expected value $\rho_{HV} \geq 0.99$

ϕ_{DP} offset

Mean Z_{DR} on the 10 first 1km-wide rings — Expected value $|Z_{DR}| < 5$dB

Montancy – 7th June 2009 (TR tube failure)

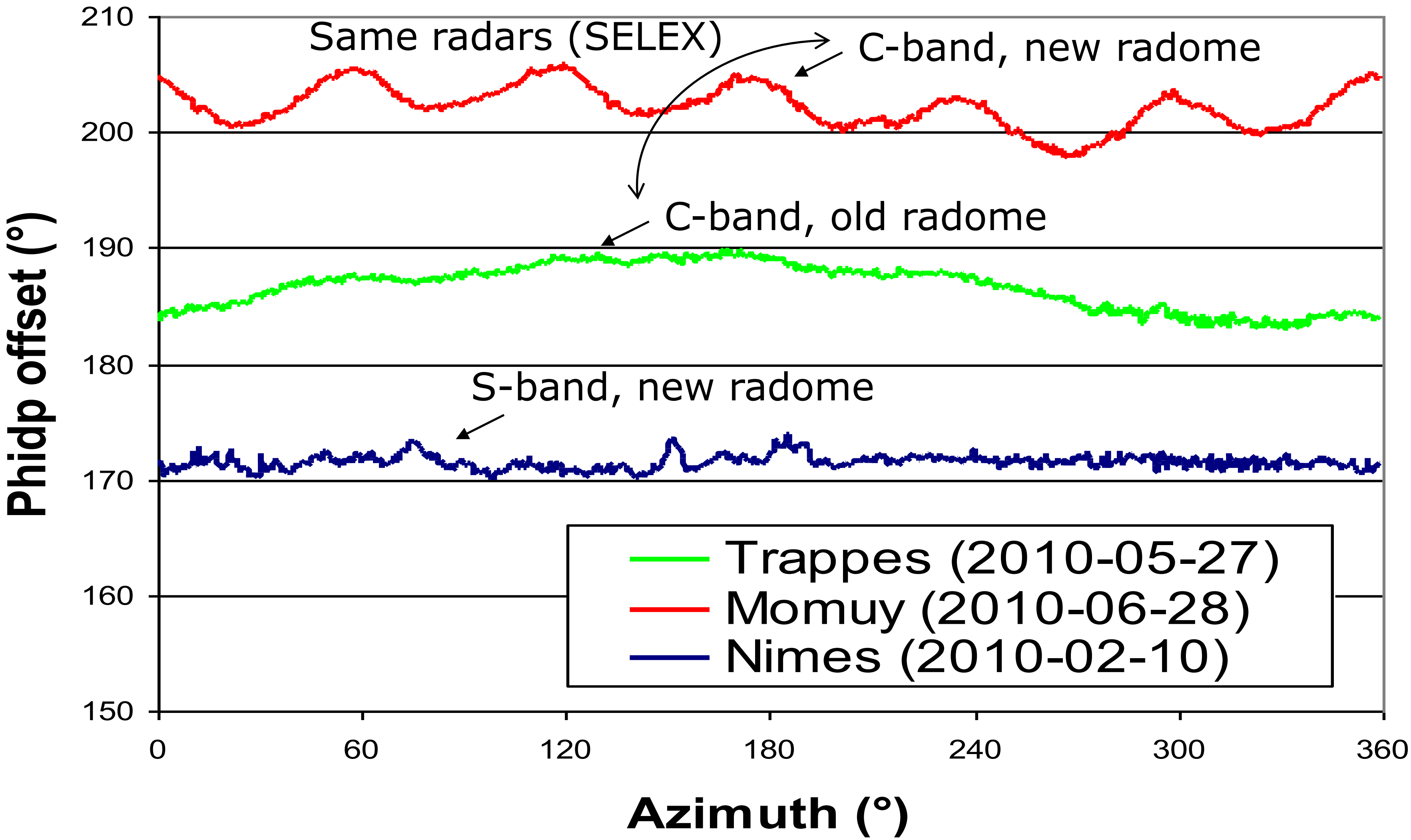


✓ One curve (or value) per day

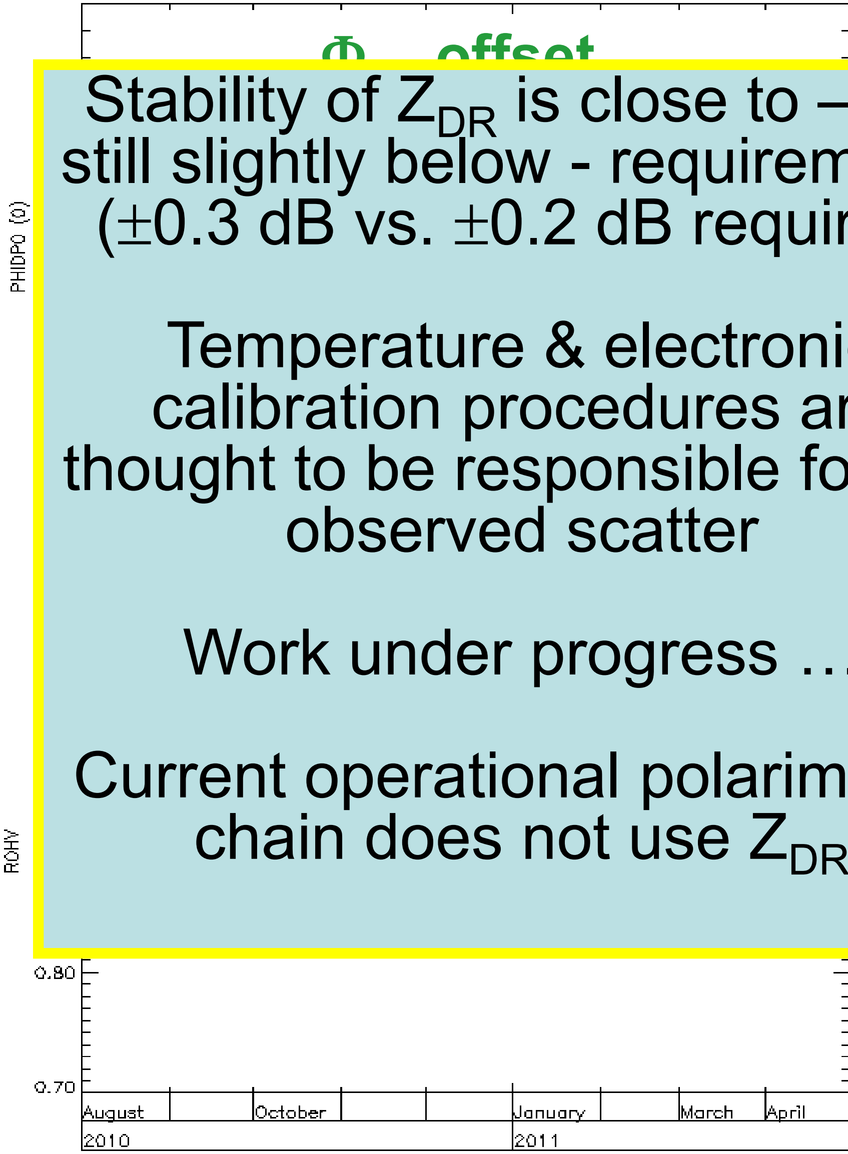
✓ Indicators have been produced routinely on all polarimetric radars (> 10) since August 2010

⇒ We have now a robust experience of what can be achieved in terms of stability / precision of the dual-pol variables <u>given the current calibration procedures</u>

Φ_{DP} offset as a function of azimuth for 3 different radars



Long-term monitoring of polarimetric indicators (Avesnes – C-band)

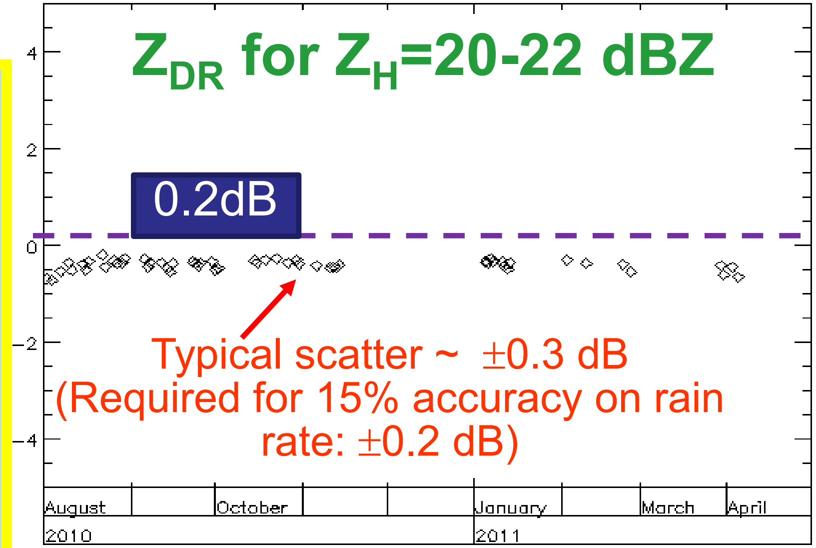


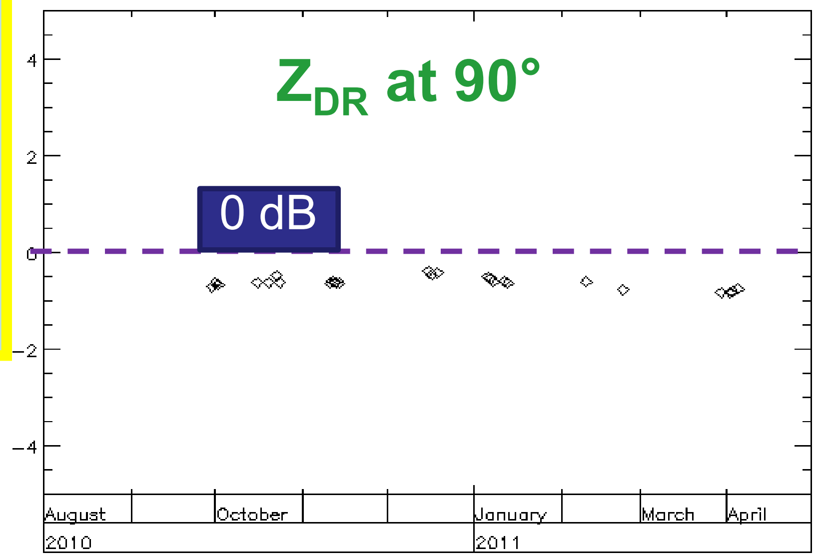
Stability of Z_{DR} is close to – but still slightly below - requirements (±0.3 dB vs. ±0.2 dB required)

Temperature & electronic calibration procedures are thought to be responsible for the observed scatter

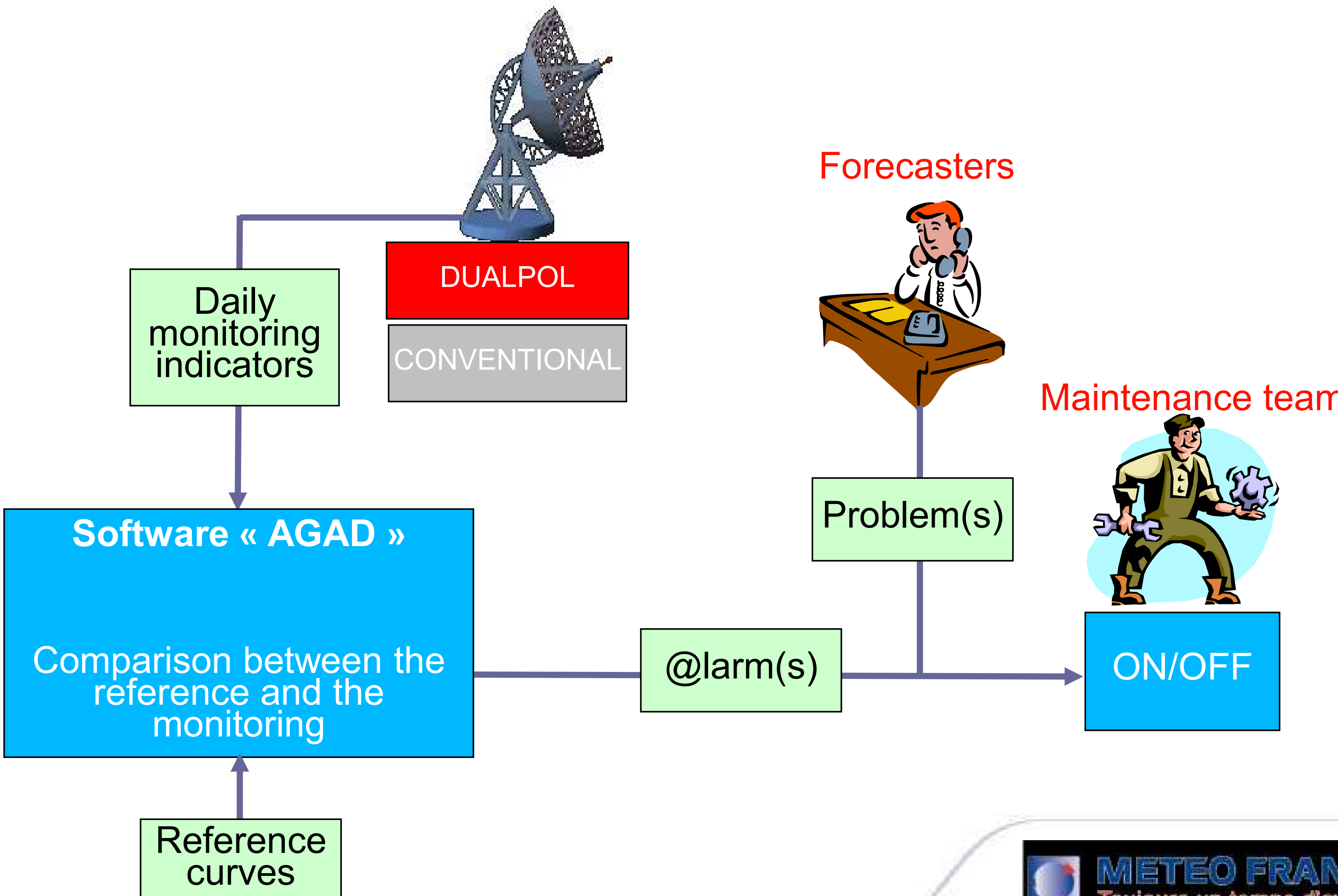
Work under progress …

Current operational polarimetric chain does not use Z_{DR}

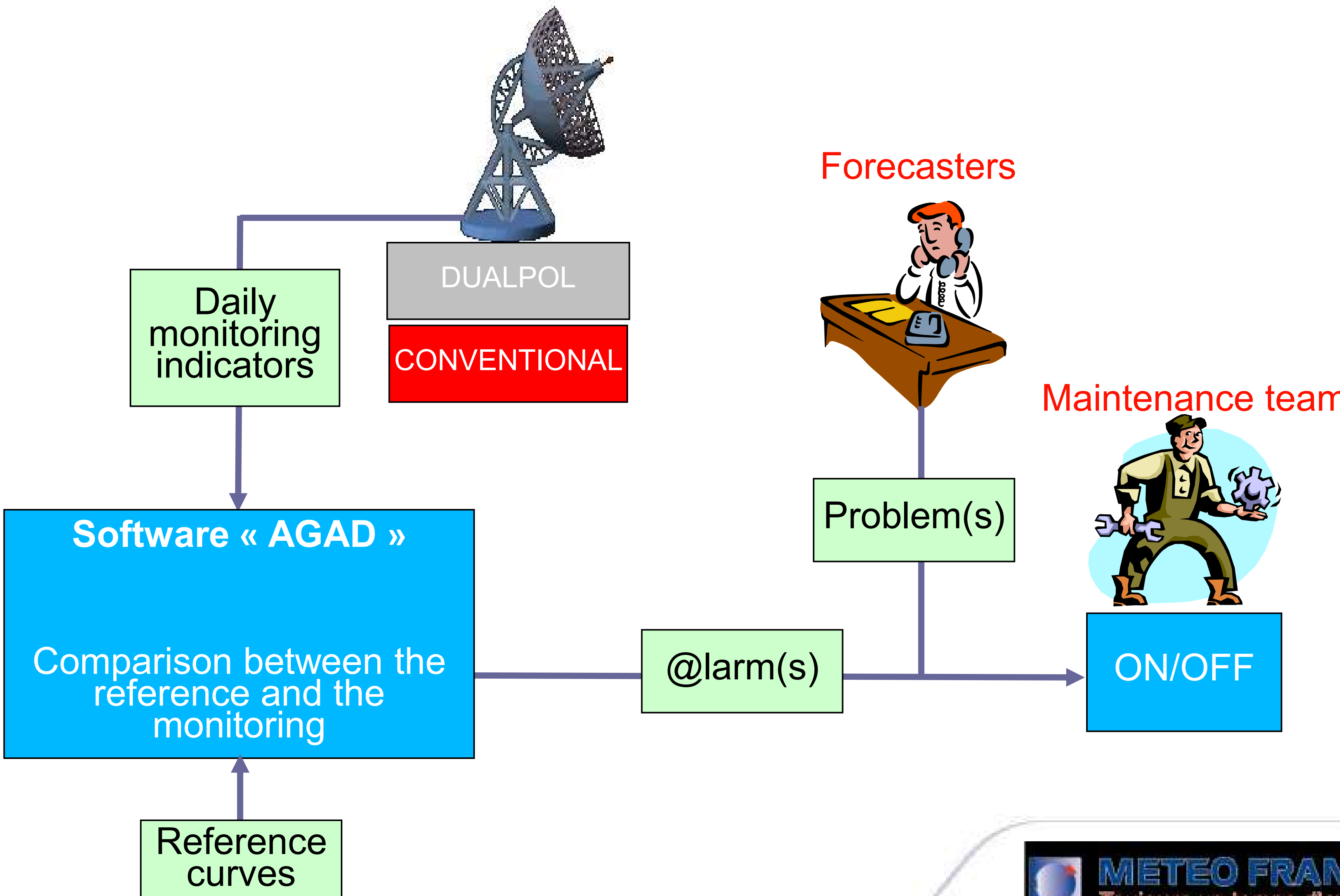




Operational procedures



Operational procedures



Questions on the joint use of gauges & polarimetry

✓ Is gauge adjustment still needed in the context of dual-pol radars ?

✓ Does dual-polarization lead to a reduction in gauge networks density ?

✓ is there a potential detrimental effect of gauge adjustment when applied to dual-pol QPE ?

Questions on the joint use of gauges & polarimetry

Some reasons why gauge adjustment may still have some value in the future:

- Polarimetric rain rate estimators have reached a mature stage. Estimators in snow (wet or dry) are still in the research stage. In low bright band cases (1000 m), the radar beam at low elevation angle may enter into the wet snow region at short ranges (a few tens of kilometers).

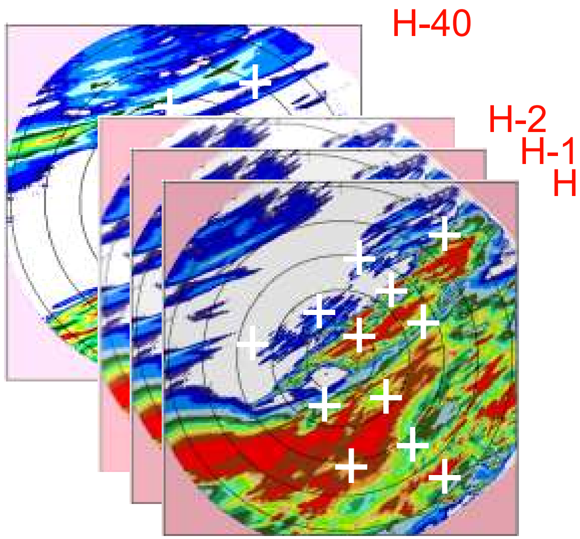
- Z_H absolute calibration is still a challenge (and almost impossible in dry periods and in real-time). Gauges may help mitigating the (dramatic) consequences of a miscalibration of Z_H.

- (Especially at C and S band) K_{DP} usable only at high rain rate. Quantitative use of Z_{DR} is challenging. Gauge adjustment may improve the Z_H-based estimation of low to moderate rain rates.

- Gauge adjustment may correct inappropriate statistical relationships between radar variables and rain rate (e.g. $R=aK_{DP}^{b}$)

THE RAIN GAUGE REAL TIME ADJUSTMENT SCHEME

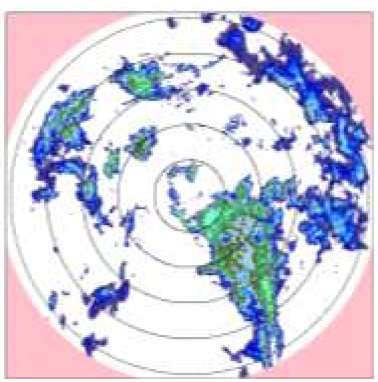
(USED FOR CONVENTIONAL AND POLARIMETRIC RADARS)



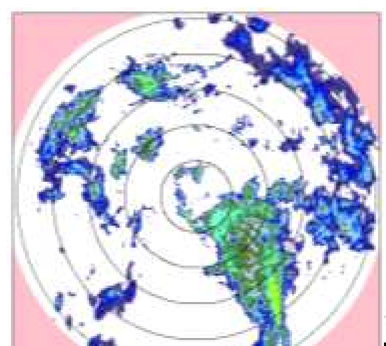
At the end of each hour a global adjustment factor is computed based upon the comparison of past (H, H-1, H-2, …) radar hourly estimates with co-located rain gauge

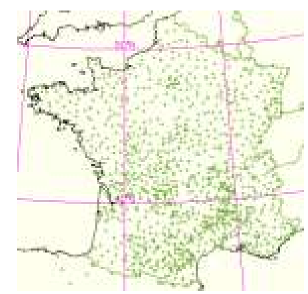
More recent hours receive more weight in the estimation than “older” hours

The global adjustment factor is subsequently applied to all incoming 5’ raw radar QPE



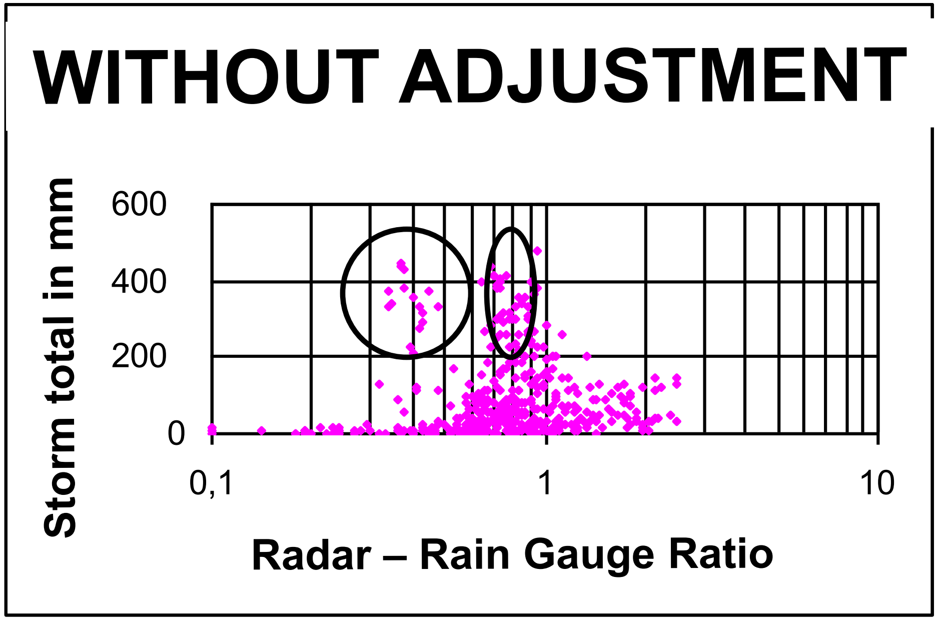
$QPE_{5'}$ $\times C_H \Rightarrow$ $QPE_{5'}^{ADJUSTED}$

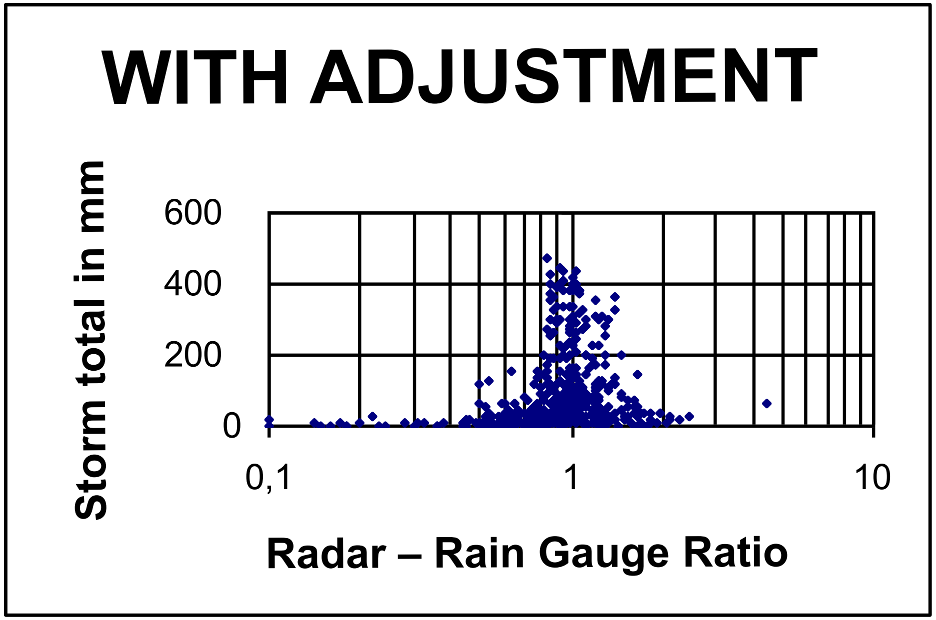




~1 gauge every 25 km

Real-time radar – rain gauge adjustment





Each point on the graphs above = one couple

[rain gauge storm total / radar storm total at the gauge location]

Validation rain gauge data are not the ones that were used for adjusting the radar QPE.

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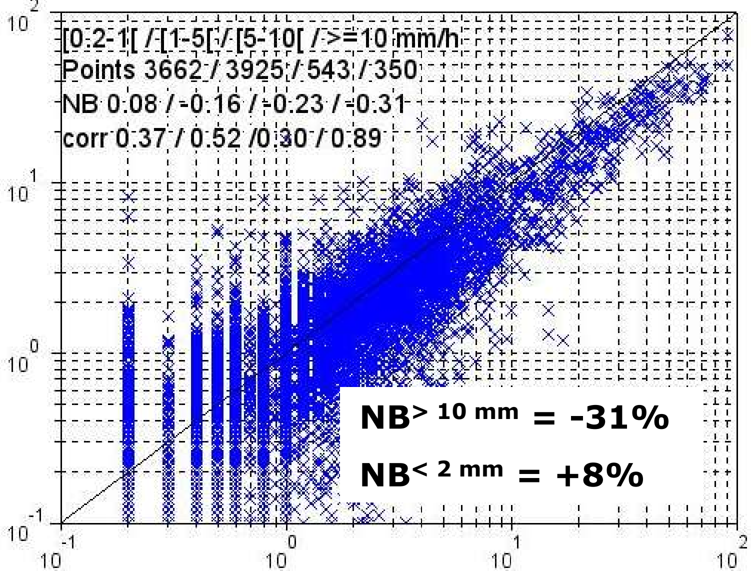
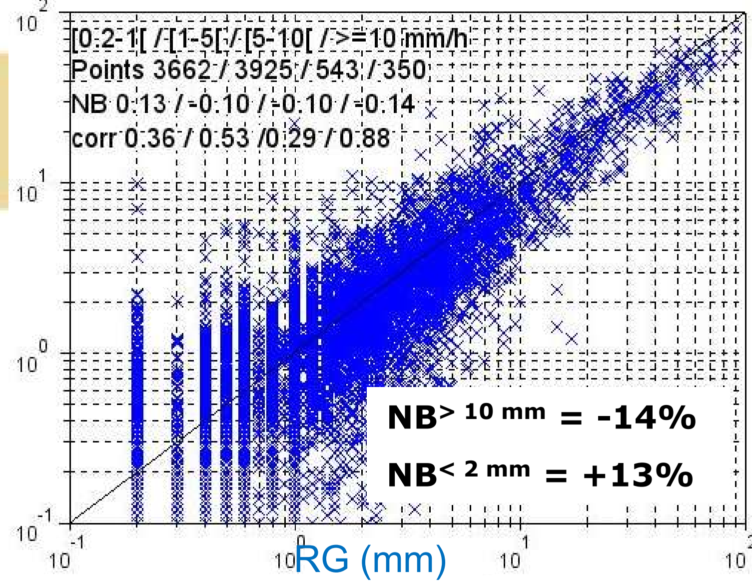


CONVENTIONAL

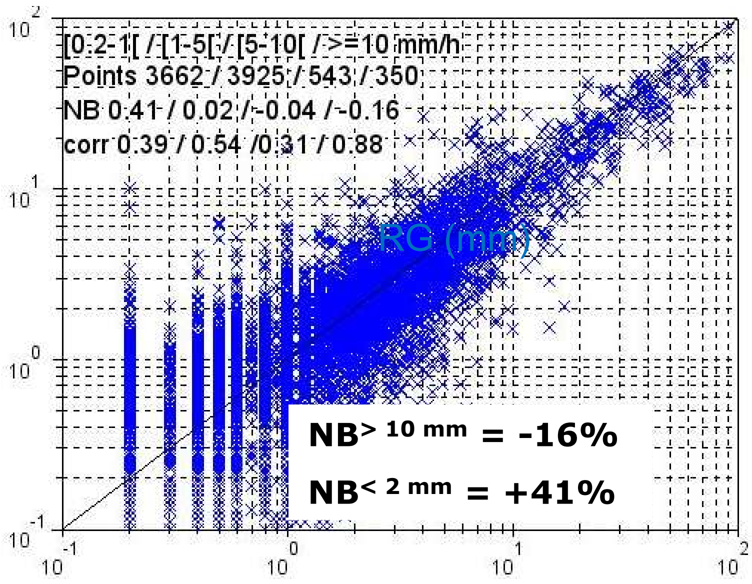
Polarimetric attenuation correction →



DUAL POL QPE (ATT CORR.)

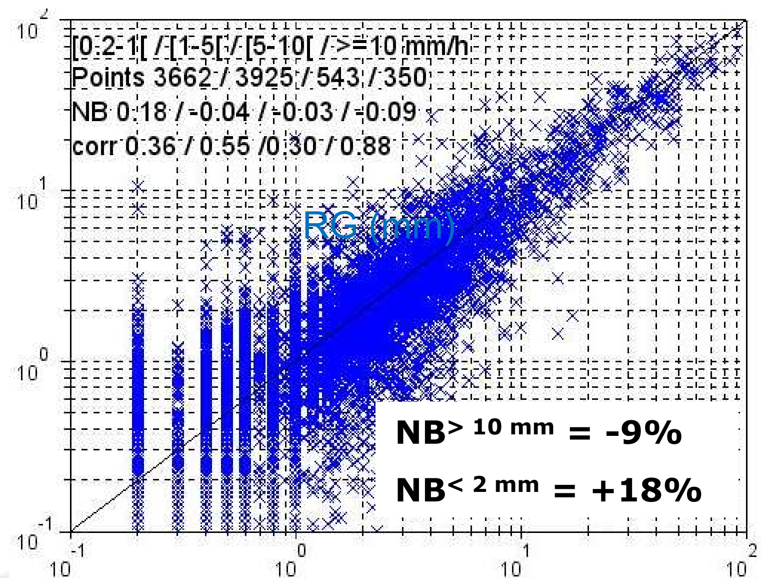
12 SUMMER EVENTS – HOURLY ACCUMULATIONS - C-BAND

CONVENTIONAL + RG ADJUSTMENT



↓ RG adjustment

DUAL POL + RG ADJUSTMENT



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Topic#2 X-band versus C-band performance: experiences

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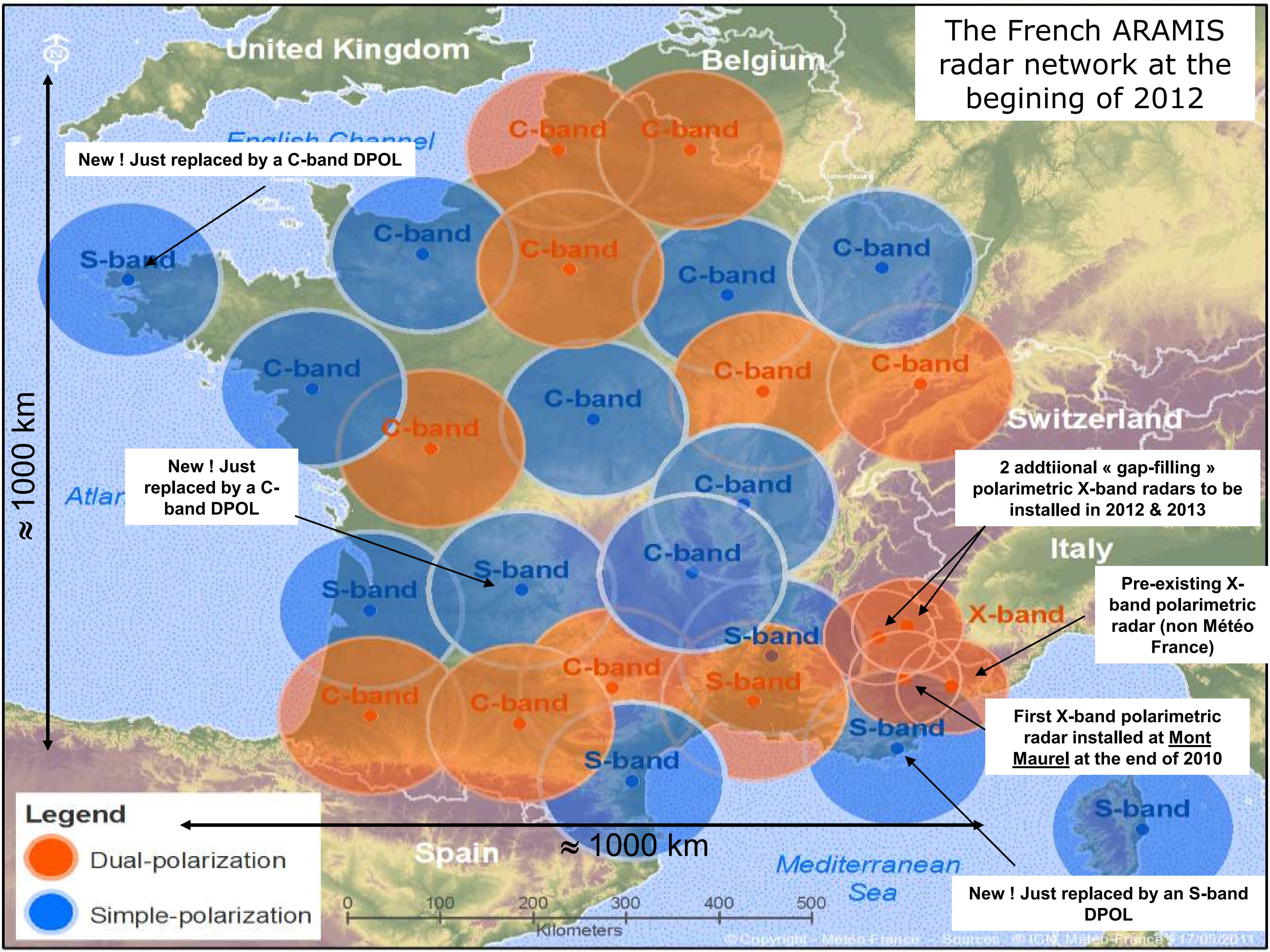

The French ARAMIS radar network at the begining of 2012
United Kingdom
Belgium
English Channel
Switzerland
Italy
Spain
Mediterranean Sea
New ! Just replaced by a C-band DPOL
New ! Just replaced by a C-band DPOL
2 addtiional « gap-filling » polarimetric X-band radars to be installed in 2012 & 2013
Pre-existing X-band polarimetric radar (non Météo France)
First X-band polarimetric radar installed at Mont Maurel at the end of 2010
New ! Just replaced by an S-band DPOL
S-band
C-band
X-band
≈ 1000 km
≈ 1000 km
0
100
200
300
400
500
Kilometers
Legend
Dual-polarization
Simple-polarization
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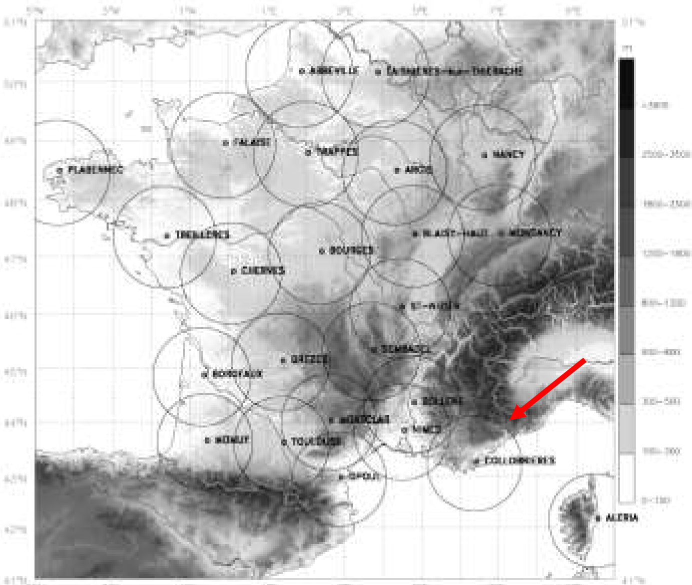
The first Météo France X-band polarimetric radar: SELEX Meteor-50DX radar installed in the southern French Alps (alt. 1772 m)

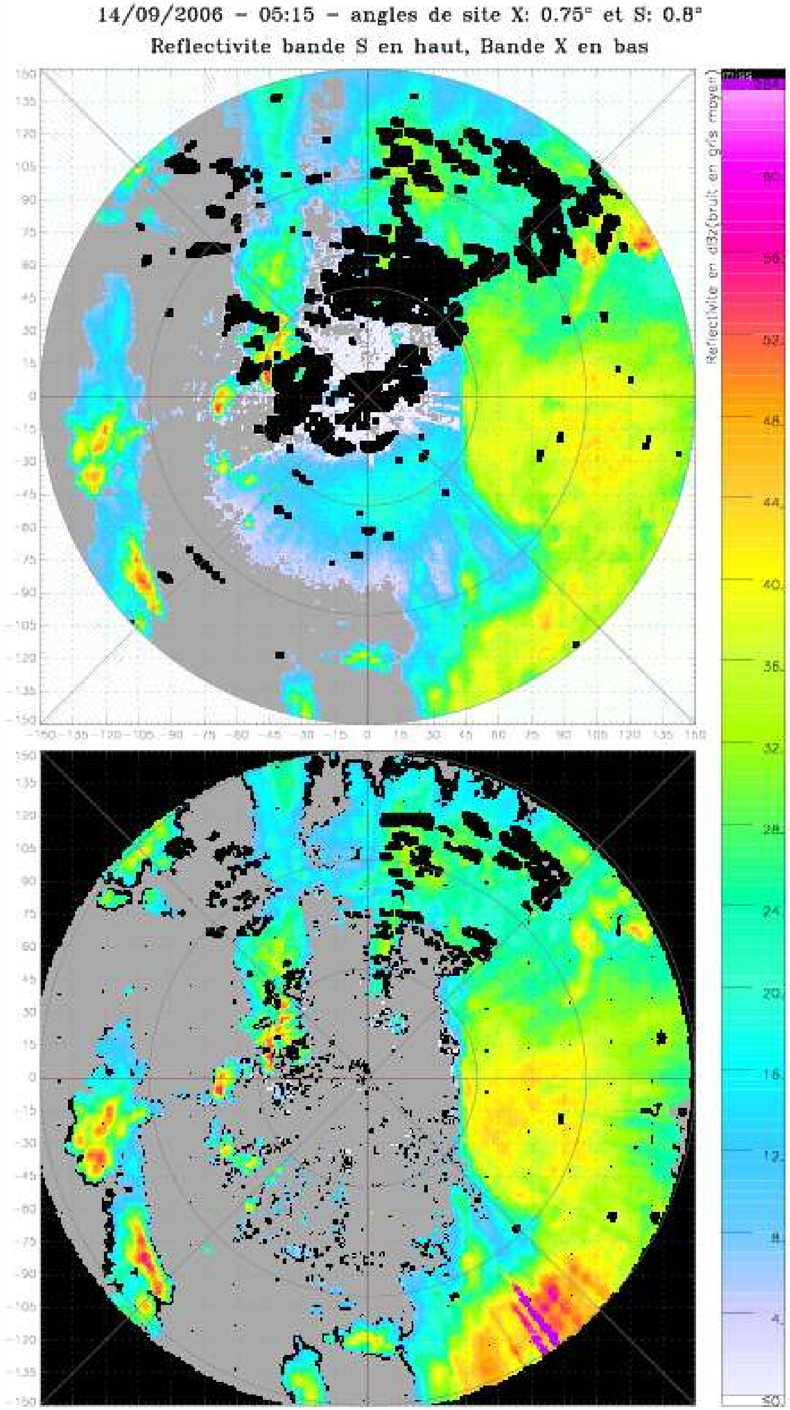


Some facts

✓ Resolution does not depend upon the wavelength. Resolution is dictated by pulse width and beam width. All French radars, whatever their wavelength, have approximately the same pulse widths (2 microsec / 300 m) and beamwidth (0,9 – 1,3°). Using X-band does not imply getting higher resolution data.

✓ All French radars – whatever their wavelength - have the same sensitivity (about 0 dBZ at 100 km). The pulse peak power is adjusted according to the wavelegth (75 kW – 250 kW – 650 kW for X, C and S-band). X-band radars are not more sensitive.

✓ Ground-clutter intensity and extension (e.g. arising from diffraction) goes down with increasing frequency: 10 to 20 dB decrease when going from S to X-band. 5 to 10 dB decrease when going from C to X-band. A major advantage in mountainous areas.



Ground clutter

FRAMEA Project

S

X & S-band co-located radars near Toulon (SE France)

Same elevation angles

Same measurement time

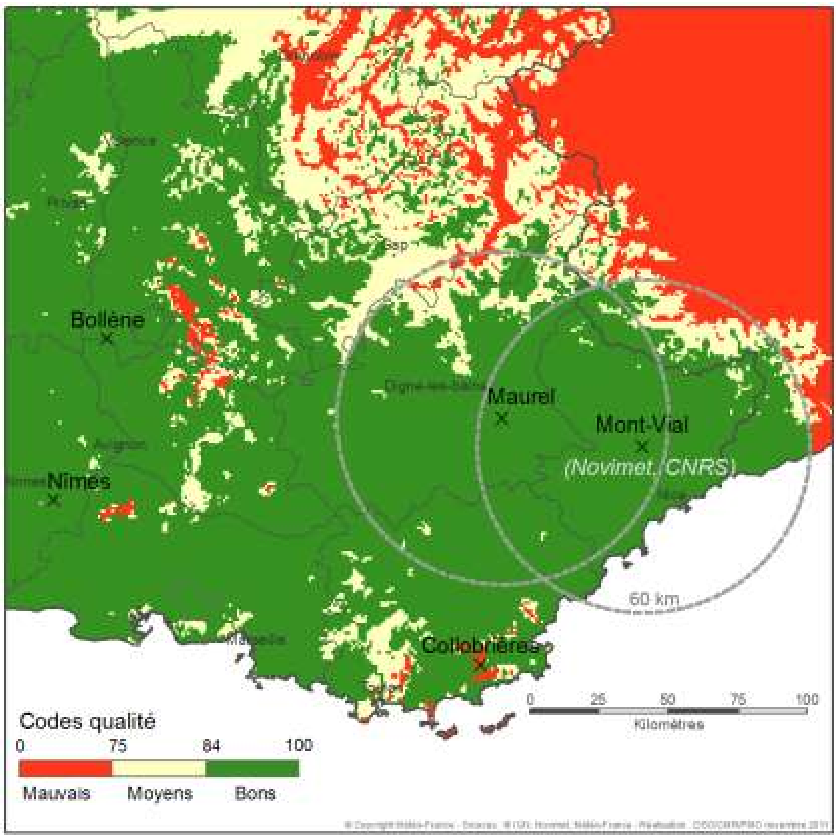
Almost same beam width

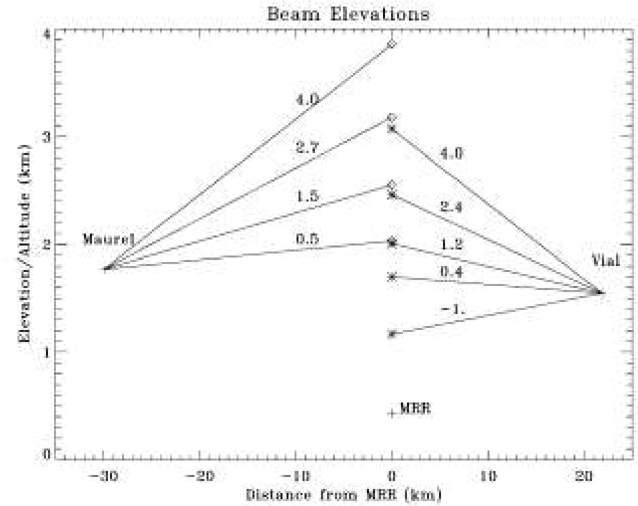
Black areas stand for clutter-identified pixels

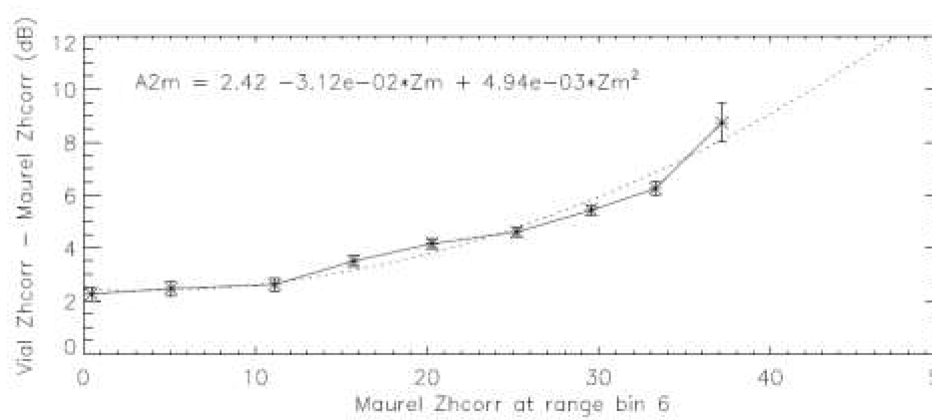
X

Wet radome attenuation

✓ Wet radome attenuation probably more important at X-band than at C-band







Courtesy of S. Frasier (UMass), currently on sabbatical at Météo France - Toulouse

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Wet radome attenuation

✓ Wet radome attenuation probably more important at X-band than

Mitigation measures

No radome (viable in elevated terrain during winter time ?)

Use of (magic) KDP (does not alleviate the loss of detection capability)

Use of an empirical correction curve (what about azimuth-dependent biases due to water loading on the downwind side ?)

Use of noise measurements to infer the radome-induced attenuation (how to disentangle wet-radome & precipitation induced attenuation ?)

0 10 20 30 40 50

Maurel Zhcorr at range bin 6

Courtesy of S. Frasier (UMass), currently on sabbatical at Météo France - Toulouse

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Attenuation

✓ Attenuation much more important at X-band than at C and even more S-band.
✓ Extinction ?

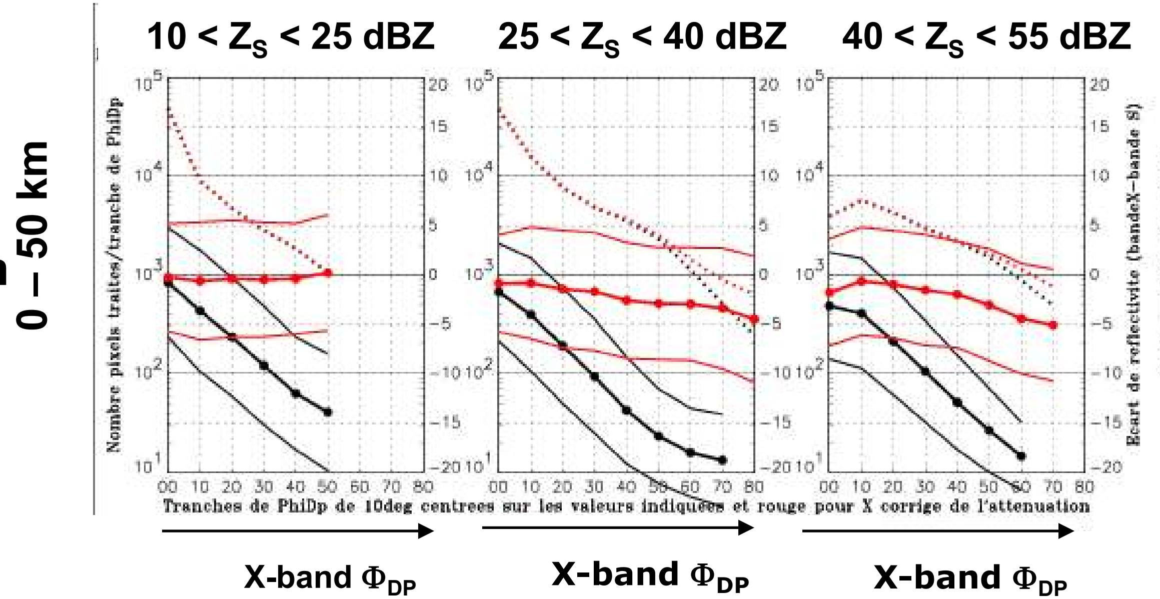
FRAMEA Project

Co-located X / S band radars in Toulon (SE France)

Same elevation angle

Same measurement times

15 Septembre 2006



Linear correction does a decent job: $Z_H$corrected = $Z_H + \gamma_H \cdot \Phi_{DP}$

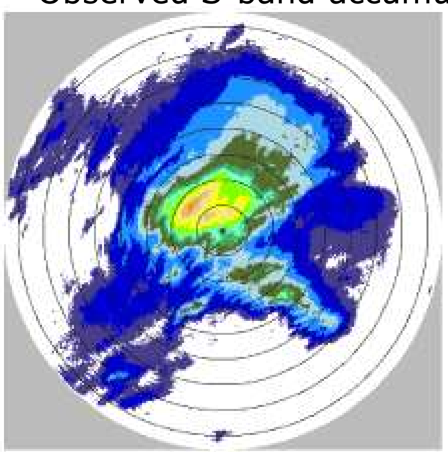
with γ_H = 0.28 dB / degree

Simulation of attenuation & extinction at X-band

✓ Attenuation much more important at X-band than at C and even more S-band.

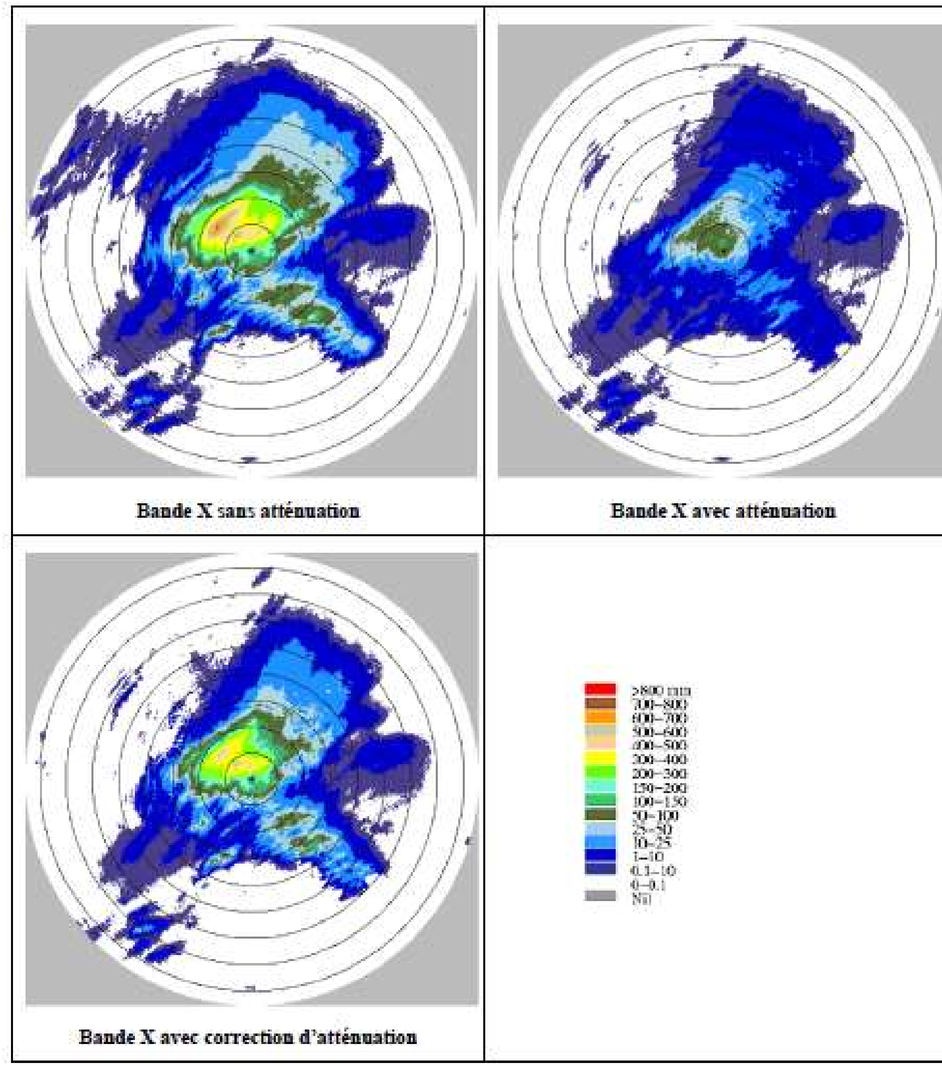
✓ Extinction ?

Observed S-band accumulation



Simulated X-band accumulation assuming **perfect attenuation correction for pixels above noise level.** Pixels at noise level are lost.

Simulated X-band accumulation without (left) and with (right) attenuation

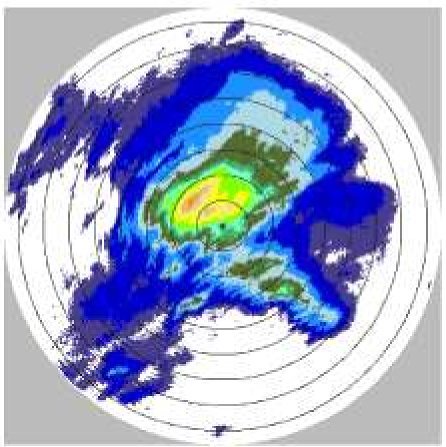


Simulations of X-band measurements, attenuation and extinction from S-band data on the Gard 2002 case (8 – 9 September 2020, > 600 mm of rainfall accumulation)

Simulation of attenuation & extinction at X-band

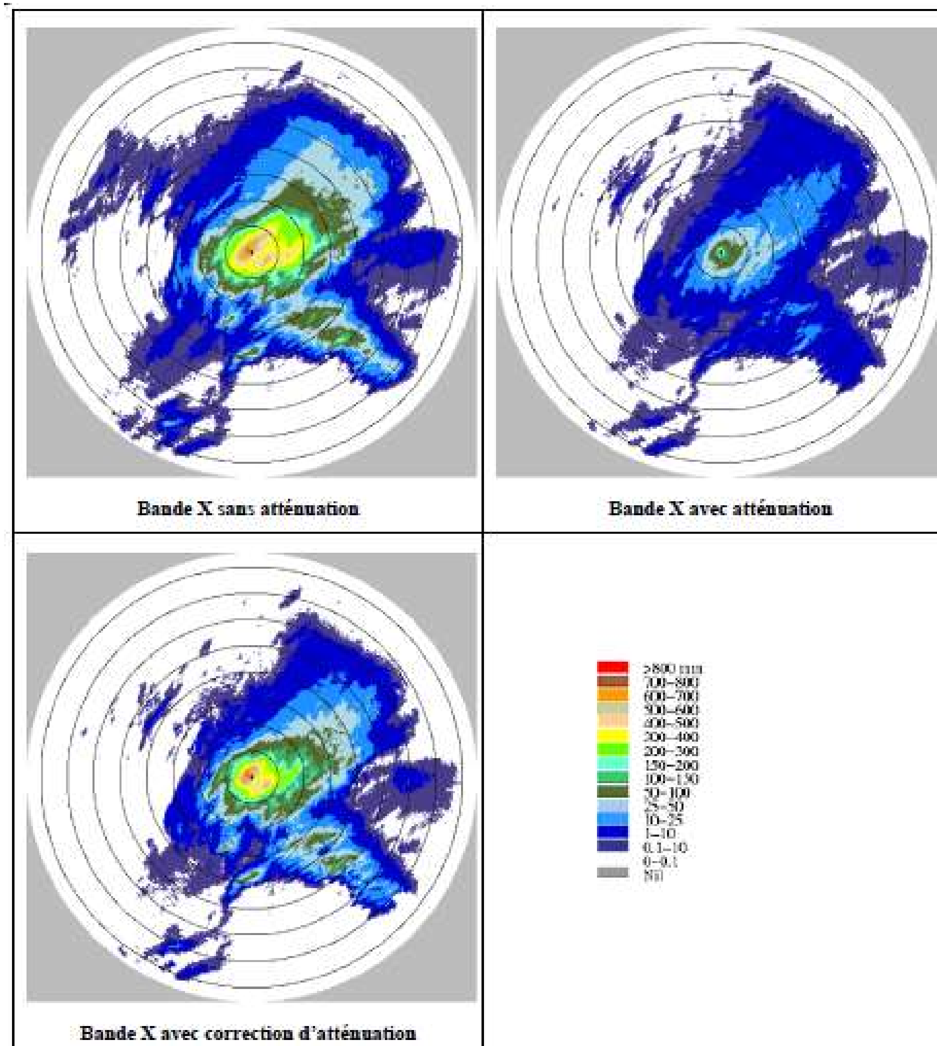
✓ Attenuation much more important at X-band than at C and even more S-band.
✓ Extinction ?

Observed S-band accumulation



Simulated X-band accumulation assuming **perfect attenuation correction for pixels above noise level.** Pixels at noise level are lost.

Simulated X-band accumulation without (left) and with (right) attenuation



Simulations of X-band measurements, attenuation and extinction from S-band data on the Gard 2002 case (8 – 9 September 2020, > 600 mm of rainfall accumulation in 48 h !)

Benefits of polarimetry for rain rate estimation at S, C & X-band

✓ (magic) K_{DP} usable at lower rain rates at X-band compared to C-band (and even more compared to S-band)

✓ **Next slide**:

✓ Respective performance at S, C & X-band of three estimators :

✓ CONV = Z-R (Marshall-Palmer) & RG adjustment
✓ DBP1 = Z-R (Marshall-Palmer) with att. correction & RG adjustment
✓ DPB2 = DBP1 + high rain rates estimated using K_{DP}

✓ Evaluation is done against (independent) gauges at hourly time step over a significant number of (Summer) events at distances < 60 km. High freezing level height – no bright band problems.

✓ **Warning**: The X – C – S band radars are not co-located and did observe the same events !

✓ **Warning 2**: Conclusions are function of the chosen polarimetric estimator. Here we decided not to consider Z_{DR} (because stability / calibration is challenging in operations)

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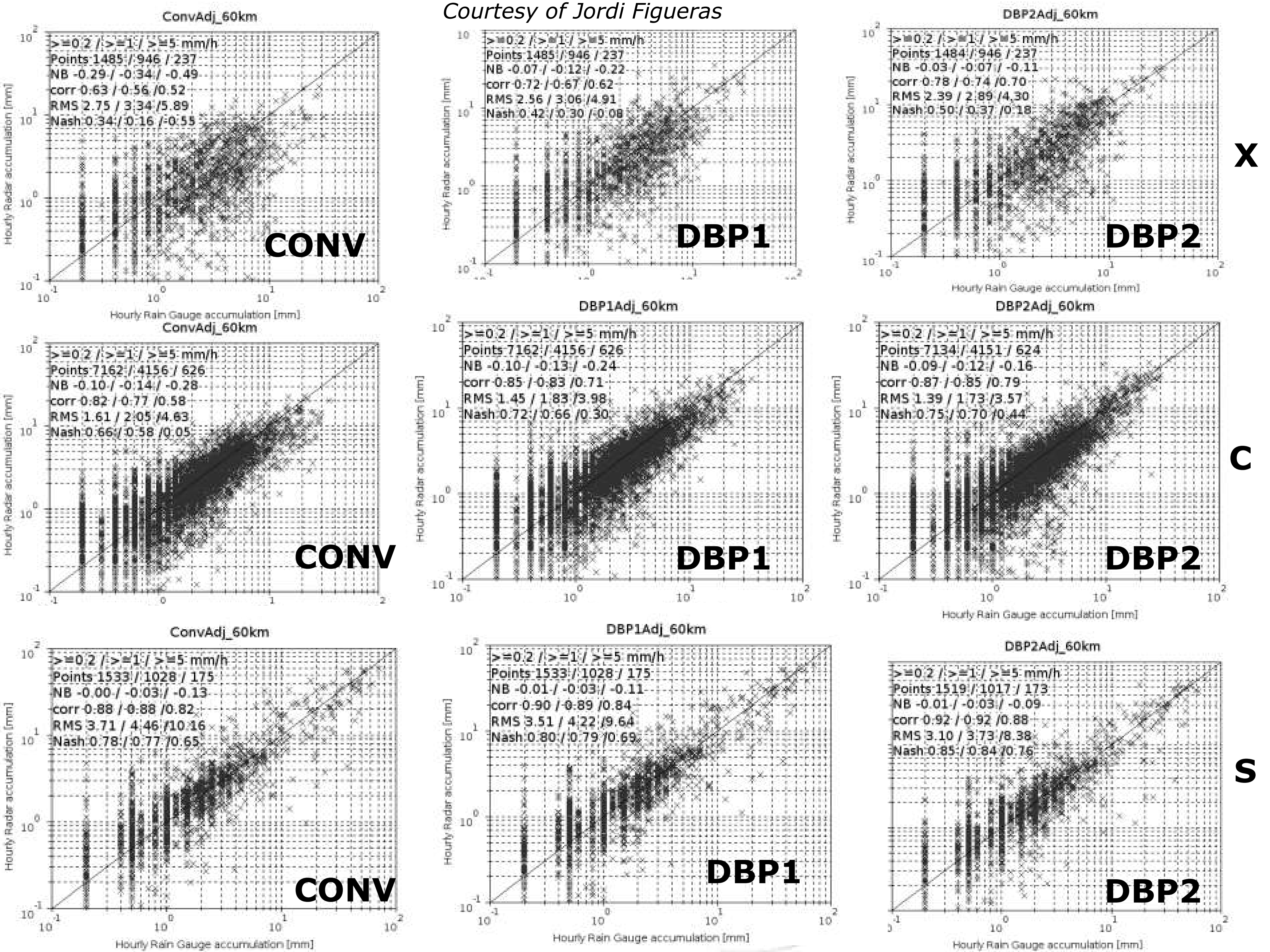
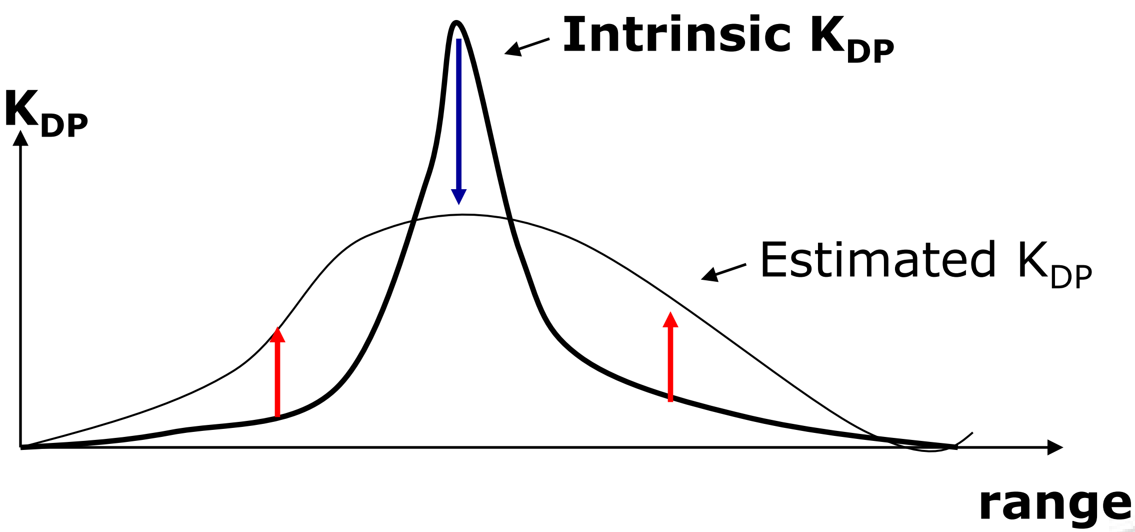


Courtesy of Jordi Figueras

Benefits of polarimetry for rain rate estimation at S, C & X-band

- K_{DP} looks very promising for rain rate estimation according to hourly radar – rain gauge comparisons; even more attractive at X-band where the quality of Z_H (and even more Z_{DR}) is diminished by attenuation.

- K_{DP} is estimated from (noisy) Φ_{DP} using a running 24-gates median filter. Spatial representativity = 6 km
  - ⇒ Might be a problem for estimation at high spatial resolution
  - ⇒ Oversampling ? Downscaling of K_{DP} using Z_H small-scale variability ?



Note : backscatter differential phase (δ): another potential problem at X-band ?

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Topic#3 Integration of X-band, C-band and rain gauge measurements : methods and experiences

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Radar – radar mosaicking

- Rules for mosaicking radar QPE should take into account :

Done currently operationally at MF

- Height above ground of radar measurement
- Amount of PBB (case of Z_H-based estimator)

- Amount of attenuation (based on ϕ_{DP} or HB ?). Very important at X-band !
- Type of estimator: Z_H-based ? K_{DP} based ?
- Type of hydrometeor (wet snow ? Rain ? Hail ?)
- Detection threshold (pixels at noise level should not be implicitly interpreted as 0 mm h^{-1}). Very important at X-band !

To be done in the future. Very important to gracefully mosaick X-band QPE with C or S-band QPE

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Radar – radar mosaicking

- **Current compositing rule (see Tabary 2007 and Tabary et al. 2007, Weather & Forecasting):**

$$R = \sum \omega_i Ri / \sum \omega i$$
$$\omega = (1-T^{MSK}/100) * \exp[-(h-h_{terrain}) / h_0]$$

- **The future (?):**

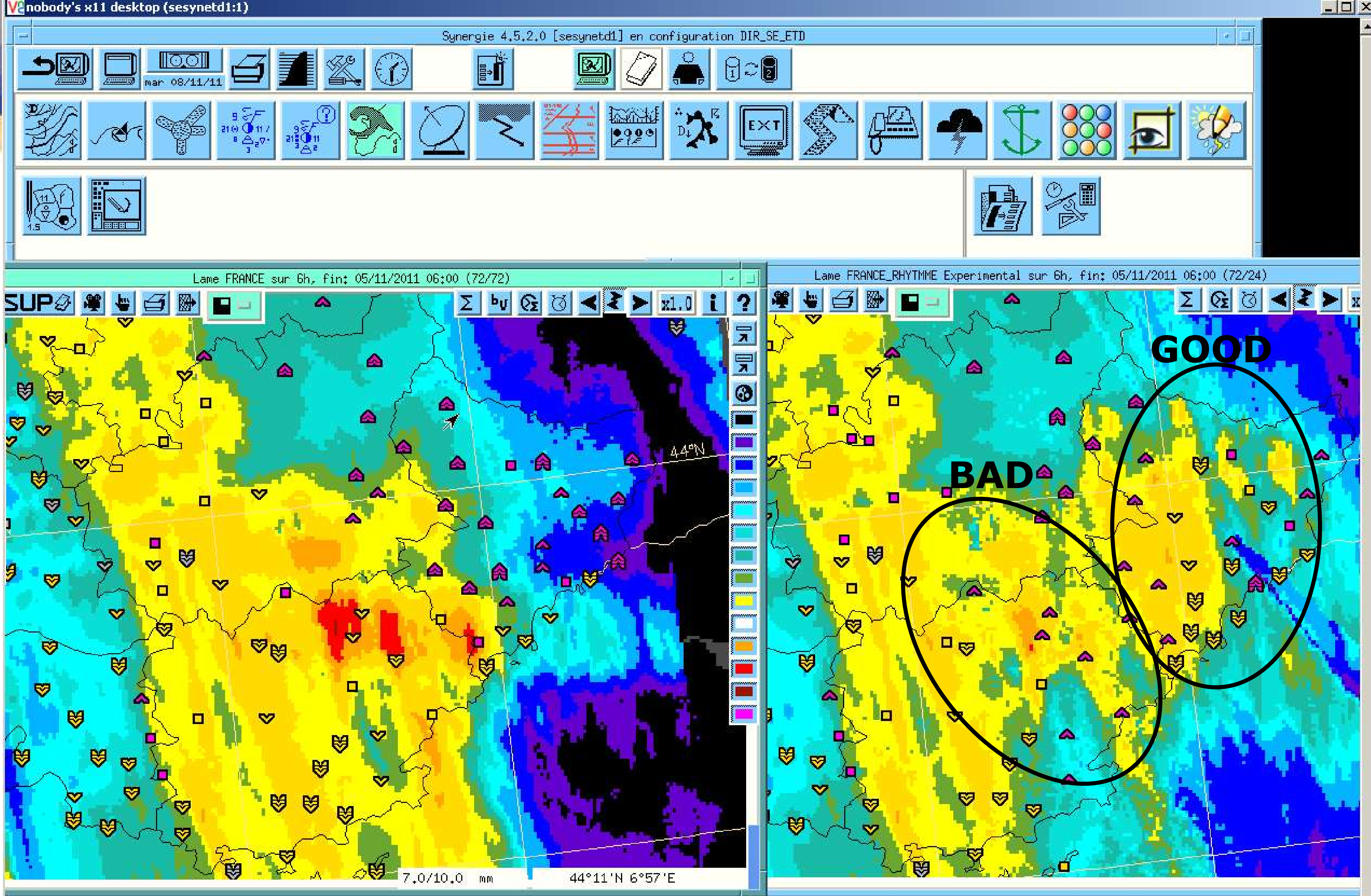
$$R = \sum \omega i Ri / \sum \omega i$$

$$\omega = (1-T^{MSK}/100) * \exp[-(h-h_{terrain}) / h0]$$
$$*F(PIA)*G(\text{type of estimator})*H(\text{type of hydrometeor}),$$
in case of Z_H-based estimator

$$\omega = \exp[-(h-h_{terrain}) / h_0]$$
$$*G(\text{type of estimator})*H(\text{type of hydrometeor}),$$
in case of K_{DP}-based estimator

+ Need to produce detection thresholds maps!

Comment 1: formula above are very empirical .. Can we do better ?
Comment 2 : Are the above formula applicable to non dual-pol radars ?



French operational national QPE – 6 h accumulation – Area (SE France) is covered with conventional S-band radars

French operational national QPE with integration of X-band QPE <u>WITH BASIC COMPOSITING RULES</u>– 6 h accumulation

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Topic#4 Fine-scale rainfall estimation: recommendations and guidelines

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Dear Pierre,

Thanks for your quick reaction and suggestions/questions for clarification!

Let me first clarify that the final aim of the RainGain project is to obtain good quality fine-scale rainfall estimates (about 100 meter space scale; about 5-10 minutes time scale) that can serve urban drainage impact modeling. So, we have to keep this in mind for all topics. The idea of the workshop is to bring current knowledge together + organize interfacing of knowledge between meteorologists and urban hydrologists, in order to come up with practical recommendations/guidelines. The focus of the workshop is limited to rainfall estimation (for historical periods) and does not cover real-time forecasting or integration with numerical weather prediction. The latter topic will be for a next workshop!

I propose the following subtopics:

Topic 1: X-band and C-band radar calibration : methods and experiences
calibration of reflectivity, differential reflectivity, differential phase, … single vs. dual polarization
adjustment to rain gauges: useful? methods? experiences?
monitoring/maintenance of the radar system (e.g. routine checks of radar parameters & variables)

Topic 2: X-band versus C-band performance : experiences
2.1 limitations/differences of X-band and C-band radars in rain rate estimation performance: influence of attenuation, clutter, maximum effective range, detection capability, stability, …
2.2 accuracy estimation of rain rate estimation (e.g. taking rain gauge observations as reference?) methods? typical results?

Topic 3: Integration of X-band, C-band and rain gauge measurements : methods and experiences
: methods to merge different rainfall products from different sources (X-band, C-band and rain gauges) to come to a most reliable fine-scale rainfall estimate for urban drainage applications
3.1 mosaicking radars of different wavelengths, with focus on nesting Xpol in Cpol
3.2 radar - rain gauge merging

Topic 4: Fine-scale rainfall estimation : recommendations and guidelines
: here we will formulate general conclusions, based on the outcomes from the discussions on topics 1, 2 and 3. I will prepare an outline with main recommendations during the workshop, to be agreed on at the end of the workshop, which will be used as starting basis to write a guidelines publication after the workshop.

Please do not hesitate to contact me if you have further questions or suggestions reg. the topics or programme! It is good to clarify on beforehand such that we can have a fruitful workshop. Although time is indeed very limited, the main aim of the workshop is to have first discussions and consensus. Details of methods can be further specified while writing the guidelines afterwards.