Next Generation Operational Met Office Weather Radars and Products

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Part I :
Infrastructure

The European radar network

Currently (EUMETNET/OPERA Database) :

192 radars :
159 C, 32 S, 1 X
187 Doppler
30 dual-pol

A European Data Centre currently under development

We still need ≈ 10 years to arrive at the same level of coordination as in the US

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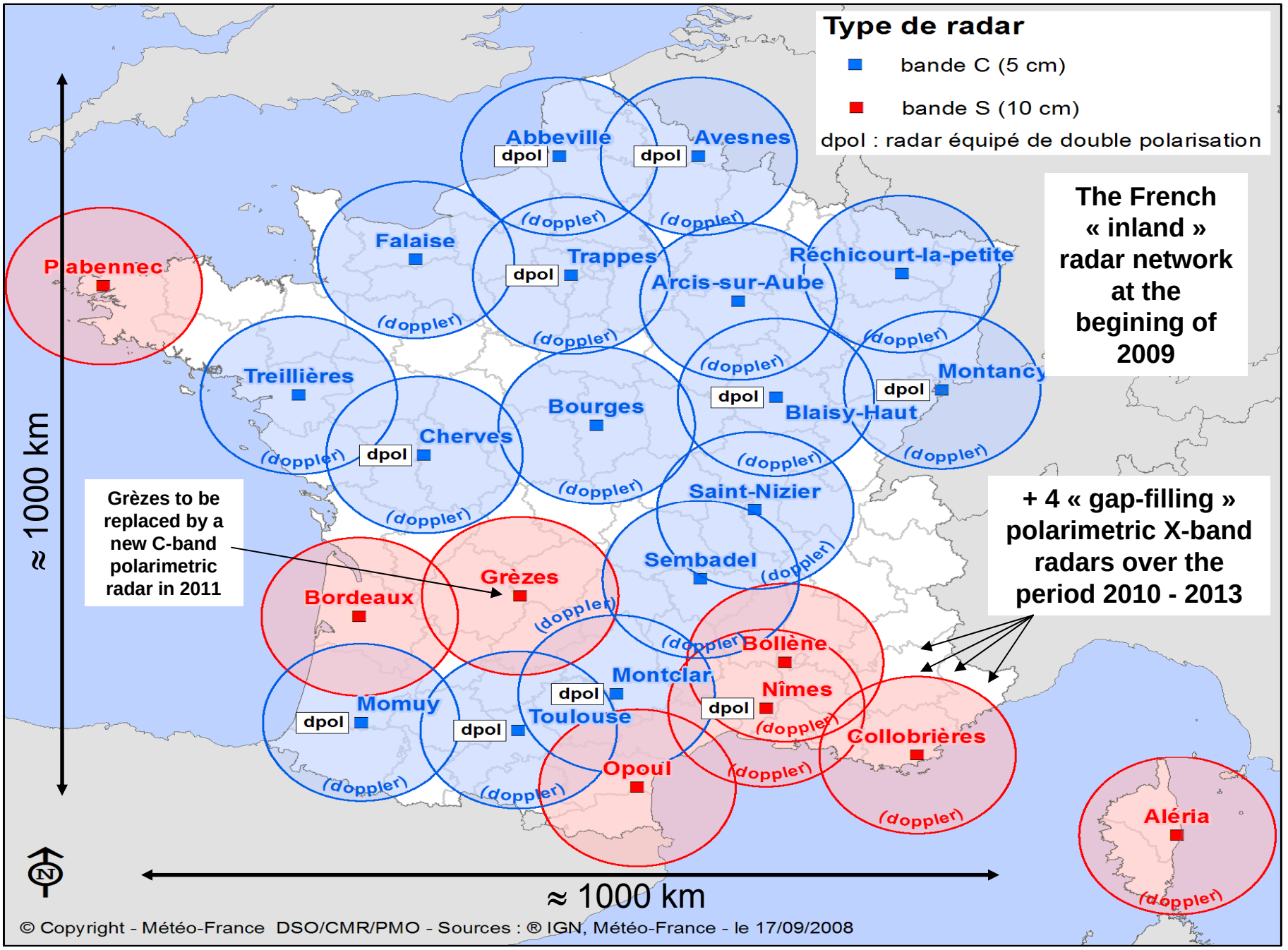
Type de radar
bande C (5 cm)
bande S (10 cm)
dpol : radar équipé de double polarisation
The French « inland » radar network at the begining of 2009
+ 4 « gap-filling » polarimetric X-band radars over the period 2010 - 2013
Grèzes to be replaced by a new C-band polarimetric radar in 2011
Abbeville
Avesnes
Falaise
Trappes
Réchicourt-la-petite
Arcis-sur-Aube
Pabennec
Treillières
Montancy
Blaisy-Haut
Bourges
Cherves
Saint-Nizier
Sembadel
Grèzes
Bordeaux
Bollène
Nîmes
Montclar
Momuy
Toulouse
Collobrières
Opoul
Aléria
dpol
(doppler)
≈ 1000 km
≈ 1000 km
N
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0 50 100 200 300 400 500 Kilomètres

- **Currently : 24 magnetron-equipped weather radars covering about 90 % of the French territory (≈ 1000 x 1000 km²).**

- **A "composite" network of radars having :**
  - ✓ **different wavelengths (16 C, 8S, soon 4X),**
  - ✓ **different ages (between ≈ 20 and 1 y.o.),**
  - ✓ **different manufacturers (THALES / SELEX / …),**
  - ✓ **different scanning strategies.**

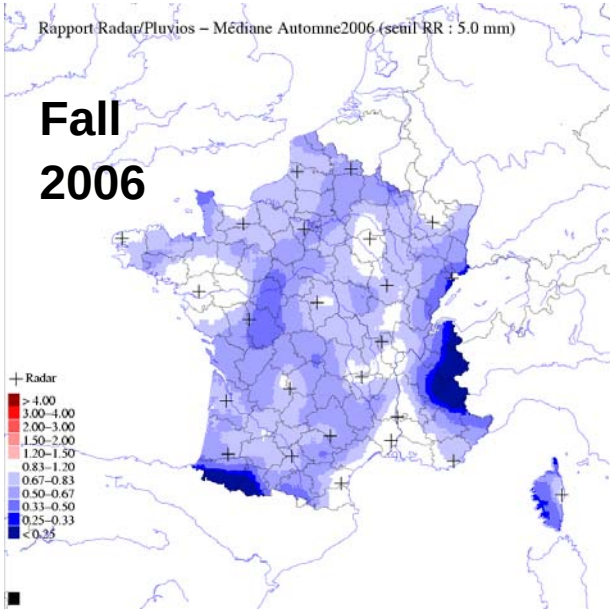
Yet all radars are equipped with the same "home-made" radar processor (named CASTOR2), which guarantees homogeneity of the products

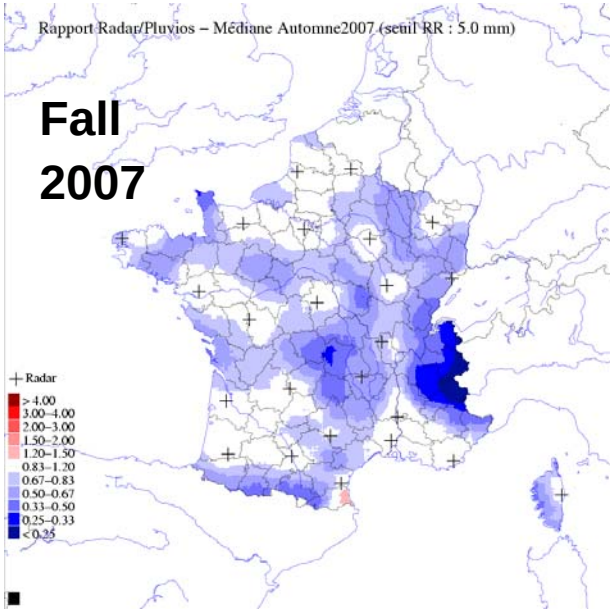
Design, evolution and operations of the network essentially driven, so far, by hydrological applications

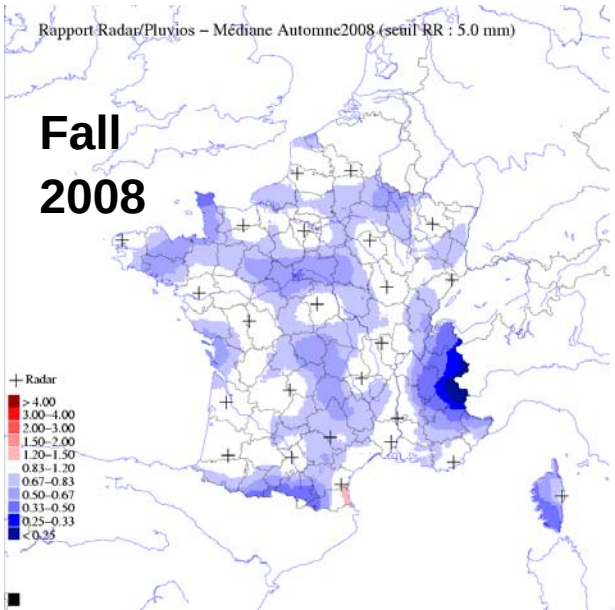
Maps of median daily radar / rain gauge ratio

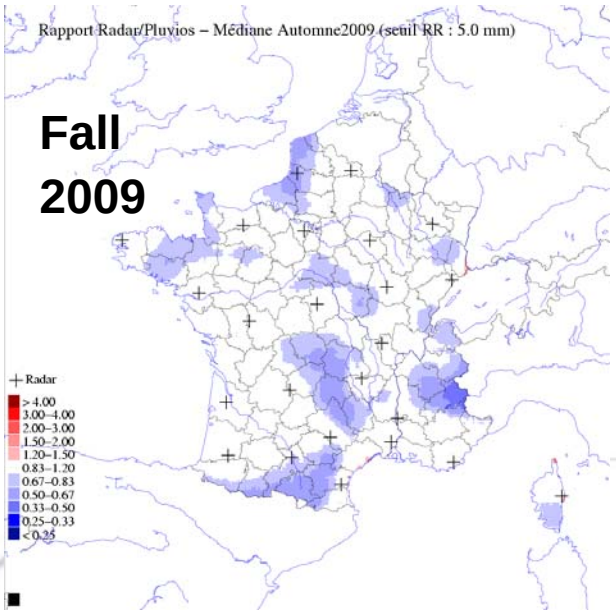
Daily Rain Gauge Accumulation > 5 mm

- > 4.00
- 3.00–4.00
- 2.00–3.00
- 1.50–2.00
- 1.20–1.50
- 0.83–1.20
- 0.67–0.83
- 0.50–0.67
- 0.33–0.50
- 0.25–0.33
- < 0.25









❑ **The VCP (Volume Coverage Patterns) of the radars are not uniform and are adapted according to the surrounding topography and the mechanical scanning capabilities.**

❑ **At best, radars perform ≈ 13 independent elevation angles every 15 minutes, with the 3 – 4 lower tilts being revisited every 5 minutes to generate 5' products (such as QPE).**

❑ **All radars are Doppler and equipped with a staggered triple-PRT (Pulse Repetition Time) scheme that solves the range – folding dilemma and provides radial velocity with no ambiguity up to long ranges (≈ 250 km).**

Tabary, P., F. Guibert, L. Périer and J. Parent-du-Chatelet, 2006 : An operational triple-PRT Doppler scheme for the French radar network, *J. Atmos. Oceanic Technol.*,, 23, No 12, 1645-1656.

The Doppler upgrade

- **In 2002 : Only one Doppler radar in the network !**
  France : last dinosaur in Europe ?

- **Beginning of 2008 : 15 Doppler radars;**

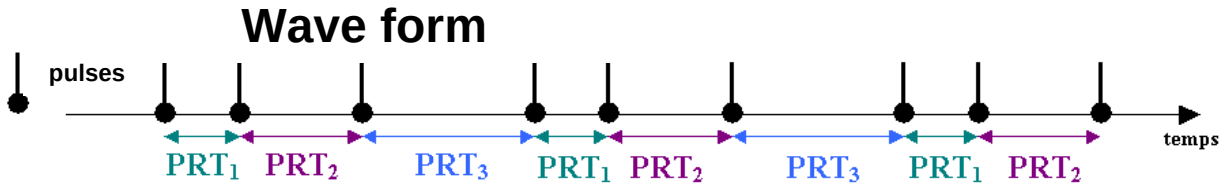
- **2010 : 24 Doppler radars;**

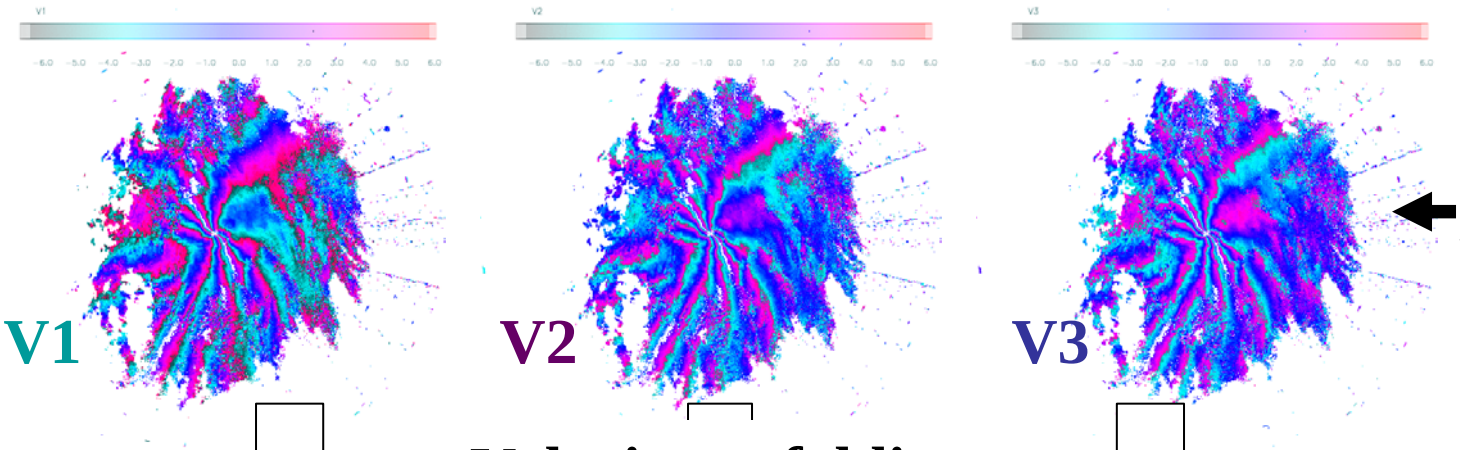
The upgrade was strongly supported by the NWP community

Radars = A strategic data source for regional, high-resolution models (AROME at the French level).

→ Reflectivity (Z_H) and radial velocity (V_R) data are currently assimilated operationally in AROME

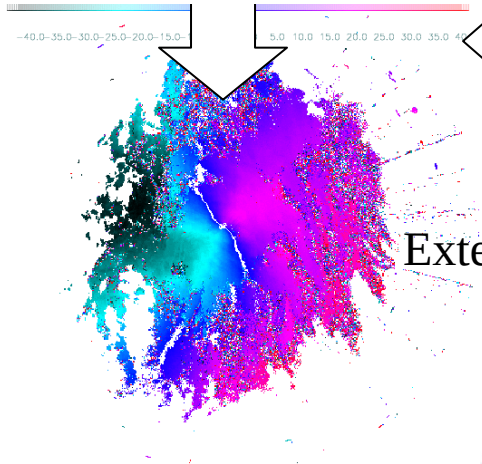
The triple PRT (Pulse Repetition Time) technique





Folded velocities [Nyquist velocity : ≈ 5 m s^{-1}]

Velocity unfolding



Unfolded velocity
Extended Nyquist velocity : ≈ 60 m s^{-1}

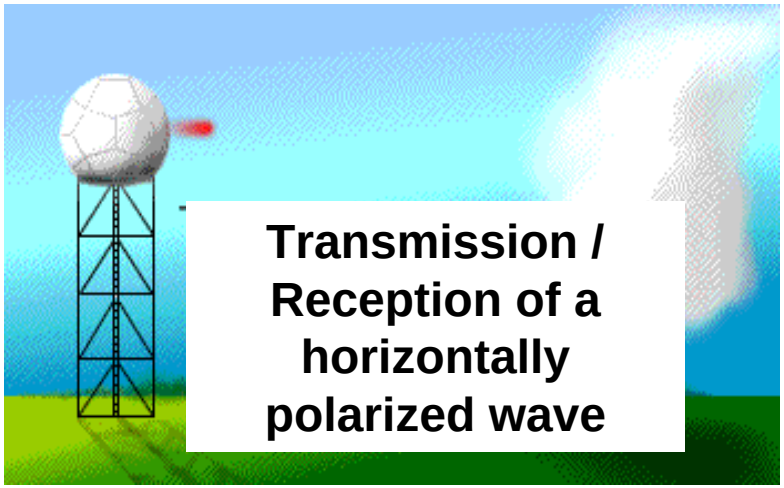
Current (low) PRFs on C-band radars : 379 Hz, 325 (6/7) and 403 Hz (4/5)

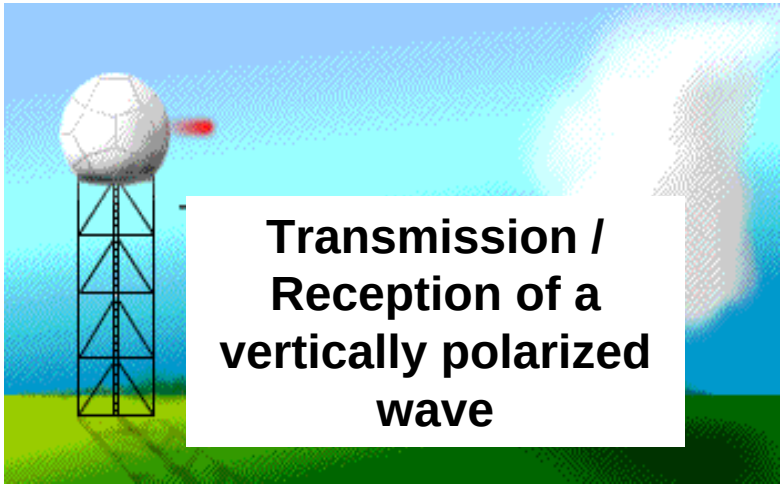
Tabary, P., F. Guibert, L. Périer and J. Parent-du-Chatelet, 2006 : An operational triple-PRT Doppler scheme for the French radar network, *J. Atmos. Oceanic Technol.*,, 23, No 12, 1645-1656.

The polarimetric upgrade

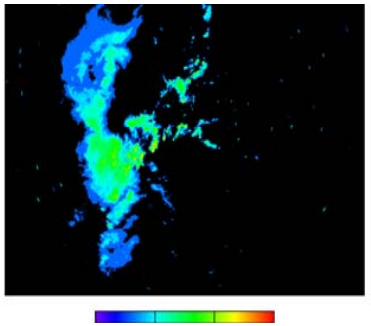
Polarimetric radar

Conventional radar

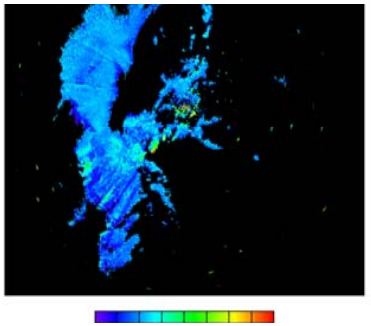




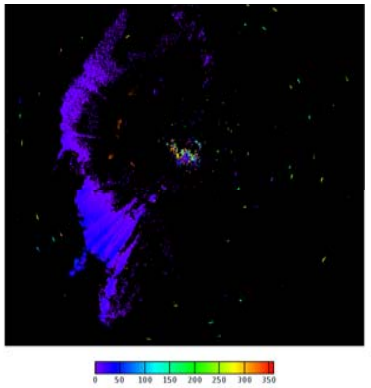
Horizontal reflectivity Z_H (dBZ)



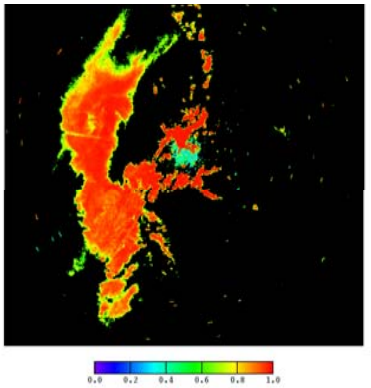
Differential reflectivity $Z_{DR} = Z_H - Z_V$ (dB)



Differential phase Φ_{DP}(°)



Correlation coefficient ρ_{HV}(0)



French C-band Trappes radar

1.5° elevation angle - 18 August 2004 - 12.00 → 13.45 UTC

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The polarimetric upgrade

- **The network currently comprises 10 polarimetric radars (9 C, 1S, simultaneous H & V transmit & receive)**

- **All of them were manufactured by SELEX (GEMATRONIK). Digitized I and Q data are fed into the CASTOR2 radars processor, which computes all polarimetric and Doppler moments.**

- **4 more X-band polarimetric SELEX systems (with transmitters and receivers mounted on the antenna) to be deployed over the period 2010 – 2013.**

- **Polarimetry has become the new standard for operational weather radars.**

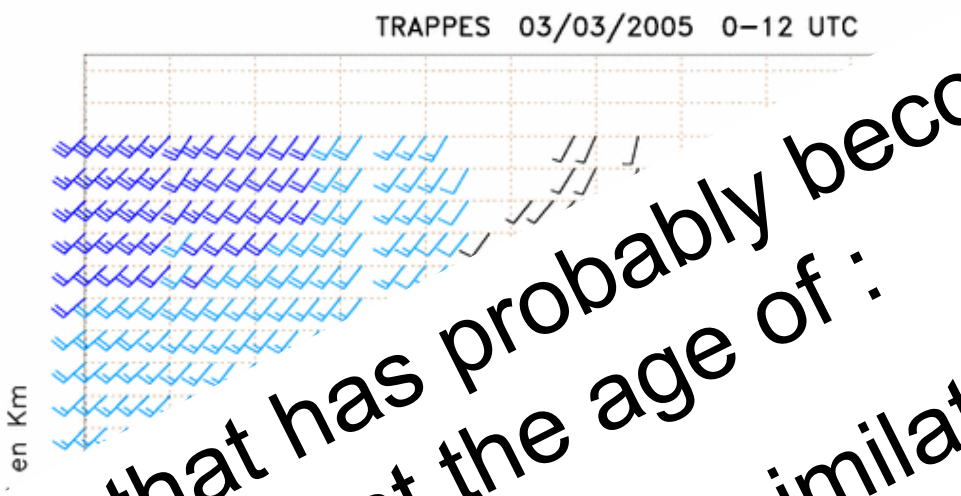
2004 : First polarimetric radar installed in Trappes

Part II :
Products

European radar networks are multi-purpose

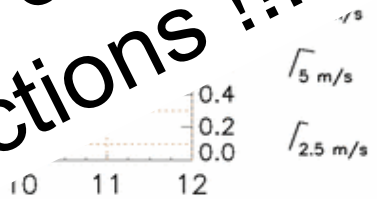
- ❑ 2D & 3D Mosaicks of Reflectivity and Derived parameters (Z_{MAX}, ECHOTOP, VIL, …) → Nowcasting (aviation-oriented …);
- ❑ Quantitative Precipitation Estimation (QPE) with uncertainties → Hydrology;
- ❑ 3D Hydrometeor Classifications (using polarimetry);
- ❑ Refractivity products → low-level moisture field;
- ❑ Doppler products;

Doppler products (1) : VAD Wind Prof



A product that has probably become obsolet at the age of :

- Radial velocities assimilation by NWP models and
- Multiple-Doppler 3D wind field reconstructions !!!



Wind
assum

ical of the radar
linear) in the vicinity
Wexler 1968)

Doppler products (2) : Specific Product for NWP

- **A collection of all PPIs of Z_H, V_R and echo type measured by each radar over 15 minutes.**

- **Input for data assimilation in NWP models. The impact on NWP forecast scores is positive !**

- **The echo types are currently : ground-clutter, clear-air, sea clutter, noise, sunrise / sunset and precipitation.**

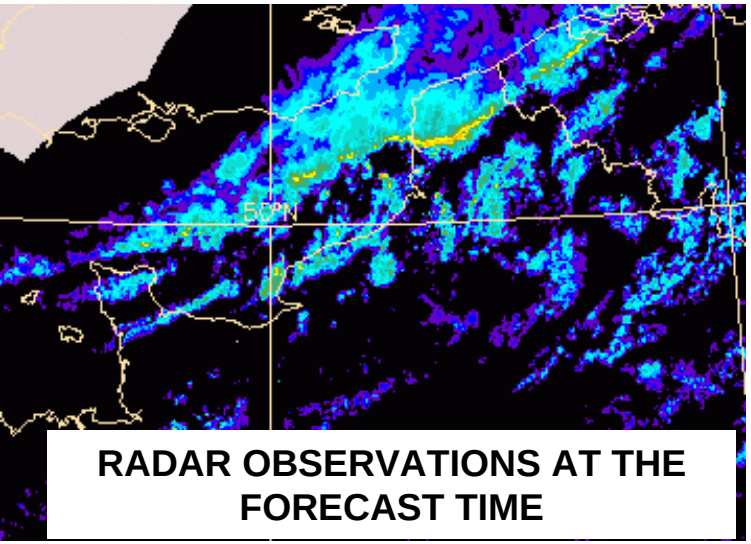
- **Next step (with dual-pol) : document the precipitation type (rain / hail / snow / …) and distinguish between insects and birds.**

Impact of radial velocity assimilation in the French operational AROME model

8 November 2007

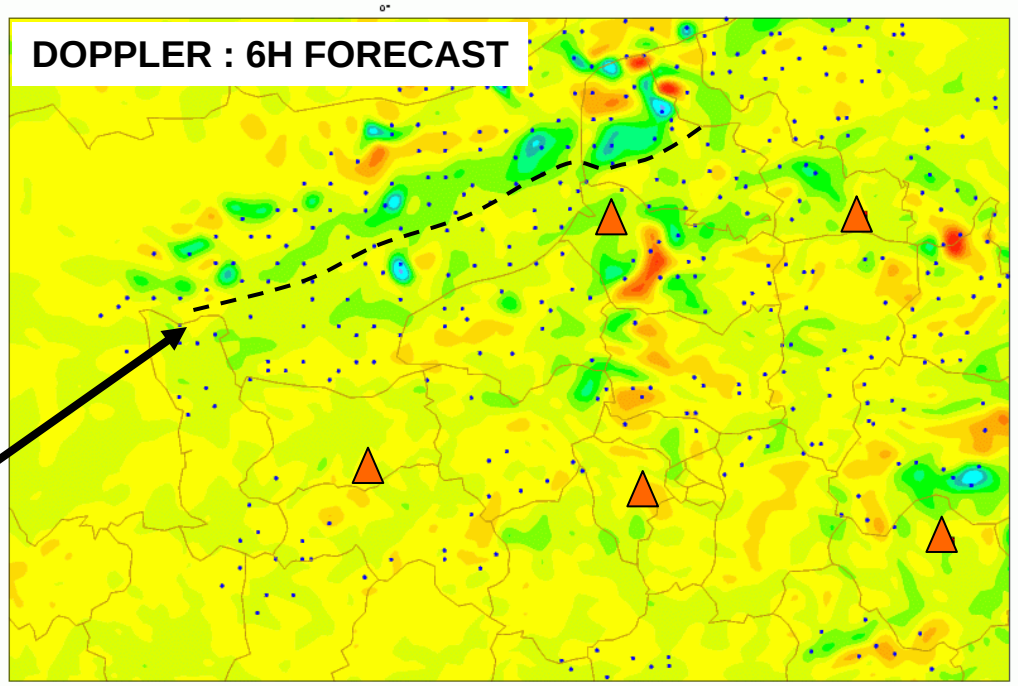
Analysis of the divergence field at 925 HPa

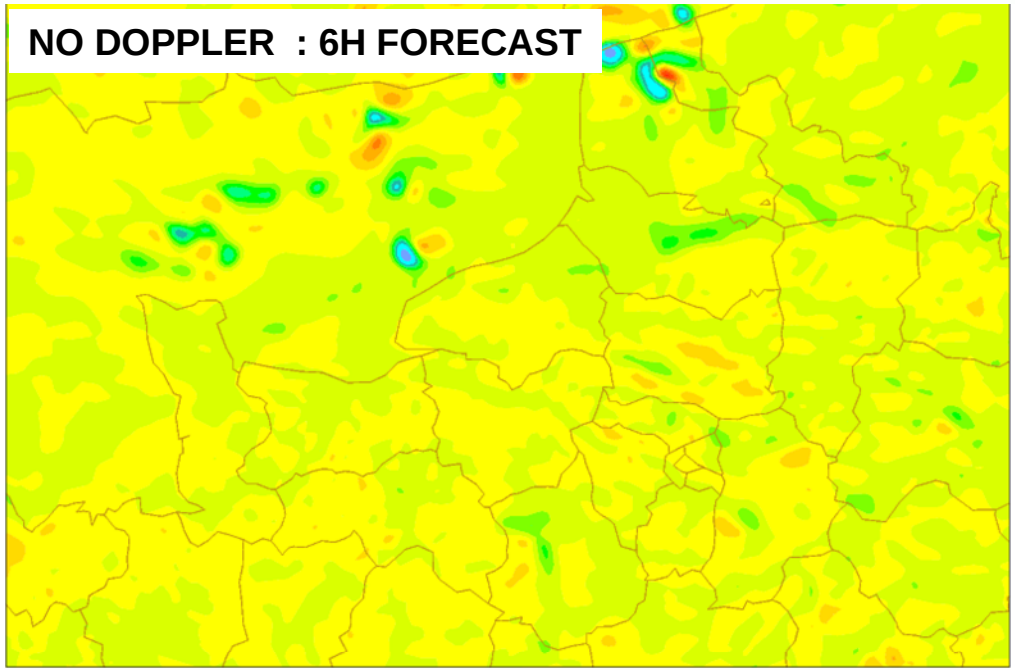
Convergence line is much better forecasted with radar data assimilation



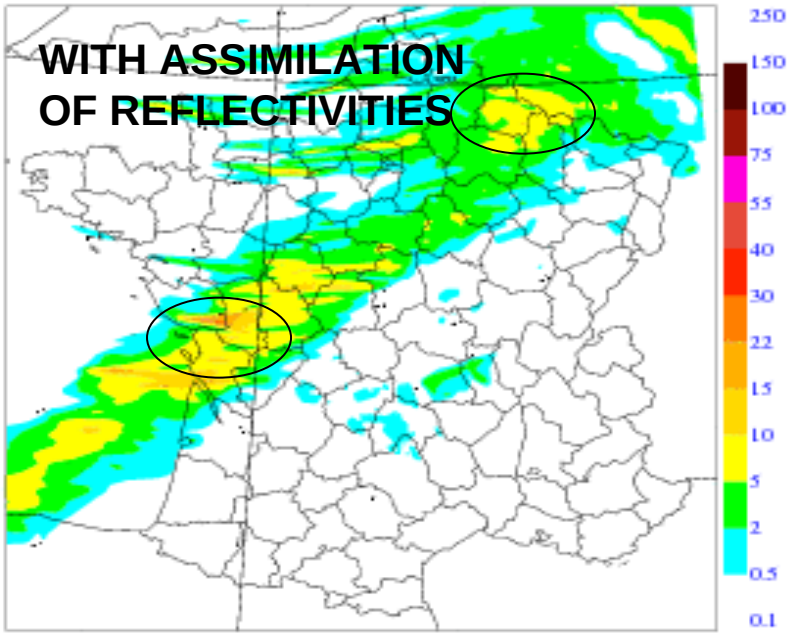
RADAR OBSERVATIONS AT THE FORECAST TIME

PARIS Analysis VT:Thursday 8 November 2007 18UTC 950hPa relative divergence

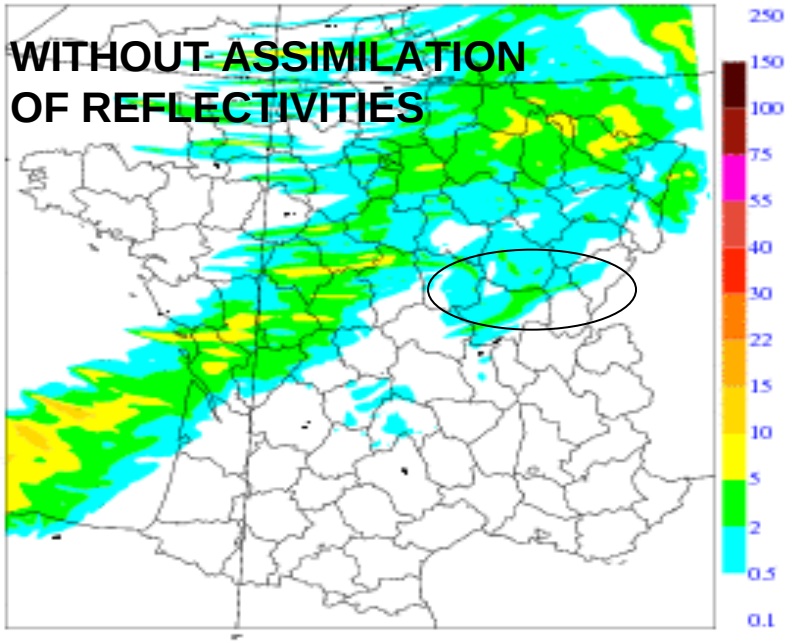




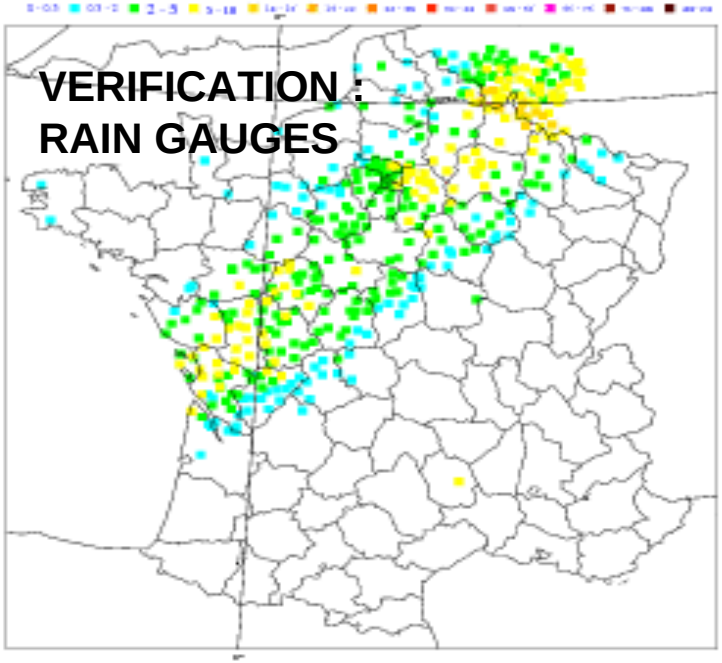
2007120103 73BL / RR P03-P00



2007120103 61Z7 / RR P03-P00

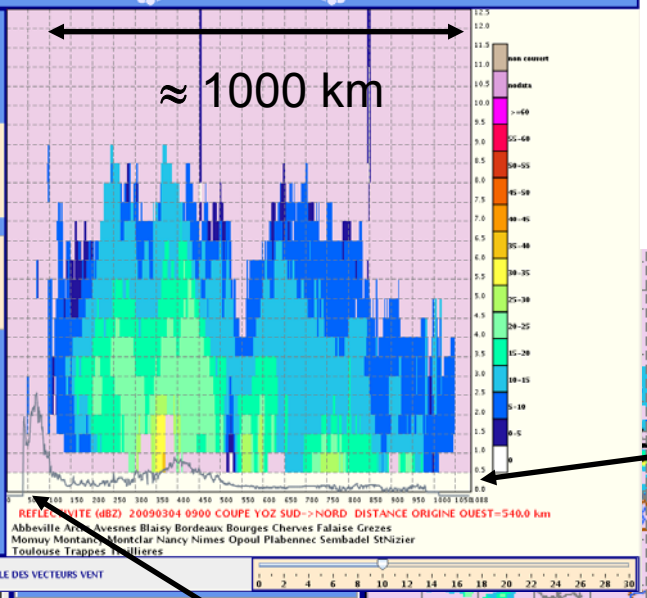


2007120103 Pluvio RR P03-P00



AROME forecasted 3h precipitation accumulation w and w/o radar reflectivity assimilation

Doppler products (3) : Operational, nation-wide, 2.5x2.5x0.5 km^3, 15' Multiple-Doppler 3D wind and reflectivity fields



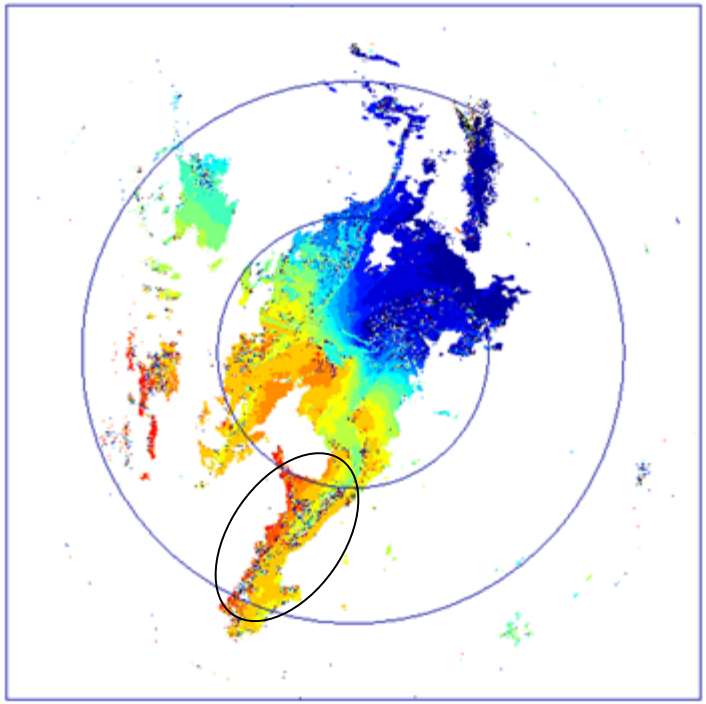
Bousquet, O., P. Tabary, and J. Parent du Châtelet, 2008 : Operational Multiple-Doppler Wind Retrieval Inferred from Long-Range Radial Velocity Measurements, *Journal of Applied Meteorology and Climatology* Volume 47, Issue 11 (November 2008) pp. 2929–2945

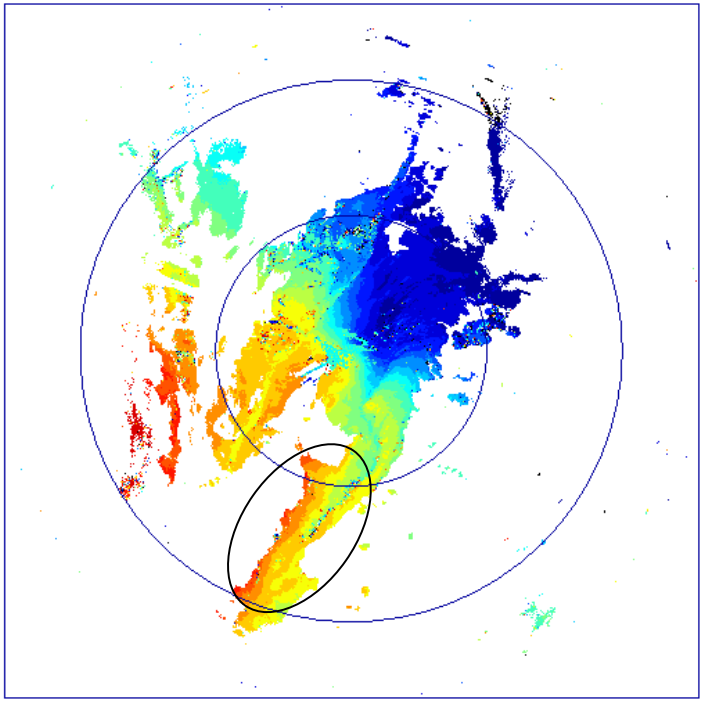
Roadmap on Doppler (2009 – 2012)

- ❑ **Improve the quality of radial velocities (by increasing the PRF)**
- ❑ **Develop WindShear and Turbulence mosaicks based on spectrum widths and V_R gradients (in range / azimuth)**
- ❑ **Extend 3D wind retrievals to the European scale;**
- ❑ **Develop high-resolution (< 1km², < 5') multi-Doppler products wherever radar density makes it possible (e.g. airports)**
- ❑ **Introduce spectral filtering techniques on staggered time series to recover weak signals (e.g. clear air and weak rain)**
- ❑ **Distinguish between insects from birds in clear-air data;**
- ❑ **Adapt Doppler schemes and products to X-band systems**
- ❑ **Increase the amount of Doppler data assimilated by the NWP model (AROME) by one order of magnitude;**

Increasing the PRF to improve Doppler measurements

Trappes (C) - Radial velocity PPI – 0.8° - 19 January 2009 – 15.00 UTC
High vs. Low PRFs [still using the staggered triple-PRT scheme]

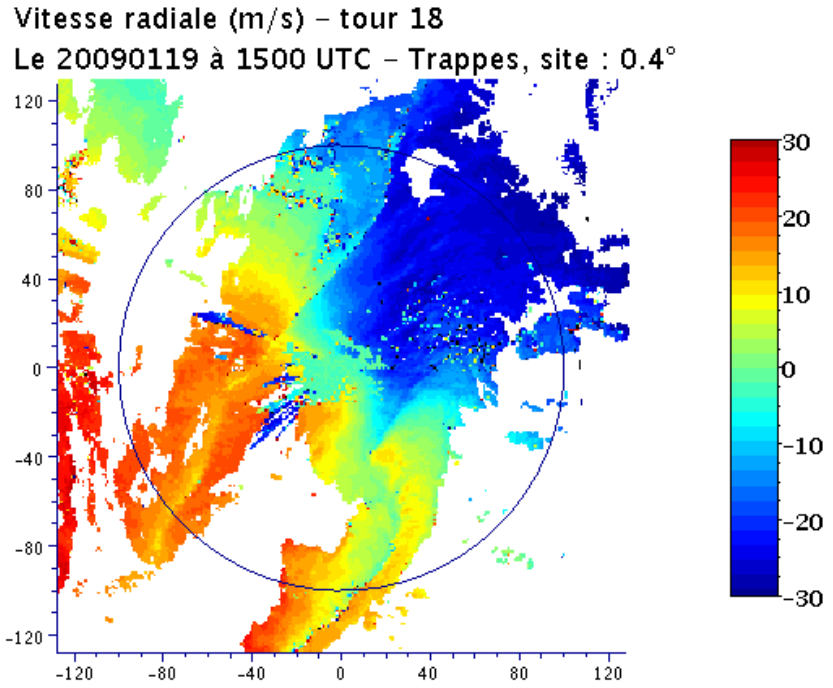


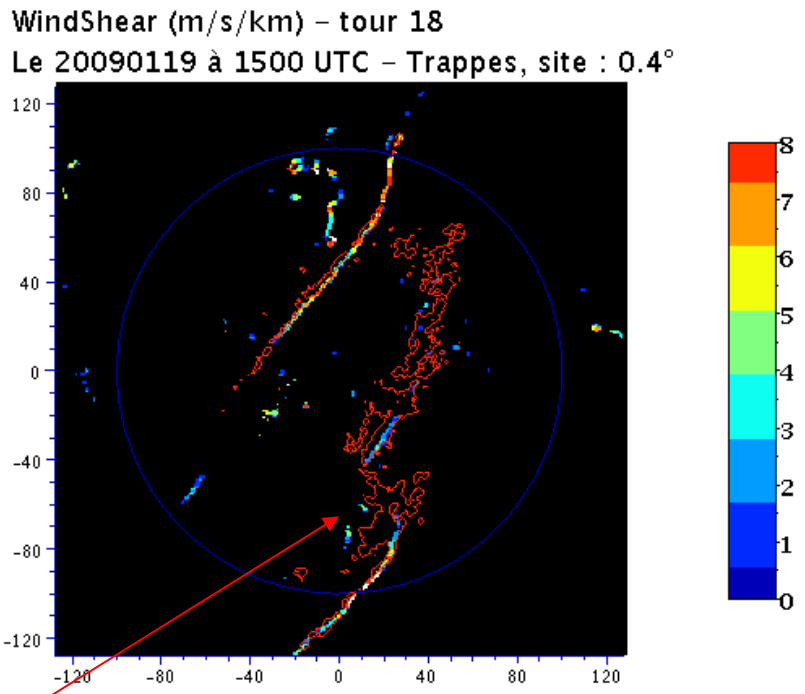


Low PRFs (Mean = 333 Hz) and V_{NE}=60 m/s
→ Error rate = 17 %

High PRF (Mean = 471 Hz) and V_{NE}=44 m/s
→ Error rate = 5 %

Summer of 2010 : Real-time Demo of a nation-wide low-level 5', 1 km² WindShear composite





In red : contours of Z_H > 35 dBZ

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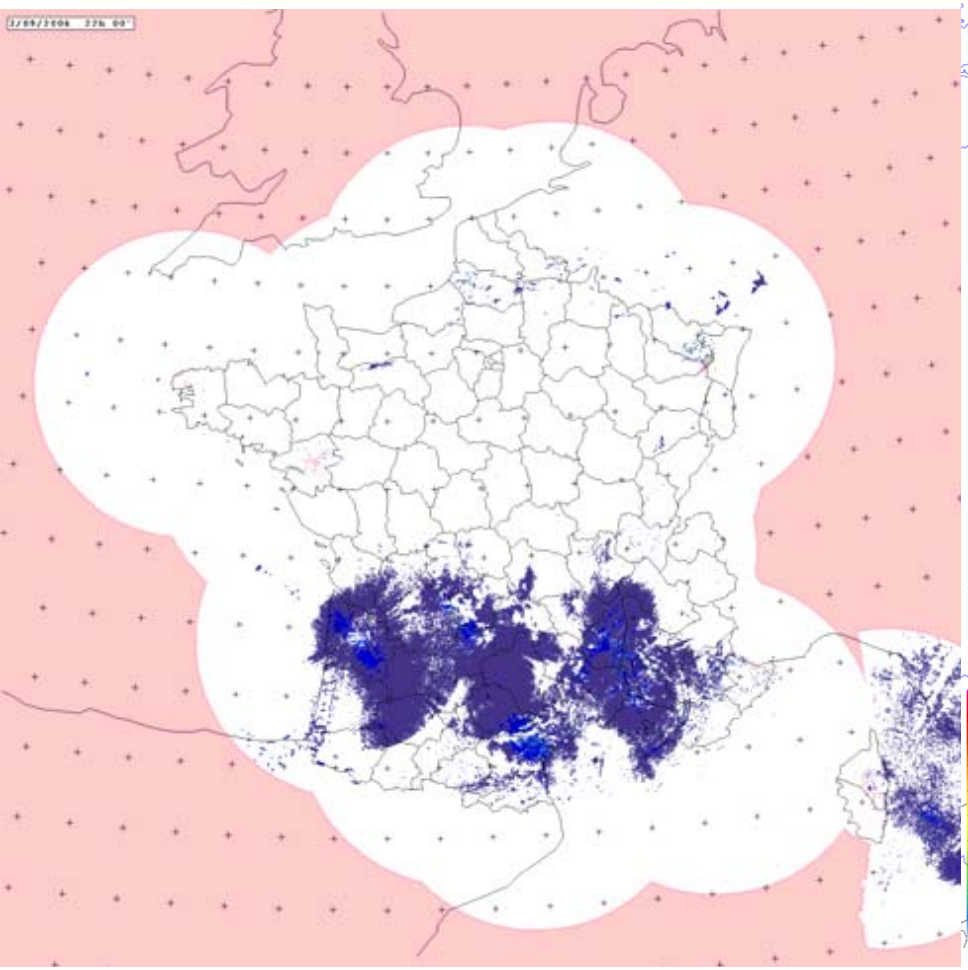
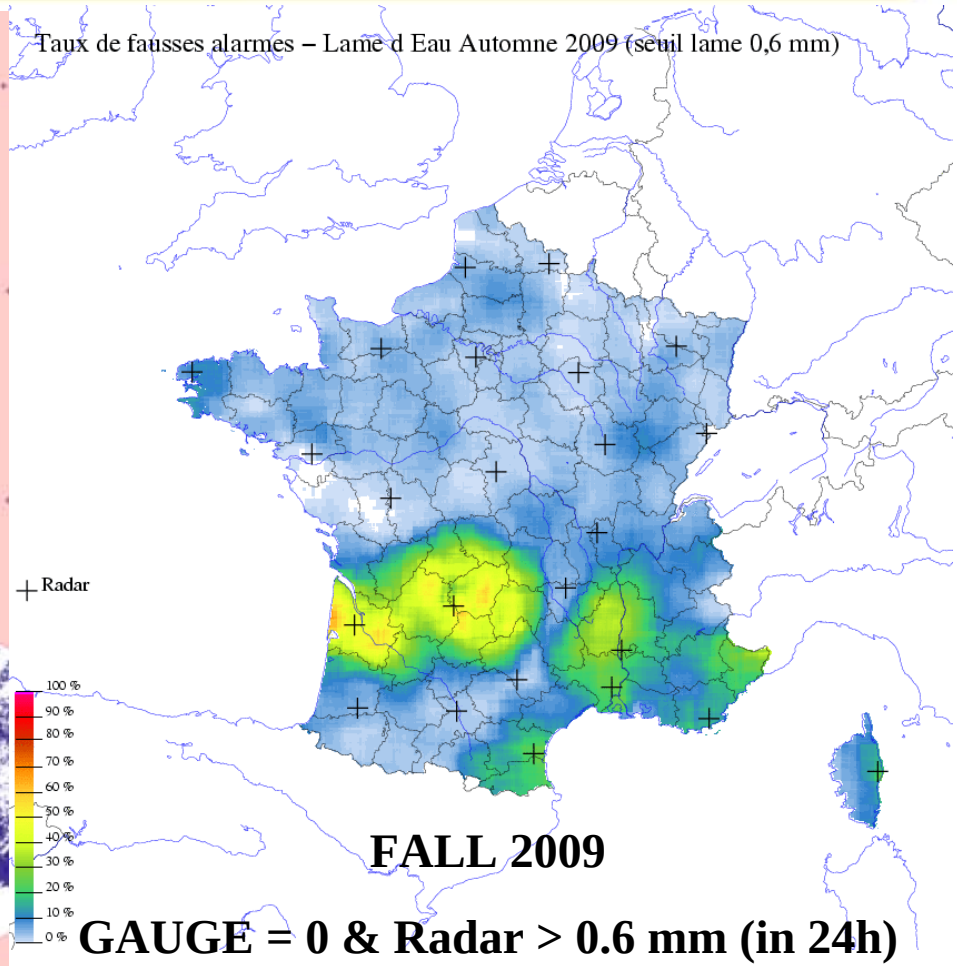
Clear-air measurements : some statistics …



A typical autumn night over France …

(3 September 2006 – 22.00 UTC)



FALL 2009

GAUGE = 0 & Radar > 0.6 mm (in 24h)

Bird Migration

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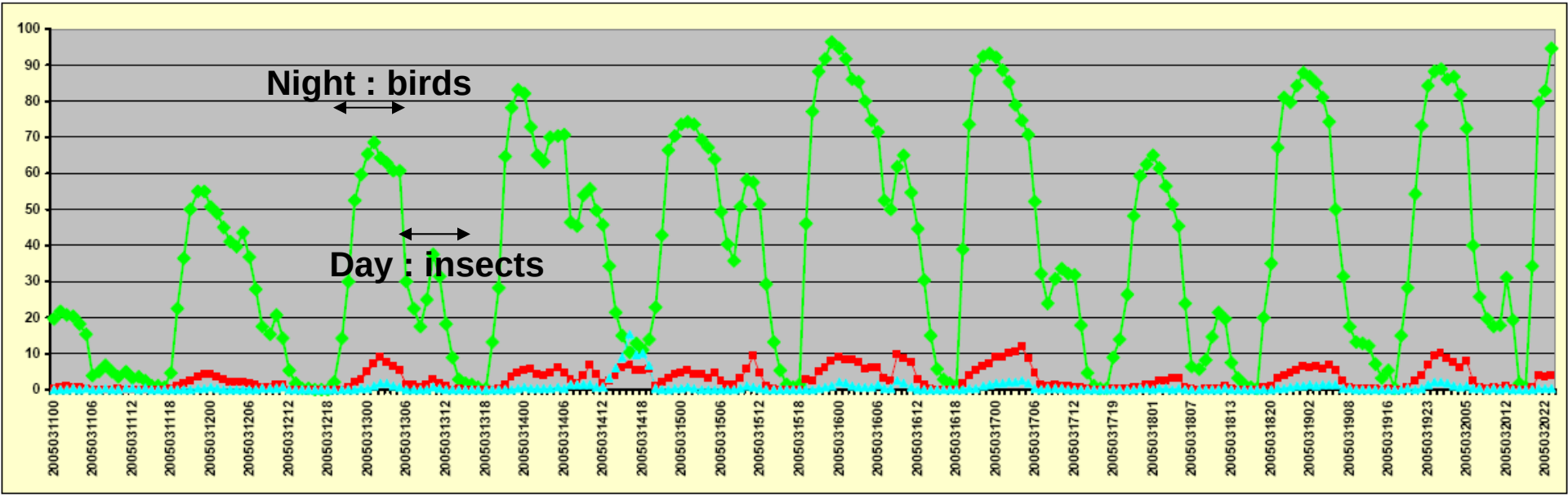
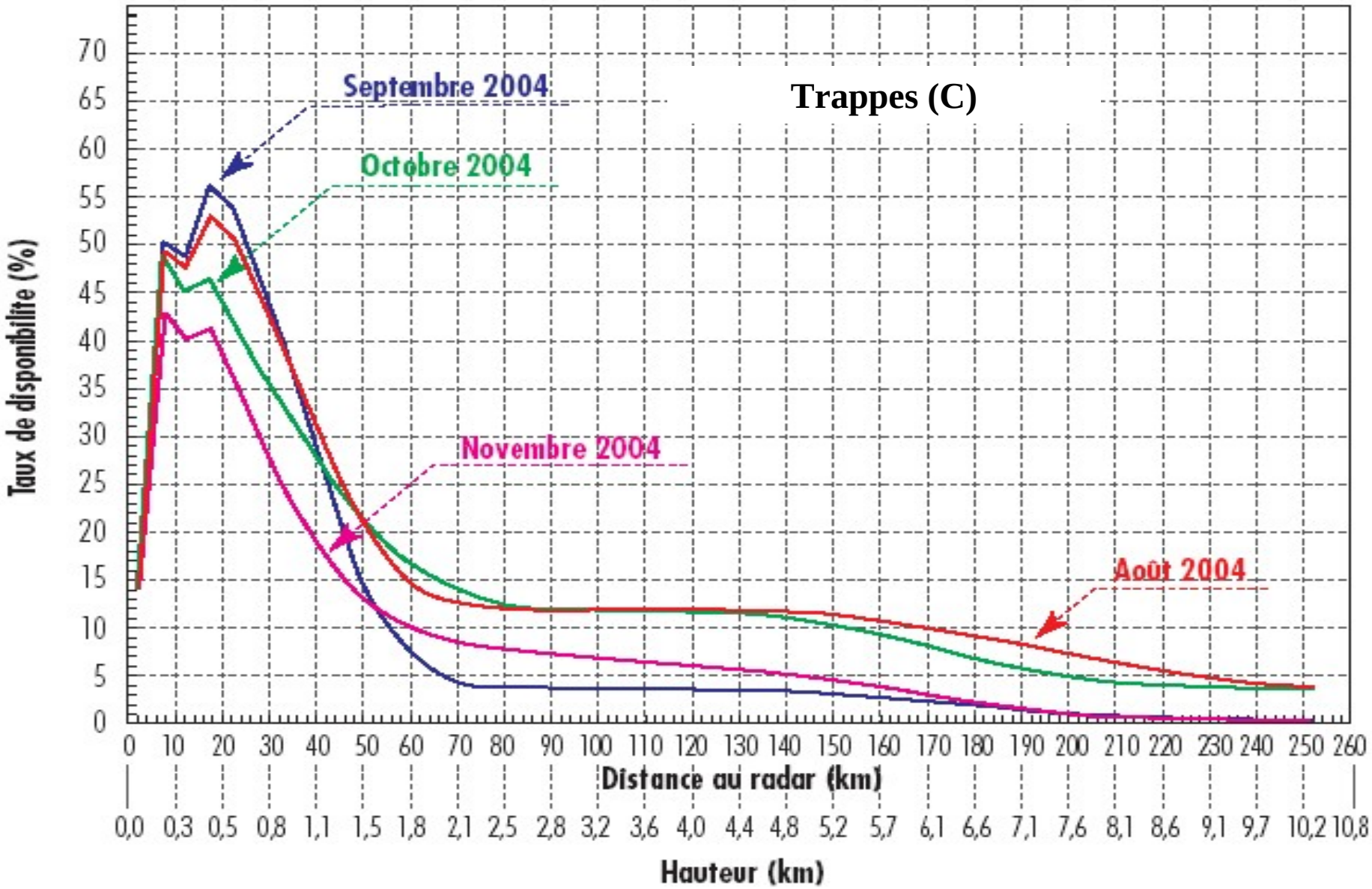
Clear-air measurements : some statistics



Number of clear-air pixels over a 10-day period (in March 2005) over the Grèzes (S) radar

Clear-air measurements : some statistics



Clear-air measurements : refractive index gradients

- Doviak et Zrnic (1993) : $Cn^2 = 7.489\ 10^{-16}\ \lambda^{-11/3}\ Z$

Cn^2 turbulence structure parameter in $m^{-2/3}$, λ wavelength in m et Z en $mm^6\ m^{-3}$

- Typical Cn^2 in Nice (from airborne measurements) : $10^{-13}\ m^{-2/3}$

- Computations : Maximum detection distance in red (with a sensitivity of 0 dBZ at 100 km)

Cn^2 ($m^{-2/3}$)	S (10 cm)	C (5 cm)	X (3 cm)
10^{-15}	-35 dBZ (1 km)	-46 dBZ (0.4 km)	-54 dBZ (0,2 km)
10^{-14}	-25 dBZ (5 km)	-36 dBZ (1.4 km)	-44 dBZ (0,5 km)
10^{-13}	-15 dBz (15 km)	-26 dBZ (4,4 km)	-34 dBZ (1,9 km)
10^{-12}	-5 dBZ (45 km)	-16 dBZ (14 km)	-24 dBZ (5,6 km)

Assumption : ½ wavelength in the inertial range !!!

Typical Taylor scale : 5 – 15 cm → higher wavelength (S) better but then aggressive ground-clutter filtering is needed …!

Thank you !

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