Overview of current developments in AROME-France convective scale operational model

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Outlines

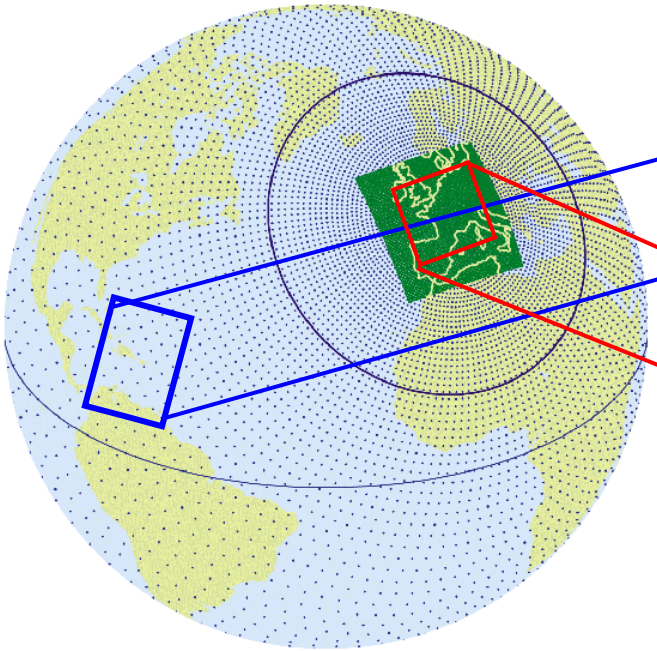
- Introduction

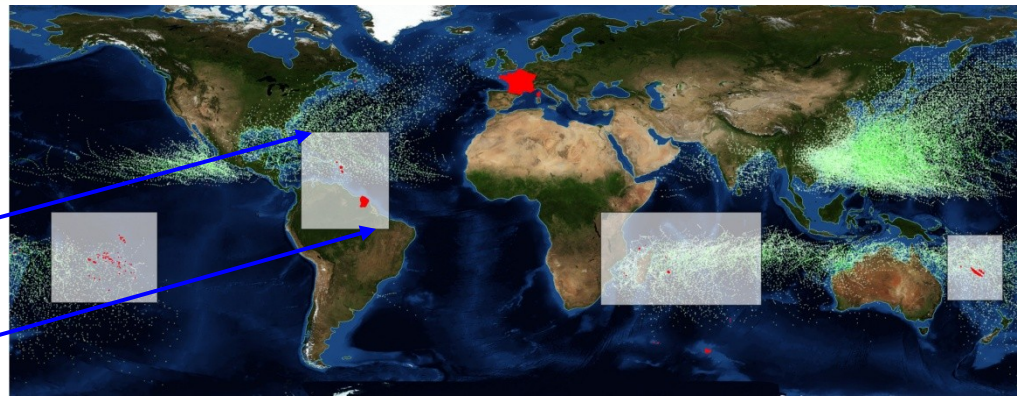
- Presentation of AROME-France configuration
- Examples of recent work in physics
- In data assimilation

- Perspectives

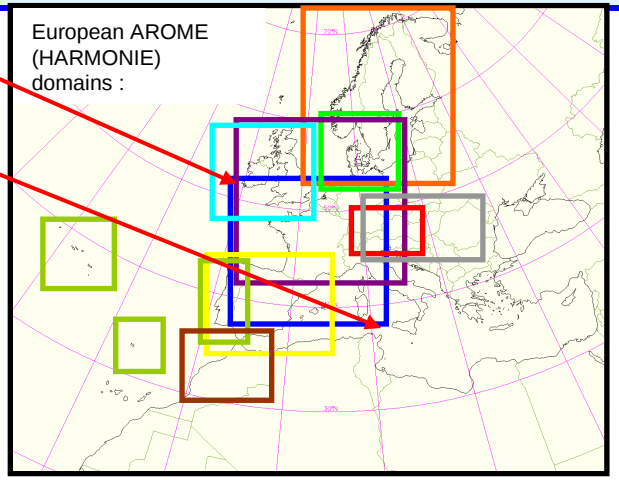
Operational Weather forecasting systems

ARPEGE/ALADIN and AROME





LAM ALADIN : ~3-days forecasts, dx~8km, 70 vertical levels, dt=450s - *3DVar Data Assimilation*

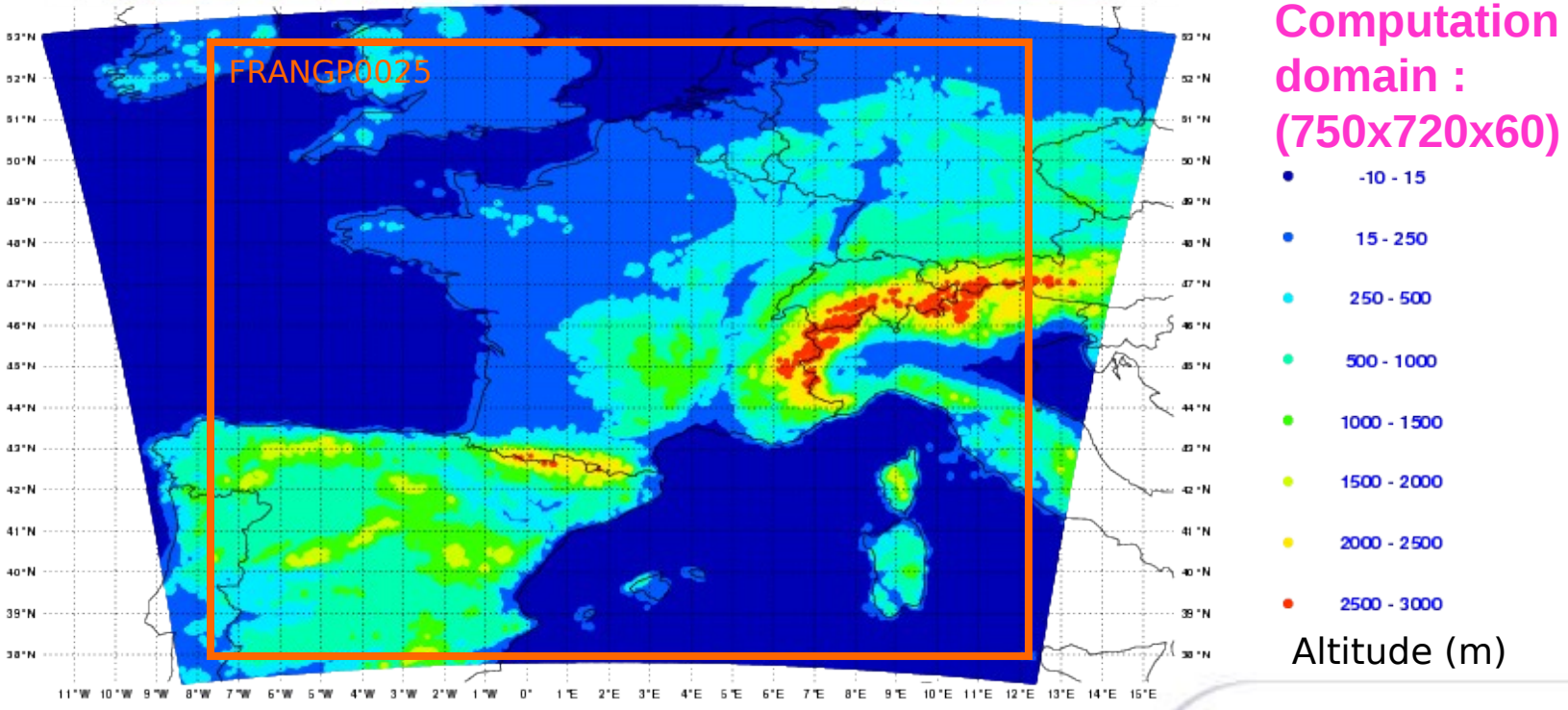


Global ARPEGE : T798c2.4L70
~4-days forecasts every 6 hours
dx~10km over France, ~60km over antipodes, dt~9mn, 70 vertical levels
4DVar incremental Data Assimilation
Low resolutions : T107c1L70 (~180km) and T323c1L70 (~60km)

LAM Cloud Resolving Model AROME-France
30 h forecasts every 6h, dx=2.5km, 60 vertical levels, dt=1mn, ALADIN-NH dynamics, MesoNH physics
3DVar (RUC3h) with radar (reflectivities and winds)

AROME-France 2.5km - Oper

- Oper since December 2008 (CY33T1_op1)
- V2 in April 2010 (direct coupling with ARPEGE, L60, Assim radar Refl) (CY35T2_op1)
- V3 November -2010 (FRANXXL, surface analysis) (CY36t1_op1)
- V4 September 2011 (Hail diagnostic, improvments for low clouds) (CY36t1_op2)
- V5 September 2012 (Improved cloud scheme and shallow convection, GTOPO30 orog, clay sand HSWB) (CY37t1 op1)



5 main forecasts per day (0+30,3+30,6+30,12+36,18+30)

ARPEGE/ALADIN and AROME atmospheric physics

	ARPEGE/ALADIN	AROME
Vertical diffusion	1.5 closure scheme with prognostic TKE (Cuxart et al., 2000) modified according (Cheng et al., 2002)	
L Mixing length	Non local mixing length (Bougeault, Lacarrere, 1989)	
Shallow convection	Moist shallow convection. Cape closure. (Bechtold et al, 2001) (available also in AROME)	Dry and moist shallow convection. Surface flux closure. (Pergaud et al, 2009) (under tests in ARPEGE)
Cloud scheme	Statistical scheme with climatological triangular PDF. (Smith, 90)	Statistical scheme with possibly mixed symmetric (Gaussian) and asymmetric (Exponential) functions. (Bougeault, 82)
Microphysics	1 moment bulk scheme with 4 prognostic variables for cloud droplets, rain, ice crystals and snow (Lopez, 2002)	1 moment bulk scheme with 5 prognostic variables for cloud droplets, rain, ice crystals, snow and graupel (Pinty and Jabouille, 1998)
Deep Convection	Mass flux scheme based on moisture convergence for closure and intensity. (Bougeault, 1985) + modifications	
Subgrid orography	Gravity wave drag. Form drag. Anisotropy. (Catry et al., 2008)	
Radiation	ECMWF codes : LW=RRTM (Mlawer, 97), SW=old IFS scheme (Fouquart, Morcrette)	

SURFEX

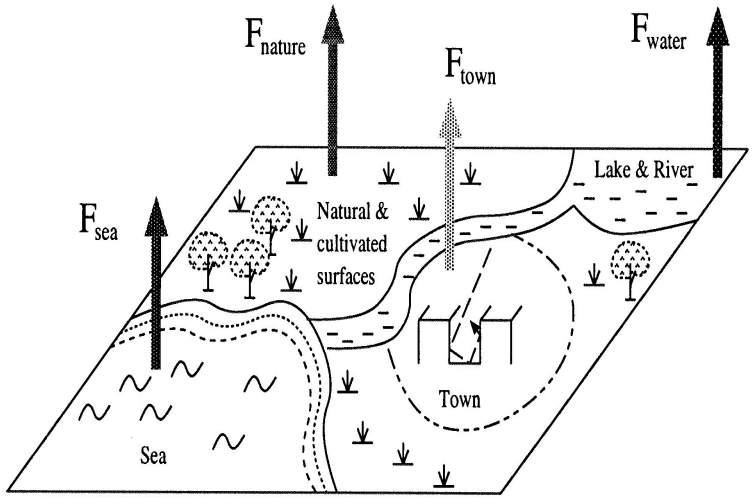
1

Atmospheric model

Atmospheric forcings:
Lowest model level + fluxes

3

Surface turbulent and radiative fluxes



Surfex

interface

Mean operator

2

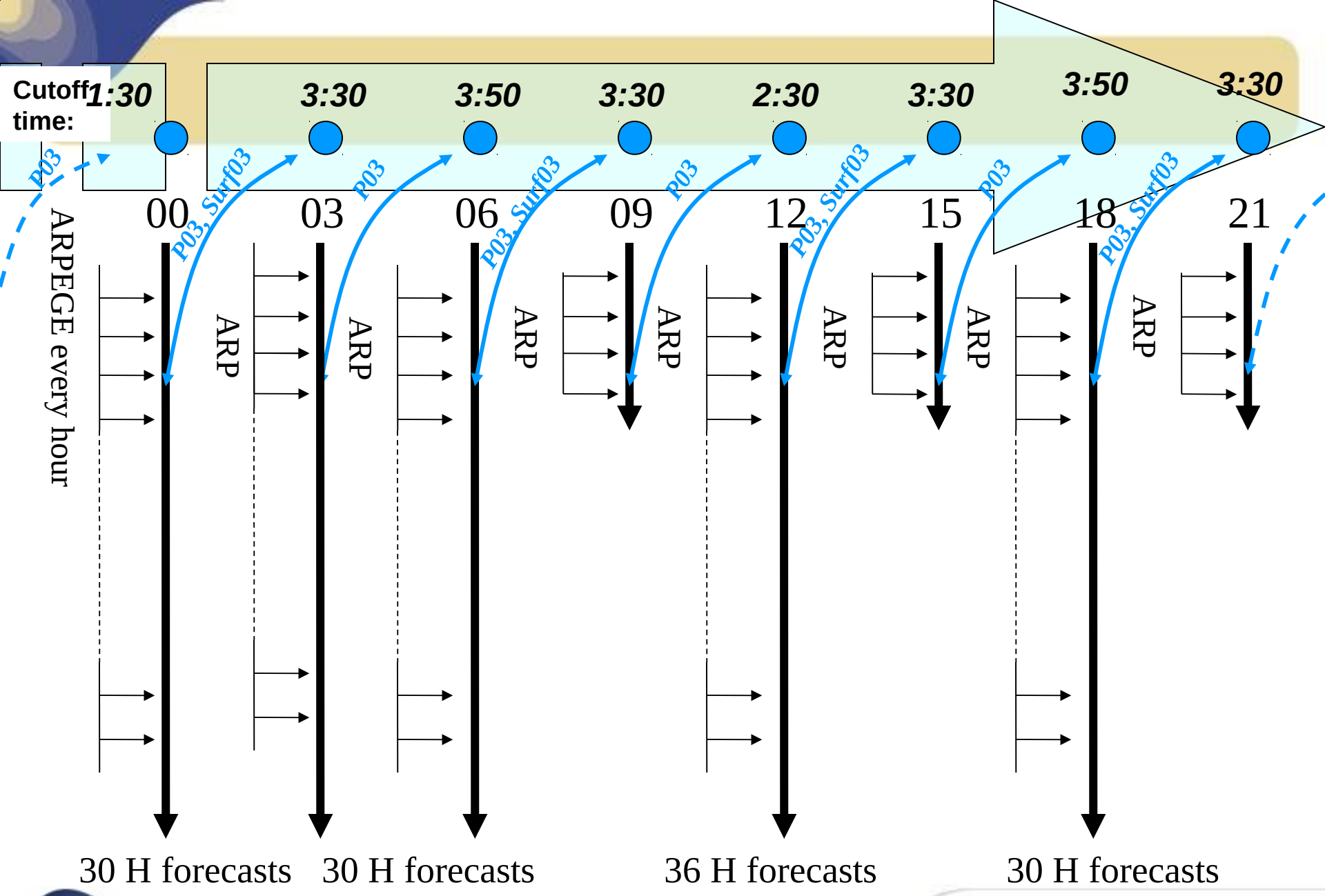
ISBA

TEB (town)

seaflux

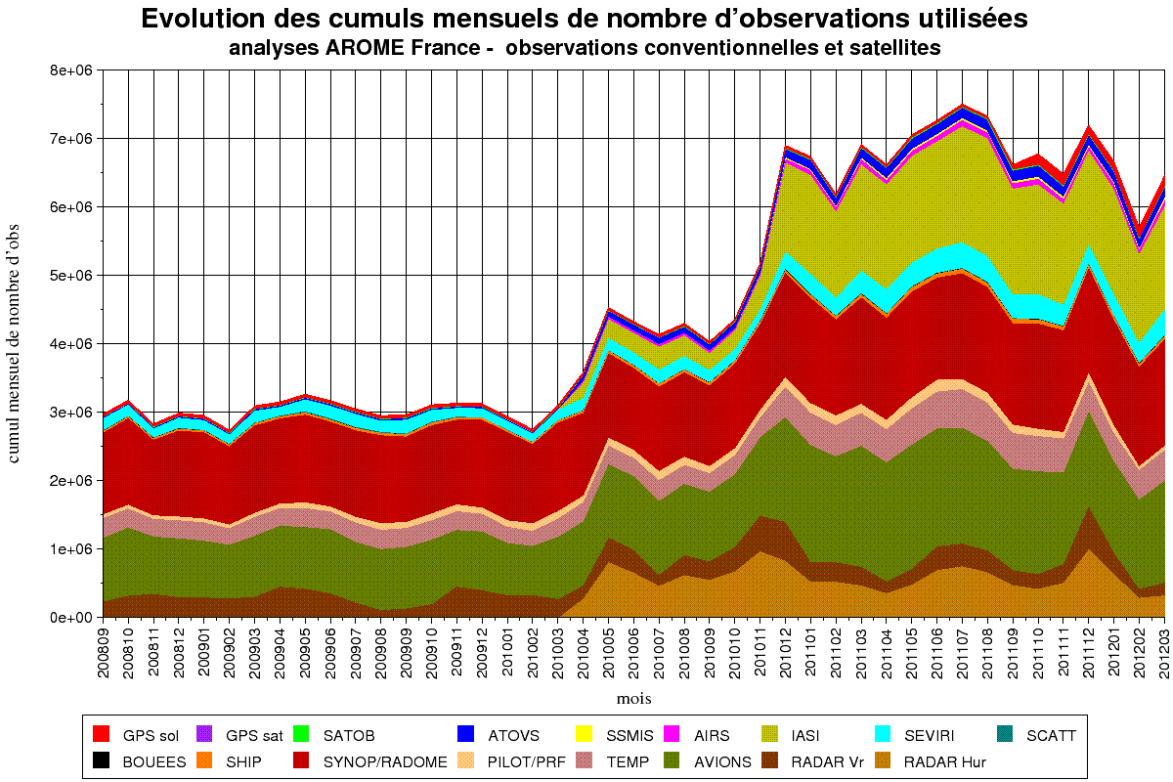
waterflux

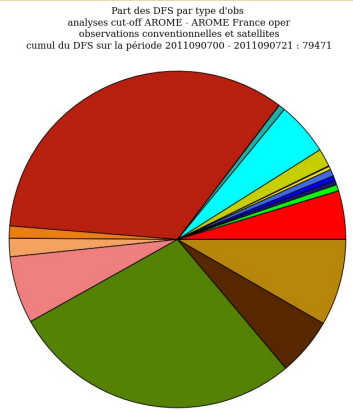
Lowest model level currently at 10m.



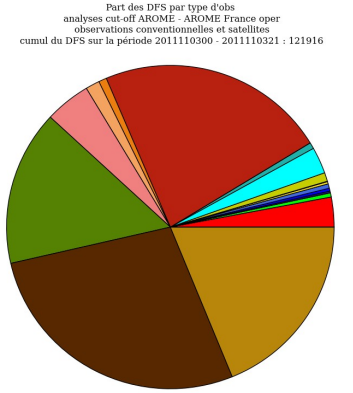
AROME RUC 3h organisation

Observations in AROME-France





DFS (rain +)



DFS (rain +++)

RADARS

AIRCRAFTS

SYNOP/RADOME

IASI

SEVIRI

TEMP

Ground GPS

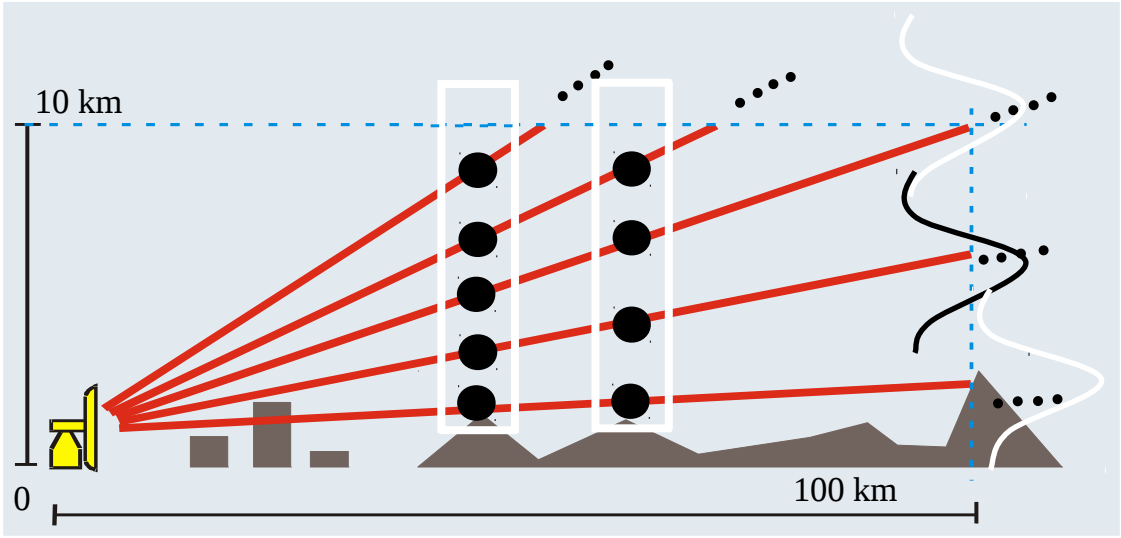
Differences with ARPEGE : radars+use of T2m Hu2m during

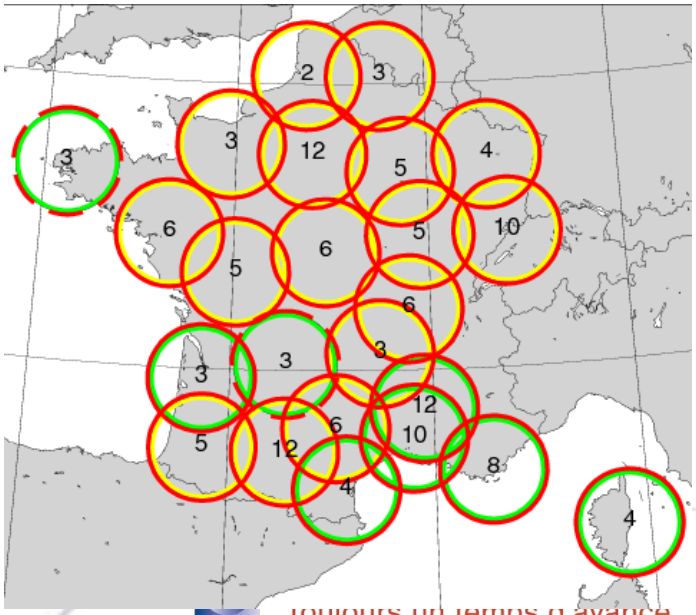
METEO FRANCE
Toujours un temps d'avance

Radar assimilation - introduction

French ground based radar network :

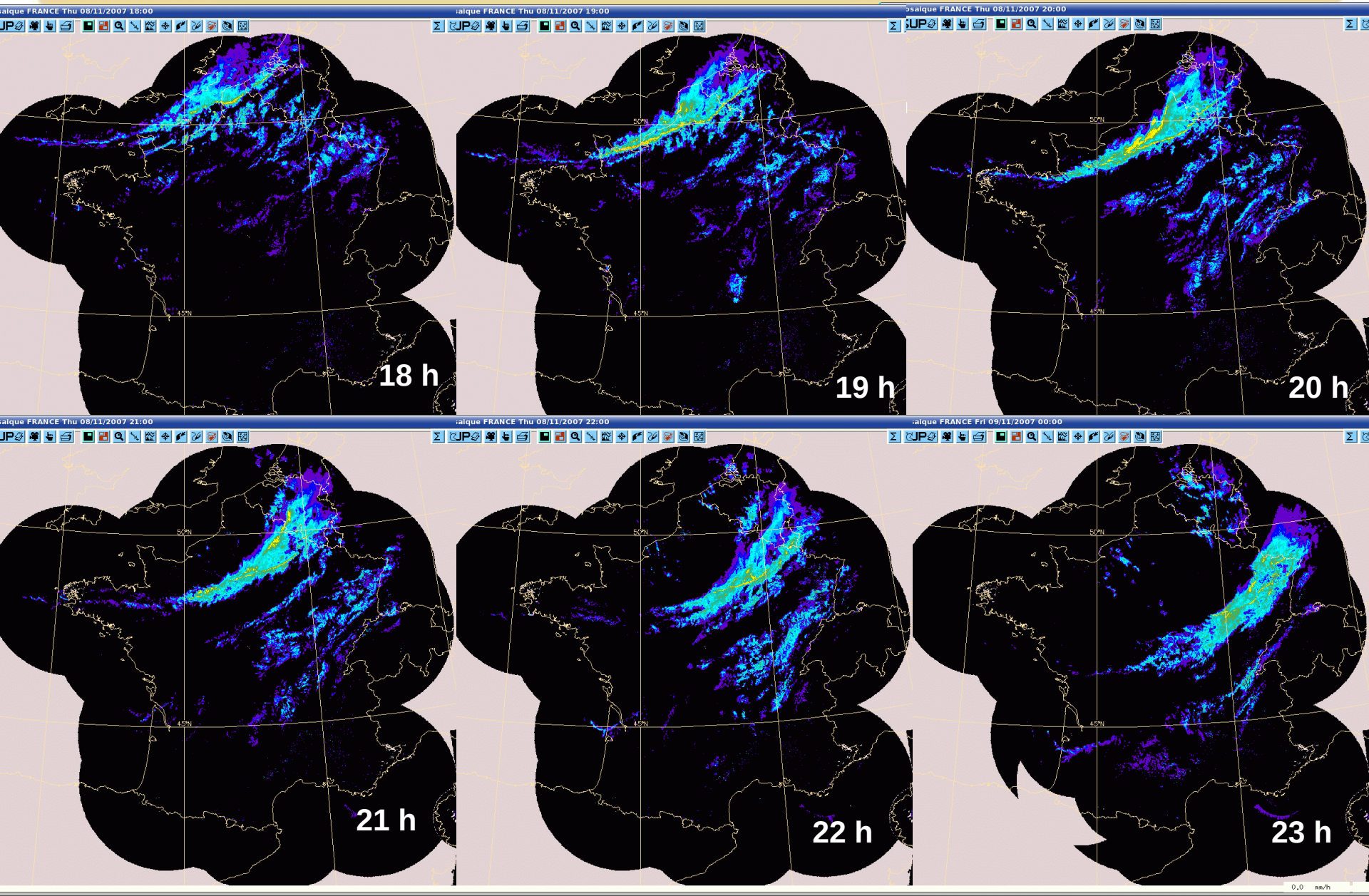
- 3D scans
- **Doppler radial winds**
- **Radar réflectivity**
- resolution ~ 1km x 300m x 15mn





Impact of Doppler winds assimilation in AROME

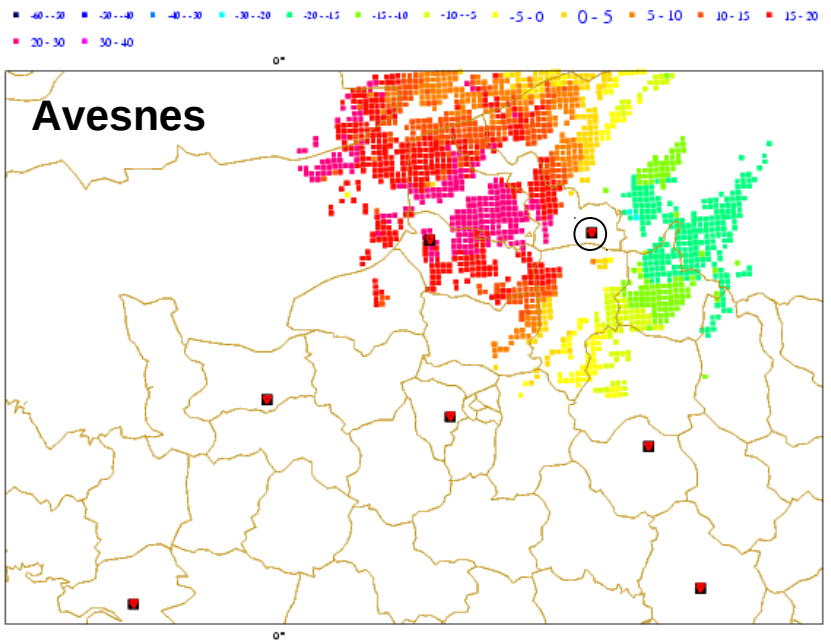
8 Nov. 2007 : Cold front case

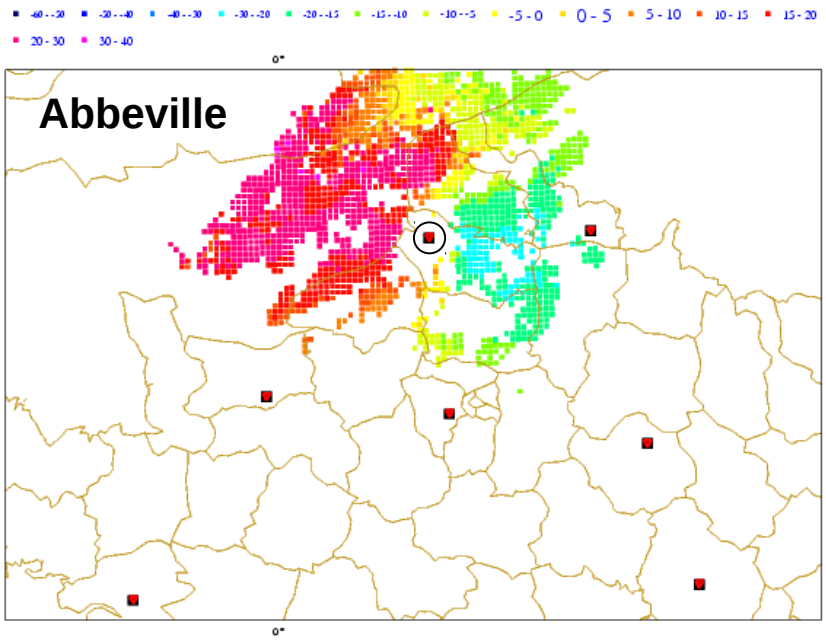


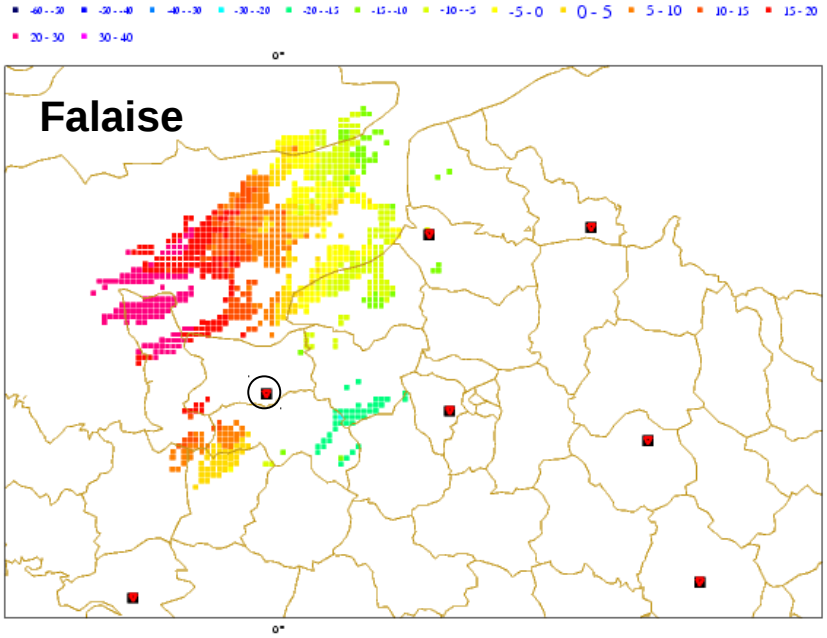
- **CNTRL:** AROME without radar winds
- **RADAR:** CNTRL with 17 doppler radar winds data)

Ex V_r 1st scans

18 UTC





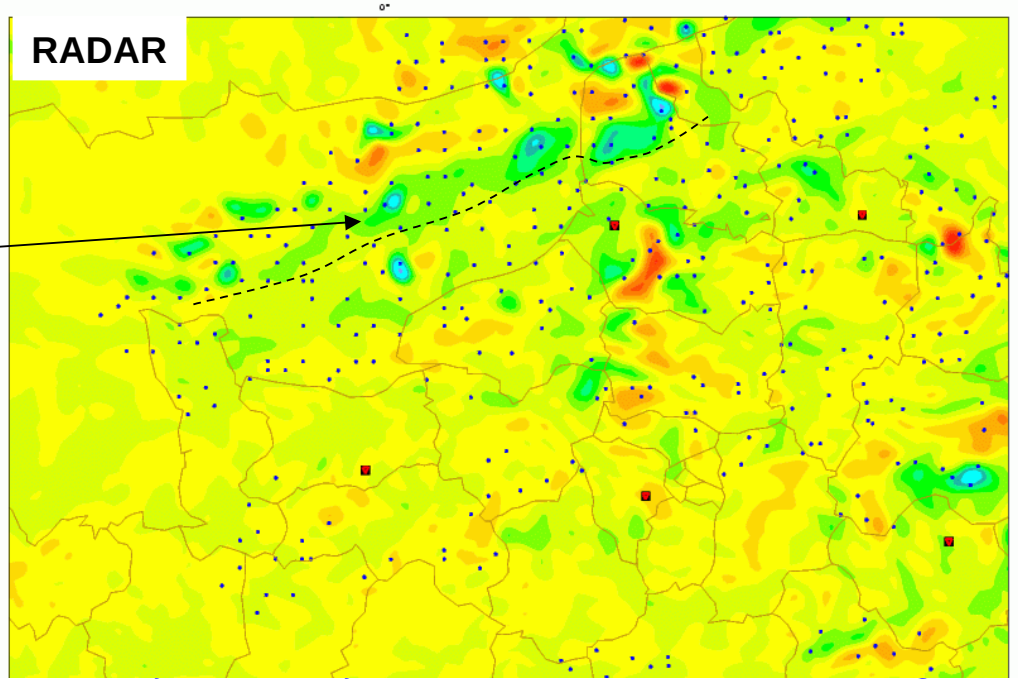


Analysed divergence at 950 hPa
18 UTC

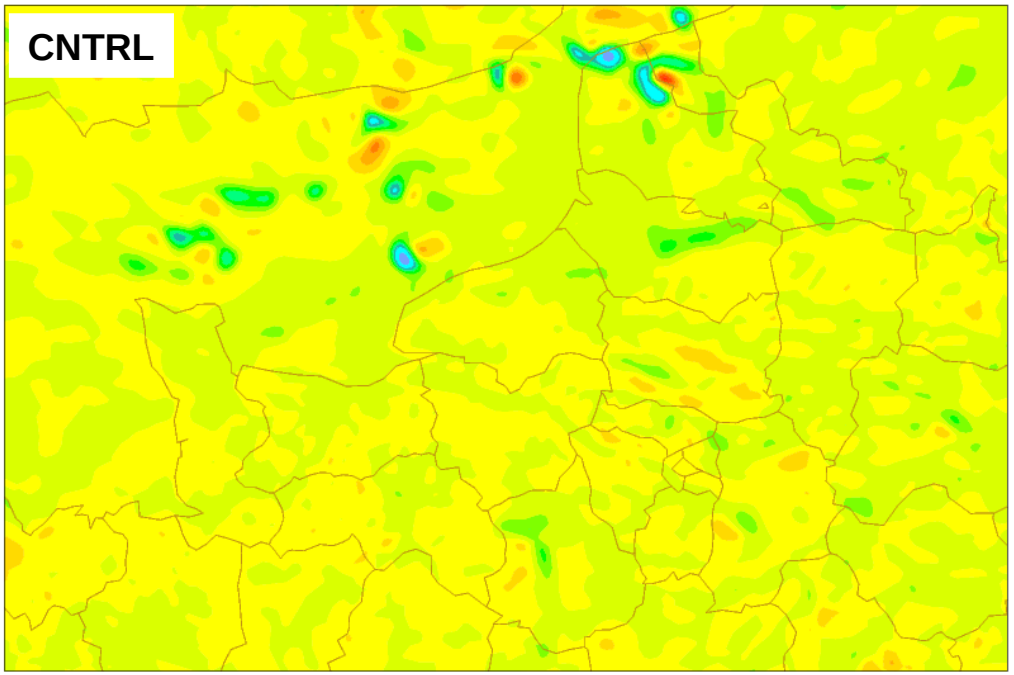
- Main convergence line well analysed

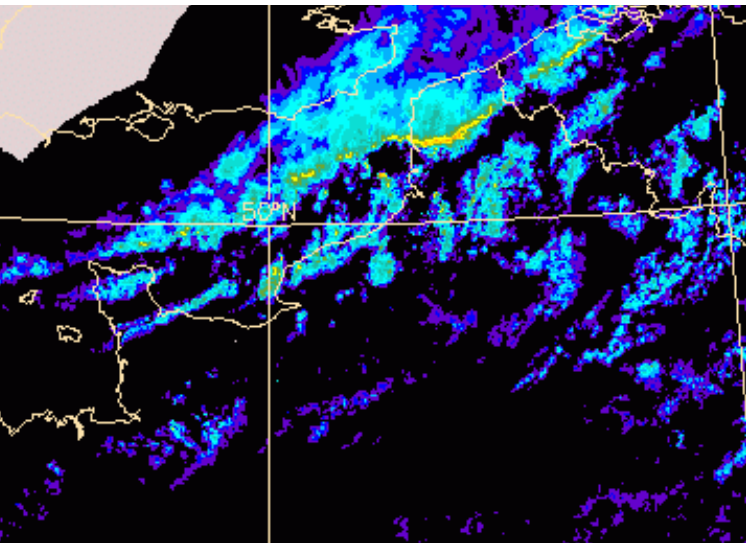
PARIS Analysis VT:Thursday 8 November 2007 18UTC 950hPa relative divergence

RADAR



CNTRL

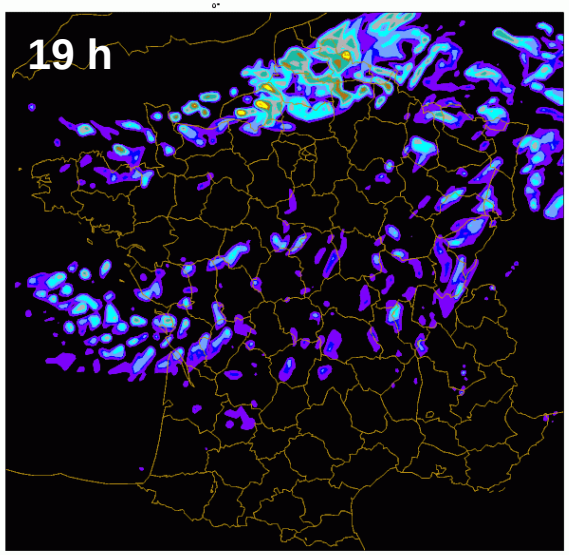




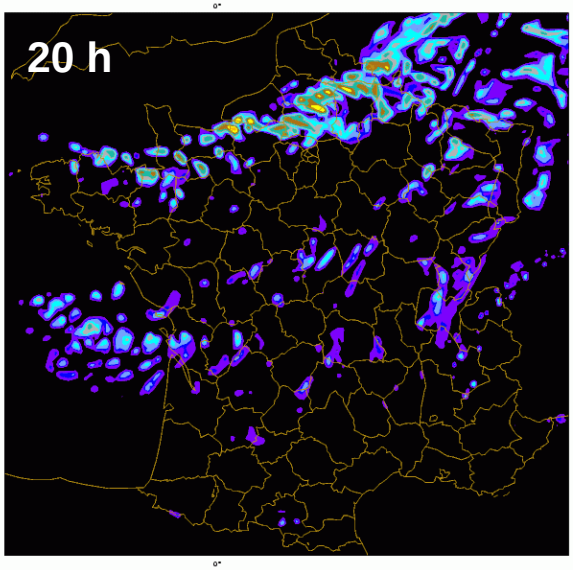
Simulated reflectivities (analyse 18 UTC)

CNTRL

Thursday 8 November 2007 18UTC PARIS t+1 VT: Thursday 8 November 2007 19UTC Surface:

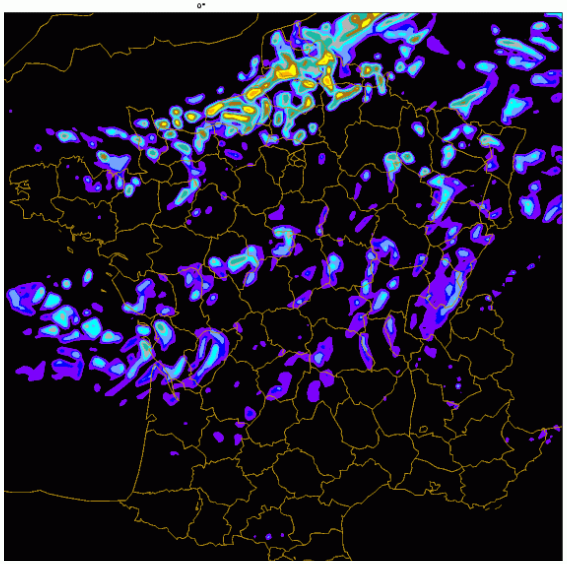


Thursday 8 November 2007 18UTC PARIS t+2 VT: Thursday 8 November 2007 20UTC Surface:

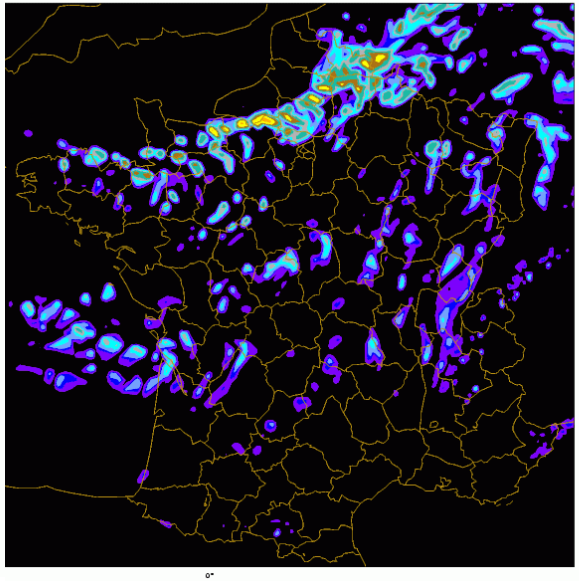


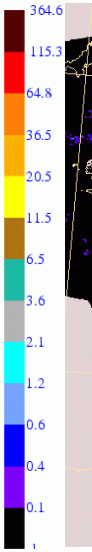
RADAR (winds)

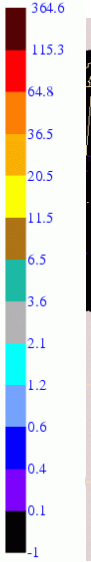
rsday 8 November 2007 18UTC PARIS t+1 VT: Thursday 8 November 2007 19UTC Surface:



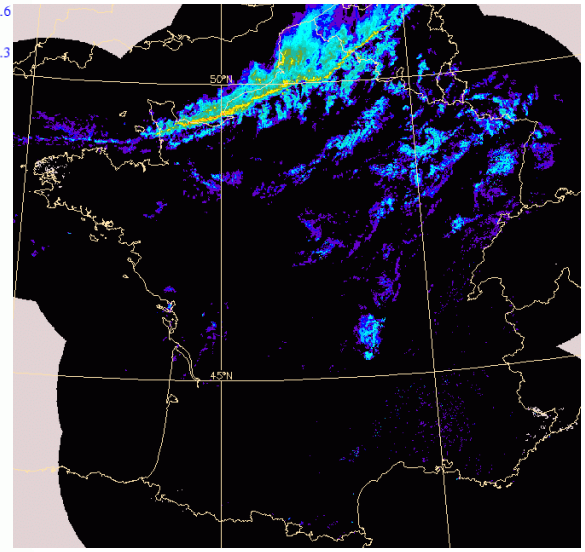
ursday 8 November 2007 18UTC PARIS t+2 VT: Thursday 8 November 2007 20UTC Surface:

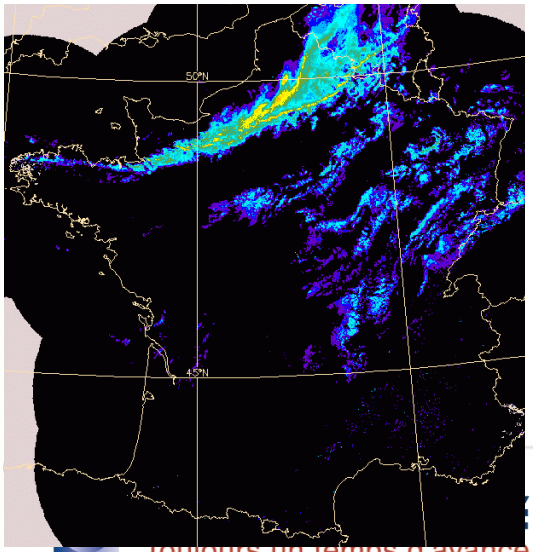






OBS

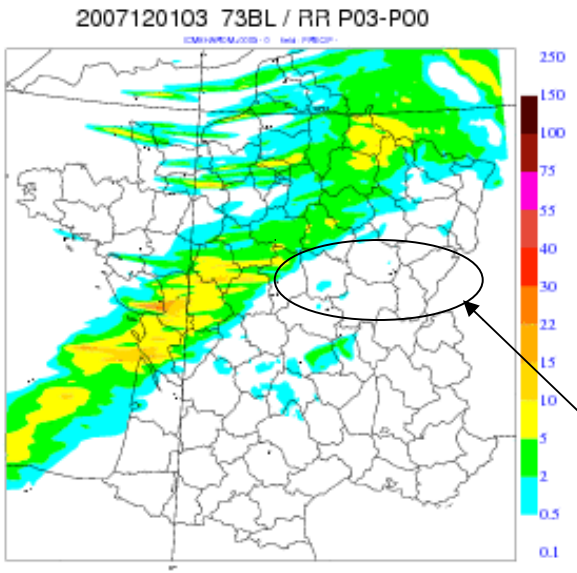


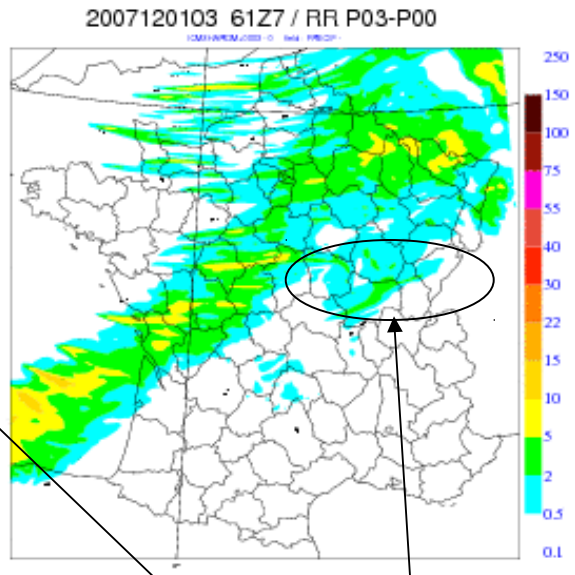


Impact of radar reflectivity assimilation

3h - cumulated rain - P3-P0

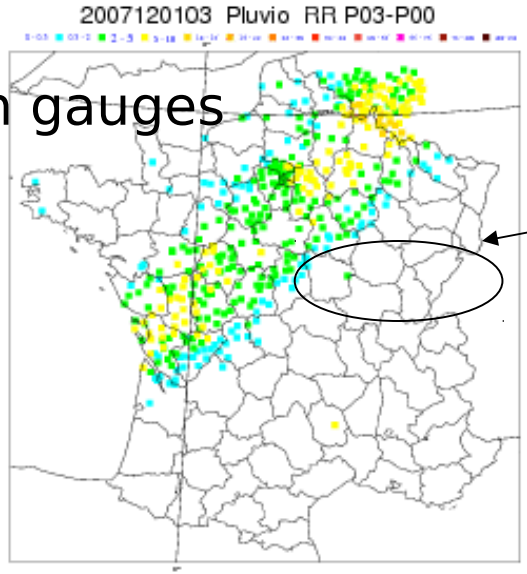
With REFL





Without reflectvity assimilation

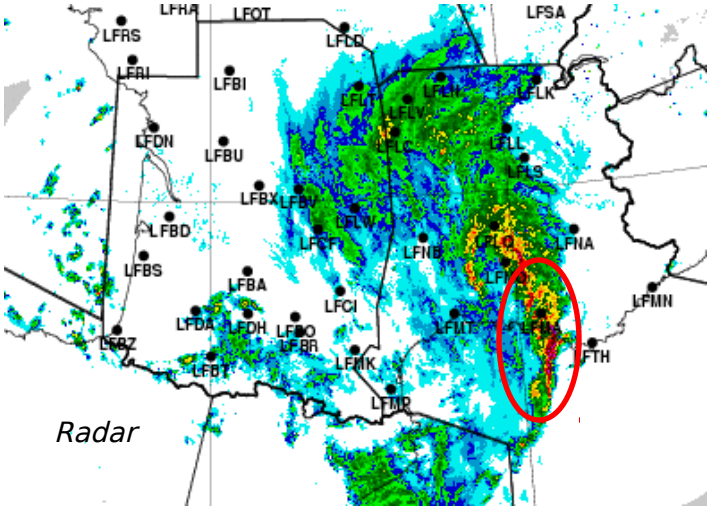
rain gauges



Good drying in front of the main rainfalls of the cold front with the run REFL.

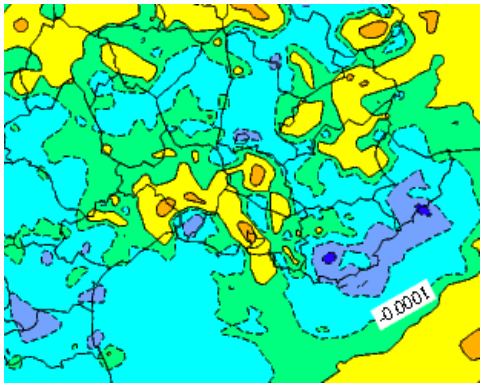
And still good impact on 12-hour forecast QPF scores for this case

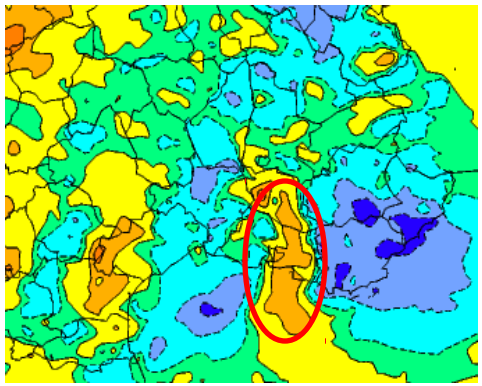
Squall line 8 October 2008



Radar

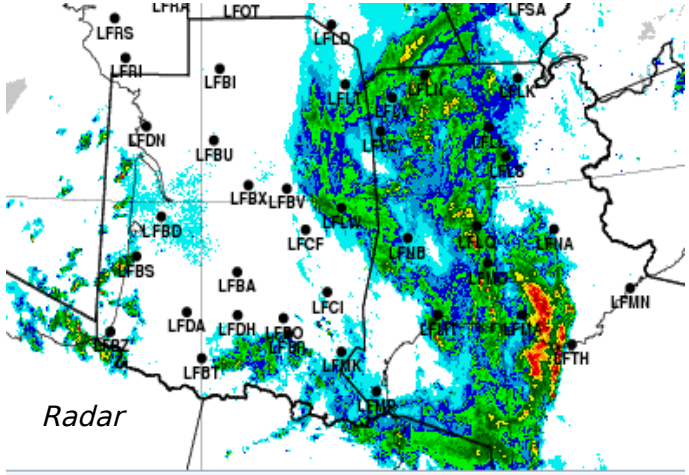
06h





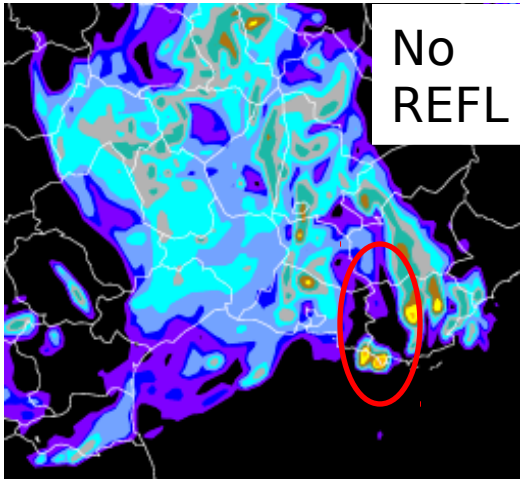
Specific humidity Incr

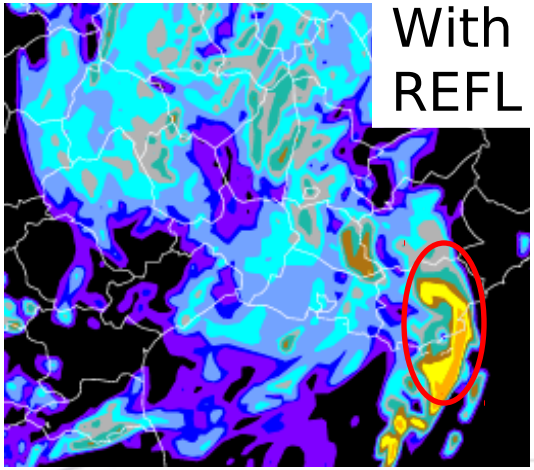
Simulated reflectivity field from 3-hour forecast



Radar

09h



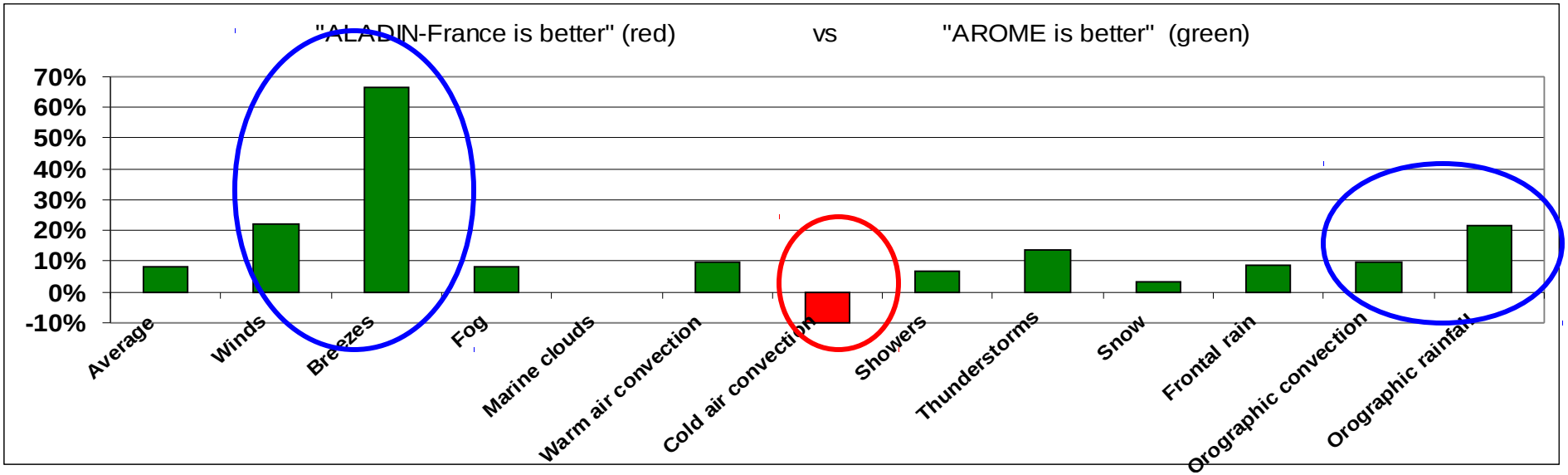


METEO FRANCE
Toujours un temps d'avance

AROME : Forecasters' Point of View

Comparison between AROME and ALADIN-France (2009-2011)

- Comparison a posteriori, for each type of meteorological situation

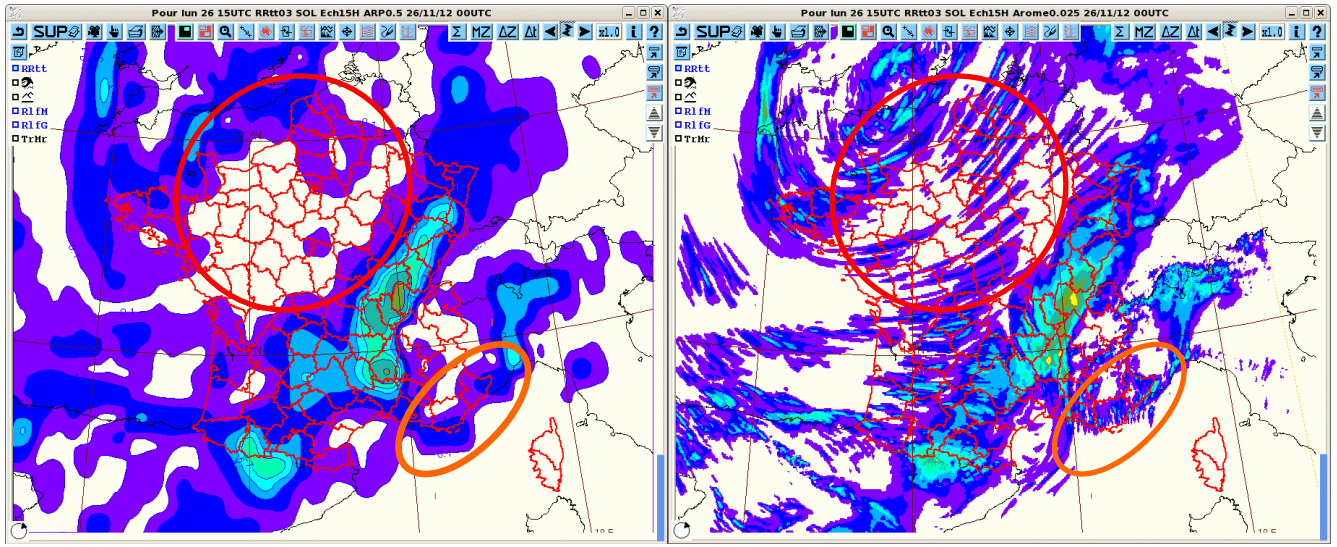


- AROME is able to improve ALADIN forecasts in average.

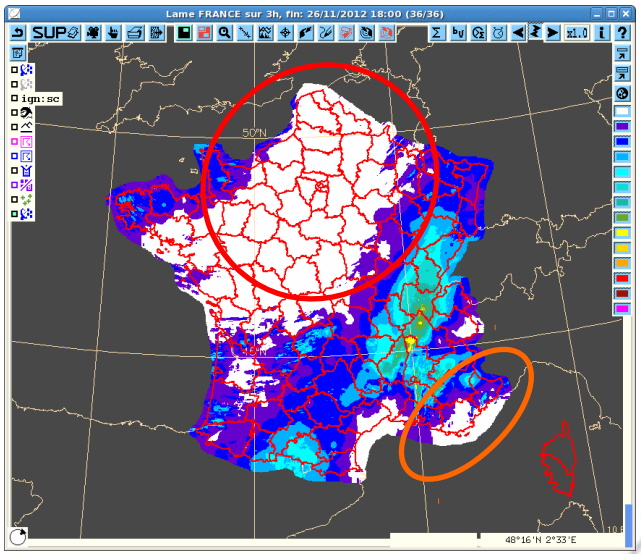
Cold air convection over-estimated : 26 novembre 2012 15 UTC

Arpege P15

Arome P15



Observation : 26/11/2012 à 15 UTC



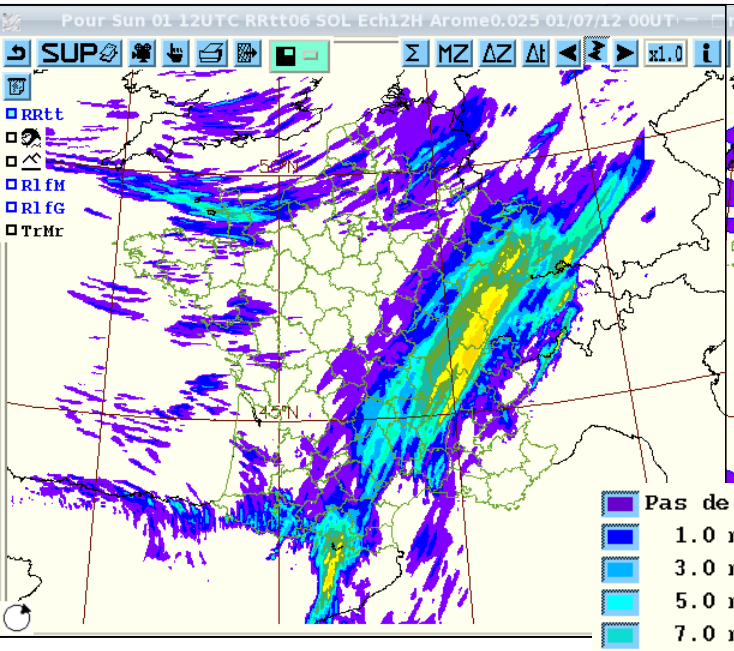
METEO FRANCE
Toujours un temps d'avance

Example of 1st July 2012 :

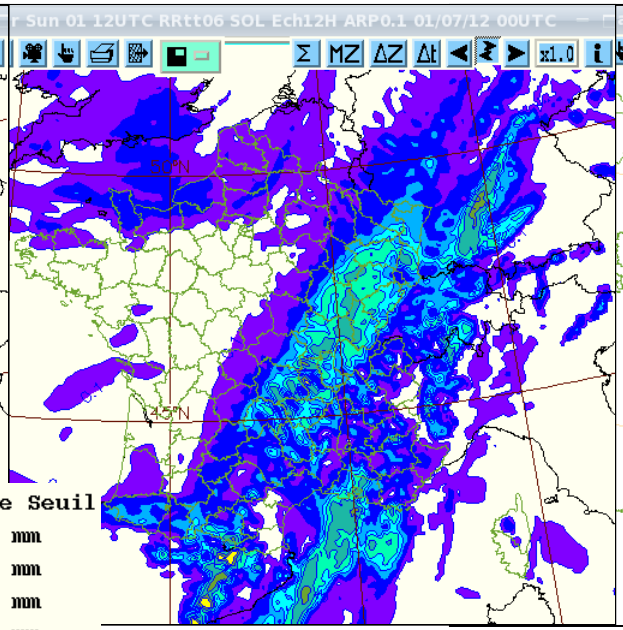
A summer convective event

24h cumulative rainfalls :

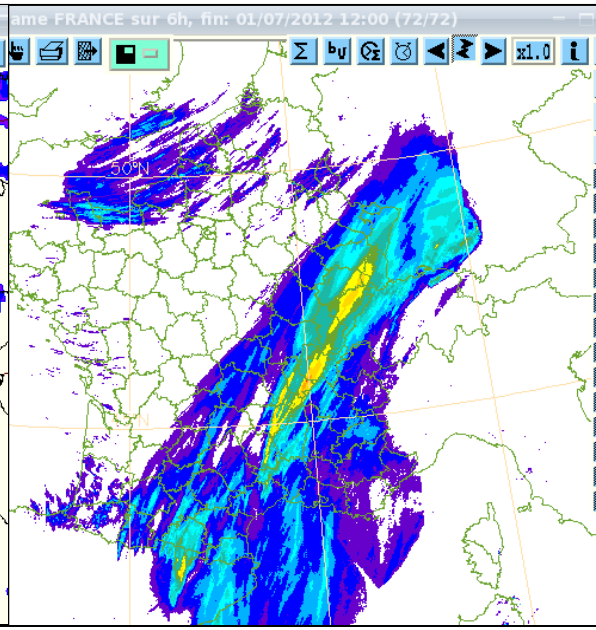
AROME :

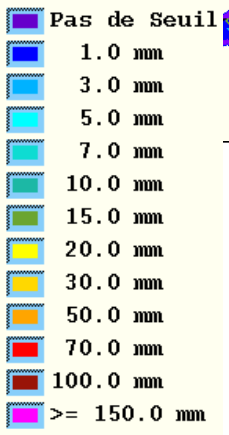


ARPEGE :



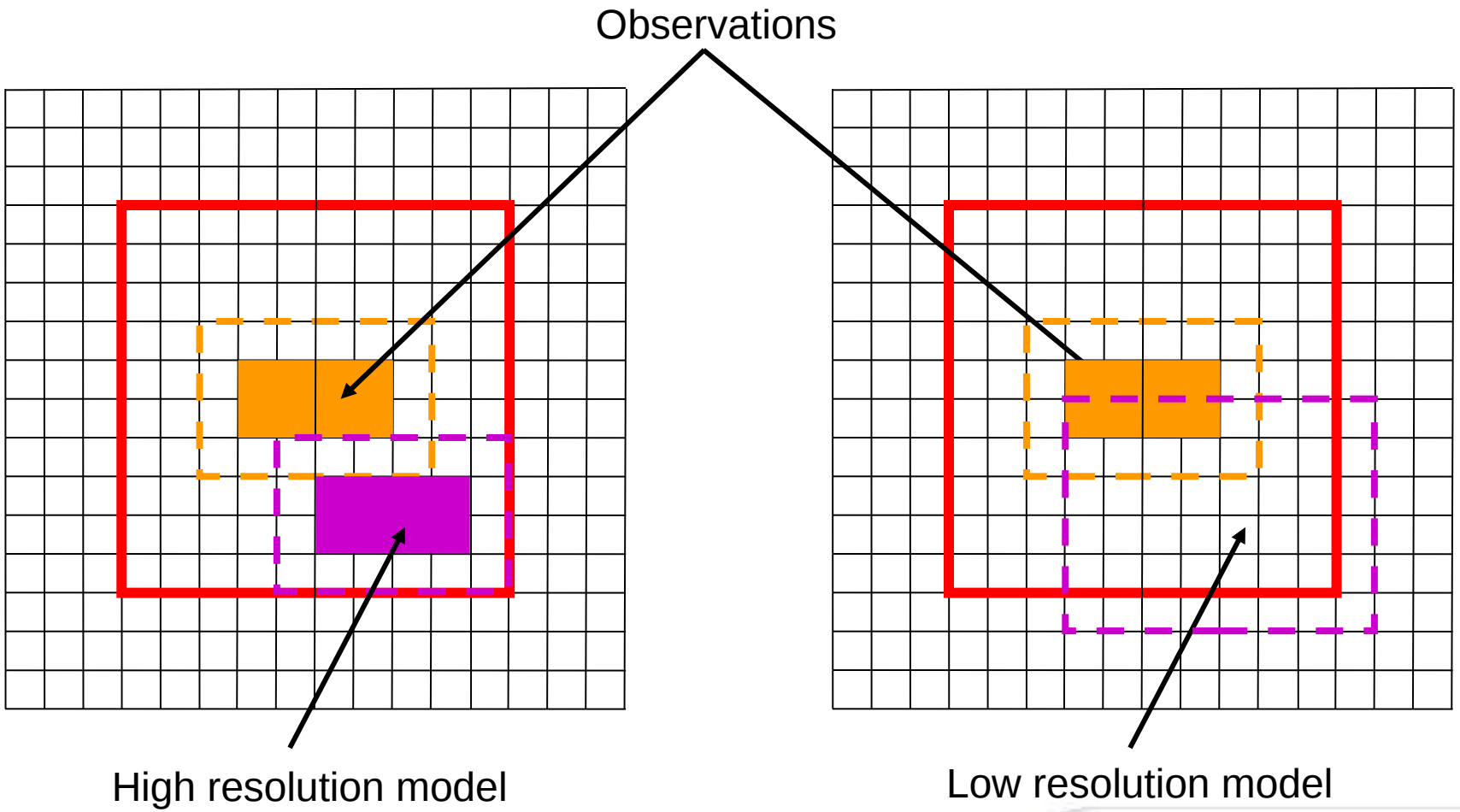
RADAR :





METEO FRANCE
Toujours un temps d'avance

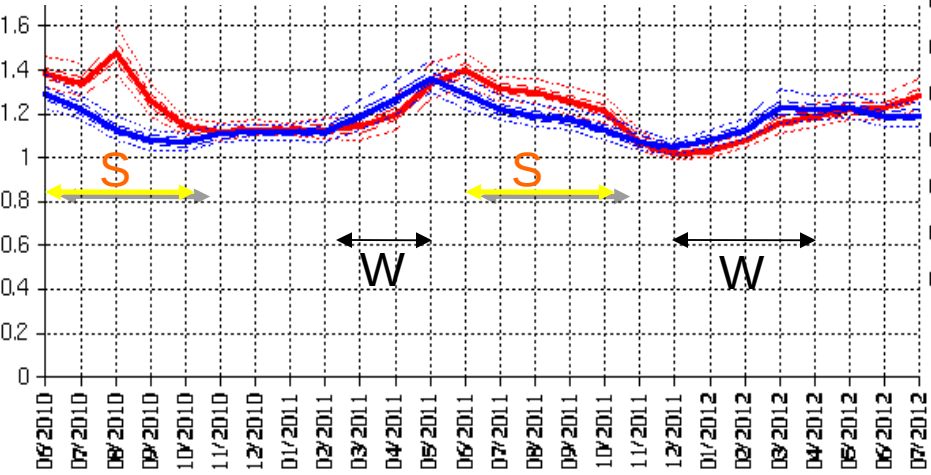
Probabilistic scores



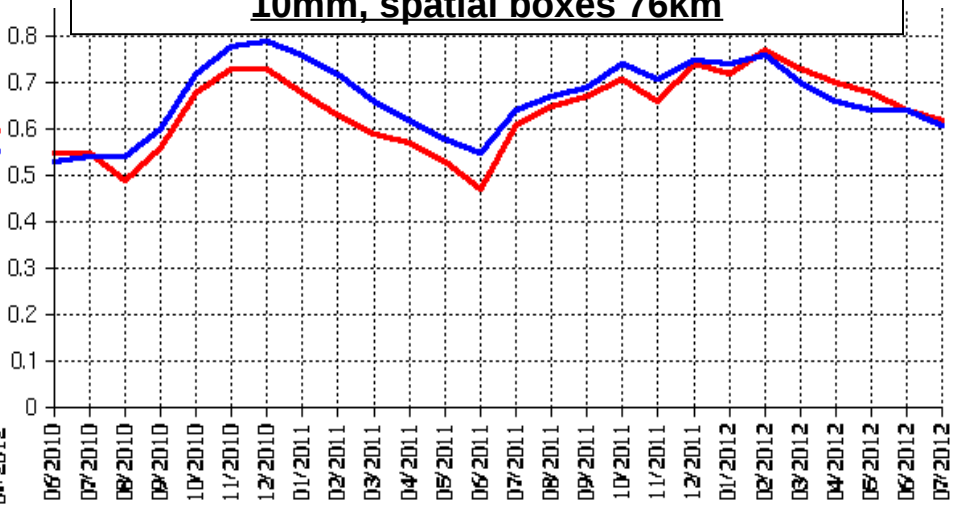
Brier skill score for example

Evaluation of ARPEGE/AROME RR24

Monthly averaged bias for RR24 > 2 mm



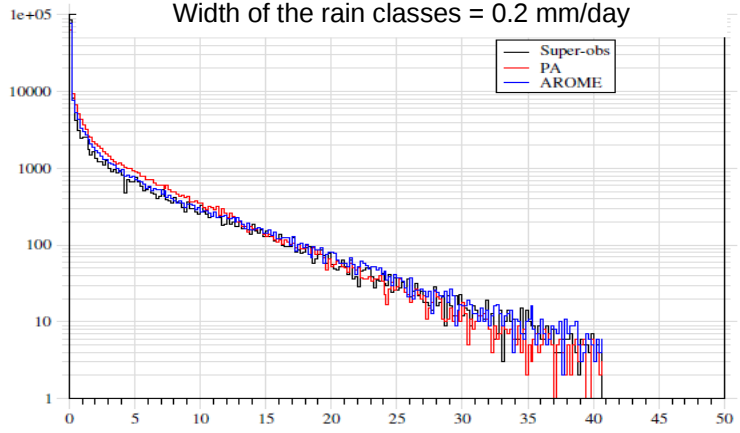
Monthly averaged BSS-NO for RR24 > 10mm, spatial boxes 76km

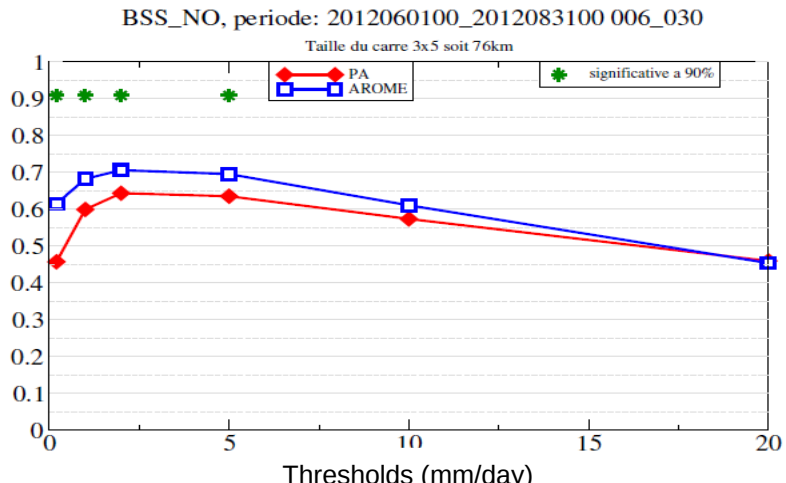


AROME performs better than ARPEGE mostly in summer.

Zoom over last summer : Distribution (JJA 2012) BSS against persistence

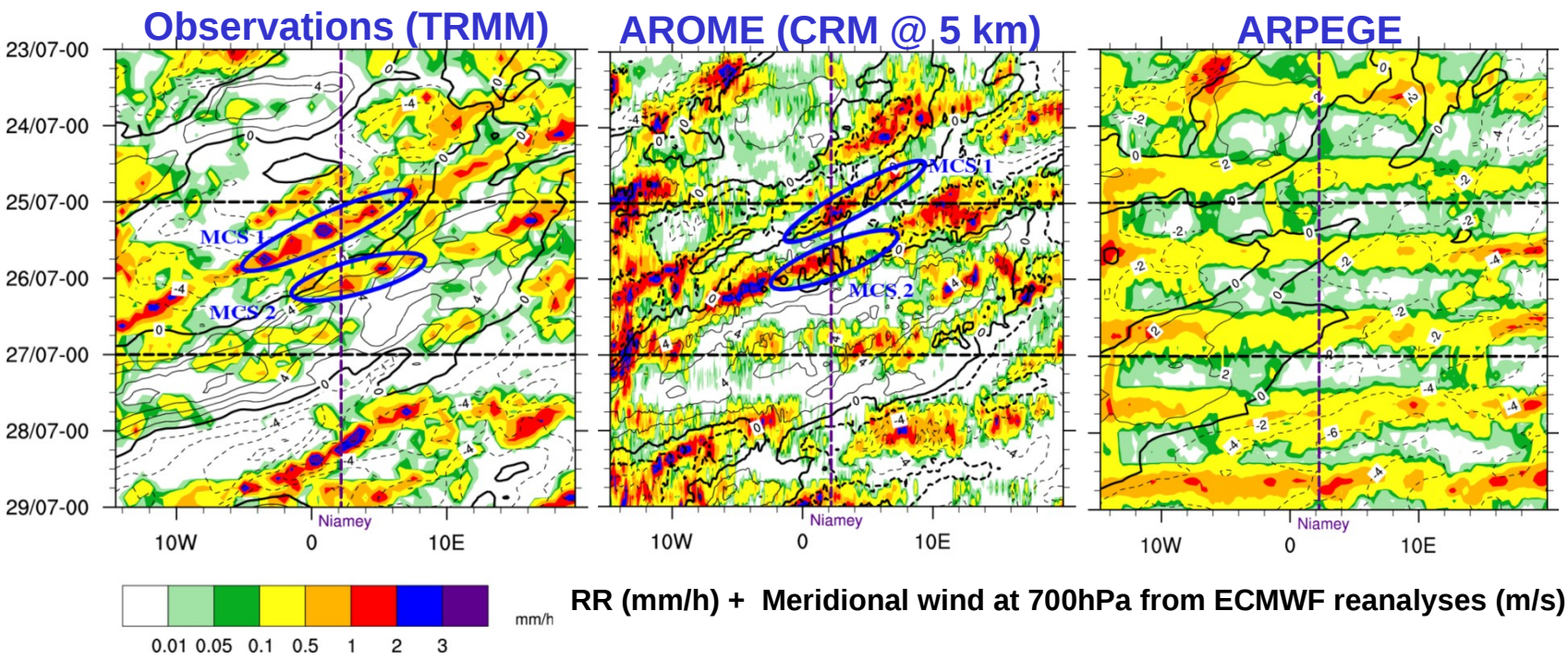
Histograms of observed and forecasted precipitation
Width of the rain classes = 0.2 mm/day





AROME-AMMA

- **AMMA well-documented case 23-29 July 2006** *Barthe et al., 2010*
  - **Intense Monsoon surge over Sahel propagating westward with AEW : Convective events**



RR (mm/h) + Meridional wind at 700hPa from ECMWF reanalyses (m/s)

• NWP at low resolution: fails to reproduce AEW and the coupling with convection
• High-resolution (CRM): Better representation of the AEW-convection link. Small overestimation of the strong precipitation

Beucher et al., to be submitted

Outlines

- Introduction

- Presentation of AROME-France configuration

- **Examples of recent work in physics**

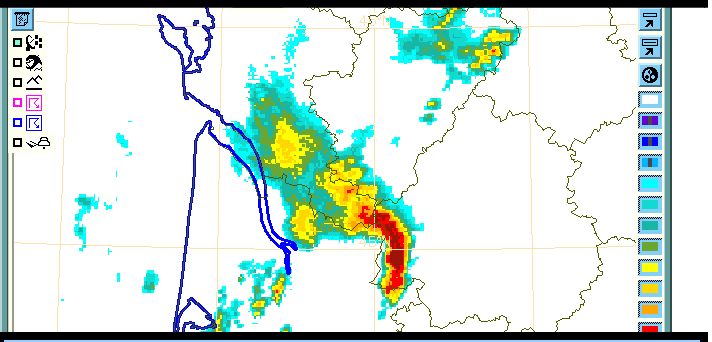
- In data assimilation

- Perspectives

About Hail in AROME

OBSERVATIONS :

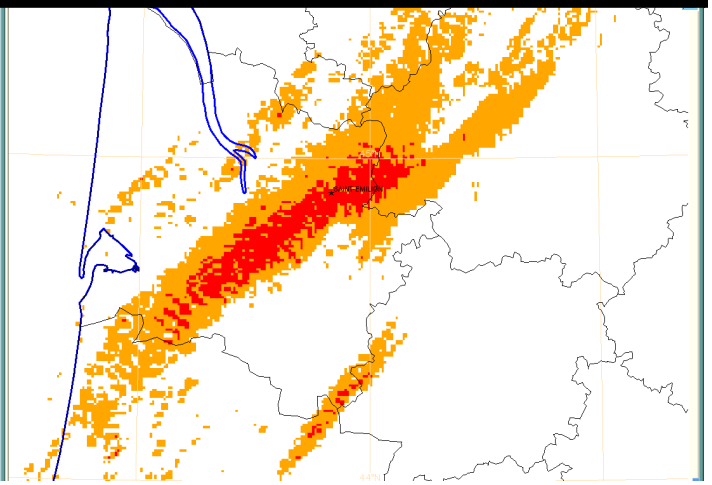
Observation (reflectivity at 2h30 UTC)



Hail risk (from radar)

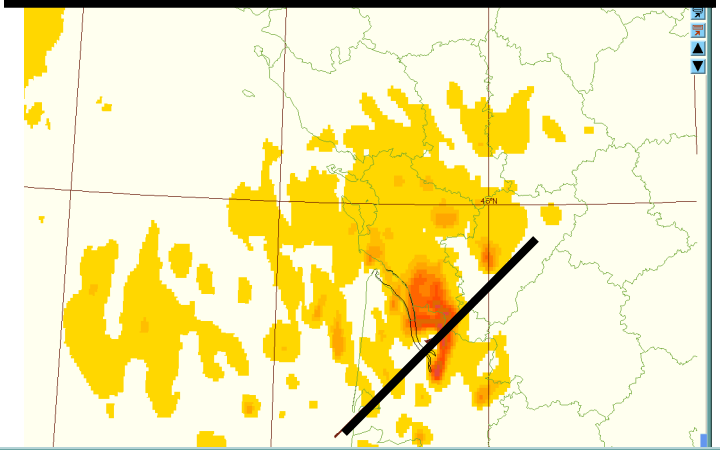
Orange : hail

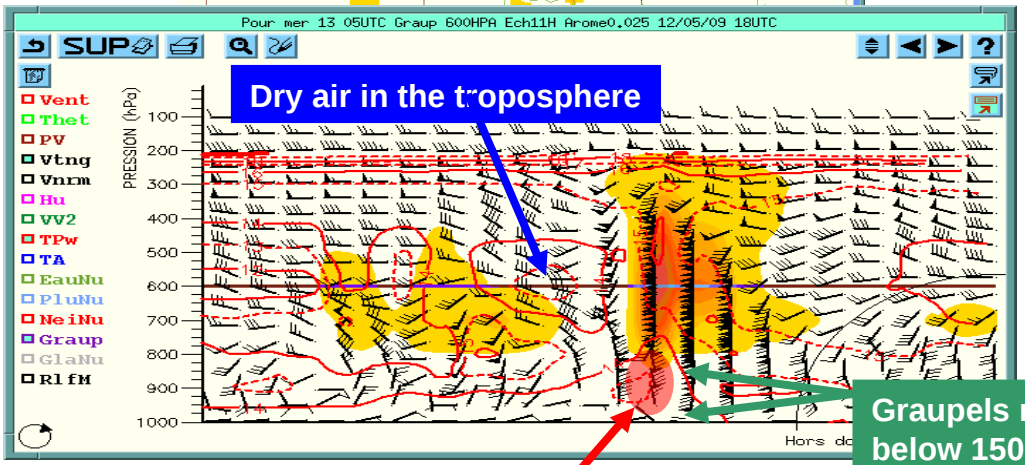
Rouge : strong hail



AROME :

Graupels at 600hPa at 5UTC (r18)





In ICE3 microphysics scheme, hail is part of ‘graupel’, but graupel never reach the soil *(except in winter or/and over montains)* -> Forecasters need something else to forecast hail with AROME

Hail diagnostic

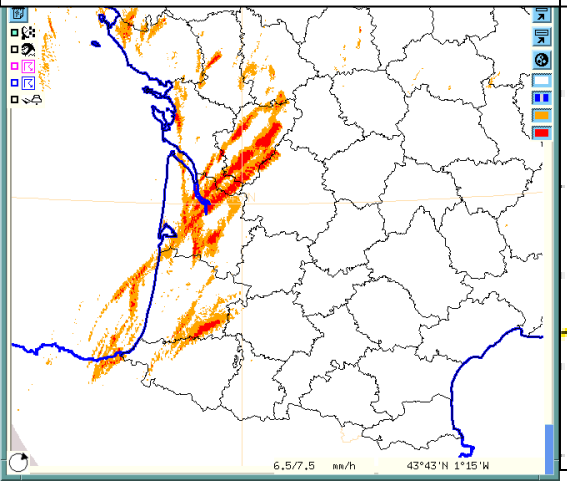
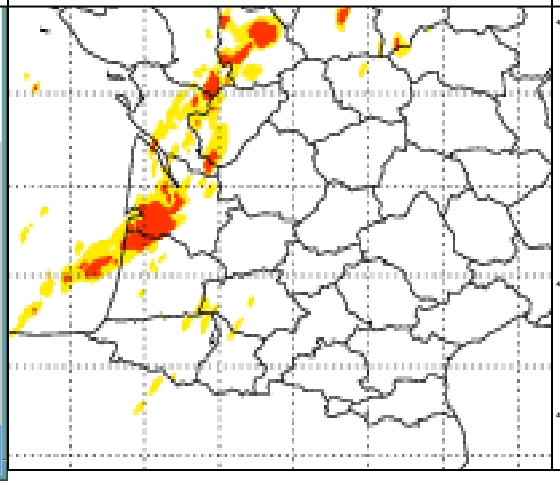
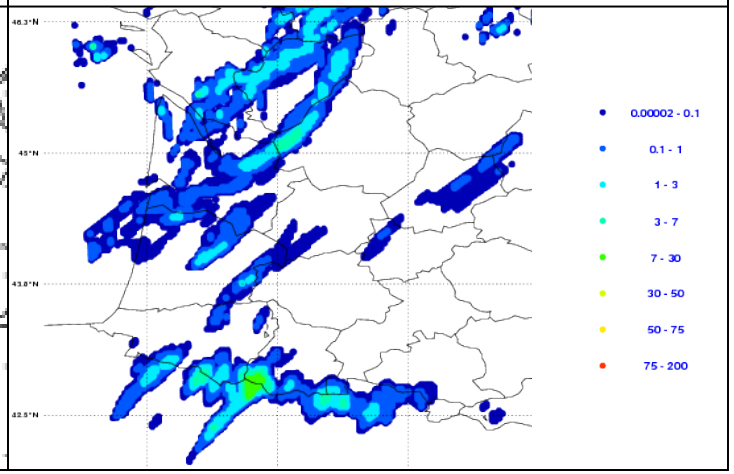
- ICE4 tests : disappointing results : very sensitive to the time step, and too active (small amount of hail but everywhere there is graupel in altitude)

- Despite a lot of sensitivity tests, we did not manage to tune the scheme correctly

=> not ready for operational use

=> We tried to diagnose hail in the model with ICE3 :

1. Compute each time step, vertically integrated graupel content
2. write in output files the maximal value since last file

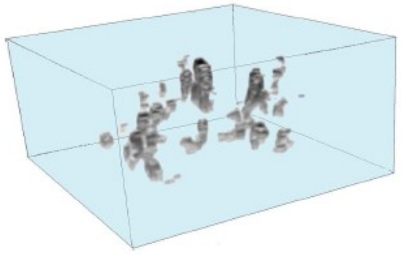
Radar hail diagnostic	AROME hail diagnotic	AROME prognostic hail (ICE4)
		

(Example of 11 May 2009, diag available for forecasters since September 2011)

Positively evaluated from 2009 year

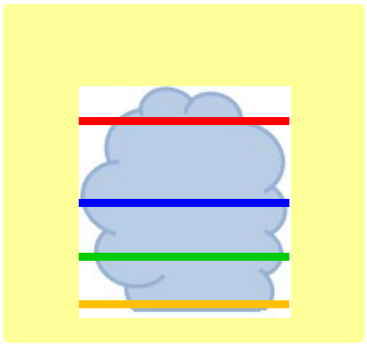
Improvement of the cloud scheme

Saturation deficit distribution

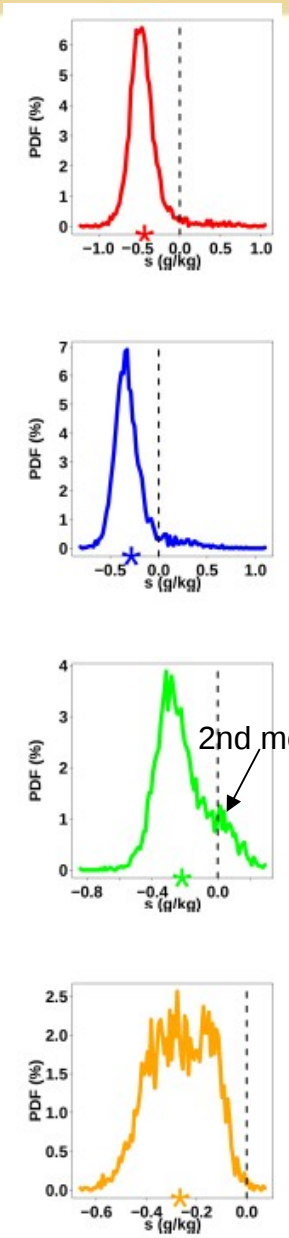


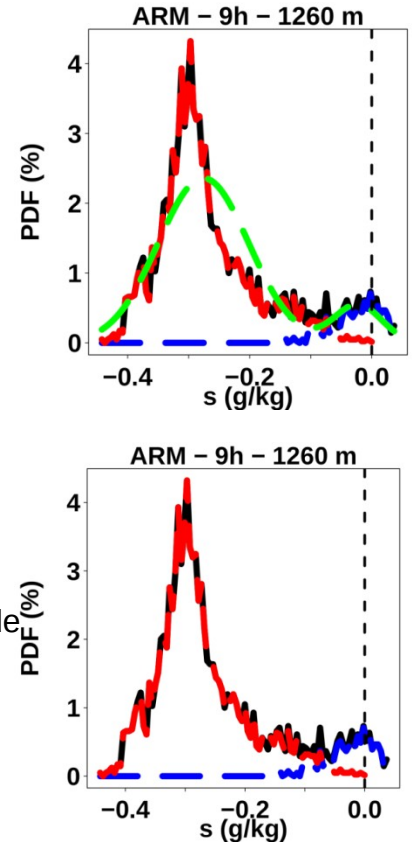
(a) ARM case - 9h

Statistical analysis of BL clouds to characterize the distribution of horizontal subgrid cloud variability



Non symetric bell shaped curves





Conditional sampling (Couvreux et al., 2010)

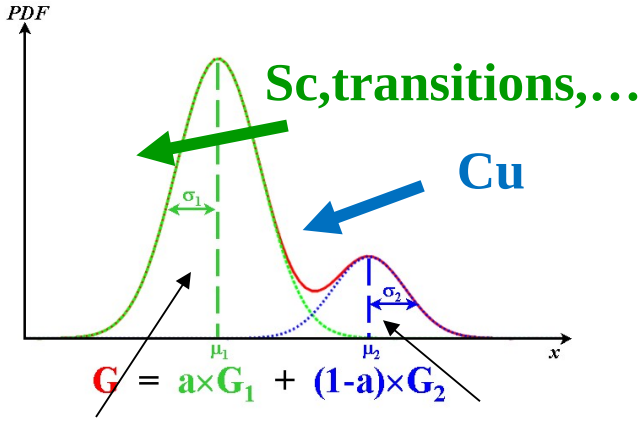
Whole domain
Thermals
Environment (clear sky)

Perraud et al, BLM, 2011

Larson et al (2001), Golaz et al (2002)

Double gaussian

(linear combination of two simple Gaussian distributions)



Turbulence scheme

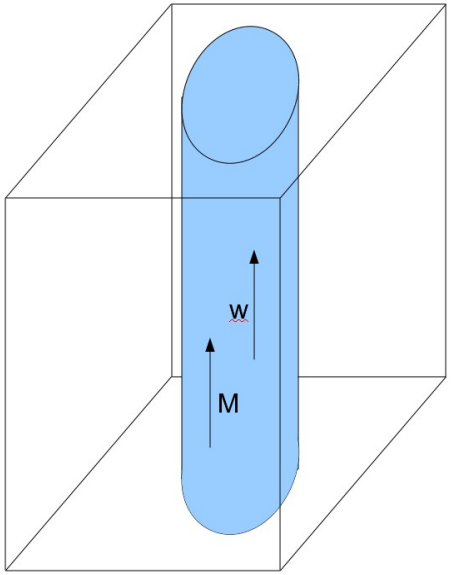
Shallow convection scheme (Pergaud et al., 2009)

Improvement of the cloud scheme

3 options in test in AROME

« DIRECT » (oper)

CF and Rc/Ri are diagnosed directly from updraft variables. (Pergaud et al, 2009)

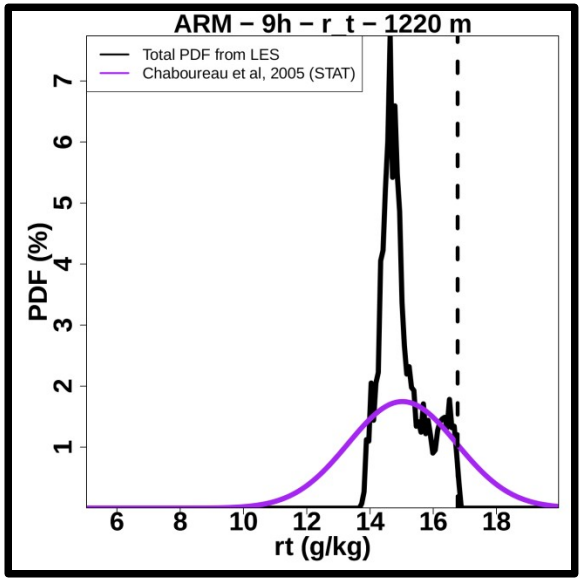


$$CF = \alpha \times \frac{M}{\rho w}$$

Riette et al., to be submitted

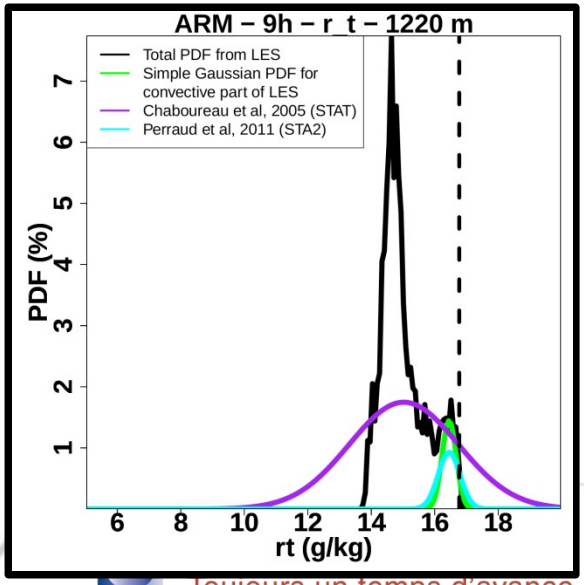
« STAT »

A variance is diagnosed from updraft variables, added to the turbulence one and applied to an uni-modal PDF (Chaboureau et al, 2005)



« BI-GAUSSIAN »

A variance is diagnosed from updraft variables applied to a double-Gaussian PDF with one mode for the environment (turbulence) and one for shallow convection (Perraud et al, 2011)

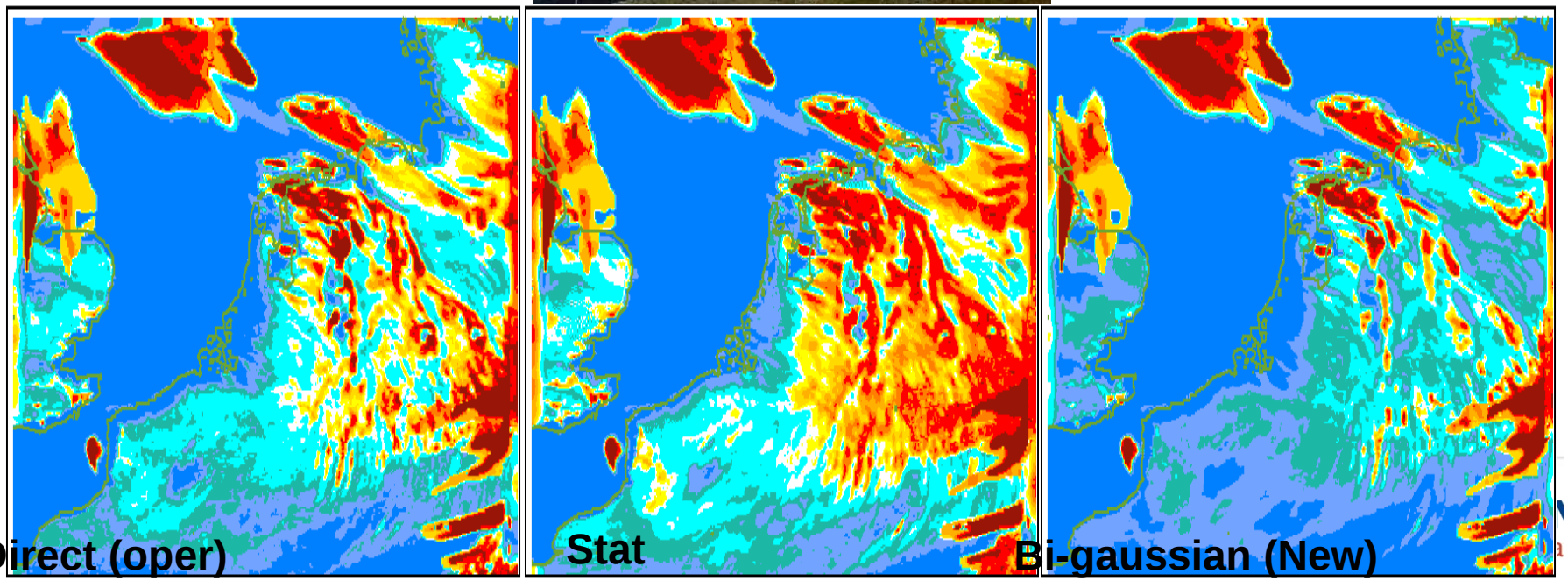


Improvement of the cloud scheme

(9 April 2010 at 12h)

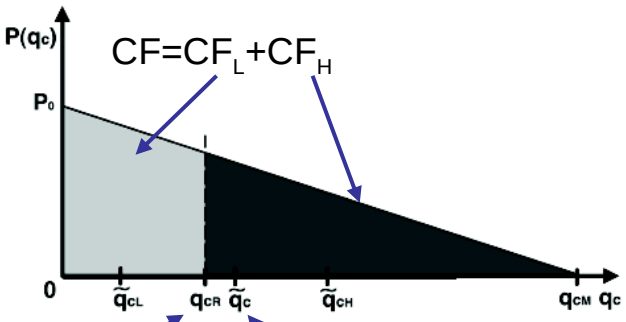
Riette et al., to be submitted

On-going evaluation with soundings and satellite products



Meso-NH : Subgrid rain *Turner et al, GMD, 2012*

To represent the gradual transition from non precipitating to fully precipitating grids

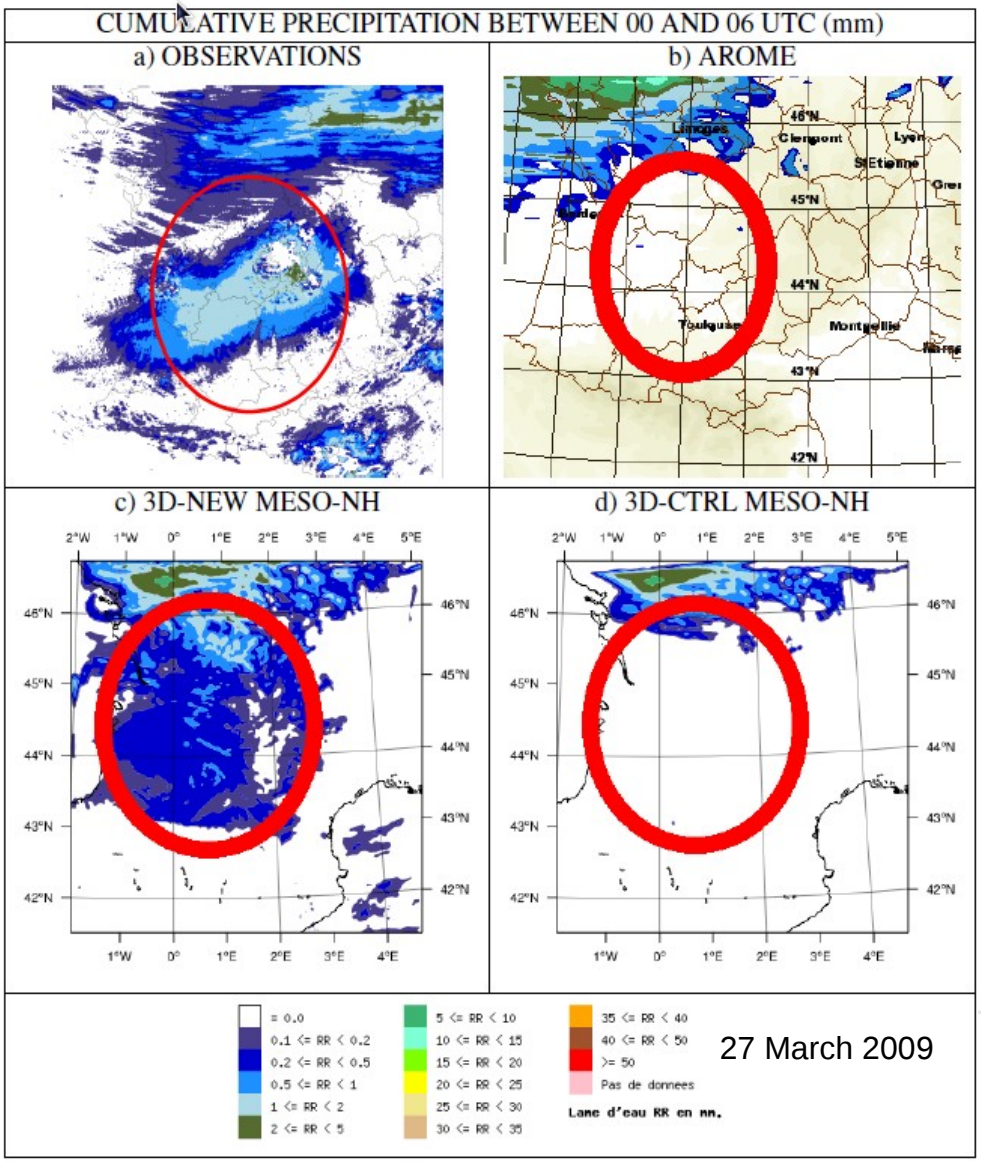


$$\tilde{q}_c = \frac{\overline{q_c}}{CF}$$

Rain fraction : $\tilde{q}_R = \frac{\overline{q_R}}{RF}$ without adding a prognostic variable

Maximum overlap assumption for RF

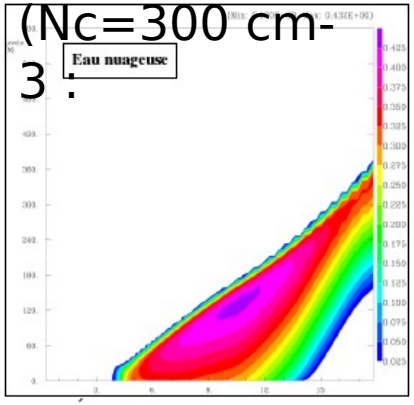
Will be evaluated in AROME in 2013



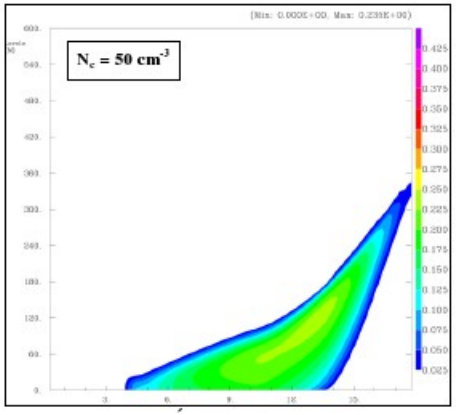
Simulation of polluted/non polluted areas with ICE3 :
Fog case studies of variation of Nc in microphysics and radiation

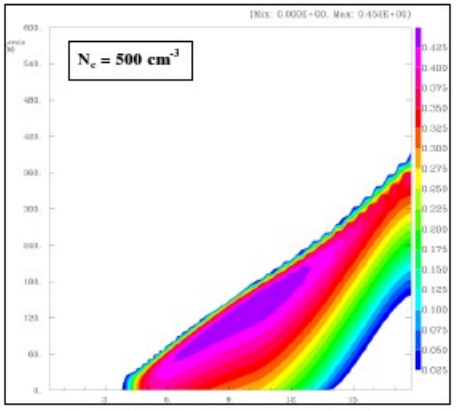
q_c :

ICE3 Ref (Nc=300 cm-3 :



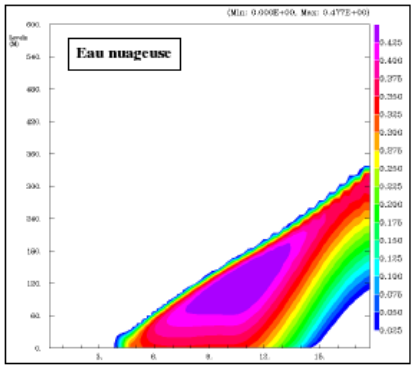
z





time

KHKO (2 moments microphysics scheme):



-The variation on Nc has a significant impact on fog structure (qc content and vertical extent of the fog). The impact is smaller on formation and dissipation times.

-Impact of a more sophisticated 2-moments microphysics scheme is reduced.

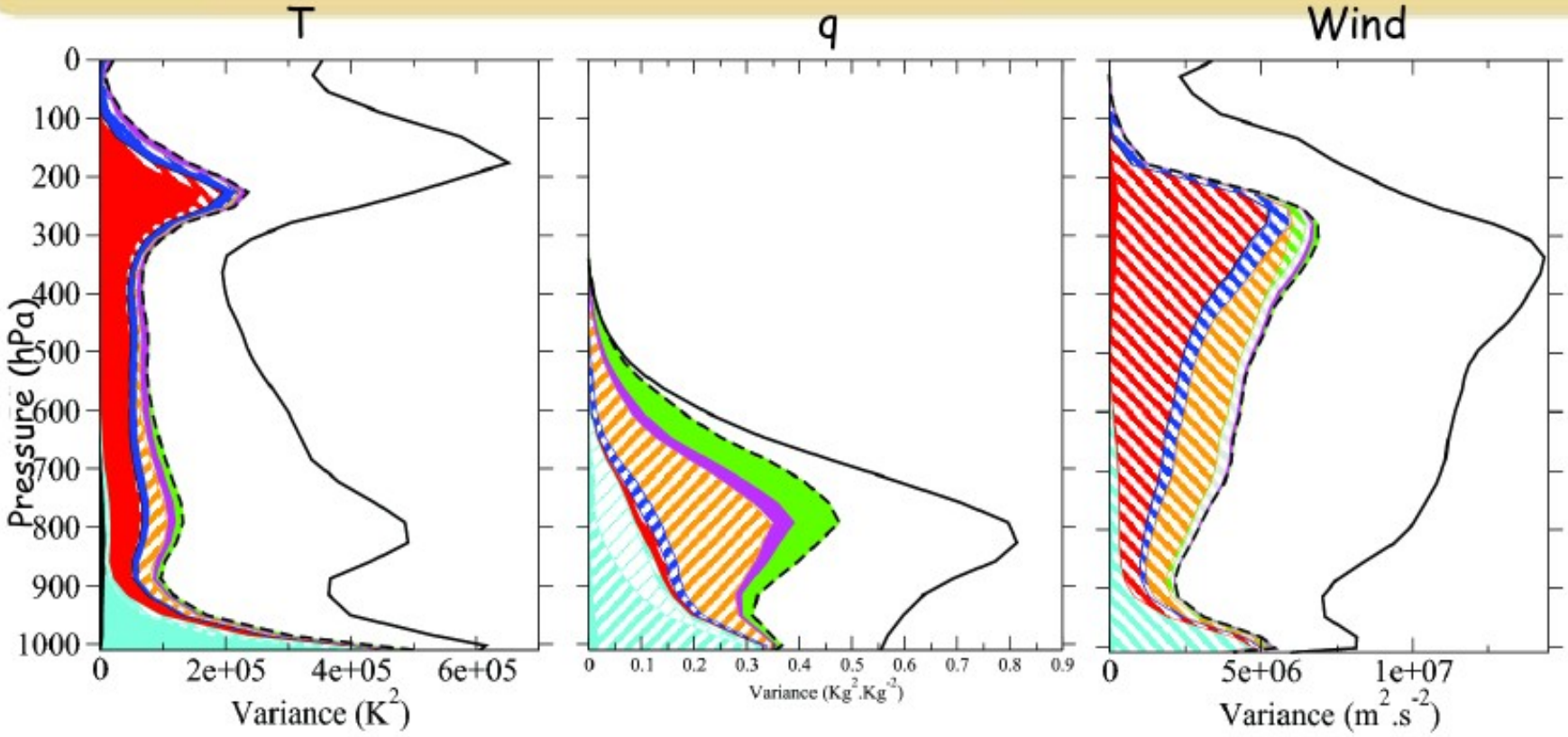
Outlines

- Introduction

- Presentation of AROME-France configuration
- Examples of recent work in physics
- **In data assimilation**

- Perspectives

Diagnosis of the impact of observations in AROME analysis



- Most important parts of *r* are provided by :
  - Surface observations
  - Plane
  - Radar

Increase of the assimilation cycle frequency

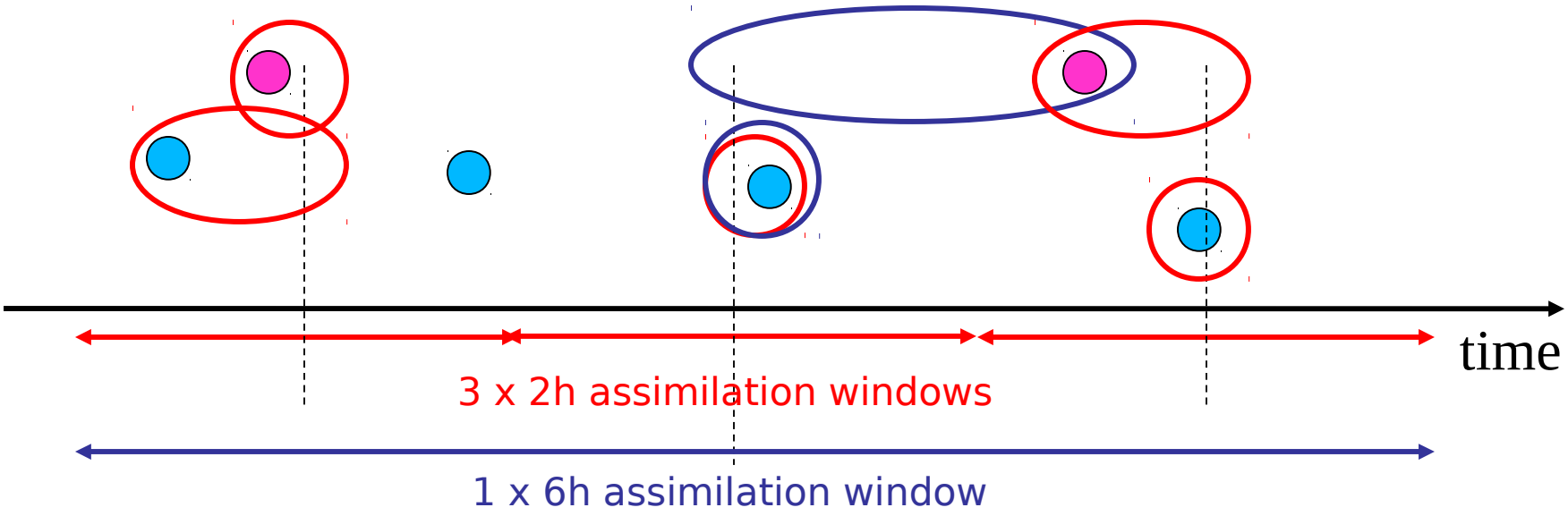
- Weakness of the representation of the temporal dimension in AROME-France data assimilation system (3D-Var) : inefficient use of observations with high temporal and often spatial coverage (radar measurements), which are quite very informative at meso-scale.

- Scheme as 4D-Var or EN-Var could solve this problem but : difficult implementation, important numerical costs.

- 3D-FGAT has been evaluated : allows to compare the observation with the background at the observation time (as in 4D-Var) but assumes the innovation vector to be constant both in time and space during the minimization (as in 3D-Var) :
  - Useful for observations far from the center of the assimilation window
  - Not adapted for static stations with numerous observations along the assimilation window : the different innovations are averaged.

- At short term, increase of the cycle frequency in order to assimilate more observations.

3DVar RUC



- 3D-Var : reducing RUC assimilation window allows to assimilate more observations, and more properly.

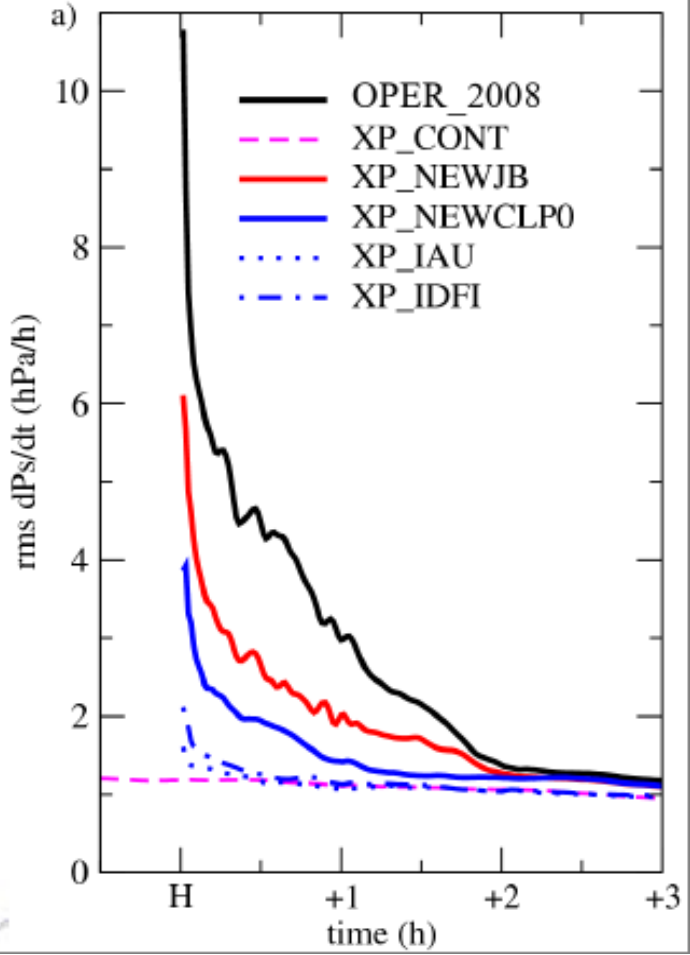
Problem of spin-up

- Spin-up : numerical noise in the first ranges of a model integration.
- Risk of accumulating noises and imbalances through the assimilation cycle decreasing system performances : choice of a 3-h period for the AROME-France operational cycle.
- Some sources of imbalance have been identified and reduced

  - Imbalances in the 3D-Var increment : the use of a new B matrix (Brousseau et al. 2011) more representative of small scales allows to reduce it substantially (XP_NEWJB). This B is estimated with forecast differences from an AROME-France assimilation ensemble instead of forecast obtained in dynamical adaptation (operational since April 2010).

  - Inconsistency at initial time between LBC (ARPEGE analysis) and the initial state (AROME analysis) : the use of the AROME analysis as LBC also allows to reduce spin-up in the first hour (operational since November 2011).

- Residual spin-up can be reduced using filtering methods as Incremental Digital Filter Initialization or Incremental Analysis Update

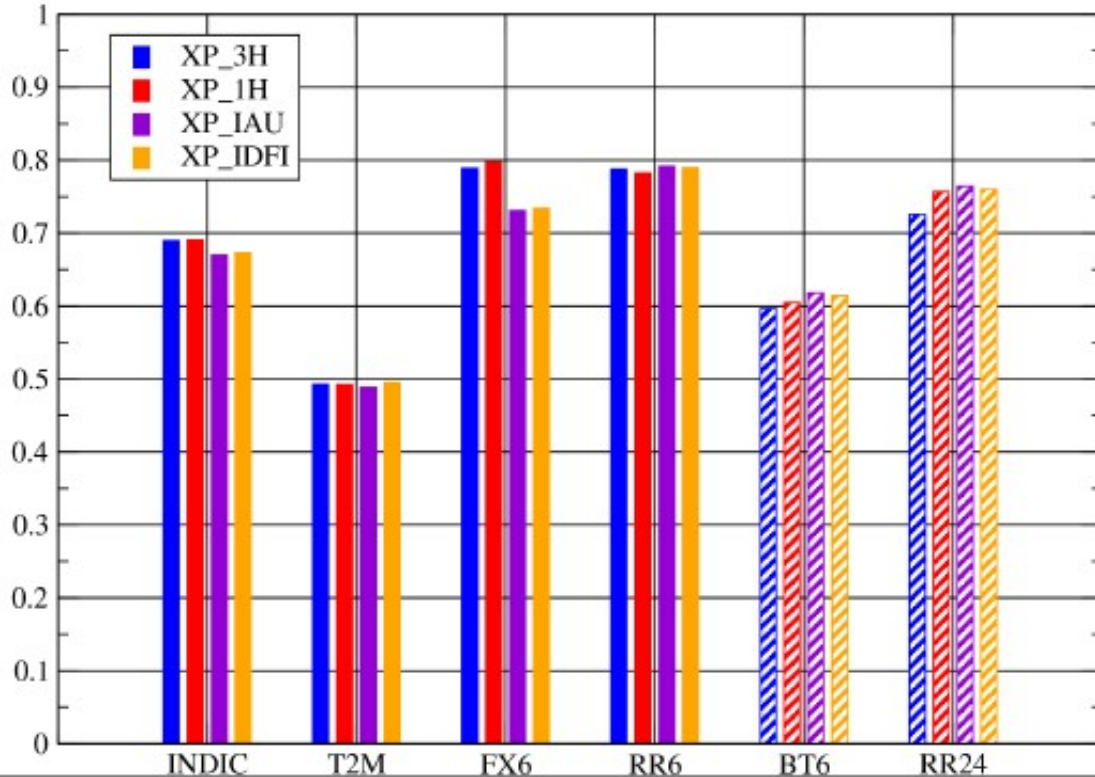


1-h/3-h cycle comparison : composite indicator

- 1 month experiment
- Composite score composed by normalized RMSE of T2m and Brier Skill Scores of maximal wind gust and 6h cumulative precipitations with a tolerance of 50 km averaged
  - for 6, 12, 18 and 24-h forecast ranges
  - For different excess thresholds
- BSS of brightness temperature of 10.8 µm SEVIRI channel
- BSS of 24-h cumulative precipitation (6-30h ranges)

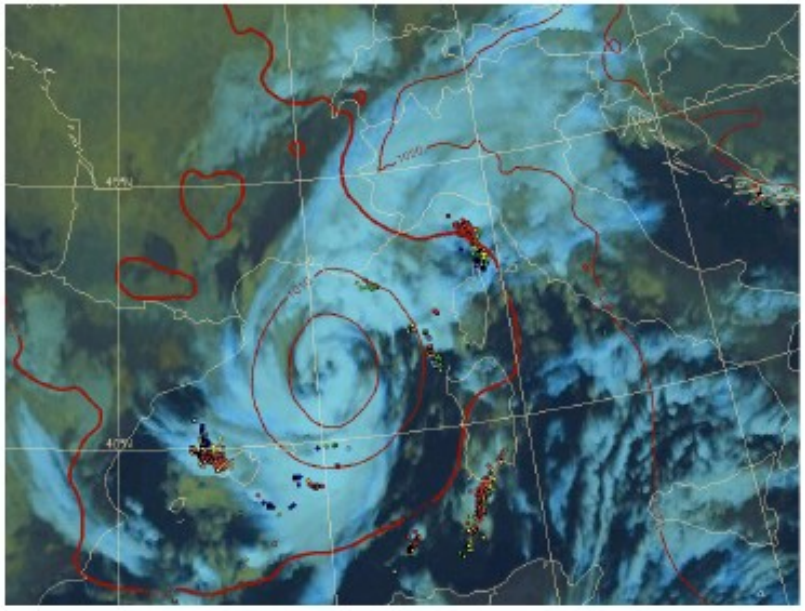
- Improvements, except for T2m (neutral) and RR6 (deterioration at 6 and 12-h forecast ranges, while other ranges are improved).

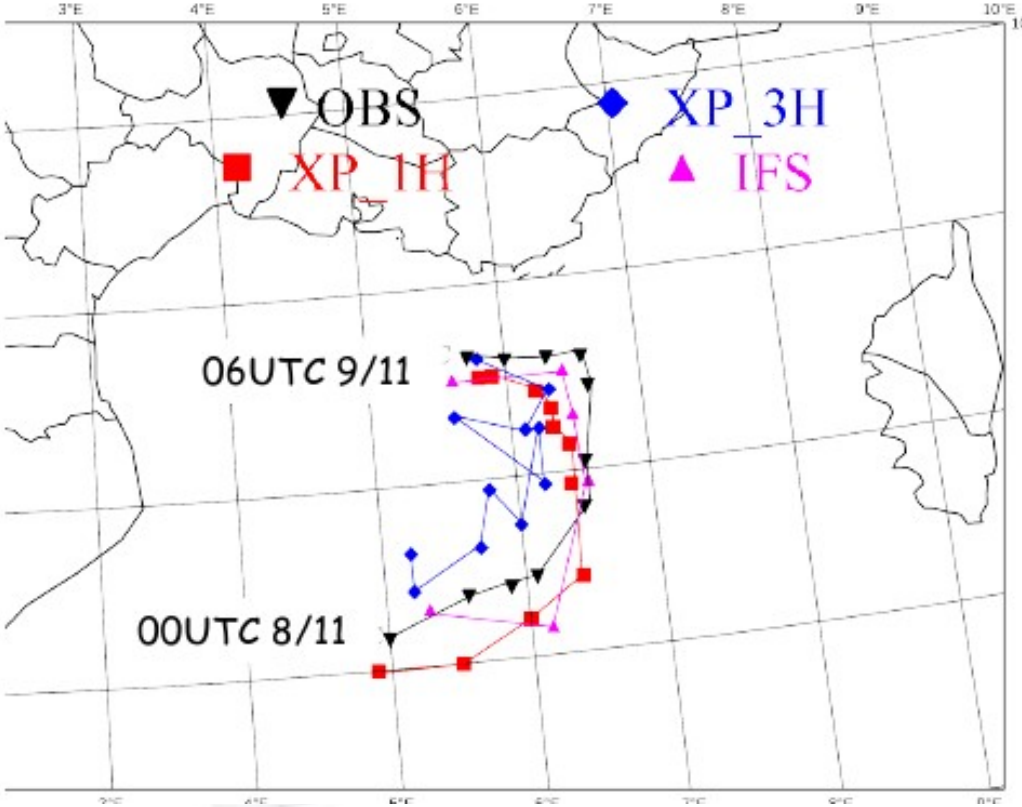
- The use of the 2 filtering methods do not correct this problem and leads to a deterioration of wind scores



7-9 November 2011 case study

- Tropical-like Mediterranean Storm
- Location of the pressure minimum estimated from MSG images and analyzed by AROME-France 3-h and 1-h assimilation cycle (each 3-h from 00UTC the 8/11 to 06 UTC the 9/11) and IFS (each 6-h) :
  - Both data assimilation systems using more observations (IFS with 4D-Var and AROME-France with a 1-h assimilation cycle) are able to analyze a trajectory spatially and temporally consistent with the observation
  - The 3-h cycle analyzed trajectory is more erratic.





Perspectives

By 2014 (thank to our new Bull machine) :

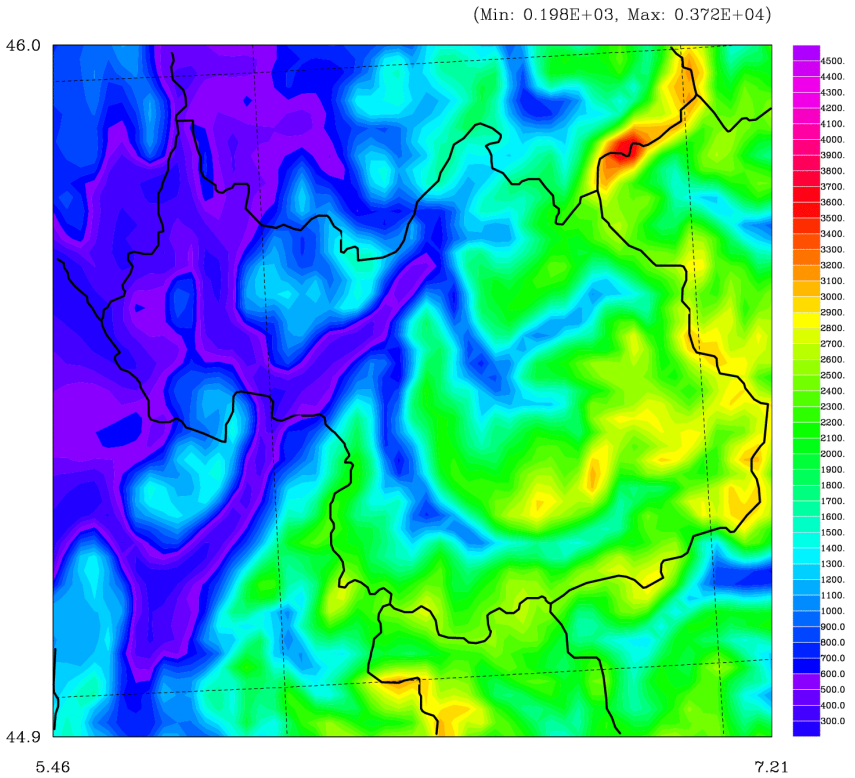
- Deterministic AROME 1.3 km
- Ensemble forecasts at 2.5 km (~10 members)

Plans for 2014 : AROME 1.3 km

- AROME : Dx~1.3 km x ~L90

OPER ZOOM Savoie
Relief

Zoom_Savoie_2.5km :

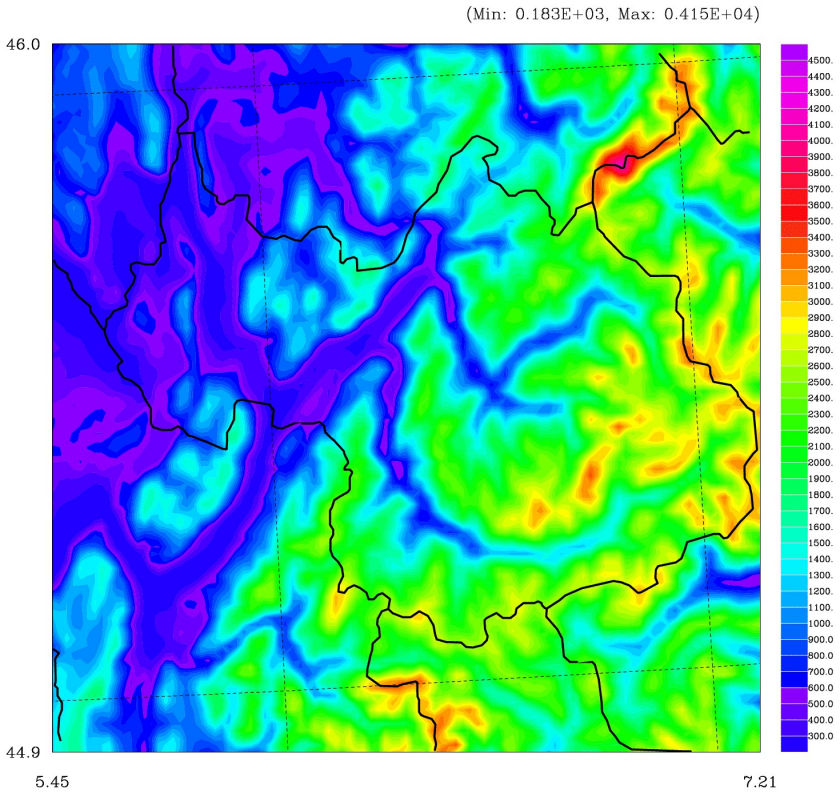


PROJECTION LAMBERT

25/02/11 09H34M50
PGDFILE-FRAM

1.3km ZOOM Savoie
Relief

Zoom_Savoie_1.3km :



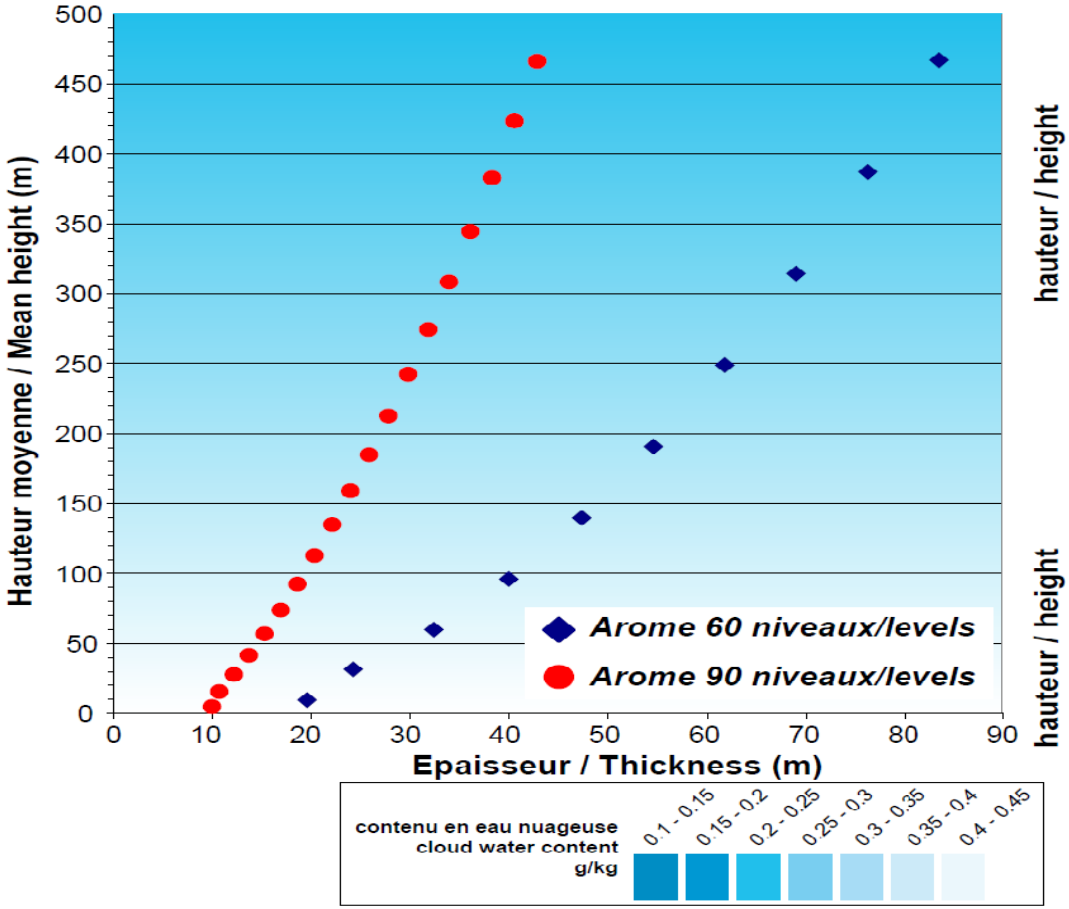
PROJECTION LAMBERT

25/02/11 09H40M22
PGDFILE-BRET 46.dia

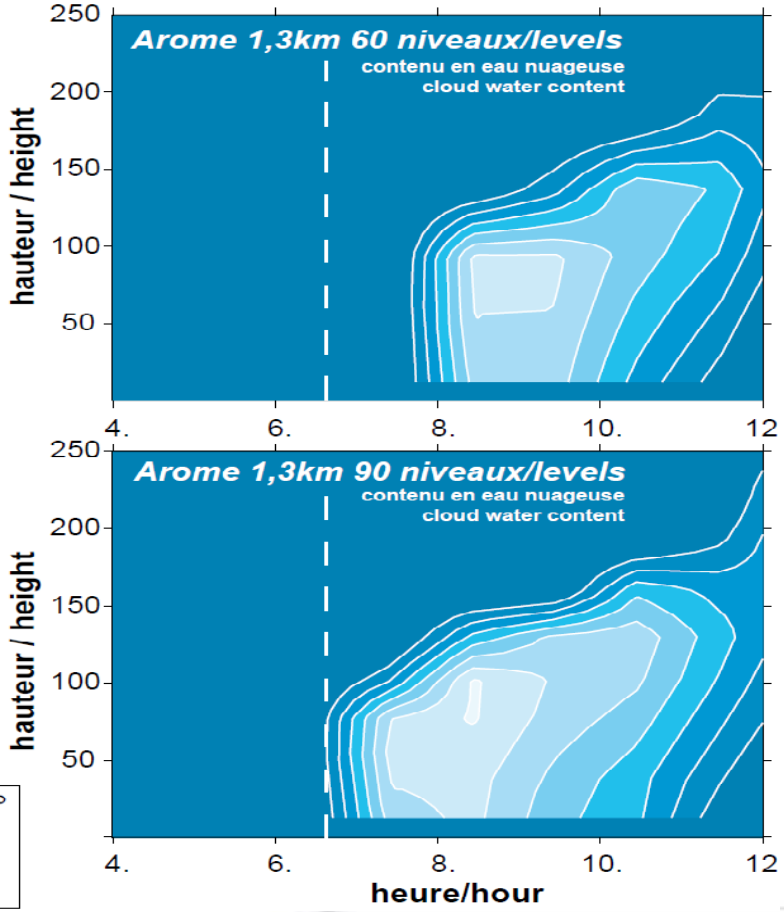
ZS M

Vertical resolution

Vertical resolution near the surface



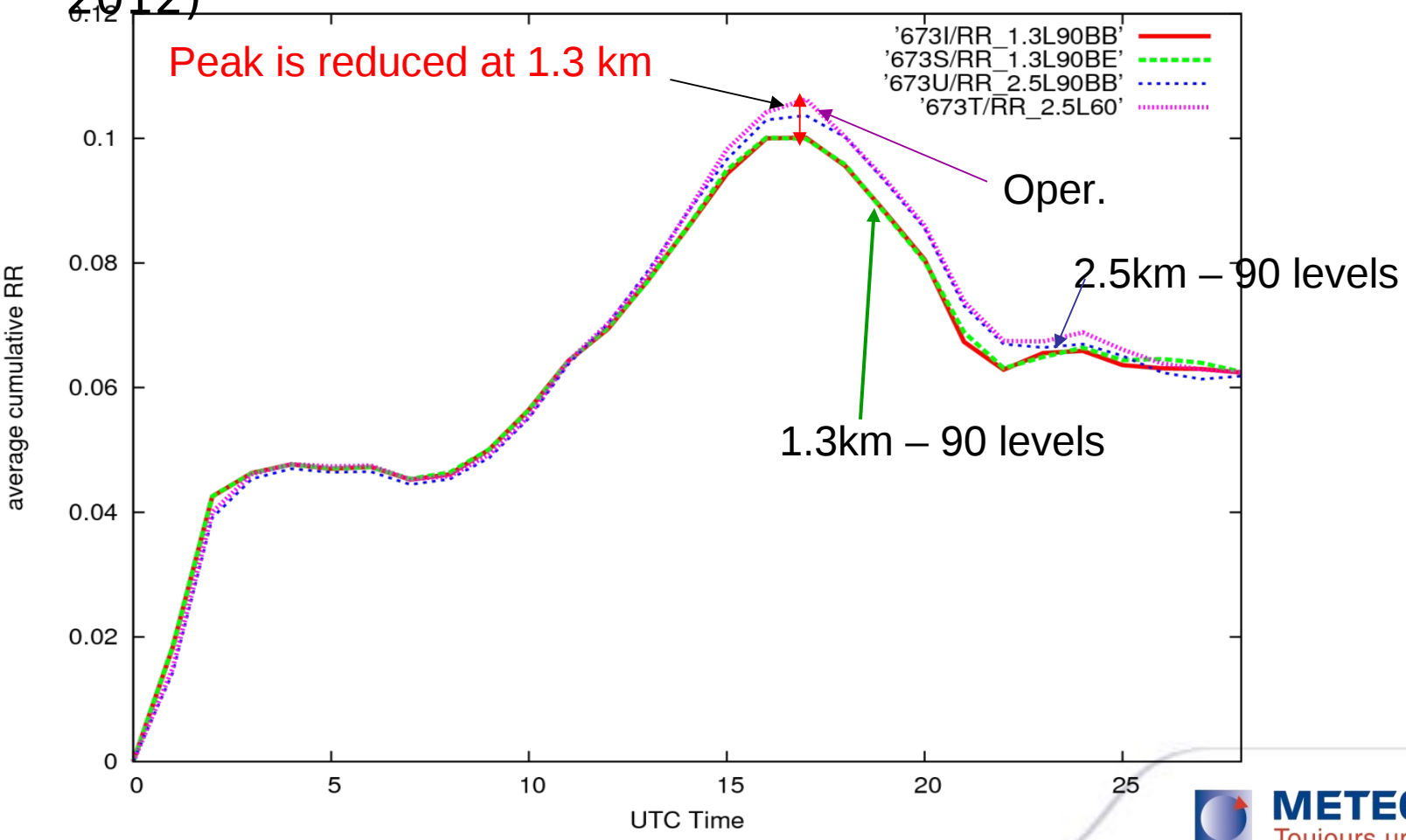
Arome forecasts over Roissy from operational analysis 20101115r18



Firsts results from AROME 1.3km

Planned to be oper in 2014

Evolution of mean hourly cumulated rainfalls over France (JJA 2012)



METEO FRANCE
Toujours un temps d'avance

Overview of current developments in AROME-France convective scale operational model

Y. Seity, C.Lac, F. Bouyssel, Y.Bouteloup, S.Riette, V.Masson, F.Beucher, P. Brousseau, E. Wattrelot, T. Montmerle