

AROME : a high resolution model for NWP

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E. Bazile, S. Riette, F. Bouttier...

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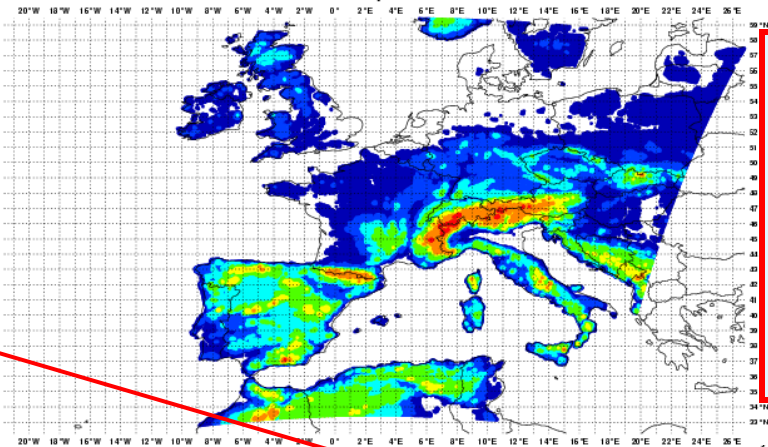
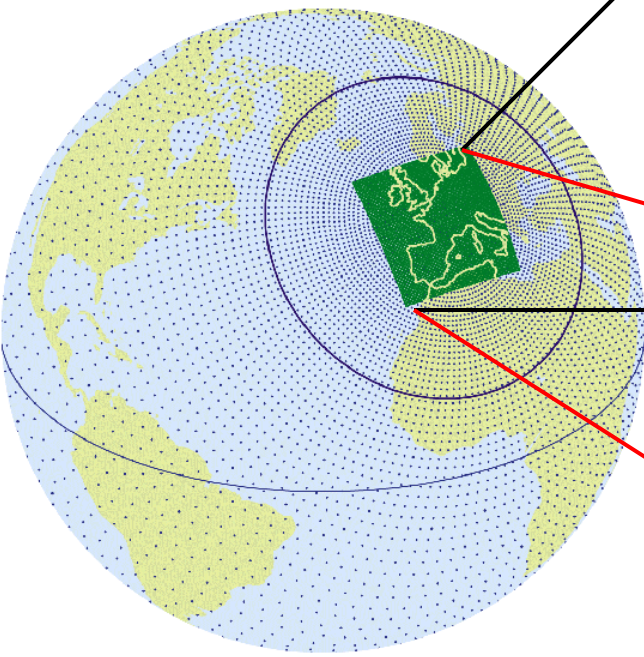


MÉTÉO FRANCE
Toujours un temps d'avance

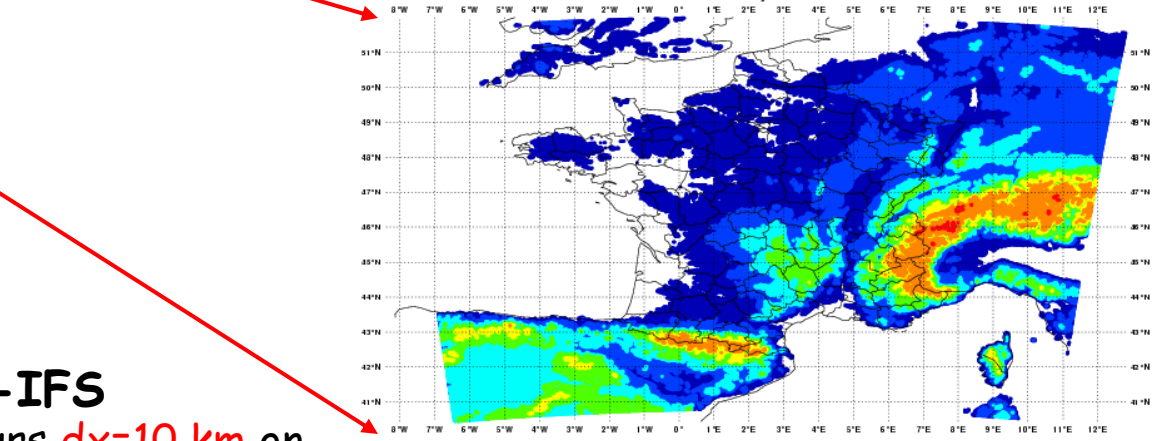
Outline

- The NWP system at Météo-France : the global model ARPEGE and the Limited Area Models: ALADIN and AROME
- AROME : a convective scale operational model (Y. Seity et al, submitted)
- Objective evaluation: QPF, clouds ...
- Impact of the tunings of the HD in AROME
- Perspectives ...

Operational Weather forecasting at Météo-France: ARPEGE/ALADIN and AROME



ALADIN :
54h h forecasts
every 6h
dx=7.8 km,
70levels,
time-step=450s (SL)
3DVar Data
Assimilation system



Cloud Resolving Model AROME
30 h forecasts every 6h
dx=2.5 km, 60 Levels, **time-step=1mn** (SL)
3DVar Data Assimilation system (RUC3h)

Global ARPEGE-IFS

4-day forecasts every 6 hours **dx=10 km** on
France, **55km** on Australia **dt=10mn**
Stretching factor **c=2.4** and turning of the pole
over the zone of interest
Stretched vertical grid with **70 levels**
4DVar Inc Data Assimilation system
(T107 25iter and T323 30iter dx=60km)



AROME: operational since December 2008

Seity et al. 2010 submitted

- **AROME**: Applications of Research to Operations at MEsoscale
- expected to improve **heavy precipitation forecasts** (among other features) with strong emphasis on Mediterranean flash-floods, fog, etc ...
- claim of originality : **efficient numerics** ($dt=1mn$ @ $dx=2.5km$) and **advanced data assimilation**: **3D Var with mesonets, radars (Doppler wind and reflectivities)**
- **dynamics**: NH 'Laprise' compressible, spectral semi-implicit semi-Lagrangian dynamics on terrain-following mass vert. coordinate
- **physics**: 5-species prognostic cloud microphysics, TKE mixing, subgrid shallow convection, RRTM/FM ECMWF radiation
- **interactive soil/town/biosphere/ocean & chemistry/aerosols modules**: **SURFEX**
- **ECOCLIMAP** physiographic database
- **software** directly derived from ECMWF's IFS, the ARPEGE/ALADIN models & assimilation, the Mésos-NH physics
- a cooperation of the **ALADIN & HIRLAM** European consortia

PHYSICS in ARPEGE/ALADIN/AROME

	ARPEGE (10km to 55km)	ALADIN 7.5km	AROME 2.5km
Surface	ISBA (Noilhan, Planton (89), Giard Bazile (2000))		SURFEX With ISBA, TEB, Ecume, etc
Turbulence	TKE (Cuxart et al 2000)		
Mixing length	Bougeault Lacarrere (89)		
	Modified by the shallow cloud thickness and deep convection		
Shallow Convection	KFB (Bechtold et al 2001)		PMMC09 (Pergaud et al 2009)
Deep Convection	Moisture Convergence (Bougeault 85)		Explicitly resolved
Clouds (PDF)	Smith (90)		Bougeault (82)
GWD	Described in annexe of Catry et al. 2008		no
Microphysics	Ql, Qi, Qr, Qs Lopez(2002) Bouteloup et al (2005)		Ql, Qi, Qr, Qs, Qg Pinty and Jabouille 1998
Radiation	RRTM for LW (Mlawer et al. 1997) and Morcrette et al. 2001 for SW (6b)		

SURFEX

- 4 tiles : Sea, Water, Towns and Nature. 2 levels inside the soil for T, 3 for hydrology.

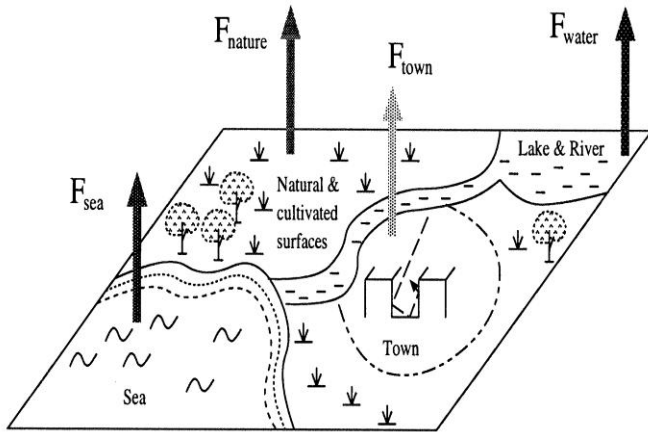
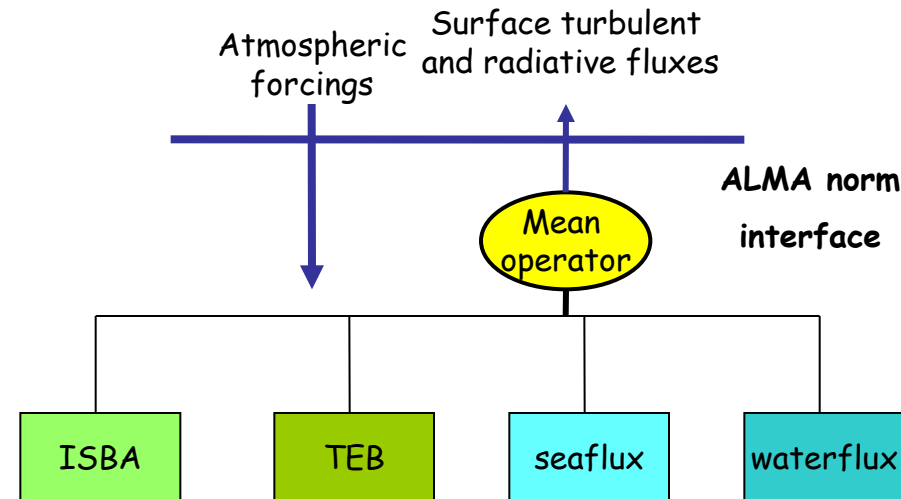
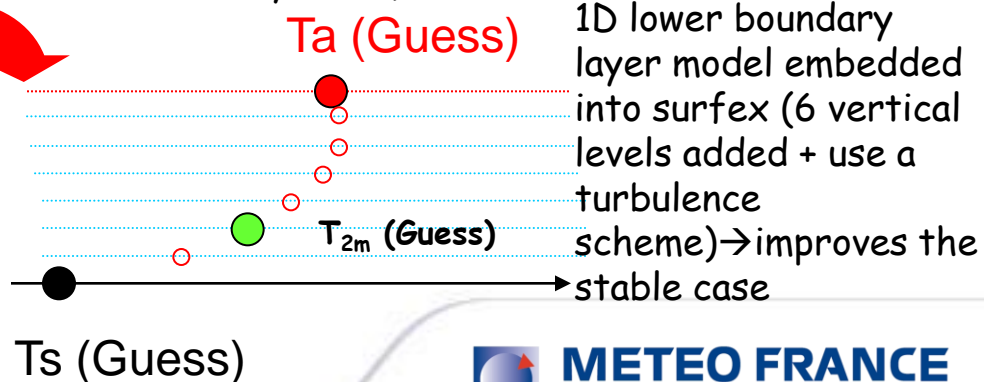
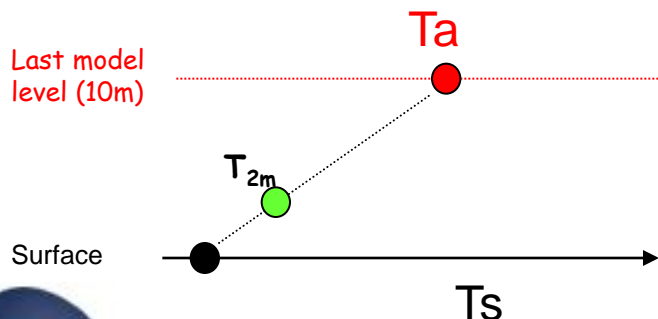



Figure 15.1: Partitioning of the Meso-NH grid box, and corresponding turbulent fluxes. F stands either for M (momentum flux), H (sensible heat flux), LE (latent heat flux), S^\uparrow (the reflected solar radiation) or L^\uparrow (the upward longwave radiation).



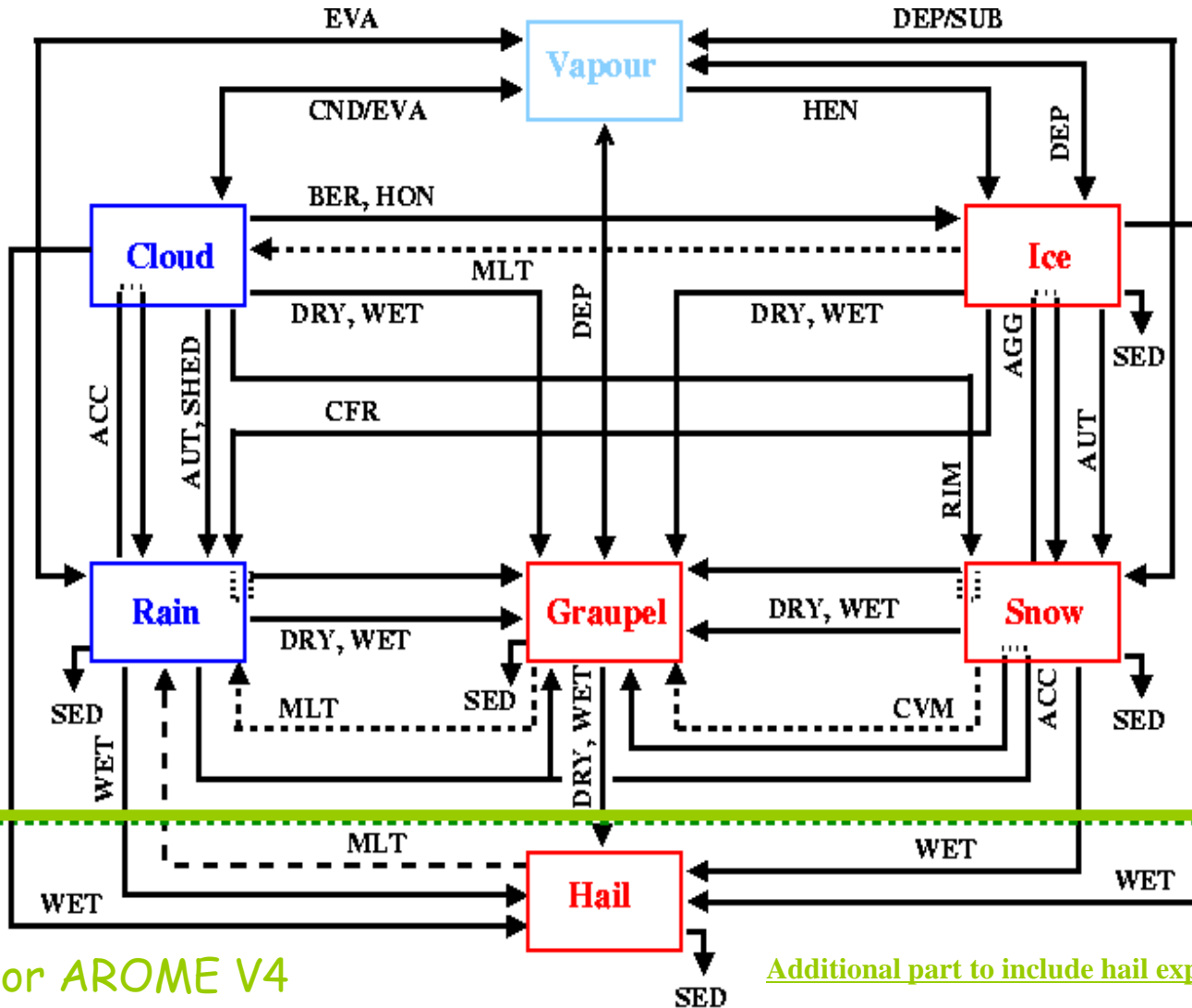
CANOPY (Masson and Seity 2009)



1D lower boundary layer model embedded into surfex (6 vertical levels added + use a turbulence scheme) → improves the stable case

 T2m, Rh based on dry static energy (Geleyn,88)

Microphysics



For AROME V4

Additional part to include hail explicitly

Turbulence and shallow convection

EDMF concept proposed by Siebesma and Teixeira, (2000) and Hourdin et al., (2002) and Soares et al., 2004

$$\overline{w'\psi'} = -K \frac{\partial \psi}{\partial z} - M(\psi - \psi_{updraft})$$

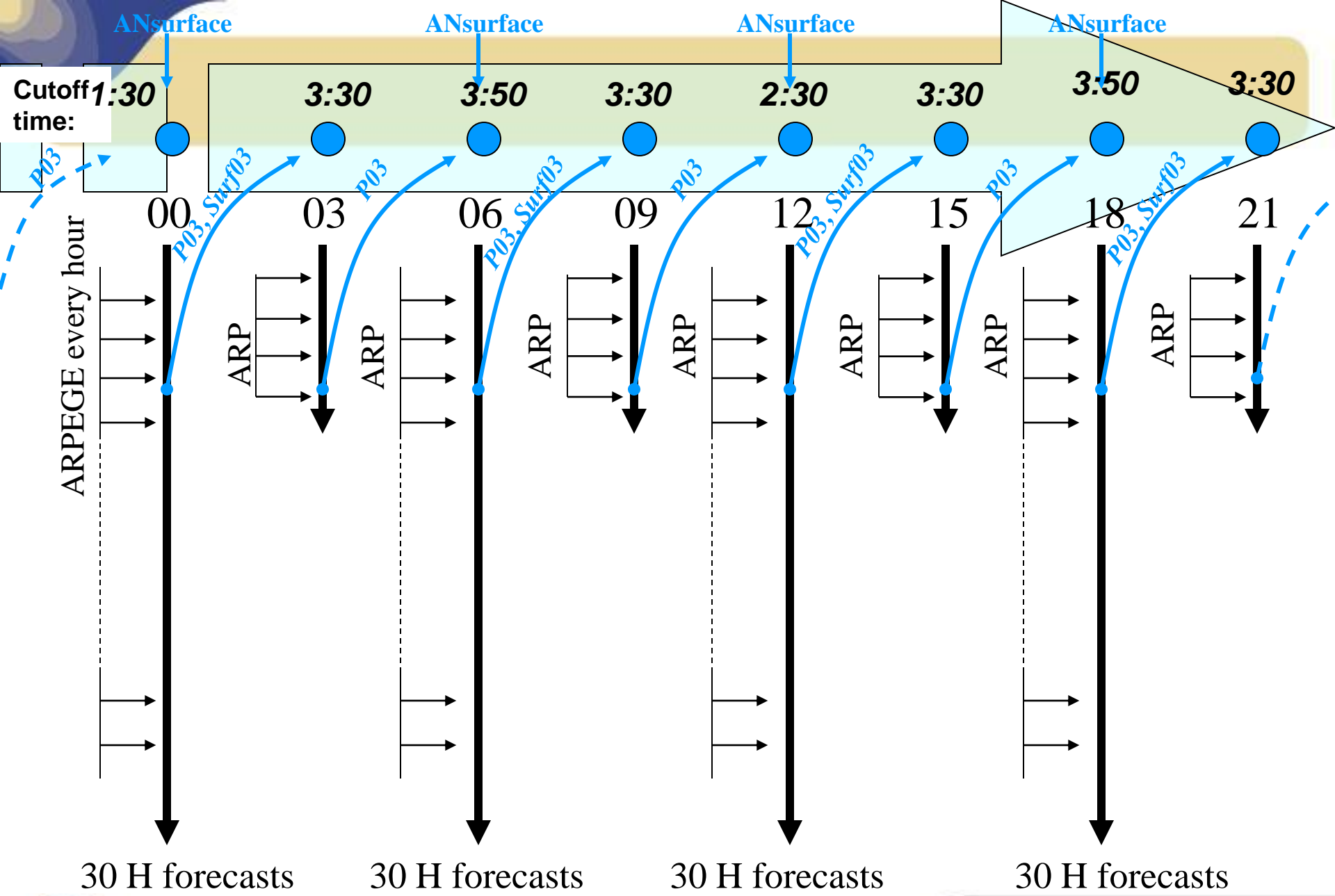
TKE Scheme CBR(2000), BL(89), F0,F1 :
Bougeault (81),
F2 et I3 Bougeault(82) and Bechtold(95)

PMMC09 Shallow convection
Pergaud et al 2009

$$K_u = \alpha_u \cdot l \cdot \sqrt{e_T}$$

$$\frac{\partial \bar{e}_T}{\partial t} = advect + P_d + P_\theta - \frac{\partial \overline{w'e_T}}{\partial z} - c_\varepsilon \frac{\bar{e}_T^{3/2}}{l_\varepsilon}$$

- w equation is used to stop the updraft
- σ : the fractional updraft area, deduced from w and MF equation, can vary vertically
- ε , δ depend on buoyancy and w in the PBL and come from Kain & Fritsch for the cloud
- Momentum mixing with effect of pressure perturbations from Gregory et (97)



RUC 3h, with +30h forecasts every 6h



METEO FRANCE
Toujours un temps d'avance

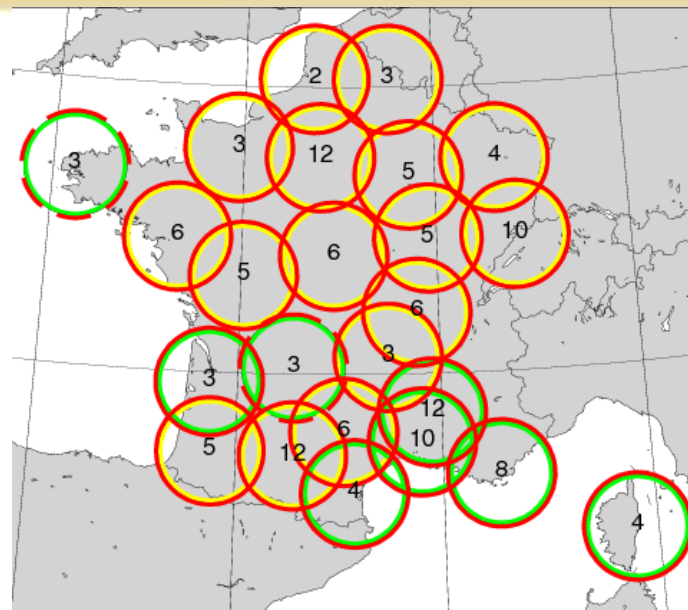
And assimilation part :

- Radar reflectivities Z :

24 radars: 16 C-band (yellow) +

8 S-band (green). Volumic Z

(from 2 to 13 elevation)



- Satellite Obs :

- As in ARP/ALD (radiance density 250-→125km)

- AIRS/IASI

- New Jb calculated from an ensemble of AROME assimilations

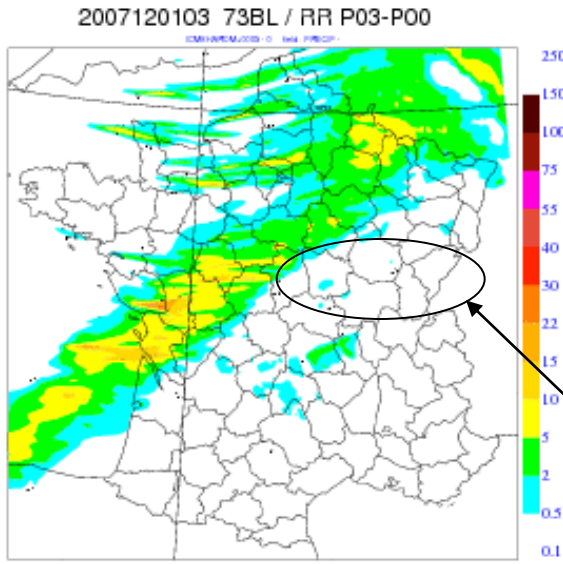
- Day to day gridpoint Sigma B provided by ARPEGE ensemble assimilat

- vorticity, divergence, temperature, Ps

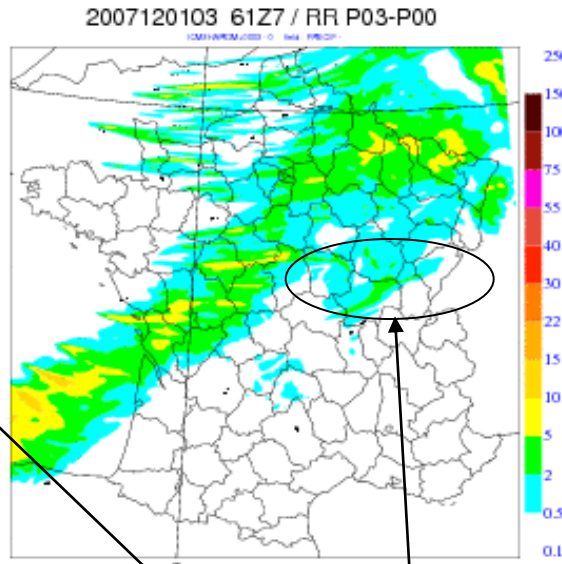
One cycling more: r03 – 4 cycling

3h - cumulated rain - P3-P0

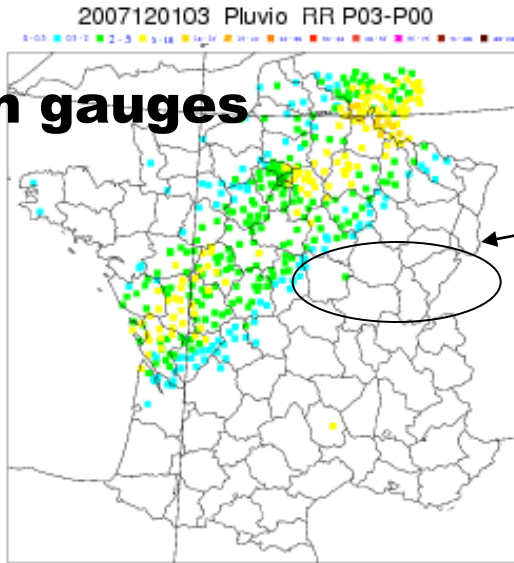
With REFL



Without reflectivity assimilation



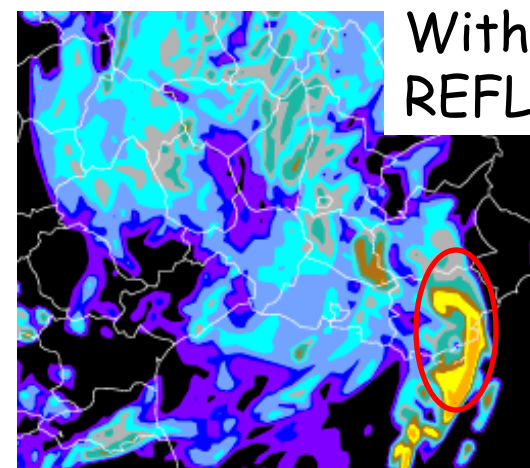
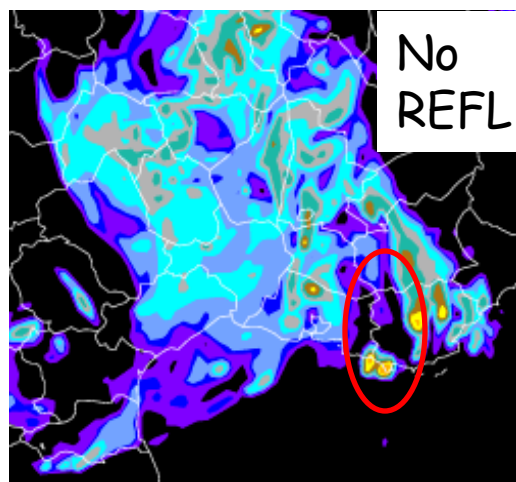
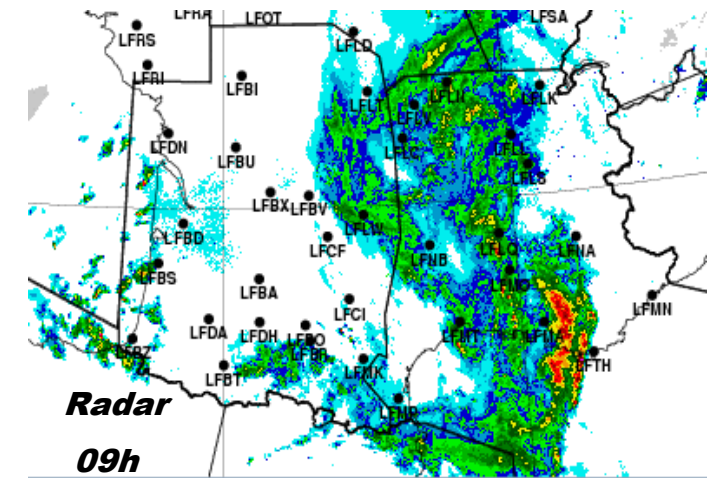
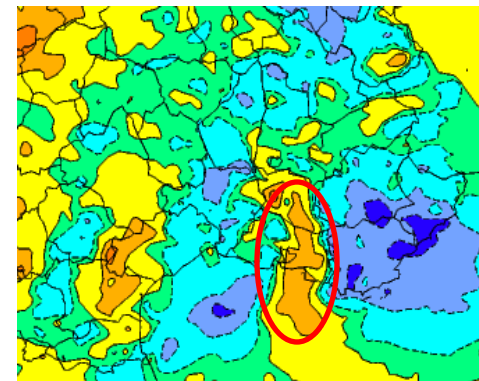
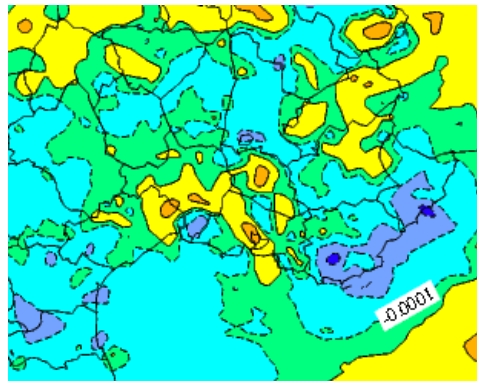
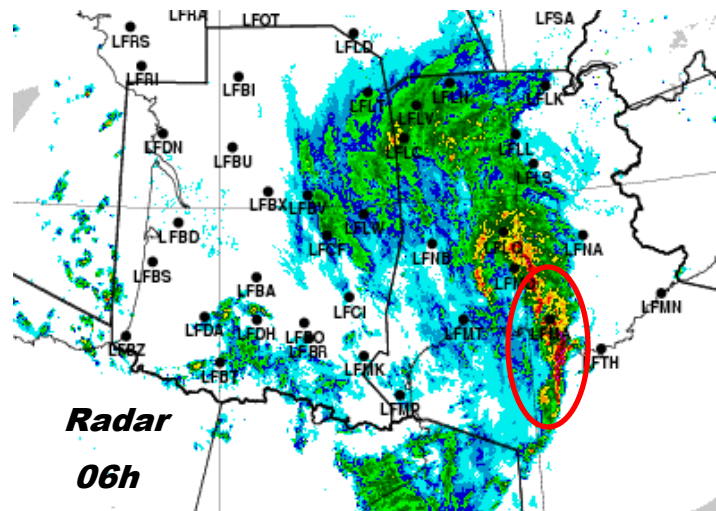
rain gauges



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

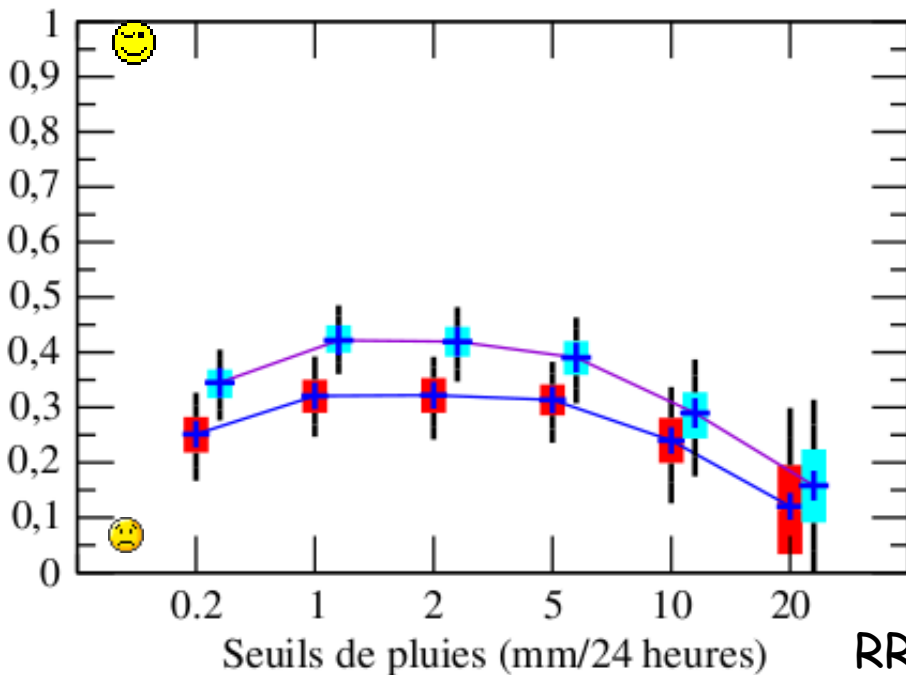
Squall line 8 October 2008



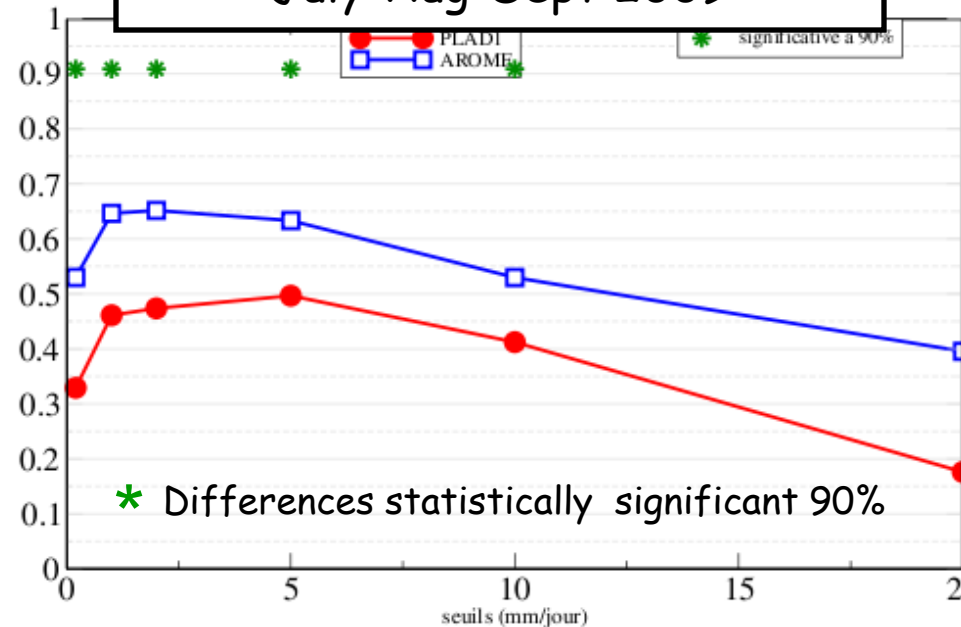
Objective evaluation for RR

Heidke Skill Score
July-Aug-Sept 2009

— AROME
— ALADIN



BSS_SO = Brier Skill Score
on a Single Observation
July-Aug-Sept 2009



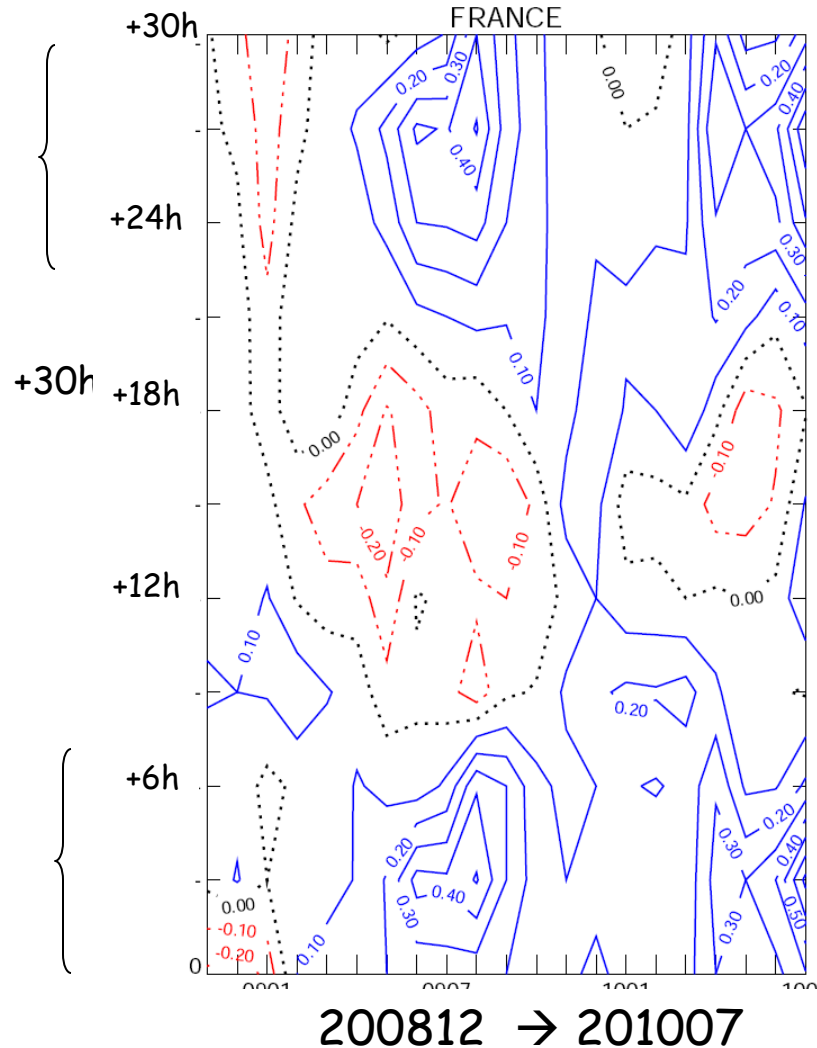
Deterministic and fuzzy verification methods for a hierarchy of numerical models
 Amodei and Stein, Meteorol. Appl. 16: 191-203 (2009)

Objective evaluation for T2m

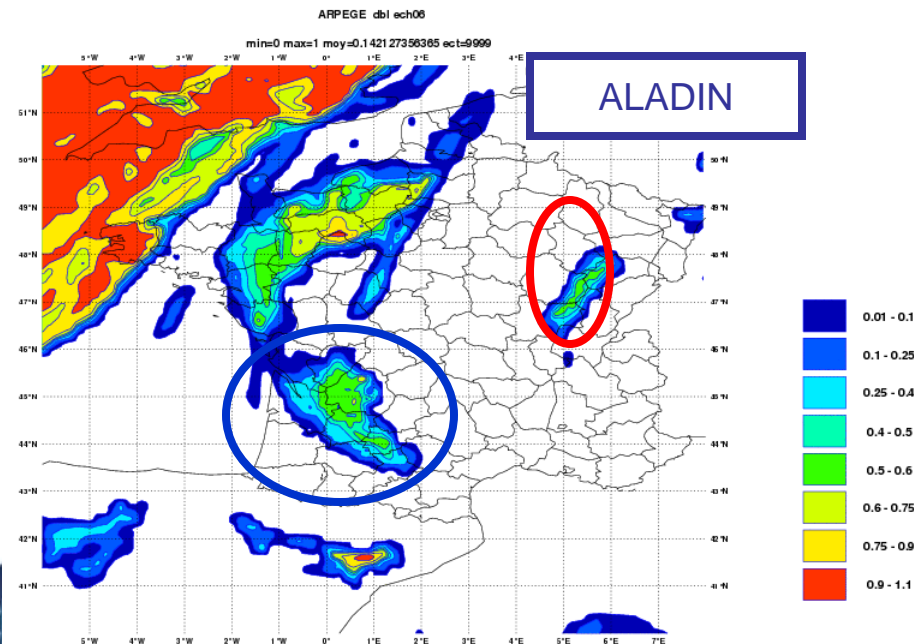
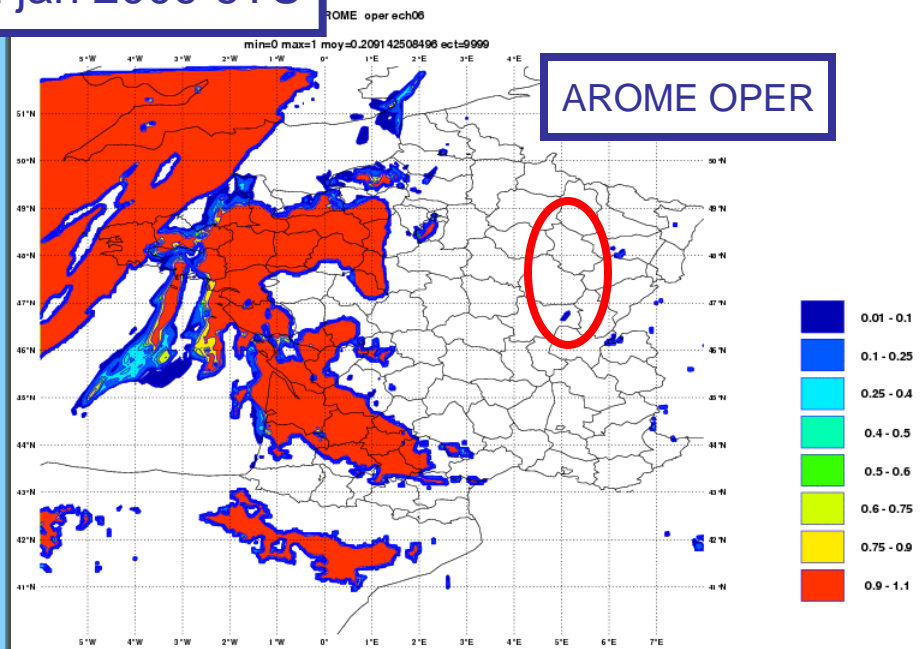
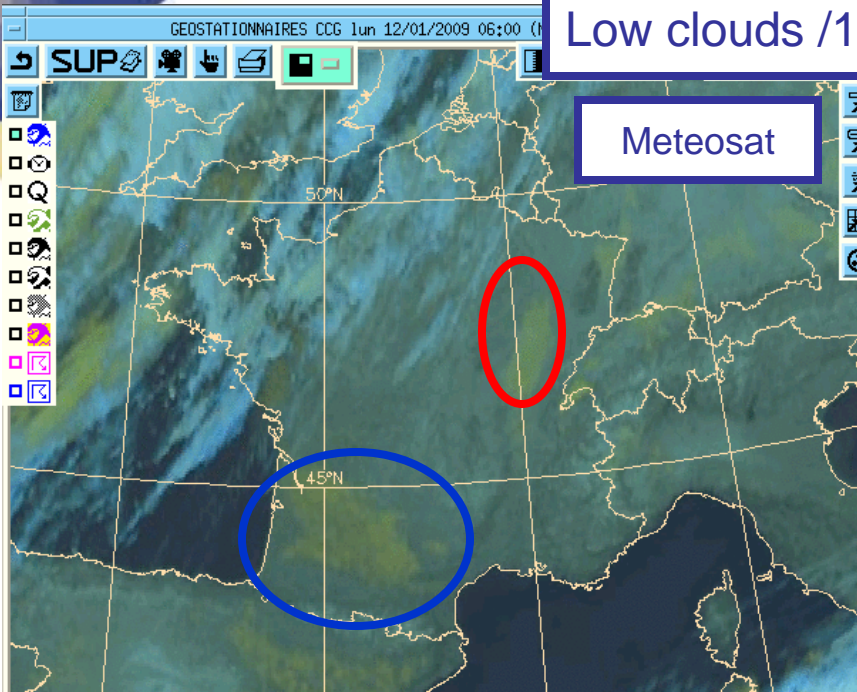
CANOPY impact

AROME is better in blue
RMS ALADIN - RMS AROME

CANOPY impact

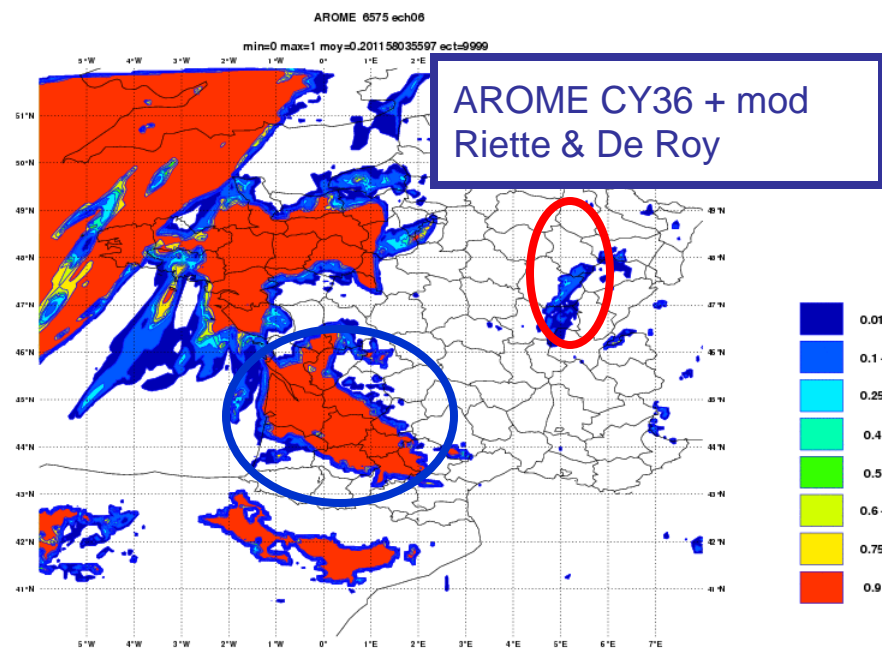
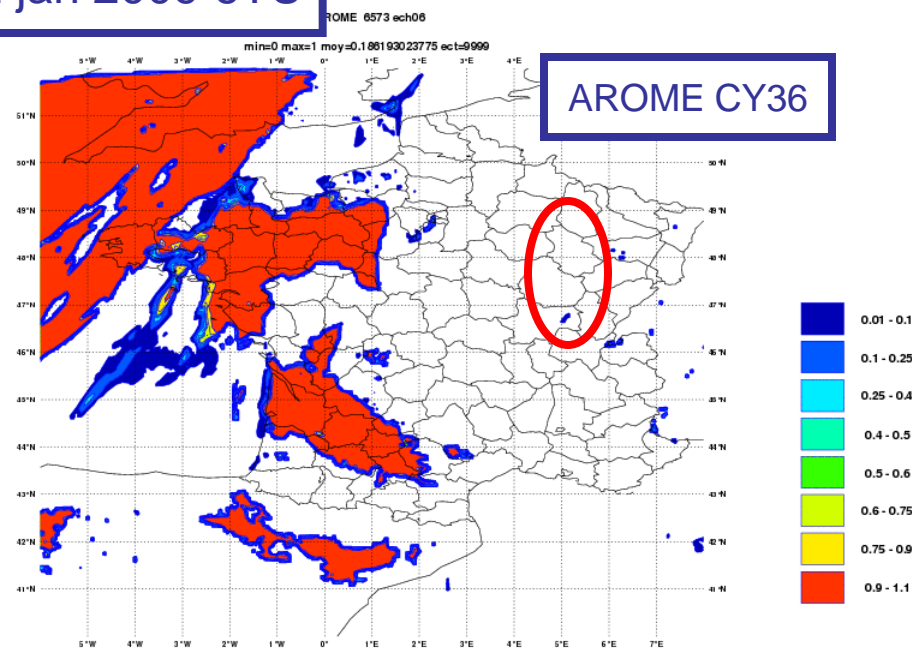
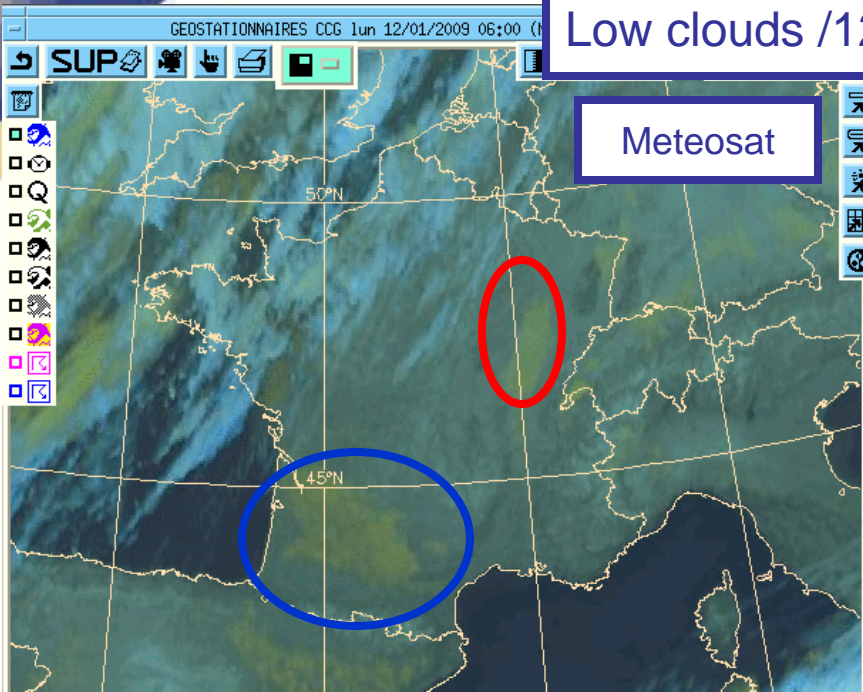


Low clouds /12 jan 2009 6TU



From forecasters point of view, the main drawback in AROME concerns low clouds and in a less extend a too binary cloud cover

Low clouds /12 jan 2009 6TU



In oper:

- PDF (sigma_turb) → Qc, CC
- Shal. Conv → Qc_shal, CC_shal

With Riette & De Roy

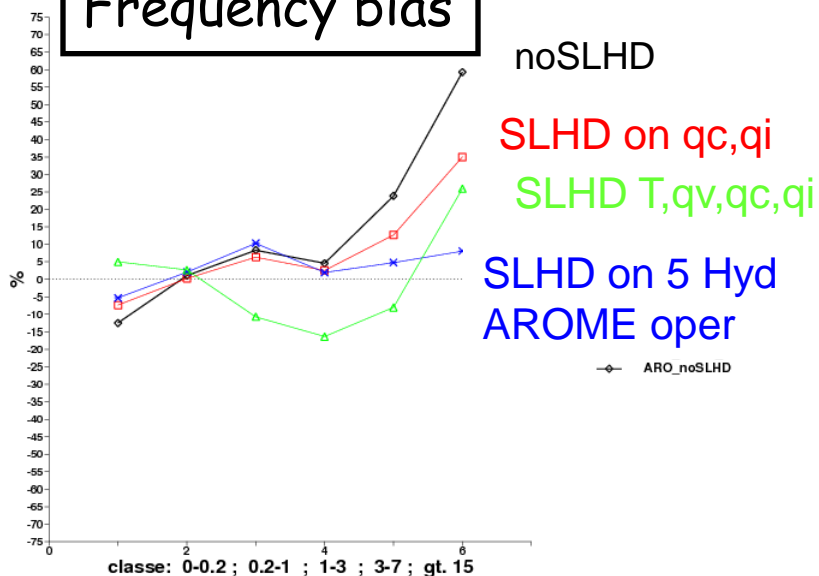
- PDF(sigma_turb+sigma_Rhc) → Qc, CC
- Shal. Conv → Qc_shal, CC_shal

Impact of the Horiz. Diffusion

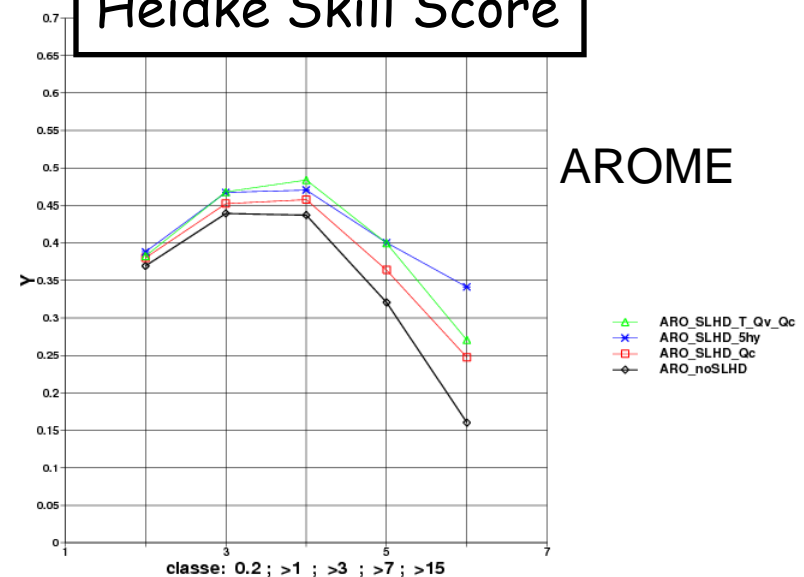
- HD damps the short wave or suppose to replace the effects of the horizontal mixing. In general, the tuning of the HD depends on the mesh size, time step and ... parametrization ?
- In AROME it is possible to activate a more sophisticated scheme : SLHD (Vana et al., 2008). It is a flow dependant scheme by controlling the damping of the SL-interpolators.

June and November 2007

Frequency bias



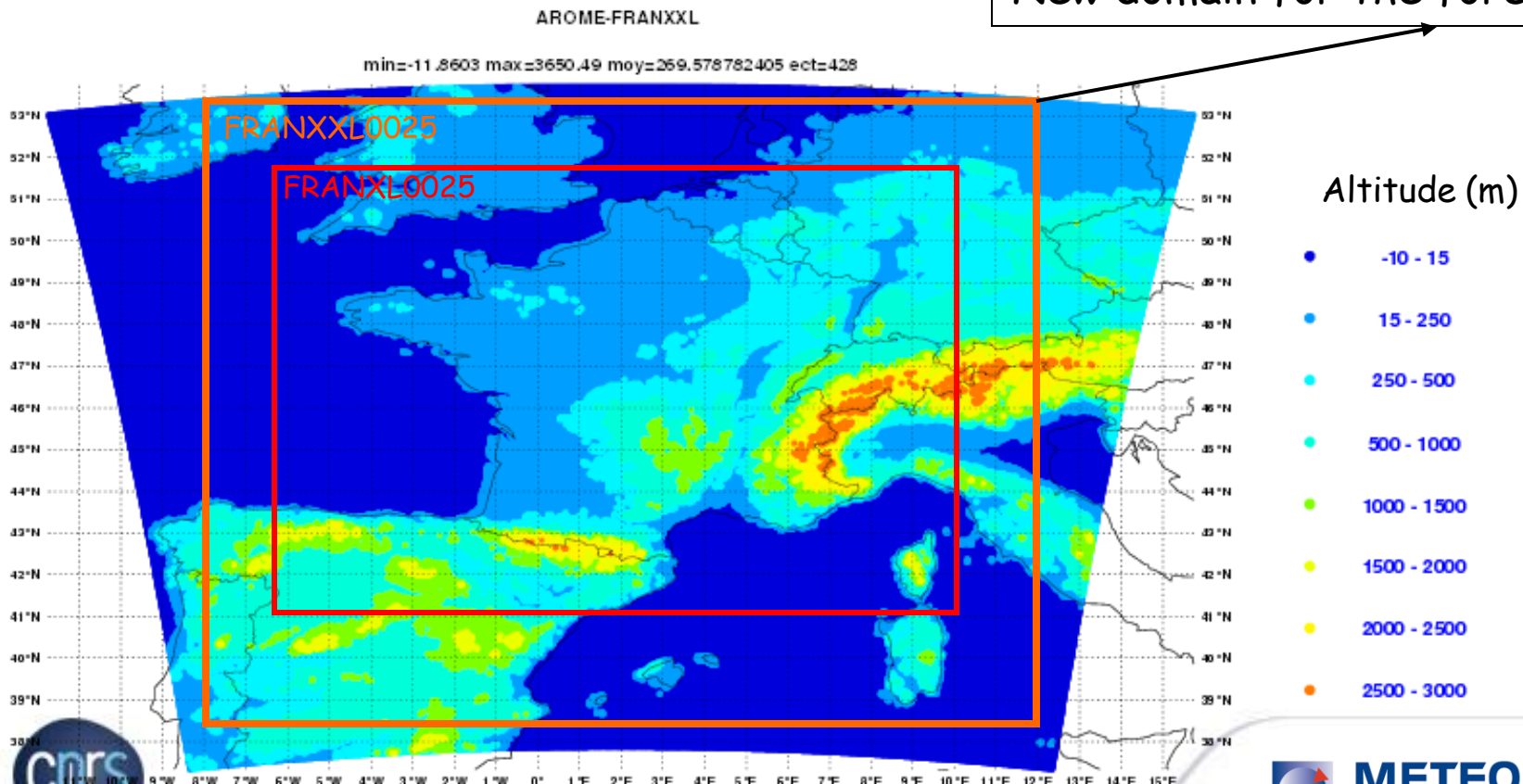
Heidke Skill Score



AROME-France v3 Automn 2010

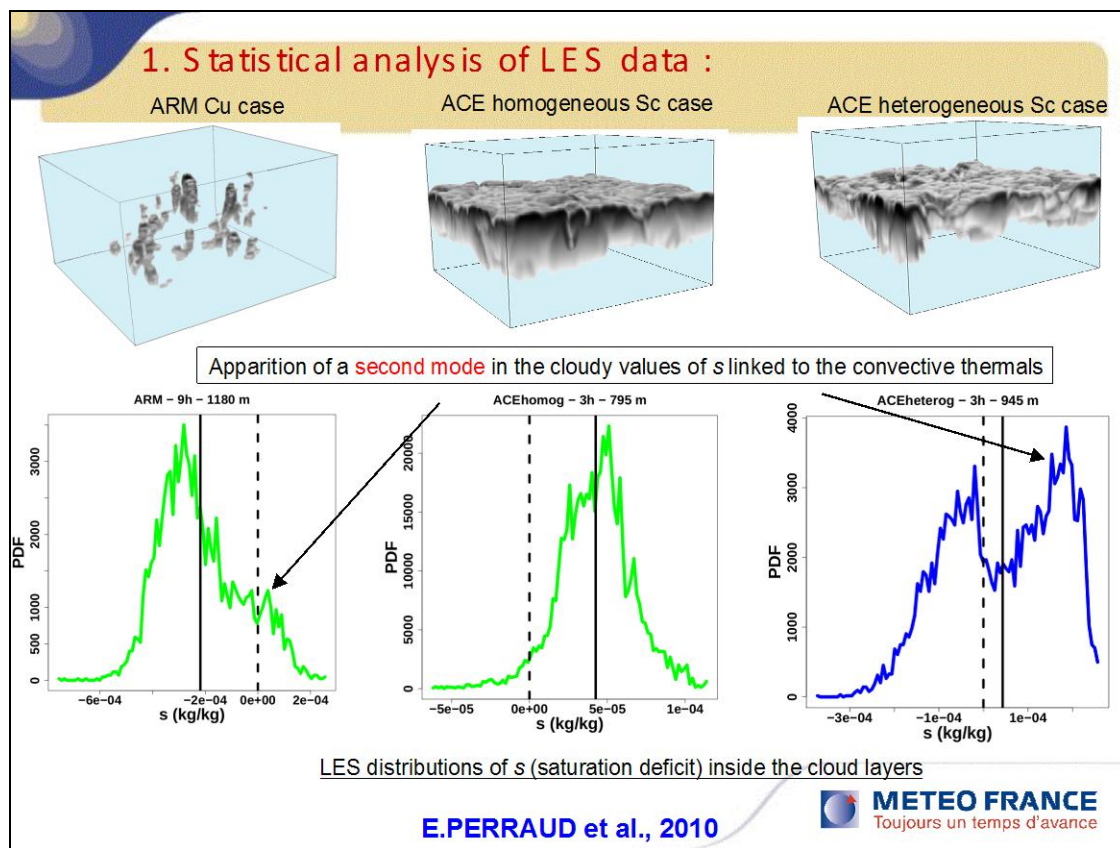
- Thanks to added processors on our NEC SX9, the domain size will increase 750x720 points(+70 %)
- Surface assimilation in SURFEX (J.F. Mahfouf)
- Low clouds modification = Sigma_hu from Riette and DeRoy ?

New domain for the forecasters



And for AROME V4 : 2011 ?

- HAIL
- New version of the surface database ECOCLIMAP v2
- SL modifications: S. Malardel works
- PDF of clouds : E. Perraud (PhD works) based on the statistical analysis of LES



Conclusions

- Forecasters consider that AROME provides a better physical realism particularly during summer with convective processes.
- The fine scale structure in the surface layer for the fog prediction has been also improved.
- Nevertheless, it seems that the size and the intensity of the convective cells are overestimated, this work is on going at Météo-France and with S. Malardel for the SL aspect and HIRLAM people (L. Bengstrom, S. Tijm, ...)
- AROME at 1Km and 500m is under evaluation and the need of a 3D-physics remains open.