Successes and challenges of a seamless development of physical parameterizations

F. Bouyssel

WGNE-28, 5-9 November 2012, Toulouse, France

cnrs INSU Observer & comprendre
METEO FRANCE Toujours un temps d'avance

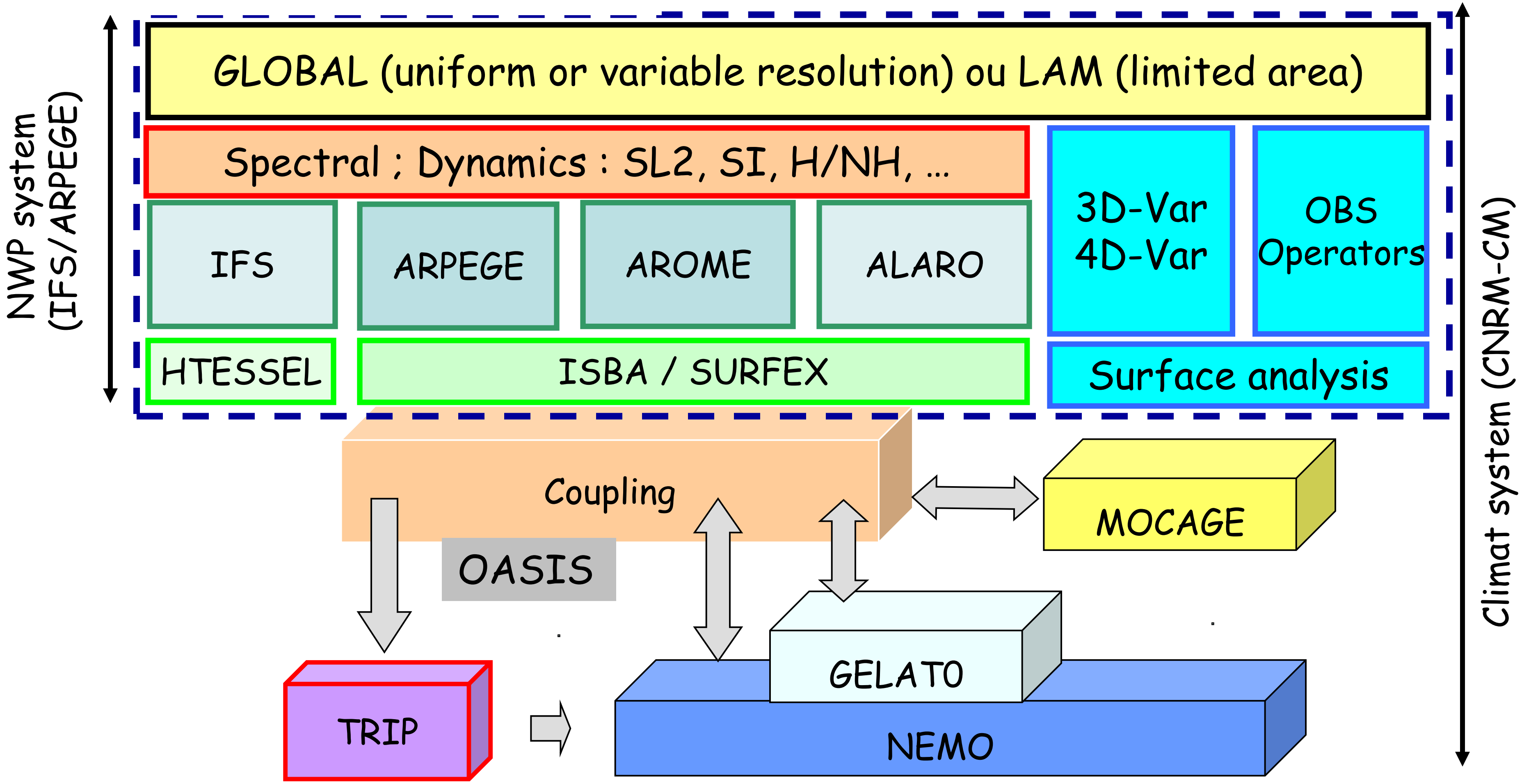
Outline

- ✓ Introduction (NWP and Climate models, motivations for some convergence on physical parameterizations)
- ✓ Some successes (surface, radiation, PBL schemes)
- ✓ Some challenges (microphysics, convection)
- ✓ Perspectives

1) Introduction

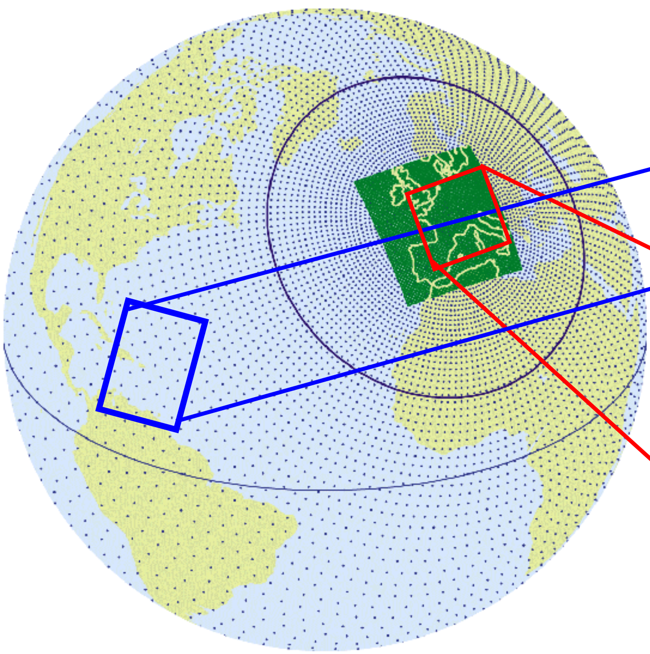
Numerical codes

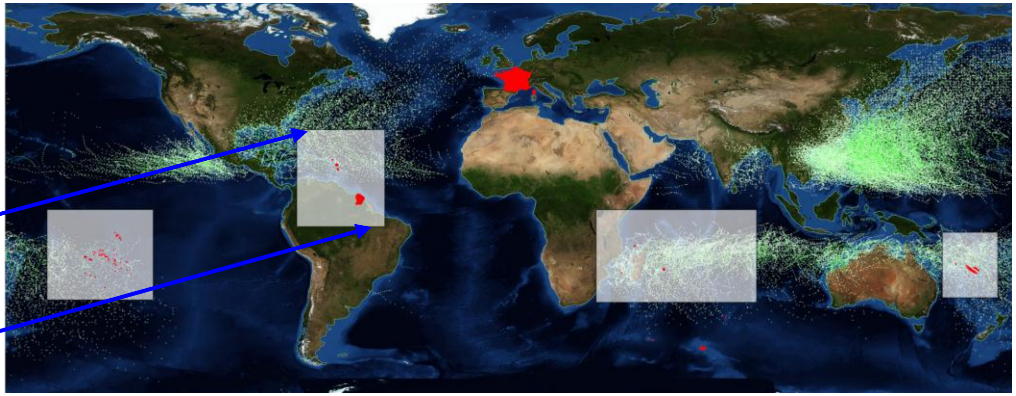
✓IFS/ARPEGE and CNRM-CM



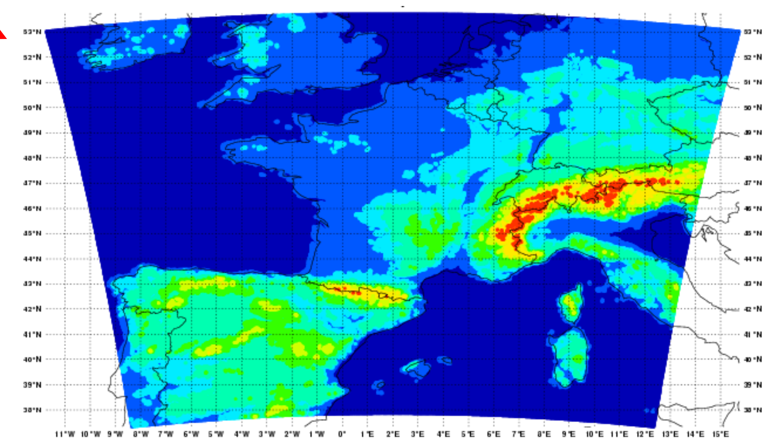
✓MESO-NH : research model for meso-alpha scale to micro-scale, anelastic system, two way nesting, advanced physical parameterizations for kilometric scales, process studies, tracers, more diagnostics, 1D, 2D

Oper NWP deterministic systems with assim





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
30 h forecasts every 6h
dx=2.5km, 60 vertical levels, dt=1mn
3DVar Data Assimilation (RUC3h)

Physical parameterizations

	ARPEGE/ALADIN NWP 2005 physics	ARPEGE/ALADIN Climat CMIP3 physics	AROME/MESO-NH prototype 2005 physics
Turbulence	Louis 82	TKE-2.0 / Mellor -Yamada 82	Cuxart et al. (2000) {tke}
Mixing length	Int. HCLA Troen & Mahrt	Profil cubique Troen & Mahrt	Bougeault-Lacarrère (1989)
Shallow convection	Modified Ri Geleyn 87	via the moist TKE-2.0 + PDF's	KF-Bechtold (2001)
Clouds	Xu & Randall 96	Ricard-Royer (93) PDF Bougeault (82)	PDF : Bougeault (1982)
Microphysics	Kessler	Kessler + Smith (90)	ICE3 {ql,qi,qr,qs,qg}
Deep convection	Bougeault (85) / Gerard (… 99)	Bougeault 85 (figé V3=cycle-18)	
GWD	Geleyn	Geleyn	
Radiation	ECMWF-FMR15	ECMWF–FMR15	ECMWF : SW6+RRTM
Surface	ISBA	ISBA	SURFEX (3L, ECUME, …)

Motivations for some convergence on physical parameterizations

✓ Need of renewal of NWP and Climat large scale physics (towards prognostic schemes, maturity of some research developments)

✓ Limited resources to maintain and develop several independent physical packages

✓ Increasing work needed for physical parameterization development : physical processes, algorithmics, validations (obs, analyses, 1D, 2D, CSRM, LES)

✓ Multi-scale validations with complementary diagnostics : 1D, NWP vs Climat, LAM vs global

✓ Potential benefits : coupling (reduce spinup), data assimilation, etc.

Physical parameterizations

✓R&D on two physical pakages : « large scale » and « convective scale », with convergence on some physical parameterizations (surface, radiation, PBL)

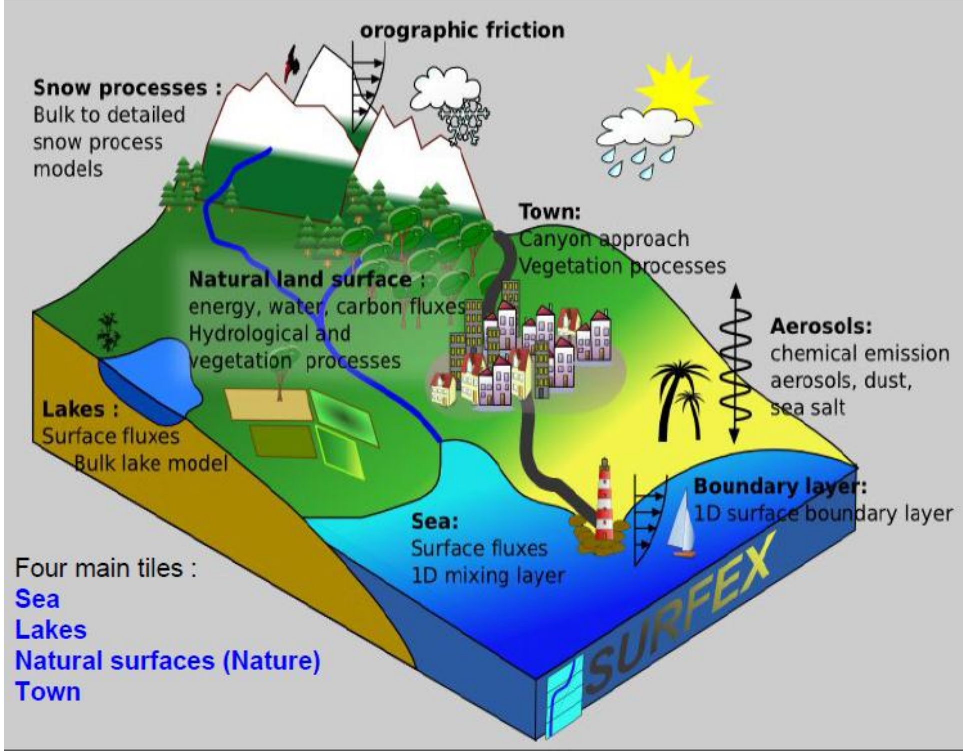
	ARPEGE/ALADIN **NWP** **Oper physics**	**ARPEGE/ALADIN** **Climat** **CMIP5 physics**	**AROME/MESO-NH** **NWP** **Oper physics**	**ARPEGE/ALADIN** **NWP + Climat** **targeted physics, CMIP6 ?**
Turbulence	Cuxart et al. (2000) {tke}	TKE-2.0 / Mellor -Yamada 82	Cuxart et al. (2000) {tke}	Cuxart et al. (2000) {tke}
Mixing length	Bougeault-Lacarrère (1989)	Profil cubique Troen & Mahrt	Bougeault-Lacarrère (1989)	Bougeault-Lacarrère (1989)
Shallow convection	KF-Bechtold (2001)	via the moist TKE-2.0 + PDF's	Pergaud et al. (2009)	Pergaud et al. (2009)
Clouds	PDF : Smith (1990)	Ricard-Royer (93) PDF Bougeault (82)	PDF : Bougeault (1982)	PDF : Bougeault (1982)
Microphysics	Lopez (2002) {ql,qi,qr,qs}	Kessler + Smith (90)	ICE3 {ql,qi,qr,qs,qg}	Bulk Lopez (2002) {ql,qi,qr,qs}
Deep convection	Bougeault (85) / Gerard (… 99)	Bougeault 85 (figé V3=cycle-18)		PCMT Piriou (2007) Gueremy (2011)
GWD	Catry-Geleyn (2008)	Catry-Geleyn (2008)		Catry-Geleyn (2008)
Radiation	ECMWF : SW6+RRTM	ECMWF : SW6+RRTM	ECMWF : SW6+RRTM	ECMWF : SW6+RRTM
Surface	ISBA+ECUME	SURFEX (3L, ECUME, …)	SURFEX (3L, ECUME, …)	SURFEX (3L, ECUME, …)

2) Some successes with seamless

SURFACE

"SURFEX", an "externalized" surface model, is progressively used in MESO-NH, AROME, ALADIN, ARPEGE

Same physiography and surface schemes are currently used in AROME and ARPEGE_climat : ECOCLIMAP database, ISBA soil/vegetation/ hydrology, D95 snow scheme, ECUME sea surface fluxes, except Town Energy Model used only in AROME



New surface parameterizations developed simultaneously for AROME and ARPEGE : Explicit soil diffusion scheme (ISBA-DIF), Explicit snow scheme (ISBA-ES), Multi-Energy balance (MEB), Carbon options (ISBA-A-gs)

CNRS INSU Observer & comprendre

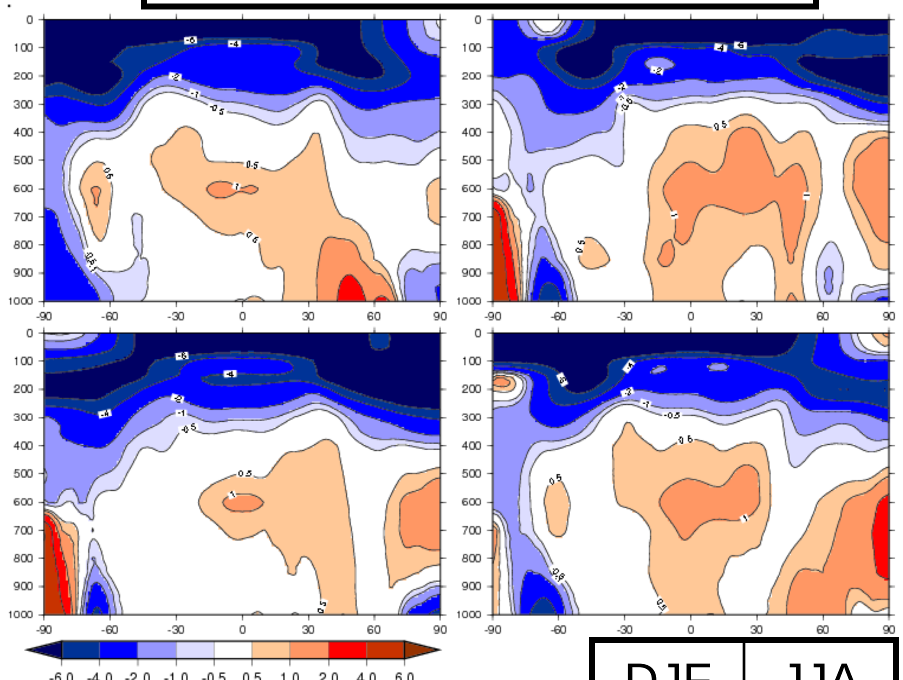
METEO FRANCE
Toujours un temps d'avance

RADIATION

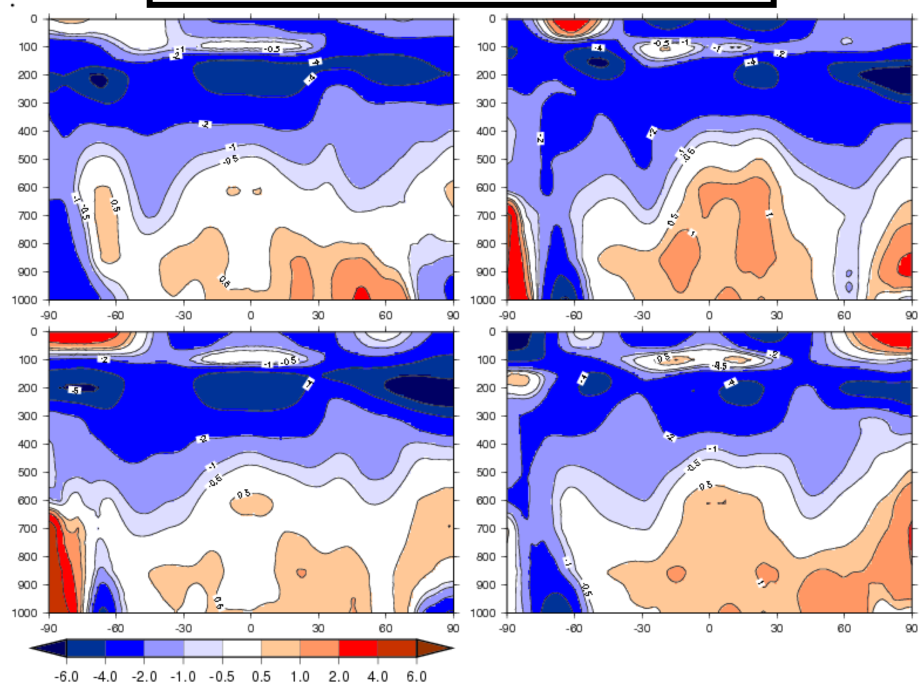
Same radiation schemes used in MESO-NH, AROME, ALADIN, ARPEGE. Firstly validated in NWP, then in Climat. The code originates from IFS : RRTM (Mlawer et al.), SW6 (Fouquart and Morcrette)

Temperature bias in zonal mean ARPEGE-ERA40 (T127C1L31 / 23 years / forced)

Physics climat V4 (FMR15)



Physics climat V4 + RRTM



DJF	JJA
MAM	SON

(I. Beau)

Convergence on turbulence scheme and EDMF concept

PBL parameterization used in ARPEGE / ALADIN NWP before February 2009 :

Computation of subgrid turbulent fluxes with a diffusion scheme :

$$\overline{w'\psi'} = -K \frac{\partial \psi}{\partial z}$$

Louis (82) scheme to compute K as follows: $$K_\psi = l_m \cdot l_\psi \left| \frac{\partial \vec{U}}{\partial z} \right| F_\psi (R_i)$$

And to "simulate" the mixing done by the shallow convection, an enhanced Ri is used following Geleyn 87 :

$$R_i = \frac{g}{c_p T} \frac{\partial s / \partial z + L \min\left(0, \partial\left(q - q_s\right) / \partial z\right)}{\left|\partial \vec{u} / \partial z\right|^2}$$

Convergence on turbulence scheme and EDMF concept

All NWP models (AROME, ARPEGE and ALADIN) use « EDMF » concept

$$\overline{w'\phi'} = -K\frac{\partial\bar{\phi}}{\partial z} + \frac{M_u}{\rho}\left(\phi_u - \bar{\phi}\right)$$ with $$K = cL_{BL89}\sqrt{TKE}$$

and $$L_{BL89} = \left[\frac{\left(l_{up}\right)^{-\frac{2}{3}} + \left(l_{down}\right)^{-\frac{2}{3}}}{2}\right]^{-\frac{3}{2}}$$

Where l_{up} and l_{down} are computed using dry buoyancy following Bougeault and lacarrère (1989)

ARPEGE and ALADIN-MF

- Prognostic turbulent kinetic energy scheme « CBR » (Cuxart et al 2000)
- Shallow convection mass flux scheme « KFB » (Bechtold et al 2001)

↔

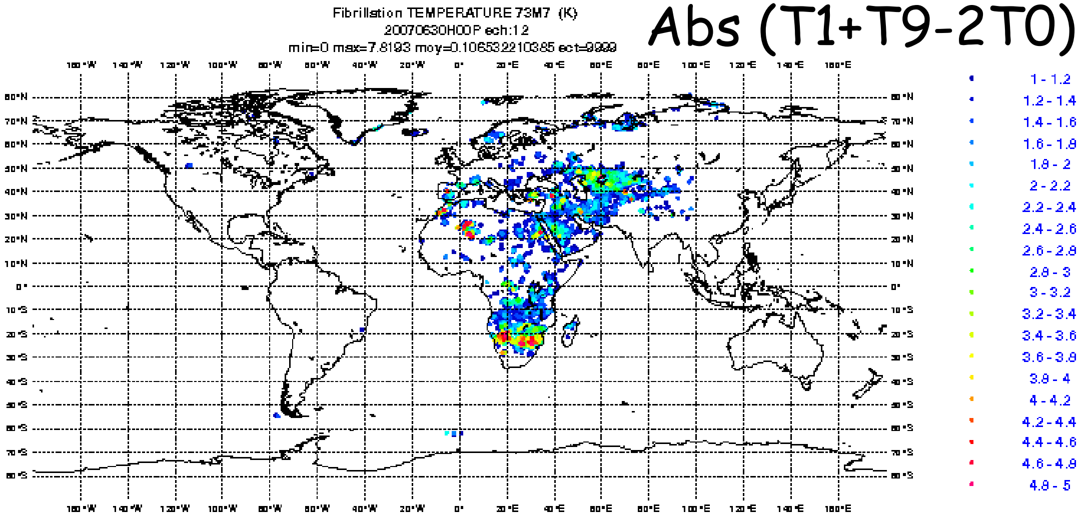
AROME

- Prognostic turbulent kinetic energy scheme « CBR » (Cuxart et al 2000)
- Shallow convection and dry thermal mass flux scheme « EDKF » (Pergaud et al 2009)

Convergence on turbulence scheme and EDMF concept

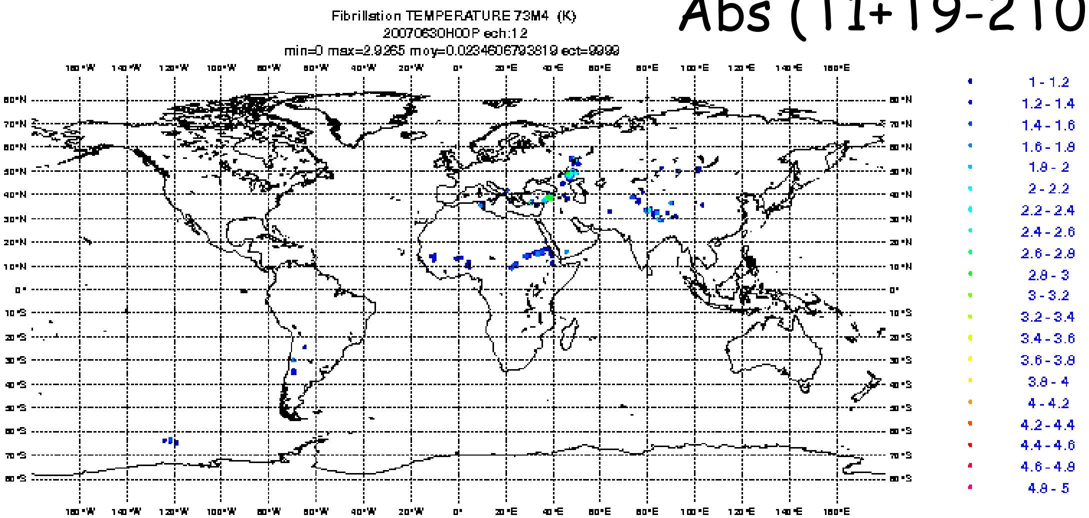
Stability: T538c2.4
dt=900s (15km over France)
Temperature at Level 60
(1st level above the surface)

Abs (T1+T9-2T0)



Louis's scheme with antifibrillation
max=7.8°C Mean=0.1

Abs (T1+T9-2T0)

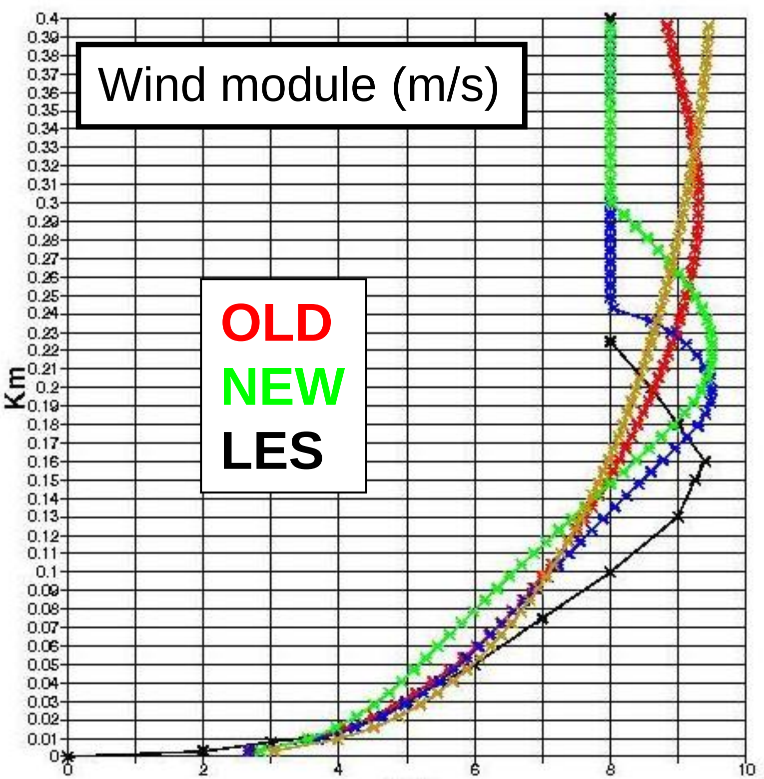


TKE without antifibrillation scheme
max=2.9°C mean=0.02
Less noisy and less dependant of the time step

(Y. Bouteloup)

Convergence on turbulence scheme and EDMF concept

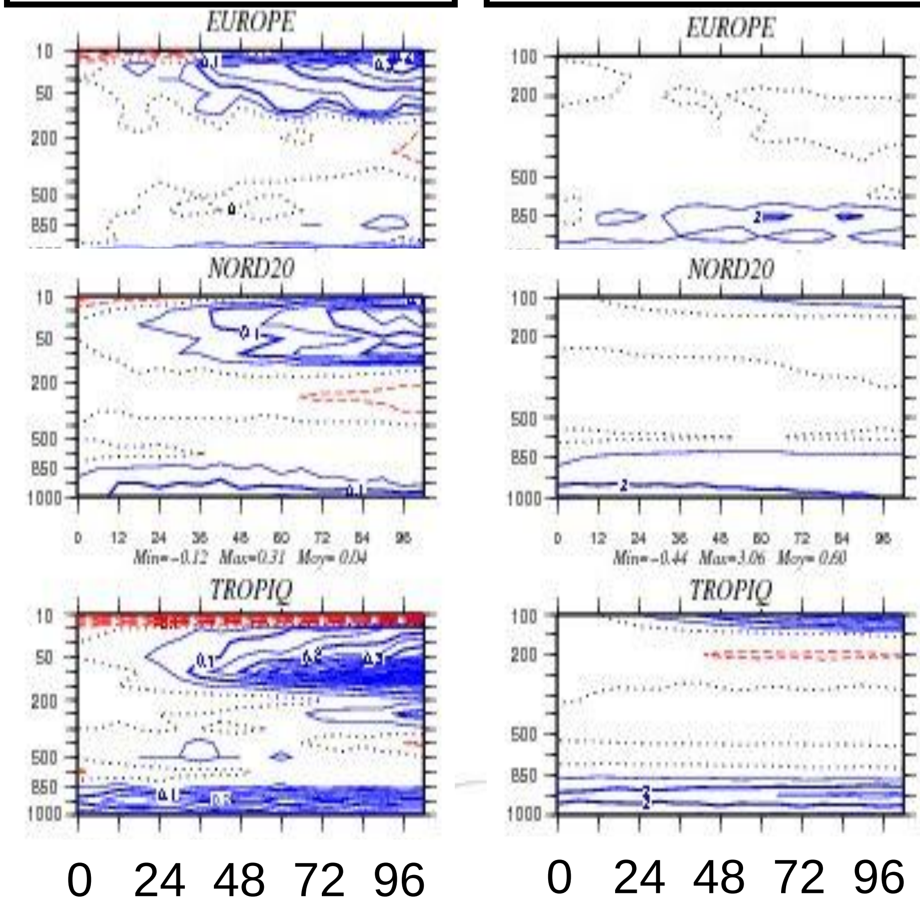
GABLS I
Cuxart et al, 2006 BLM



(E. Bazile)

Radiosoundings scores : NEW-OLD
ARPEGE-PNT (Sept-Dec 2009)

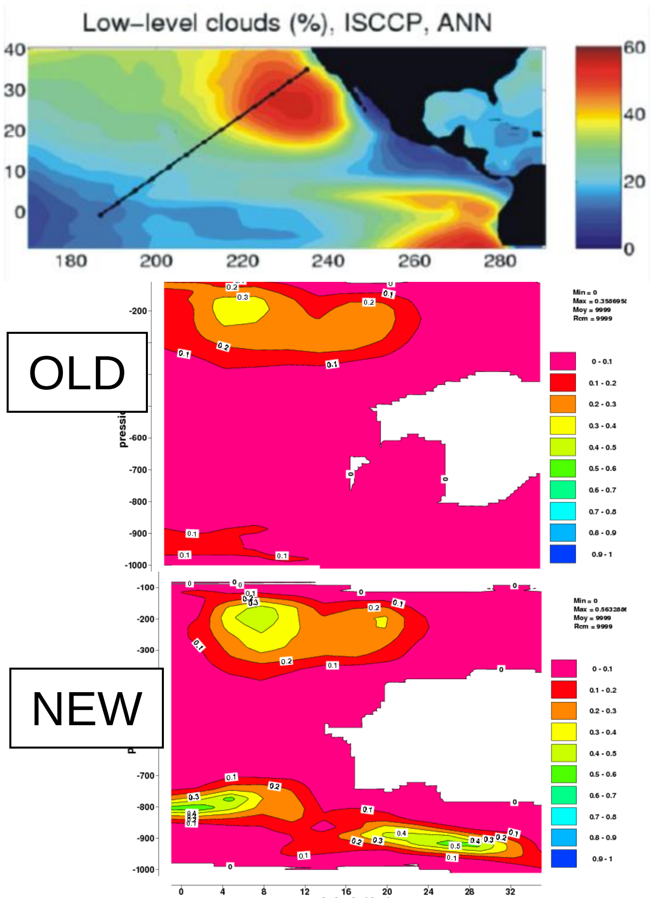
Temperature RMS	Relative humiidty RMS



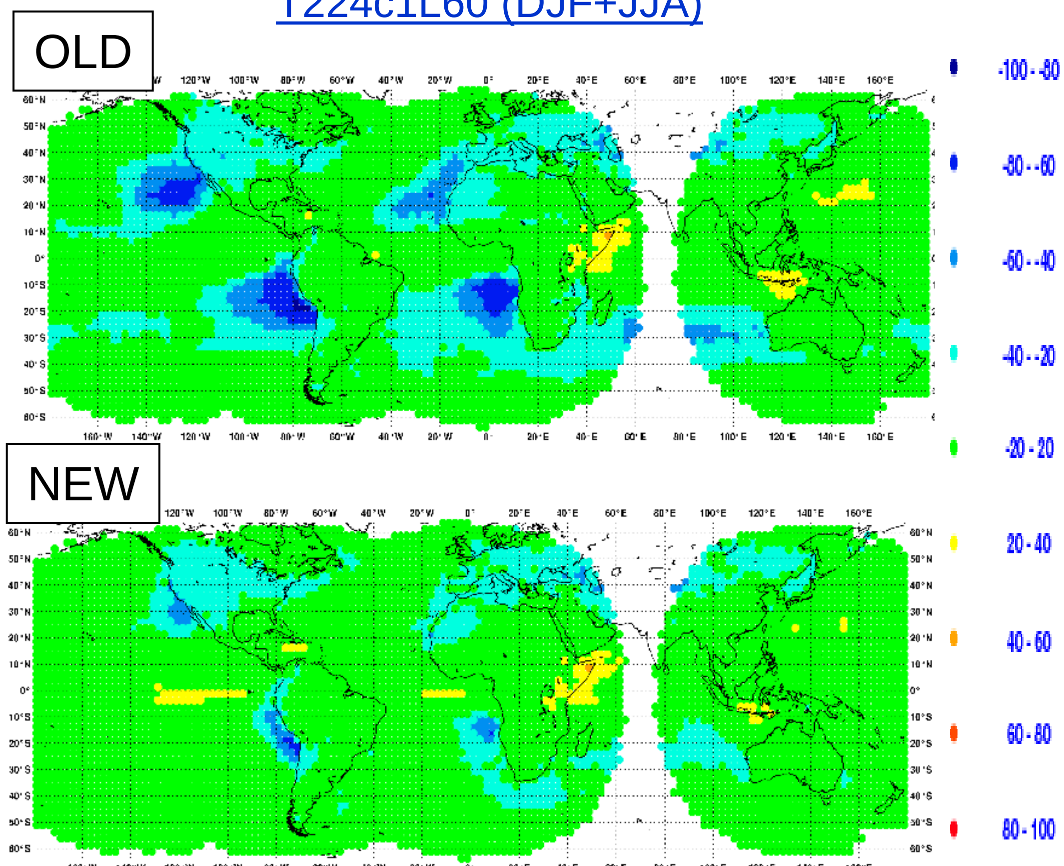
Convergence on turbulence scheme and EDMF concept

Improvement of low level cloudiness when changing PBL subgrid schemes, cloud and microphysics being unchanged

Gewex Pacific Cross-section (GPCI)



Total cloudiness model error versus ISCCP (%)
T224c1L60 (DJF+JJA)



Evaluation of AROME thermal scheme in ARPEGE

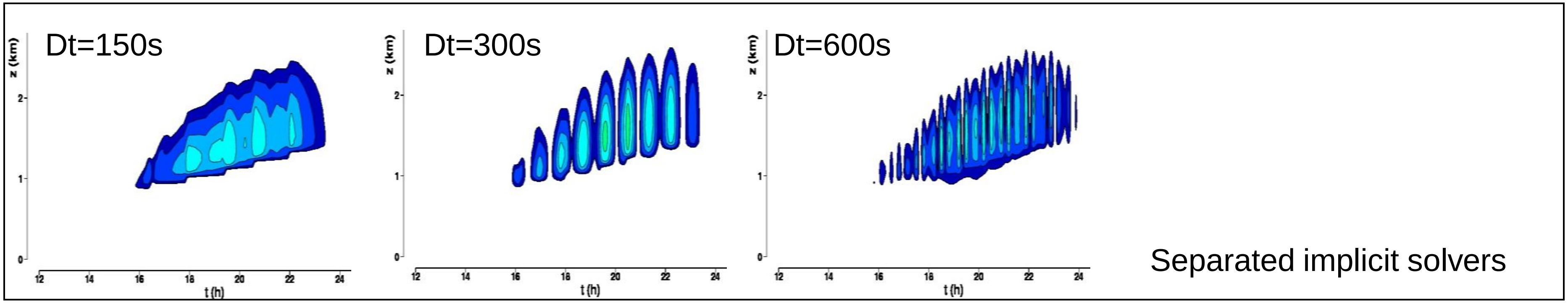
Motivations of evaluating “Pergaud et al, 2009” scheme in Arpege :

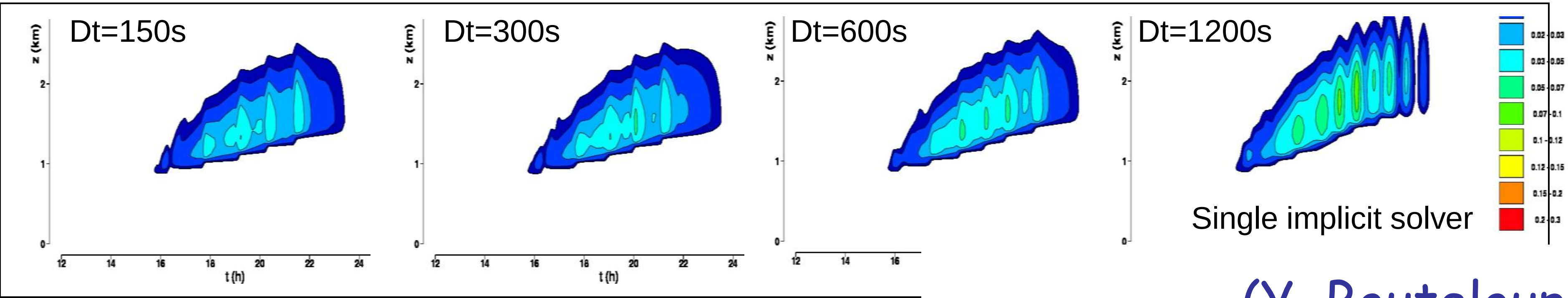
- Improve representation of thermals (dry thermals, improved closure, momentum mixing)
- Extend validation of the scheme on the globe
- Convergence of PBL schemes with Arome

Algorithmic adaptation for long time step: Unique implicit solver for mass flux and diffusion terms :

$$\left(\frac{\partial \psi}{\partial t}\right)_{edmf} = \frac{1}{\rho}\frac{\partial}{\partial z}\left(-k\frac{\partial \psi}{\partial z} + M\left(\psi_u - \overline{\psi}\right)\right)$$

ARM Cumulus 1D case (cloudiness)





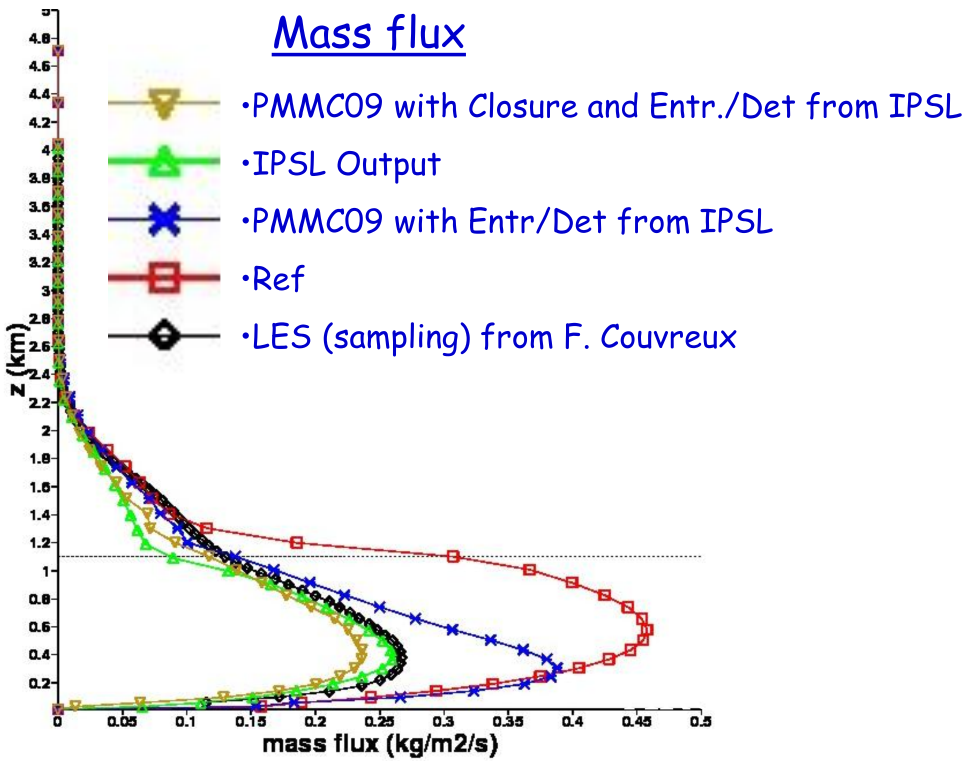
(Y. Bouteloup)

Evaluation of AROME thermal scheme in ARPEGE

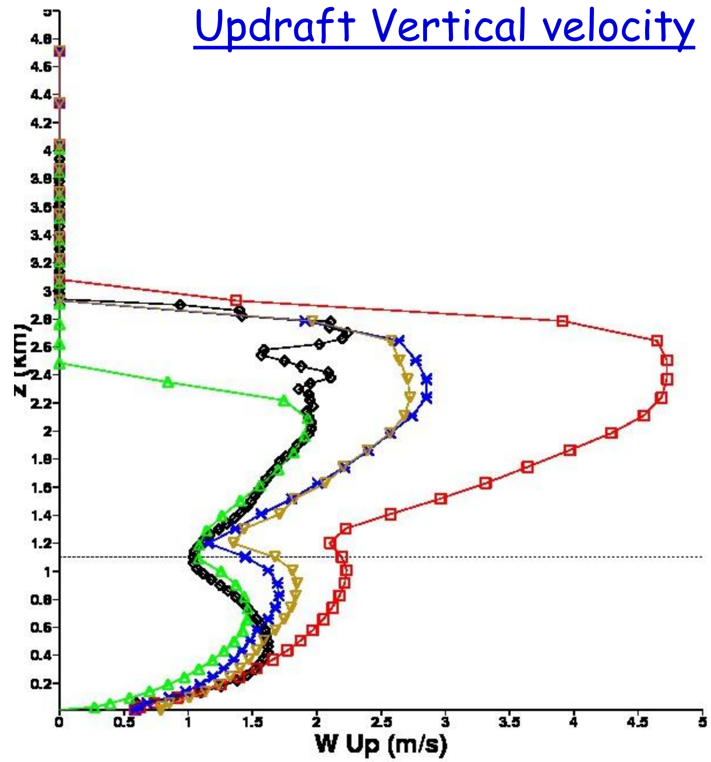
1D model for ARM cumulus

Entrainment and detrainement from Rio et al (2010)
Closure assumption from Rio and Hourdin (2008)

Mass flux



Updraft Vertical velocity



First developed for ARPEGE but will be tested in AROME

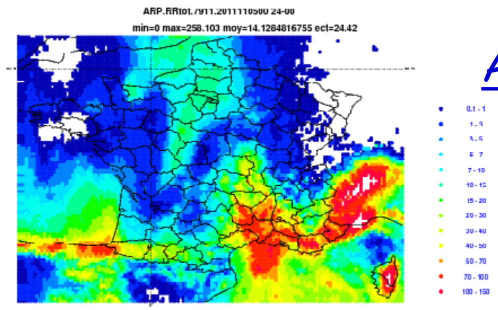
(Y. Bouteloup)

New convection scheme PCMT
(Prognostic Condensates Microphysic and Transport)

- ✓ 5 new prognostic equations ql_sg, qi_sg, qr_sg, qs_sg, w_updraft
- ✓ Separation microphysics – transport MT (Piriou, JAS, 2007) : the same microphysics is used for the resolved and the subgrid part
- ✓ Updraft mesh fraction based on CAPE closure (Gueremy, Tellus, 2011)

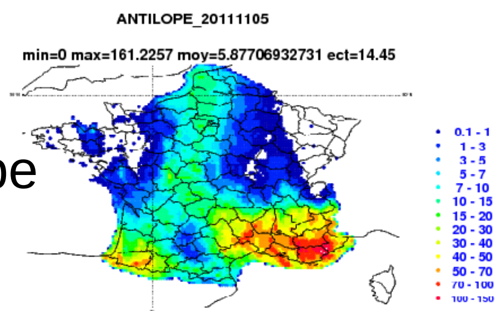
ARPEGE NWP : T798c2.4L70

DBL

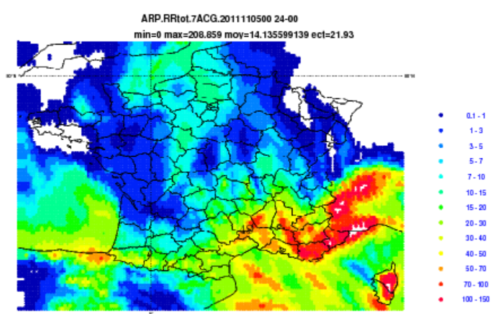


RR 24h for 5/11/2011

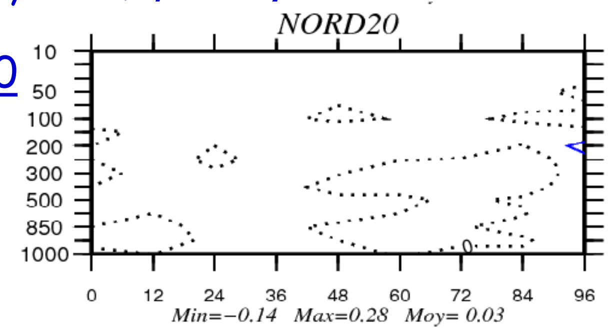
Antilope

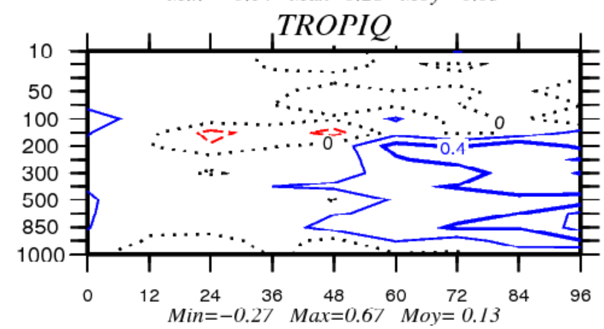


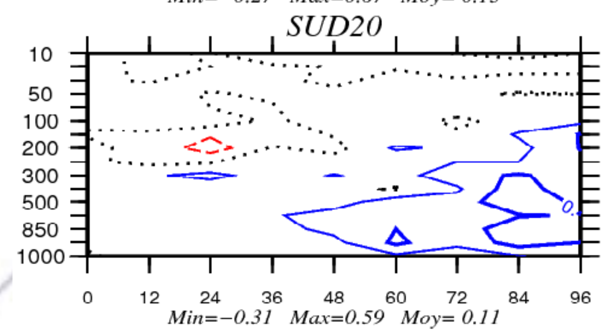
PCMT



RMS wind scores to RS December 2011



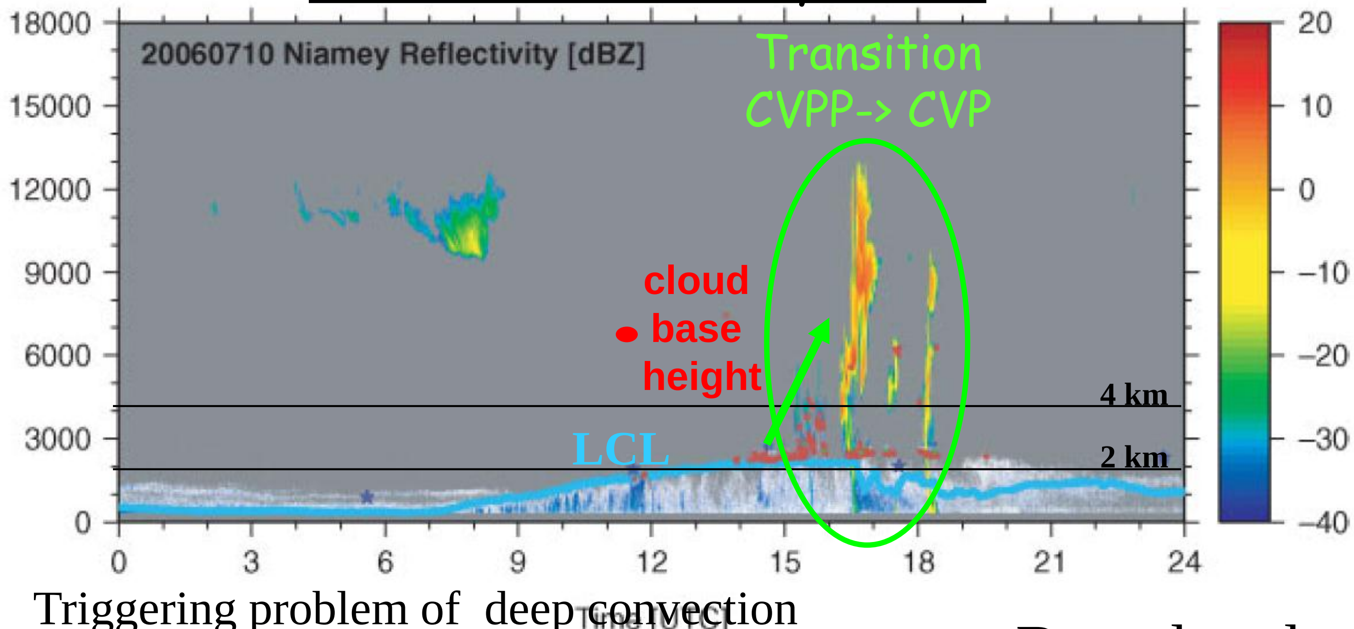




(J.M. Piriou)

New convection scheme PCMT

AMMA case (10 July) 2006

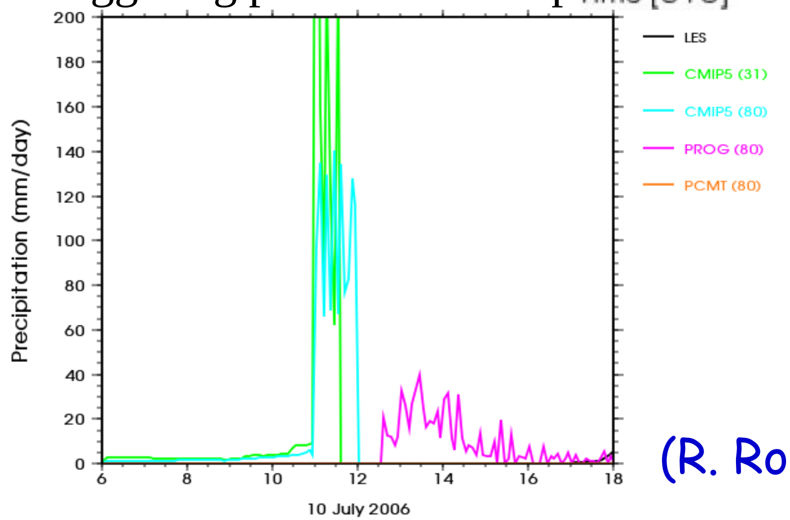


Interesting case:

- Semi-arid environment, forced by sensible heat flux, not by latent heat flux
- CAPE is decreasing during day
- Transitions dry convection, shallow and deep well documented

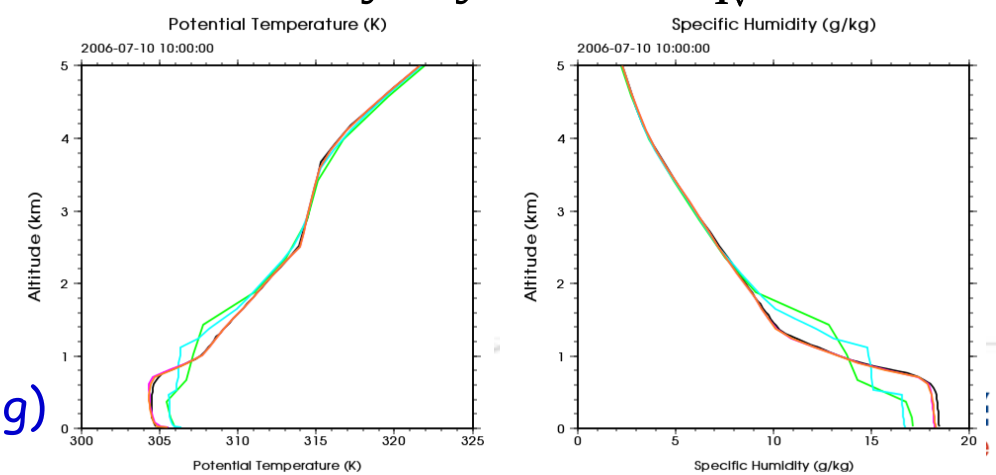
Case proposed in FP7/EMBRACE

Triggering problem of deep convection



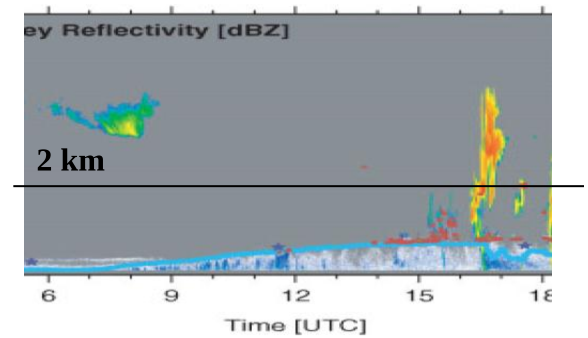
(R. Roehrig)

Boundary layer : θ et q_v at 10h



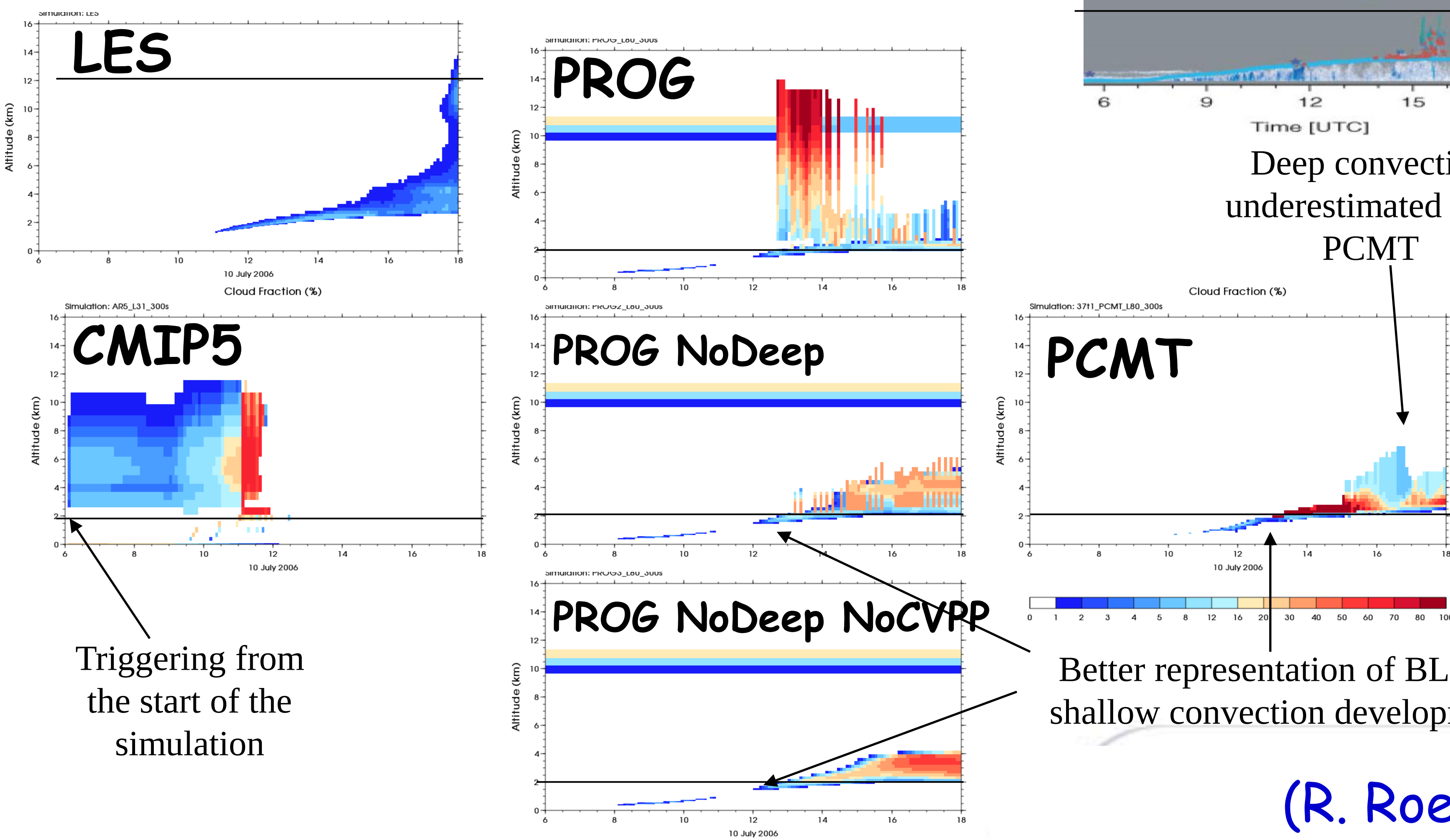
New convection scheme PCMT

AMMA case (10 July) 2006



Deep convection underestimated with PCMT

Cloud fraction



Triggering from the start of the simulation

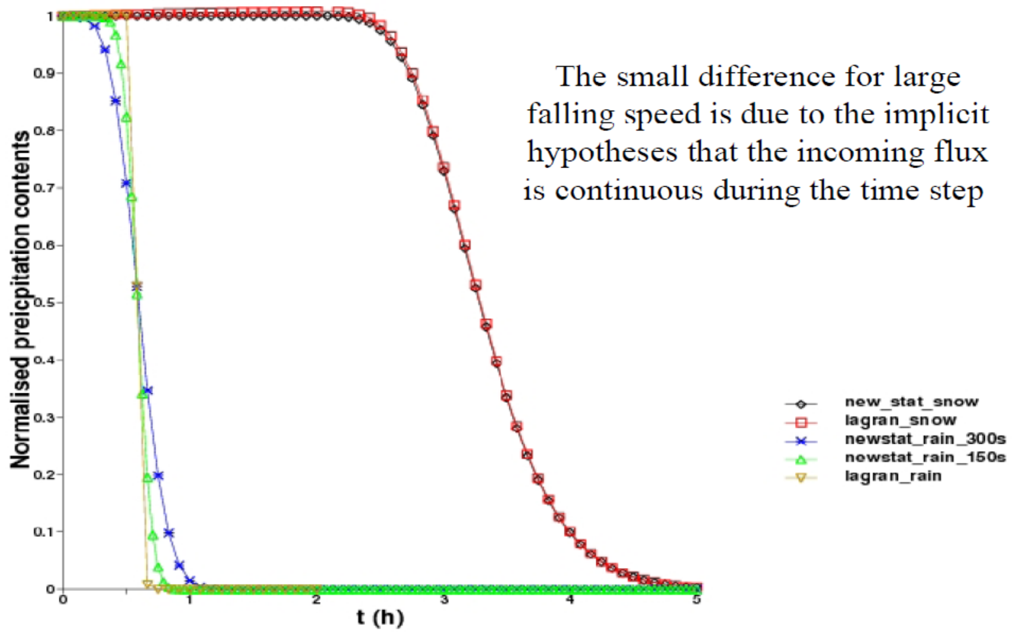
Better representation of BL and shallow convection development

(R. Roehrig)

Statistical sedimentation scheme

- ✓ Time-splitting algorithm is very expensive
- ✓ Semi-lagrangian algorithm is complicated for sophisticated microphysics
- ✓ New local approach assuming incoming flux continuous during Δt (Bouteloup, 2011)

Comparison with semi-lagrangian algorithm



AROME: applied on cloud droplets, snow, rain and graupel
ARPEGE: longer time steps need to take into account microphysics process during sedimentation (applied on rain and snow)

First developed for ARPEGE and then implemented in AROME

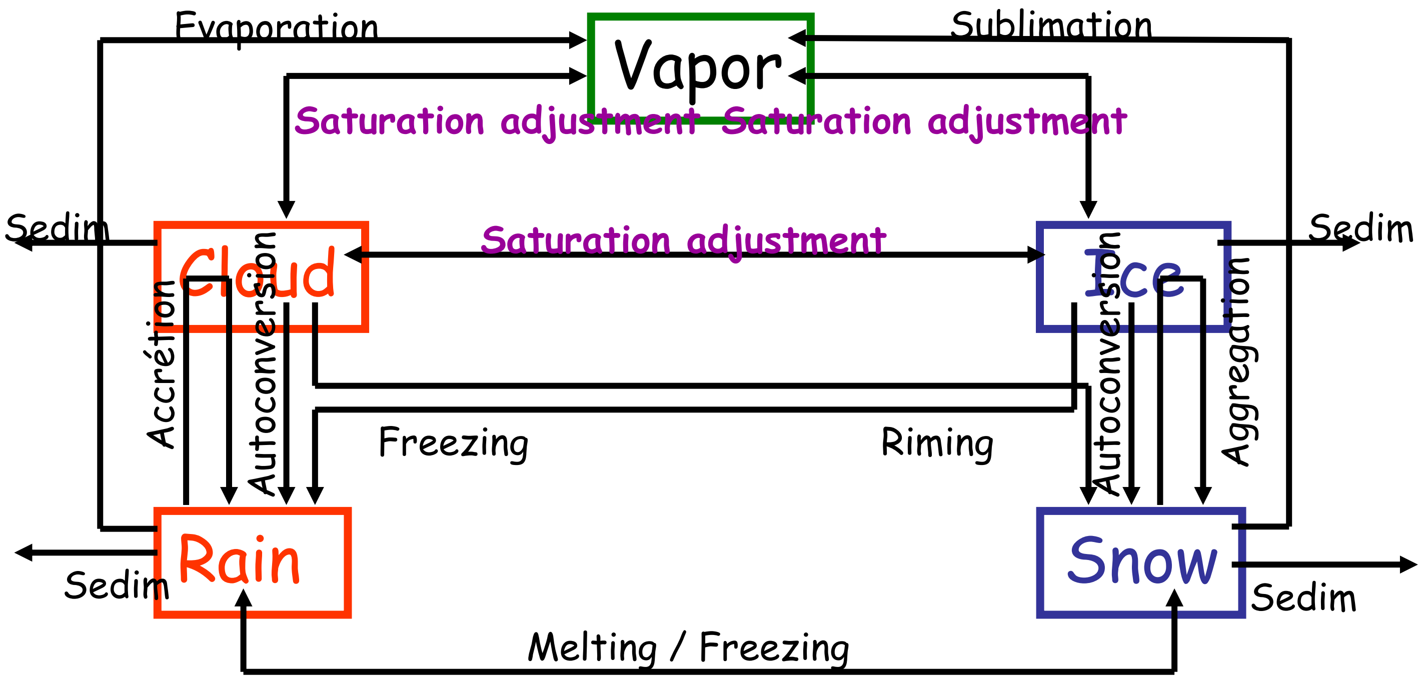
3) Some challenges

Degree of sophistication and algorithmics

Example with microphysical scheme :

✓ appropriate level of complexity in CSRM and large scale model (Dx>10km)?

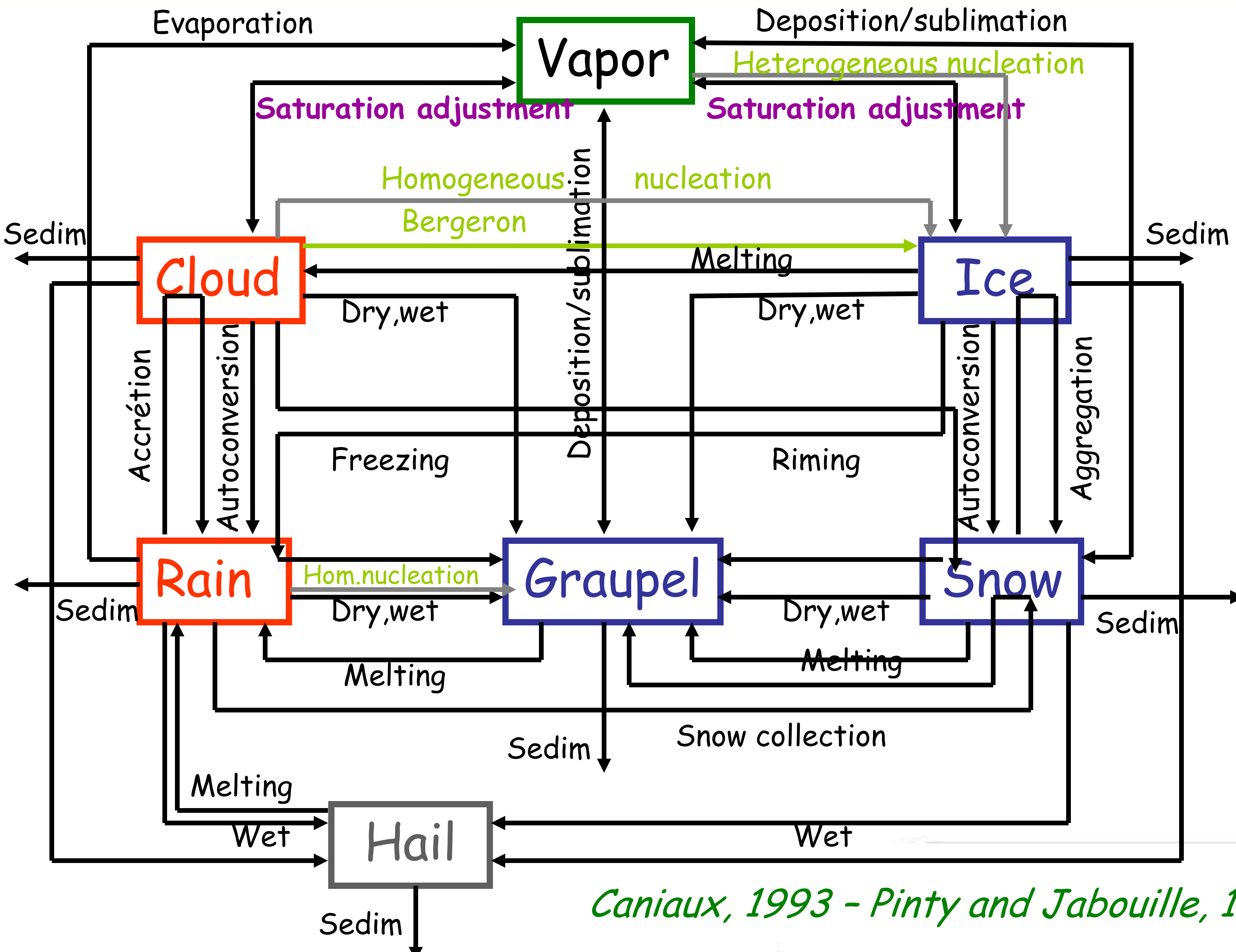
✓ difficulty to build microphysical scheme suitable for a wide range of time steps (from few seconds to tens of minutes). Algorithmics of AROME microphysics not designed for time-steps much larger than a minute



ARPEGE microphysics

Lopez, 2002 – Bouteloup et al., 2005

AROME microphysics : « ICE3 » / « ICE4 »



Caniaux, 1993 – Pinty and Jabouille, 1998

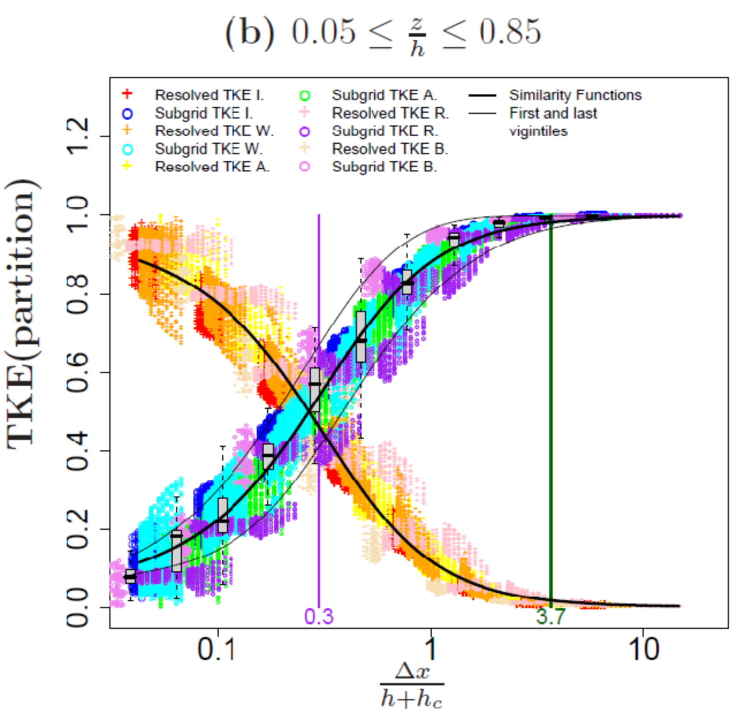
Degree of sophistication

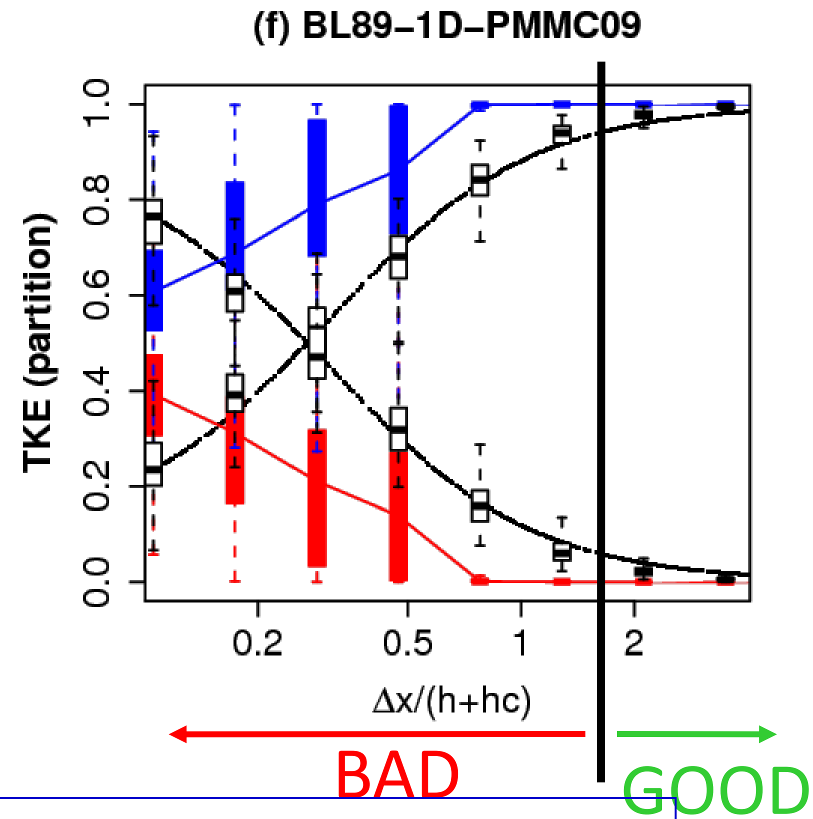
Need of R&D on 3D physical parameterizations for hectometric models :

- ✓ Orographic effects (slope, shadows, etc.)
- ✓ Atmospheric radiative effects
- ✓ Turbulence (over orography, for convection)

Grey zones (subgrid ≅ resolved)

1) For deep convection (~5km) : explicit deep convection in Arome
2) For shallow convection, ie dry and moist thermals (~500m) :





- Adaptation of the Mass-Flux scheme equations for the grey zone
- Dependence of the closure on the resolution

Honnert et al. (2011, 2012)

Perspectives

- ✓ Continuation of multi-scales validations towards common large scale physics for Arpege NWP and Climat
- ✓ Maintain and improve multi-scales parameterizations for Arome and Arpege for surface, radiation, turbulence, thermals
- ✓ Improve validation framework : 1D modeling, budget tools, observation sites, field campaigns (HYMEX, BLLAST, …), LES simulations (national project with LMD, LGGE)
- ✓ Improve physical parameterizations for future resolutions : ~5km for Arpege and ~500m for Arome. Seamless for convection (deep / shallow) is an issue !
- ✓ Work on microphysics, chemistry and aerosol needed for large scale and convective scale physics (seamless ?)