What are the differences in physical parameterizations between MF models (NWP vs climate, global vs convective scale) ?

François Bouyssel
Météo-France/CNRS (Toulouse, France)

WGNE-31, 26-29 April 2016, Pretoria, South Africa

Outline

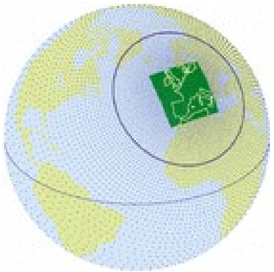
- Physical schemes used in MF models
- Algorithmic adaptations for long time-step
- Some challenges for further convergence

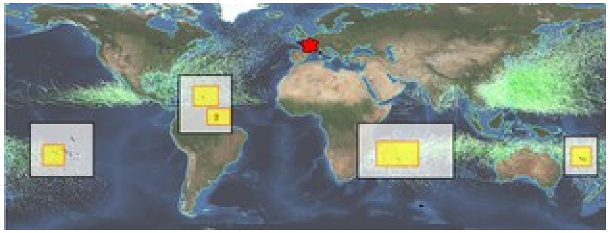
A wide range of spatial and temporal scales simulated

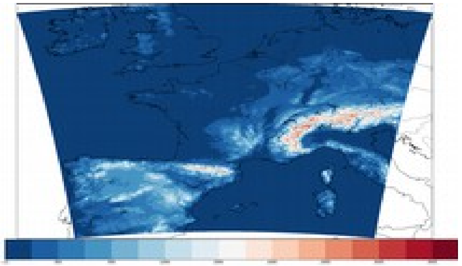
- NWP systems based on IFS/ARPEGE software developed in collaboration with ECMWF and ALADIN, HIRLAM NWP Consortia
- CNRM-CM Earth System Model developed in collaboration with CERFACS

BULLX B700 DLC

1) **NWP:**







Global ARPEGE
T1198c2.2L105 7.5-36 km
4DVar : 135 km and 50 km

LAM AROME Overseas
2.5 km, L70

LAM
AROME & AROME-Nowcasting
1.3 km, L90, *3DVar (1h)*

Global ensembles ARPEGE:
EDA : 25 members, 40 km
EPS : 35 members, 10-60 km

New systems (2016): **AROME-EPS** 2.5 km

2) **Climate models:**

Global ARPEGE: likely resolutions for CMIP6: T149 (135 km) and T359 (55 km)
but also stretched configuration: T719C2.5 (12-70 km), T159C2.5 (50-300 km)
LAM ALADIN: 12km - 50km
LAM AROME: 2km

Physical schemes needed for all these configurations!

Physical packages

	Targeted physics for hydrostatic scales (ARPEGE NWP and Climat)	Operational physics of convective scale model (AROME)
Surface	SURFEX (Masson et al., 13): surface modelling platform	
Radiation	RRTM (Mlawer, 97) + SW6* (Fouquart 80, Morcrette 01)	
Turbulence	1.5 order scheme prognostic TKE (Cuxart et al., 00)	
Mixing length	Non local, buoyancy based (Bougeault-Lacarrère, 89)	
PBL thermals	PMMC09 (Pergaud et al., 09)	
Clouds	PDF based: (Smith, 90) **or** (Bougeault, 82)	
Microphysics	Bulk scheme with 4 prog. var. (Lopez, 02)	Bulk scheme** 5 prog. var. (Pinty and Jabouille, 98)
Convection	New scheme PCMT (5 prog. var) (Piriou et al., 07) and (Gueremy, 11)	x
Subgrid orographic effects (GWD, blocking, etc.)	Catry-Geleyn (08)	x

* Plans to use SRTM (IFS scheme)

** On going researches on prognostic hail and 2-moments microphysical scheme “LIMA”

Evaluation of AROME thermal scheme in ARPEGE

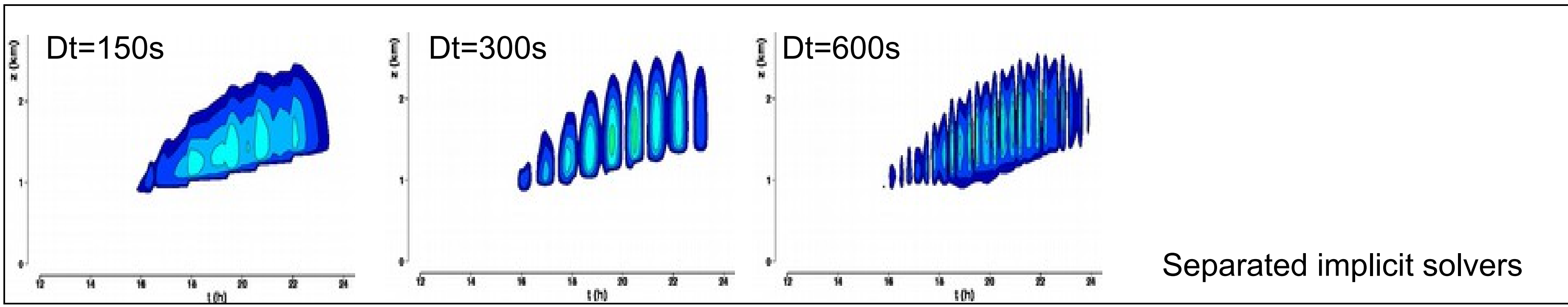
Motivations of evaluating "Pergaud et al, 2009" (PMMC09) scheme in Arpege :

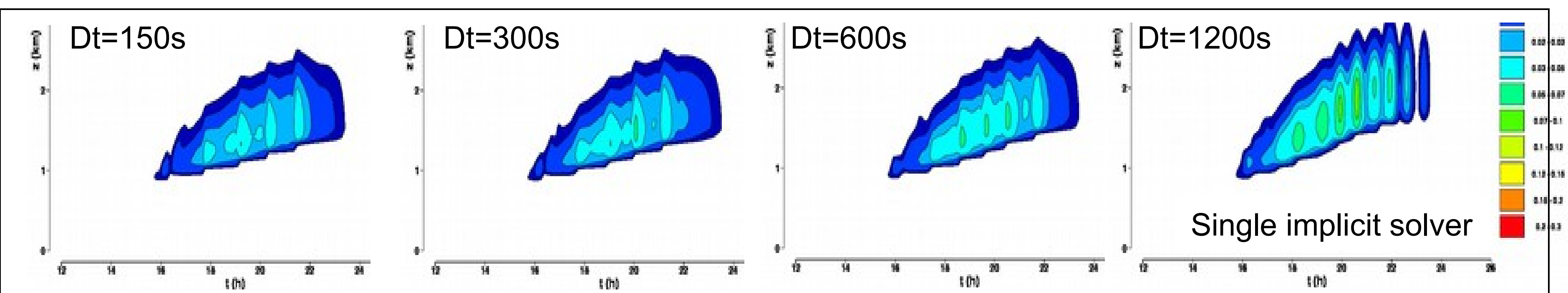
- Improve representation of thermals (dry thermals, improved closure, momentum mixing)
- Extend validation of the scheme on the globe
- Convergence of PBL schemes with Arome

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

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

ARM Cumulus 1D case (cloud water content)

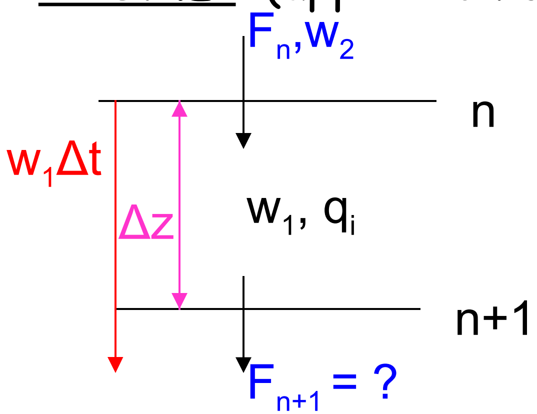




(Bouteloup)

Statistical sedimentation scheme

AROME : (applied on cloud dropplets, snow, rain and graupel)



$$P_1 = \min\left(1, \frac{w_1 \Delta t}{\Delta z}\right)$$ (Proportion of layer n leaving the layer in dt)

$$P_2 = \max\left(0, 1 - \frac{\Delta z}{w_2 \Delta t}\right)$$ (Proportion of F_n crossing the layer in dt)

$$w_2 = F_n . \frac{\Delta t}{\rho\, \Delta z}$$

$$F_{n+1} = \frac{P_1 . \rho . q_i . \Delta z}{\Delta t} + P_2 . F_n$$

ARPEGE : longer time steps -> need to take into account microphysics process during sedimentation (applied on rain and snow)

$$F_{n+1} = \left(1 - \frac{S^i_n}{q_i + (\Delta t / \rho . \Delta z)\, F_n + S^o_n}\right) \times \left(\frac{P_1 . \rho . q_i . \Delta z}{\Delta t} + P_2 . F_n + \frac{P_3\, \rho . \Delta z . S^o_n}{\Delta t}\right)$$

P_3= (P1+P3)/2 (Proportion of q_i produced in layer n during dt which leaves the layer during dt)

S^i_n = sinks of q_i (evaporation for rain, evaporation + melting for snow)

S^o_n = sources of q_i (autoconv., collection and melting for rain, autoconv. + collection for snow)

Developed for long time step (typically 15 min), but also beneficial in Arome (50s)

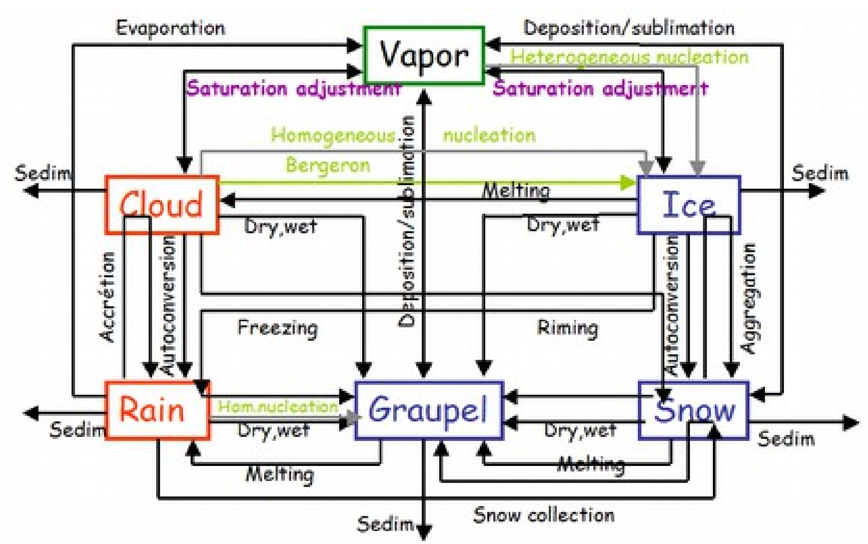
(Geleyn at al. 2008, Bouteloup et al. 2010)

Appropriate level of complexity

Example with microphysical scheme :

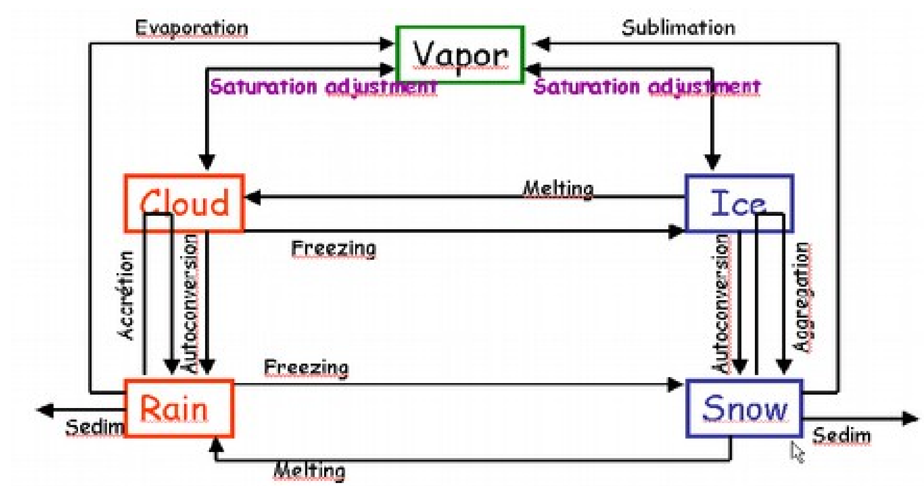
✓ appropriate level of complexity in CSRM and large scale model (Dx>10km)?

✓ difficulty to build microphysical scheme suitable for a wide range of time steps (from few seconds to tens of minutes).



AROME (ICE3)

(Caniaux, 1993 – Pinty and Jabouille, 1998)



ARPEGE

(Lopez, 2002 – Bouteloup et al., 2005)

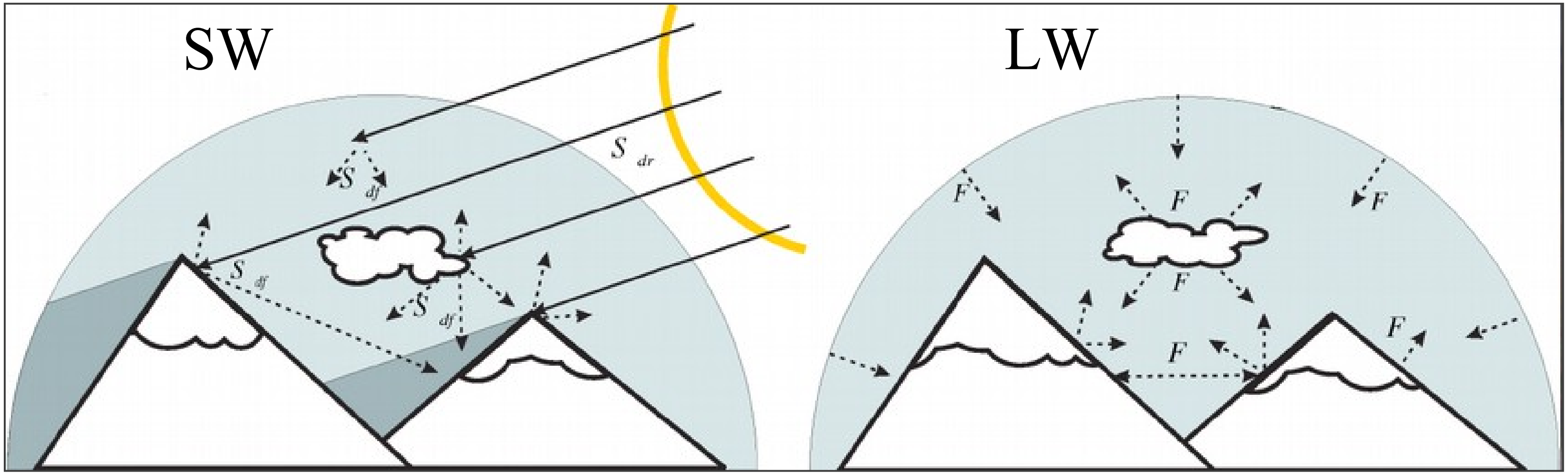
- Global NWP: One-moment prognostic scheme probably good enough for the next years.
- Convective-scale NWP: Two-moment schemes are expensive, but should be the better choice
- Data assimilation: Assimilation of cloudy pixels or convective-scale DA: more detailed microphysics schemes.

Towards hectometric resolutions for NWP

New processes to parameterize.

For instance, R&D needed on 2D/3D physical parameterizations:

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



Grey zones (subgrid versus resolved)

Modified shallow convection scheme

In the grey zone, removal of some assumption $\Longrightarrow$ Scale-adaptive scheme

At mesoscale (PM09) :

$$\frac{\partial M_u \phi_u}{\partial z} = E\overline{\phi} - D\phi_u$$

where

- ϕ is a variable
- M_u is the mass-flux
- E is the lateral entrainment
- D is the lateral detrainment
- α is the thermal fraction

$$M_u = \alpha w_u$$

In the grey zone :

$$\frac{\partial M_u \phi_u}{\partial z} = \tilde{E}\phi_e - \tilde{D}\phi_u$$

Similar to the mesoscale equation but ...

$$M_u = \alpha(w_u - \overline{w})$$

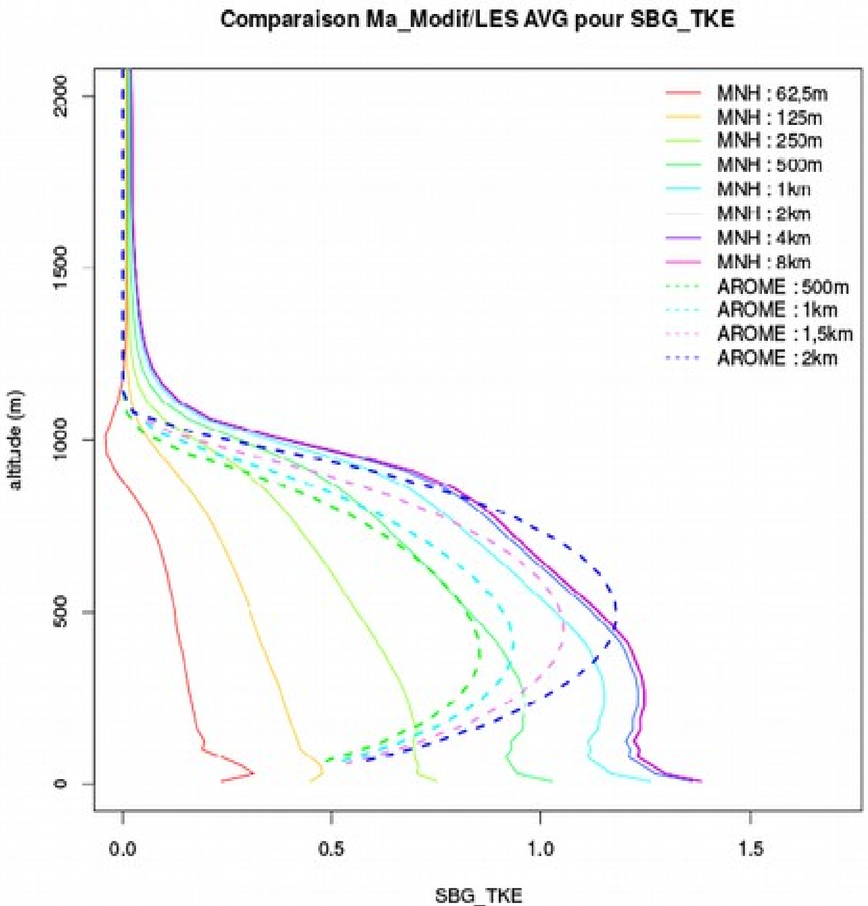
- α : the subgrid thermal fraction
- $\phi_e \neq \overline{\phi} \rightarrow \alpha$ not neglected
- $\overline{w}$ is taken into account
- $\tilde{E}$ et $\tilde{D}$ include thermal/environment exchanges and non-stationarities.
- $M_{u_{z=0}} = f(\frac{\Delta x}{h+h_c})$

(R. Honnert)

METEO FRANCE
Toujours un temps d'avance

Modified shallow convection scheme

Subgrid TKE IHOP, 12h, HRIO-LES



- Idealised Arome
- Good representation until 500 m
- Bad representation of the dynamical turbulence at the surface

(R. Honnert)

Summary

- ✓ Enhancing collaborations between NWP, Climat and process study communities around the development and validation of seamless physical parameterizations is beneficial (more expertise, diagnostics and resources)

- ✓ Multi-scales validation is useful to characterize the growth of model errors in climate models, BUT it remains difficult to make improvements in physical parameterizations reducing model errors in climate models.

- ✓ But, developing seamless atmospheric parameterizations is challenging, in particular for convection.

Thank you
for your attention

CNRS

METEO FRANCE