Keynote presentation on other parameterizations for Arome with a focus on turbulence

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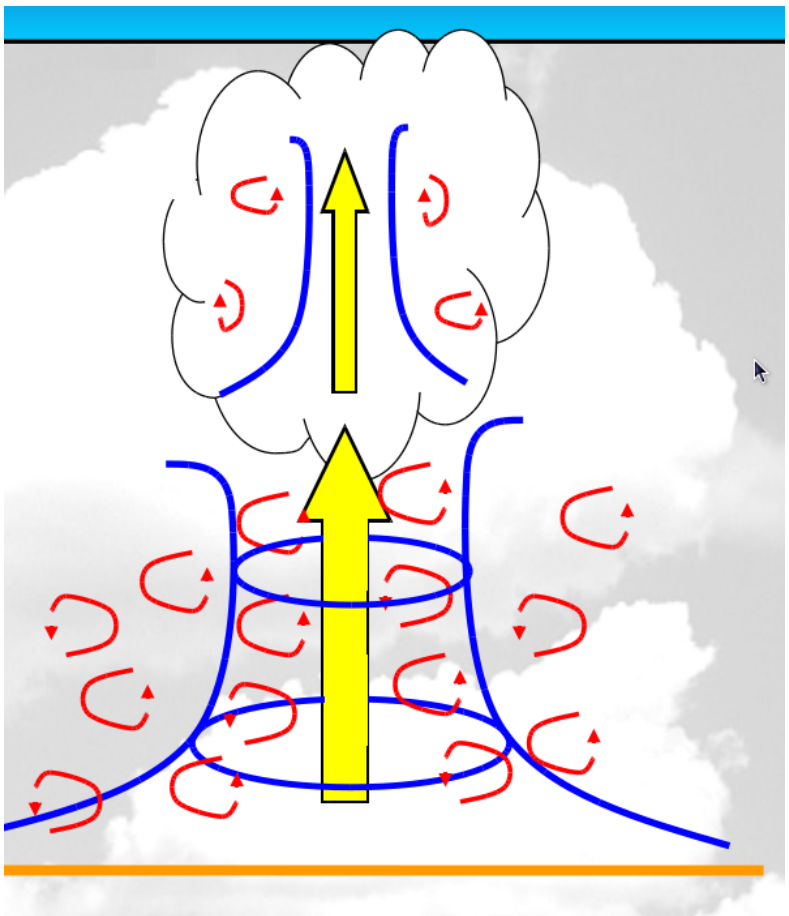
Turbulence Scheme in Arome



$$\overline{w'\phi'} = \underbrace{-K\left(\frac{\partial\overline{\phi}}{\partial z}\right)}_{\textit{Turbulence}} + \underbrace{\frac{M_u}{\rho}\left(\phi_u - \overline{\phi}\right)}_{\textit{Convection}}$$

Shallow

Updrafts

- EDMF (Eddy-Diffusivity/Masse-Flux) : Hourdin et al. (2002), Soares et al. (2004)
- CBR : K-gradient scheme (Cuxart et al. (2000)). TKE prognostic equation.
- PM09 : mass-flux scheme (Pergaud et al. (2009)). Updraft starts at the surface $\Longrightarrow$ BL Thermals.

Shallow Convection in the Grey Zone

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

At mesoscale (PM09) :

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

where

- ϕ is a time-dependent 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 :

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

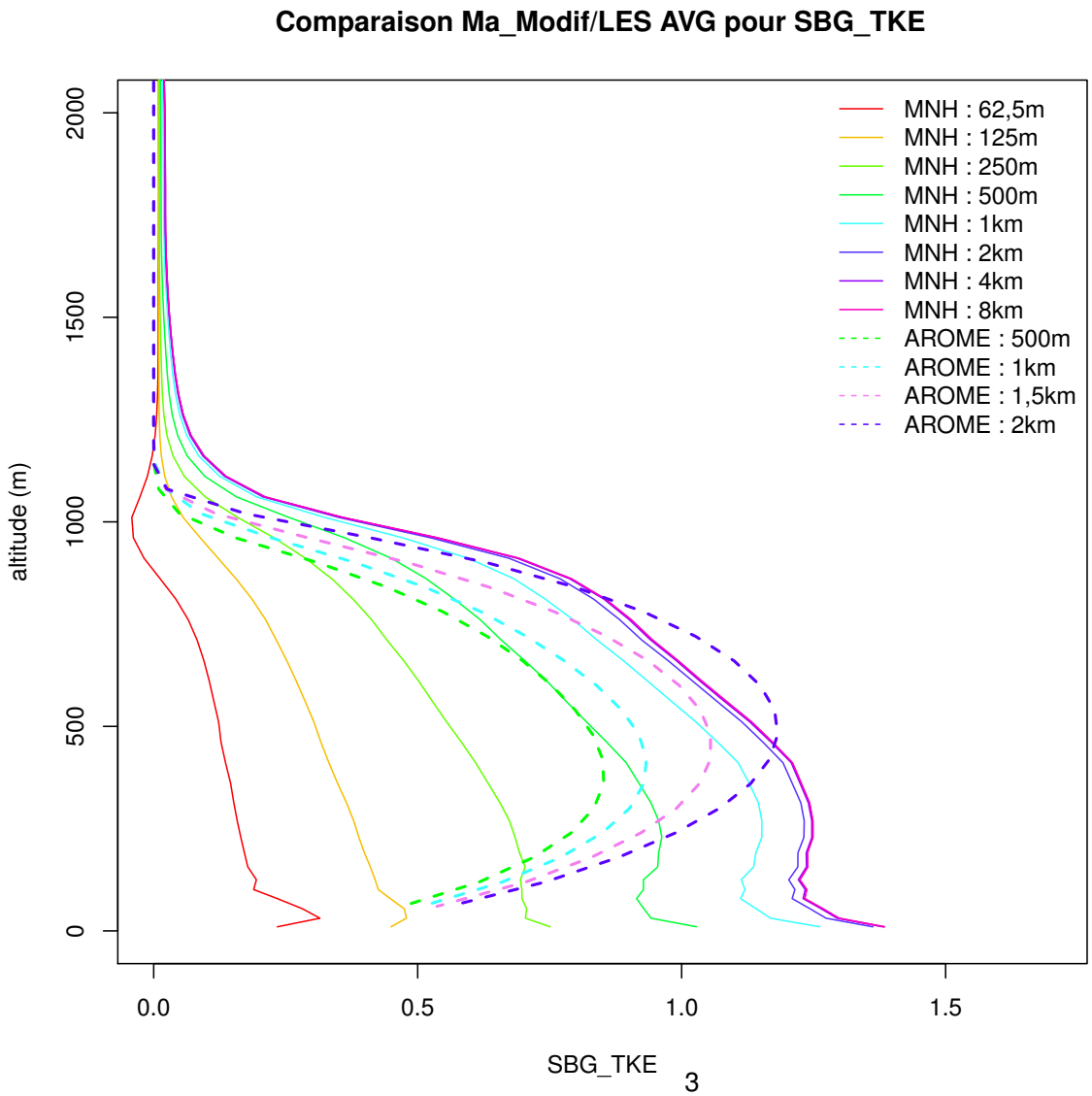
Similar to the mesoscale equation but ...

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

- 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.
- $M_{u_{z=0}} = f(\Delta x/(h + h_c))$

Modified Shallow Convection : Results

Subgrid TKE IHOP, 12h, HRIO-LES



- Idealised case in Arome
- Scale adaptive
- Bad representation of the dynamical turbulence (beyond 500 m and above the surface boundary layer)

3D turbulence scheme

Honnert and Masson (2014) suggested that a 3D turbulence scheme is needed at 500 m resolution and finer. A 3D version of CBR exists in Méso-NH. But :

- No 3D scheme in AROME $\Longrightarrow$ technical challenge.
- Méso-NH 3D version only works for isotropic turbulence : the grey zone is not isotropic $\Longrightarrow$ Quantification of vertical and horizontal mixing length by LES :

$$\overline{u_i' \phi'}^{\Delta x} = -K(\Delta x) \frac{\partial \overline{\phi}^{\Delta x}}{\partial x_i}$$

$$K(\Delta x) = \alpha L(\Delta x) \sqrt{e(\Delta x)}$$

Stable Boundary Layer (E. Bazile)

Implementation of EFB (Energy and Flux Budget) (E. Bazile) from Zilitinkevitch et al. (2013) section 4.2.

Motivations :

- To improve the stable case : avoid the collapse of the turbulence partly due to the negative thermal production.
- To allow anisotropy

Results :

- EFB (E. Bazile) tested on GABLS1 and GABLS4
- 👍 Increase the momentum mixing above 700hPa
- 👎 Costly if complete scheme (cf. Zilitinkevitch et al. (2013) section 4.1.)
- 👎 Only in **dry** atmosphere.

Perspectives :

- To study 1D cloudy cases (ARMCu and Astex)
- To add the equation for the turbulent dissipation time scale
- To study the transition stable/instable.
- To generalise (if possible) to moist atmosphere

Moist-Air Entropy (P. Marquet)

The **moist-air entropy**, θ_s, (Marquet (2011)) improvement of the Betts potential temperature, θ, to be used in moist air turbulence.

- The impact on turbulent fluxes might be specially important if the turbulent Lewis number Le_t would be different from unity.

$$Le_t = \frac{K_{\theta_s}}{K_{q_t}}$$

- Investigation of the **hypothesis "$\mathbf{Le_t \neq 1}$"** by using observations [1] and LES [2] .
- Need a "back to basic" analysis of CBR scheme

1. Daily measurements of eddy-correlation flux of moist entropy with CNRM-FLUXNET devices
2. High-Tune submitted ANR

Surface (Y. Seity) and Gusts (R. Honnert/E. Bazile)

Future plans for surface :

- Use Multiple Energy Balance (MEB) and Explicit Snow (ISBA-ES)
- Replace Force-Restore Isba 3L by Isba-Diff
- Develop surface assimilation for Isba-Diff

Wind gust diagnostics :

- $G(t) = max(G(t-1), U + f(\text{TKE}))$ calculated at each time step over one hour
- At Météo-France : under-estimations at fronts and over-estimation under thunderstorms
- Development of test-beds on observation sites (near Paris site Sirta and maybe Cabauw)

Radiation (Y. Bouteloup)

High-Tune submitted ANR :

- Tests of SRTM and McIca
- Cloud covering depending on the zenithal angles
- Tests of different cloud overlap assumptions with and without McIca

Other :

- Monitoring of the ECMWF work on radiation schemes and the emergence of a new scalable scheme.

Perspectives

Météo-France short-term priorities :

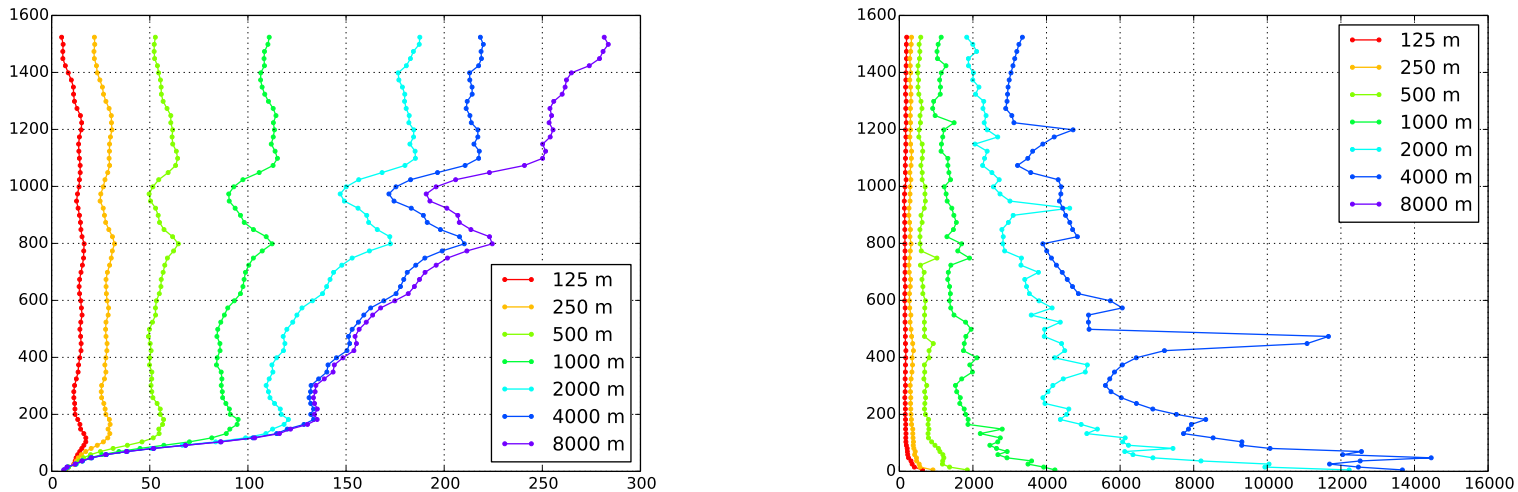
- Wind gust forecasts
- Improve stable layers, low-level clouds and fog forecasts
- Likely increase in number and diversity of diagnostic outputs from forecasts
- Build-on existing SURFEX options to improve surface forcasts

Other long-term perspectives :

- Open to cooperation on stable-layer turbulence
- Towards a unified turbulence code.
  - New common framework emerges from work on moist thermodynamics
  - Invites rebuilding a scheme by revisiting the foundation of CBR
  - Likely it should include 3D aspect
- Radiation : How to deal with the increasing gap with ECMWF ?

THANK YOU FOR YOUR ATTENTION

Horizontal mixing lengths in CBR



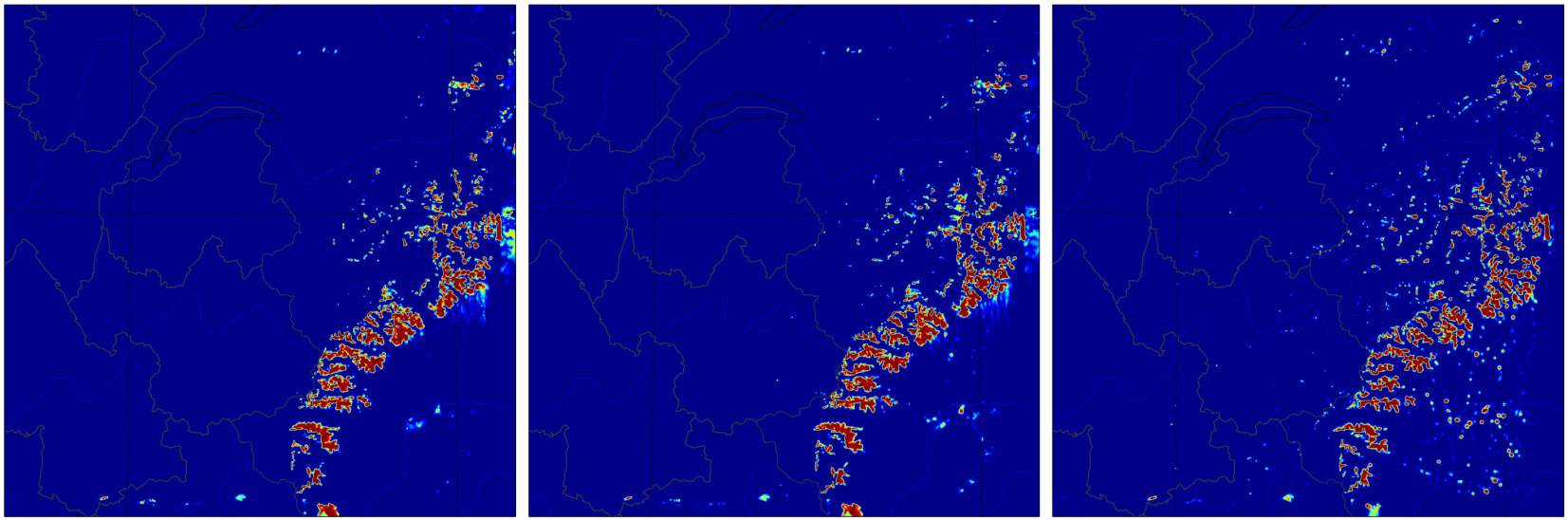
(a) Vertical

(b) Horizontal

FIGURE : (a)Vertical and (b) horizontal mixing lengths computed at resolutions from 12.5 m to 800 m. CASES-99 (neutral BL)

- Only valid in the BL $\Longrightarrow$ inadequate for too small gradients
- Vertical : consistency with existing Lengths : BL89 and DEAR $\Longrightarrow$ method valid.
- Horizontal : much largeur than vertical at meso-scale.
- In LES, same order of magnitude $\Longrightarrow$ Isotropy.

AROME-500 m



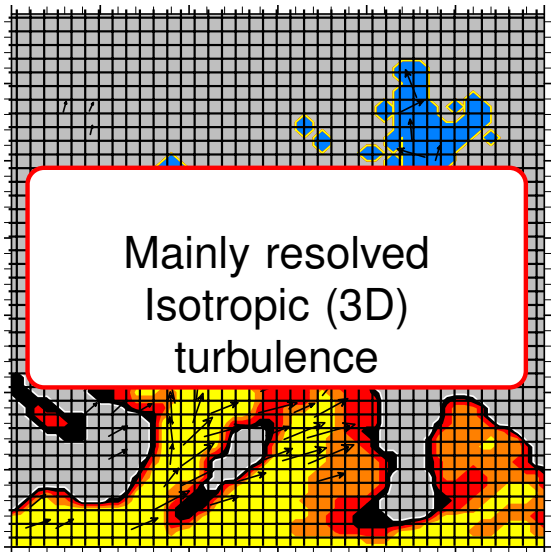
(a) PM09 (b) New Param (c) NONE

FIGURE : Low-level cloud cover on 07/06/2014 with AROME-500 m over the Alpes.

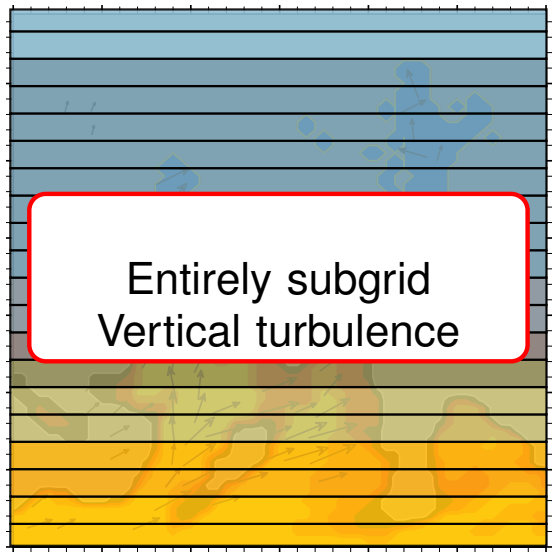
Perspectives :

- Test on a IOP of HyMeX in the ANR MUSIC (Multiscale process studies of intense convective precipitation events in Mediterranean)
- Implementation of downdraughts

Sub-km scales and grey zone of turbulence



GRAY ZONE
of BL thermals



LES

Meso-scale

1.3 km

7 km

10 100 200 500 1000 2000 Δx (m)

AROME ?

AROME

ARPEGE

Increasing computational power

References

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