Parametrisation of dry and cloudy thermals in Arome and Méso-NH

Julien Pergaud
Valery Masson
Sylvie Malardel

Context

- ✓NWP mesoscale modele Arome (dx=2.5 km, dt=60 s)
- ✓Operational in 2008
- ✓Hypothesis : the deep convection is resolved by the dynamics +detailed microphysics
- ✓The current shallow version of KFB (originally developped in Méso-NH) shows some limitations :
  - ▪Cloudy updraft only
  - ▪Closure in CAPE seems not the best for shallow clouds
  - ▪No momentum mixing
  - ▪The link with the statistical cloud scheme is problematic

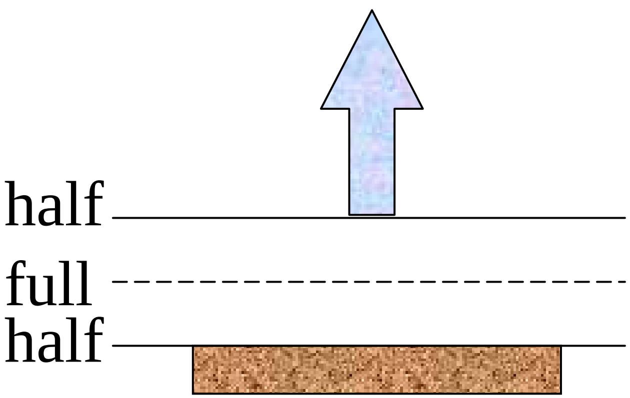
➢A new scheme largely inspired by P.Soares scheme (Soares et al, 2004)

Main choices for the updraft

- One single updraft (dry and possibly cloudy above) starting just above the surface
- Mixing of thermodynamic moist conservative variables
- Mixing of momentum (considered as a conservative variable for the time being)
- The entrainement/detrainement formulation are different below and above the LCL
- The updraft fraction is an output of the scheme

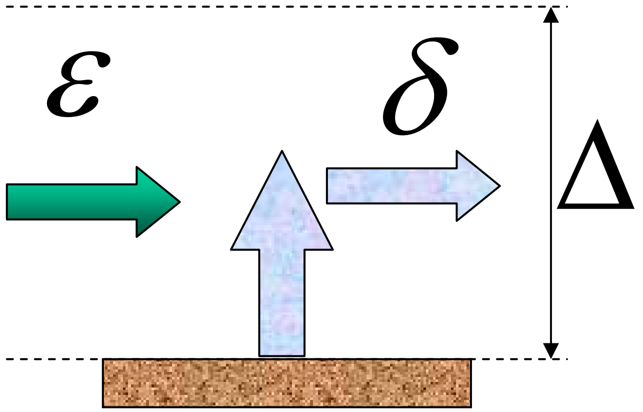
Updraft trigger

$$
\begin{cases}
\theta_{l_u} = \overline{\theta_l} + \alpha \dfrac{\left(\overline{w'\theta'}\right)_{surf}}{\sqrt{e}} \\
r_{t_u} = \overline{r_t} + \alpha \dfrac{\left(w'r'\right)_{surf}}{\sqrt{e}} \\
M_u = C \times \rho \left(\dfrac{g}{\overline{\theta_{vref}}} \left(\overline{w'\theta'}\right)_{surf} \times L_{up} \right)^{1/3}
\end{cases}
$$



SURFEX (surface fluxes)

Entrainement/detrainement below the LCL **(Lappen et Randall ,2001)**

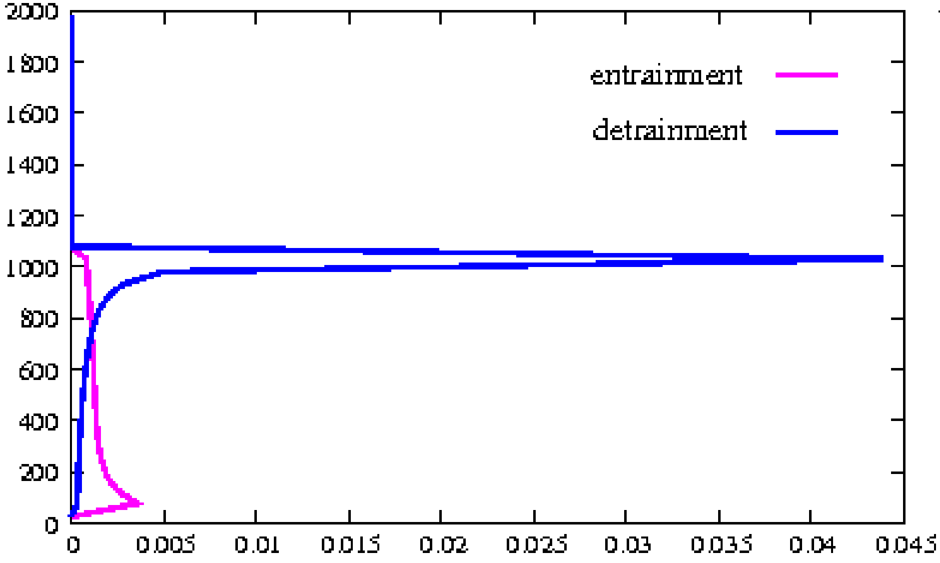


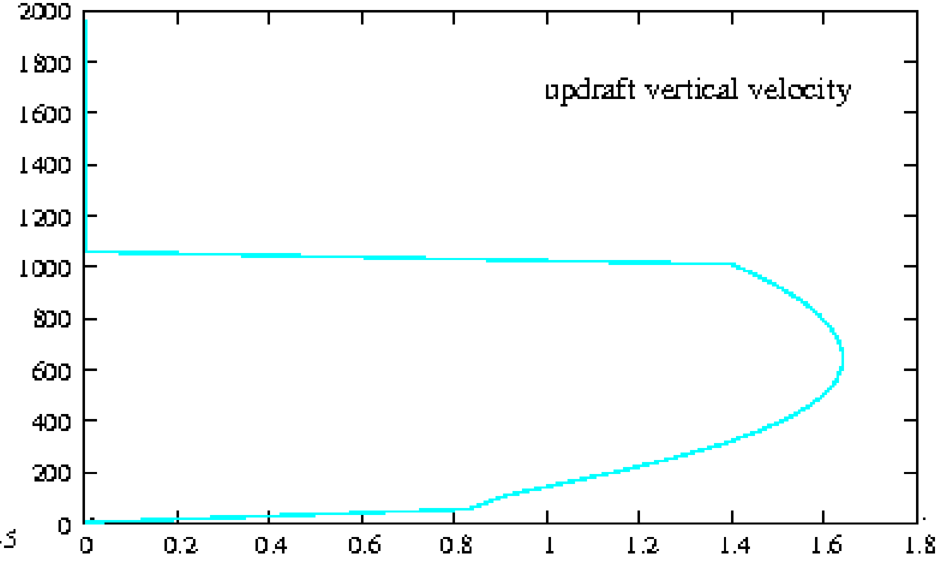
$$\begin{cases} \varepsilon = \dfrac{C_E M_u}{L_{dn}} + \boxed{C_w w_u^2} \\ \delta = \dfrac{C_D M_u}{L_{up}} \end{cases}$$

$$\Delta M_u = \varepsilon - \delta$$

$$\Delta \phi_u = \varepsilon \overline{\phi} - \delta \phi_u$$

Initiation of dry plumes above the Australian desert (Wangara case)

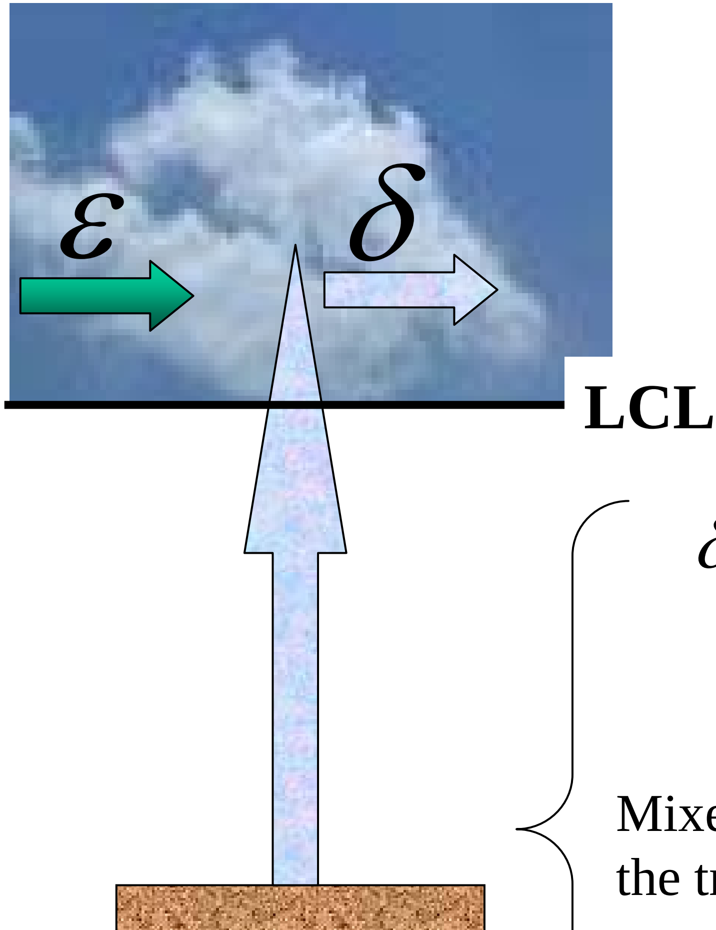




Equation for the updraft vertical velocity

$$\frac{\partial\left(\frac{1}{2}w_u^2\right)}{\partial z} = a\,Buo - b\varepsilon$$

Entrainement/detrainement above the LCL (Kain et Fritsch, 1990)



Environmental air fraction

$$\varepsilon_B = Mt \int_0^{\chi_c} \chi f(\chi) d\chi = \chi_c^2$$

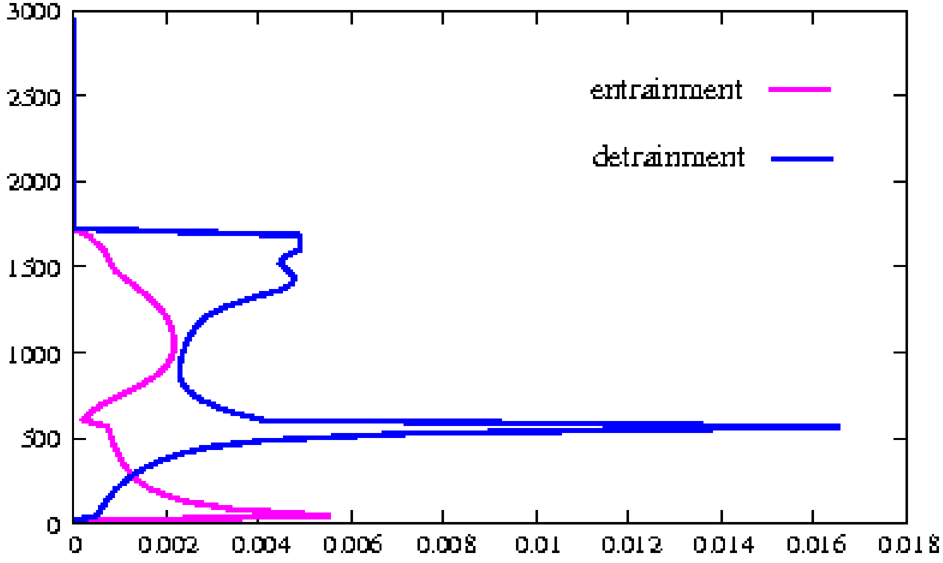
$$\delta = Mt \int_{\chi_c}^{1} (1-\chi) f(\chi) d\chi = 1 - \chi_c^2$$

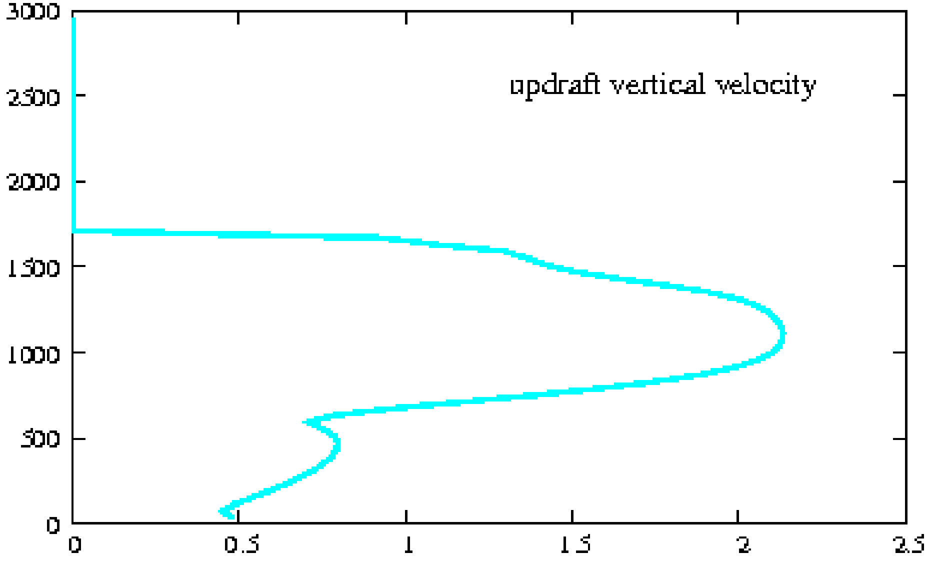
Mixed air in the transition zone

Environmental air fraction separating buoyant from non-buoyant mixing

$$\varepsilon = \varepsilon_B + C_w w_u^2$$

Stationnary cumuli in the Barbados region (Bomex)





Equation for the updraft vertical velocity

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Shallow cumuli : subgrid cloud scheme

Closure : $$q_{c_u} \Rightarrow \overline{q}_c \, ?$$

Direct cloud scheme :

$$\begin{cases} \alpha = \dfrac{M_u}{\rho w_u} = \text{updraft fraction} \\ \overline{r}_c = c_1 \times \alpha \times r_{c_u} \\ N_{ray} = c_2 \times \alpha \end{cases}$$

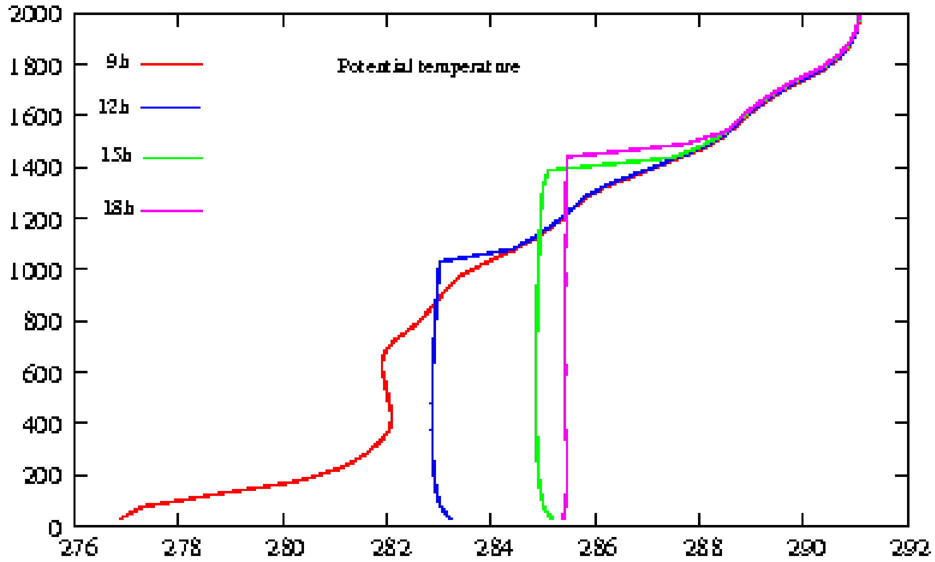
Rain in shallow cumulus : subgrid autoconversion

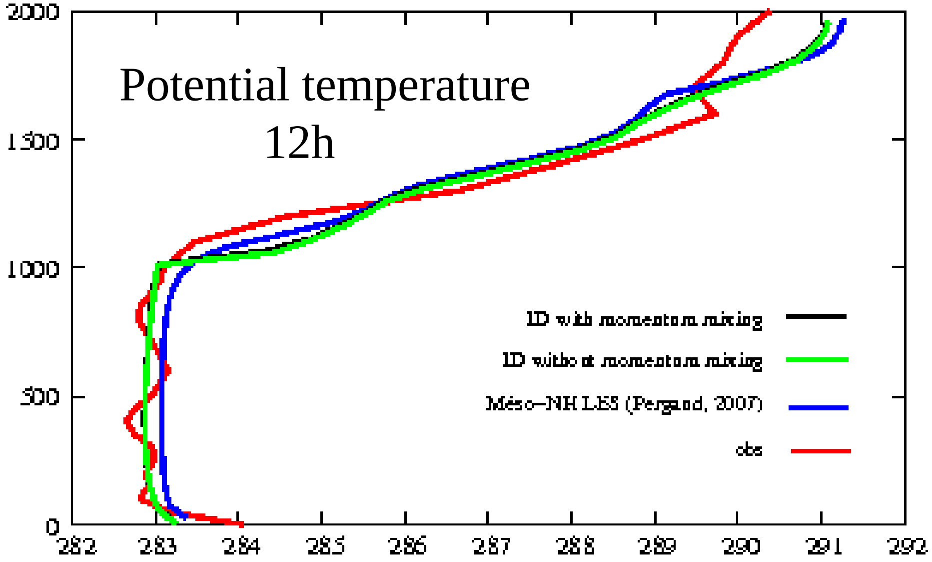
$$\Delta r_{r\,u} = \max(0, \frac{\overline{r}_c}{N_r} - XAUCV)$$

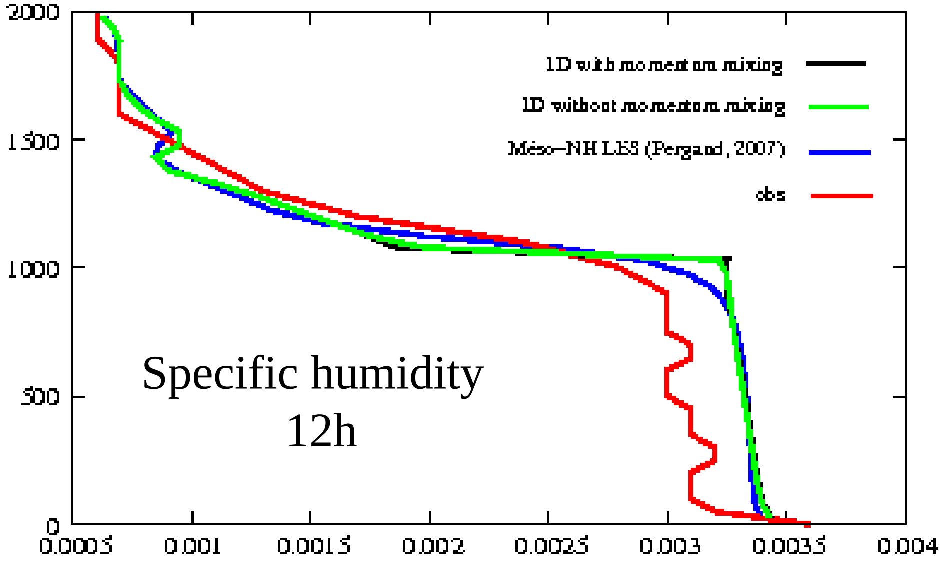
$$\Delta \overline{r}_r = N_r \times \Delta r_{r\,u}$$

Autoconversion is the only subgrid process in the microphysics

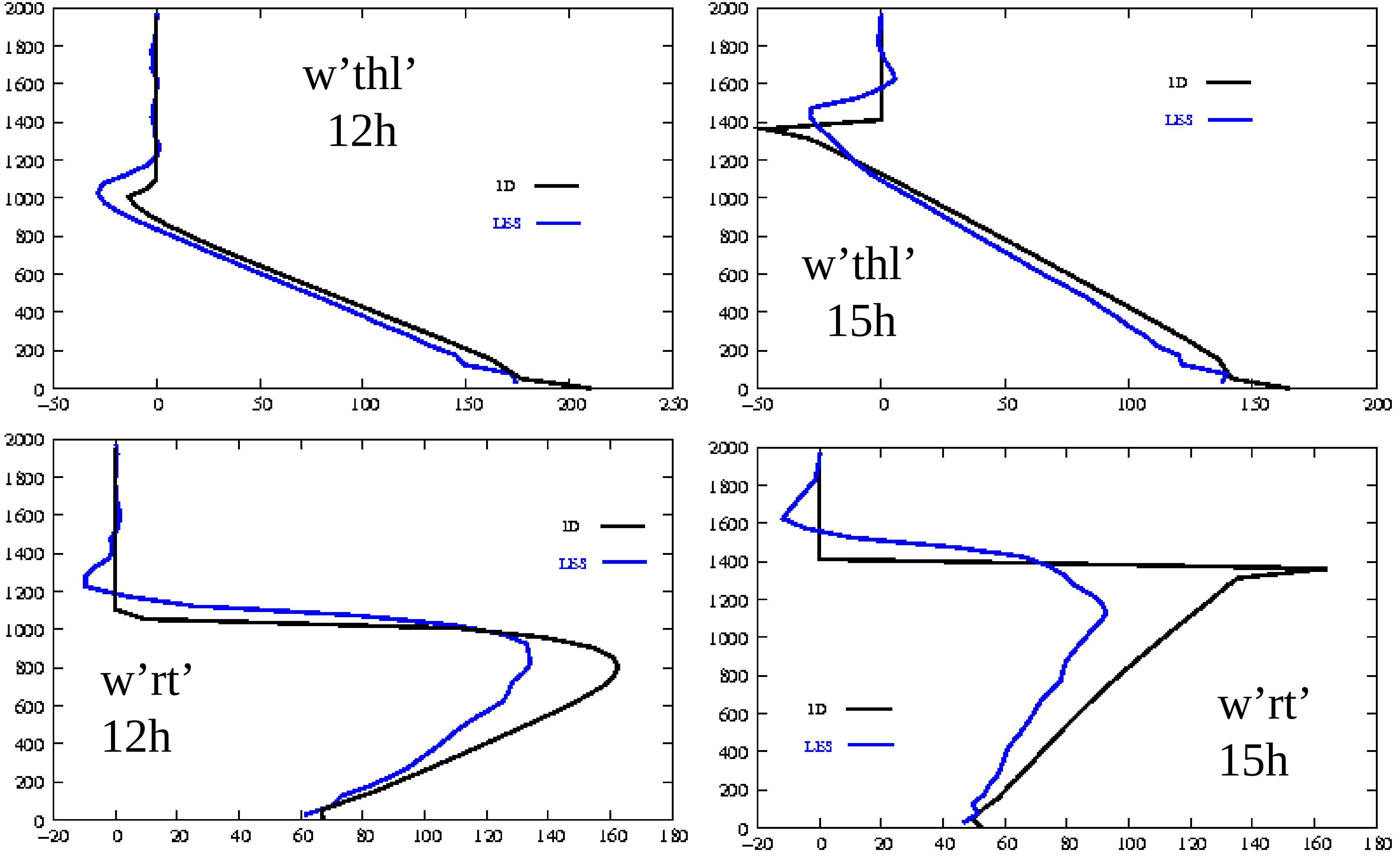
Initiation of dry plumes above the Australian desert (Wangara case)





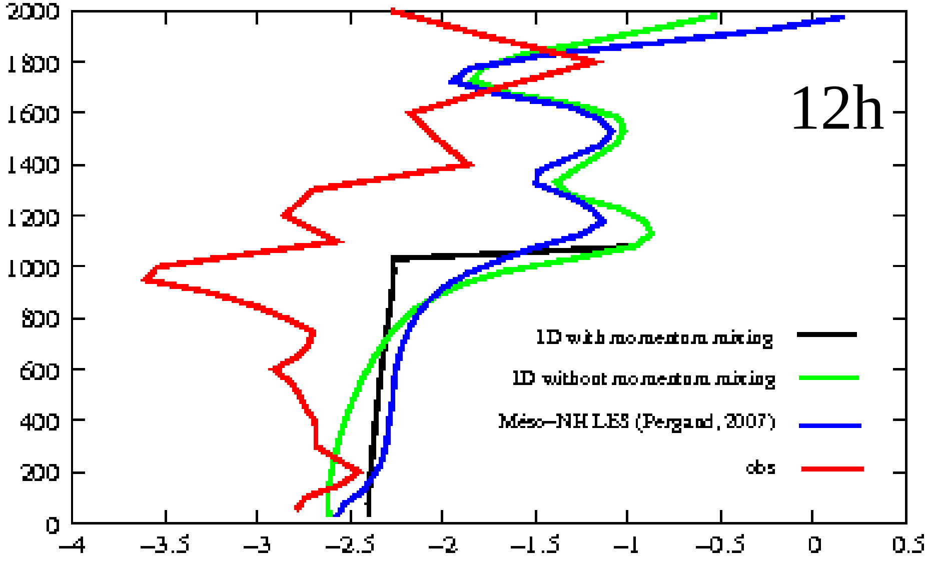


Initiation of dry plumes above the Australian desert (Wangara case)

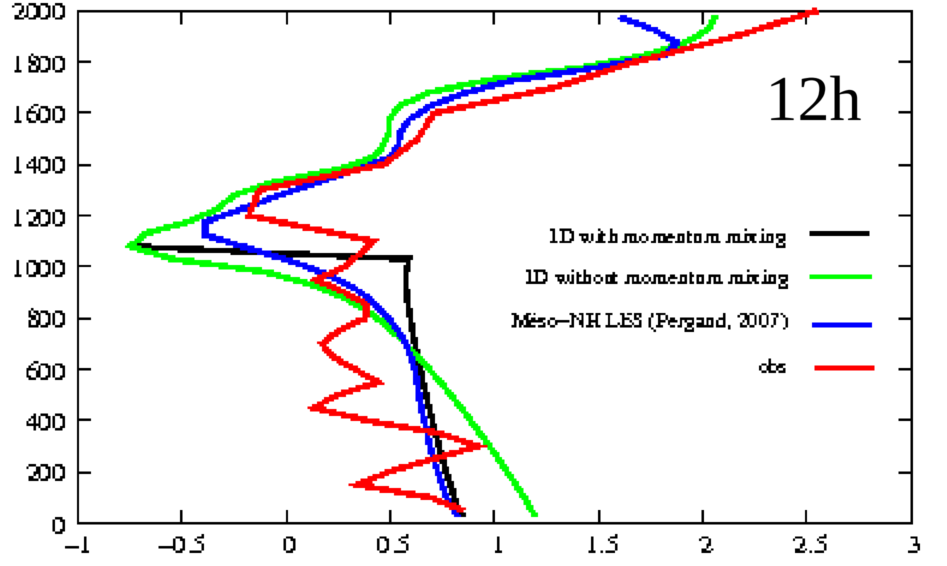


Initiation of dry plumes above the Australian desert (Wangara case)

Impact of momentum mixing

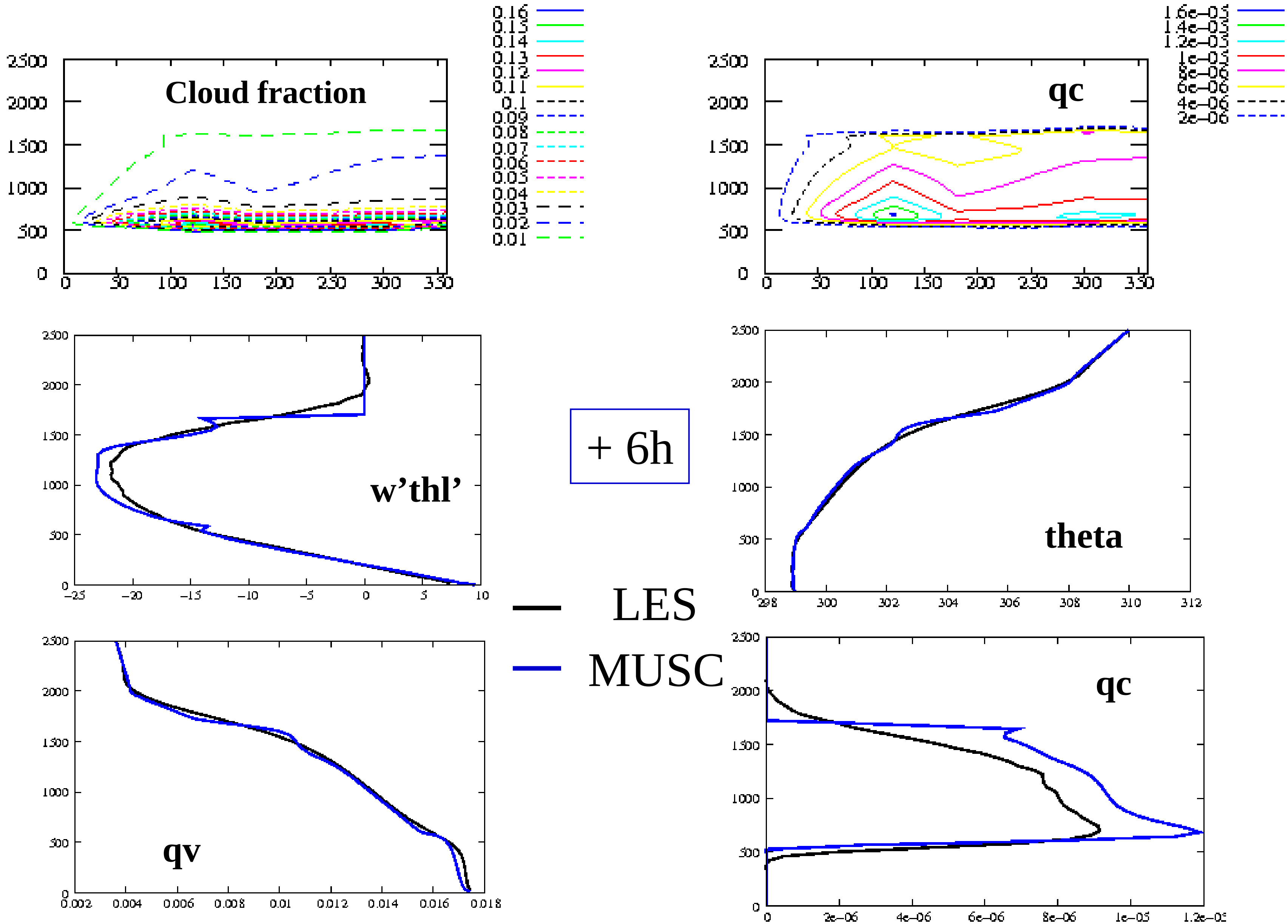


Zonal wind

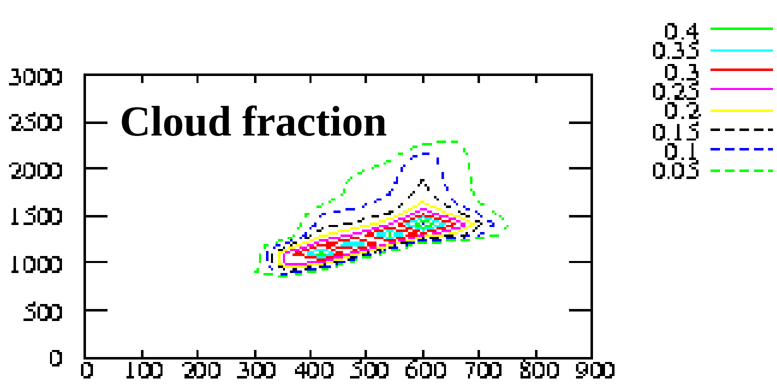


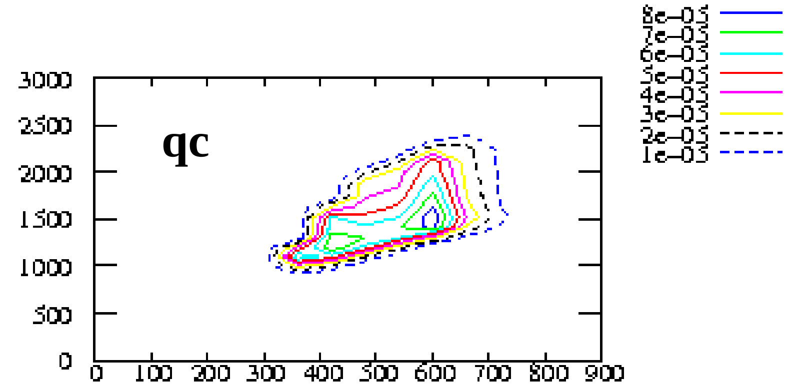
Meridional wind

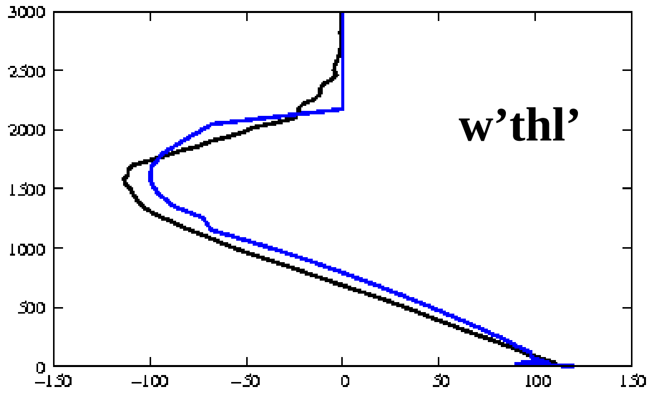
Stationnary cumuli in the Barbados region (Bomex)



Diurnal cycle of shallow cumuli (Eurocs/ARM/Cu)







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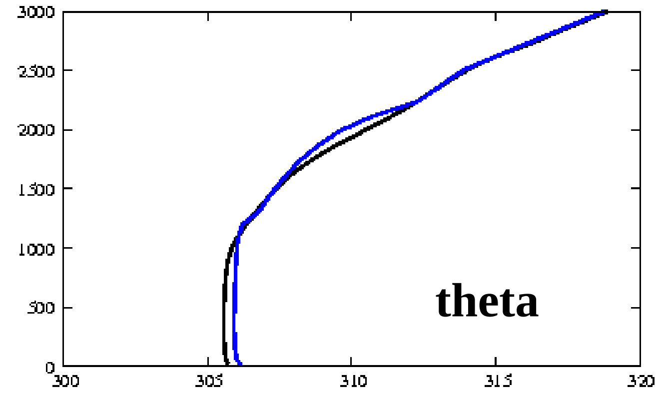

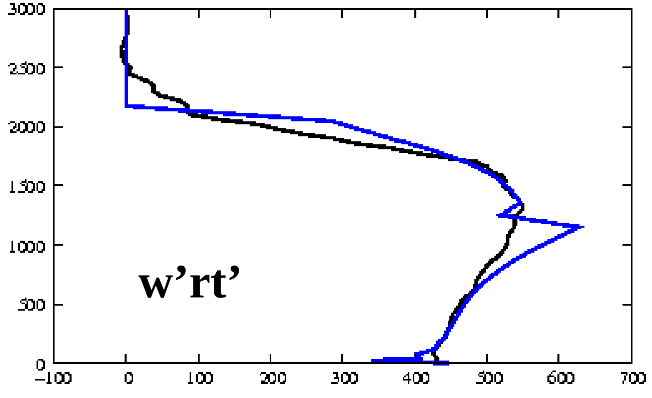

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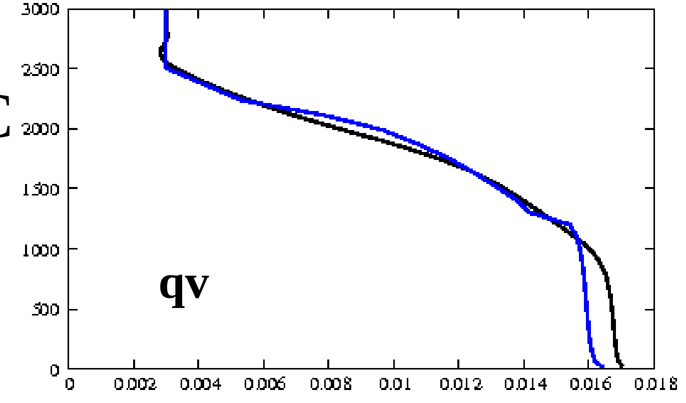
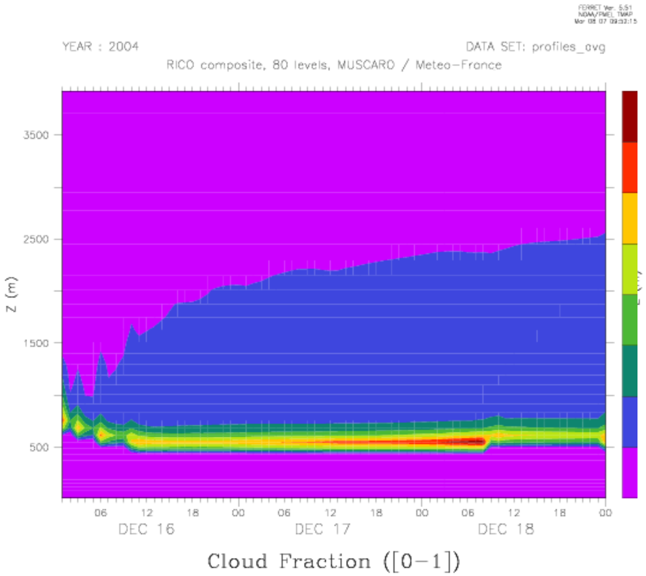
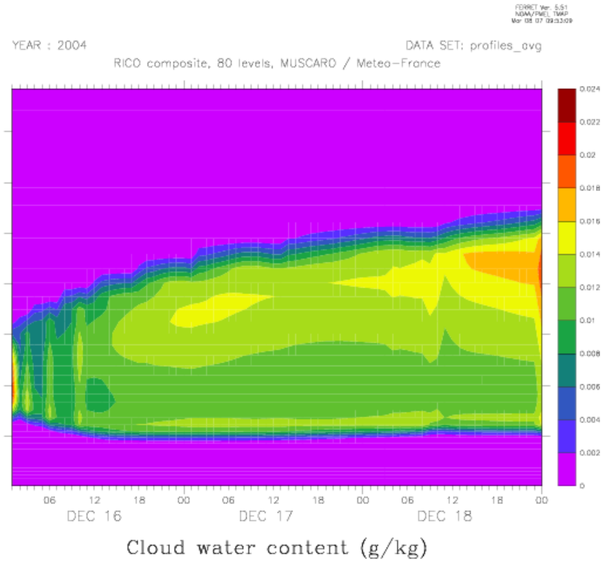
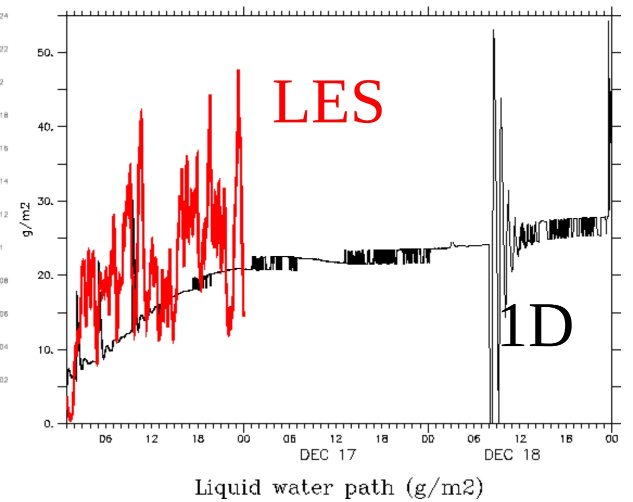
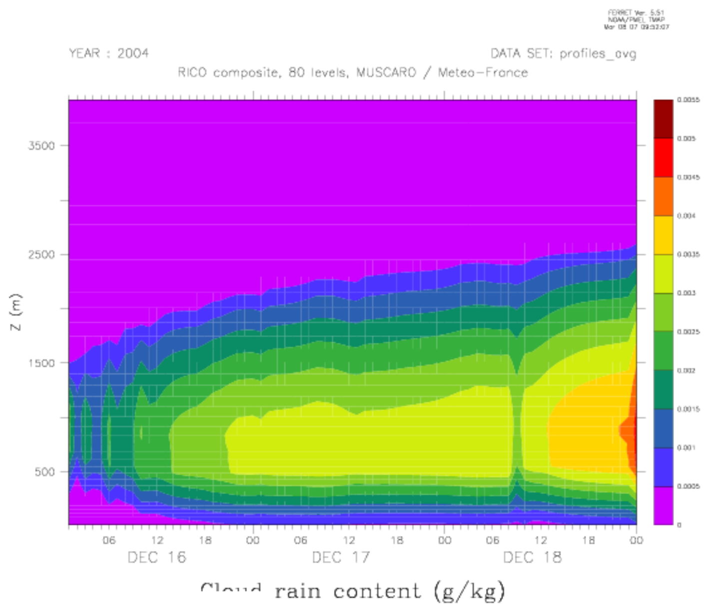


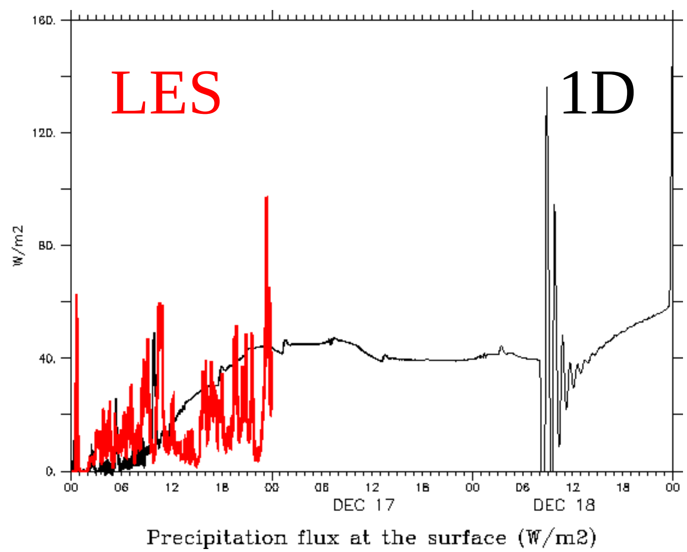
Precipitating shallow convection in the Barbados region (Rico)





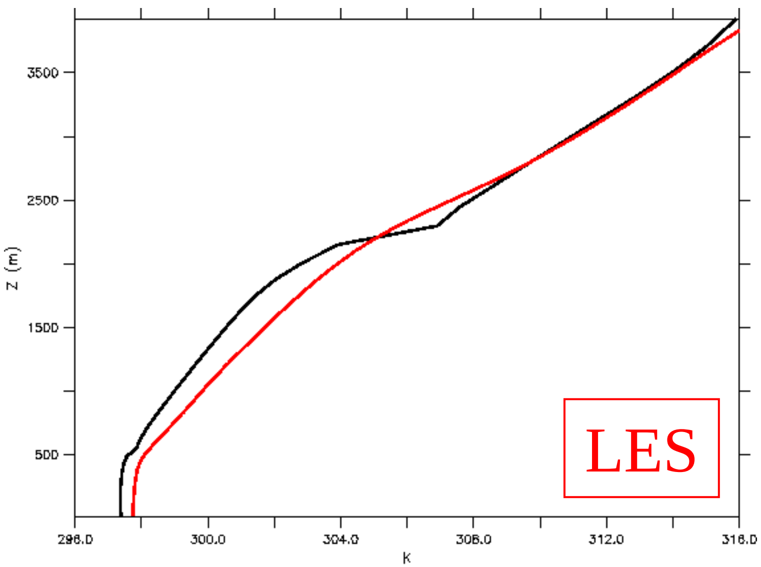




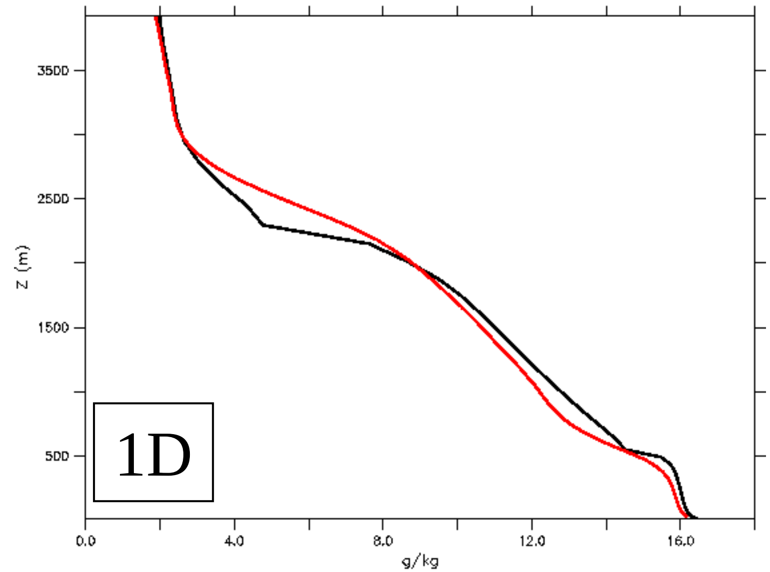


(Méso-NH LES, new setup, F. Couvreux)

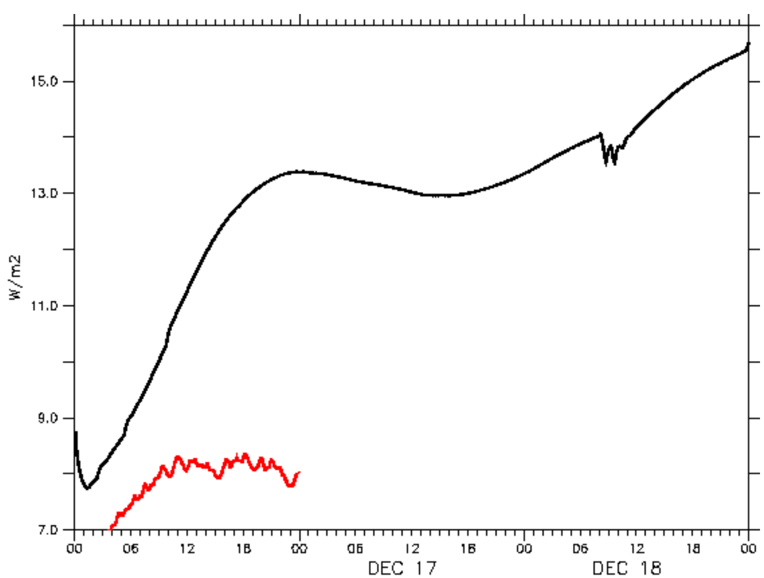
Precipitating shallow convection in the Barbados region (Rico)



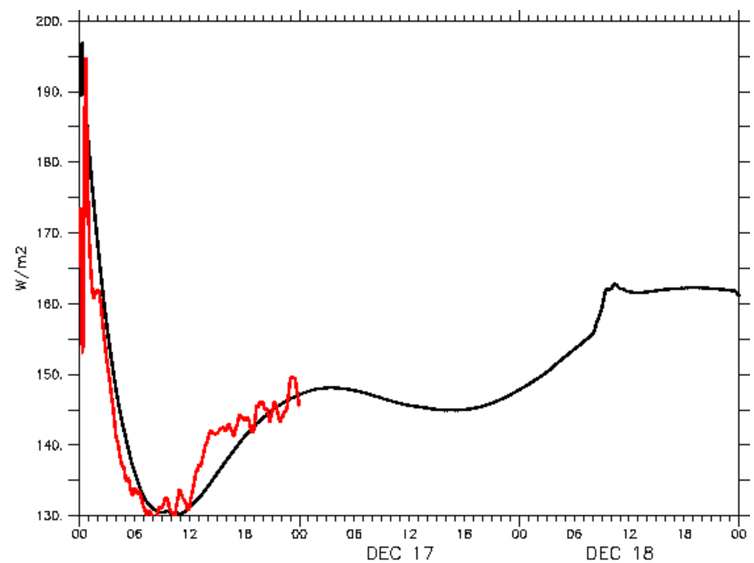
Liquid water potential temperature (K)



Total water (vapor+liquid+ice) (g/kg)



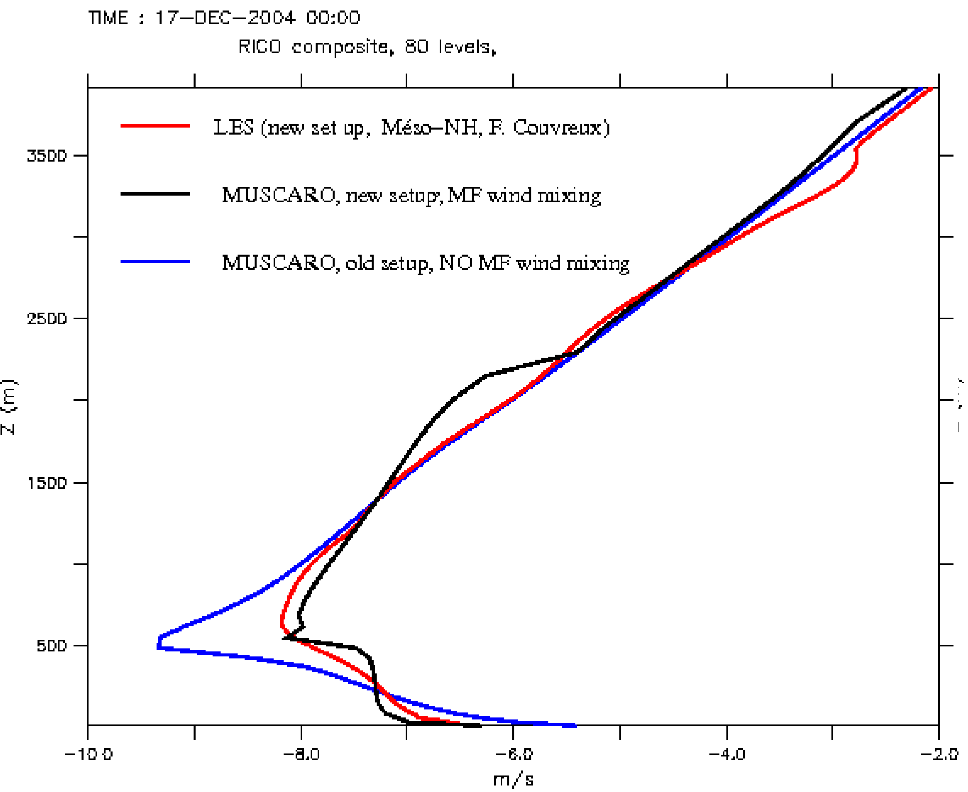
Surface sensible heat flux (W/m2)



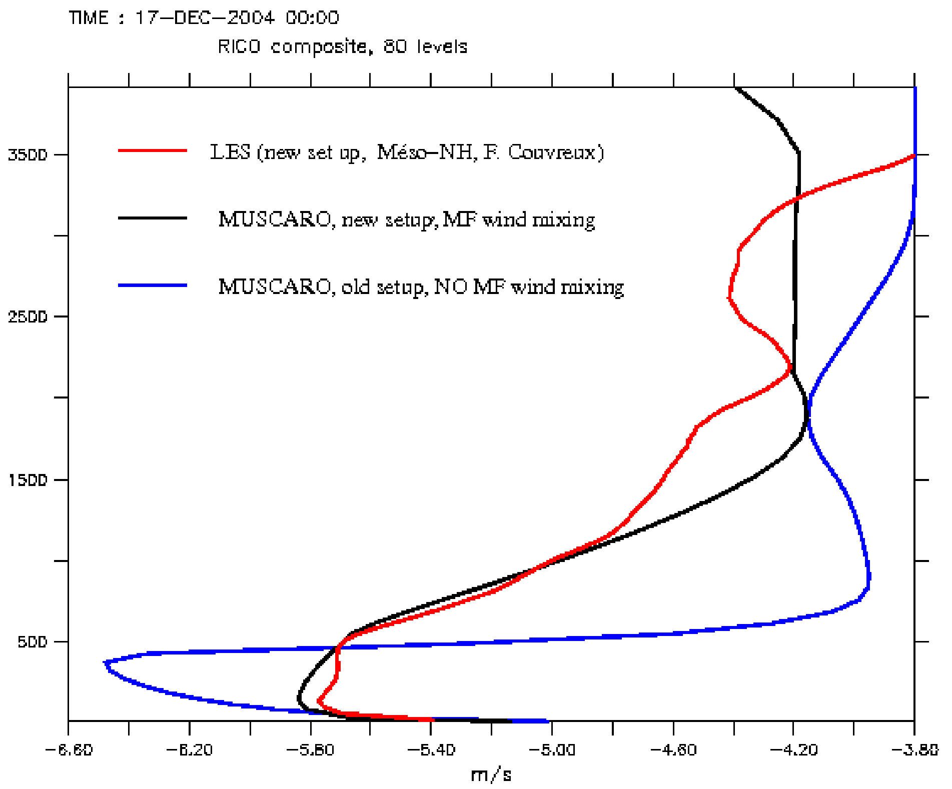
Surface latent heat flux (W/m2)

Precipitating shallow convection in the Barbados region (Rico)

Impact of MF momentum mixing



Zonal wind (m/s)



Meridional wind (m/s)

Mixing too strong, especially in the sublayer cloud : need to take into account the pressure drag?

Summary

- Implantation of a MF single updraft scheme for shallow convective transport in Méso-NH and Arome
- Modification of the cloud scheme and of the autoconversion in the microphysics
- Dry plumes and cloudy/precipitating shallow cumuli are well reproduced with the 1D versions of the models
- Some tunning are still needed (in particumar to adjust the feedback between the entrainment and the updraft vertical velocity)
- Try a more physical formulation for wind mixing
- 3D validations started with case studies and with a more systematic comparison with Cloudnet observation on Cabauw (Cu but also Sc)