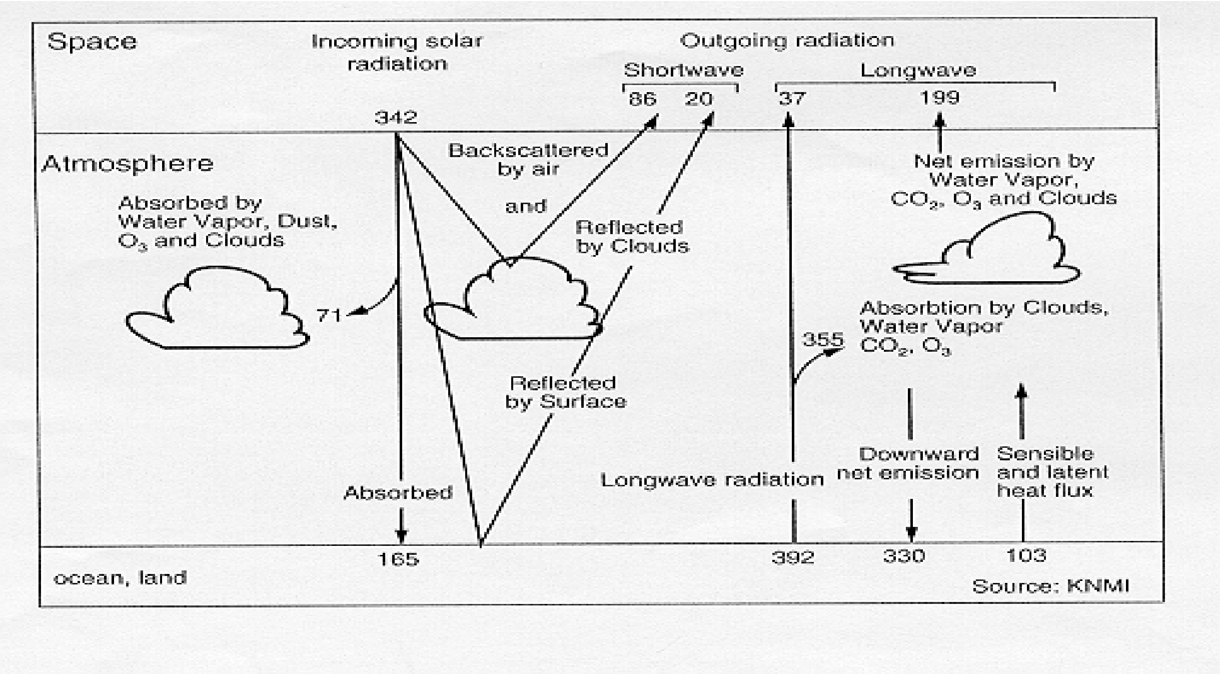
Current status for the PBL parameterization in ARPEGE-ALADIN, the GABLS experiment and the future with a TKE scheme

BAZILE E. CNRM June 2005

METEO FRANCE

PBL parameterization:

- scheme for the representation of the vertical eddy fluxes of heat, momentum and water
- The chosen solution must be valid for the whole earth (over land and over sea)
- For NWP, the scheme must be stable, cheep and gives smooth results



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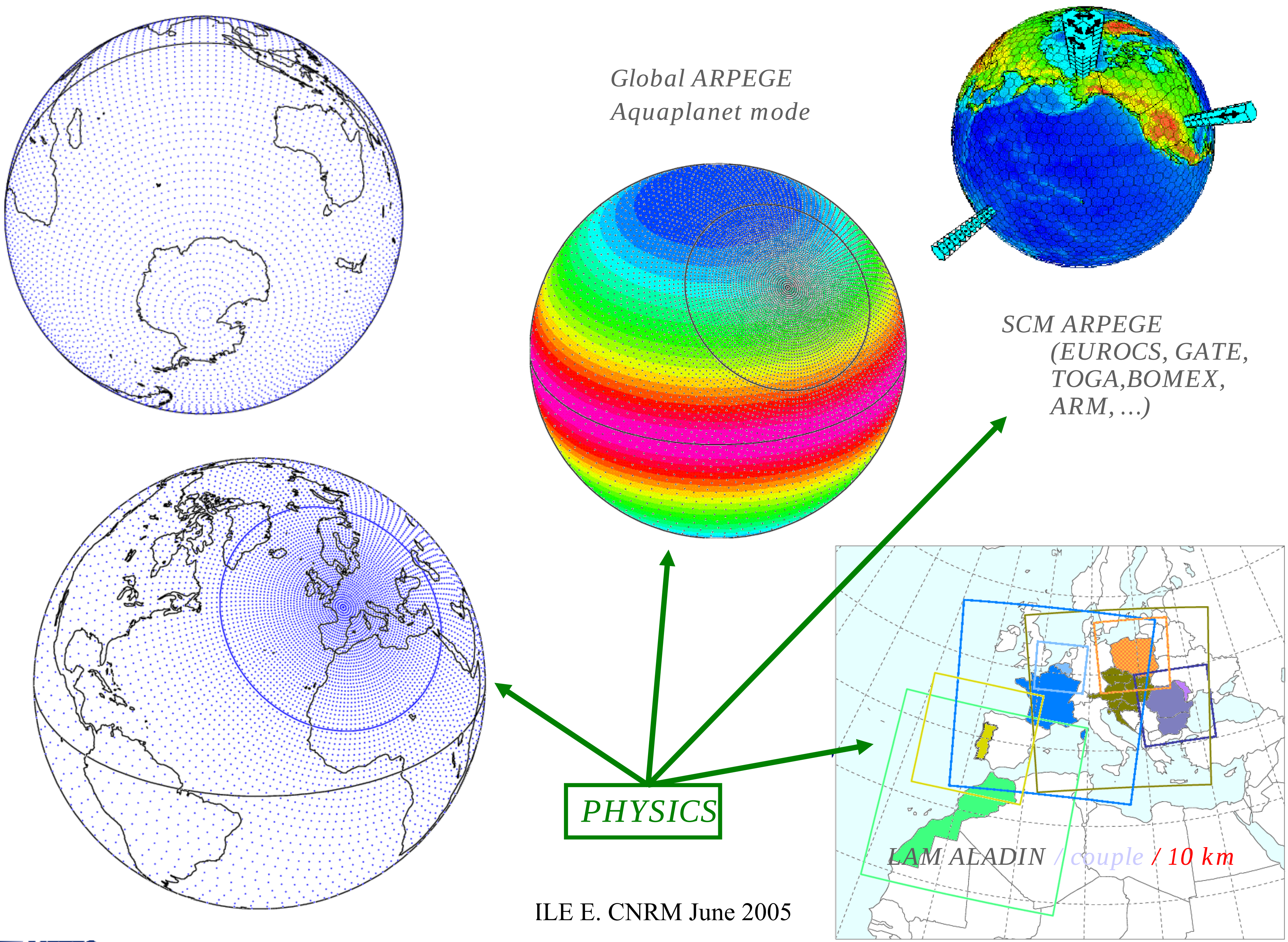

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Reynolds equations:

$$\frac{\partial \overline{u}}{\partial t} = -\frac{\partial}{\partial z}\left(\overline{w'u'} - \nu \frac{\partial \overline{u}}{\partial z}\right) + f \cdot \left(\overline{v} - v_g\right)$$

$$\frac{\partial \overline{v}}{\partial t} = -\frac{\partial}{\partial z}\left(\overline{w'v'} - \nu \frac{\partial \overline{v}}{\partial z}\right) + f \cdot \left(\overline{u} - u_g\right)$$

$$\frac{\partial \overline{\theta}}{\partial t} = -\frac{\partial}{\partial z}\left(\overline{w'\theta'} - \nu_\theta \frac{\partial \overline{\theta}}{\partial z}\right)$$

for $z >> z_0$ $\quad \overline{w'\chi'} >> \nu_\chi \frac{\partial \overline{\chi}}{\partial z}$ molecular viscosity

Semi-empirical theory: $\overline{w'\chi'} = -K_\chi \frac{\partial \chi}{\partial z}$

To close the system some hypothesis are required for : K_χ

Zilintinkevitch, Laikhtman and Monin (1967) and Wippermann (1973) give a exhaustive list for the formulation of K but …

The exchange coefficient depends on the PBL structure, Prandl mixing length (1925):

$$K_u = l_p^2 \cdot \left(\left(\frac{\partial u}{\partial z} \right)^2 + \left(\frac{\partial v}{\partial z} \right)^2 \right)^{0.5}$$

$$l_p = l_p(z) = \frac{k \cdot z}{1 + \frac{k \cdot z}{l_\infty}}$$ Blackadar (1962)

It seems more natural that the exchange coefficients depends on the turbulent structure instead of the mean value:

Kolmogorov, 1942 $K_u = \alpha \cdot l \cdot \sqrt{\overline{e_T}}$ $K_\theta = \alpha_\theta \cdot K_u$

Wippermann (1971) : $l_p = l_\infty - (l_\infty - k \cdot z_0) \left(\frac{\sqrt{\overline{u'w'}^2 + \overline{v'w'}^2}}{u_*^2} \right)^p$

- J.F. Louis in Boundary Layer Meteorology (1979 vol:17, pp:187-202)
- the first requirement is speed, so it is necessary to keep the parameterisation at a simple level
- no higher order closure methods
- the diffusion coefficients must depend not only on the wind shear as in the Prandl formulation but also on the static stability
- Drag coefficient formulation at the surface
- Exchange coefficient formulation throughout the atmosphere with a consistent transition with the surface
- The author felt that the introduction of auxiliary prognostic variables (like height of PBL) might produce some incorrect feedback mechanisms in the model

The equation of vertical diffusion of any conservative quantity is:

$$\frac{\partial \chi}{\partial t} = \frac{1}{\rho}\frac{\partial}{\partial z}\left(\rho \cdot K_{\chi}\frac{\partial \chi}{\partial z}\right) \qquad \overline{w'\chi'} = -K_{\chi}\frac{\partial \chi}{\partial z}$$

The surface fluxes are based on Monin-Obukhov similarity theory:

$$\frac{\partial \chi}{\partial z} = \frac{\chi_*}{k \cdot z} \cdot \phi_{\chi}\left(\frac{z}{L}\right) \qquad L = -\frac{\overline{\theta} \cdot u_*^3}{k \cdot g \cdot \overline{w'\theta'}}$$

$$u_* = \left(\overline{w'u'}^2 + \overline{w'v'}^2\right)^{0.25}$$

$$Ri_b = \frac{g}{\theta}\frac{\frac{\partial \theta}{\partial z}}{\left|\frac{\partial u}{\partial z}\right|^2}$$

$$\theta_* = -\overline{w'\theta'} / u_*$$

with k= Von Karman constant, g the gravity and L is the Monin-Obukhov length

$$u(z)=\frac{u_*}{k}\left[\ln(z/z_{0m})-\psi_m(z/L)+\psi_m(z_{0m}/L)\right]$$

$$\Delta\theta_0=\frac{\theta_*}{k}\left[\ln(z/z_{0h})-\psi_h(z/L)+\psi_h(z_{0h}/L)\right]$$

$$Ri_b=\frac{z}{L}\frac{\left[\ln(z/z_{0h})-\psi_h(z/L)+\psi_h(z_{0h}/L)\right]}{\left[\ln(z/z_{0m})-\psi_m(z/L)+\psi_m(z_{0m}/L)\right]^2}$$

With the Businger's functions for the flux-profile relationships and knowing the bulk Richardson number and L (computed with the friction velocity and the sensible heat at the previous time step) it is possible to compute L with the Newton iteration method.

$$u_*^2=\frac{k^2}{\left[\ln(z/z_{0m})-\psi_m(z/L)+\psi_m(z_{0m}/L)\right]^2}\cdot u^2$$

$$\overline{w'\theta'}=-\frac{k^2\cdot u\cdot\Delta\theta}{\left[\ln(z/z_{0m})-\psi_m(z/L)+\psi_m(z_{0m}/L)\right]\left[\ln(z/z_{0h})-\psi_h(z/L)+\psi_h(z_{0h}/L)\right]}$$

However, to avoid iterative method, Louis suggest to write the fluxes as follows:

$$u_*^2 = \frac{k^2}{\left[\ln(z/z_{0m})\right]^2} \cdot u^2 \cdot F_m\left(\frac{z}{z_{0m}}, Ri_b\right) \qquad \overline{w'\theta'} = -\frac{k^2 \cdot u \cdot \Delta\theta}{\left[\ln(z/z_{0m})\right]\left[\ln(z/z_{0h})\right]} \cdot F_h\left(\frac{z}{z_{0m}}, \frac{z}{z_{0h}}, Ri_b\right)$$

VERTICAL EDDY FLUXES IN THE ATMOSPHERE 191

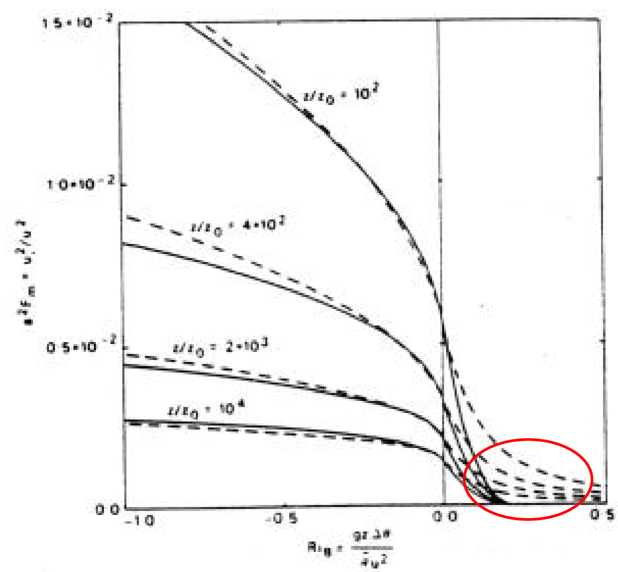


Fig. 1a. Drag coefficient for momentum, in terms of the bulk Richardson number and the roughness length. Computed by iterations: ———, using analytical formulae: – – – – – –.

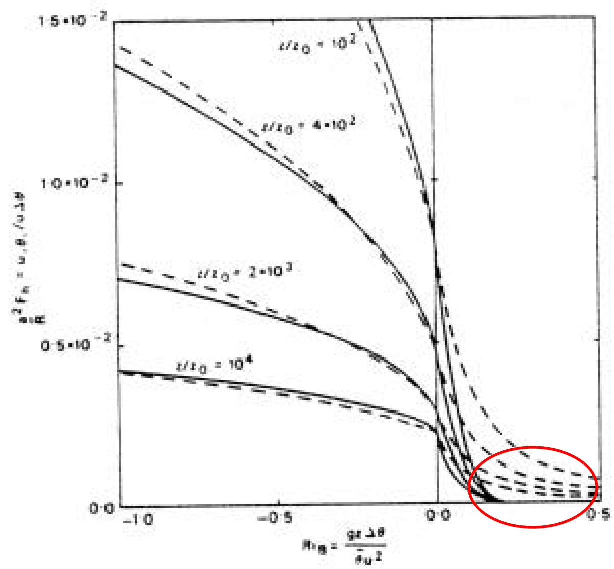


Fig. 1b. Same as Figure 1a, but for heat.

Above the surface layer, for the sake of continuity with the surface fluxes the dependence of K with stability is assumed to be the same as the surface.

Surface : Wind — Temperature/humidity

$$C_{dn} = \frac{k^2}{\left[\ln((z+z_{0m})/z_{0m})\right]^2} \qquad C_{hn} = \frac{k^2}{\ln((z+z_{0m})/z_{0m})\cdot\ln((z+z_{0h})/z_{0h})}$$

Stable

$$F_m = \frac{1}{1+2b\,R_i\Big/\sqrt{1+d\cdot R_i}} \qquad F_h = \frac{1}{1+3bR_i\sqrt{1+d\cdot R_i}}$$

Unstable

$$F_m = 1-\frac{2bR_i}{1+3bc\cdot C_{dn}\sqrt{(z+z_{0m})/z_{0m}\left|R_i\right|}} \qquad F_h = 1-\frac{3bR_i}{1+3bc\cdot C_{hn}\sqrt{(z+z_{0h})/z_{0h}\left|R_i\right|}}$$

Above the surface layer stable case

$$F_m = \frac{1}{1+2b\,R_i\Big/\sqrt{1+d\cdot R_i}} \qquad F_h = \frac{1}{1+3bR_i\sqrt{1+d\cdot R_i}}$$

Unstable

$$F_m = 1-\frac{2bR_i}{1+3bc\cdot\frac{1}{3\sqrt{3}}\left(\frac{l_m}{z+z_{0m}}\right)^2\sqrt{\left|R_i\right|}} \qquad F_h = 1-\frac{3bR_i}{1+3bc\cdot\frac{1}{3\sqrt{3}}\left(\frac{l_m l_h}{(z+z_{0m})(z+z_{0h})}\right)\sqrt{\left|R_i\right|}}$$

$$K_m = l_m^2 \left| \frac{\partial \vec{U}}{\partial z} \right| F_m(R_i) \qquad K_h = l_m \cdot l_h \left| \frac{\partial \vec{U}}{\partial z} \right| F_h(R_i)$$

The mixing lengths are constant in space and in time:

$$l_{m/h}(z) = \left(\frac{k(z + z_{0m/h})}{1 + \frac{k(z + z_{0m/h})}{\lambda_{m/h}}} \right) \cdot \left(\beta_{m/h} + \frac{1 - \beta_{m/h}}{1 + \left(\frac{z + z_{0m/h}}{H_{m/h}} \right)^2} \right)$$

The non simulation of enhanced vertical exchange at the top of PBL in presence of shallow convective clouds and the use of dry coefficient (K) is commonly resolved by a specific parameterisation

Shallow convection

- Modified Ri (Geleyn 87):

$$R_i = \frac{g}{C_p T} \cdot \frac{\partial s / \partial z}{(\partial u / \partial z)^2} + \frac{g}{C_p T} \cdot \frac{L \cdot \min(0, \partial(q - q_s)/\partial z)}{(\partial u / \partial z)^2}$$

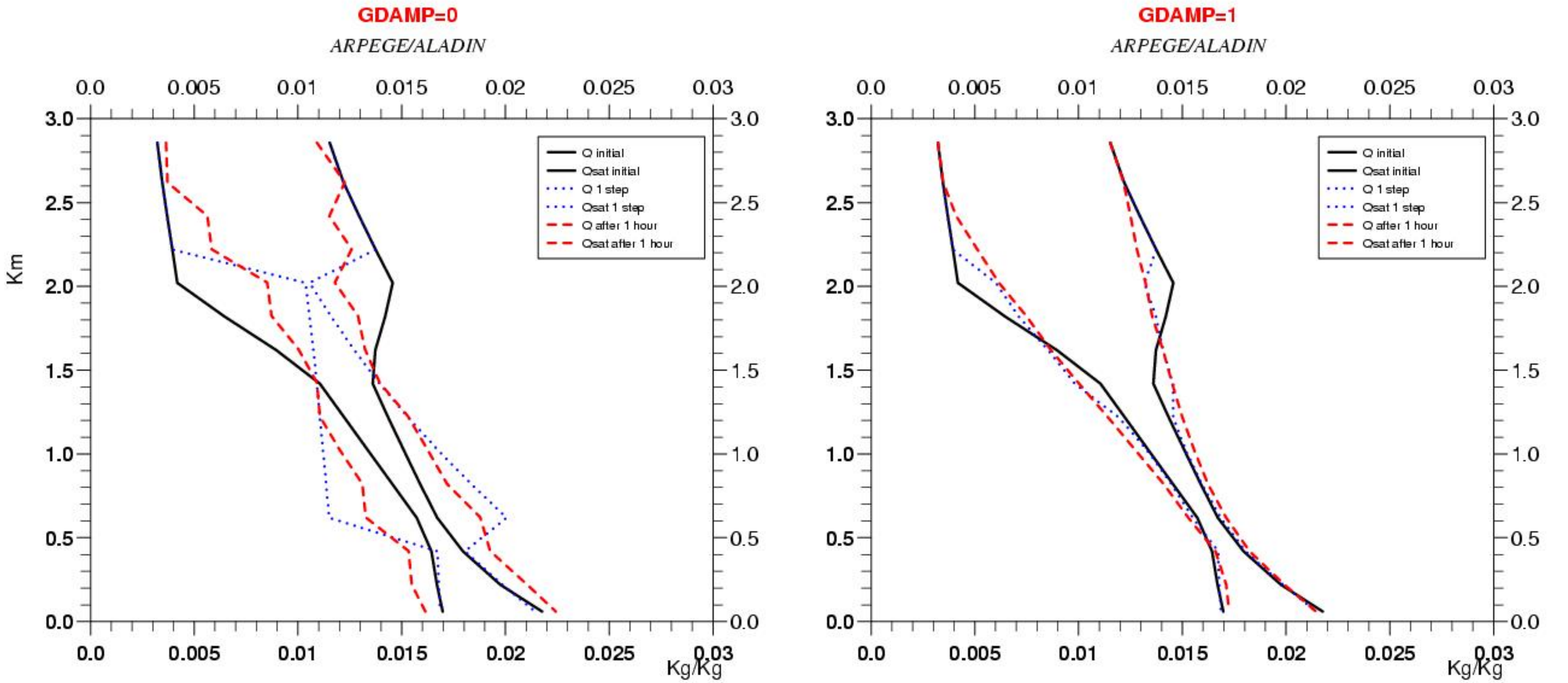
Caution (already mentioned by Geleyn 87 !!):

•The scheme can not do more than what it was designed for: to parameterize in a simple way a process that the models cannot effectively simulate for lack both of a sufficient vertical resolution and of a prognostic liquid water variable

•1d integration also reveals a tendency of the scheme to an on/off behaviour from on time step to the next

•Vertical diffusion is treated implicitly but the vertical exchange coefficients are diagnosed explicitly:

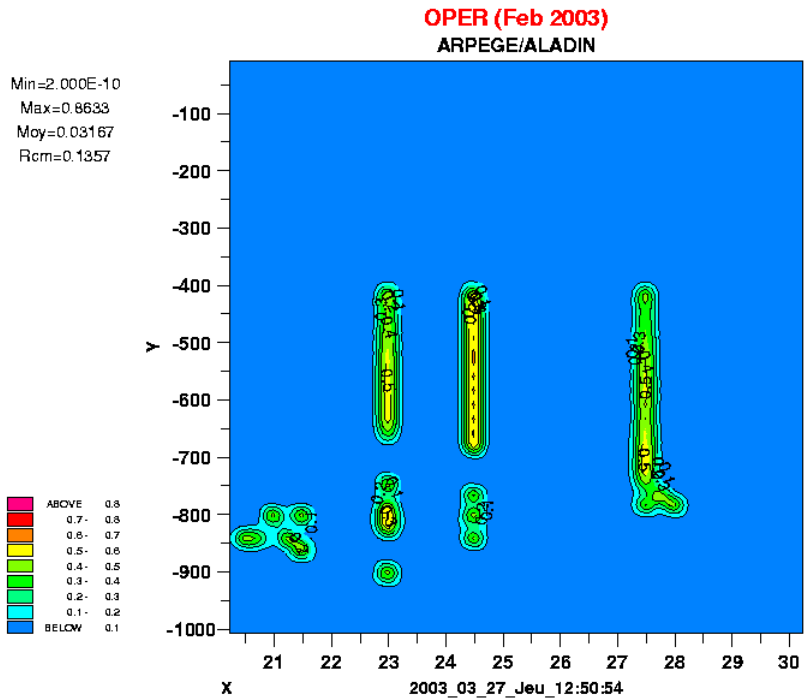
the scheme is only conditionally stable



1D simulation on the BOMEX profile. 1 hour with 900s. Only vertical diffusion !!

Blue dotted line after 1 time step. Red dashed line after 1 hour.

The blue dotted line is obtained independently of the time step !!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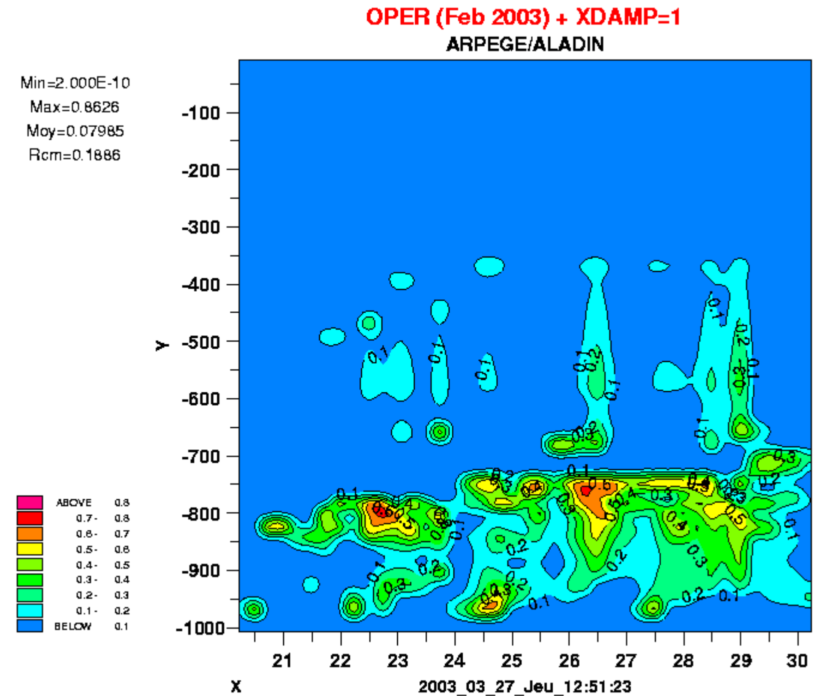
ARPEGE/ALADIN
Min=2.000E-10
Max=0.8633
Moy=0.03167
Rcm=0.1357
ABOVE 0.8
0.7 - 0.8
0.6 - 0.7
0.5 - 0.6
0.4 - 0.5
0.3 - 0.4
0.2 - 0.3
0.1 - 0.2
BELOW 0.1
Y
X
2003_03_27_Jeu_12:50:54


OPER (Feb 2003) + XDAMP=1
ARPEGE/ALADIN
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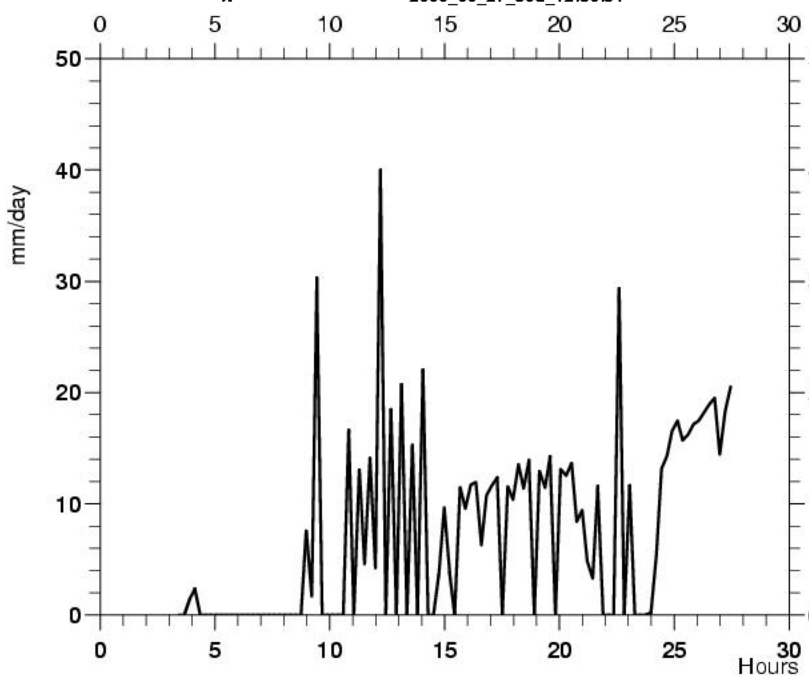
Max=0.8626
Moy=0.07985
Rcm=0.1886
ABOVE 0.8
0.7 - 0.8
0.6 - 0.7
0.5 - 0.6
0.4 - 0.5
0.3 - 0.4
0.2 - 0.3
0.1 - 0.2
BELOW 0.1
Y
X
2003_03_27_Jeu_12:51:23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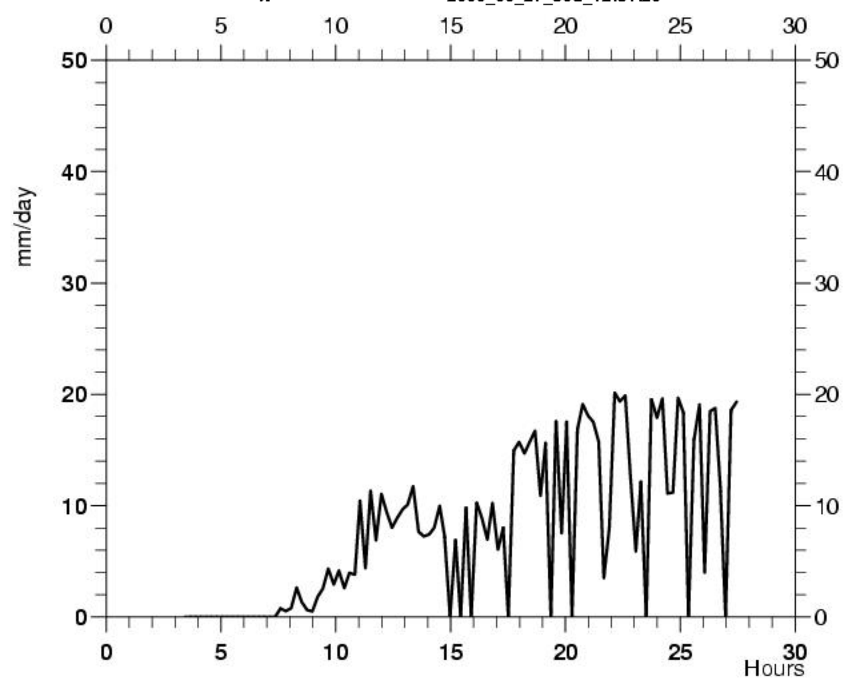
Hours


mm/day
Hours

GABLS

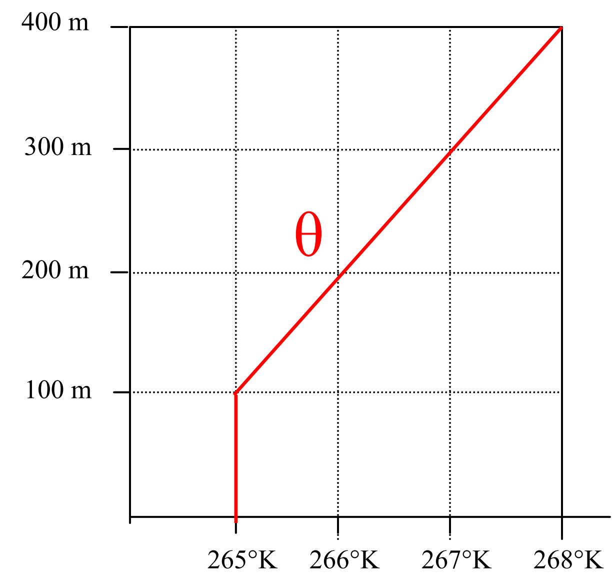
GEWEX **A**tmospheric **B**oundary **L**ayer **S**tudy
(GEWEX News Vol. 13, N°2 Albert A.M. Holtslag)

- Provide a platform in which scientists working on boundary layers at different scales will interact
- The case is based on the results from Kosovic and Curry 2000 (JAS 2000, Vol 57, 1052-1068)
- LES : Malcom Mac Vean (UKMO)
- 1D : Joan Cuxart (University of the Balearic Islands at Mallorca)

Rules for the 1D intercomparison GABLS

- Boundary layer is driven by an uniform geostrophic wind (Ug=8m/s) and f=1.39E-04 s-1

- For temperature θ=265K for z < 100m then increasing at 0.01K/m to domain top (400m) , where the potential temperature is thus 268K



-Ts=265K decreasing continuously at a rate of 0.25K/h
- Radiation is switched off
- Roughness length set to 0.1m both for momentum and temperature

- Standart case at the same vertical resolution as the LES: dz=6.25m with dt=10s
- Run in operational configuration with 5 levels below 400m and dt=900s
- 9 hours integration with datasets for two 1-hour averaging periods (7-8 h and 8-9h) for wind, potential temperature, turbulence fluxes and one dataset for timeseries over the whole run for BLH, friction velocity …

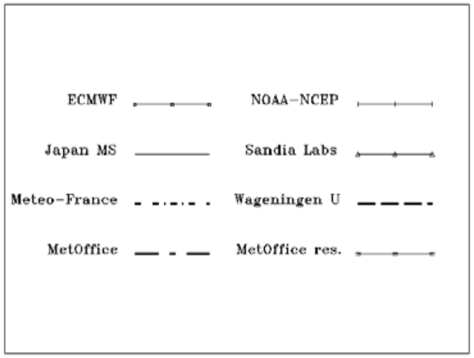
Table I. Acronyms of the participant groups and scientists

Acronym	Institution	Scientists
ECMWF	European Centre for Medium-Range Weather Forecasts	A. Beljaars
NOAA-NCEP	National Oceanic and Atmospheric Administration- National Centers for Environmental Prediction	F. Freedman M. Ek
MeteoFrance	Météo-France	E. Bazile
JMA	Japan Meteorological Agency	H. Kitagawa
Met Office	United Kingdom Meteorological Office	R.J. Beare
Wageningen U	Wageningen University of Research	G-J.Steeneveld, A.Holtslag
Sandia Labs	Sandia National Laboratories	S. Wunsch, A. Kerstein
MSC	Meteorological Service of Canada	J. Mailhot
KNMI	Royal Netherlands Meteorological Institute	G.Lenderink
UIB-UPC	University of the Balearic Islands- Politechnical University of Catalonia	J. Cuxart L.Conangla
NASA	National Aeronautics and Space Administration	K-M. Xu, A. Cheng
WVU	West Virginia University	D.Lewellen
York U.	York University	W.Weng, P.Taylor
Louvain U	Catholic University of Louvain	G. Schayes, R. Hamdi
Swedish MS	Swedish Meteorological and Hydrological Institute	V. Perov
Stockholm U	Stockholm University	G. Svensson, T. Mauritsen

Table II. Model name, use, type and reference

Model	Use	Type	Ref
ECMWF	operational	1st order	Beljaars and Viterbo, 1998
ECMWF-MO	operational-test	1st order	
NOAA-NCEP	operational	1st order	Hong and Pan, 1996
MeteoFrance	operational	1st order	Louis et al., 1982
JMA	operational	1st order	Mellor and Yamada, 1974
Met Office	operational	1st order	Louis, 1979
Met Office res	research	1st order	Williams, 2002
Wageningen U	research	1st order	Duynkerke, 1991
Sandia Labs	research	ODT	Kerstein et al., 2001
MSC	operational	$e-l$	Belair et al., 1999
KNMI-RACMO	operational	$e-l$	Lenderink and Holtslag, 2004
UIB-UPC	research mesoscale model	$e-l$	Cuxart et al., 2000
NASA	research mesoscale model	$e-l$	Xue et al, 2000
WVU	research	$e-l$	Sykes and Henn, 1989
York U.	research	$e-l$	Weng and Taylor, 2003
Louvain U-L	research	$e-l$	Therry and Lacarrère, 1983
Louvain U-eps	research	$e-\epsilon$	Duynkerke, 1988
Swedish MS	research	$e-\epsilon$	
Stockholm U	research	$e-l$	Andren, 1990
Stock.U-sim	research	$e-\theta^2$	Mauritsen et al., 2004

From Cuxart et al accepted to Bound. Layer Meteor. (Jan 2005)



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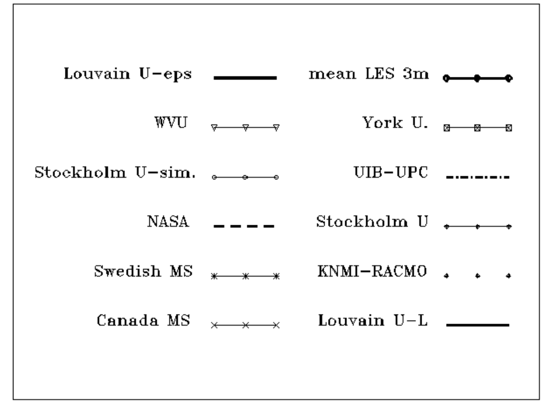
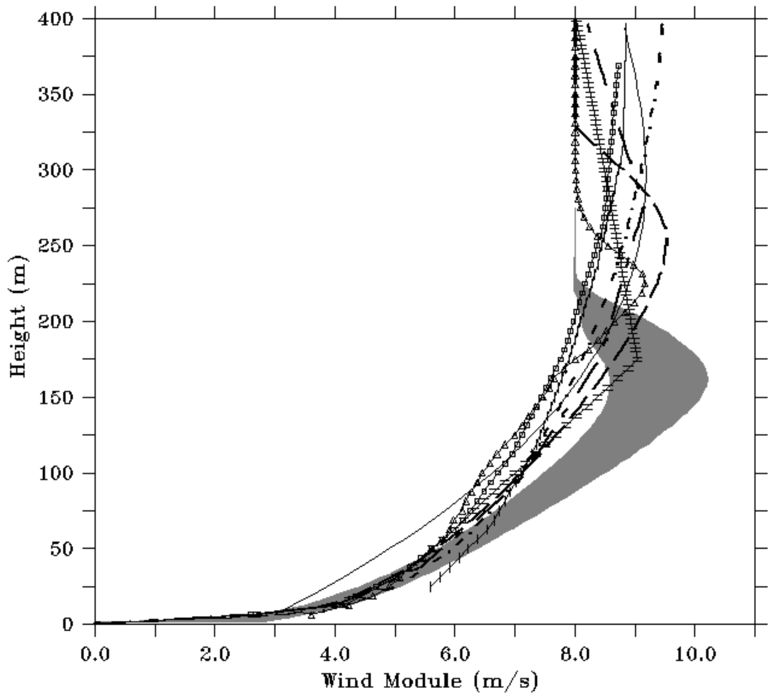
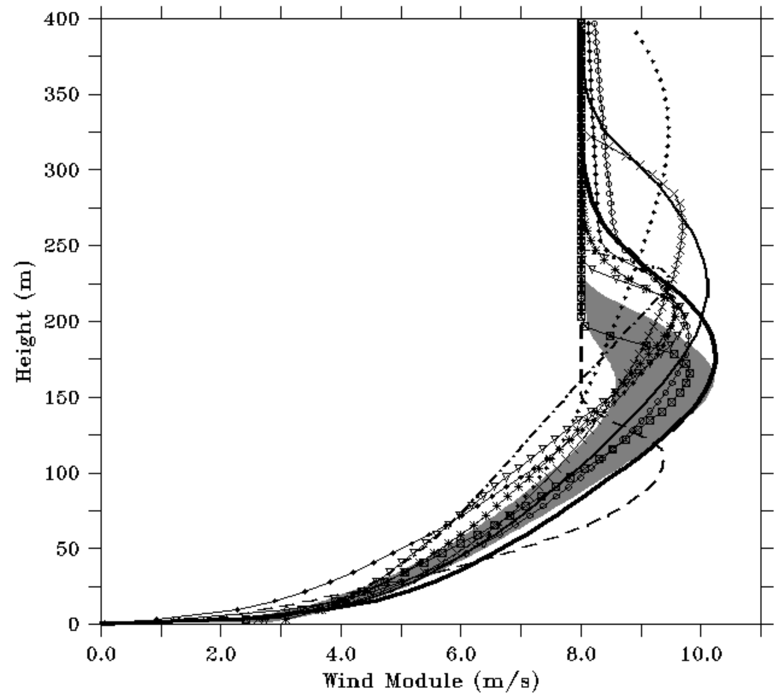
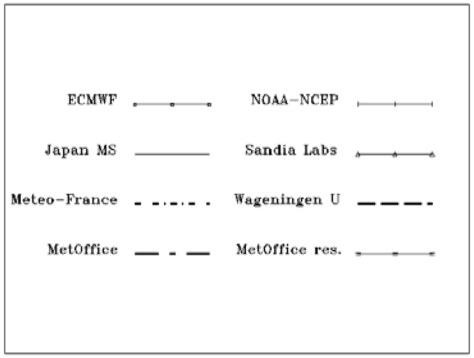


First order

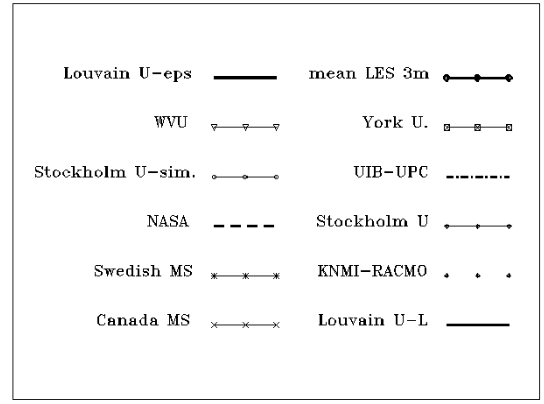


1.5 closure E-l

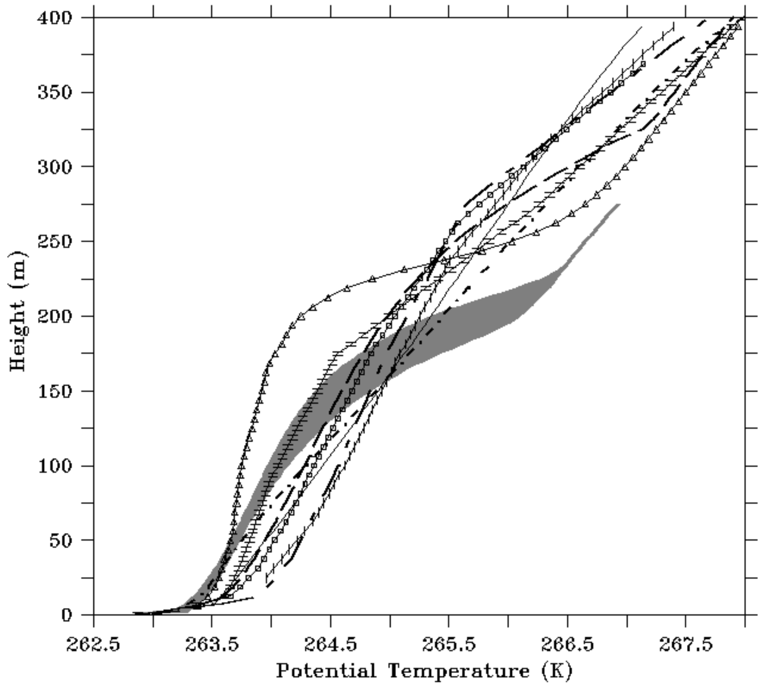




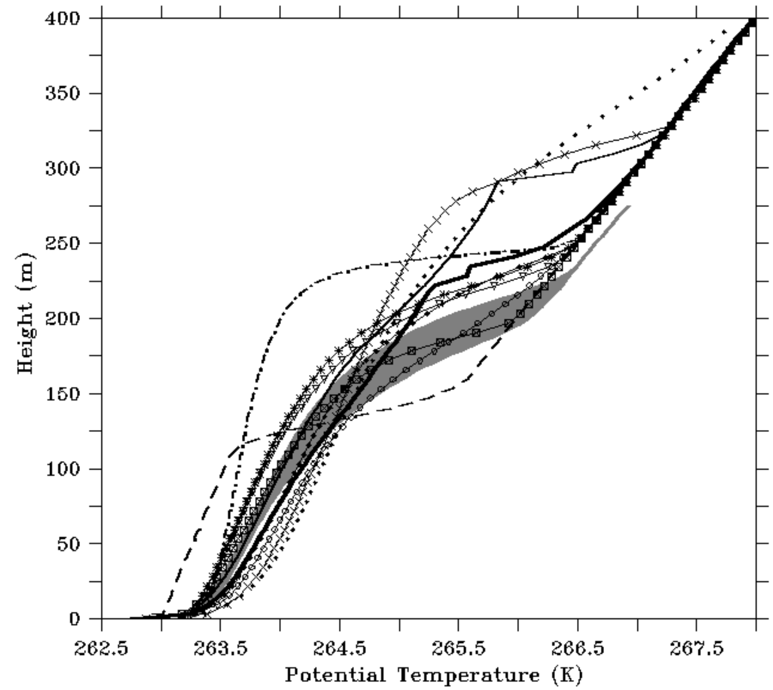
Cuxart et al accepted to Bound. Layer Meteor. (June 2004)



First order



1.5 closure E-l



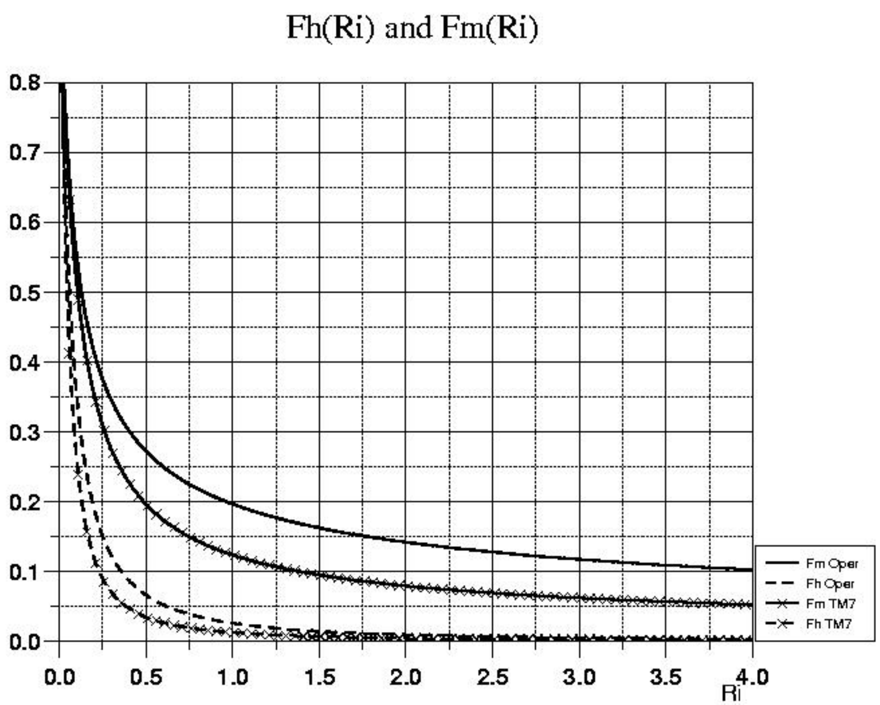
- Not able to reproduce correctly the Ekman spiral and the low level jet does not exist due to the excess mixing in the stratified boundary layer on wind and temperature.
- Nevertheless, the surface heat flux and the friction velocity are in good agreement with the LES results
- The modifications are:
  - reduce the mixing in stable conditions (Fm and Fh)
  - Interactive mixing lengths function of the PBL height

Turbulent flux: $\overline{w'\chi'} = -K_\chi \frac{\partial \chi}{\partial z}$

$$K_m = l_m^2 \left| \frac{\partial \vec{U}}{\partial z} \right| F_m(R_i)$$

Louis et al (81), PBL height Tröen & Mahrt (86). Mixing length is supposed to be constant above the PBL and below it is a cubic function

$$K_\theta = l_m l_h \left| \frac{\partial \vec{U}}{\partial z} \right| F_h(R_i)$$



$$\frac{1}{F_m} = 1 + \frac{2bR_i}{\sqrt{1 + \frac{d}{k} R_i}}$$

$$\frac{1}{F_h} = 1 + 3bR_i\sqrt{1 + dkR_i}$$

With b=d=5 et k=5

RM June 2005

PBL height (Tröen& Mahrt 86)

$$R_i(j) = \frac{(\theta_v(j) - \theta_s)}{T_m \left| \vec{v}(j) \right|} g Z_j \geq R_{icr}$$

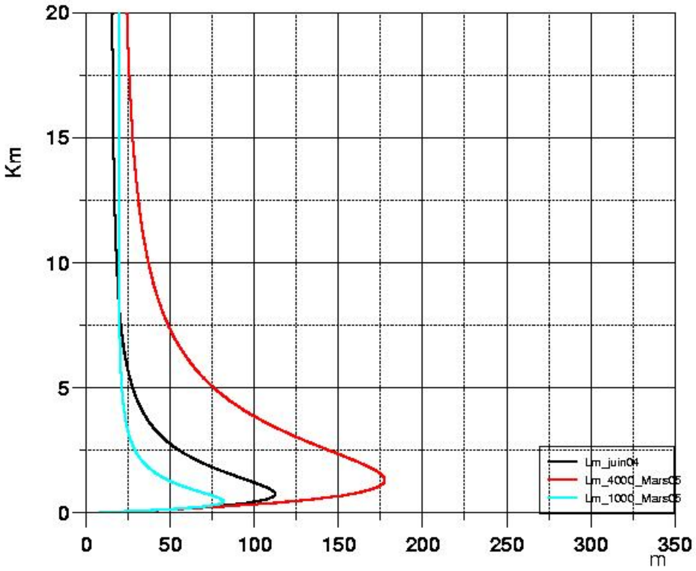
With Tm= mean temperature of the PBL, Ricr=0.5

Unstable case : $\theta_s = \theta_s + c_1 \frac{\overline{(w'\theta_v')_s}}{w_m}$ $\qquad \overline{(w'\theta_v')_s} = \overline{(w'\theta')_s} + 0.608 \cdot T_m \overline{(w'q')_s}$

$$w_m = (u_*^3 + c_2 \frac{g}{\theta_{vN}} \overline{(w'\theta_v')_s} \cdot H_{CLP})^{1/3}$$

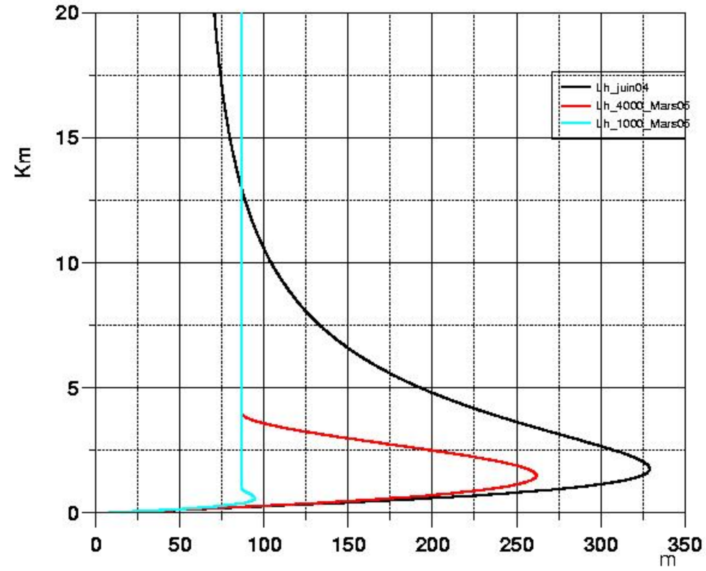
Mixing length for momentum

ARPEGE/ALADIN



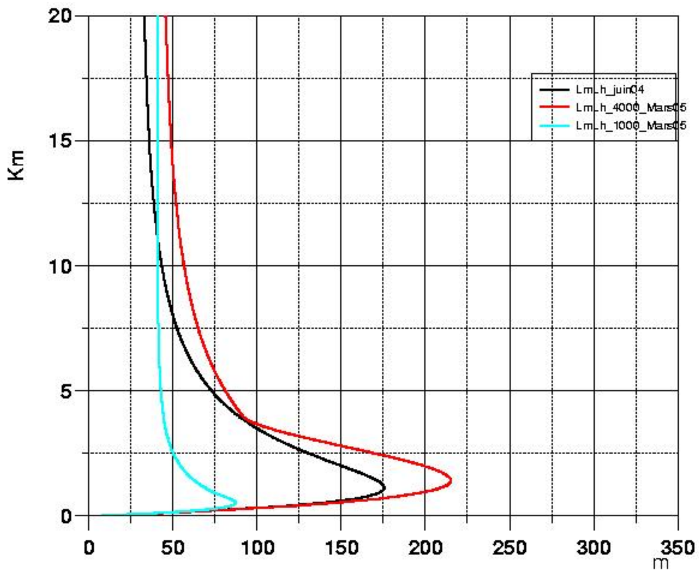
Mixing length for heat

ARPEGE/ALADIN



Sqrt(Lm*Lh)

ARPEGE/ALADIN



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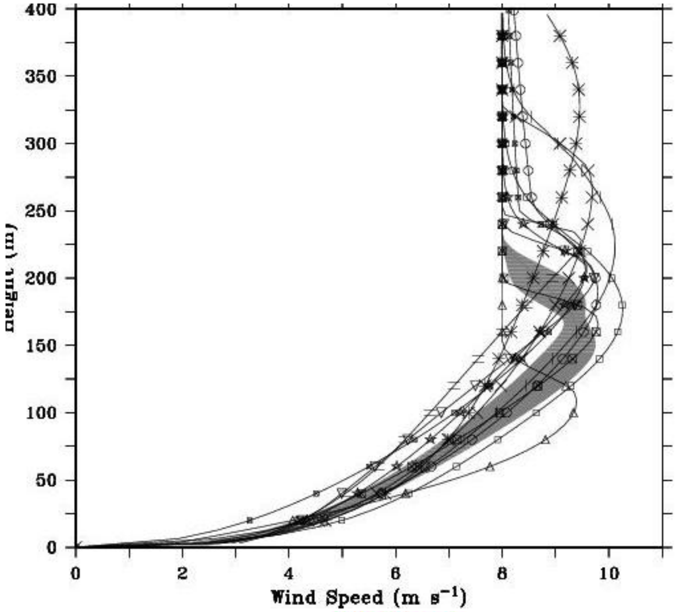
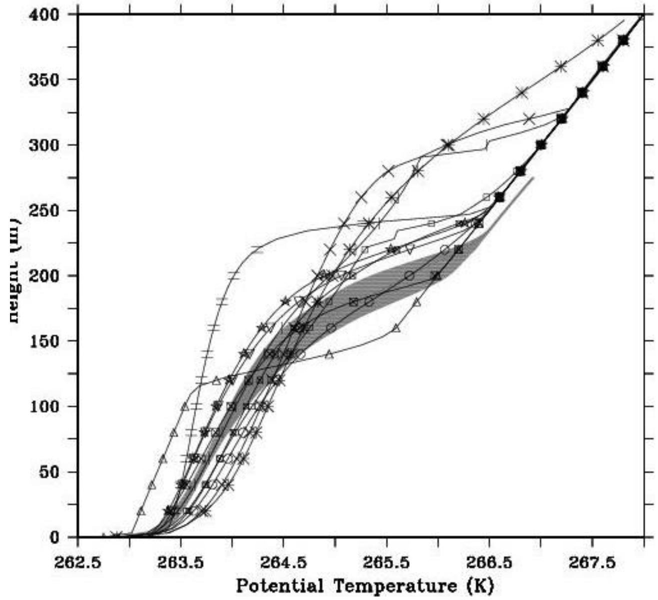


Wind Speed

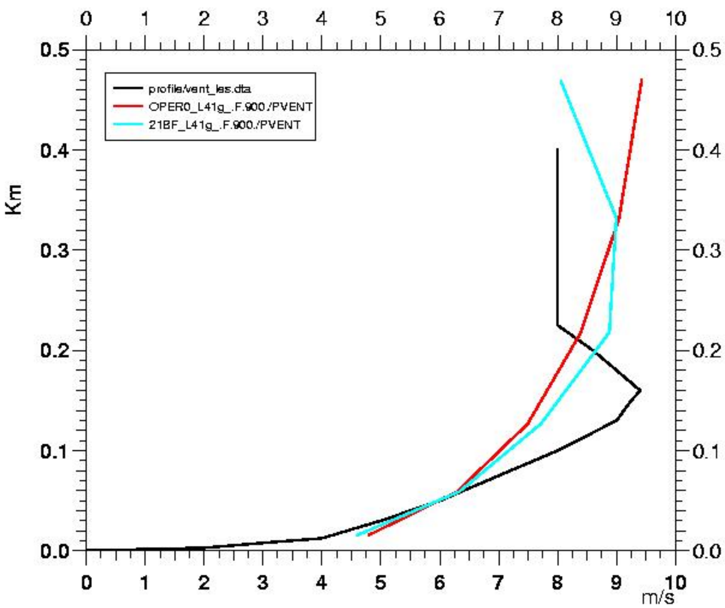
GABLS Mean H9

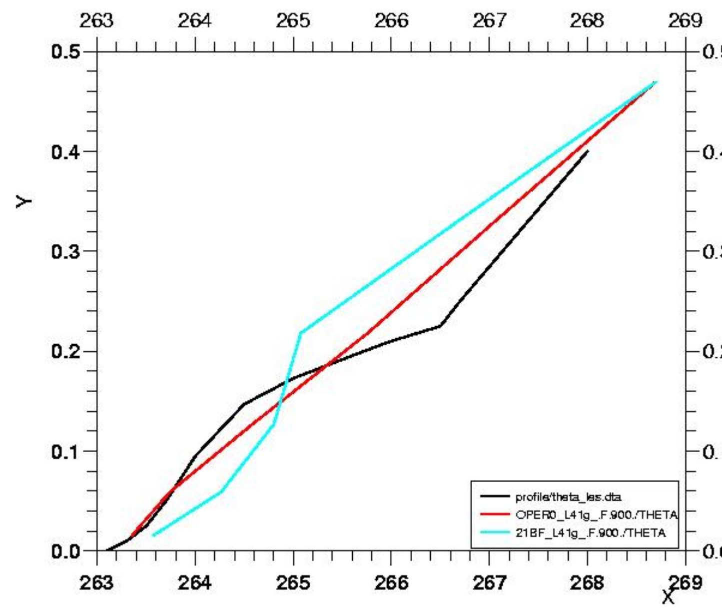
From Cuxart et al accepted to Bound. Layer Meteor. (Jan 2005)



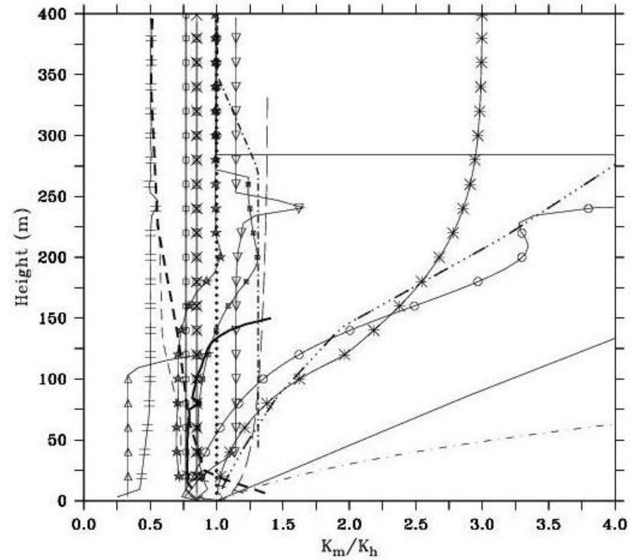
Potential Temperature

GABLS MEAN H9

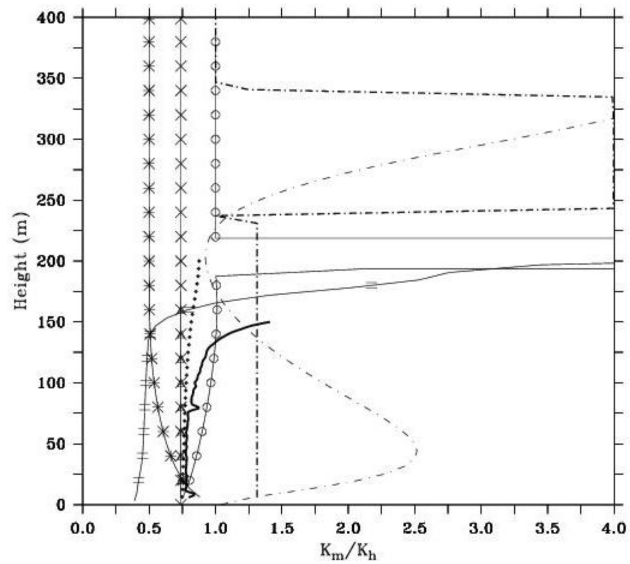




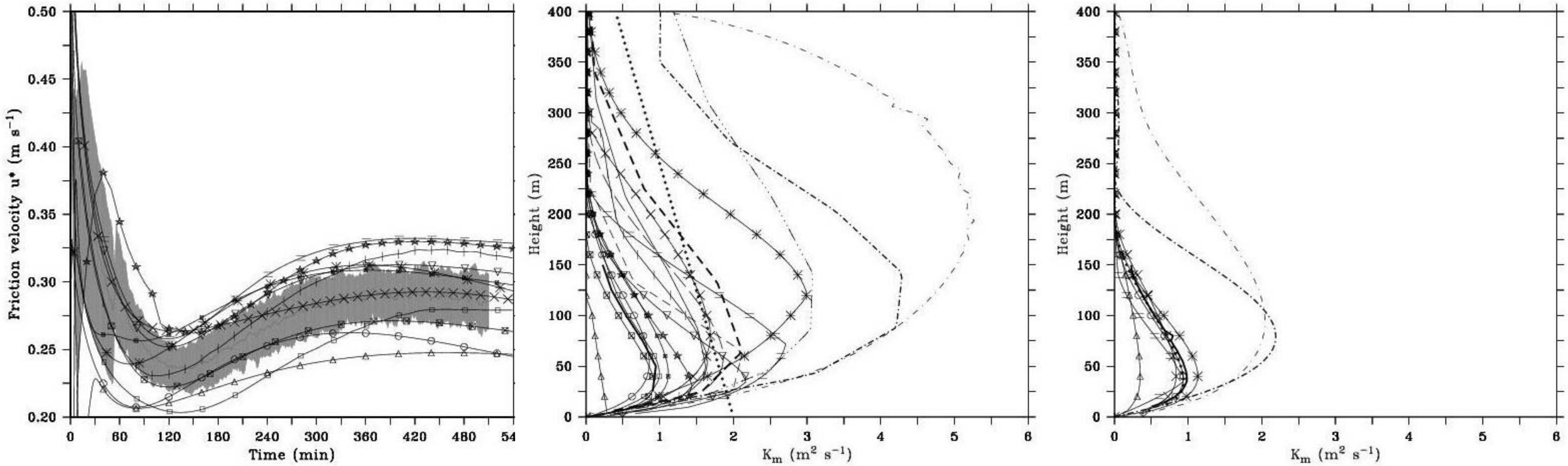
- The modified version improves the vertical profile of wind speed, the friction velocity, Lmo, and the surface angle for the wind direction.
- However, the Ekman spiral and the PBL height are not satisfactory and the Prandl number is over estimated.



Model	BLH	$\overline{w'\theta'}$	u^*	MOL	Angle
Oper	383 m	-0.013	0.34	204	23
Double	333 m	-0.014	0.31	142	29
Les	160-195	-0.010 –0.013	0.26-0.30	120-170	32-38
All 1D	120-500	-0.005 –0.027	0.25-0.36	98-200	21-46



From Cuxart et al accepted to Bound. Layer Meteor. (Jan 2005)



The main results of GABLS (Cuxart et al. 2005) are:

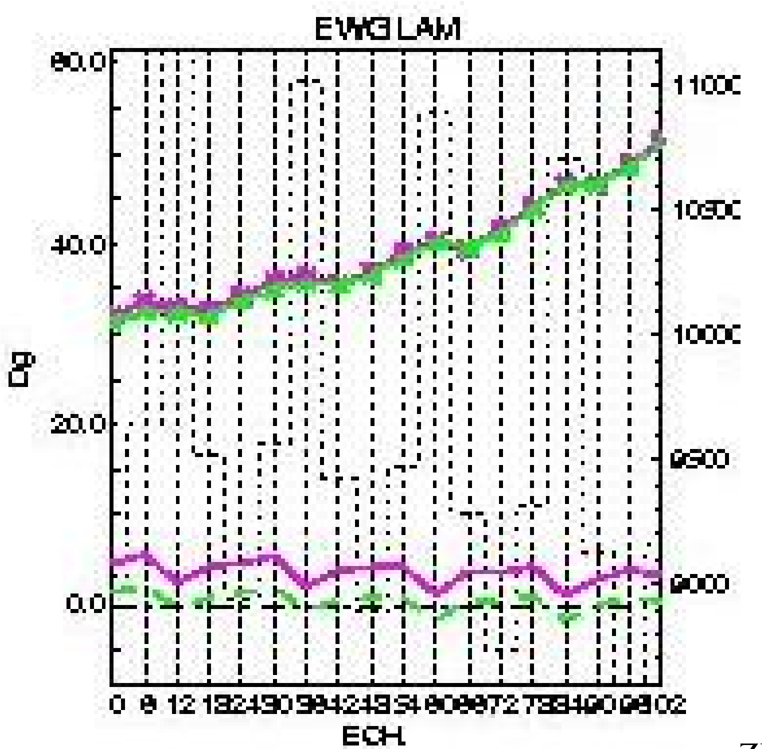
1. Operational schemes have a general tendency to mix more than the research models, with two important consequences:

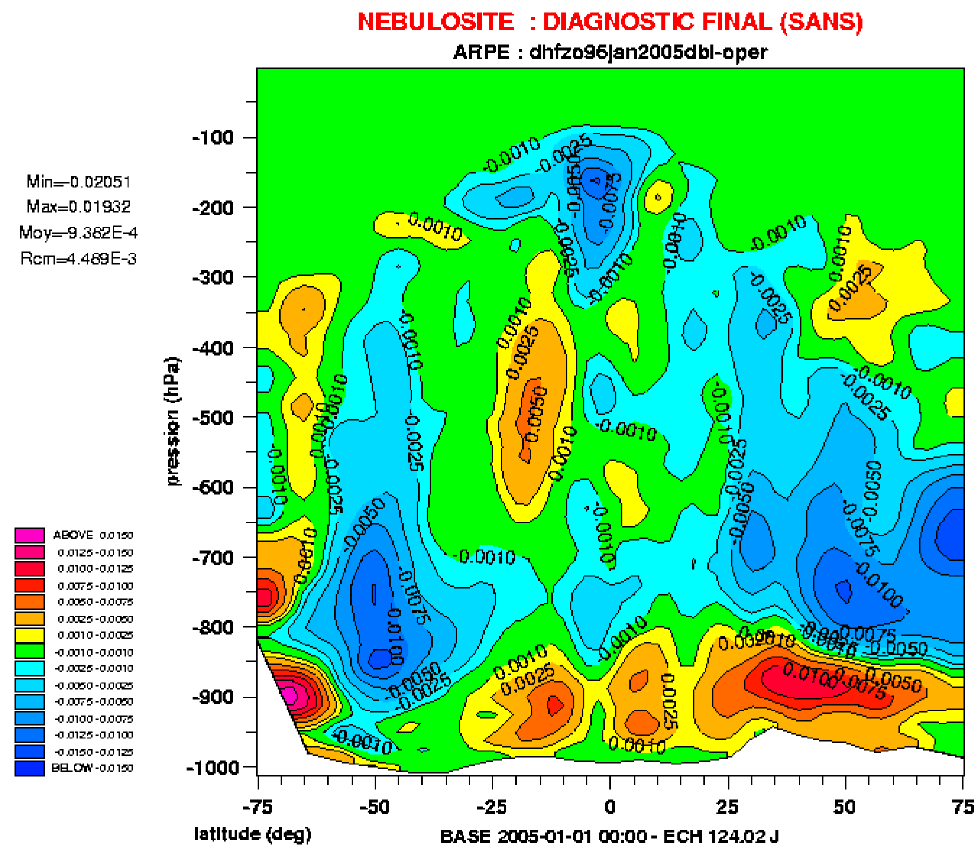
§ the upper air inversion is not seen

§ the surface friction velocity is overestimated

2. Those using a Turbulence Kinetic Energy (TKE) scheme overestimate the mixing to a smaller extent, compared to the first order schemes

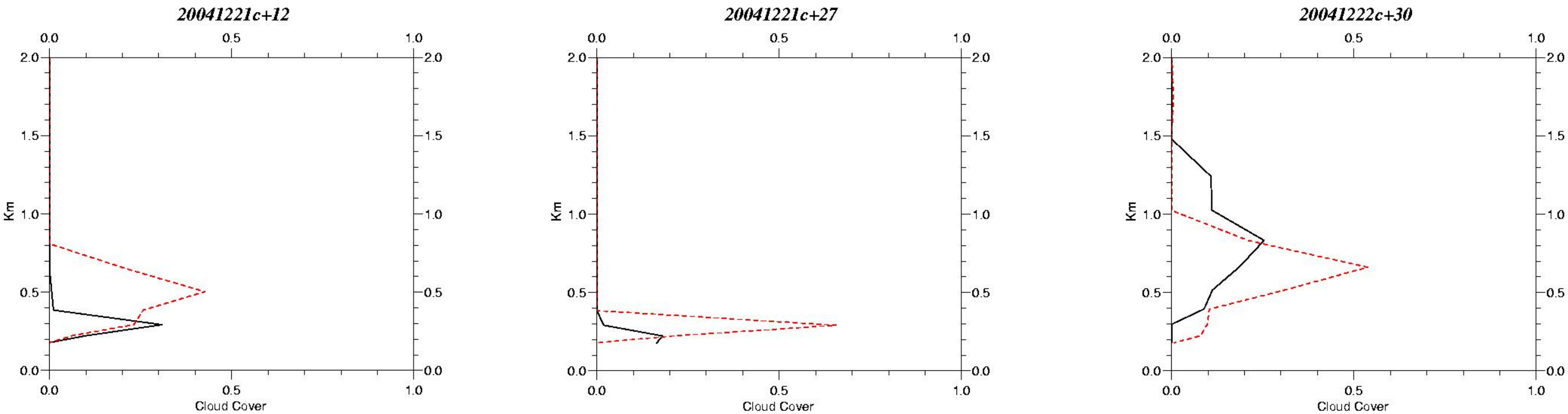
3D impacts: following the GABLS result, the impact should be limited to the cold regions in stable conditions, but the interactive mixing-length should also modified the dry PBL over Sahara where the PBL can reach 4000m. The reduced mixing should improve the humidity profile with a moister PBL and consequently provide more lower clouds.



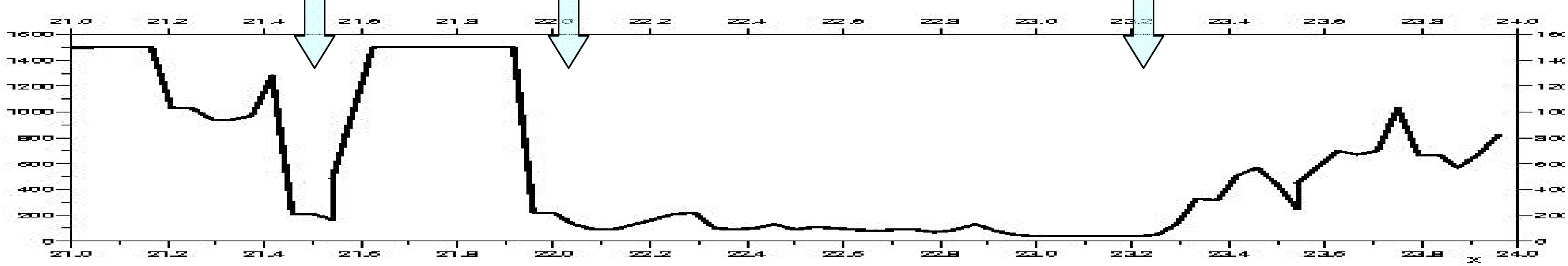


Charles de Gaulle airport (Paris)

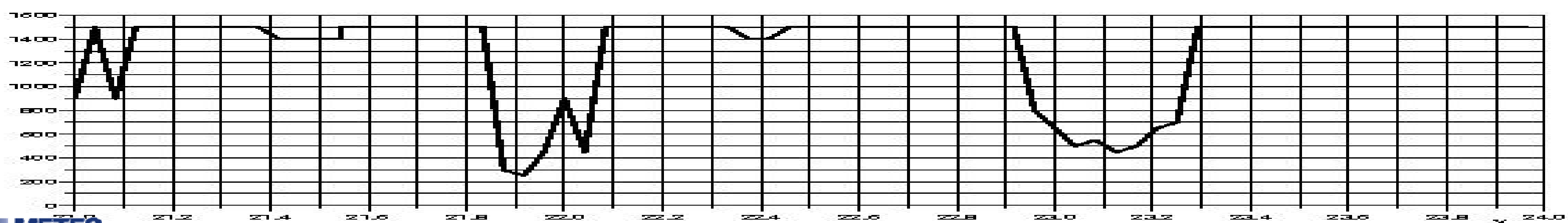
(21/12/2004 → 24/12/2004)



Cloud base

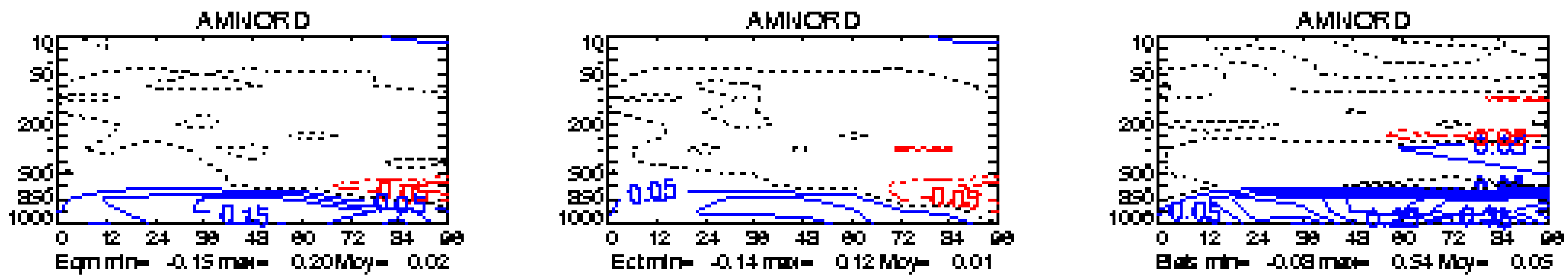


Visibility

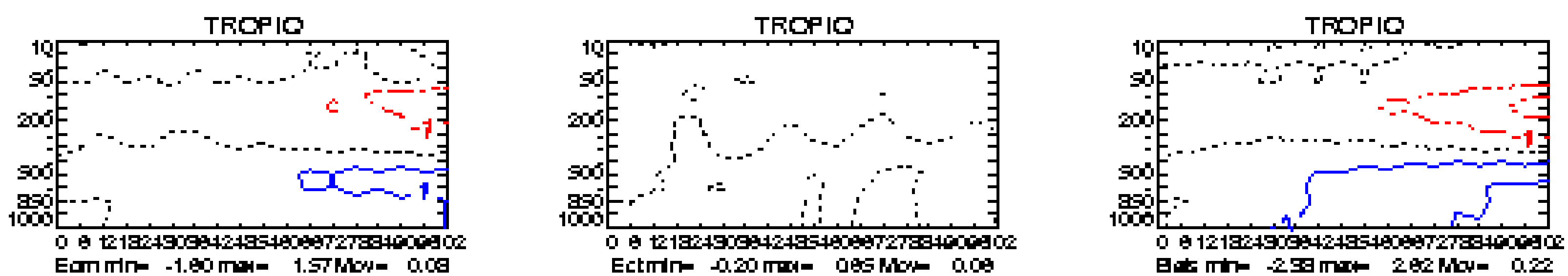


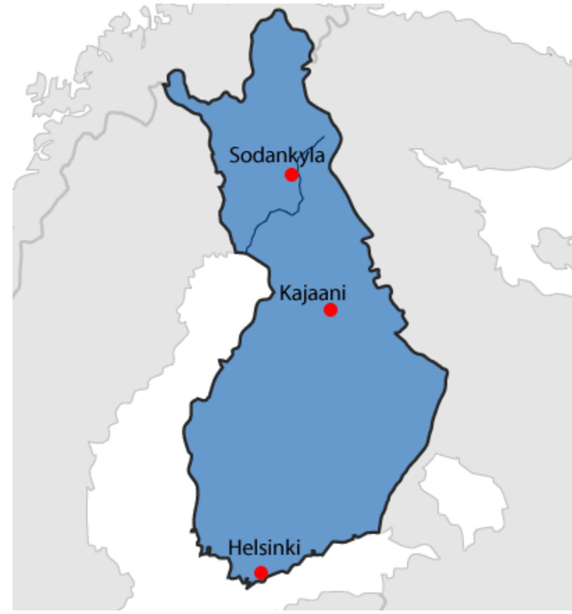
METEO FRANCE

TEMPERATURE : PA.r 0/TP-PAD.r 0/TP
(/0.05K) Chaine 2004_04, Long Melange ds le schema turbulence
43 cas, 15/12/2004_00UTC -> 30/01/2005_12UTC

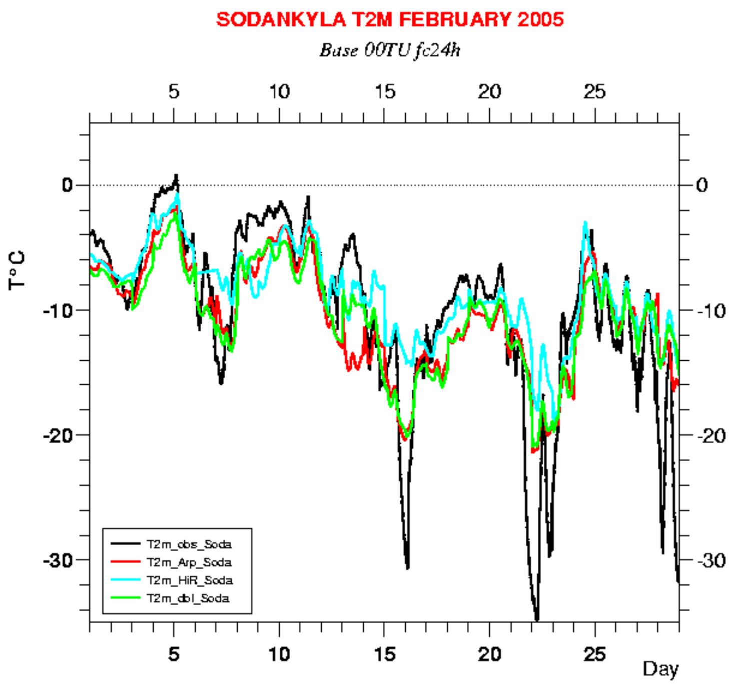


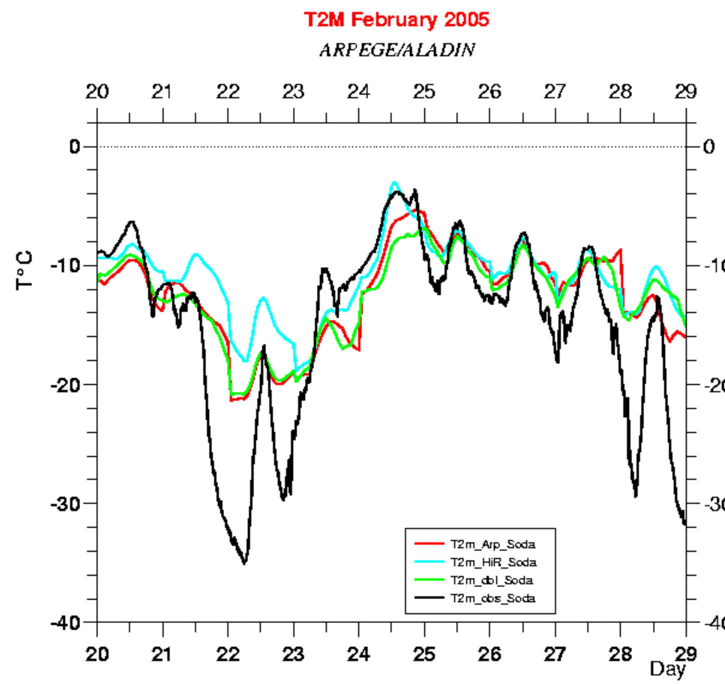
GEOPOTENTIEL : PA.r 0/AC-PAD.r 0/AC
(/1.00m) Chaine 2004_04, Long Melange ds le schema turbulence
43 cas, 15/12/2004_00UTC -> 30/01/2005_18UTC





METEO FRANCE





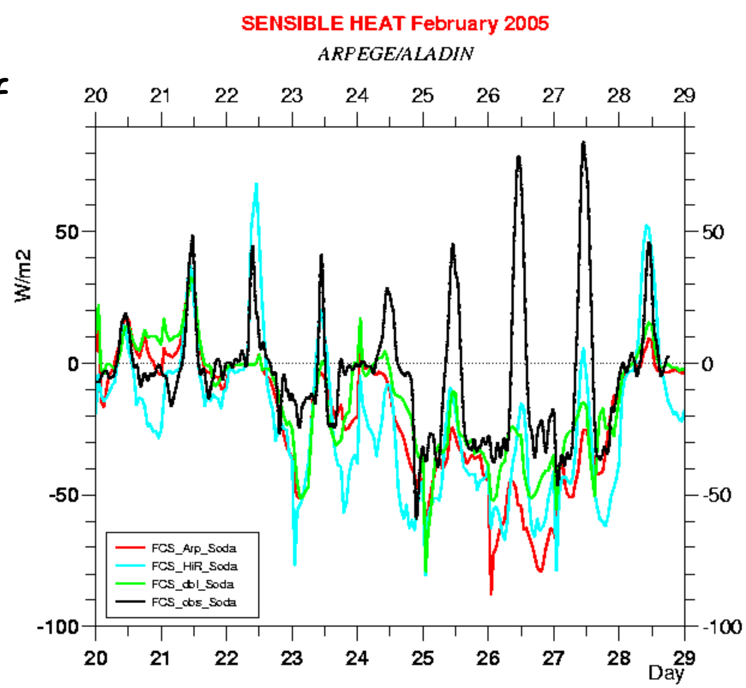
Black= obs

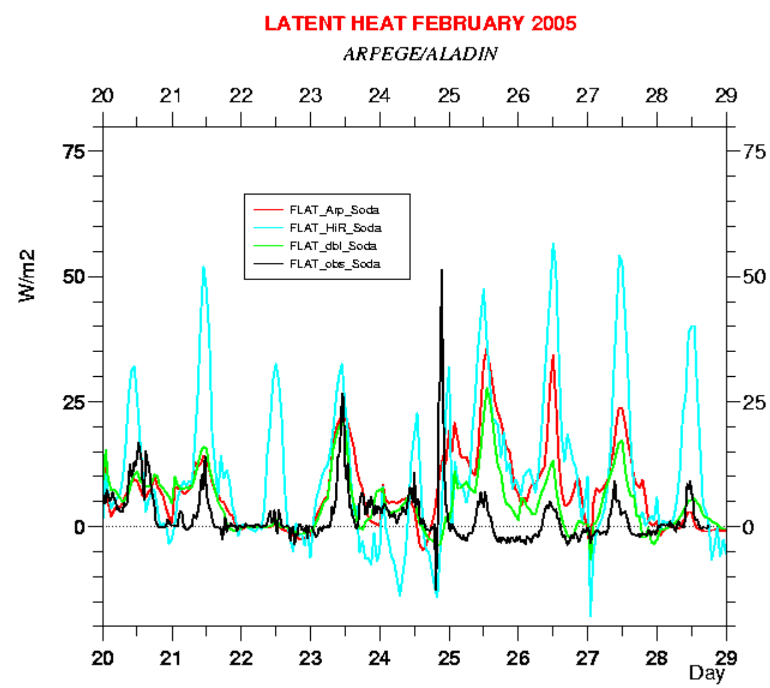
Red=Arpège

Cyan=Hirlam

Green=newdif

Thanks to M. Kangas





METEO FRANCE

The TKE scheme used in ARPEGE/ALADIN has been developped by the climate group for ARPEGE-CLIMAT and tested recently in the EUROCS exercise (Lenderink2004). It is based, like the Méso-NH scheme and HIRLAM on Cuxart et al. (2000).

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

$$K_h = \alpha_h \cdot \alpha_u \cdot l \cdot \sqrt{\overline{e_T}} \cdot \phi_h$$

Constant mixing length Redelsperger function

Louis's scheme

$$K_\chi = l_m \cdot l_\chi \left| \frac{\partial \vec{U}}{\partial z} \right| F_\chi (R_i)$$

$$1/\phi_h = 1 + \frac{1}{7.2} \cdot \frac{l^2}{\theta \cdot e_T} \cdot \frac{\partial \theta}{\partial (gz)}$$

The exchange coefficients are function of E (turbulent kinetic energy) instead of the Richardson number for the Louis approach.

TKE-l Cuxart et al (2000)

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

$$P_d = -(\overline{w'u'})\frac{\partial \bar{u}}{\partial z} - (\overline{w'v'})\frac{\partial \bar{v}}{\partial z} = \alpha_u \cdot l \cdot \sqrt{\bar{e}_T} \cdot \left(\left(\frac{\partial \bar{u}}{\partial z}\right)^2 + \left(\frac{\partial \bar{v}}{\partial z}\right)^2 \right)$$

$$P_\theta = \frac{g}{\theta_{vl}} \cdot (\overline{w'\theta_{vl}'}) = E_q(\overline{w'q_t'}) + E_\theta(\overline{w'\theta_l'})$$

Moist variables

$$\theta_l = \theta \cdot \left(1 - \frac{L \cdot q_c}{C_p \cdot T}\right)$$

Redelsperger and Sommeria(81), Bougeault (82) and Bechtold (93)

$$\theta_{vl} = \theta \cdot \left(1 + \left(R_v / R_d - 1\right) \cdot q - q_c\right)$$

$$(\overline{w'q_t'}) = -\alpha_\theta \alpha_u l \sqrt{\bar{e}_T} \cdot \frac{\partial \bar{q}_t}{\partial z} \cdot \phi_3 \quad (\overline{w'\theta_l'}) = -\alpha_\theta \alpha_u l \sqrt{\bar{e}_T} \cdot \frac{\partial \bar{\theta}_l}{\partial z} \cdot \phi_3$$

Diffusion : $$\frac{\partial \overline{w' e_T}}{\partial z} = -\frac{\partial}{\partial z}\left(\alpha_e \alpha_u l \sqrt{\bar{e}_T}\,\frac{\partial \bar{e}_T}{\partial z}\right)$$ with $\alpha_e \cdot \alpha_u = 0.4$

Mixing length : $\left(l_{up} l_{down}\right)^{1/2}$ Bougeault and Lacarrère (89)

now $$\frac{1}{2}\left(l_{up}^{2/3} + l_{down}^{2/3}\right)^{3/2}$$

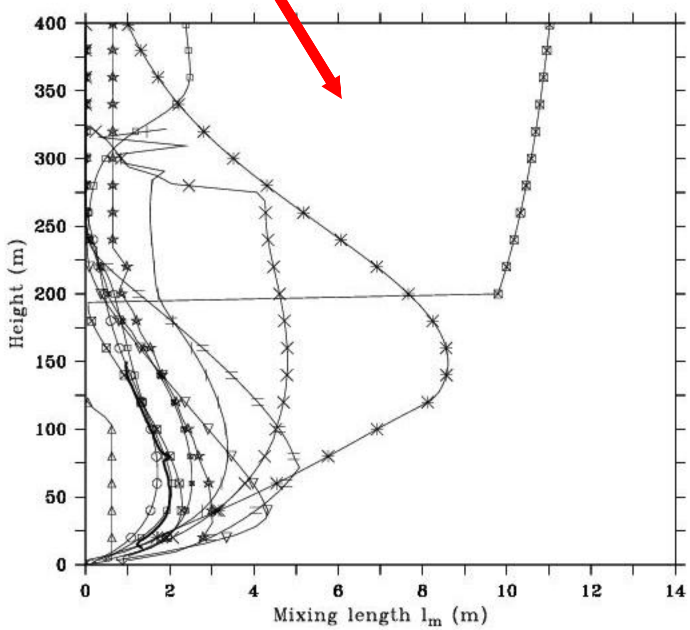
$$e_{T\,Cls} = 3.75 \cdot u_*^2 + 0.3 \cdot w_*^2$$

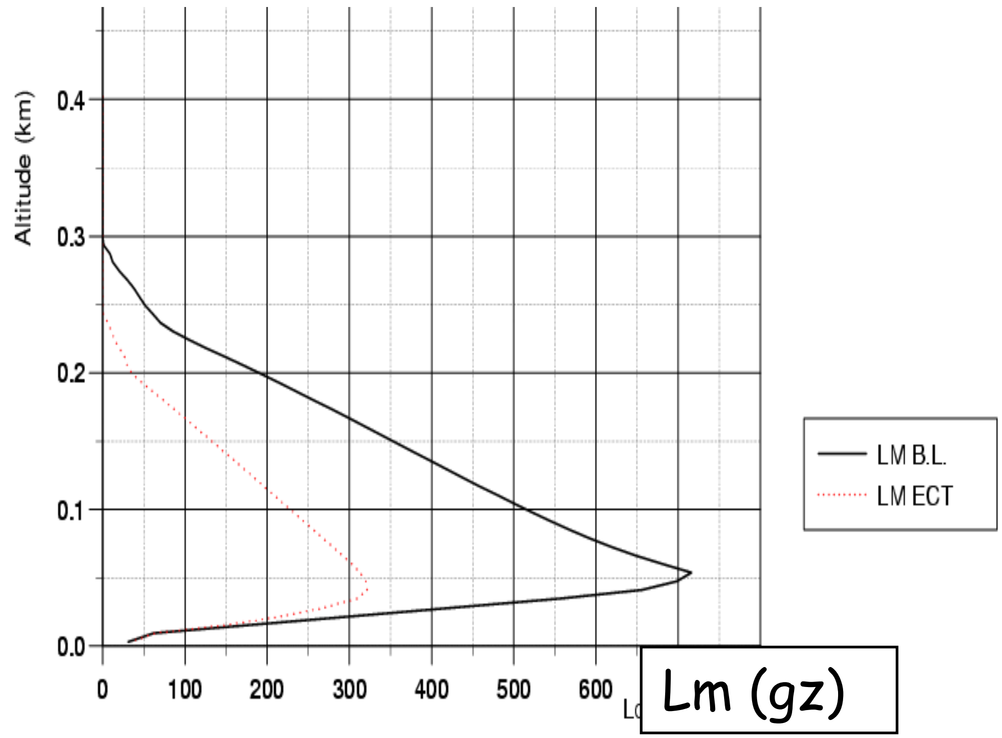
In Hirlam : $$\frac{\partial \overline{w' e_T}}{\partial z} = -2 \cdot \frac{\partial}{\partial z}\left(l \cdot \sqrt{\bar{e}_T}\,\frac{\partial \bar{e}_T}{\partial z}\right)$$ with $\frac{1}{l} = \frac{1}{l_{up}} + \frac{1}{l_{dw}}$

Several approaches are used to compute L: Météo-France uses the buoyancy (Bougeault et al. 1989) hereafter BL89, the ECHAM4 model, the moist gradient

Richardson number (Roeckner et al. 1996) and the HIRLAM model, the Brunt-Väisala frequency with TKE (Lenderink et al. 2004)

11 TKE scheme → 11 L

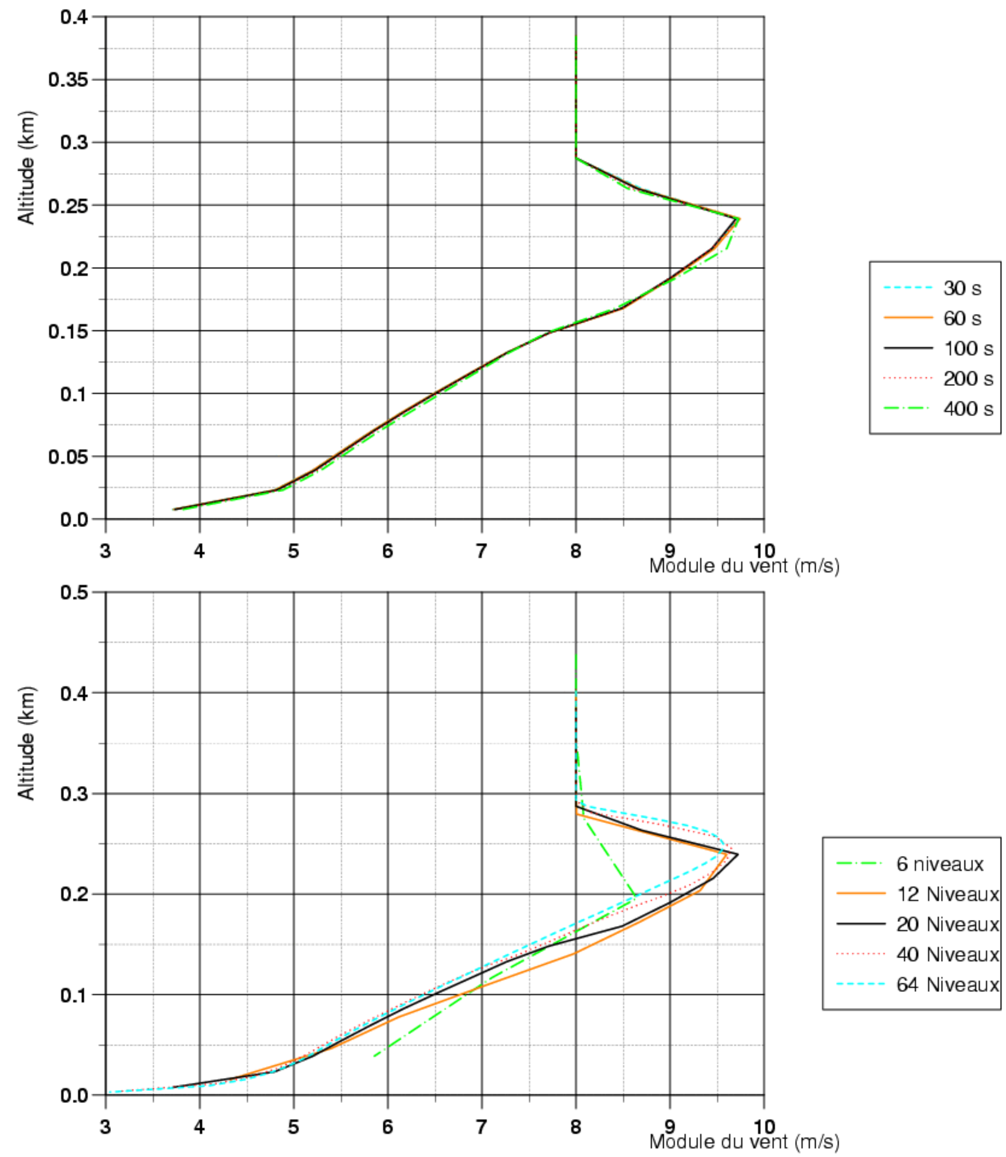




There is a wide range of possibilities to compute this key parameter !

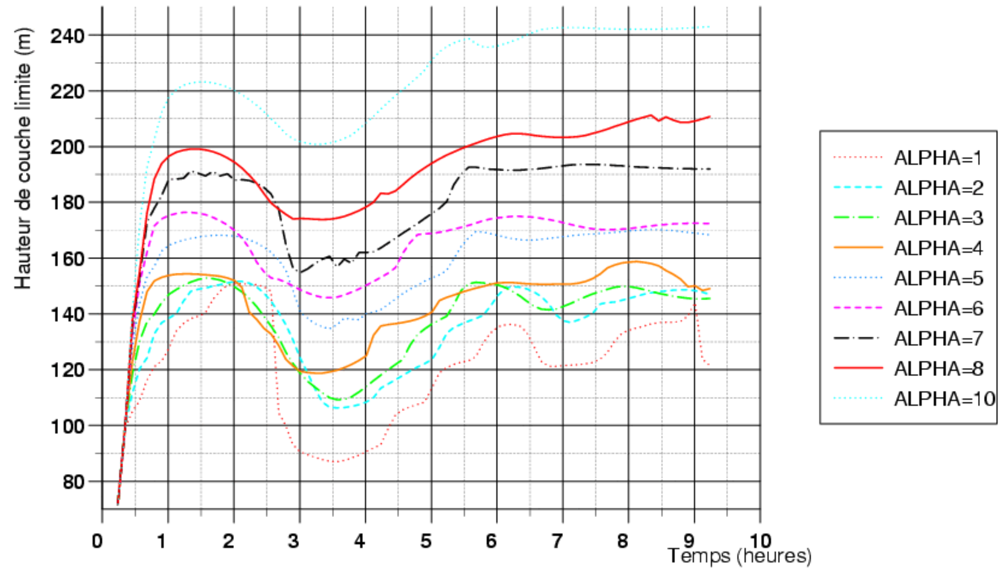
Wind speed

Time step



N	Δz(m)
6	80
12	30
20	16
40	8
64	6.25

Δz=16m

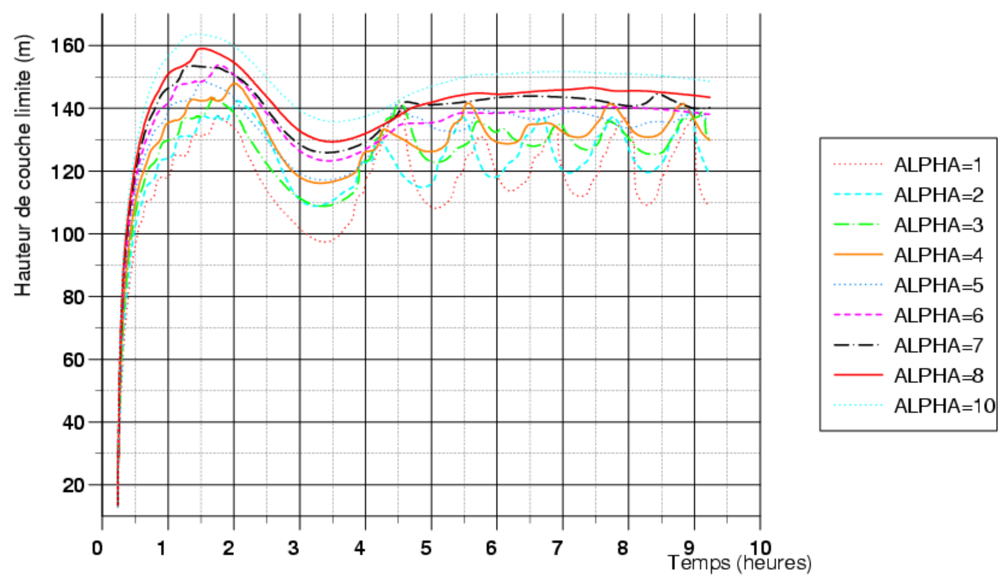


Diffusion term for TKE

$$-\frac{\partial}{\partial z}\left(\alpha_e \alpha_u l \sqrt{\bar{e}_T}\,\frac{\partial \bar{e}_T}{\partial z}\right)$$

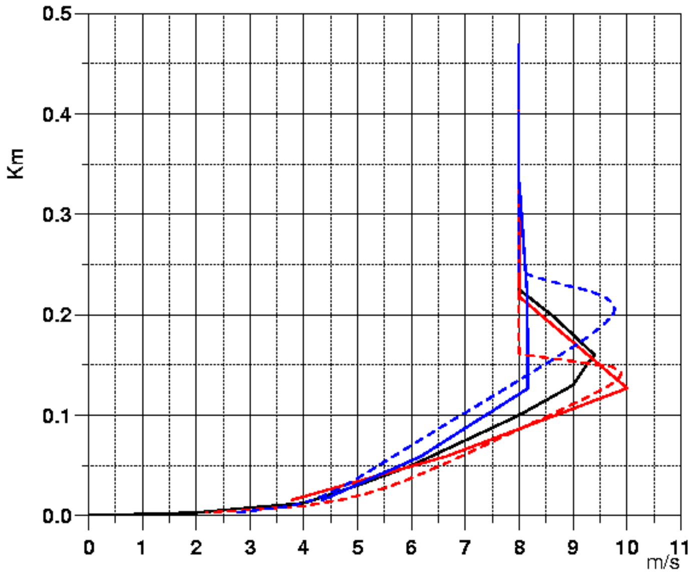
The diffusion on TKE is also important, its intensity depends essentially on the vertical resolution (some temporal oscillations has been observed on the GABLS case).

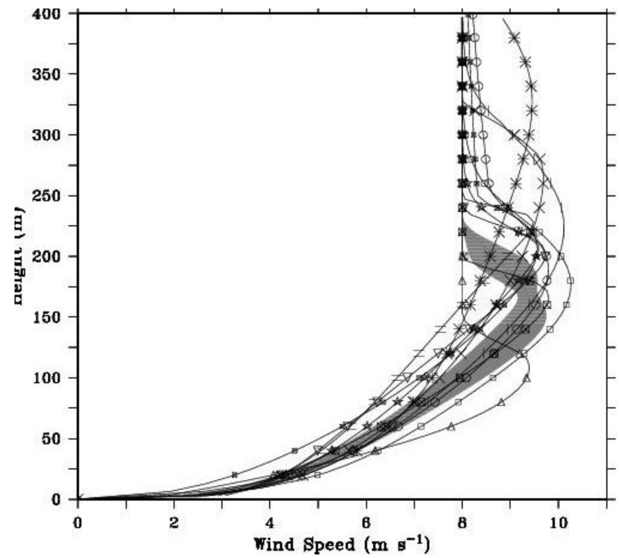
Δz=6.25m



Wind Speed H9

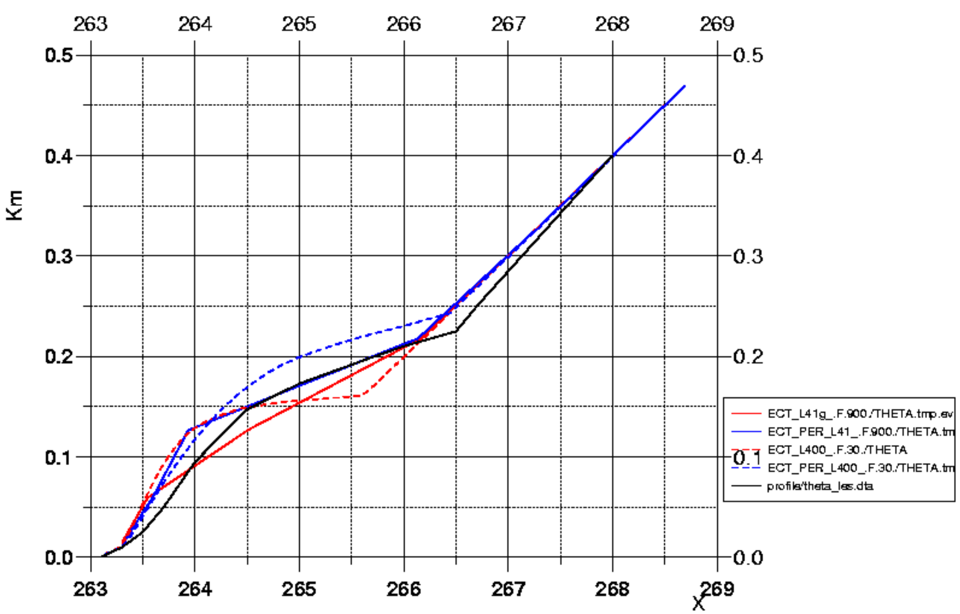
ARPEGE/ALADIN

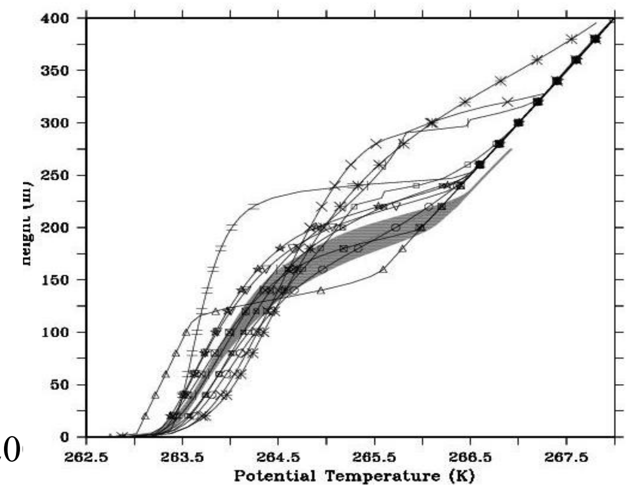




Potential Temperature H9

ARPEGE/ALADIN





METEO FRANCE

The GABLS simulation with the TKE scheme (with the tuning parameter used for the 3D test in ARPEGE-CLIMAT) has been significantly improved for the wind profile, the wind rotation and the potantial temperature.

The only negative impact is the over estimation for the friction velovity and the surface heat flux.

	PBLH (m)	$\overline{w'\theta_s'}$	u_*	Lmo	Surface angle
Oper →Feb. 05	383	-0.013	0.34	204	23
Oper (03/2005)	333	-0.014	0.31	142	29
TKE	132	-0.010	0.24	99	34
TKE (v0)	229	-0.017	0.34	161	34
Mean LES (from Cuxart et al 2005)	[160;195]	[-0.01;-0.013]	[0.26;0.3]	[120;170]]	[32;38]

For the preliminary test in 3D with the TKE scheme, we have to reduce the time step to avoid instabilities.

The first results are reasonable, but before intensive 3D test, we want to probe in to several questions:

•Do we need horizontal advection for the TKE ? probably yes, at high resolution, but we must be more explicit and precise

•The TKE is computed on half level, it is a logical choice for the computation of the turbulent exchanges coefficients but, unfortunately in ARPEGE, we cannot advect variables on half level, so, is it really a problem to have the TKE on the full level ? Probably not for high vertical resolution, but again, there is no clear conclusion for the new "grey zone" !

Second GABLS experiment

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- Based on CASES-99 experiment (Poulos et al, 2002)
- The purpose is to study the diurnal cycle
- The simulation start at 19UTC on October 22, 1999 for a 59h forecast
- http://www.joss.ucar.edu/cases99/results
- Results for the 15th August 2005
- Poulos et al 2002 Bull. Amer. Meteor. Soc. 83, 555-581
- Steeneveld G.J. et al submitted to JAS