Weaknesses of forecast model that could be addressed with BLLAST datasets

E. Bazile, F. Couvreux, and Y. Seity (CNRM/GAME)

BLLAST Workshop

Bergen 14-16 August 2013

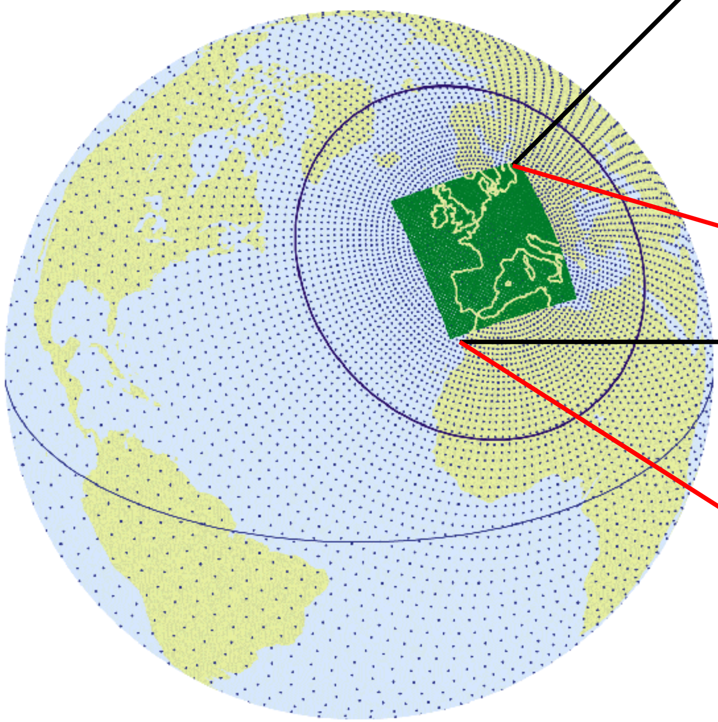
CNRS INSU Observer & comprendre

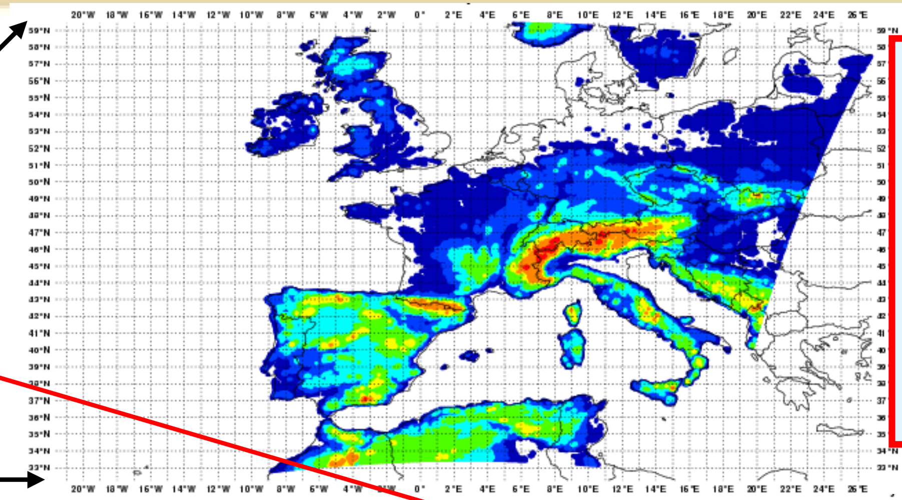
METEO FRANCE Toujours un temps d'avance

Outline

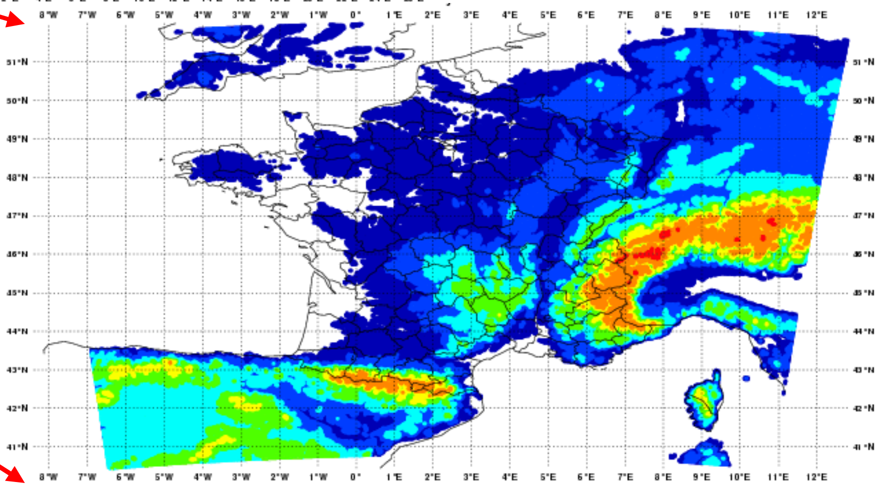
- Overview of the NWP at Meteo-France
- Specific output for BLLAST
  - spatial variability
  - how to compare with observations ?
  - Advection for a 1D case ?
- Focus on TKE and weaknesses in the turbulence in stable condition and evening transition ?
- Conclusions and perspectives

Operational Weather forecasting at Météo-France
July 2011 (BLLAST experiment)





ALADIN :
54h h forecasts
every 6h
dx=7.8 km,
70levels,
time-step=450s (SL)
3DVar Data
Assimilation system

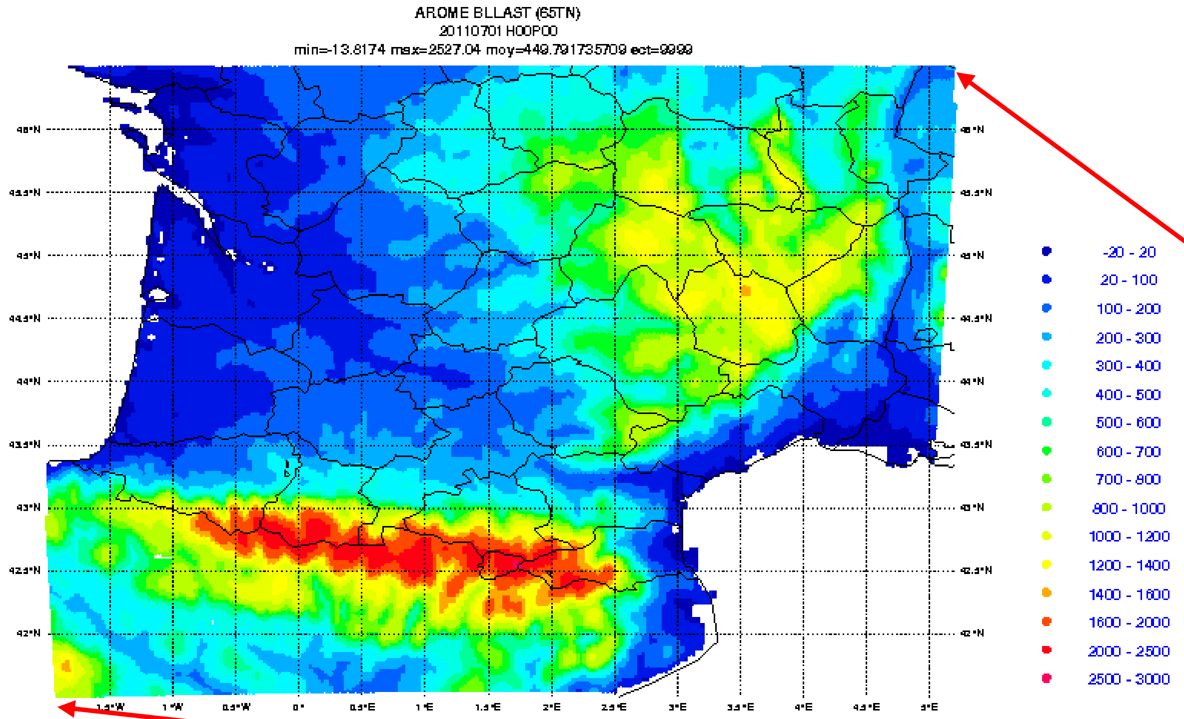


Cloud Resolving Model AROME-France
30 h forecasts every 6h
dx=2.5 km, 60 Levels, time-step=1mn (SL)
3DVar Data Assimilation system (RUC3h)

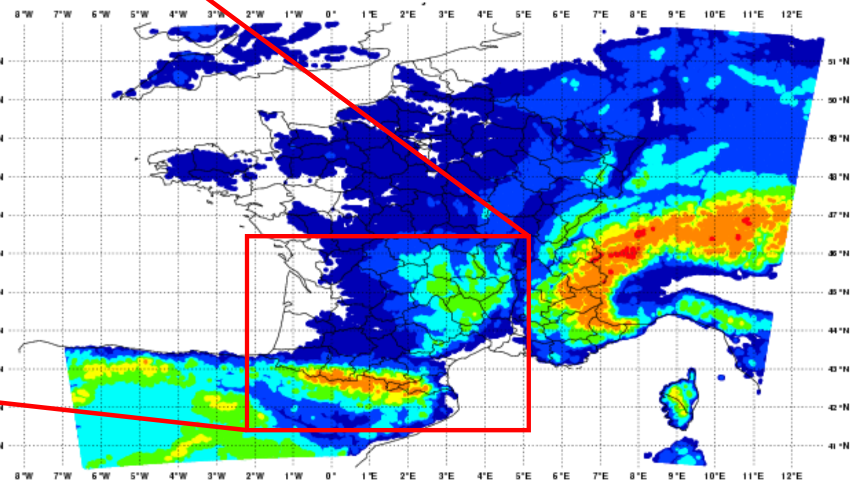
Global ARPEGE-IFS
4-day forecasts every 6 hours dx=10 km on
France, 55km on Australia dt=10mn
Stretching factor c=2.4 and turning of the pole
over the zone of interest
Stretched vertical grid with 70 levels
4DVar Inc Data Assimilation system
(T107 25iter and T323 30iter dx=60km)

METEO FRANCE
Toujours un temps d'avance

Specific experiment (almost in real time) with AROME



AROME-BLLAST (65TN) :
30h forecasts at 00h and 12utc
NH, dx=2.5 km,60levels, time-step=60s (SL)
LBC and initial file from AROME-France with specific output:
16 vertical profiles around Lannemezan with fluxes, TKE etc ….

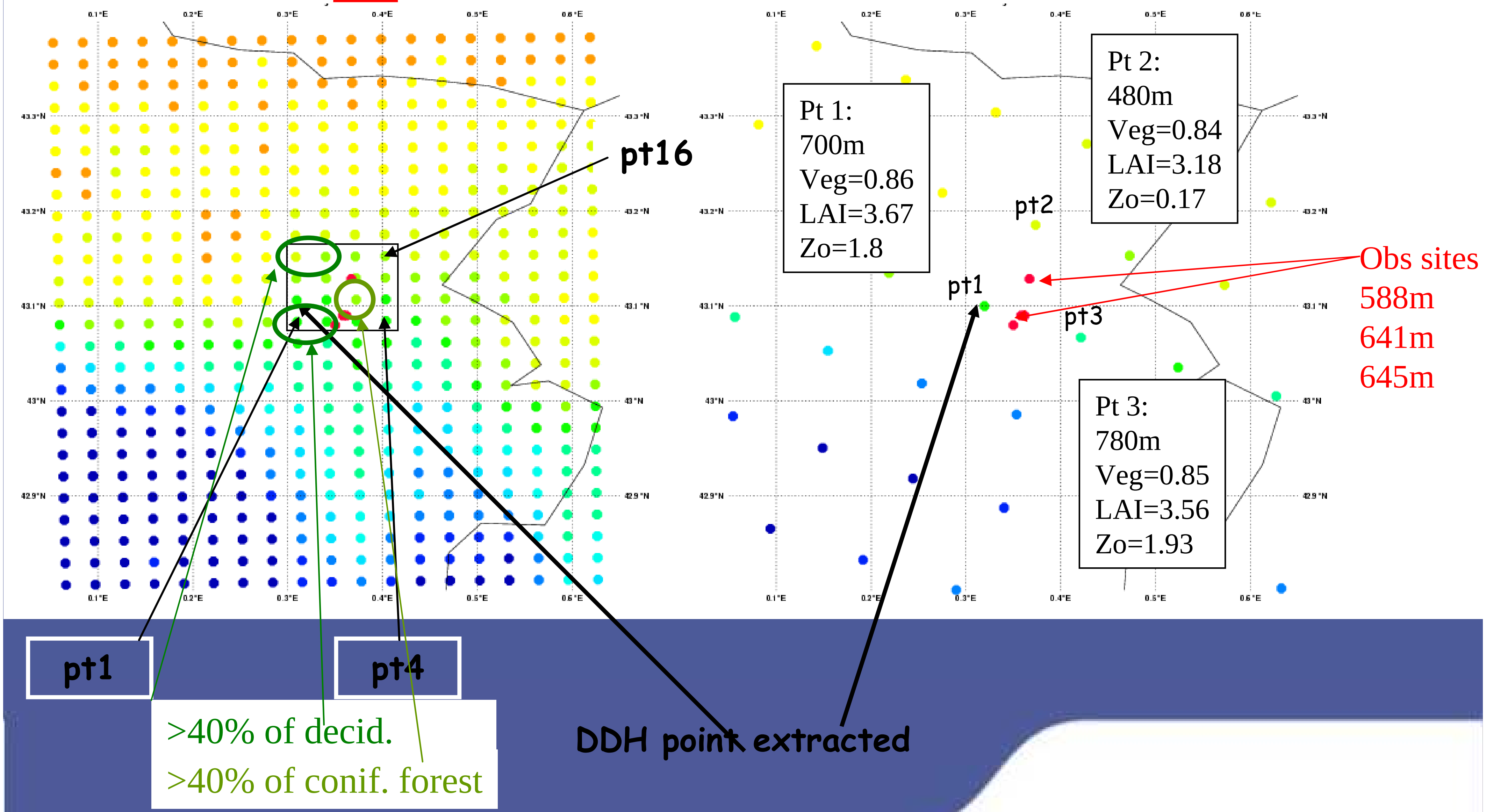


Cloud Resolving Model AROME-France
30 h forecasts every 6h
dx=2.5 km, 60 Levels, time-step=1mn (SL)
3DVar Data Assimilation system (RUC3h)

AROME

	Pt1:	Pt2:	Pt3:	Pt4:	Pt5:	Pt6:	Pt7:	Pt8:	Pt9:	Pt10:	Pt11:	Pt12:	Pt13:	Pt14:	Pt15:	Pt16:
Alt:	535.	611.	595.	558.	552.	605.	609.	593.	532.	567.	579.	575.	505.	521.	529.	527.
Veg:	0.95	0.93	0.92	0.92	0.92	0.93	0.85	0.94	0.93	0.91	0.91	0.91	0.93	0.92	0.88	0.90
LAI:	3.4	3.5	3.2	3.4	3.5	3.4	3.3	3.2	3.5	3.7	3.3	3.5	3.8	3.7	3.2	3.5
Zo:	0.78	0.53	0.26	0.16	0.24	0.38	0.45	0.39	0.49	0.37	0.18	0.47	0.83	0.64	0.23	0.38

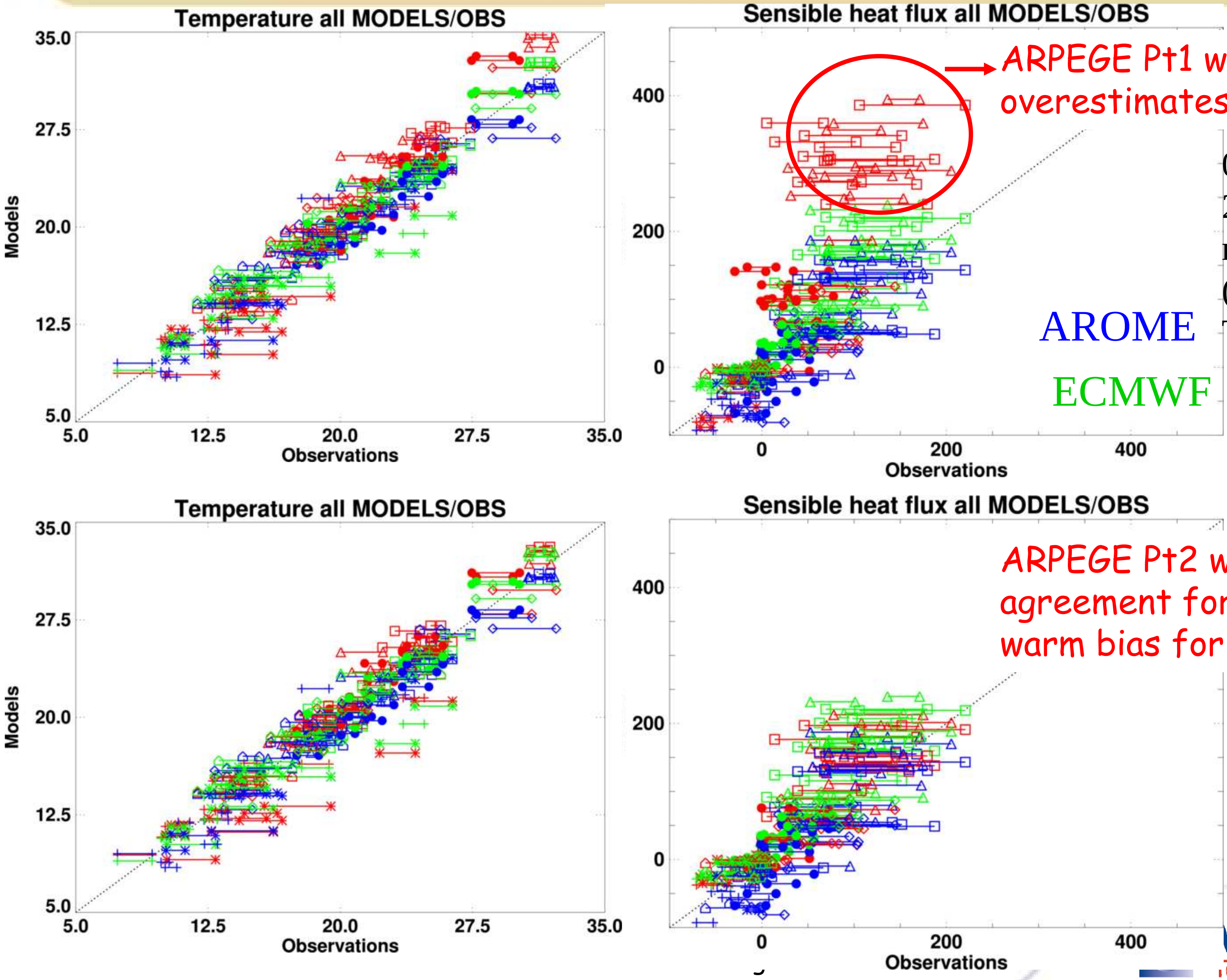
ARPEGE



PHYSICS in ARPEGE/ALADIN/AROME

	ARPEGE/ALADIN Global model (10km to 55km) and LAM (7.5km)	AROME (NH) 2.5km
Surface	ISBA (Noilhan, Planton (89), Giard Bazile (2000))	SURFEX With ISBA, TEB, Ecume, etc
Turbulence	TKE (Cuxart et al 2000)	
Mixing length	Bougeault Lacarrere (89)	
	Modified by the shallow cloud thickness and deep convection	
Shallow Convection	KFB (Bechtold et al 2001)	PMMC09 (Pergaud et al 2009)
Deep Convection	Moisture Convergence (Bougeault 85)	Explicitly resolved
Clouds (PDF)	Smith (90)	Bougeault (82)
GWD	Described in annexe of Catry et al. 2008	no
Microphysics	Ql,Qi,Qr,Qs Lopez(2002) Bouteloup et al (2005)	Ql,Qi,Qr,Qs,Qg Pinty and Jabouille 1998
Radiation	RRTM for LW (Mlawer et al. 1997) and Morcrette et al. 2001 for SW (6b)	

2M Temperature, Sensible heat flux



ARPEGE Pt1 with z0=1.8 overestimates sensible heat flux

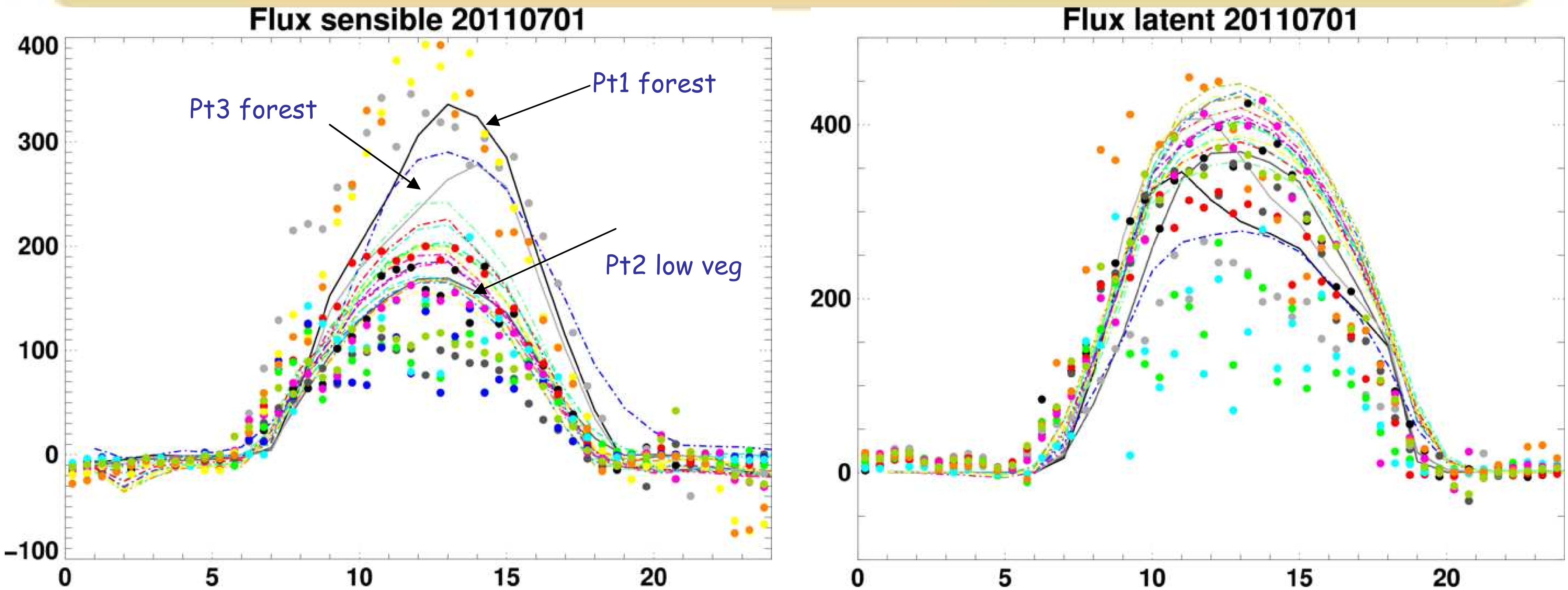
03, 06, 09, 12, 15, 18, 21 : 1 point for model range for observations (Corn, Moor and Tower) in the hour

ARPEGE Pt2 with z0=0.17 better agreement for the SHF and less warm bias for T2m

F. Couvreux (BLLAST workshop 2012)

METEO FRANCE
Toujours un temps d'avance

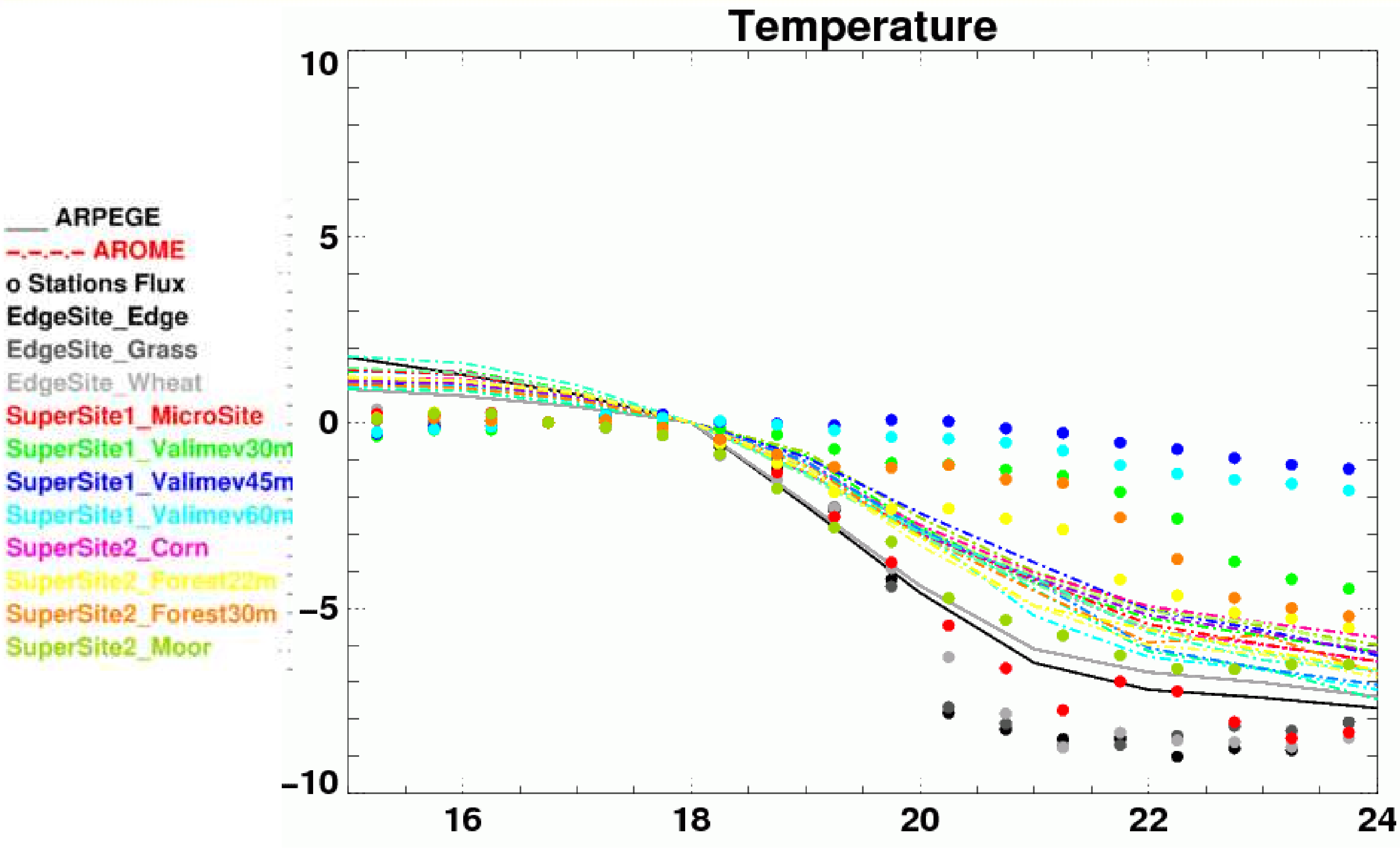
Sensible and latent heat flux 20110701



AROME tends to overestimate LHF and underestimate the SHF for forest : lower z0 than ARPEGE. Smaller variability in the models than observed especially for AROME

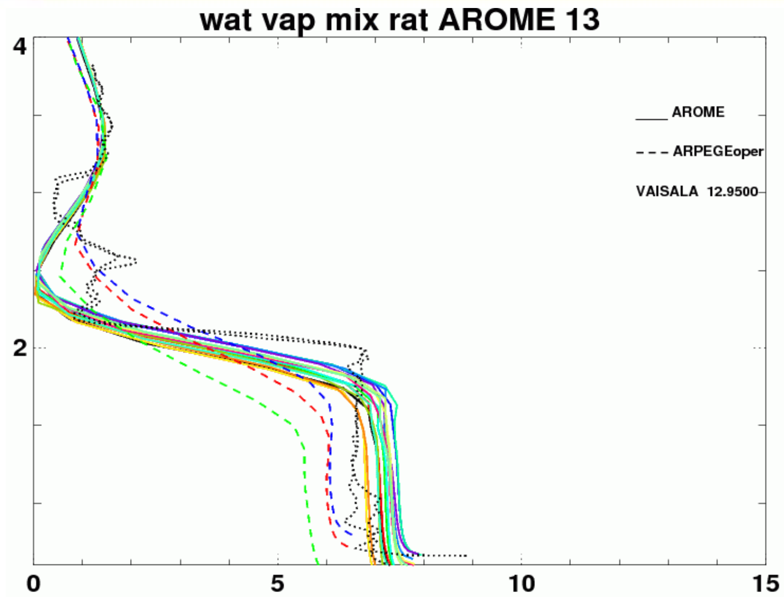
F. Couvreux (BLLAST workshop 2012)

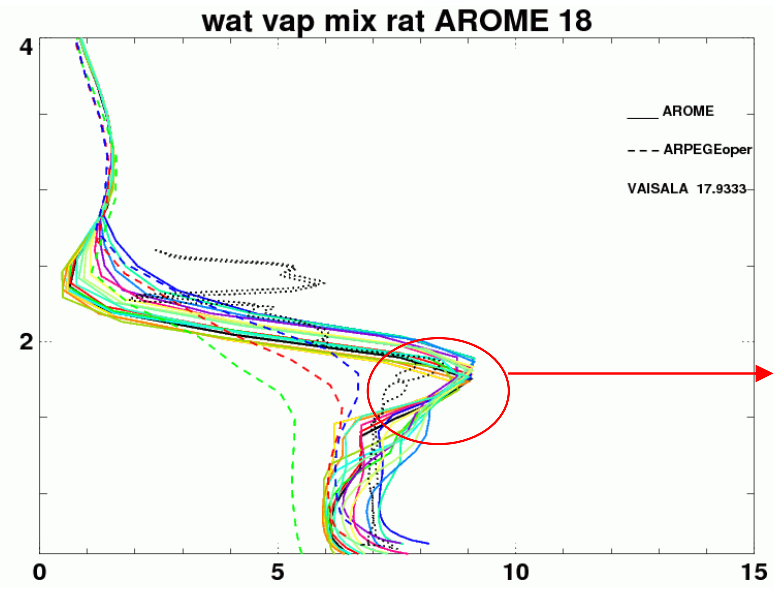
T-T18h Transition 20110701



-ARPEGE larger & quicker decrease in the afternoon than AROME
- In observations, different behaviours among the stations, more variability

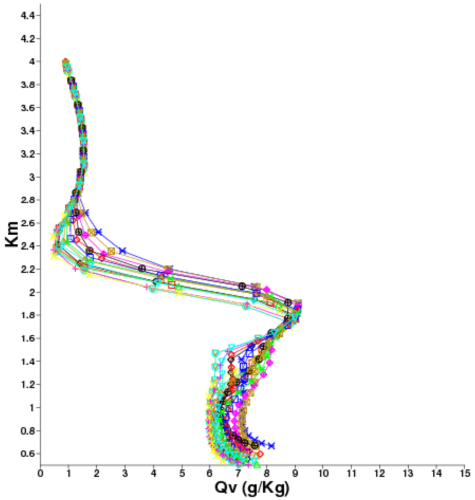
Problem of advection and fine scale structure : Qv vertical profile (20110701)



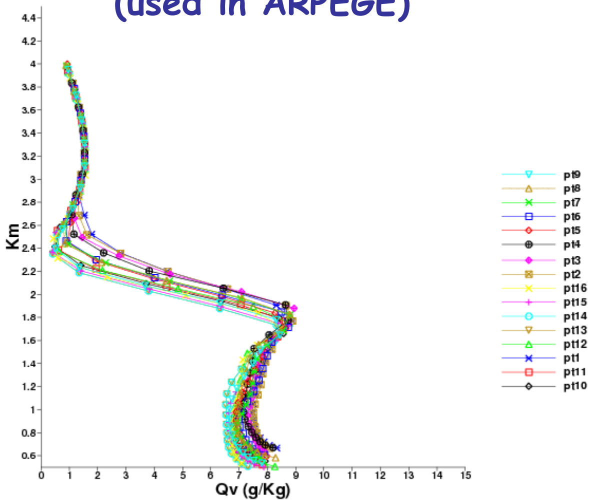


Better profile with AROME why ?
Horizontal resolution or turbulence via the shallow convection ?
Fine scale advection ?

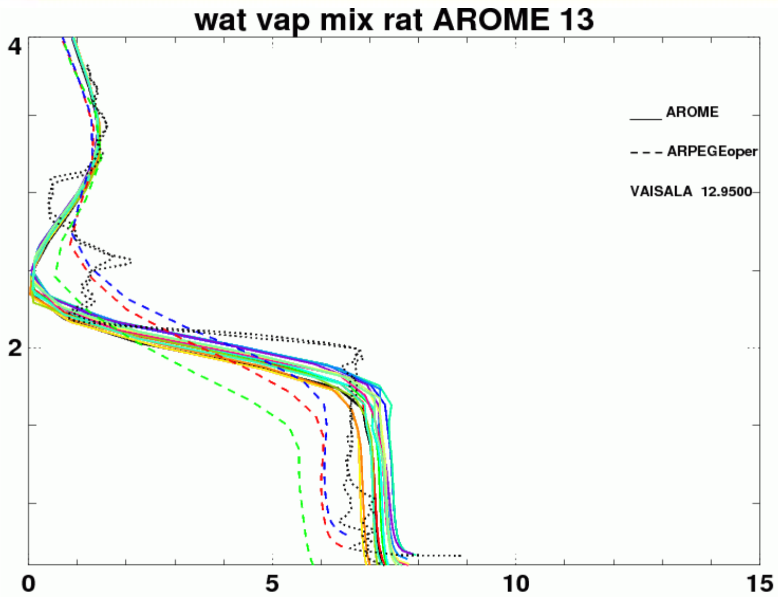
AROME

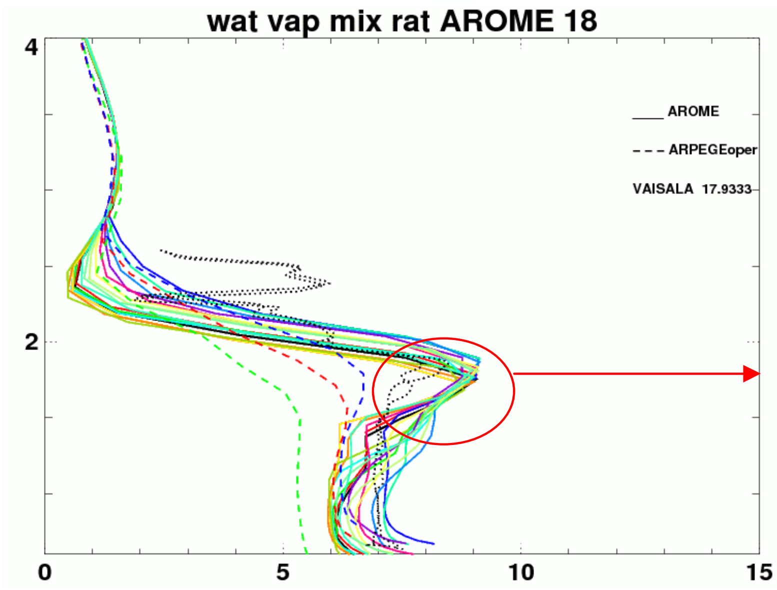


AROME with KFB (used in ARPEGE)



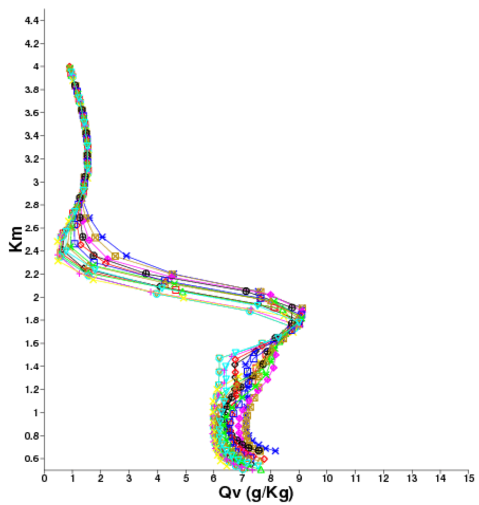
Problem of advection and fine scale structure : Qv vertical profile (20110701)



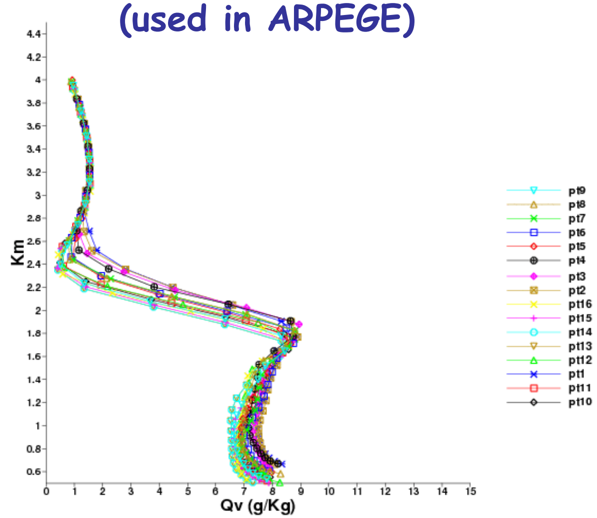


Better profile with AROME why ?
Horizontal resolution or turbulence via the shallow convection ?
Fine scale advection

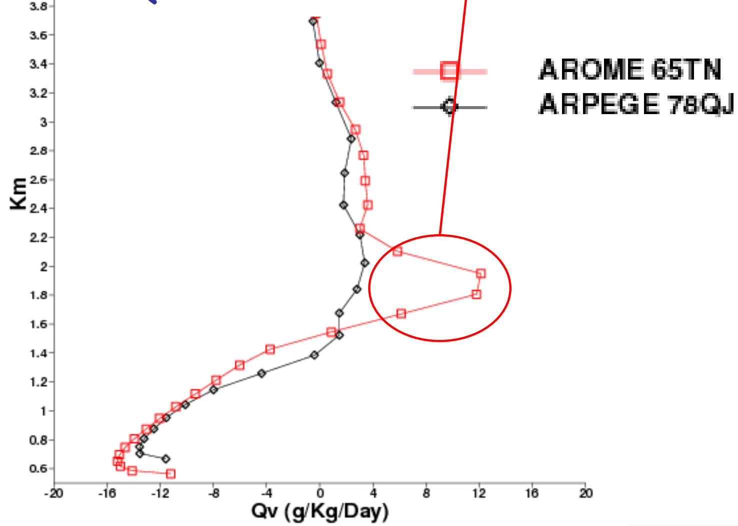
AROME



AROME with KFB
(used in ARPEGE)



Qv advection between 12-18h



METEO FRANCE
Toujours un temps d'avance

Turbulence and shallow convection in ARPEGE/AROME

EDMF concept : Siebesma and Teixeira, (2000) and Hourdin et al., (2002) and Soares et al., 2004

$$\overline{w'\psi'} = -K\frac{\partial \psi}{\partial z} - M\left(\psi - \psi_{updraft}\right)$$

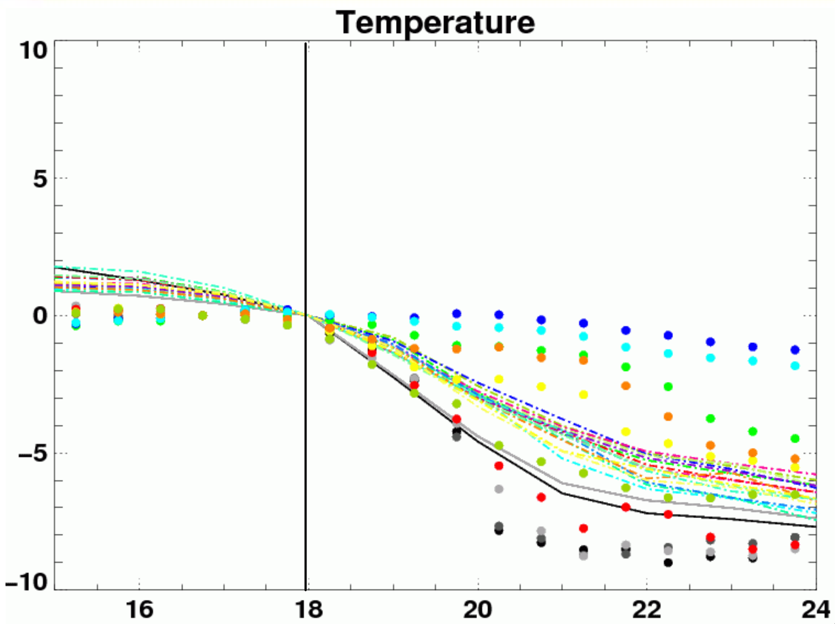
TKE Scheme CBR(2000), BL(89)

- Shallow convection from Bechtold et al (2001) for ARPEGE/ALADIN (KFB) or Pergaud et al 2009 (EDKF) for AROME

$$K_M = \alpha_M \cdot l \cdot \sqrt{e_T} \qquad K_{\theta/q} = \alpha_\theta \cdot K_M \cdot \phi_3$$

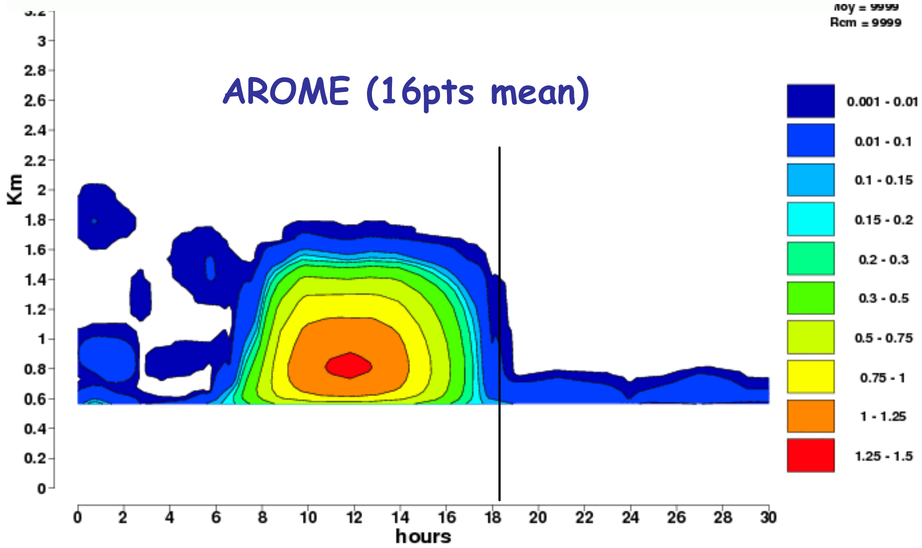
$$\frac{\partial e_T}{\partial t} = advec \underbrace{- \overline{u'w'}\frac{\partial \bar{u}}{\partial z} - \overline{v'w'}\frac{\partial \bar{v}}{\partial z}}_{Pd} + \underbrace{\beta \cdot \overline{w'\theta'_{vl}}}_{P_\theta} - \frac{1}{\rho}\cdot\frac{\partial \overline{\rho w'e'_T}}{\partial z} - c_\varepsilon \cdot \frac{\bar{e}_T^{3/2}}{l}$$

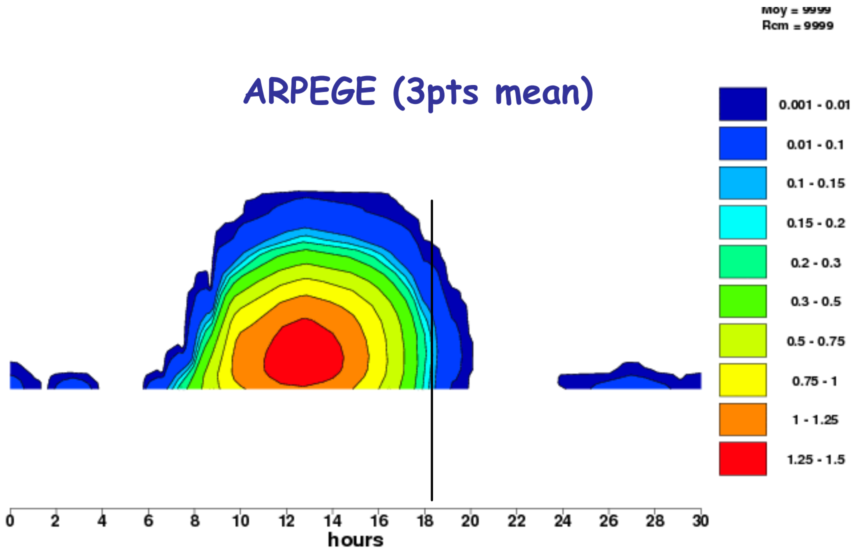
Turbulent Kinetic Energy (m2/s2) 20110701



-In ARPEGE/AROME, after 18TU, the TKE is very small (<0.1) → no vertical mixing

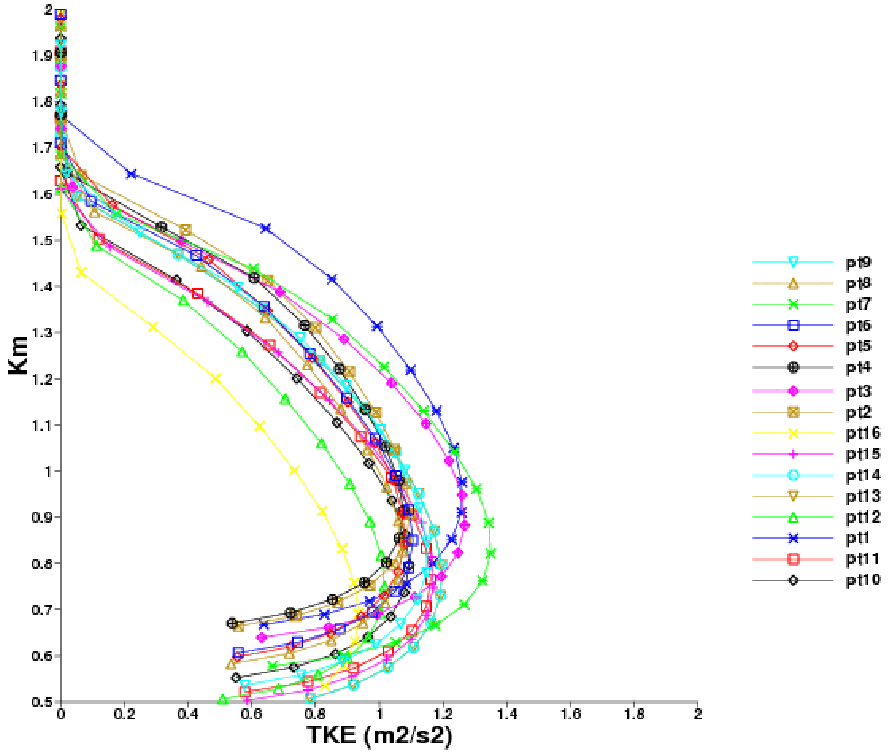
-The decrease of TKE is too fast ? If yes why ? Dissipation length ?



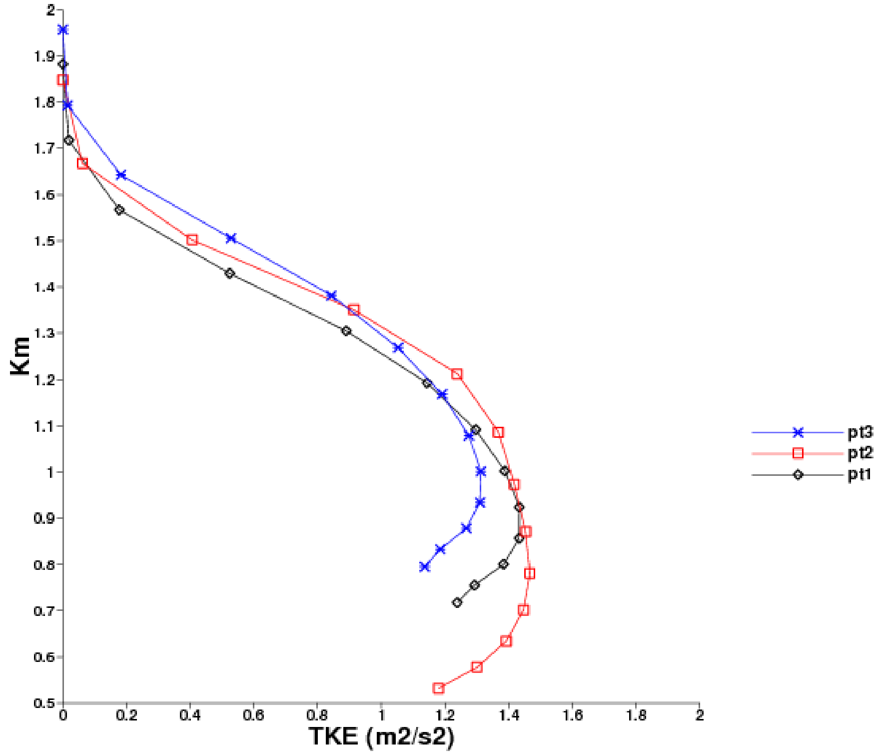


TKE profile 20110701 +12UTC

AROME

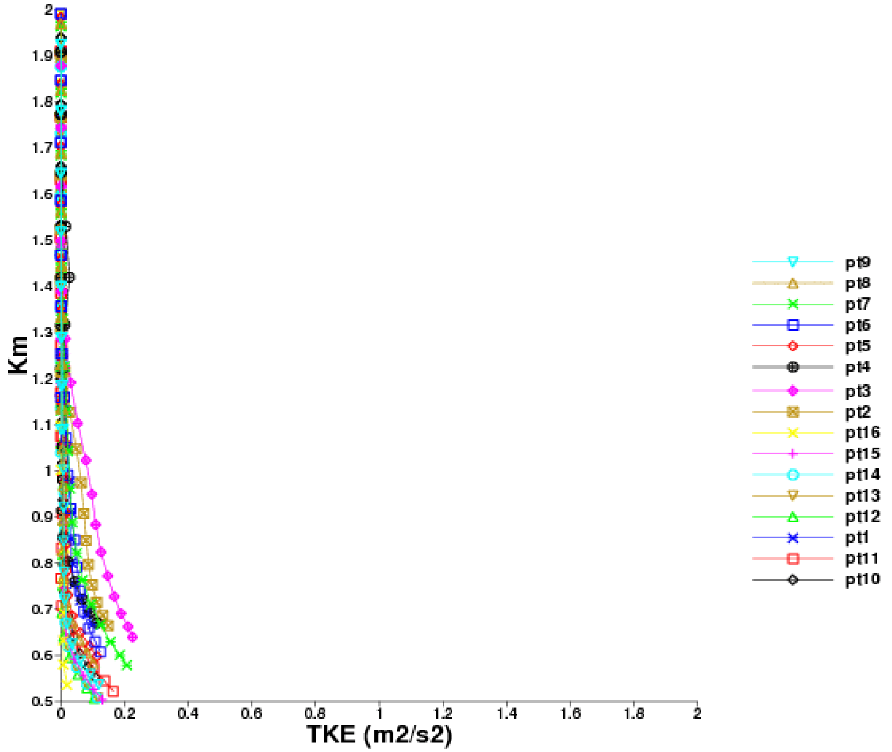


ARPEGE

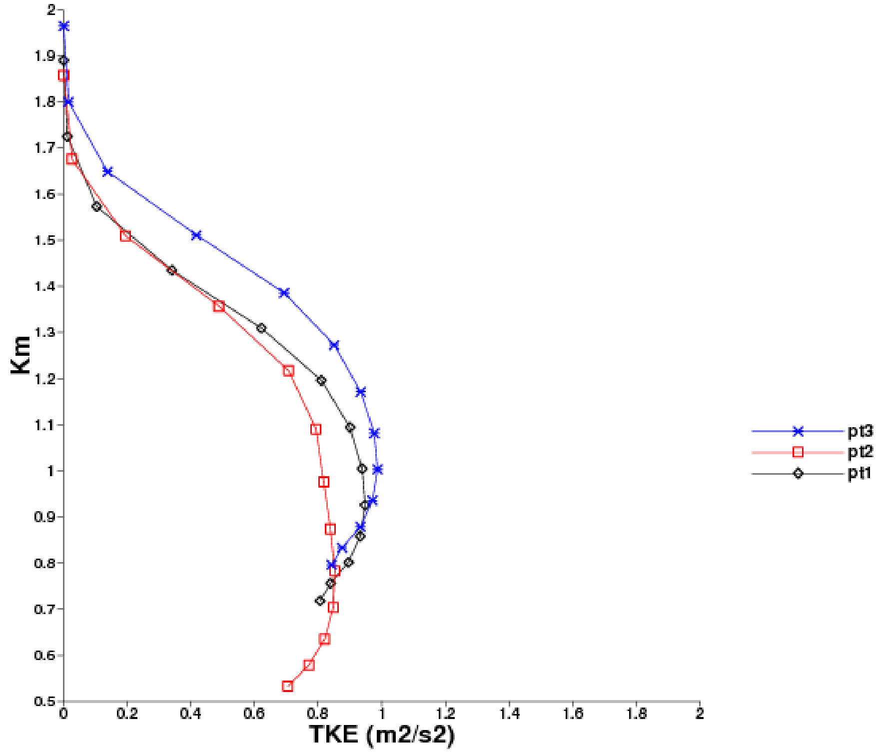


TKE profile 20110701 +16UTC

AROME



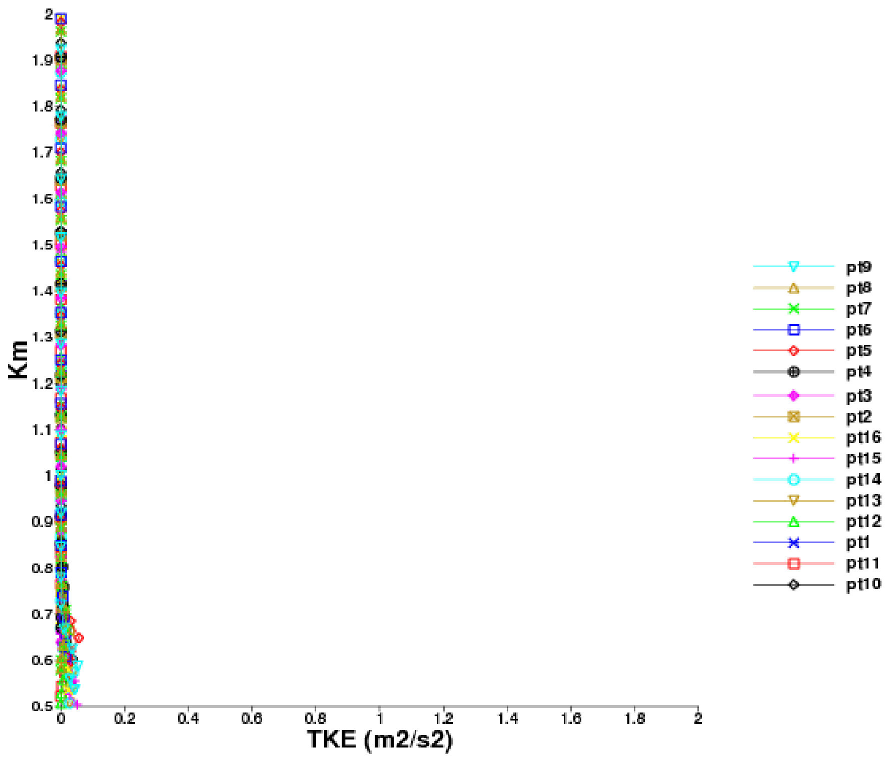
ARPEGE



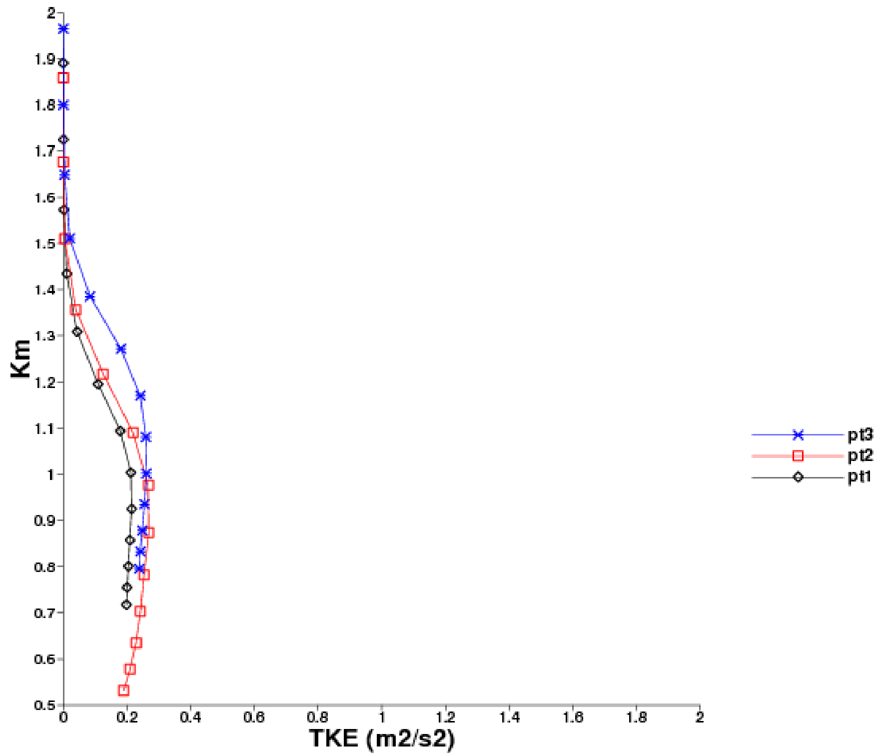
-Significant differences between ARPEGE and AROME in terms of value of TKE but also in the vertical structure, although the TKE scheme is the same ! Impact of the horizontal resolution with NH, fine scale effect ? But where is the truth ?

TKE profile 20110701 +18UTC

AROME

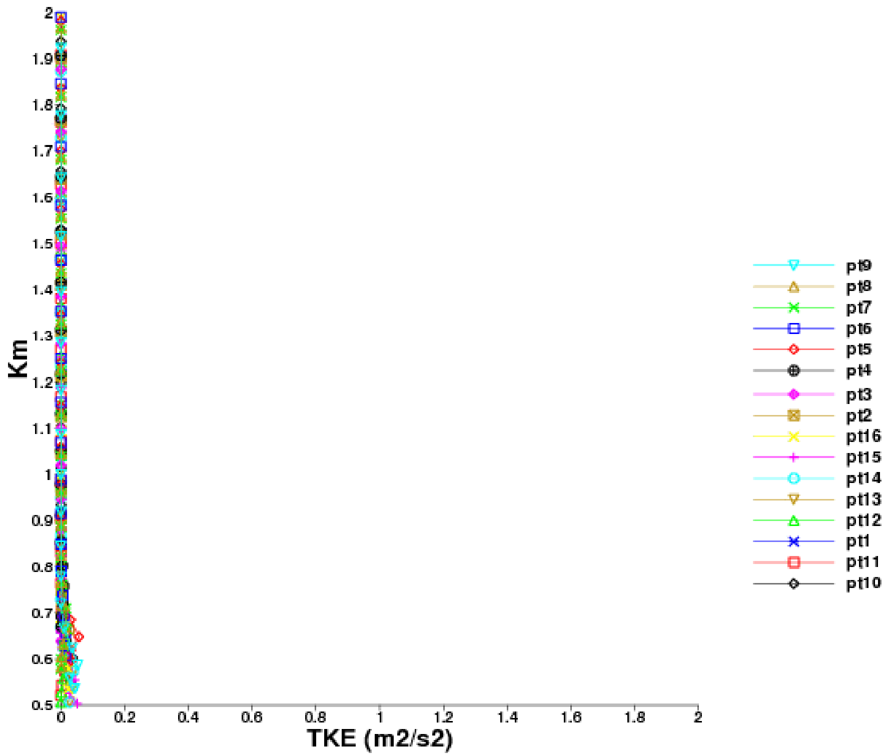


ARPEGE

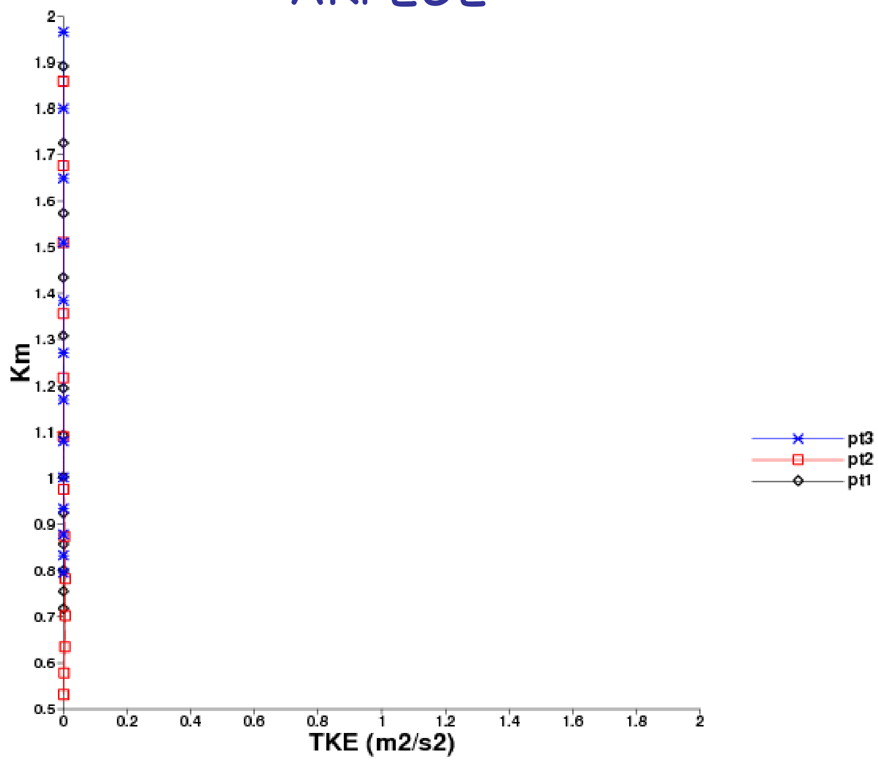


TKE profile 20110701 +20UTC

AROME



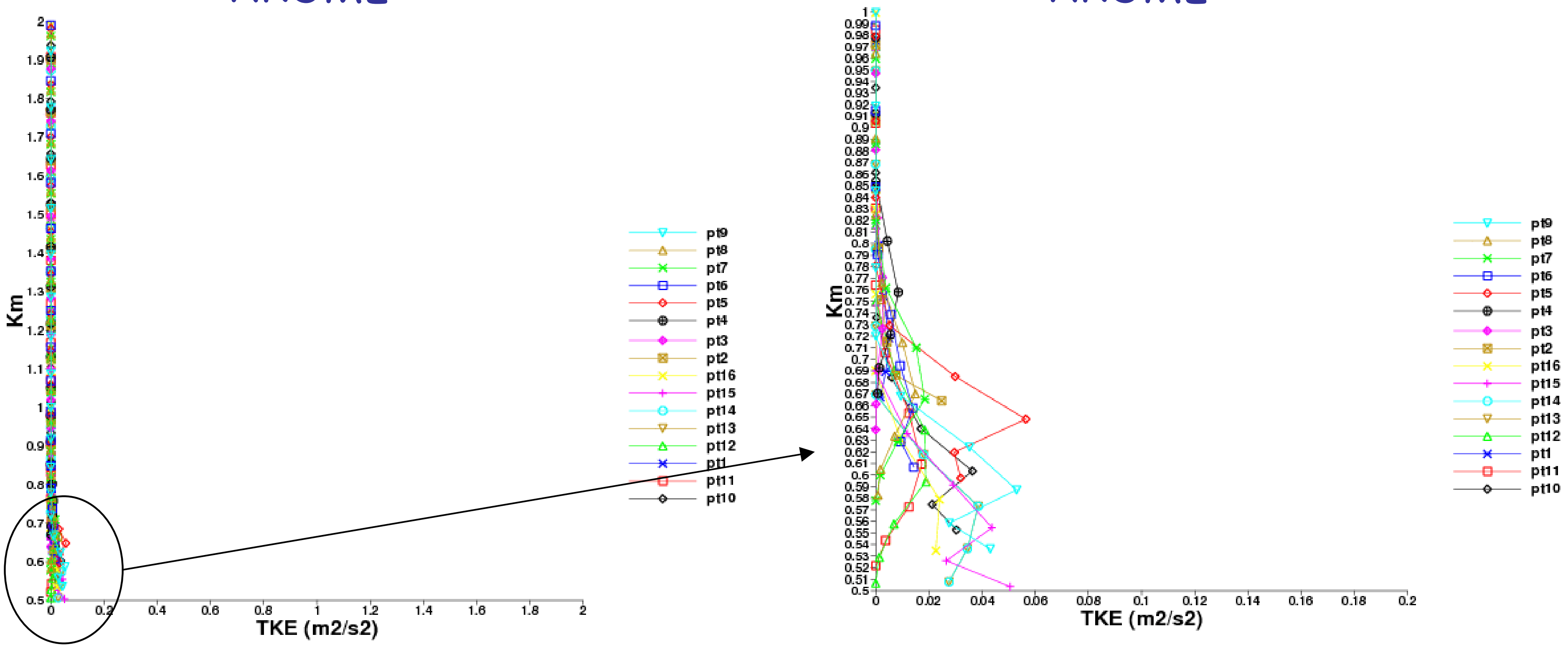
ARPEGE



TKE profile 20110701 +20UTC

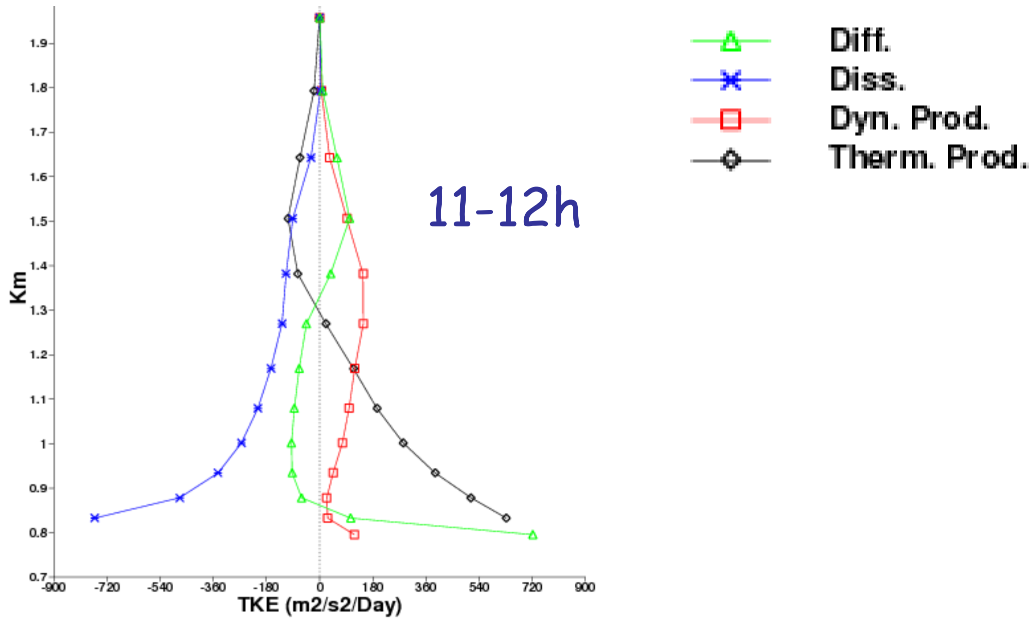
AROME

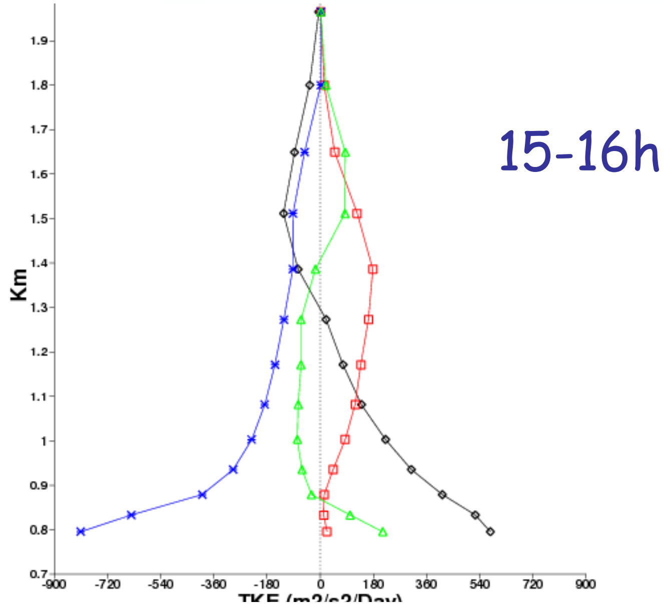
AROME

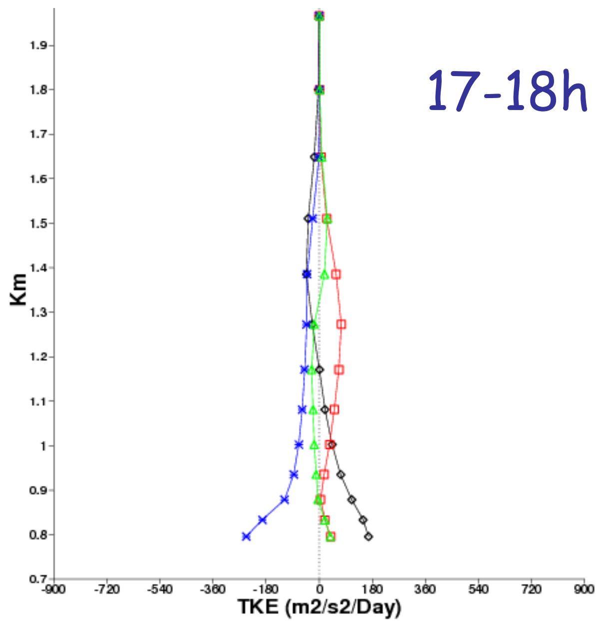


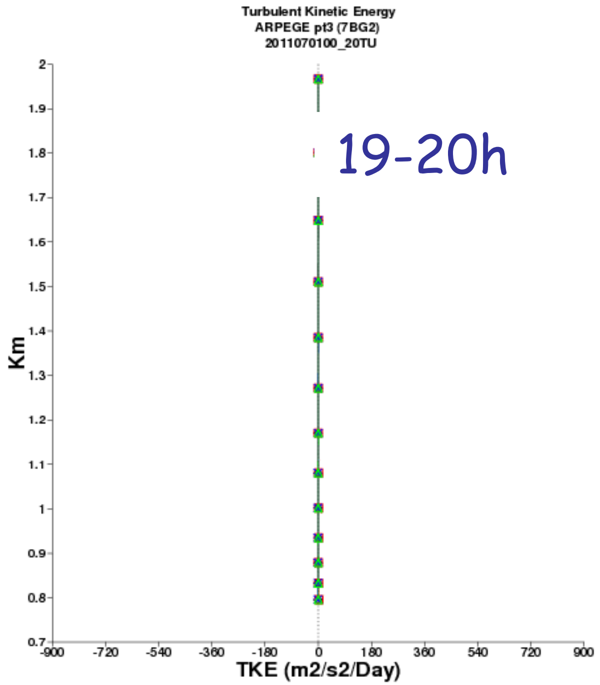
TKE is almost zero, excepted for the first levels in AROME due to a "arbitrary" minimum wind shear at the surface. BLLAST observations can probably help us !!!

Turbulent Kinetic Budget 20110701
ARPEGE (pt3)







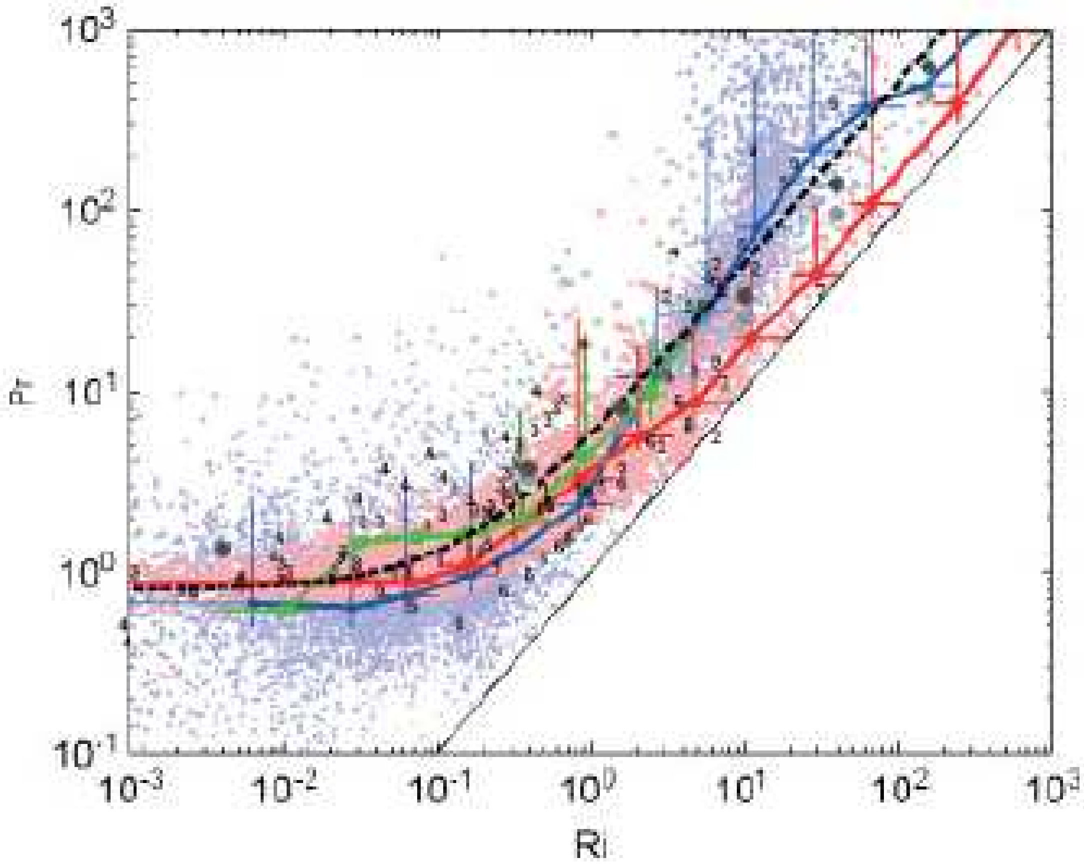


Some weaknesses …

- warm bias → interaction with the surface and the snow scheme
- Mixing length and TKE close to zero in very stable conditions → no mixing
- Following Galperin et al 2007 and Zilitinkevich et al 2008 turbulence survives for Ri>>1. Is it the case with the TKE scheme ?

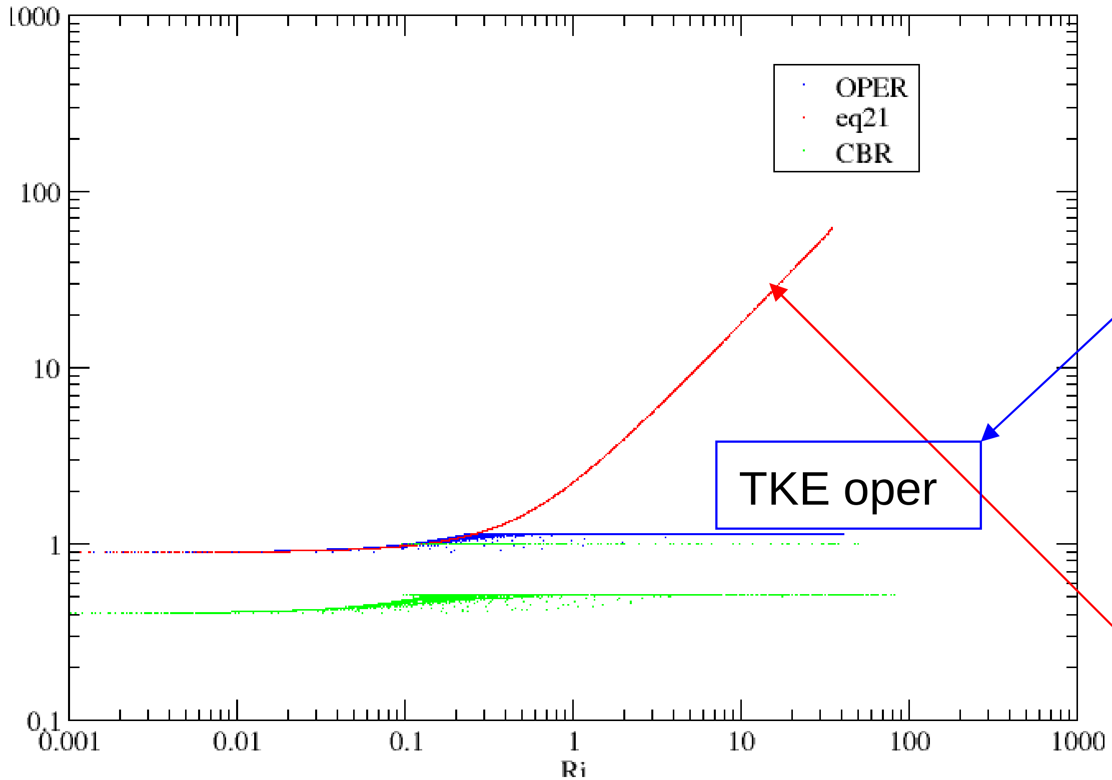
From Zilitinkevich et al 2008

$$\mathrm{Pr} = \frac{K_m}{K_h}$$



Some weaknesses …

- With the 1D case (GABLS1 and GABLS3) and the 1D Model MUSC with the AROME and ARPEGE physics, we can verify the dependency of the Pr number vs Ri



E. Bazile et al (2011) (ECMWF Proceedings)

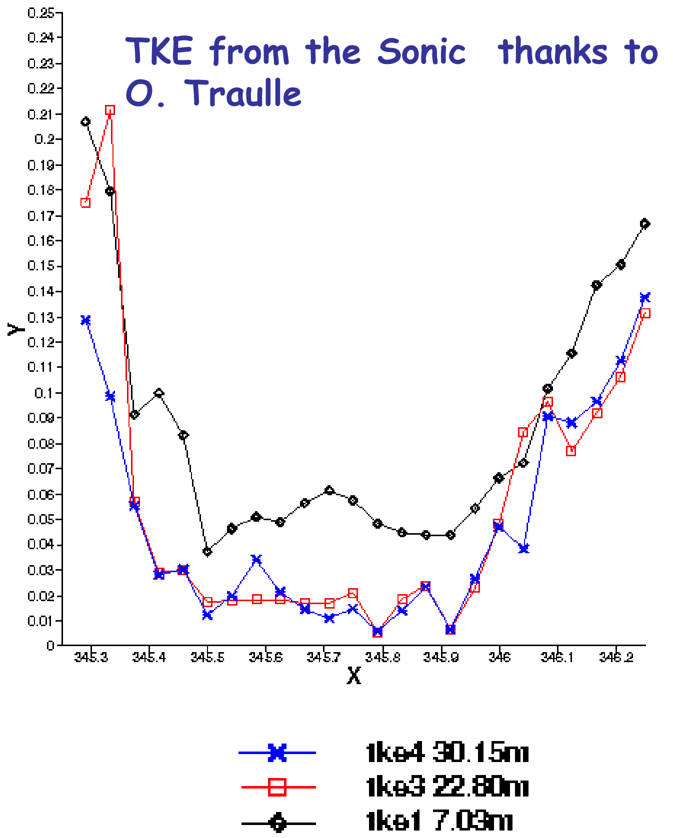
$$\mathrm{Pr} = \frac{K_m}{K_h} = \frac{1}{\alpha_\theta \phi_3} \quad \text{with} \quad \alpha_\theta = 1.13, \quad 0.78 < \phi_3 < 2.2$$

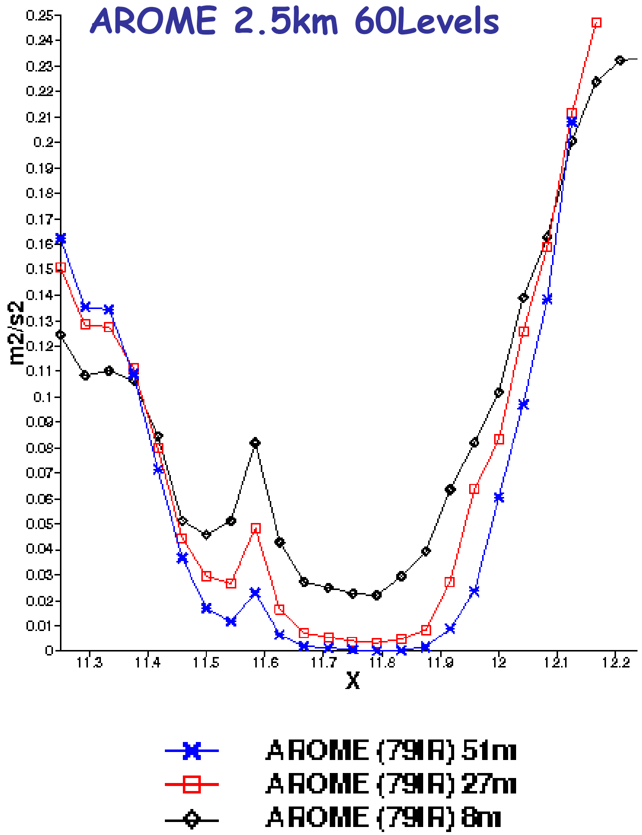
$$\phi_3 = \frac{1}{1 + C \cdot \beta \dfrac{\overline{L_m^2}}{\overline{e_T}} \dfrac{\partial \overline{\theta_{vl}}}{\partial z}}$$

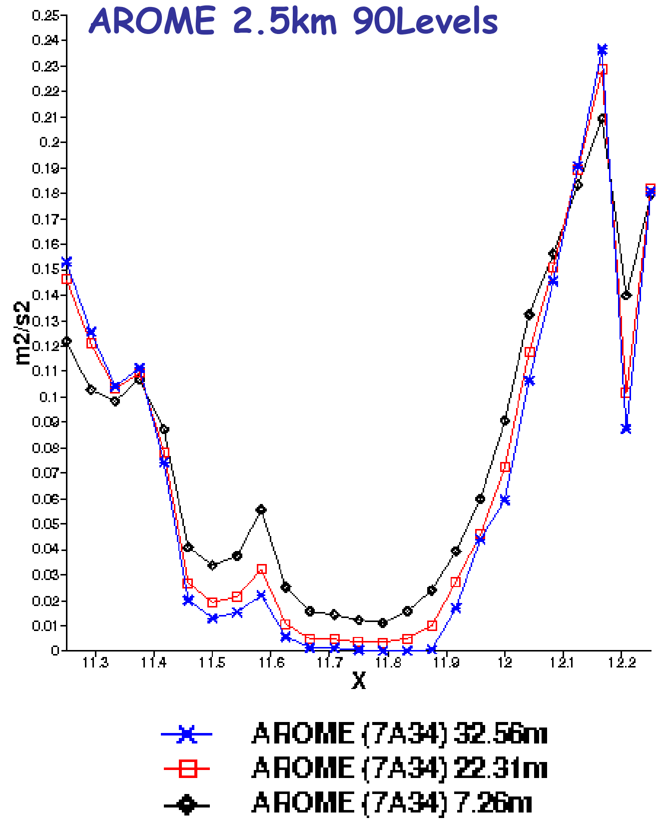
Assuming a stationary TKE without turbulent transport, it is possible to approximate Phi3 as an function of Ri (Cuxart 2000 eq 21). Moreover in cloudy case the impact is very detrimental !

TKE with $\phi_3 = f(R_i)$

TKE at Dome C Antarctica 11/12 Dec2009







TKE is underestimated at DomeC during night, although the surface temperature is well forecasted, the increase of vertical resolution does not improved the TKE and the vertical profile

Energy Flux Budget Closure (Zilitinkevitch et al, 2013)

TPE : Turbulent Potential Energy

$$E_p = \frac{1}{2}\left(\frac{\beta}{\frac{\partial \theta}{\partial z}}\right)\cdot \theta'^2$$

$$\frac{\partial E_P}{\partial t} = advec - \beta(\overline{w'\theta'}) - \frac{1}{\rho}\cdot\frac{\partial \overline{\rho w' E_P'}}{\partial z} - c_P \cdot \frac{E_P^{3/2}}{l}$$

$$\frac{\partial e_T}{\partial t} = advec + P_d + \beta(\overline{w'\theta'}) - \frac{1}{\rho}\cdot\frac{\partial \overline{\rho w' e_T'}}{\partial z} - c_\varepsilon \cdot \frac{\overline{e}_T^{3/2}}{l}$$

The buoyancy flux appears with opposite signs and describes nothing but the energy exchange between TKE and TPE. For stable conditions and during transition in late afternoon the Buoyancy flux becomes negative and can be considered as an ultimate killer of turbulence (Zilitinkevitch et al, 2013)

Energy Flux Budget Closure (Zilitinkevitch et al, 2013)

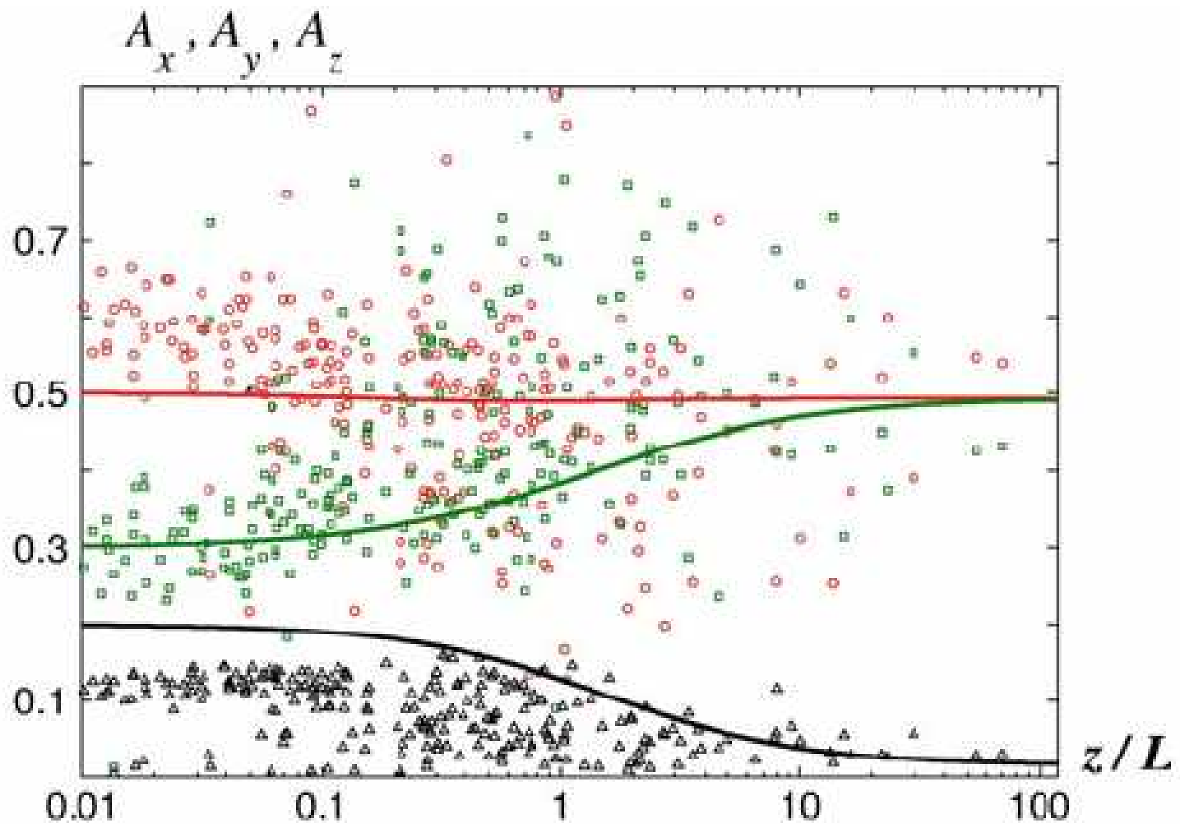


Fig. 3 The shares of the turbulent kinetic energy E_K: longitudinal $A_x = E_x/E_K$ (along the mean wind, *red circles*), transverse $A_y = E_y/E_K$ (*green squares*) and vertical $A_z = E_z/E_K$ (*black triangles*), after the Kalmykia-2007 field campaign of the A.M. Obukhov Institute of Atmospheric Physics of the Russian Academy of Sciences (courtesy of Rostislav Kouznetsov). The *lines* show our inter-component energy exchange model, Eq. 50, with $C_0 = 0.125$, $C_1 = 0.5$ and $C_2 = 0.72$, converted into z/L dependences with the aid of Eq. 71

Energy Flux Budget Closure (Zilitinkevitch et al, 2013)

Partial EFB Closure in ARPEGE :

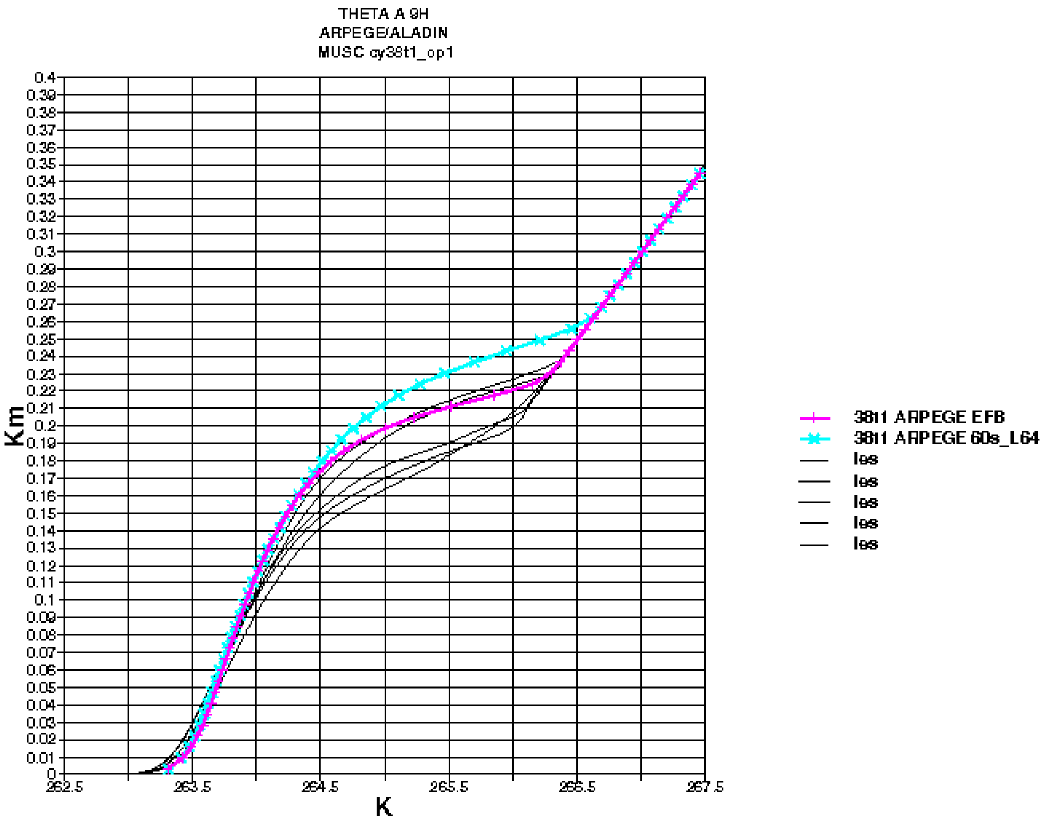
- new prognostic variable for Ep
- new computation for Km/Kh (anisotropy effect via Ez)

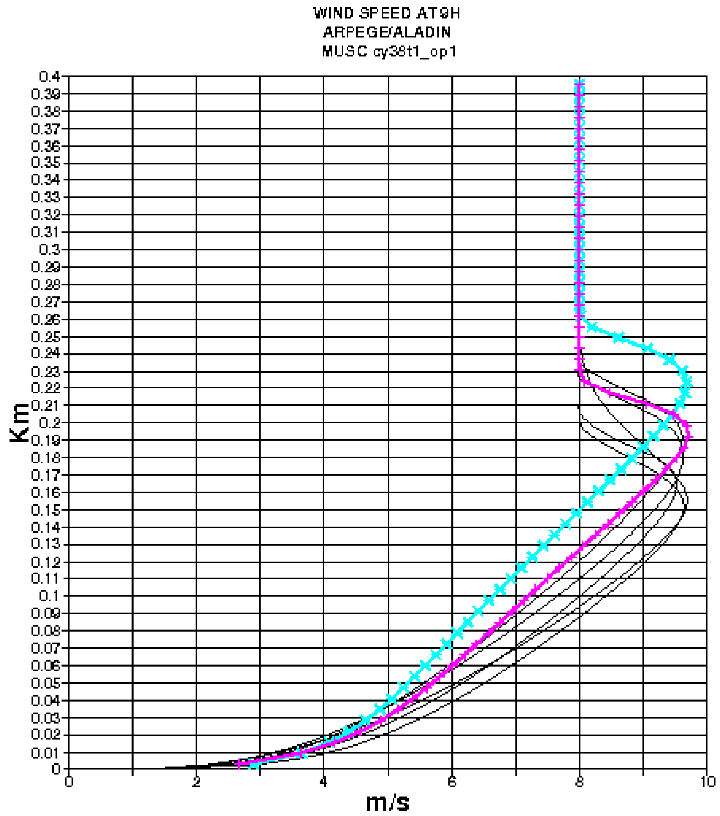
$$K_M = \alpha_M \cdot l \cdot \sqrt{e_T} \longrightarrow K_M = 2 \cdot C_\tau \cdot E_z \cdot \frac{l}{\sqrt{e_T}}$$

$$K_{\theta/q} = \alpha_\theta \cdot K_M \cdot \phi_3 \longrightarrow K_{\theta/q} = 2 \cdot C_F \cdot E_z \cdot \frac{l}{\sqrt{e_T}} \cdot (1 - C_\theta \frac{E_P}{E_z})$$

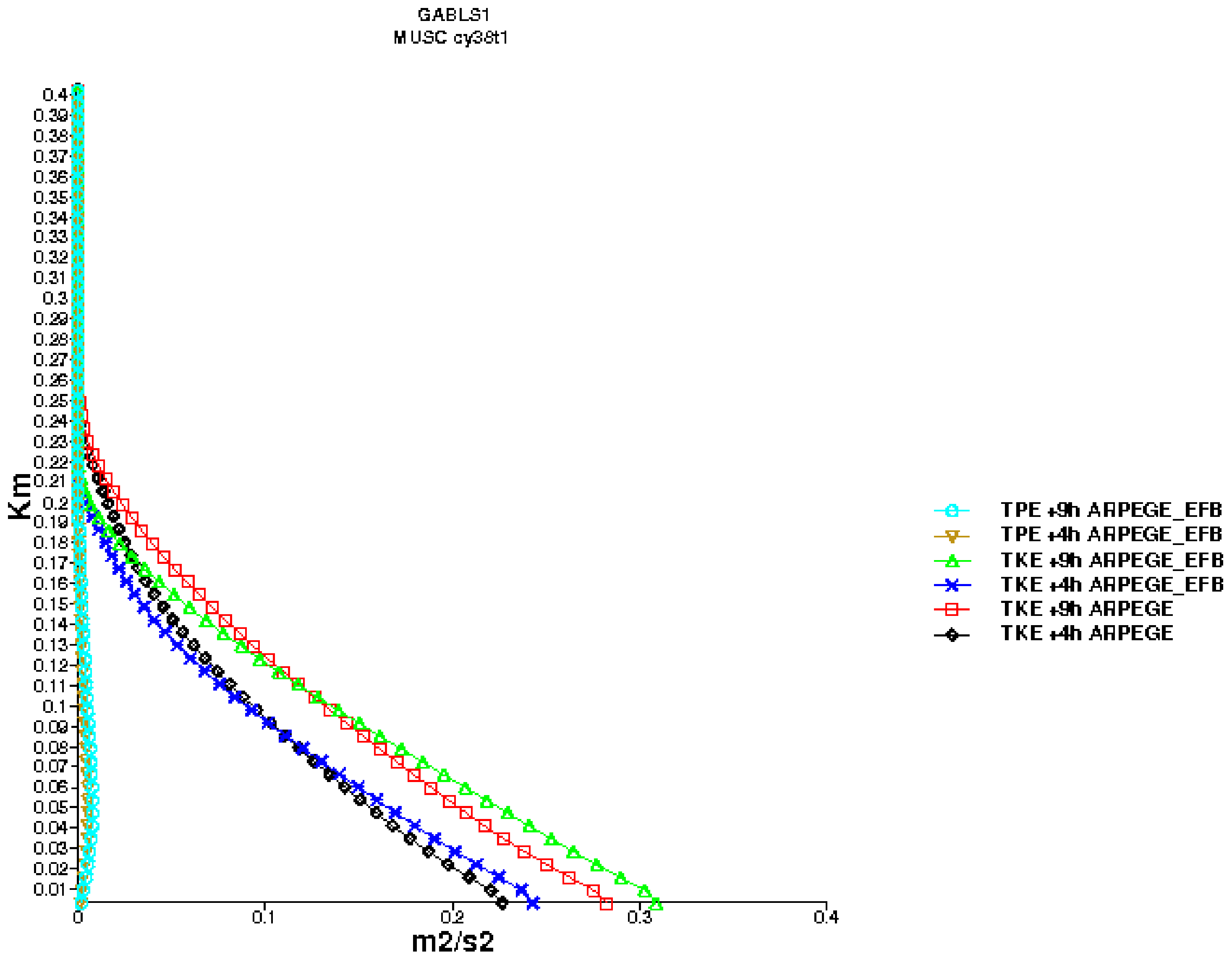
Energy Flux Budget Closure (Zilitinkevitch et al, 2013)

Very preliminary results with the Partial EFB Closure in ARPEGE for GABLS1 but positive ….





Energy Flux Budget Closure (Zilitinkevitch et al, 2013)



Conclusions & Perspectives

- TKE in AROME/ARPEGE is probably underestimated in stable conditions and during the sunset → not enough mixing
- BLLAST datasets can be very useful especially for TKE comparison in parallel with DomeC observations
- Compute advection from AROME (fine scale effect) for a 1D possible experiment
- Evaluate the impact of the EFB Closure in a 1D BLLAST case ?