NetFAM-COST WORKSHOP
Toulouse, 12-14 March 2007

Impact Studies and Validations of Clouds *as simulated by the* **ARPEGE-Climate physics** *with the use of* **3D-GCM, 1D-SCM and 2D-transects.**

P. Marquet / Météo-France. CNRM/GMGEC/EAC

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The Presentation

1) **Description of the new physics : μ-Phys+Precipitation ; Moist-Turbulence ; (Shallow+Deep) Convection .**

2) **Some Applications / Validations : ARPEGE-3D-GCM ; EUROCS-1D-SCM ; (EPCI-GPCI-AMMA)-3D/2D-GCM**

3) **Some recent developments [1D-SCM-RICO] :**

   (a) In the Dry & Moist (C.B.R.) Turb ;

   (b) In the Shallow-Convection *(& Deep)*

4) **Conclusion**

A new Physics … from the Standard (1999)

	STANDARD / V3-V4 IPCC / Diagnostic
TURB	DIAG. Mellor-Yamada $\partial e / \partial t = 0$ moist PDF / Bougeault
Micro-Phys & Précip.	DIAG. Smith / Kessler q_liq / q_ice
"Shallow" Convection	in TURB , but why ? Mass Flux Bougeault ?
"Deep" Convection	Mass Flux / Bougeault Convergence of q_vap
Entraîn. "Top-PBL"	NO

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from the standard … to a new Prognostic one

	STANDARD / V3-V4 IPCC / Diagnostic		TEST Prognostic
TURB	DIAG. Mellor-Yamada $\partial e / \partial t = 0$ moist PDF / Bougeault	from 1997 to 2007 …	PROGN. / C.B.R. $\partial e/\partial t$ = Pr+vDif–Dis moist PDF / Bougeault / Becht.
Micro-Phys & Précip.	DIAG. Smith / Kessler q_liq / q_ice	→	PROGN. Bulk / Lopez q_cloud / q_rain
"Shallow" Convection	in TURB , but why ? Mass Flux Bougeault ?		Mass Flux (w*) CAPE / Gueremy
"Deep" Convection	Mass Flux / Bougeault Convergence of q_vap		Mass Flux (w*) CAPE / Gueremy
Entraîn. "Top-PBL"	NO		YES Grenier & Breth.

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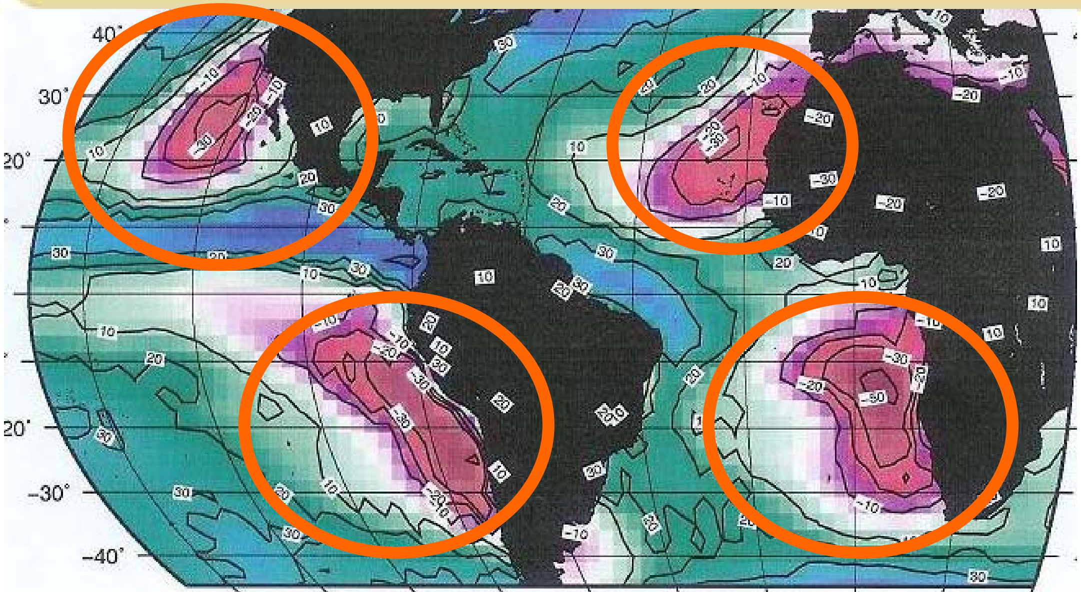
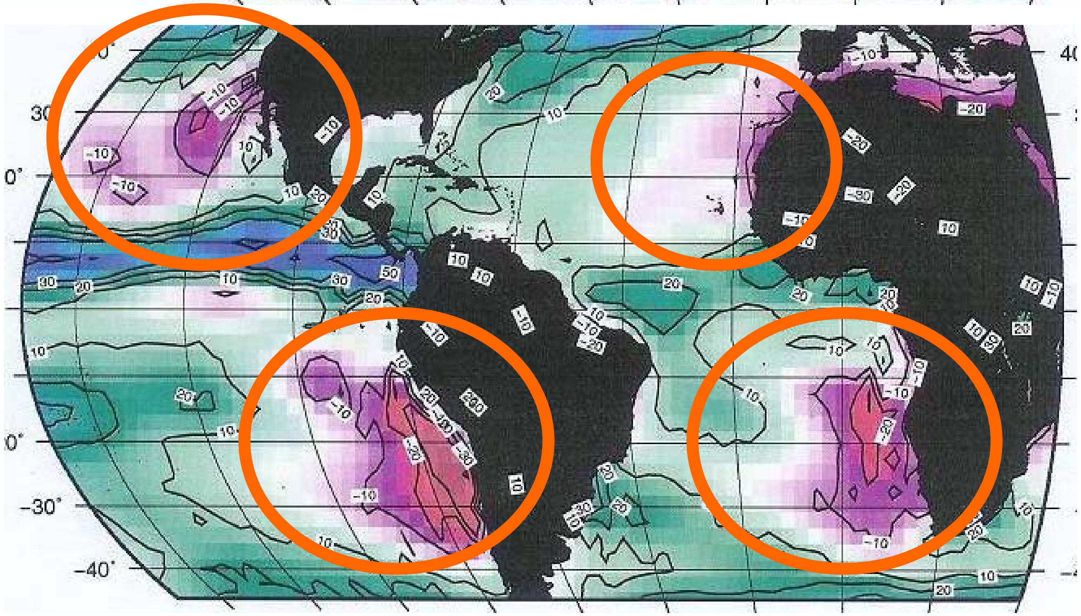
Standard → Progn. … via a Mixed Diag./Prog.

	STANDARD / V3-V4 IPCC / Diagnostic	MIXED Diag+Prog	TEST Prognostic
TURB	DIAG. Mellor-Yamada $\partial e / \partial t = 0$ moist PDF / Bougeault	DIAG. M&Y $\partial e / \partial t = 0$ moist PDF / Bougeault	PROGN. / C.B.R. $\partial e/\partial t$ = Pr+vDif–Dis moist PDF / Bougeault / Becht.
Micro-Phys q_liq / q_ice	DIAG: Smith / Kessler q_liq / q_ice	semi-PROGN: Bulk / Lopez q_cloud / q_rain	PROGN:
? ougeault ?	Mass Flux (w*) CAPE / Gueremy	Mass Flux (w*) CAPE / Gueremy	
ult of q_vap	Mass Flux (w*) CAPE / Gueremy	Mass Flux (w*) CAPE / Gueremy	
my	Grenier & Breth.	Grenier & Breth.	

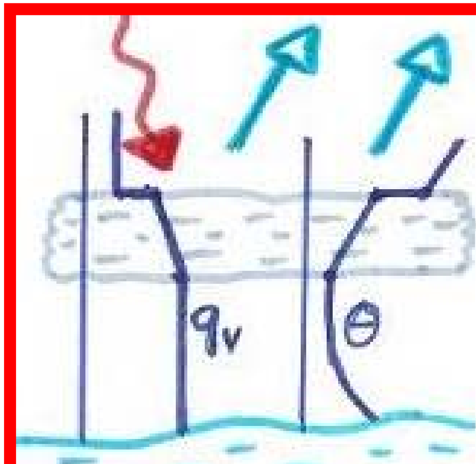
The prog. physics (4.6) : ***some best ocean Sc ...***



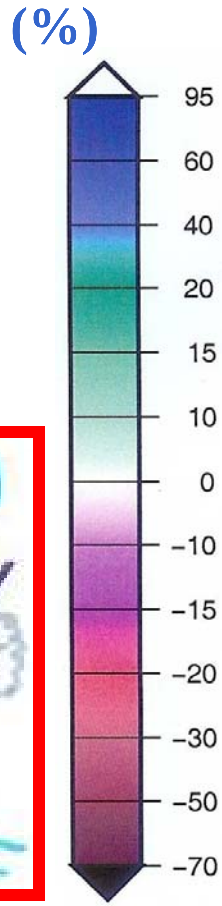


N_low / ISCCP
(DJF+JJA)/2

Strato Cu
<- STAND.

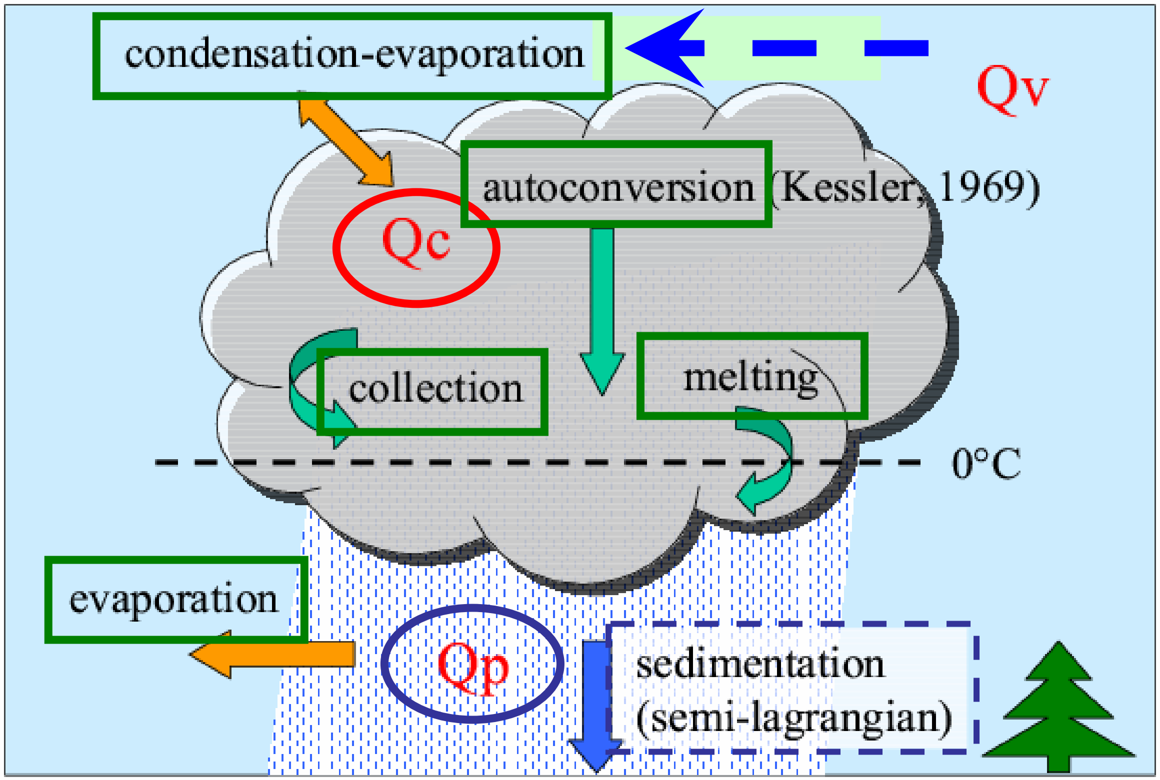


Strato Cu
<- PROG.



The Bulk μ-Phys + Precip. : Diag. -> Pron. (Kessler)

- Work of P. Lopez (2002) ; CNRM/GMME ; F&R (1996)
- Suitable for the variational assimilation (Precip / Clouds)
- ***ARP-GCM*** : 2 prognostic variables : ***q_cloud*** & ***q_precip***
- A Semi-Lagrangien treatment of the falling of precip.



: ***no time-stepping*** !

(even with dt=1800 s)

(Lopez, 2002)

Link with moist CBR-TKE

Bulk μ-Phys

No link with convection…

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A moist prognostic TKE : C.B.R. + BL89

TKE-C.B.R. (2000) + B.L. (1989) + Bougeault (1982) / Bechtold (1995)

with : PCI <-> GCM <-> SCM

≈ TURB-1D
Meso-NH
& AROME

$$\frac{\partial \overline{e}}{\partial t} = \overbrace{-\left[\left(\overline{w'u'}\right)\frac{\partial \overline{u}}{\partial z} + \left(\overline{w'v'}\right)\frac{\partial \overline{v}}{\partial z}\right]}^{\text{Prod/dyn.}} + \overbrace{\frac{g}{\overline{\theta_{vl}}}\,\overline{w'\theta'_{vl}}}^{\text{Prod/ther.}}$$

$$\underbrace{-\frac{1}{\rho}\frac{\partial}{\partial z}\left(\rho\,\overline{w'e'}\right)}_{\text{Diffus./vert.}} \underbrace{-\,C_e\frac{(\overline{e})^{3/2}}{L_d}}_{\text{Dissipation}} + \underbrace{\text{Advections}}_{=0}$$

$$\overline{w'\theta'_{vl}} = f\left[\,\overline{w'\theta'_l}\;;\;\overline{w'q_t'}\;;\;F_2(Q_1) * \lambda_3(Q_1)\right]$$

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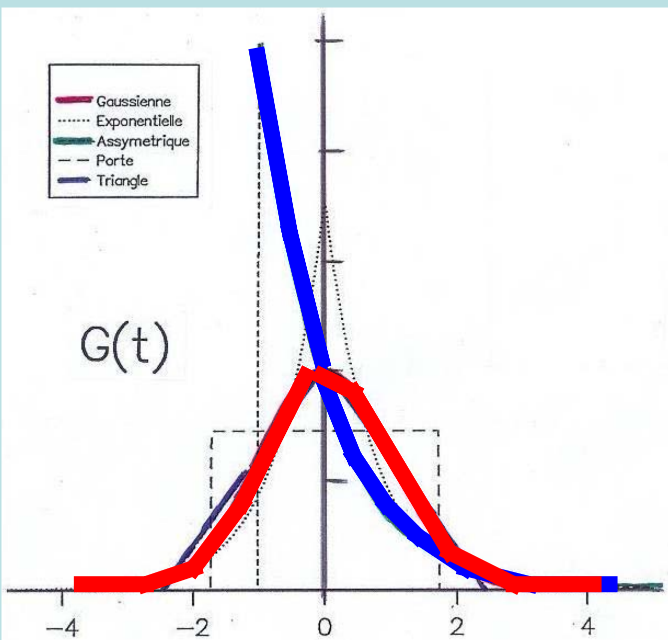
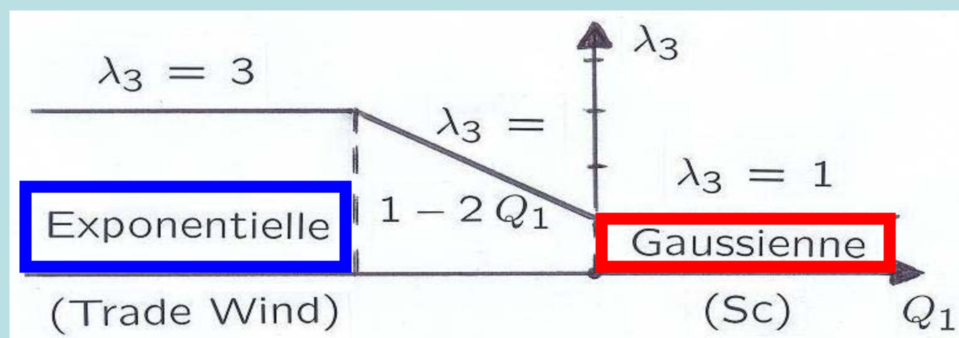
A moist prognostic TKE

TKE-C.B.R. (2000) + B.L. (1989)
+ Bougeault (1982) / Bechtold (1995)

Mixed Exp. & Gauss pdf



		Exponentielle	Gaussienne
	$G(t)$	$H(t+1)\, e^{-(t+1)}$	$\frac{1}{\sqrt{2\Pi}} e^{-t^2/2}$
F0	N	$Q_1 \leqslant 1 \quad e^{Q_1-1}$ $Q_1 > 1 \quad 1$	$\frac{1}{2}\left(1 + \text{erf}\, \frac{Q_1}{\sqrt{2}}\right)$
F1	$\frac{\overline{q_l}}{\sigma_s}$	$Q_1 \leqslant 1 \quad e^{Q_1-1}$ $Q_1 > 1 \quad Q_1$	$NQ_1 + \frac{e^{-Q_1^2/2}}{\sqrt{2\Pi}}$
F2	$\frac{\overline{sq_l'}}{\sigma_s^2}$	$Q_1 \leqslant 1 \quad (2 - Q_1)\, e^{Q_1-1}$ $Q_1 > 1 \quad 1$	$\frac{1}{2}\left(1 + \text{erf}\, \frac{Q_1}{\sqrt{2}}\right)$



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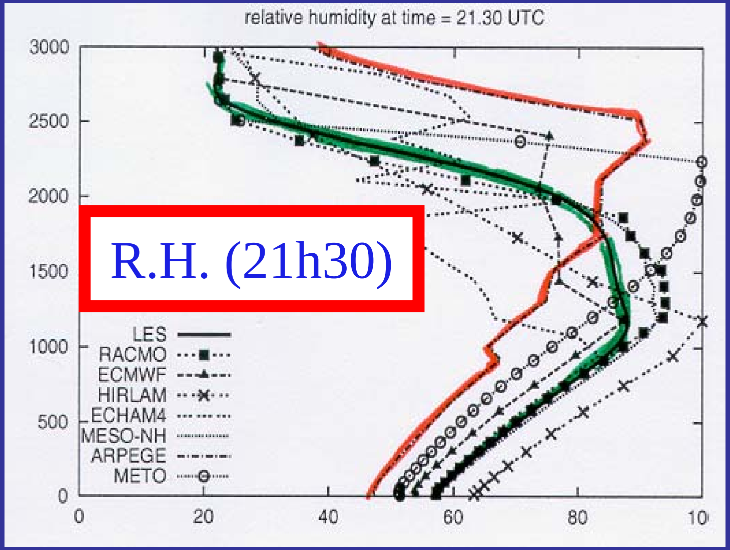
Prog. Phys : 1D SCM / EUROCS (2000-2002)

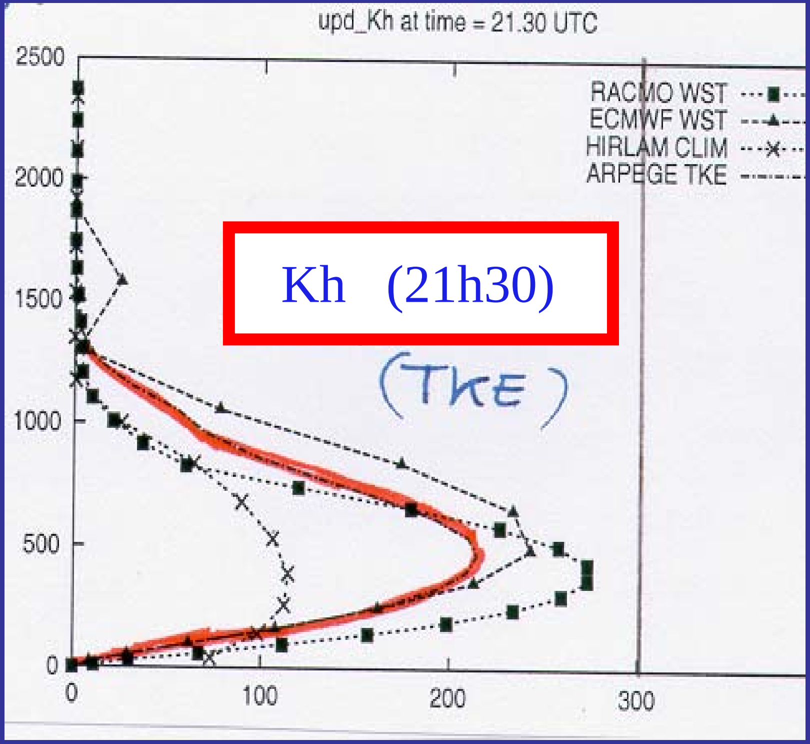
ARM-Cumulus (Lenderink) case

(Δz = 20/100m ; Δt = 5 mn) :

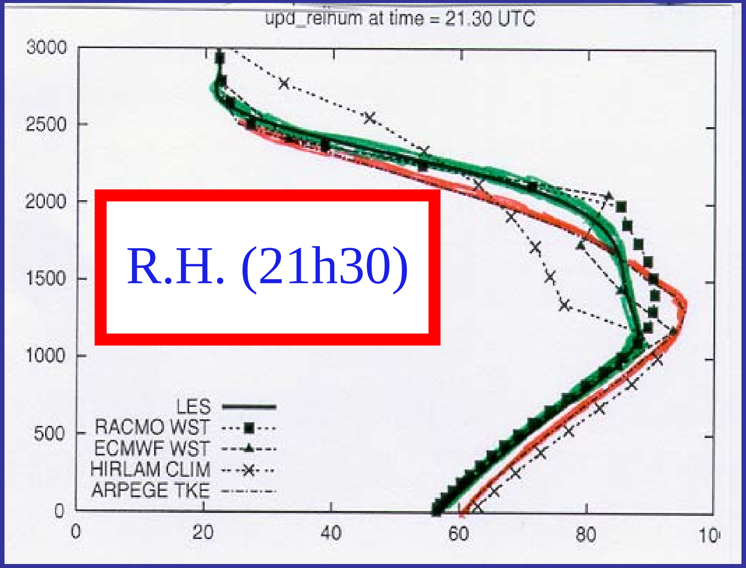
Lopez+TKE-CBR ***+ CV/Bechtold***

M.&Y. Diag.TKE >

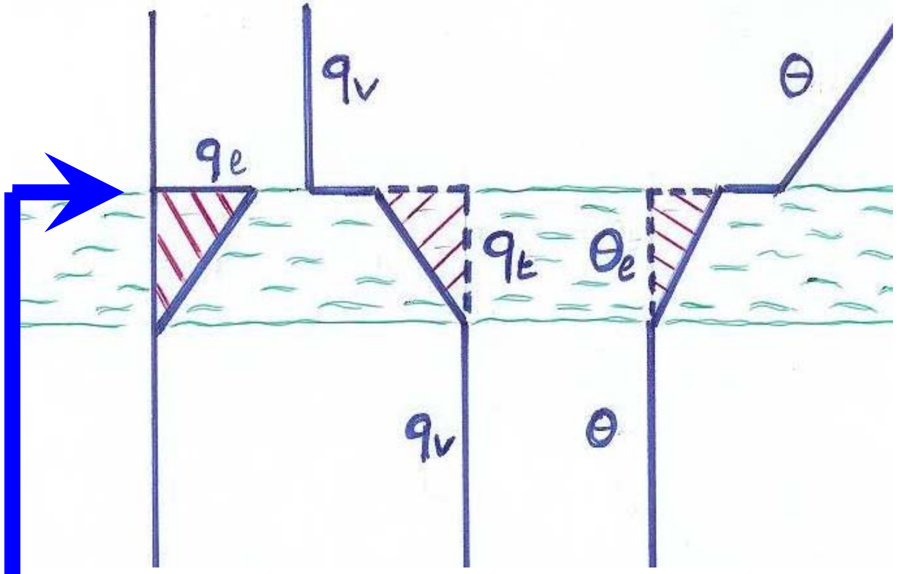




< Prog. CBR TKE >



The Top-PBL-entrainment



Vertical Diffusion of the Betts variables : θ_l and q_t

Grenier (ARPEGE)

$$\langle e \rangle = z_i^{-1} \int_0^{z_i} e(z)dz$$

$$K_{\mathrm{inversion}} \sim AL\langle e \rangle^{1/2} \frac{\langle e \rangle}{N_i^2 L^2}$$

$$A = A_1 \left(1 + A_2 \frac{Lq_l}{C_p \Delta\theta_{vl}}\right)$$

($A_1 = 0.16$)

($A_2 = 0.0$)

A Shallow + Deep Convection

The Gueremy schemes (one subroutine) ; in some words :

- Mass-Flux scheme $M = -\alpha \sigma \omega_c$ $\frac{\partial M}{\partial p} = D - E$
- Based on the boyancy and « ω_c » ➔ dry thermals
- « ω_c » is first computed from :

$$\frac{\partial \omega_c}{\partial t} = -\frac{1}{2}\frac{\partial \omega_c^2}{\partial p} - \frac{\rho g^2}{(1+\gamma)}\frac{(T_{vc} - \bar{T}_v)}{\bar{T}_v} + \left(\frac{\varepsilon_t}{\rho} + \varepsilon_o + K_d\right)\omega_c^2$$

- then « σ » (the conv. frac. area)

$$\frac{1}{\sigma\omega_c}\frac{\partial \sigma\omega_c}{\partial p} = \delta_o - \varepsilon_o$$

+ CAPE

$$\left(\frac{\partial CAPE}{\partial t}\right)_c = -\frac{CAPE}{\tau}$$

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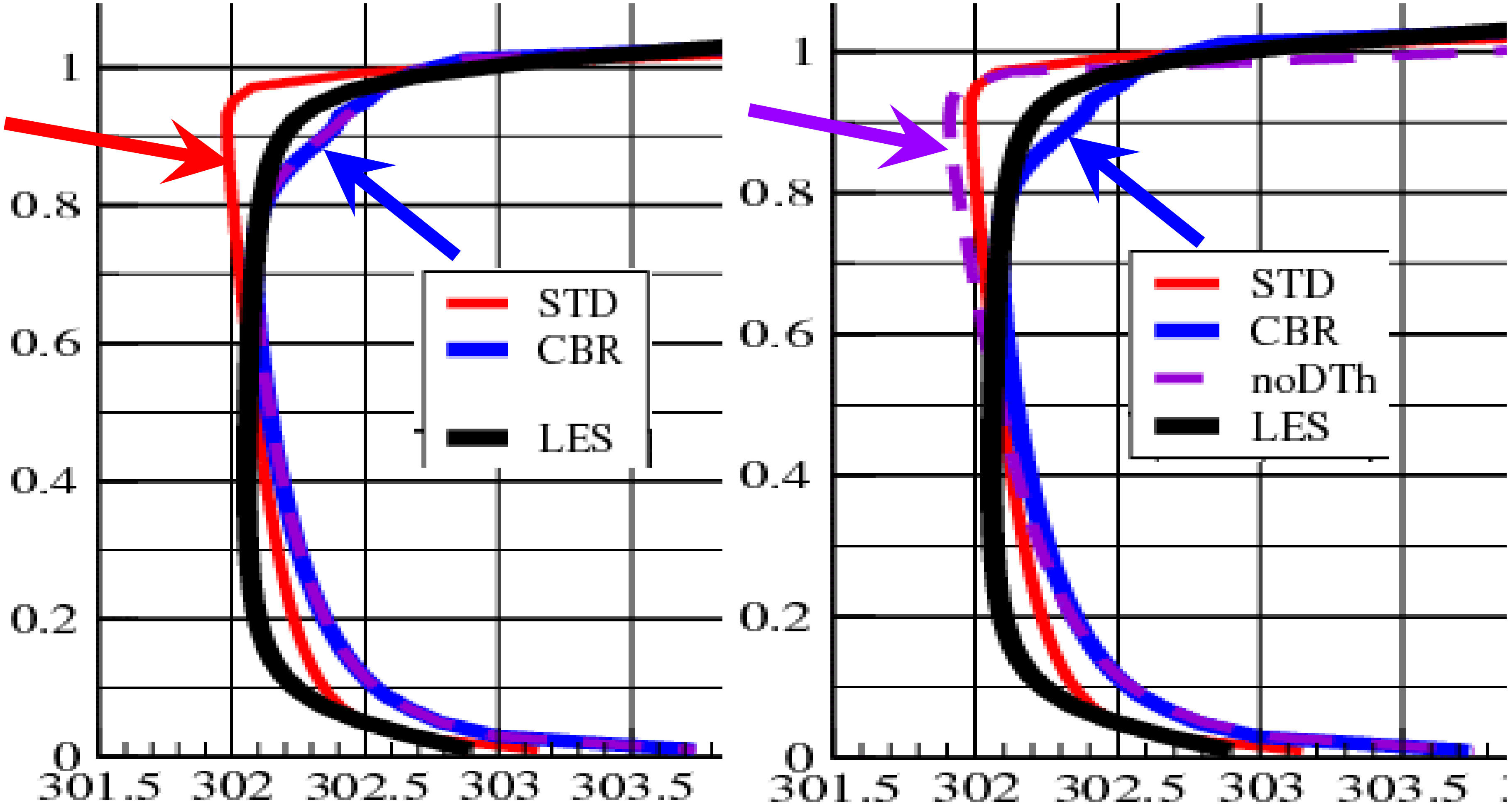
Impact of “thermals” : 1D-SCM Ayotte case “24SC” L96 for θ



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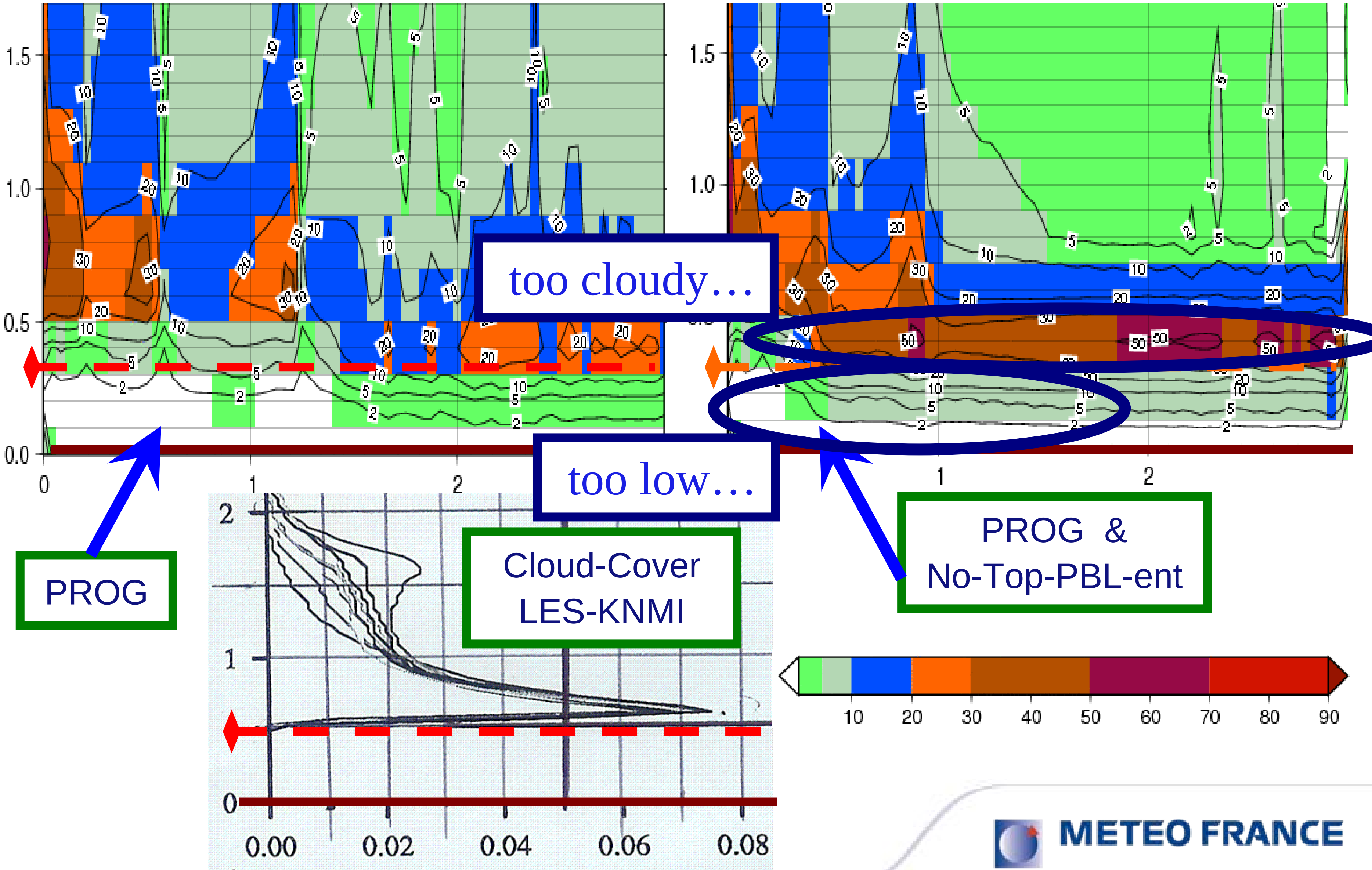
RICO-1 ***L31*** (idem GCM) : *Top-PBL-entrainment*



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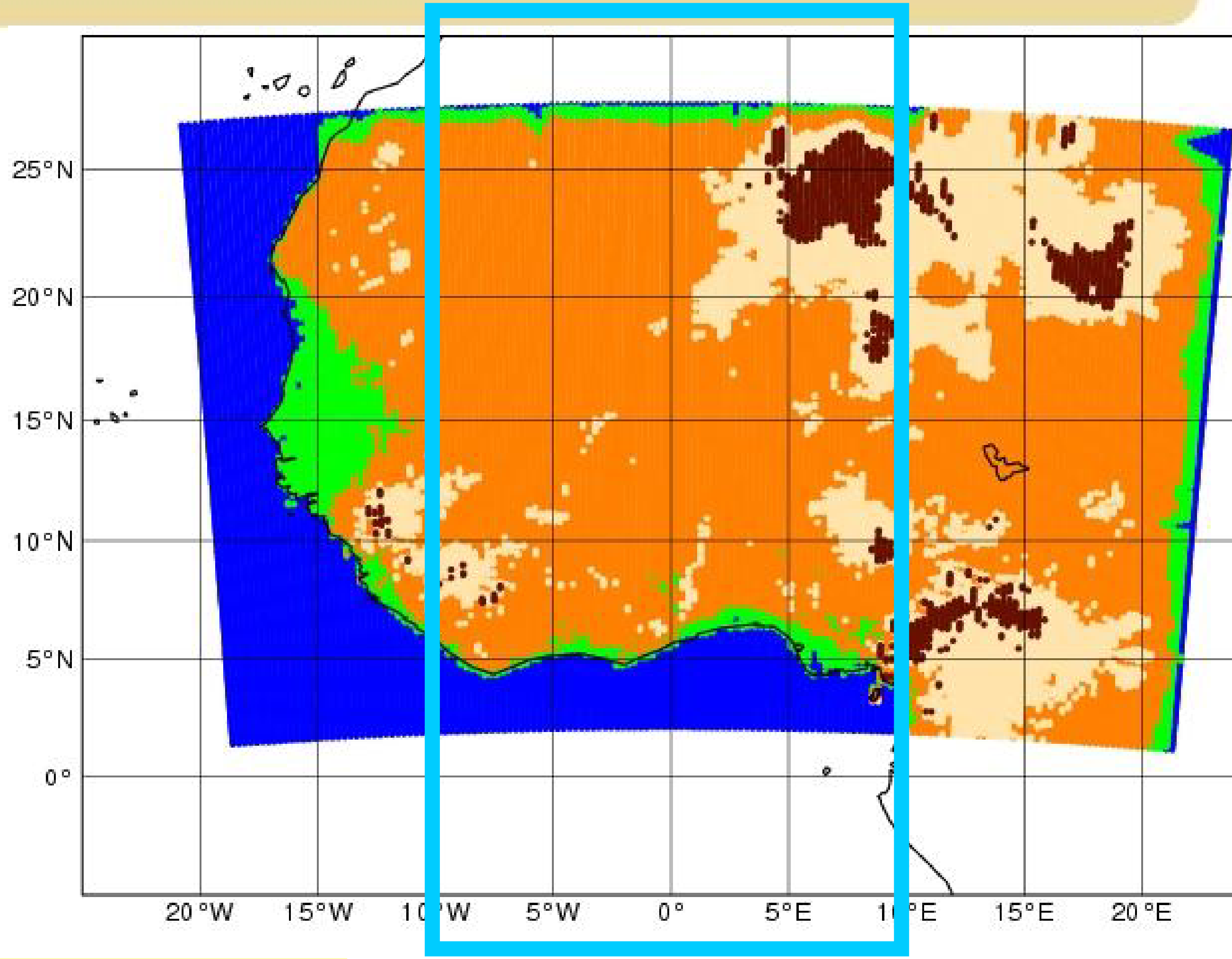
The GCM-AMMA transect (L31) : *Top-PBL-entrainment ?*

CROSS :
20S-40N
Average over :
10W-10E

MAP2D : all the points within :
10S-30N
35W-30E



AMMA = African Monsoon Multidisciplinary Analysis

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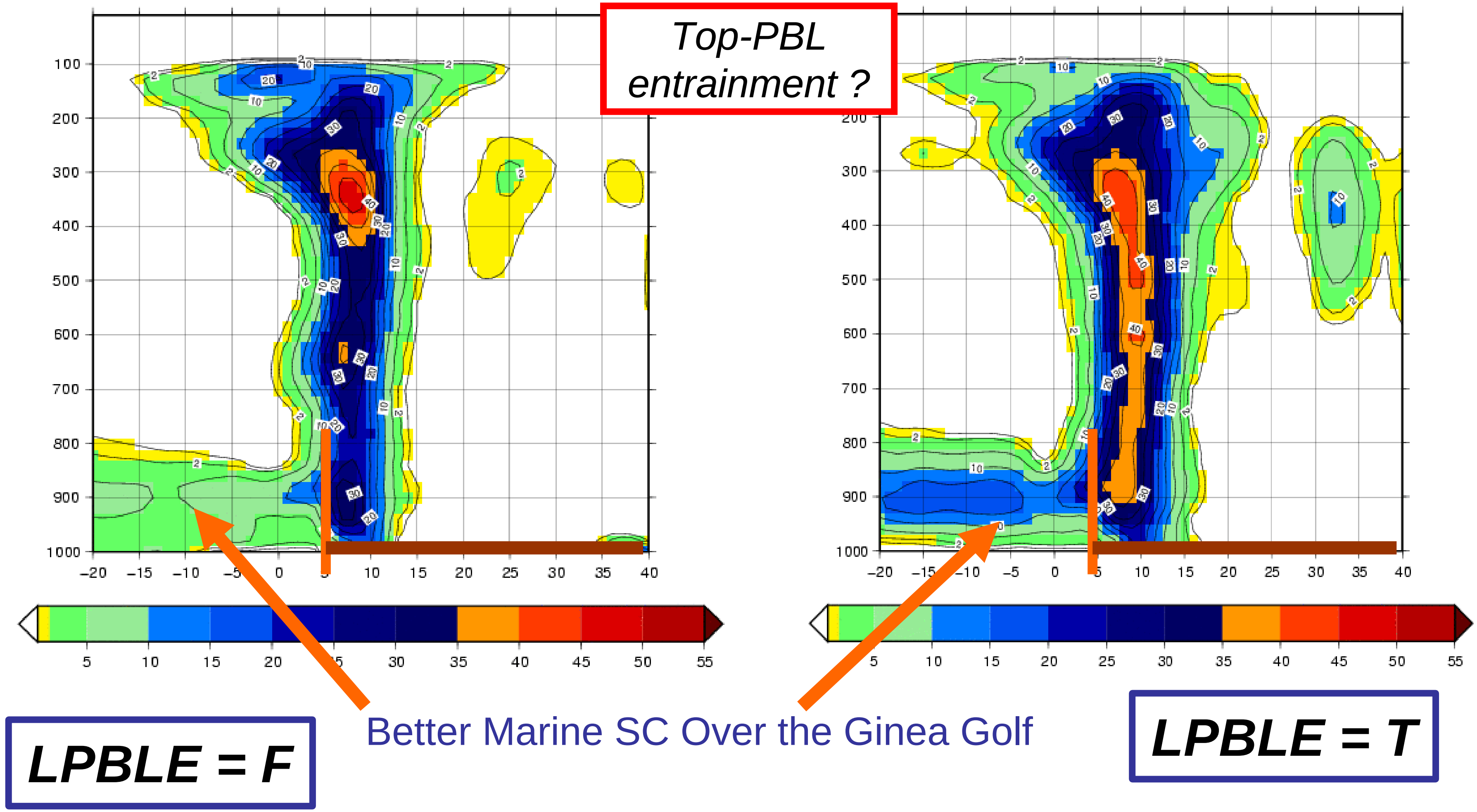
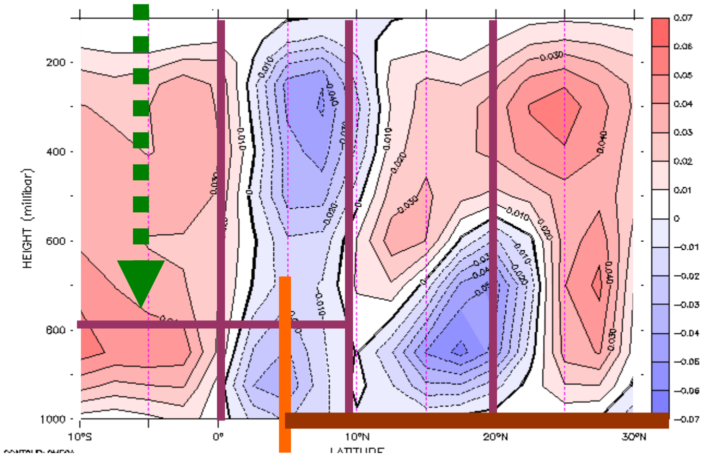
GCM-AMMA transect L31 (10W-20E) 2000-06 : Cloud Cover

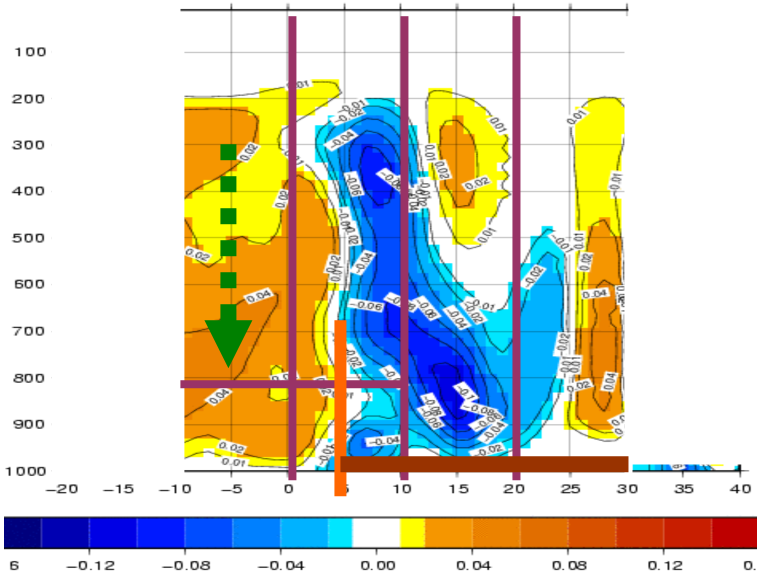


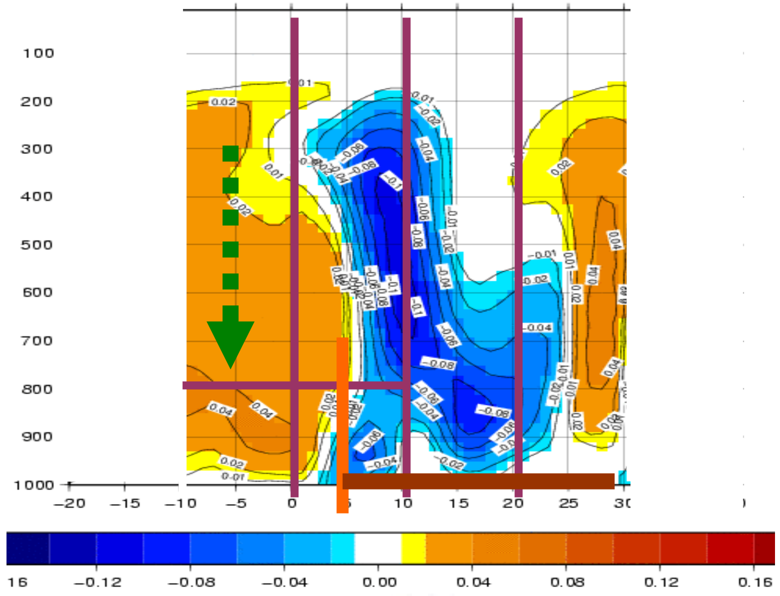
GCM-AMMA transect L31 (10W-20E) 2000-06 : ω (Pa/s)

2000-06
NMC
Reanalyses :



Top-PBL entrainment ?





PROG / LPBLE=.F.

LPBLE=.TRUE.

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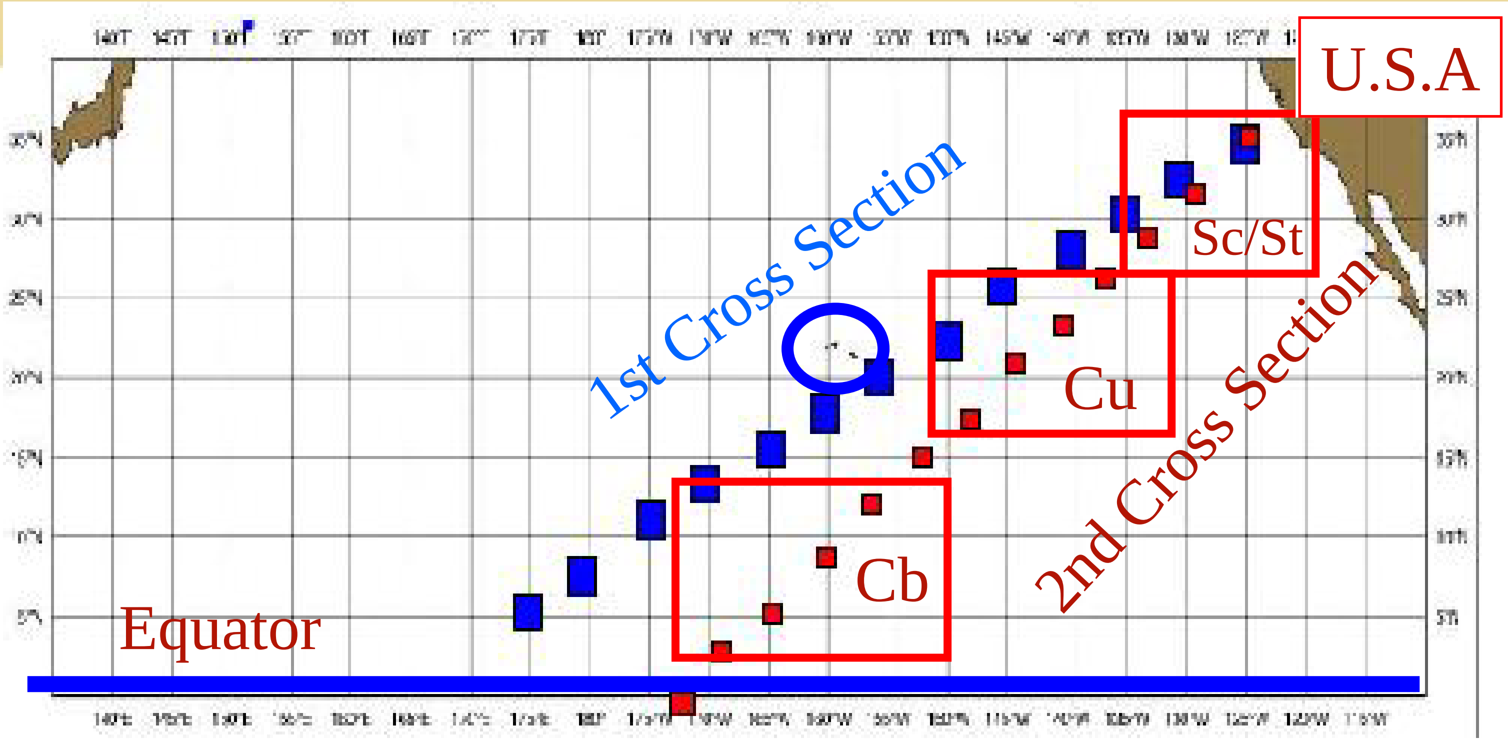
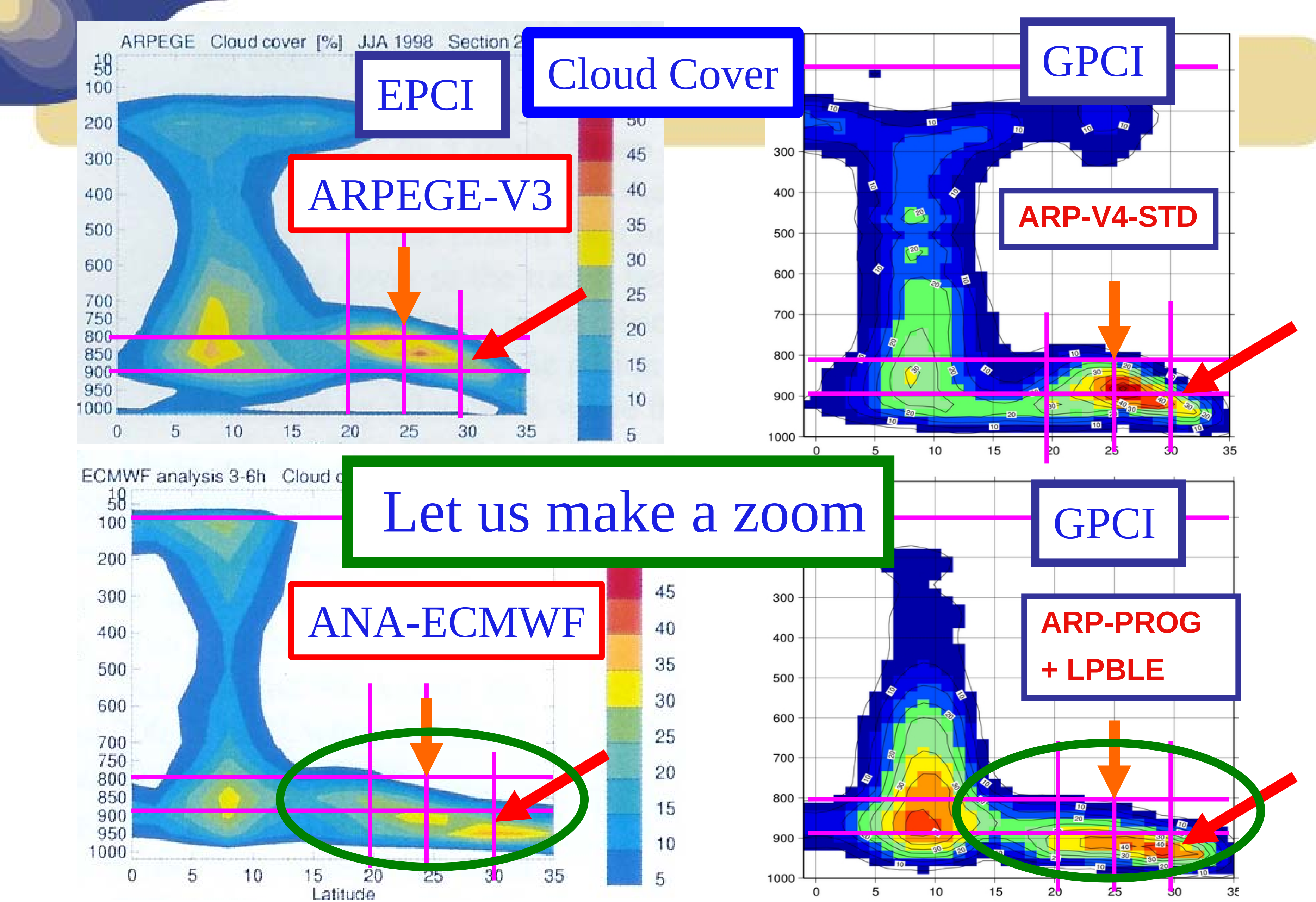
GPCI = Gewex Pacific Cross-section Intercomparison (L31)



GCM runs Arpege / V4.5 : 2 years : 1998 and 2003

10 days of spin-up in June (lost) + JJA every 3 h

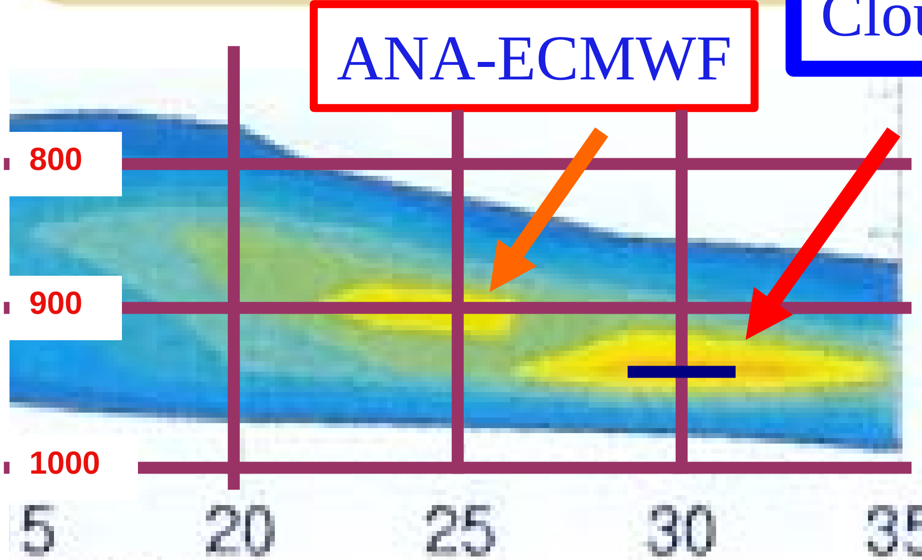
Impact / Validation of LPBLE : Top PBL Entrainment ?

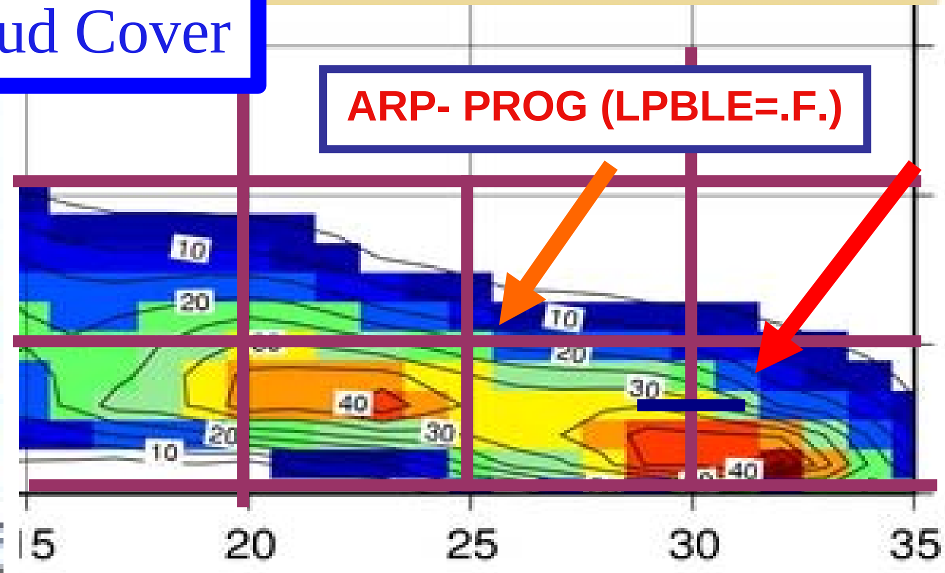


GPCI = Gewex Pacific Cross-section Intercomparison L31

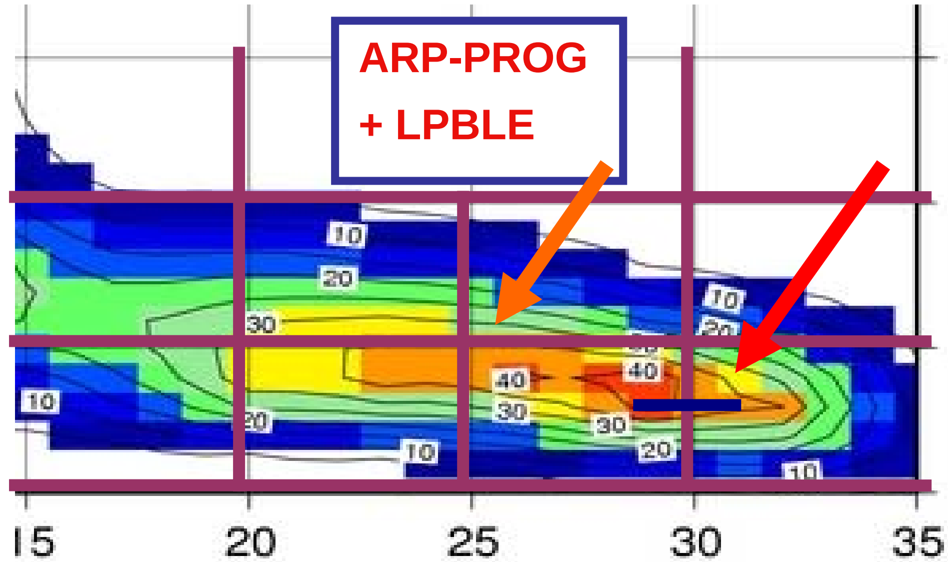
GPCI = Gewex Pacific Cross-section Intercomparison L31

Cloud Cover





More realistic results
with PROG. + ***LPBLE***



The new “RICO-2” 1D-SCM inter-comp.(L80+L31)

PROG-1 (2006-06) → PROG-2 (2007-02) :

which modifications ?

TURB / a new limitation for ϕ_3 : 2.2 → 1.5 ;

TURB / vertical diffusion for Betts (θ_l , q_t) but apply on Dry (θ , q_v) ;

TURB / for lowest level : $N_c = q_c = 0$ if Instable ;

Convection / from $\omega_{N-1} = 0$ to : $\omega_{N-1} = -\rho\, g\, (2/3\ TKE)^{1/2}$;

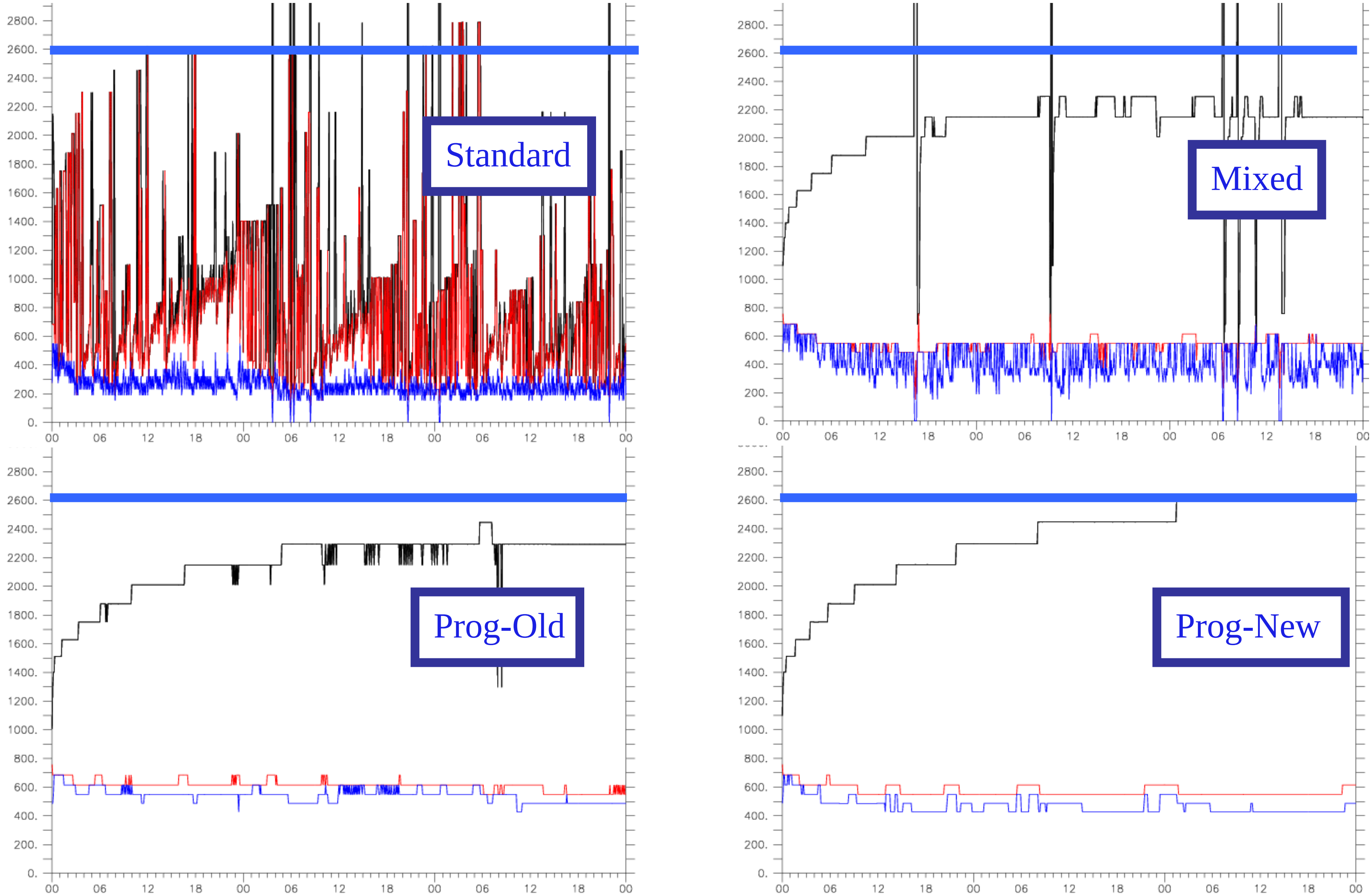
Convection / smoother comput. for M.F. and $\omega(p)$ from $\omega^{-2}\partial\omega^2/\partial p = \ldots$;

Convection / limitations for σ (Norm. Frac. Conv. Area) : $0.4 < \sigma$;

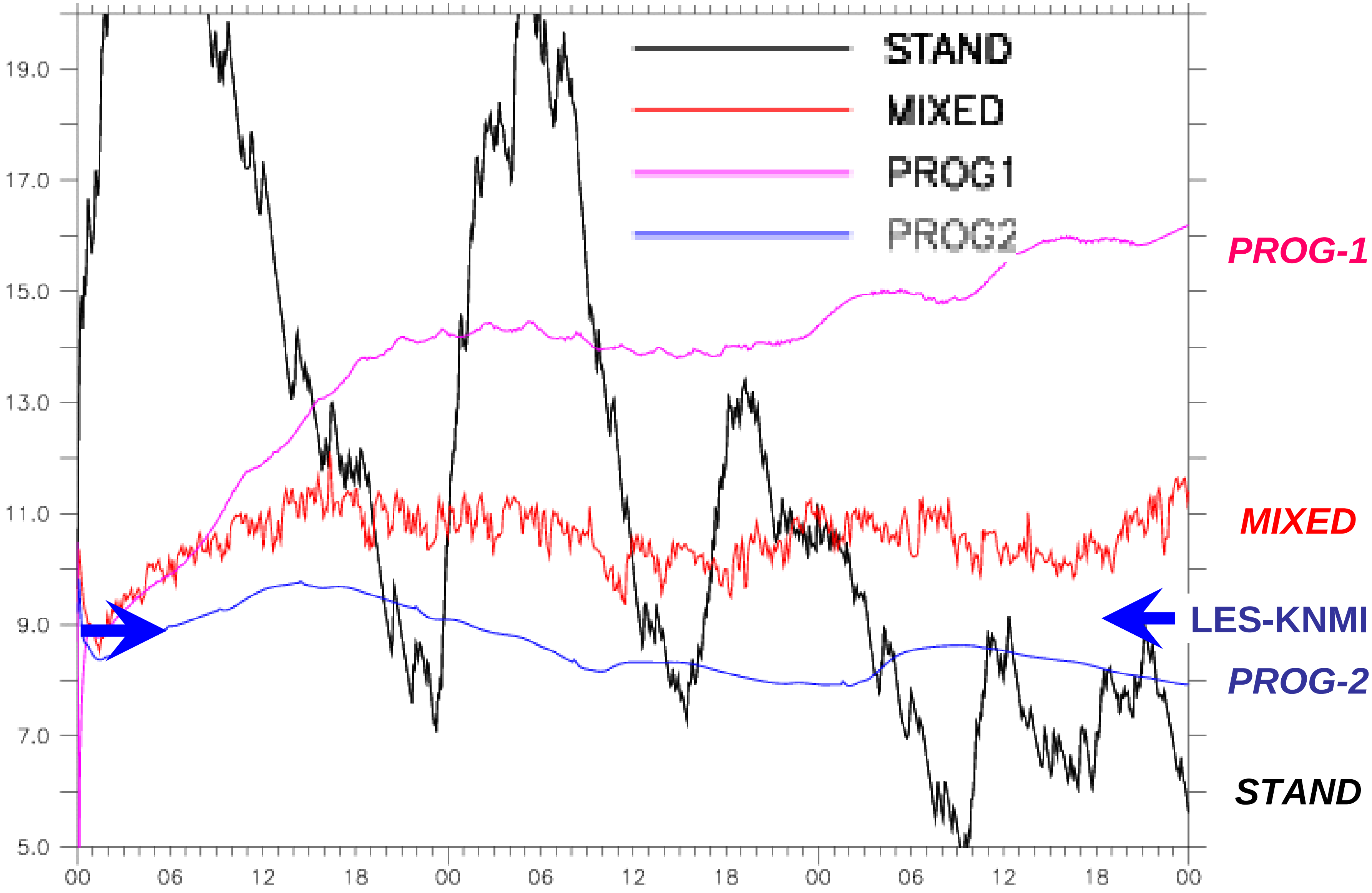
Convection / tunings for the forcing $(\Delta x)^2$ → $\partial(CAPE)/\partial t = \ldots$

Convection / tunings for the Gregory & Kershaw : 0.7 → 0.2 ;

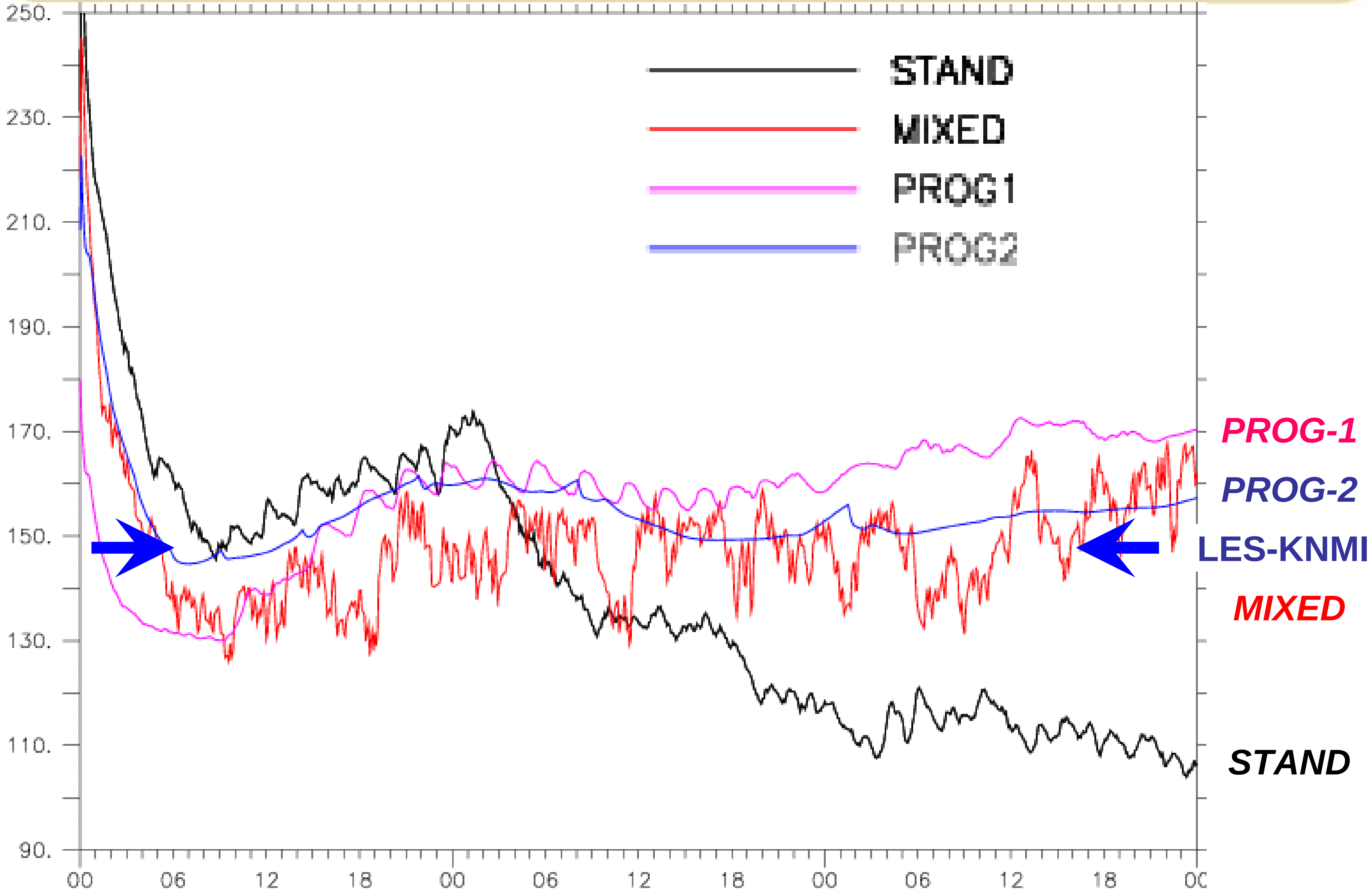
“RICO-2” (ARP-L80) : Cloud Heights (m)



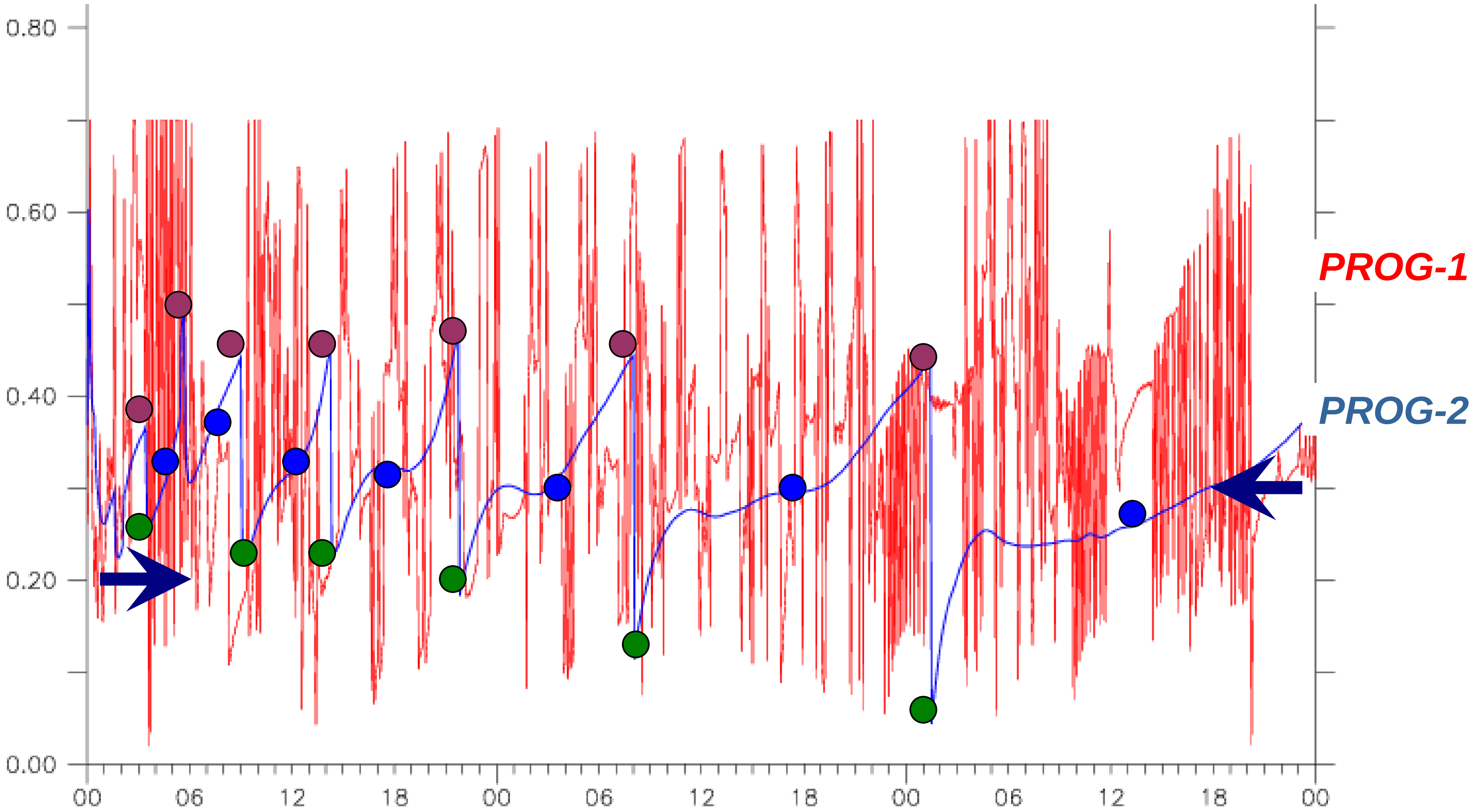
"RICO-2" (ARP-L80) : SH Flux (W/m2)



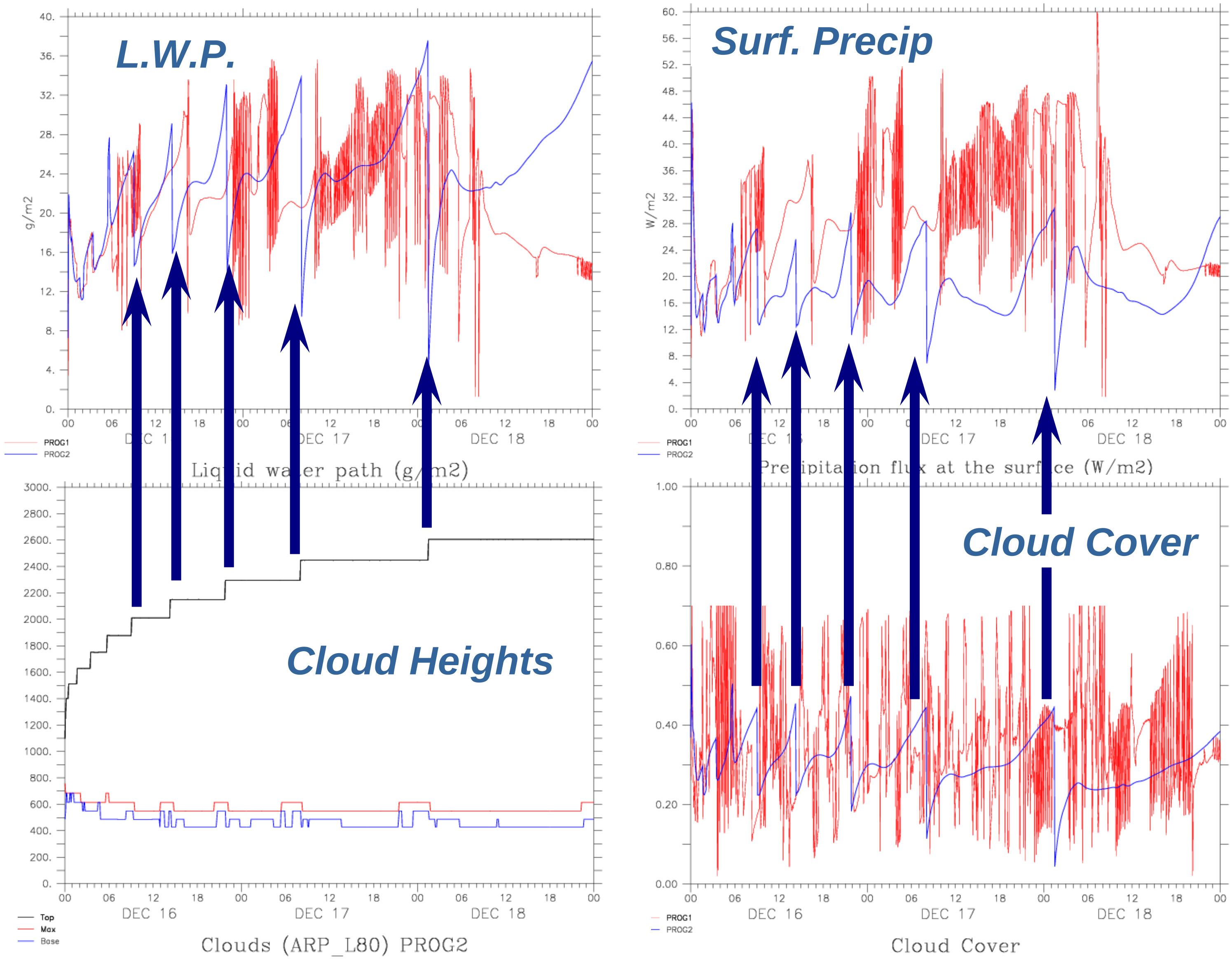
"RICO-2" (ARP-L80) : LH Flux (W/m2)



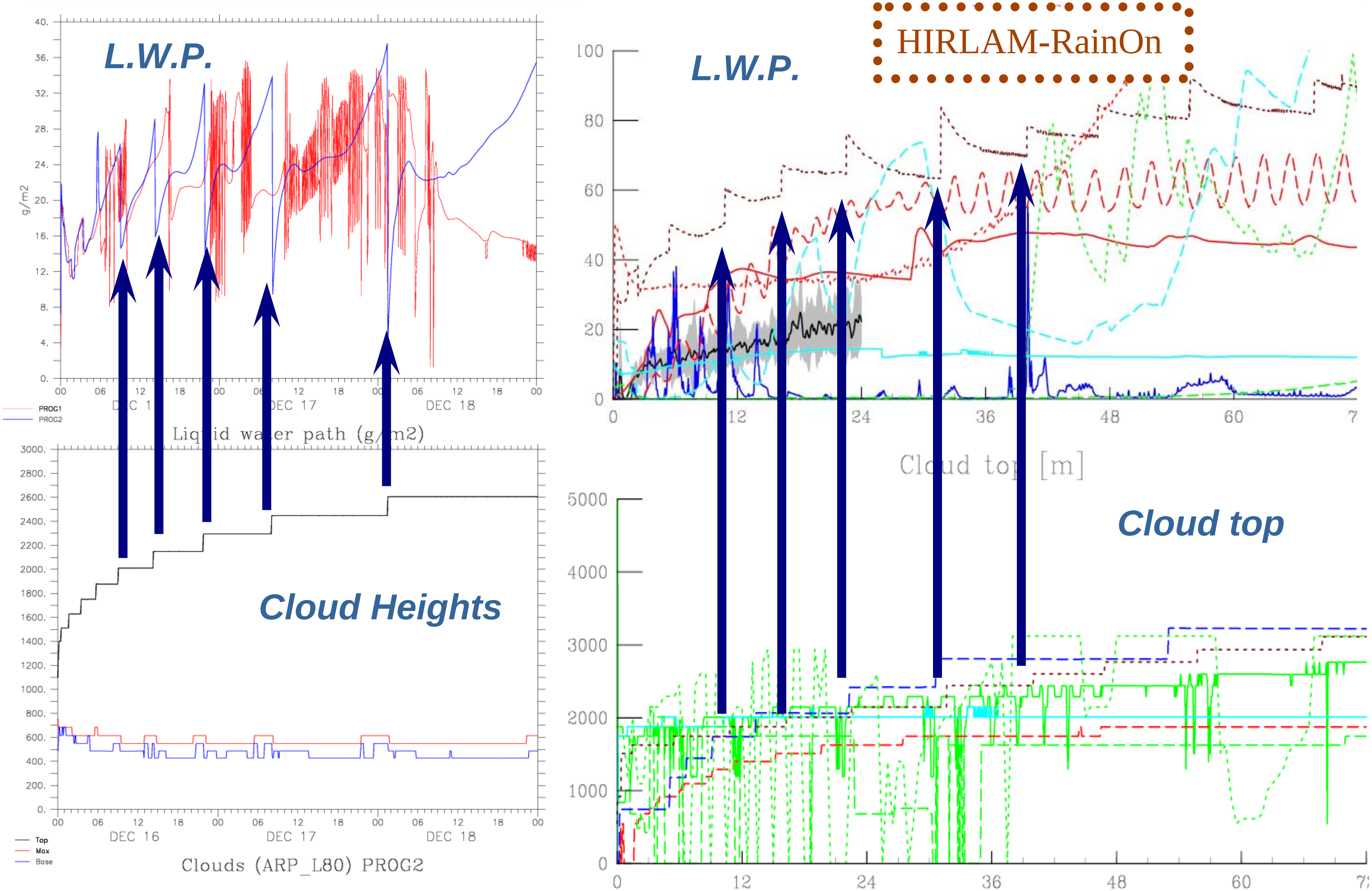
“RICO-2” (ARP-L80) : Cloud Cover (0-1)



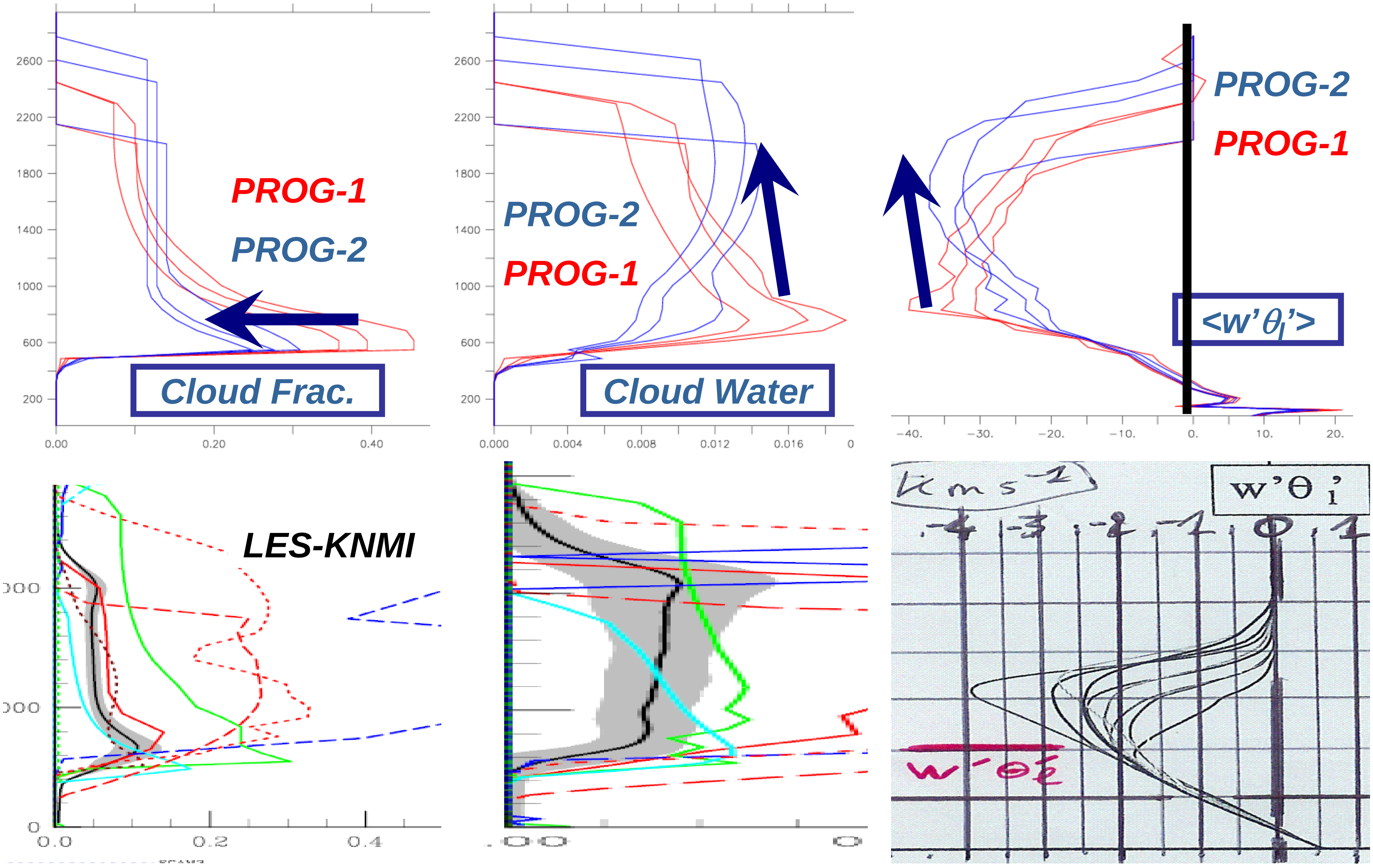
“RICO-2” (ARP-L80) : low-freq. oscillations ?



“RICO-2” (ARP-L80) : low-freq. oscillations ?



"RICO-2" (ARP-L80) : profiles (12h/36h/60h)



Conclusions (1/2) : *The Prognostic Physics ?*

→ *There are positive 3D impacts : enhanced ocean Sc*

→ *But still problems : wind bias ; global budget ; …*

→ **Lopez Bulk-scheme =** *already in ARP-PNT ; and even improved !*

→ **The moist CBR-TKE :** *in test in ARP-PNT (with other convections)*

→ ∃ **Several Shallow & Deep convections :** *Bechtold ; Bougeault ; Gueremy ; EDMF (Pergaud, Suares) ; Tiedke ; Emmanuel ; … ??*

→ **And other possible improvements :** *convection (detrain. / down.) → bulk μ–phys (ALARO) ? Tuning of the moist-Turb. "pdf" ?*

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Conclusions (2/2) : GCM/RCM applications !

OK if better SCM or CRM Shallow Conv. schemes exist …

But for NWP (GLOBAL/LAM) and GCM/RCM :

- → *ΔT >> 30 s ! (say from 200 s to 1800 s …)*
- → *Δz >> 100 m ! (say from 200 s to 500 m …)*
- → *The dynamics ! (3D interactions with Physics)*
- → *Hor. : form Equator to Poles ! (not only one CRM ; not a few SCM)*
- → *Vert. : Surface ←→ Stratosphere ←→ Mesosphere !*
- → *Winter time Jet : instabilities ? (High mountains…)*
- → *… internal secrets of parameterizations : “ugly” numericals …*

Thanks for your attention ! Questions ?

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The end

A moist prognostic TKE

TKE-C.B.R. (2000) + B.L. (1989)
+ Bougeault (1982) */ Bechtold (1995)*

The Liquid Betts' variables are

$$\theta_l = \theta - \frac{L}{c_p}\frac{\theta}{T} q_l \quad \leftrightarrow \quad T_l = T - \frac{L}{c_p} q_l$$
$$q_{tot} = q_v + q_l$$

The "saturation deficit" (of q_c, at T_l) is

$$\Delta(q_l) = q_{tot} - q_{sat}(T_l)$$

Let us introduce

$$a = \left[1 + \frac{L}{c_p}\left(\frac{\partial q_{sat}}{\partial T}\right)(T_l)\right]^{-1}$$
$$\alpha_1 = \frac{T}{\theta}\left(\frac{\partial q_{sat}}{\partial T}\right)(T_l)$$

Let us introduce the so-called variable "s"

$$s = \frac{a}{2}\left(q_{tot} - \alpha_1\,\theta_l\right)$$

Then $q_l = a\,\Delta(q_l) + 2\,s$

The standard deviation of "s" is $\sigma_s = \sqrt{\overline{s'^2}}$

$$\sigma_s = \sqrt{\frac{a}{2}\left[\overline{(q'_{tot})^2} - 2\,\alpha_1\,\overline{(\theta'_l\,q'_{tot})} + (\alpha_1)^2\overline{(\theta'_l)^2}\right]}$$

The "normalized saturation deficit" Q_1 is

$$Q_1 = \frac{a\,\Delta(q_l)}{2\,\sigma_s}$$

Express everything in terms of θ_l and q_{tot} ?

For q_l, an hypothesis (Bougeault, 1982)

$$\overline{w'q'_l} = \overline{w's'}\left[\frac{\overline{s'q'_l}}{(\sigma_s)^2}\right]$$
$$s' = \frac{a}{2}\left(q'_{tot} - \alpha_1\,\theta'_l\right)$$
$$F_2(Q_1) = \frac{\overline{s'q'_l}}{2\,(\sigma_s)^2}$$

$$(N)_{Strat} = F_0(Q_1) = \int_{-Q_1}^{+\infty} G(t)\,dt$$
$$\frac{(q_c)_{Strat}}{2\,\sigma_s} = F_1(Q_1) = \int_{-Q_1}^{+\infty} (Q_1 + t)\,G(t)\,dt$$
$$\frac{\overline{s'q'_l}}{2\,(\sigma_s)^2} = F_2(Q_1) = \int_{-Q_1}^{+\infty} t\,(Q_1 + t)\,G(t)\,dt$$

"RICO-2" (ARP-L80) : Cloud Cover (0-1)