Impacts of changes in:
(1) the conservation of “pseudo-enthalpy” (Arpege/Alaro)
(2) the turbulent mixing length (Arpege/Arome)

By **Pascal Marquet** (Météo-France / DESR / CNRM / GMAP)
with **Yves Bouteloup, Eric Bazile, Yann Seity,**
and **Jean-François Gueremy**

ACCORD Workshop, Toulouse (15th April, 2021)

Outline

1) The conservation of “Pseudo-enthalpy”: a need to set “ZDEC=0” in CPUTQY

2) Impacts of “ZDEC=0” in CPUTQY

3) A new way to compute the mixing length “L” in “ACBL89” and “BL89”

4) Impacts of the new “L” in “ACBL89” + “BL89”

5) Conclusions

Equations for: (1) ***kinetic*** energy, (2) ***potential*** energy, and (3) "***Cp T***"

(1): $K = (u^2 + v^2)/2$

(2): $\phi = g\,z$

(3): $c_p\,T$

$$c_p = q_d\,c_{pd} + q_v\,c_{pv} + q_l\,c_l + q_i\,c_i$$

$$\frac{dK}{dt} = -\vec{v}\,.\,\vec{\nabla}_\eta(\phi) - \frac{R\,T}{p}\,\vec{v}\,.\,\vec{\nabla}_\eta(p) - D_K$$

$$\frac{d\phi}{dt} = \left.\frac{\partial\phi}{\partial t}\right|_\eta + \vec{v}\,.\,\vec{\nabla}_\eta(\phi) + \dot{\eta}\,\frac{\partial\phi}{\partial\eta}$$

$$\frac{d(c_p\,T)}{dt} = \frac{1}{\rho}\,\left.\frac{\partial p}{\partial t}\right|_\eta + \frac{R\,T}{p}\,\vec{v}\,.\,\vec{\nabla}_\eta(p) - \dot{\eta}\,\frac{\partial\phi}{\partial\eta} + G_{cpT}$$

Changes in K

Changes in $c_p\,T$

(1) + (2) + (3):

"$c_p\,T + K + \phi$"

The "pseudo-enthalpy"

$$\frac{d(c_p\,T + K + \phi)}{dt} = \frac{1}{\rho}\,\left.\frac{\partial p}{\partial t}\right|_\eta + \left.\frac{\partial\phi}{\partial t}\right|_\eta + G_{cpT} - D_K$$

Equations for the "pseudo-enthalpy": **physical tendencies**?

(neglected or =0...)

Changes in $c_p\,T$

Changes in K

$$\text{“}c_p\,T + K + \phi\text{”} \qquad \frac{d(c_p\,T + K + \phi)}{dt} = \frac{1}{\rho}\left.\frac{\partial p}{\partial t}\right|_{\eta} + \left.\frac{\partial \phi}{\partial t}\right|_{\eta} + G_{cpT} - D_K$$

“pseudo-enthalpy”

(neglected)

$$\left.\frac{\partial u}{\partial t}\right|_{\text{phys}} \equiv \text{PTENDU} \approx \frac{\Delta u}{\Delta t}$$

$$\left.\frac{\partial v}{\partial t}\right|_{\text{phys}} \equiv \text{PTENDV} \approx \frac{\Delta v}{\Delta t}$$

$$\left.\frac{\partial (c_p\,T + K\,(+\phi?))}{\partial t}\right|_{\text{phys}} \equiv \text{PTENDH} \approx \frac{\Delta (c_p\,T + K)}{\Delta t}$$

Question: is PTENDH = changes in $c_p\,T + K$?

Equations for the "pseudo-enthalpy": **physical tendencies**?

Changes in (*u*,*v*) and thus K

NO: changes in $c_p\,T$ alone in the code!

In CPUTQY:

$$u_{(+)} = u_{(-)} + \text{PTENDU} \times \Delta t$$

$$v_{(+)} = v_{(-)} + \text{PTENDV} \times \Delta t$$

$$c_{p(+)}\,T_{(+)} = c_{p(-)}\,T_{(-)} + \text{PTENDH} \times \Delta t - \text{ZDEC} \times \Delta t$$

$$\frac{\Delta(c_p\,T + K)}{\Delta t} \approx \text{PTENDH}$$

"ZDEC" = a term added in CPUTQY to keep $c_p\,T + K$ constant locally?

… for the **Gravity Wave Drag** for instance,
where changes in (*u*,*v*), and thus *K*, but with **PTENDH=0**,
and changes in K implies local heating or cooling in CPUTQY!

Equations for the "pseudo-enthalpy": **physical tendencies**?

Changes in (*u*,*v*) and thus K

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$$u_{(+)} = u_{(-)} + \mathrm{PTENDU} \times \Delta t$$

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$$c_{p(+)}\,T_{(+)} = c_{p(-)}\,T_{(-)} + \mathrm{PTENDH} \times \Delta t - \mathrm{ZDEC} \times \Delta t$$

$$\frac{\Delta(c_p\,T + K)}{\Delta t} \approx \mathrm{PTENDH}$$

… the same for GWD, convection, turbulence, … : **a need to set ZDEC=0?**

- a too strong constraint revealed by Yves Bouteloup (test of Tiedtke scheme)
- **ZDEC** was just for "debug" mode (dixit Michel Déqué, who told with JFG...)
- even if local conservation ⇒ global one / the reverse must not be applied!
- nothing similar to ZDEC in IFS or other models...

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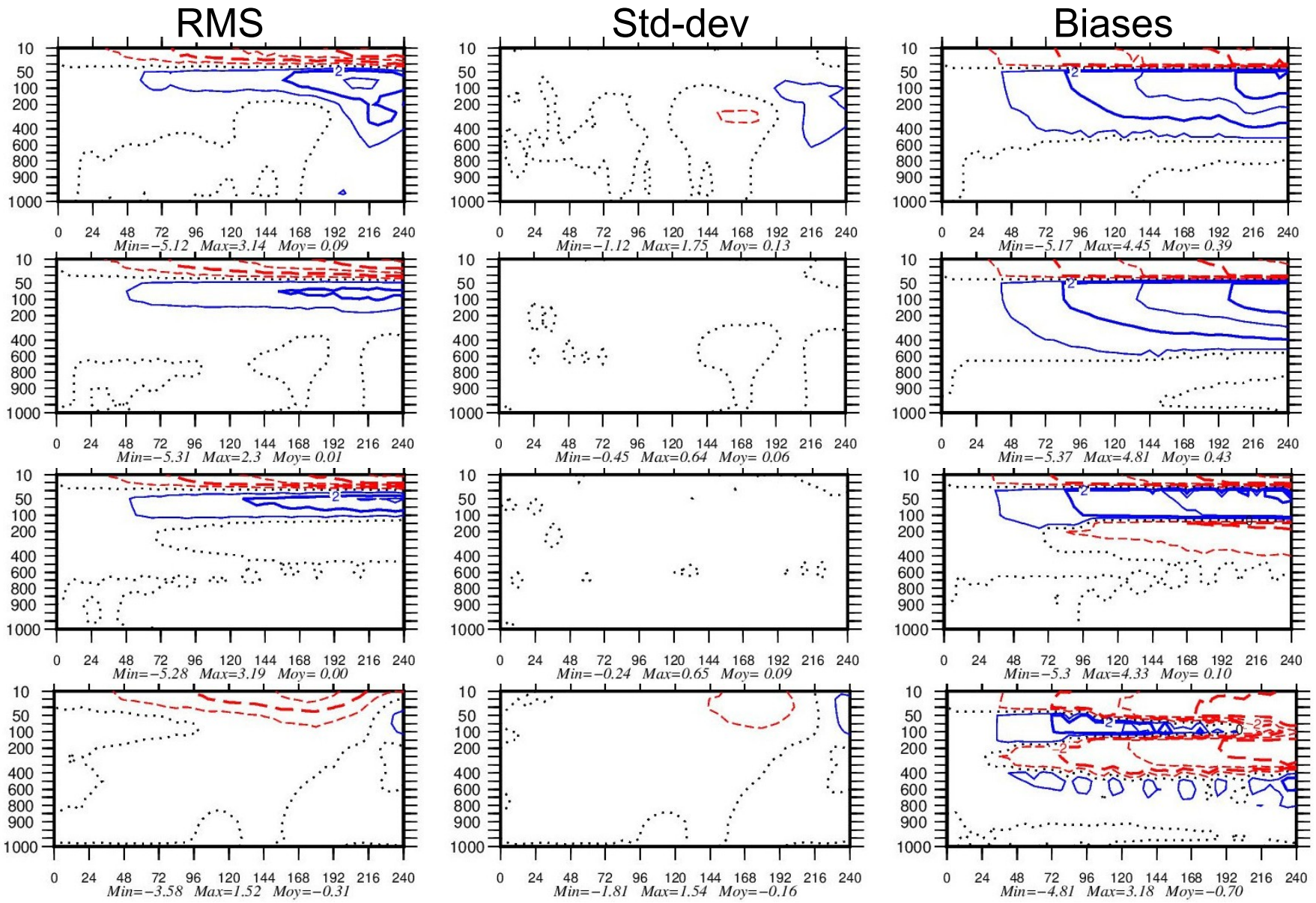
5) Conclusions

Impacts of **“ZDEC=0” all param.** / **Geopotential** [51 days / 240 h / analyses]



:EUROPE

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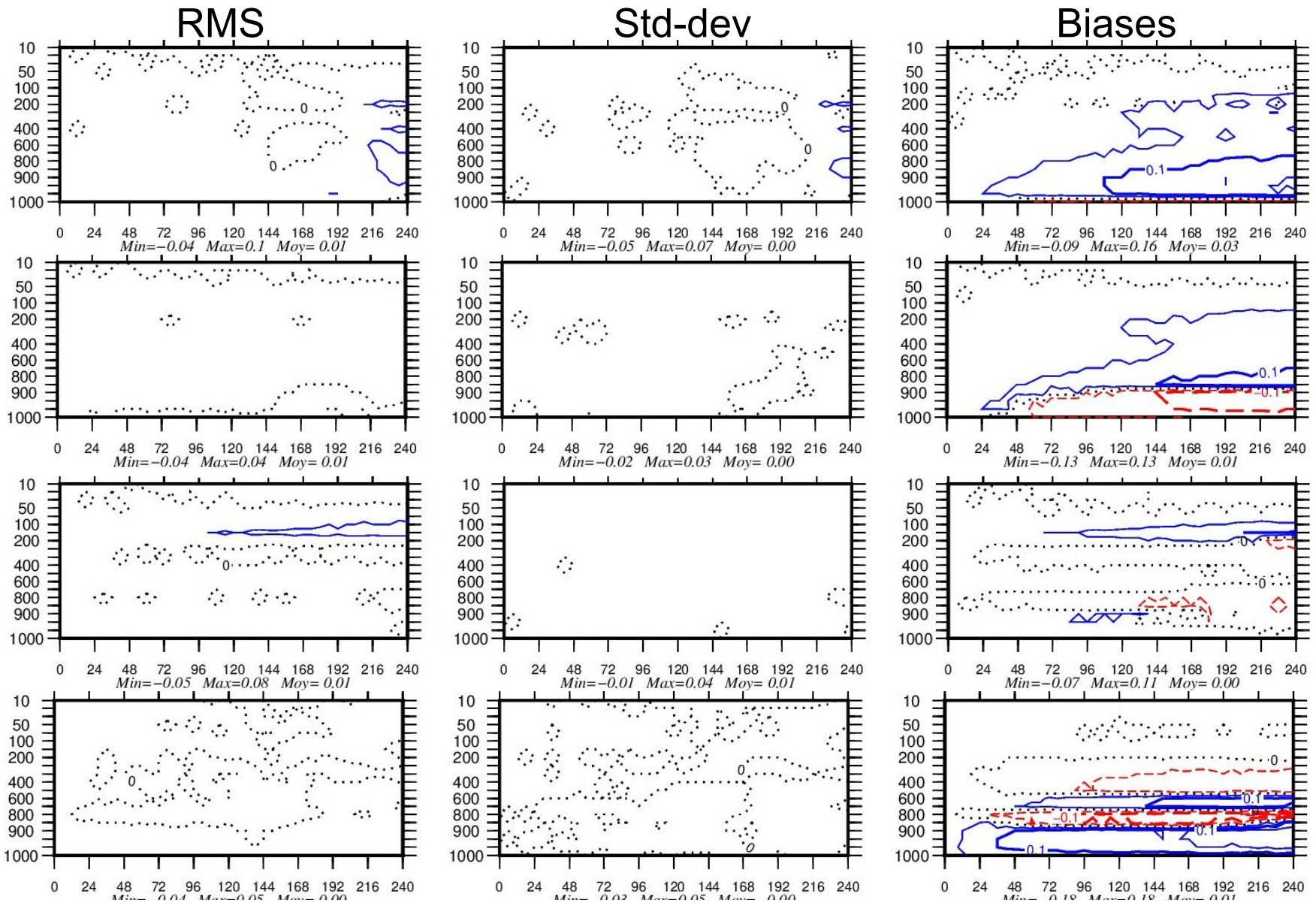
Scores for ARPEGE
by Eric Bazile

“blue = better
“red” = worse
(June/July 2020)

improvements
in Biases and RMS

Impacts of **“ZDEC=0” all param.** / **Temperature** [51 days / 240 h / analyses]



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Scores for ARPEGE
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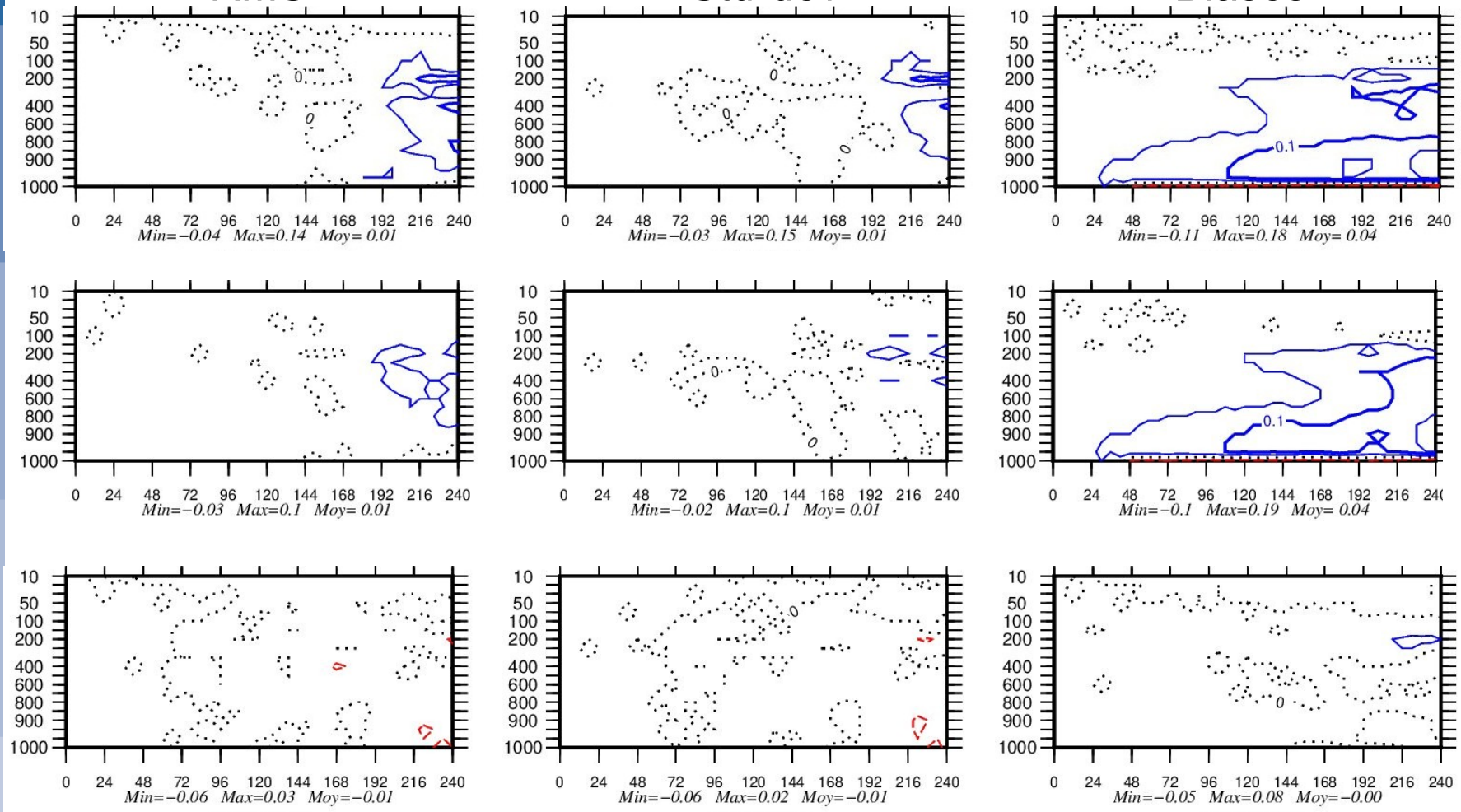
improvements
in Biases (and RMS)

Impacts of **“ZDEC=0”** / **Temperature / EUROPE** [37 days / 240 h / analyses]

RMS | Std-dev | Biases



Scores for ARPEGE
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“blue = better
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(June/July 2020)

all params removed in ZDEC

all removed in ZDEC **except GWD**

Small impacts of GWD alone (weak GWD in ARPEGE...)

all removed in ZDEC **except TURB**

Main impacts coming from turbulence? (+ links with convections)

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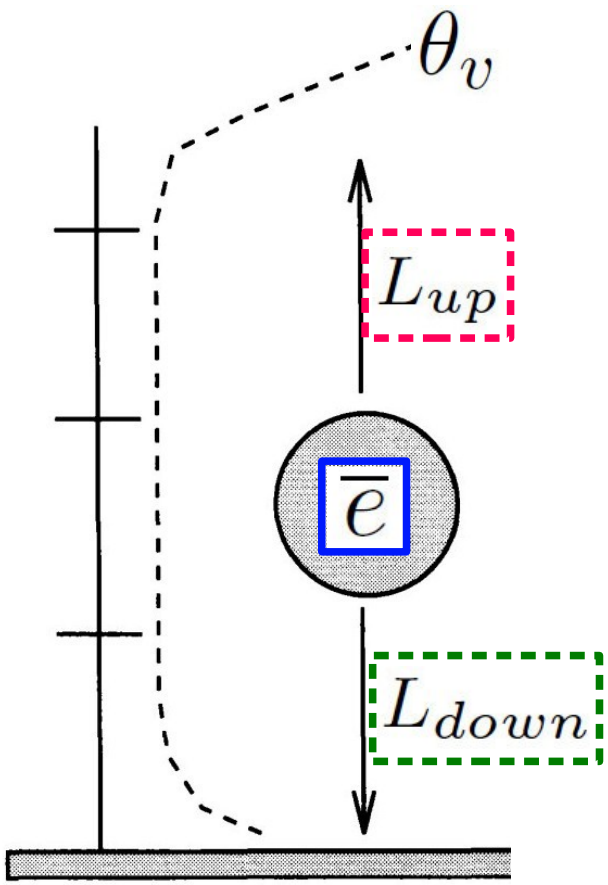
The "BA86" & "BL89" non-local mixing length



(from "CBR00")

The vertical distances to equalize the TKE $\boxed{\overline{e}}$ with the work done against buoyancy force:

$$\int_z^{z+L_{up}} \frac{g}{\overline{\theta_v}} \left[\overline{\theta_v}(z') - \overline{\theta_v}(z) \right] dz' = \boxed{\overline{e}}$$

$$\int_{z-L_{down}}^{z} \frac{g}{\overline{\theta_v}} \left[\overline{\theta_v}(z) - \overline{\theta_v}(z') \right] dz' = \boxed{\overline{e}}$$

"BA86":

$$\frac{1}{L} = \frac{1}{L_m} = \frac{1}{L_\epsilon} = \frac{1}{2}\left(\frac{1}{L_{up}} + \frac{1}{L_{down}}\right)$$

Bougeault & André (1986)

"BL89":

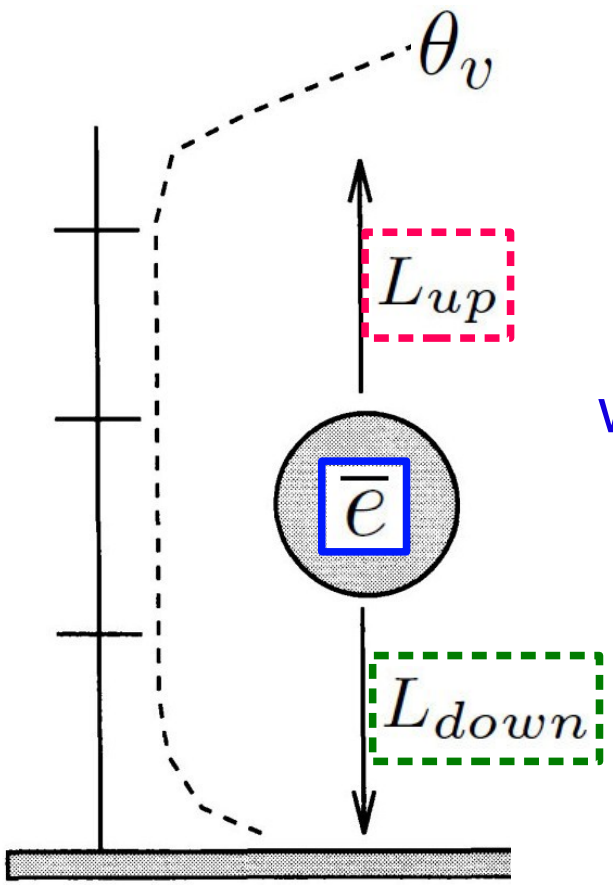
$$L_m = \min\left(L_{up}\,,\ L_{down}\right)$$

$$L_\epsilon = \sqrt{L_{up}\,L_{down}}$$

Bougeault & Lacarrère (1989)

(PERIDOT)

The ARPEGE & AROME & Meso-NH non-local mixing length



(from "CBR00")

present ARPEGE:
and AROME:
and Meso-NH:

$$\frac{1}{L^{\alpha}} = \frac{1}{2}\left[\frac{1}{(L_{up})^{\alpha}} + \frac{1}{(L_{down})^{\alpha}}\right]$$

where: $\alpha = 2/3$ and: $L \approx 2.8\, z$

Close to surface if neutral (or unstable)

(very different from the von Kármán law $L \approx 0.4\, z$)

But why?

The ARPEGE & AROME & Meso-NH non-local mixing length

$$\alpha = \frac{\log(16)}{4\,\log(\kappa) + \log(C_\varepsilon) - 3\,\log(C_m)}$$

Surface Neutrality:

$$L \approx A\,(z + z_0)$$

$$A = \kappa\,\frac{(C_\varepsilon)^{1/4}}{(C_m)^{3/4}}$$

Hints in RMC (2001), Lemarié *et al.* (G.M.D. 2021)

Table 1: Values of constants and derived values for different papers and models.

	BL89	Peridot	CBR00	CCH02	ARPEGE	AROME
C_m	0.40	0.20	0.0666667	0.1264	0.126	0.1264
C_ε	0.7143	0.70	0.70	0.845	0.8475	0.85
$A = \kappa\,(C_\varepsilon/C_m^3)^{1/4}$	0.73	1.22	2.79	1.809	1.815	1.812
$\alpha = \ln(2)/\ln(A)$	−2.21	3.44	$0.676 \approx 2/3$	$1.1692 \approx 7/6$	1.1631	1.1663

(0.6666...) $\alpha \approx 2/3$

(1.16666...)

Still $\alpha \approx 2/3$! should be $\alpha \approx 7/6$!

(0.6666...)

With "A" reduced from 2.8 to 1.8

→ reduced surface fluxes?

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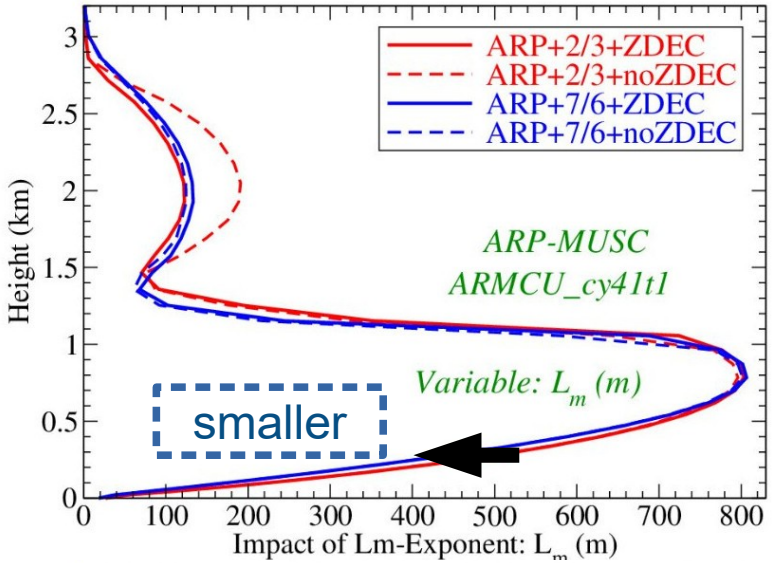
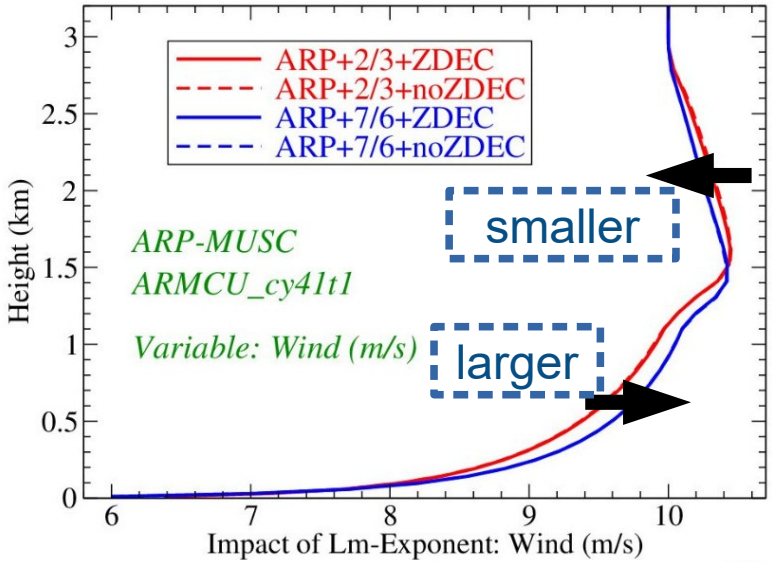
Impacts of "L": "2/3"→"7/6" ("ACBL89" ARPEGE MUSC-1D ARM-Cumulus)

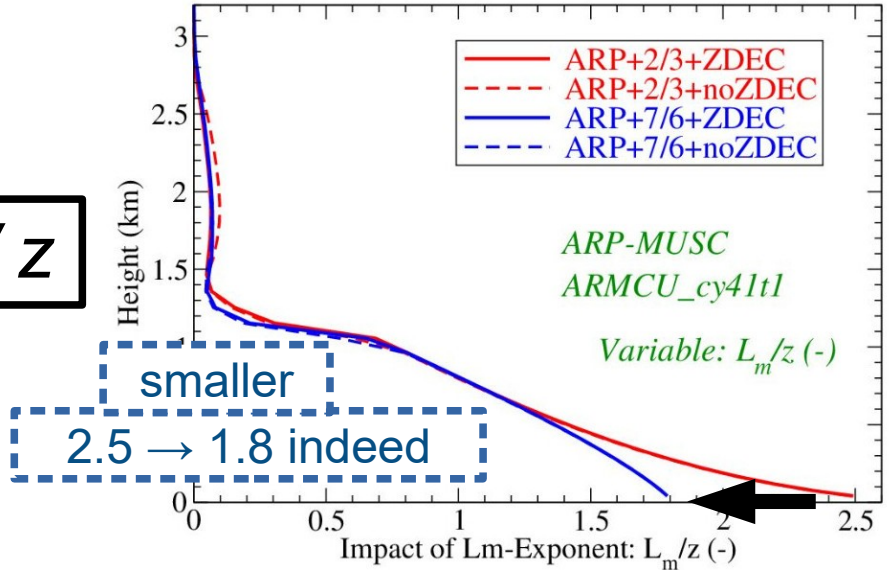
L

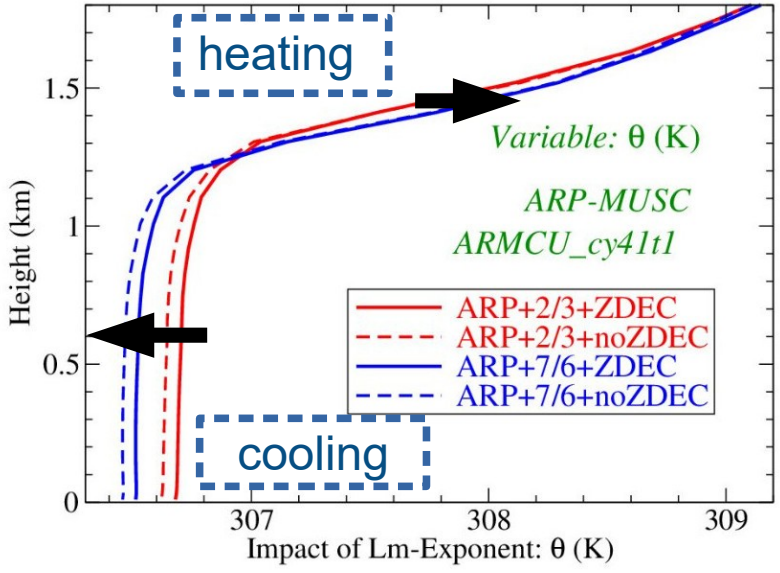




||v||

L / z





θ

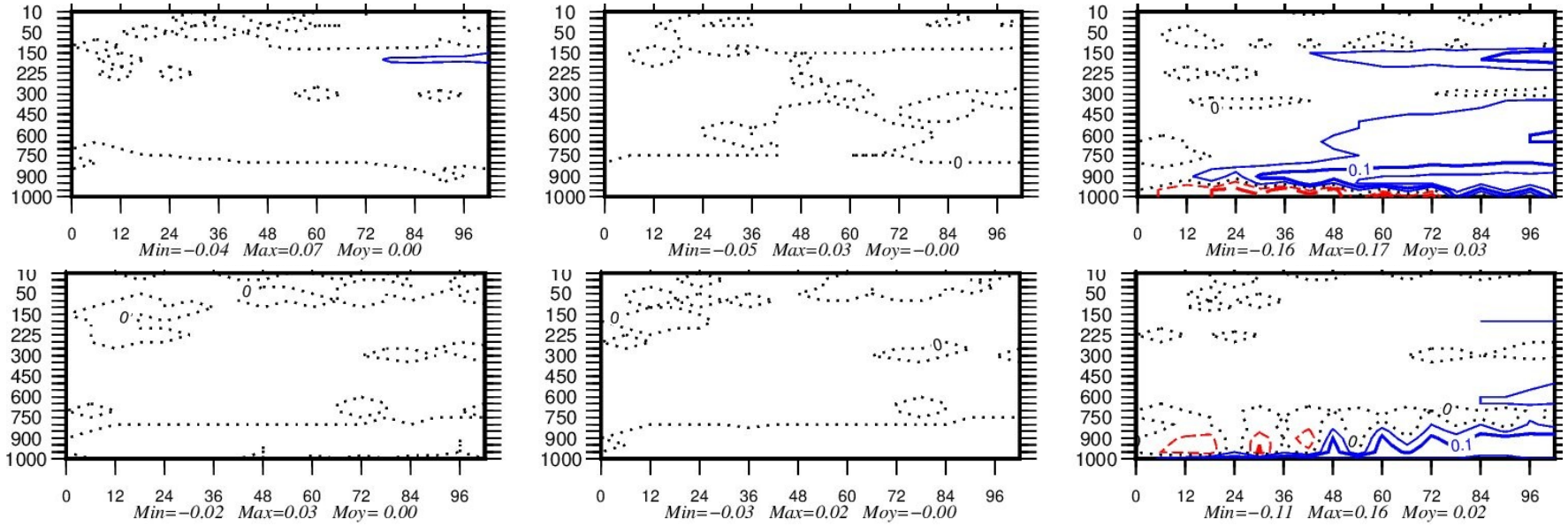
Impacts of the new “L” with “7/6” in “ACBL89” (ARPEGE)

Temperature [44 days / 96 h / analyses]

“blue = better
“red” = worse

(Jan./Feb. 2021)

RMS | Std-dev | Biases



:EUROPE

improvements (cooling)

:NORTH-20N

improvements (cooling)

Impacts of the new “L” with “7/6” in “ACBL89 / BL89”

Jean-François Gueremy (ARPEGE / Seasonal-Forecast / 5 years coupled AOGCM)

- smaller surface fluxes
- E and P: from 3.17 to 3.09 mm/day
- reduced “warm bias” in continental Europe (JJA)

Yann Seity (AROME-NWP / 1 month 3DVar)

- neutral classical scores (u, v, T, HU)
- neutral precipitation and gustiness scores

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Conclusions

1) To be aware that **"*Cp T*"** or **"Moist Static Energies"** are <u>neither enthalpy nor energy</u>

"*Cp T*" or **"*Cp T + K*"** or **"MSE"** might be conserved and <u>not energy</u>, and <u>vice versa</u>!

The <u>safer</u> method is likely the <u>simplest</u>: update the basic variables ("*u*", "*v*", **"*Cp T*"**),

→ this is done with **"*ZDEC=0*"**

Conclusions

1) To be aware that **"*Cp T*"** or **"Moist Static Energies"** are <u>neither enthalpy nor energy</u>

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The <u>safer</u> method is likely the <u>simplest</u>: update the basic variables ("*u*", "*v*", **"*Cp T*"**),

→ this is done with ***"ZDEC=0"***

2) A need to change "alpha (C_m, C_ε)" in ARPEGE, AROME, Meso-NH, … ("BA/BL" codes)

A need to maintain competence in turbulence, and likely to revisit the CBR scheme

Thanks! Questions ?