Pseudo-prognostic TKE scheme in ALARO

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Outline of the talk

- TKE: what's in ALADIN
- pTKE: idea
- implementation
- ALARO results

TKE in ALADIN

- Louis type scheme:
  - only vertical diffusion
  - diagnosed values for turbulent coefficients
- current scheme is performing well for scales around 10km (we don't want to throw away that!)
- anti-fibrillation treatment

Pseudo what?!

- still compute diagnosed coefficients
- replace full TKE equation with a pseudo one (such that its solution will be the diagnosed coefficients)
- follow and extend the idea of Redelsperger, Mahé and Carlotti (2001)
- minor code changes, keep what is good

Full TKE going pseudo

full

$$\frac{\partial \text{TKE}}{\partial t} = \text{advection}$$

+ diffusion

+ mechanical or shear production/destruction

+ buoyancy production/consumption

+ viscous dissipation

pseudo

$$\frac{\partial \text{TKE}}{\partial t} = \text{advection}$$

+ diffusion

+ Newtonian relaxation towards something

Pseudo prognostic TKE equation

$$\frac{\partial \mathrm{E}}{\partial \mathrm{t}} = Adv(E) + \frac{1}{\rho}\frac{\partial}{\partial z}\rho K_E \frac{\partial E}{\partial z} + \frac{1}{\tau_\varepsilon}(\widetilde{E} - E)$$

Where do we get $K_E, \tau_\varepsilon, \widetilde{E}$ from?

And what do we relax towards? $\left(\widetilde{E}\right)$

Procedure (1)

$$\widetilde{K}_m, \widetilde{K}_n \Rightarrow \widetilde{K}_* \Rightarrow \widetilde{E}, K_E, \tau_\varepsilon$$

$$\frac{dE}{dt} = f(E, \widetilde{E}, K_E, \tau_\varepsilon)$$

$$E \Rightarrow K_*$$

$$K_*, \widetilde{K}_*, \widetilde{K}_m, \widetilde{K}_h \Rightarrow K_m, K_h$$

RMC01

- match subgrid scale turbulence scheme ("full TKE scheme") and similarity laws (Monin-Obukhov) at surface
- extension of RMC01: extend this to the whole depth of the atmosphere (not just $l = \kappa z$)

Procedure (2)

$$\widetilde{K}_* = K_n^{1-\gamma} K_m^{\gamma} \Rightarrow \widetilde{E} = \left(\frac{\widetilde{K}_*}{\nu l_m}\right)^2$$

$$\widetilde{K}_m, \widetilde{K}_n \Rightarrow \widetilde{K}_* \Rightarrow \widetilde{E}, K_E, \tau_\varepsilon$$

$$K_E = \frac{l_m}{\nu}\sqrt{E_?}, \frac{1}{\tau_\varepsilon} = \frac{\nu^3}{l_m}\sqrt{E_?}$$

$$\frac{dE}{dt} = f(E, \widetilde{E}, K_E, \tau_\varepsilon)$$

$$E \Rightarrow K_* \qquad K_* = \nu l_m \sqrt{E}$$

$$K_*, \widetilde{K}_*, \widetilde{K}_m, \widetilde{K}_h \Rightarrow K_m, K_h \qquad K_m = K_*\left(\frac{\widetilde{K}_m}{\widetilde{K}_*}\right), K_h = K_*\left(\frac{\widetilde{K}_h}{\widetilde{K}_*}\right)$$

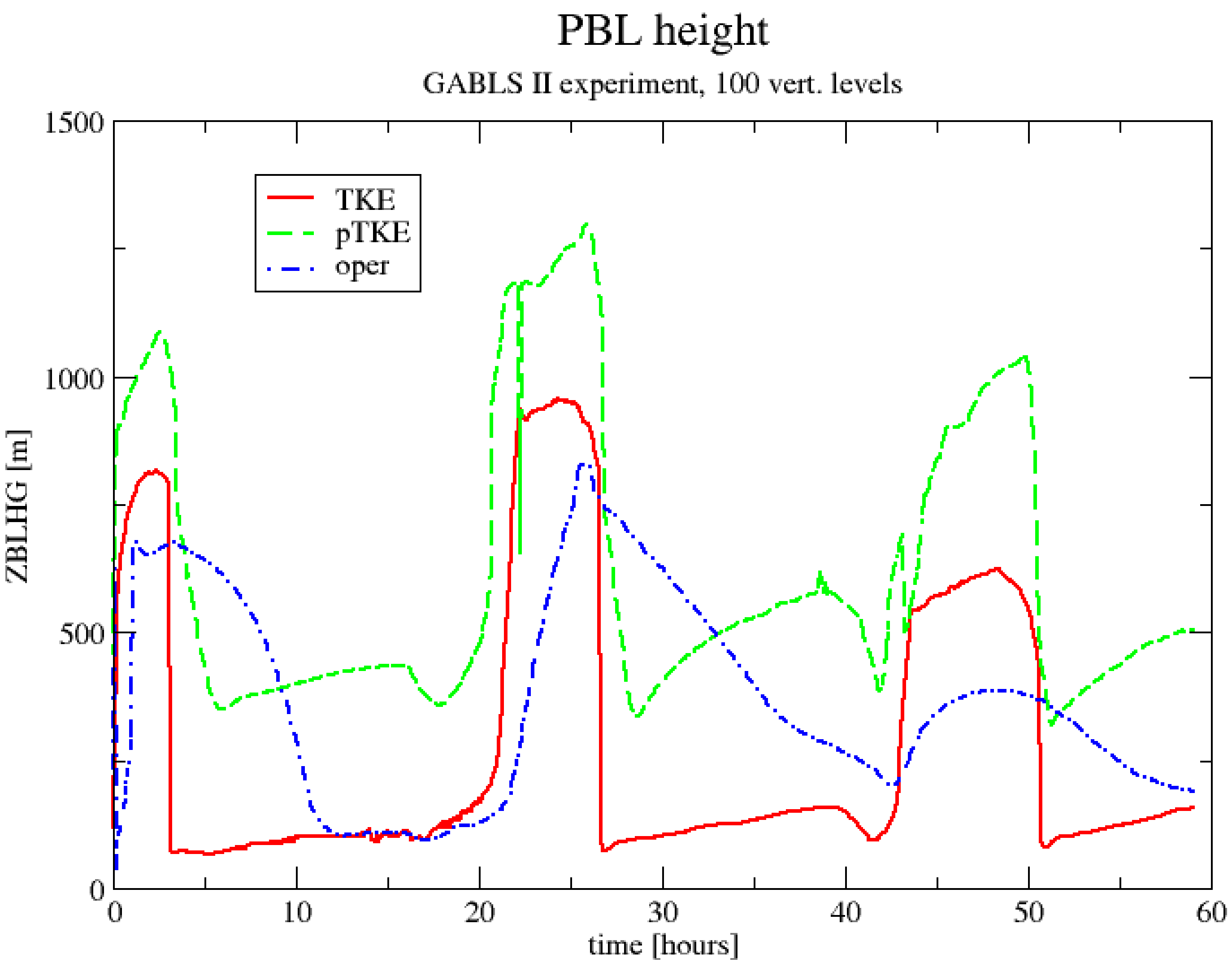
The only tuning parameter: $\nu \approx 0.5$

Algorithmics

- three level stencil in the vertical for the Newtonian relaxation (τ_εs are on half levels) [a relaxation for a given layer is a weighted average of relaxations on neighbouring half levels]
- such a relaxation operator is compatible with the diffusion one – the matrix is diagonal dominant and the solution is linearly stable
- make sure that the diffusion part is dominant (no oscilating mode coming from relaxation)

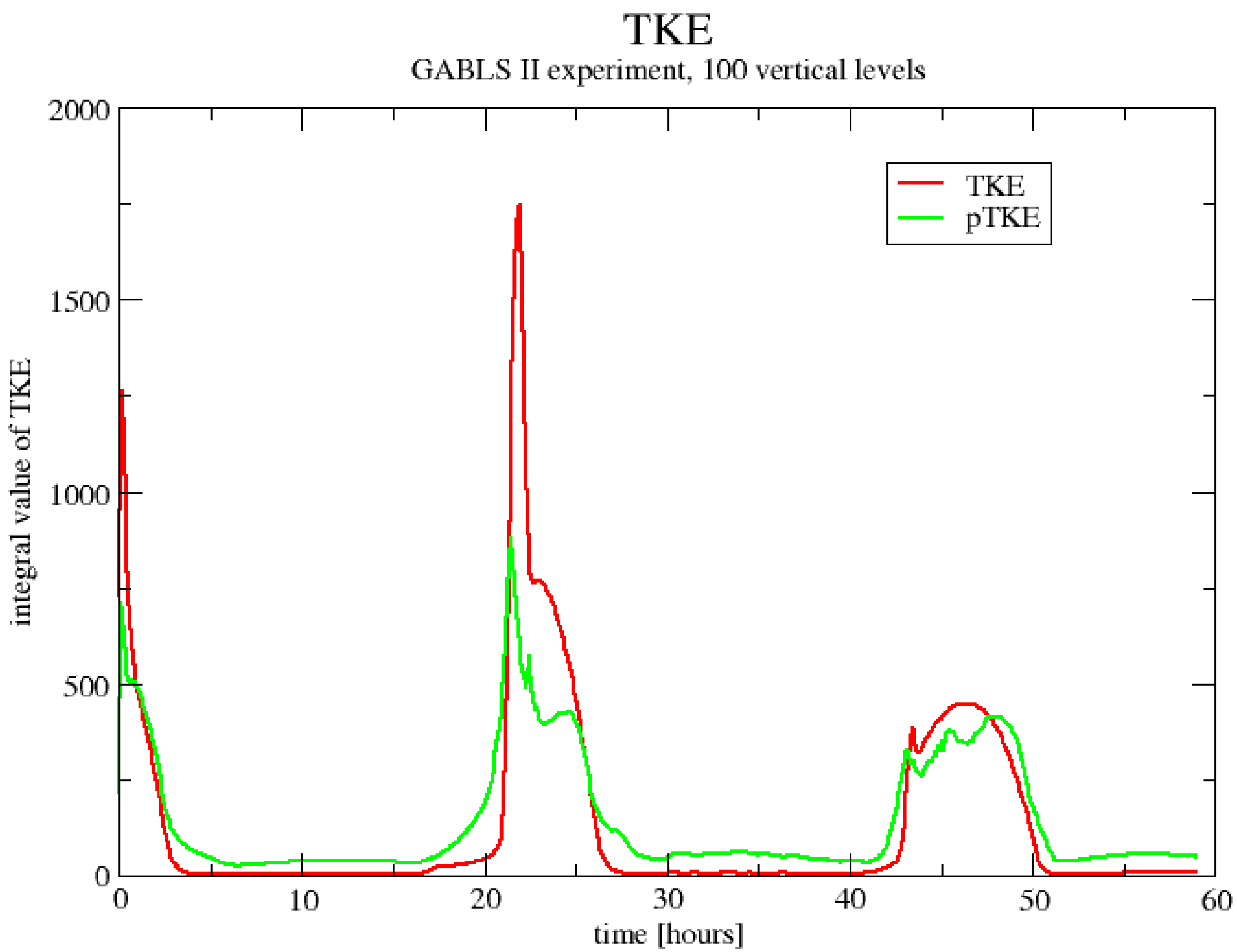
Results (1)

Academic test with 1D model: GABLS II experiment



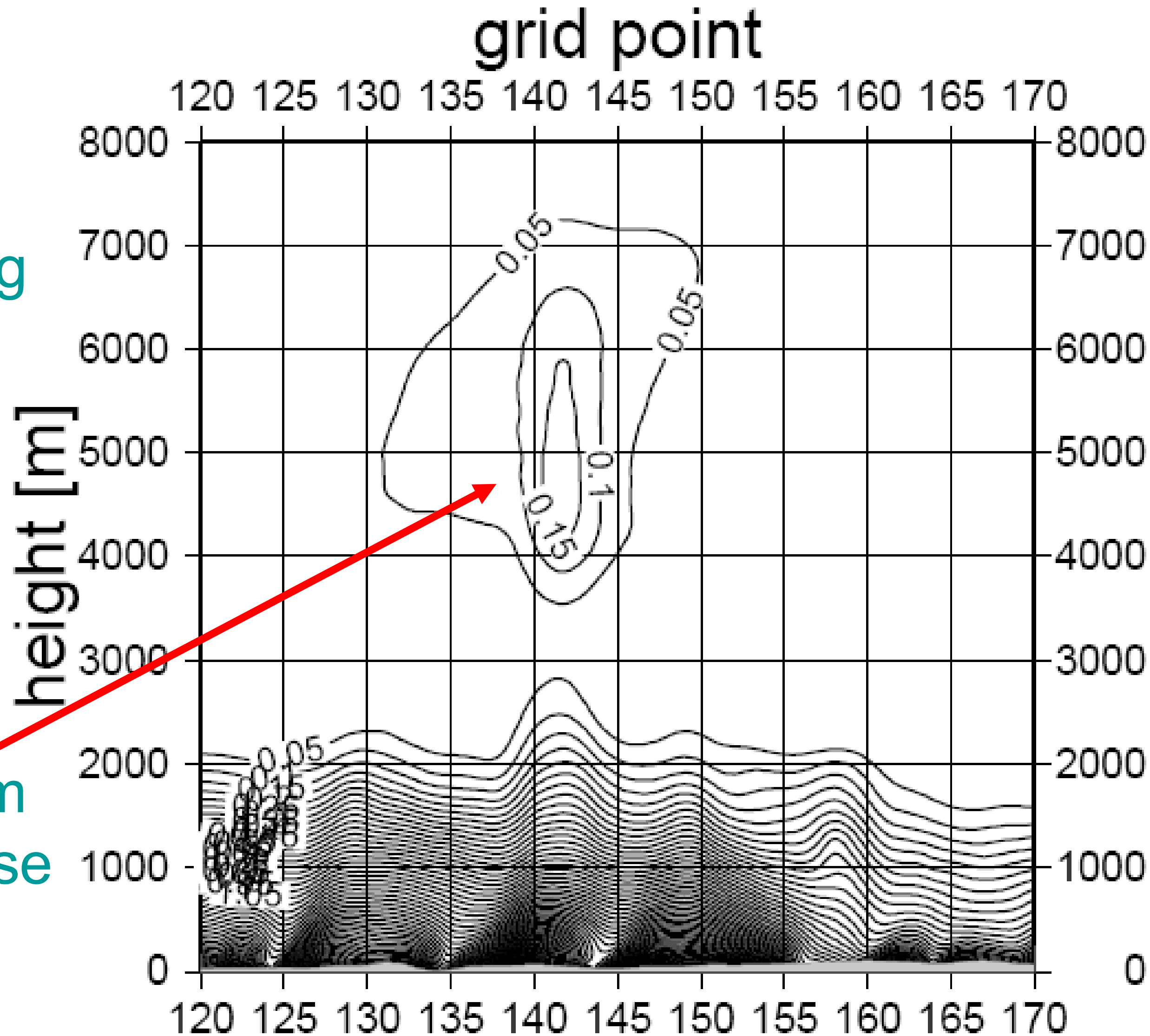
Results (2)

Academic test with 1D model: GABLS II experiment



Results (3)

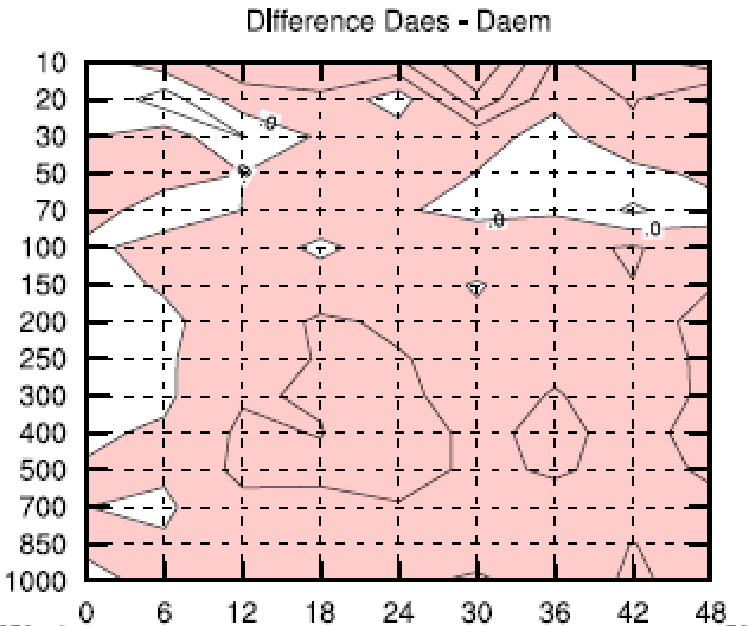
TKE vertical cross-section.
Situation with strong baroclinic zone.

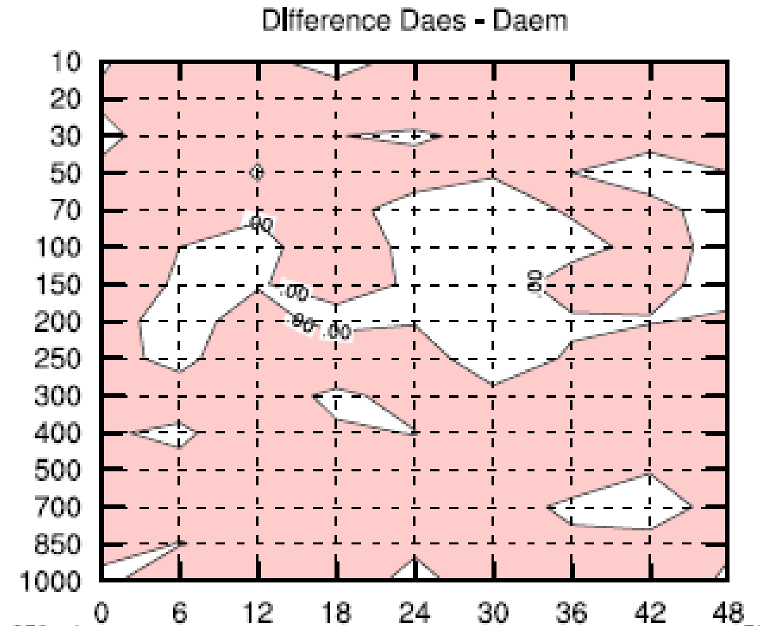


Local TKE maximum where the tropopause folds down

Results (4)

Parallel suite scores, Dec 2005

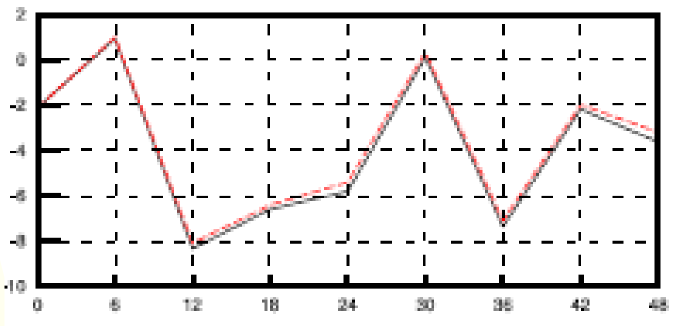




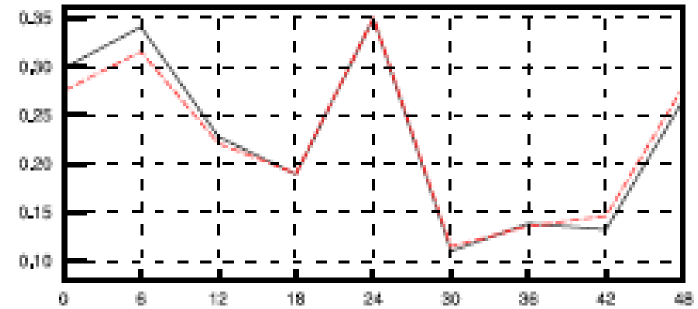
RMSE difference maps
pTKE – Oper, vs TEMPs (8 days): left geopotential (m); right: temperature (K). Negative values (color) -> e-suite is better.

Results (5)

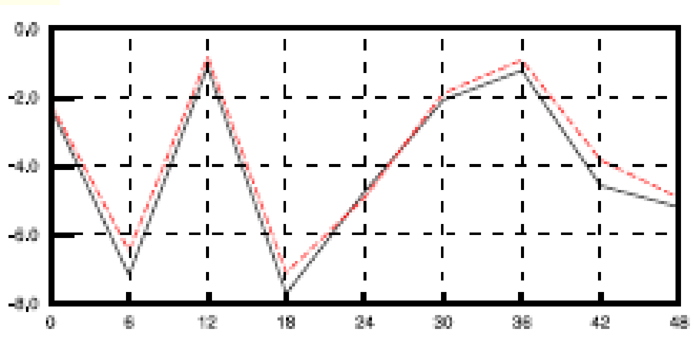
Parallel suite scores, Dec 2005



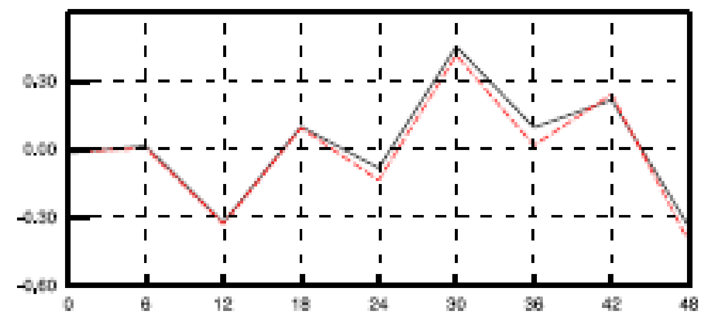
Z500



T850



RH850



W700

Bias: black solid: operational, red dashed: pTKE

Conclusions

- time stability for long time steps
- stable vertical staggering - full level TKE values – no problems with SL advection
- anti-fibrilation treatment is very easily applicable
- Ks are on half levels – suitable choice of lm fixes potential problems
- SLHD works well with precise SL interpolators (not necessary to use QM)
- pTKE is able to mimic fTKE - provided one can compute $\tilde{E}$ differently, taking into account more precisely shear and buoyancy production/consumption and mixing lentgh specification as well (future work....)

Procedure (2)

$$\widetilde{K}_m, \widetilde{K}_n \Rightarrow \widetilde{K}_* \Rightarrow \widetilde{E}, K_E, \tau_\varepsilon$$

$$\widetilde{K}_* = R_l K_n^{1-\gamma} K_m^{\gamma} \Rightarrow \widetilde{E} = \left(\frac{\widetilde{K}_*}{\nu l_m}\right)^2$$

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The only tuning parameter: $\nu \approx 0.5$