Transition from shallow to deep convection: Interactions between the thermal plume model and the deep convection scheme in LMDZ

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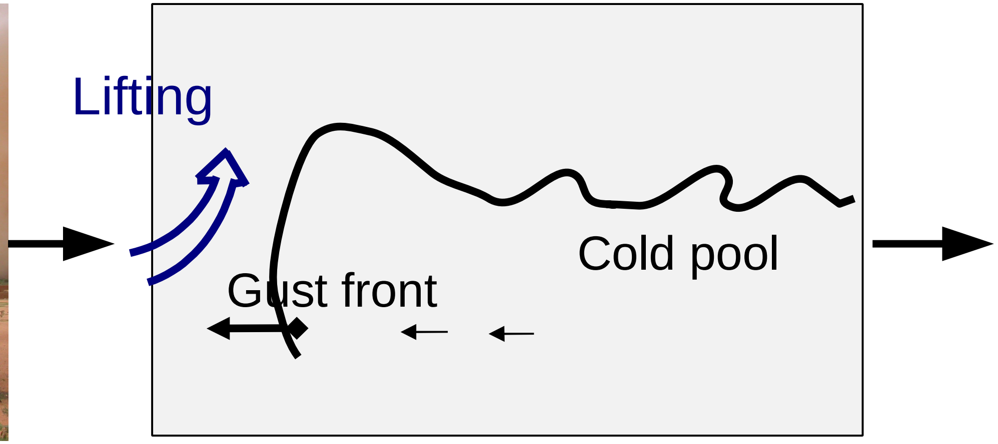
EDMF meeting, 15 June 2011, Delft

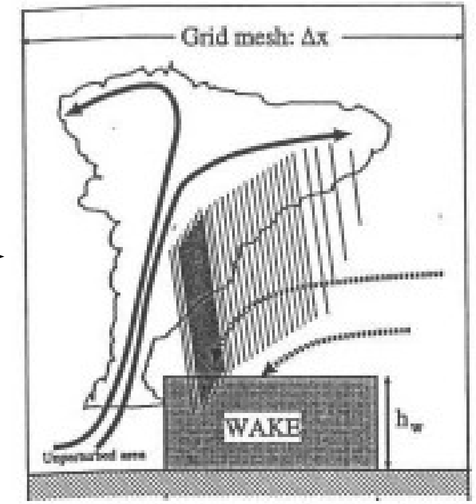
The LMDZ deep convection scheme

A parametrization of cold pools

Grandpeix & Lafore, JAS, 2010

Guichard Françoise

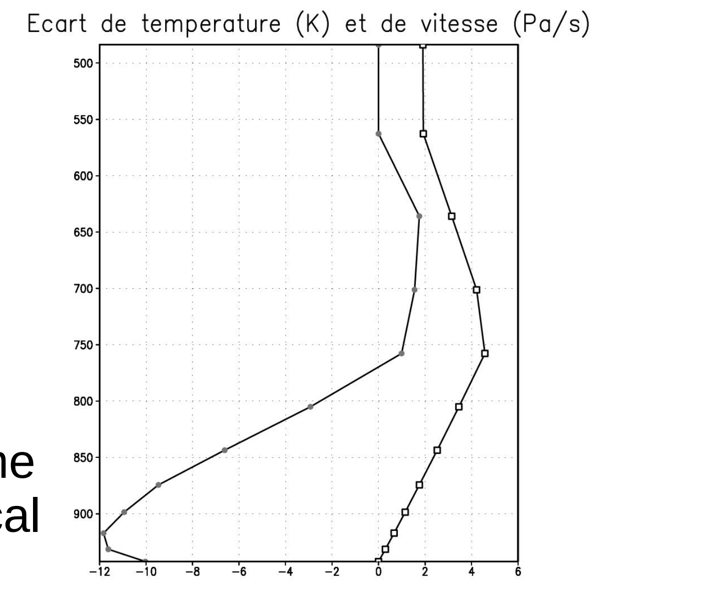




- Population of identical circular wakes dispatched uniformly over an infinite plane containing the grid cell:
Radius r, height hw and density Dwk

- Pronostic variables:
fractional area of the wakes $\sigma_w = D_{\rm wk}\,\pi\, r^2$
δθ, δq between wakes and environment

- Conservation equations for δθ and δq include turbulence and phase change effects given by the deep convection scheme as well as vertical advection assuming a piecewise linear vertical profile of δω.

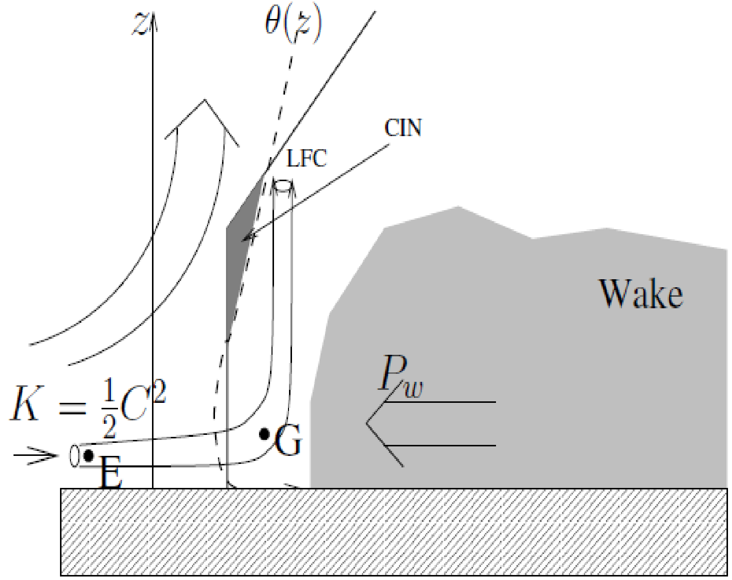


- Spreading speed of the wake leading edge:

$$C_* = k_* \sqrt{2\mathrm{WAPE}} \qquad \text{with} \qquad \mathrm{WAPE} = -g \int_0^{h_w} \frac{\delta\theta_v}{\overline{\theta_v}}\, dz$$

Triggering and closure of the deep convection scheme

Modified version of Emanuel, JAS, 1991 convection scheme

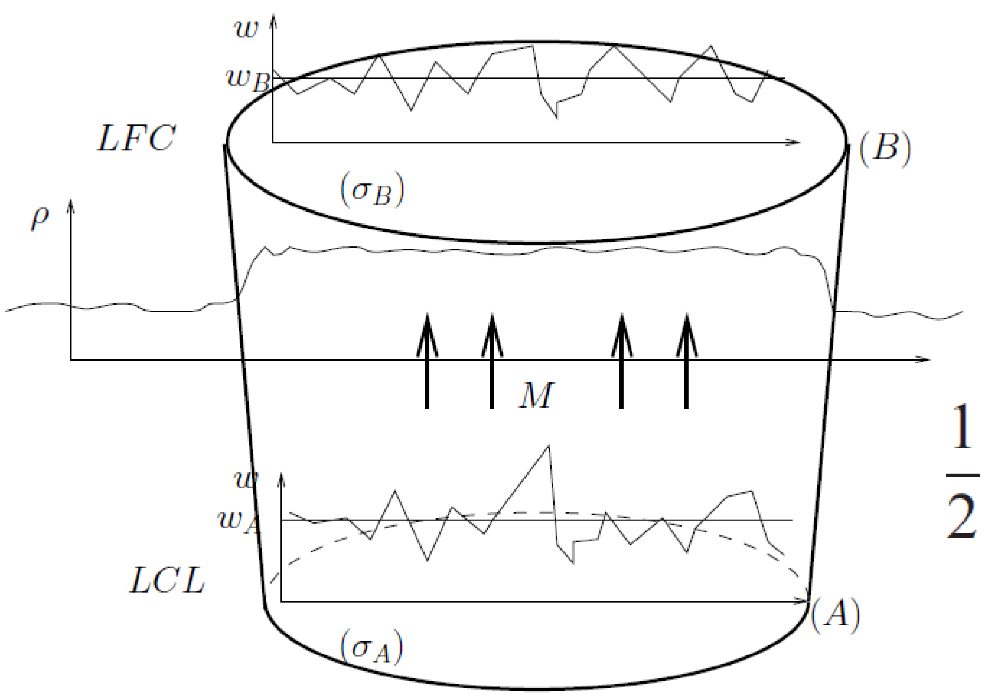


Triggering

ALE: Available Lifting Energy (J/kg)

$$ALE_{wake} = 0.5c^{*2}$$

Convection is triggered when ALE > |CIN|



Closure

ALP: Available Lifting Power (W/m2)

$$ALP_{wake} = k' \, 0.5 \, \rho \, c^{*3}$$

$$\frac{1}{2} M_b {w_b}^2 = ALP - M_b \left[|CIN| + \gamma w_b^2 \right]$$

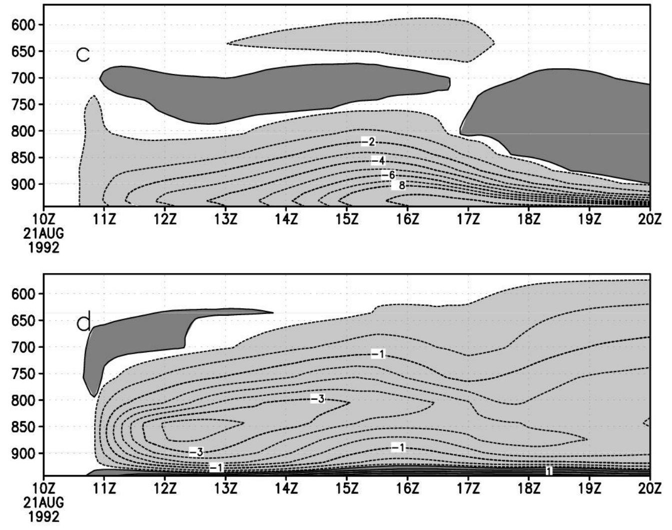
Squall line case

Grandpeix & Lafore, JAS, 2010

HAPEX: 21 August 1992

δT (K/h)

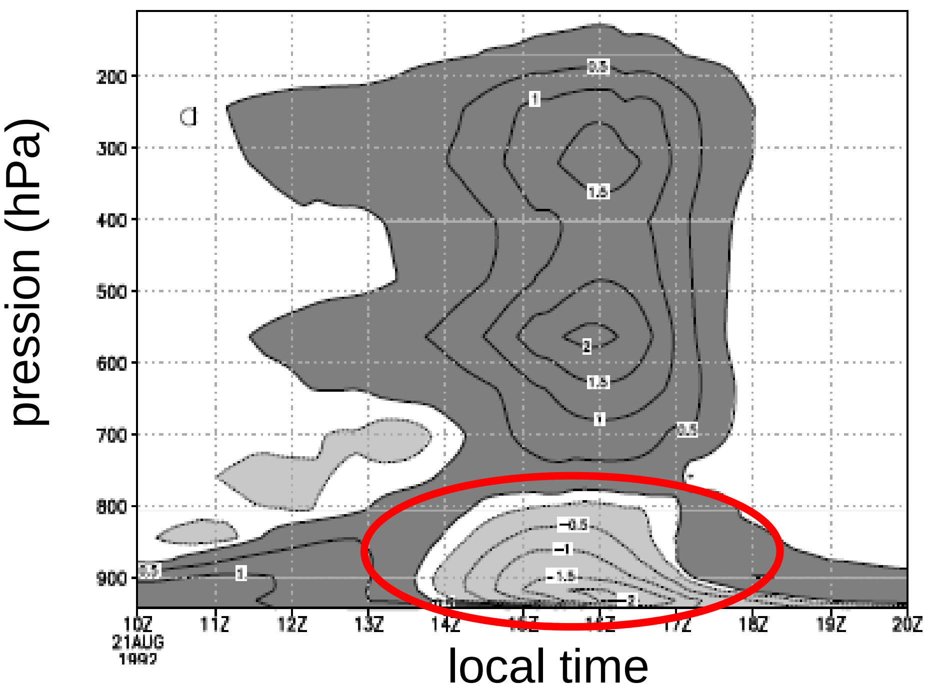
δq (g/kg/h)

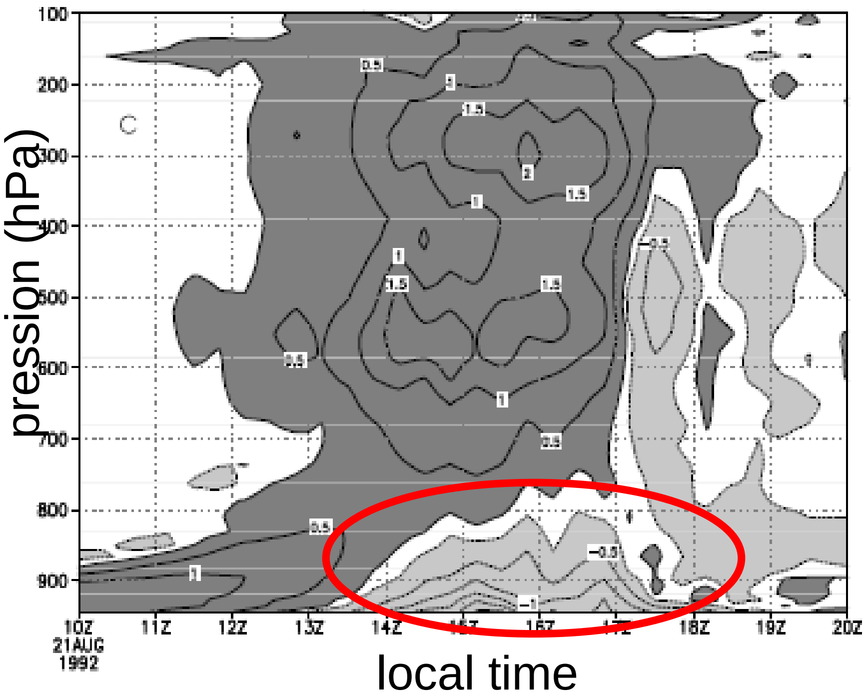


Heating rate (K/day)

LMDZ

MESO-NH





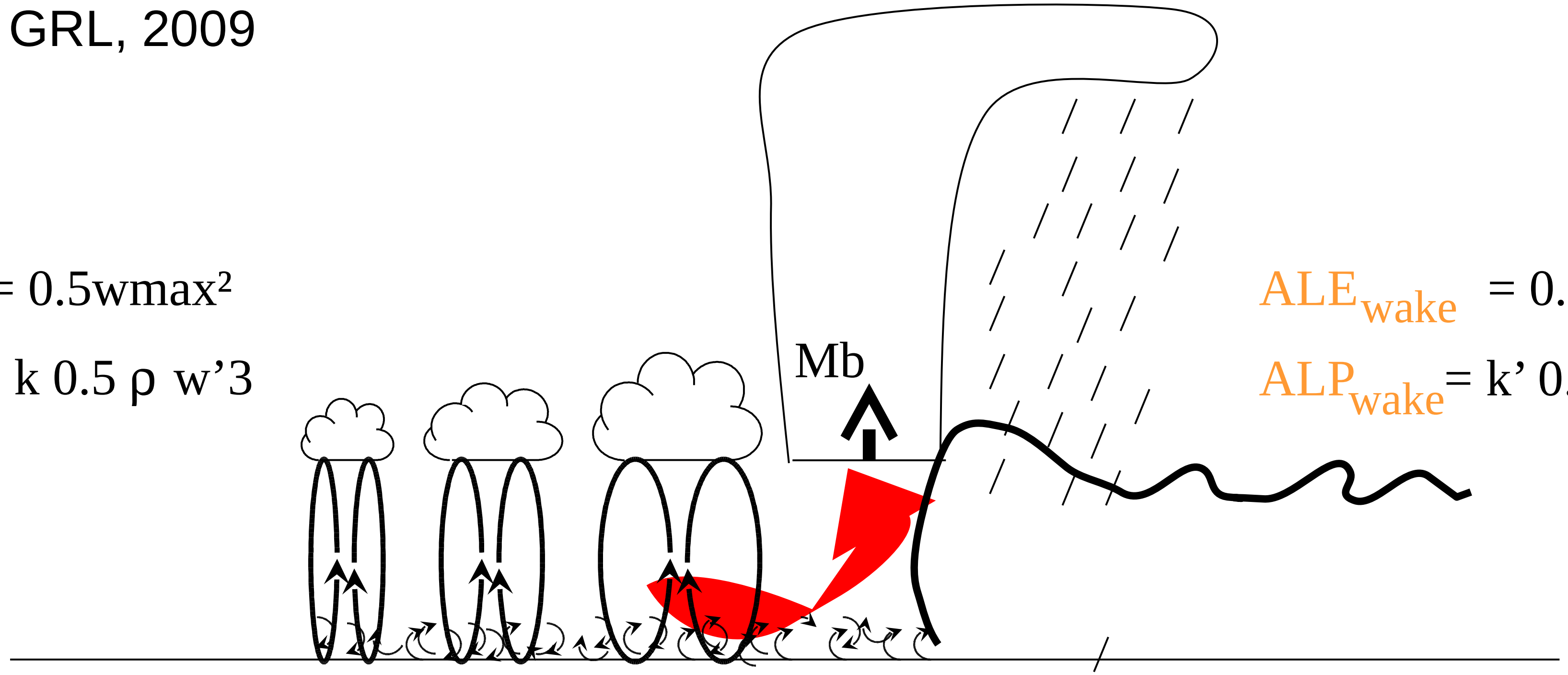
Coupling the thermal plume model with the deep convection scheme

Coupling the thermal plume model with deep convection

Rio & al., GRL, 2009

$ALE_{th} = 0.5 wmax^2$

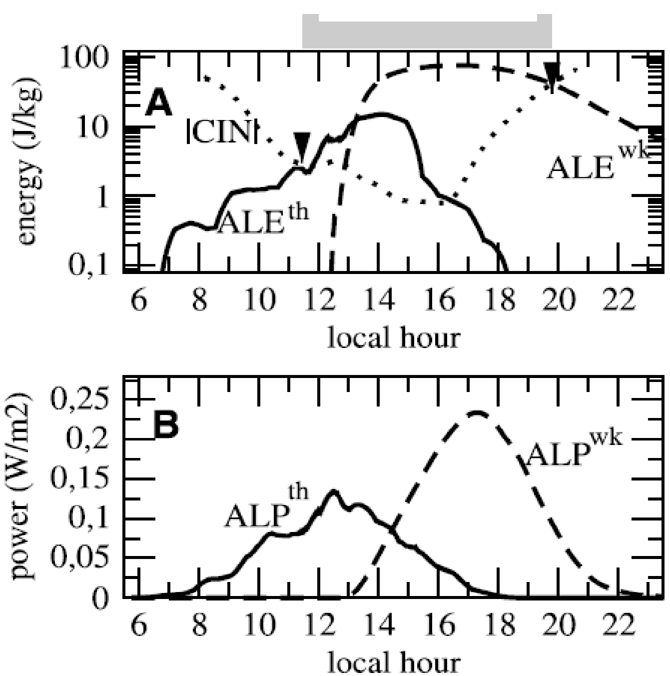
$ALP_{th} = k\ 0.5\ \rho\ w'3$



$ALE_{wake} = 0.5 c^{*2}$

$ALP_{wake} = k'\ 0.5\ \rho\ c^*3$

Illustration on the EUROCS case (Guichard & al., QJRMS, 2004)



Triggering:

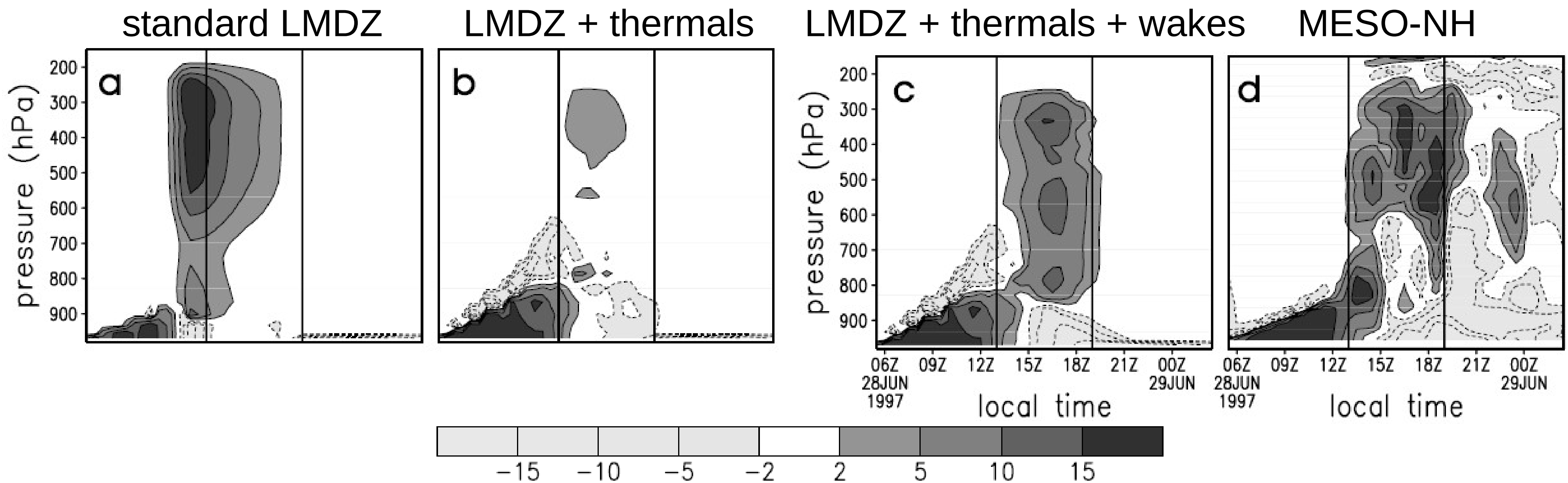
$MAX\,(ALE_{th}\ ,\ ALE_{wk}\ ) > |CIN|$

Closure:

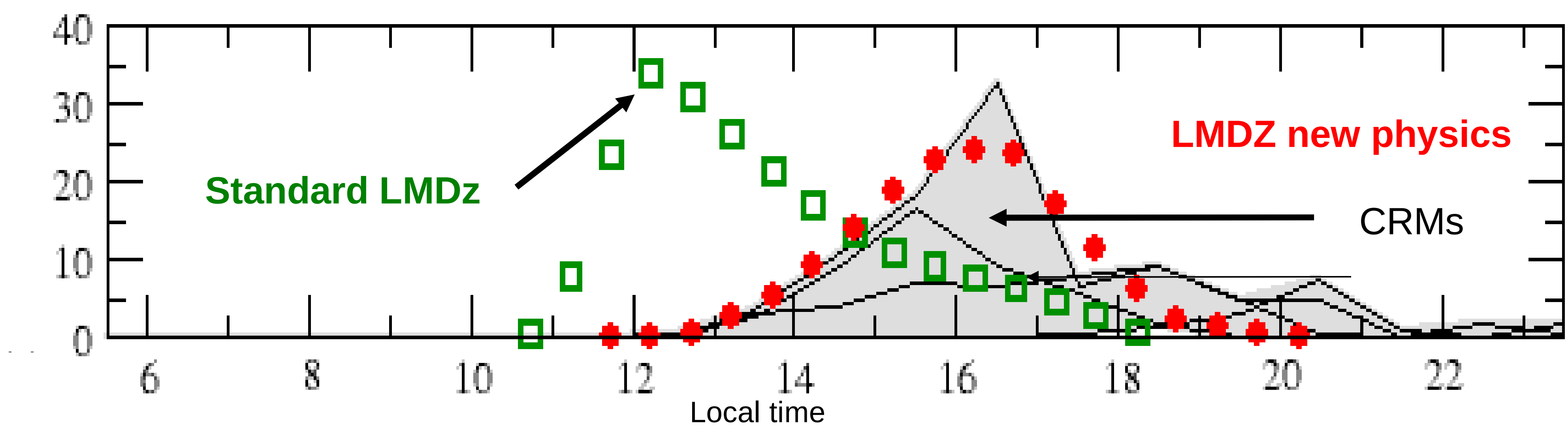
$Mb = f(ALP_{th} + ALP_{wk})$

Diurnal cycle of precipitation for the EUROCS case

Diurnal cycle of heating rate (K/day)

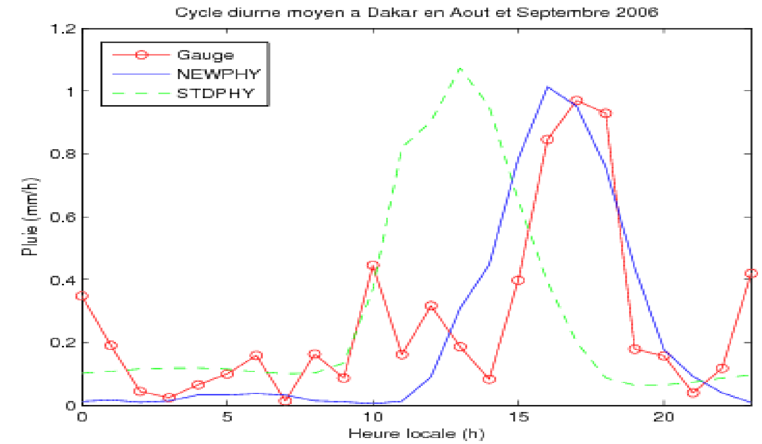


Diurnal cycle of precipitation, 27 June 1997, Oklahoma

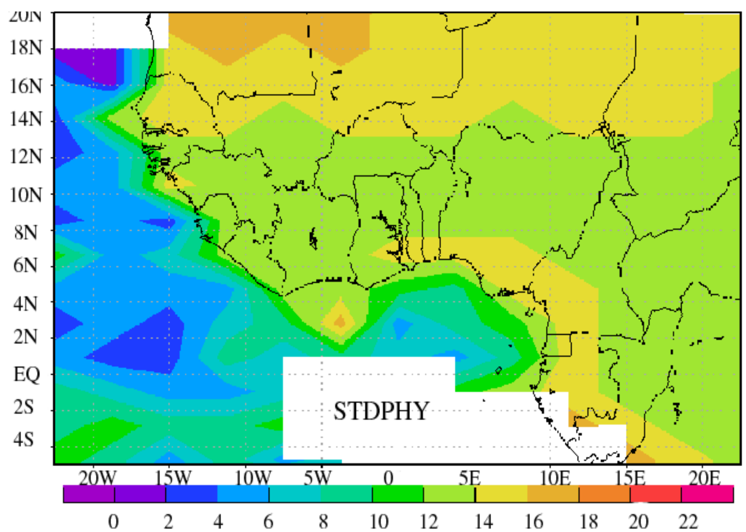


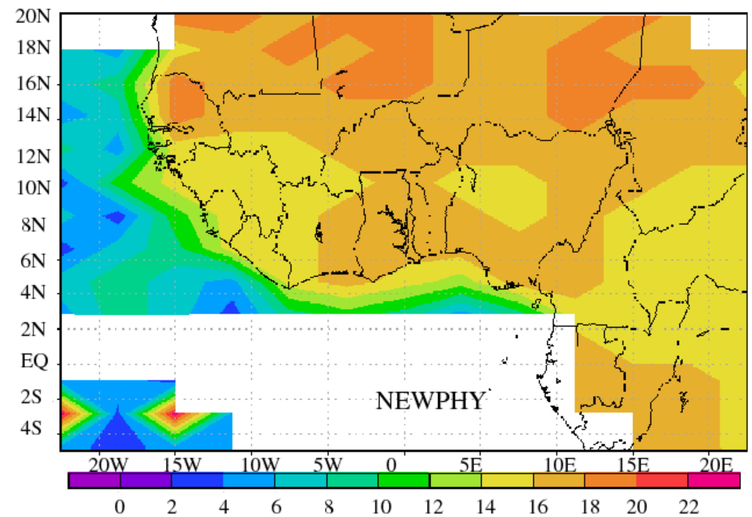
3D results

Diurnal cycle of precipitation in August/September 2006 in Dakar

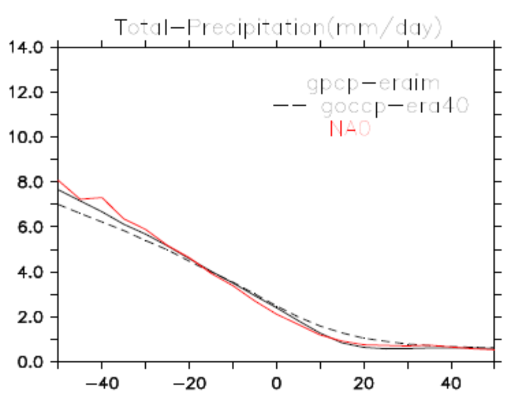


Local hour of the maximum of precipitation in August/September 2006 in West Africa
Sane & al., in preparation

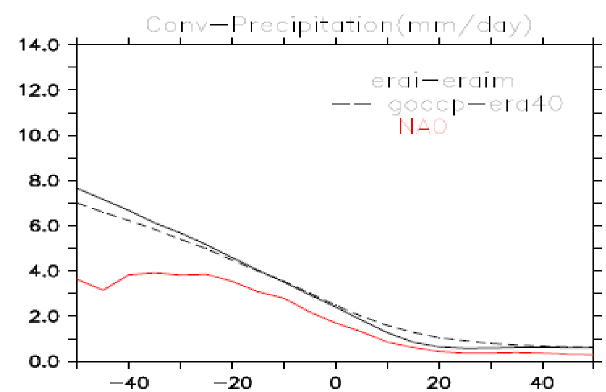




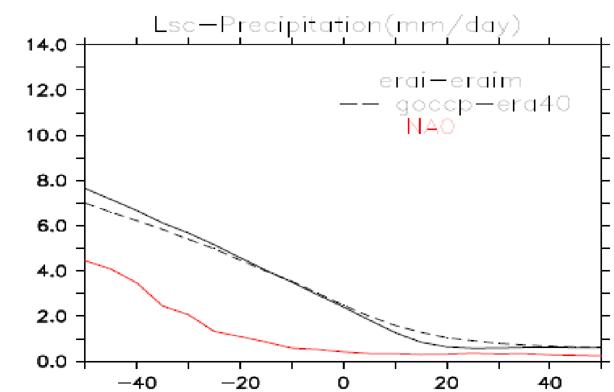
BUT: weak convective precipitation in ascending regions in some simulations



ω500



ω500

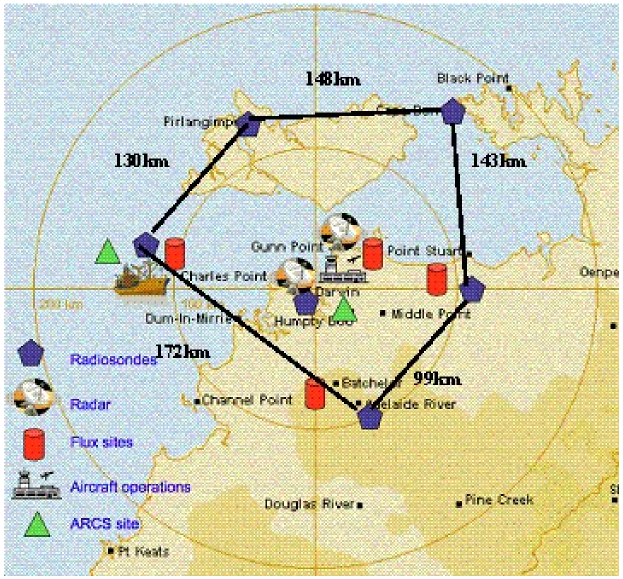


ω500

Further investigations

The Tropical Warm Pool-International Cloud Experiment (TWP-ICE)

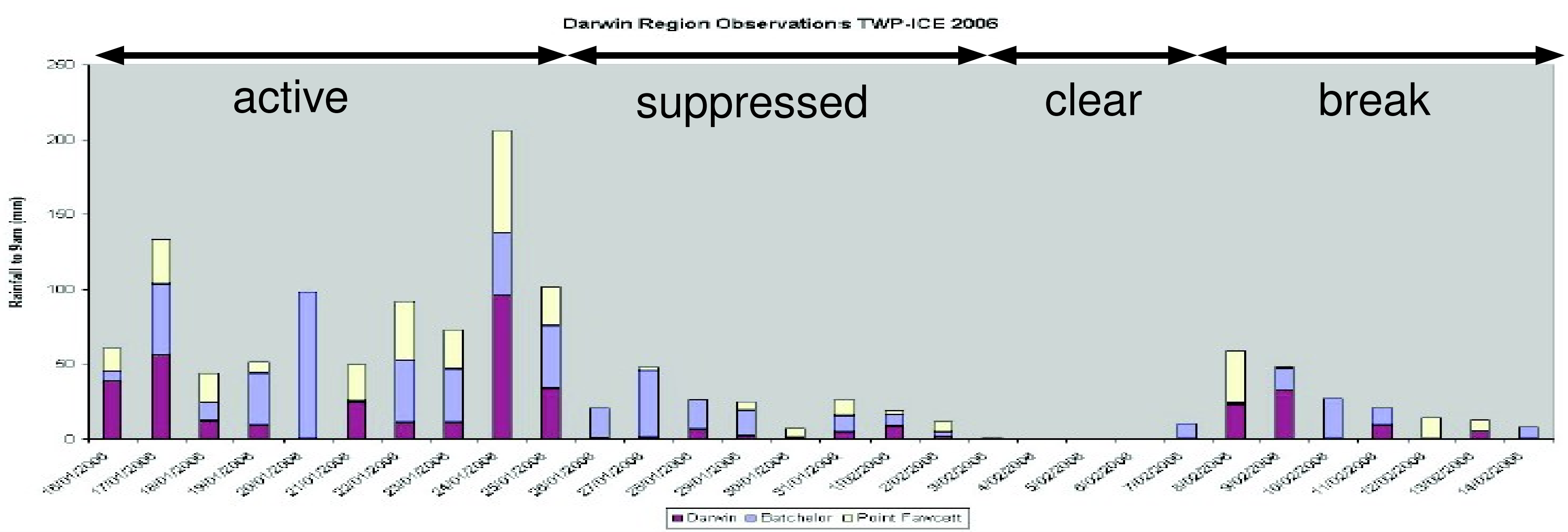
Darwin, Australia,
19 January-13 February 2006



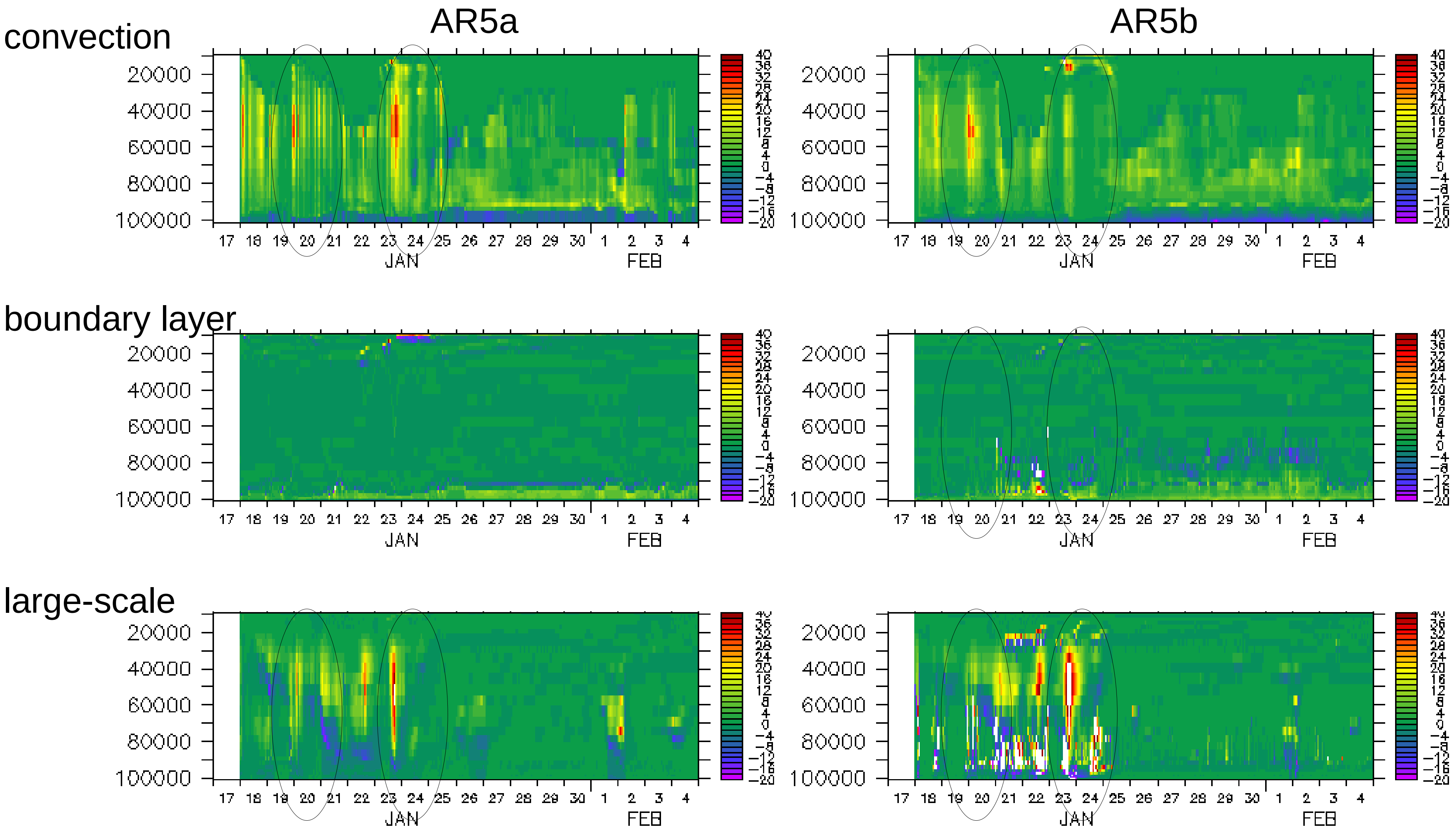
> *Observations*
- surface flux
- soundings
- CPOL RADAR

> *CRMs intercomparaison* (Fridlind et al., en préparation)
- constant SST forcing
- large-scale forcing deduced from variational analysis

> *SCM simulation with LMDZ*
AR5a: diffusion + KE
AR5b: MY + thermals + KE modified + cold pools



Temperature tendencies during TWP-ICE (K/day)



Active period:

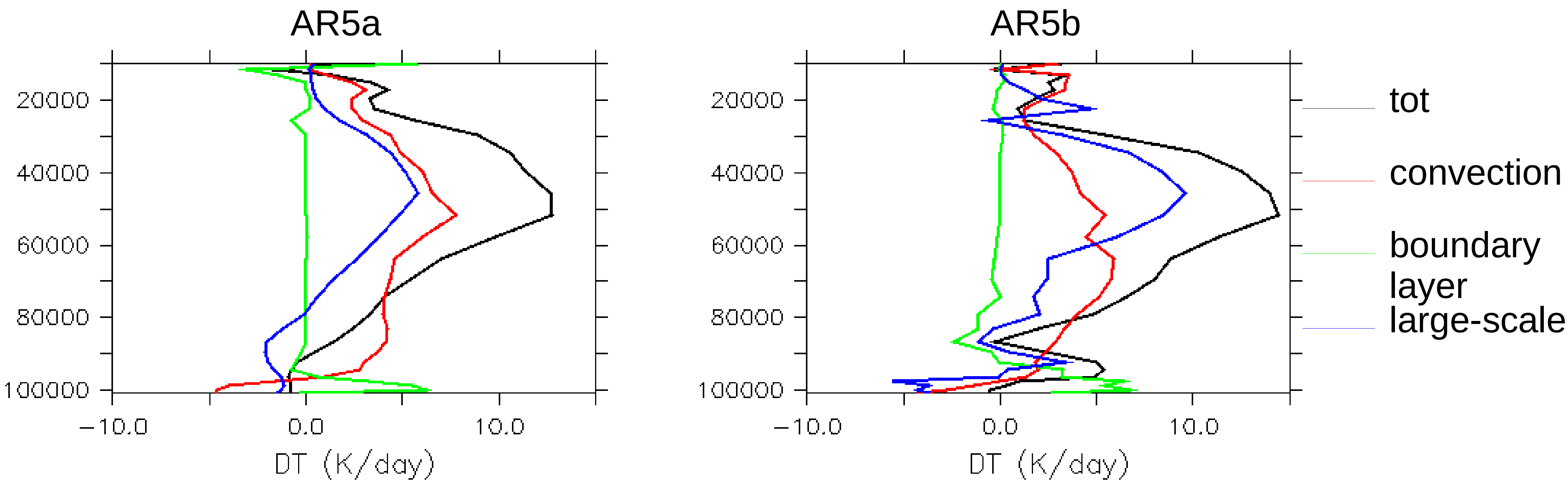
- Convection is weakened when the thermal plume model is active.
- This is compensated by the large-scale scheme.

Suppressed period:

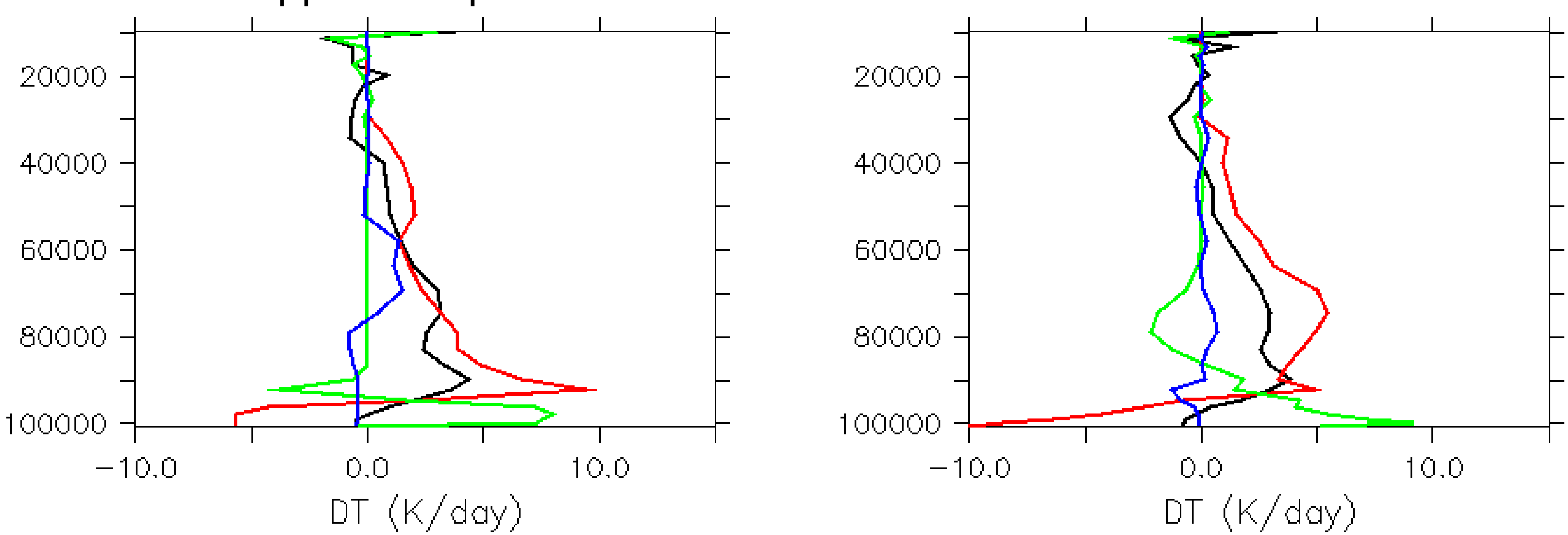
- Deep convection scheme and thermal plume model active simultaneously all the time.

Temperature tendencies during TWP-ICE (K/day)

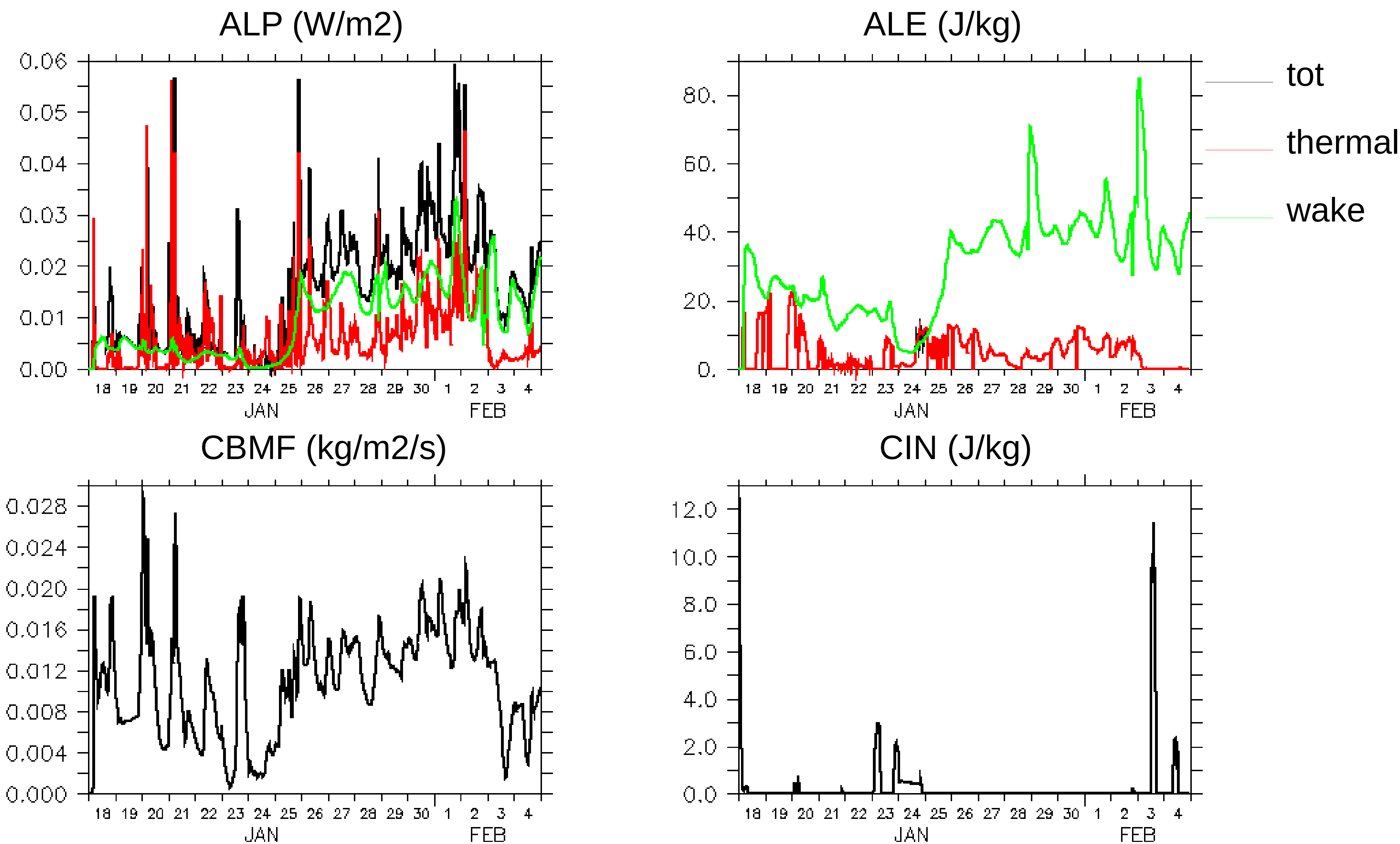
Mean over active period



Mean over suppressed period

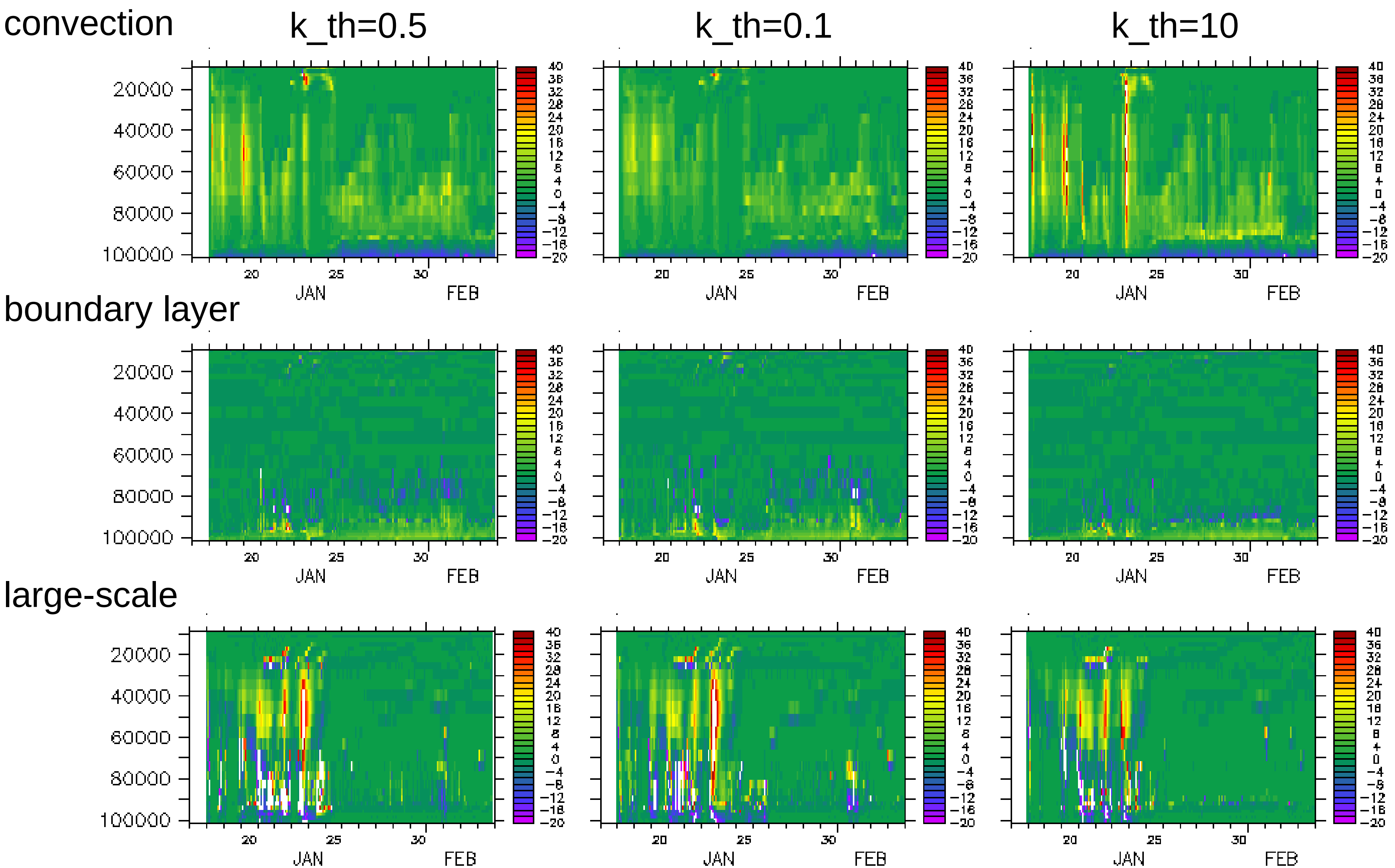


Lifting energy and power during TWP-ICE



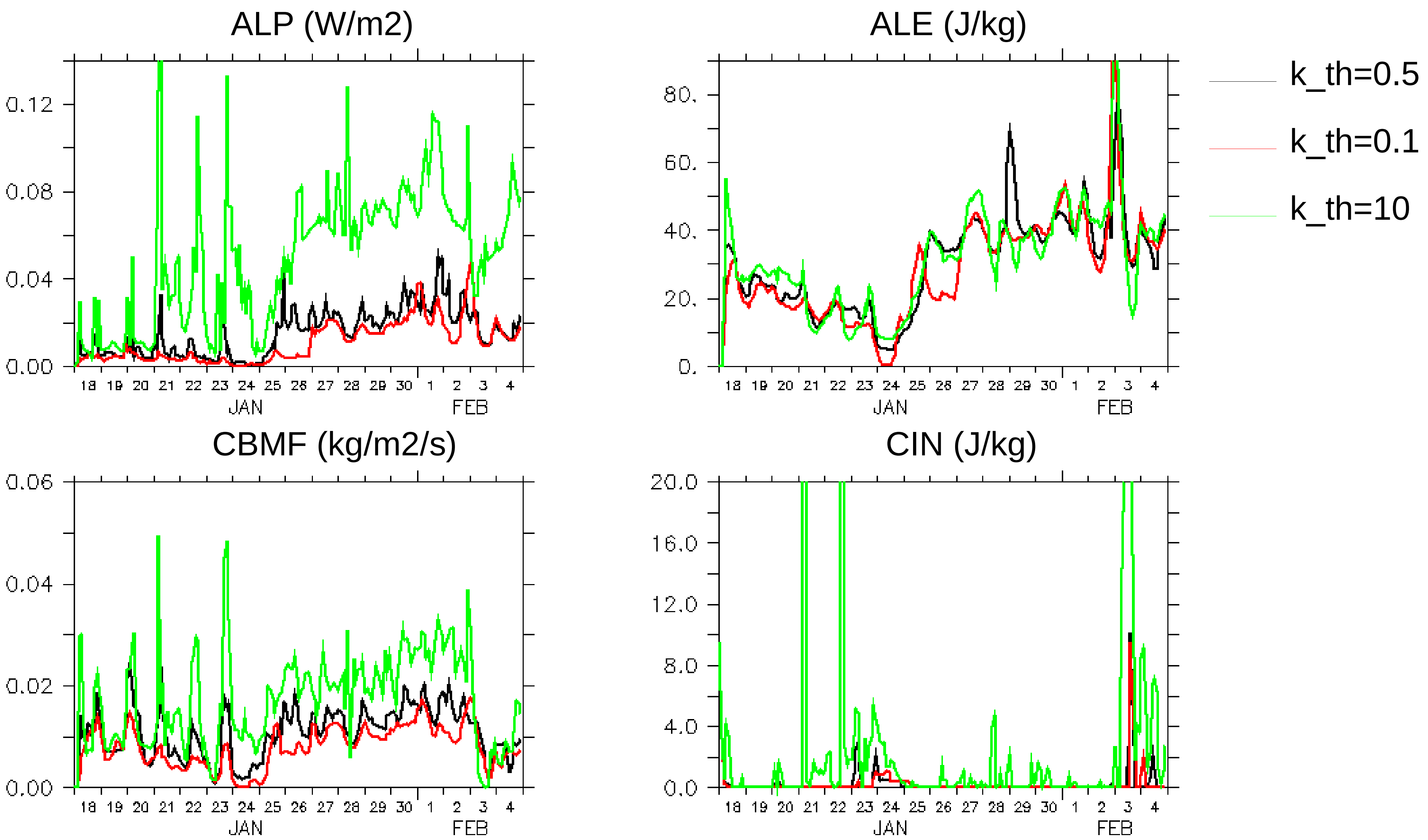
- Wakes maintain convection during both the active and suppressed periods.
- Thermals provide energy for convection: less than wakes during the suppressed period but more during strong events of the suppressed period.

Sensitivity to ALP_TH



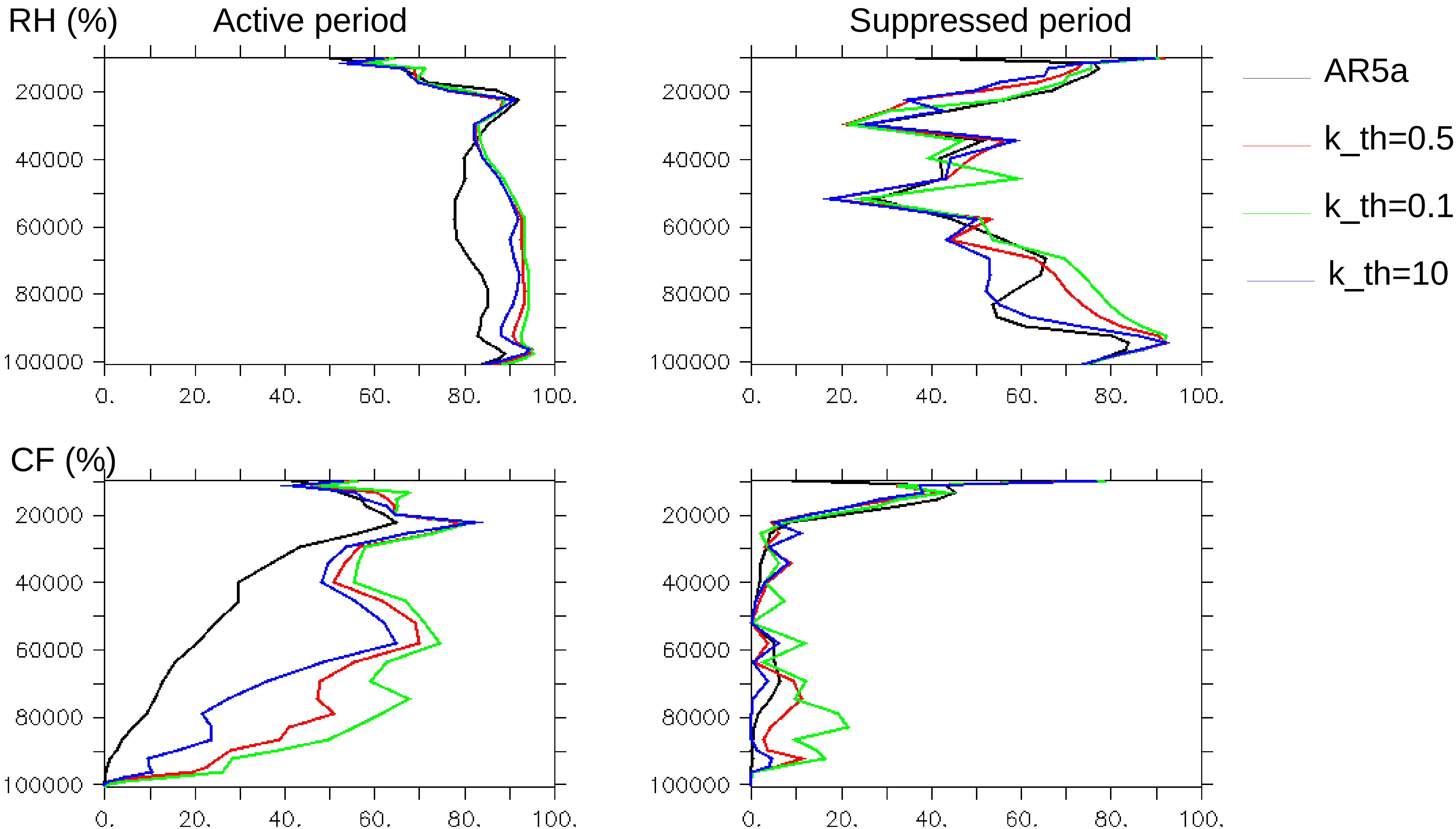
- the more lifting power thermals supply to convection, the more convection is strong and thermals are suppressed.

Sensitivity to ALP_TH



- The CBMF increase is reduced by the increase of CIN.

Sensitivity to ALP_TH



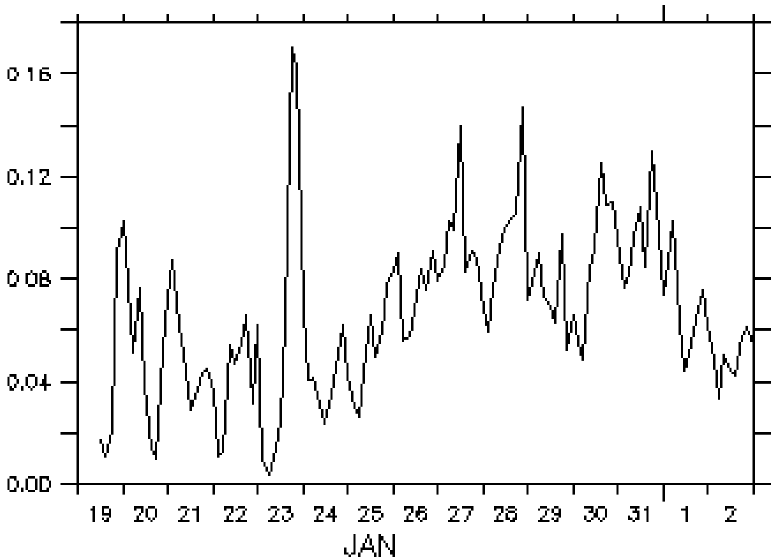
The more thermals are active, the more humid is the 900-600hPa layer
and the more low clouds we get.

Ongoing work

Using CRM simulations further to test assumptions
at the basis of the parameterizations

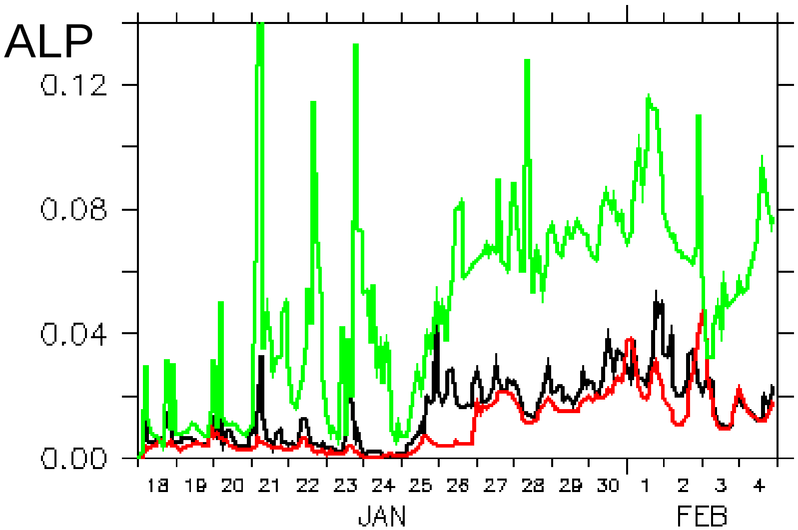
DHARMA

w'3

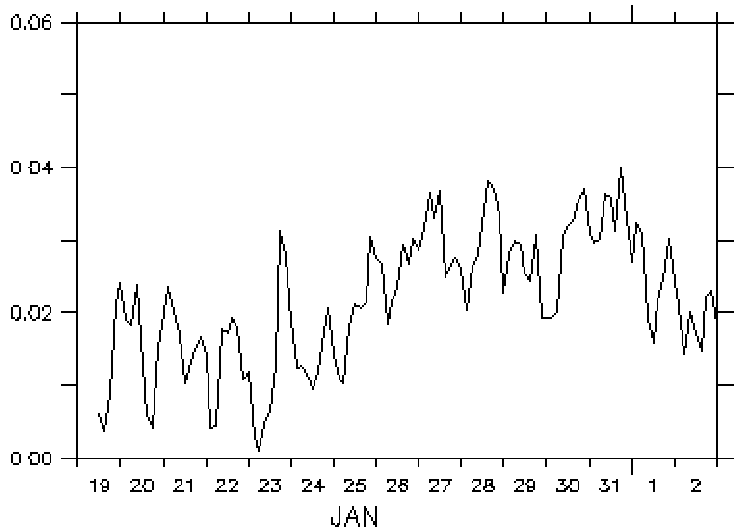


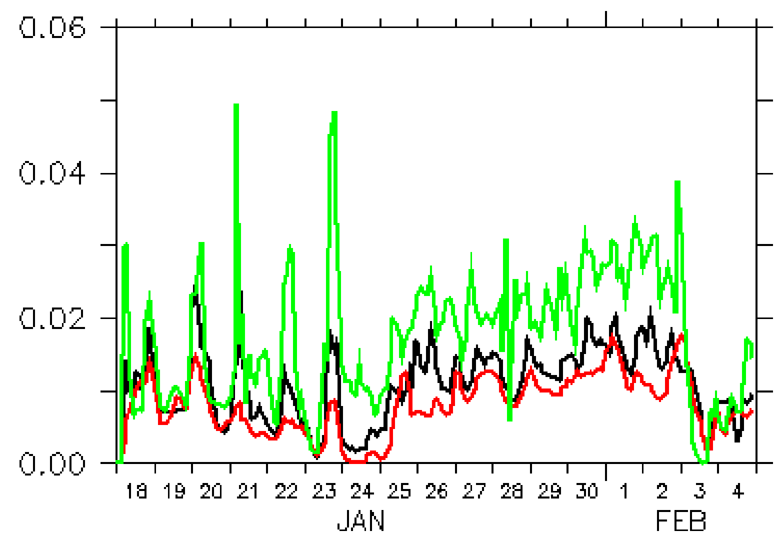
LMDZ

ALP



CBMF

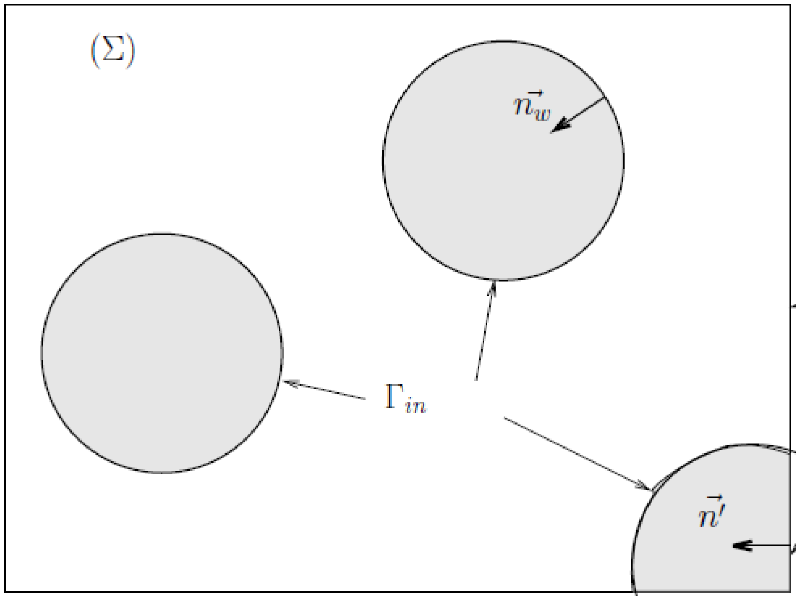




Ongoing work

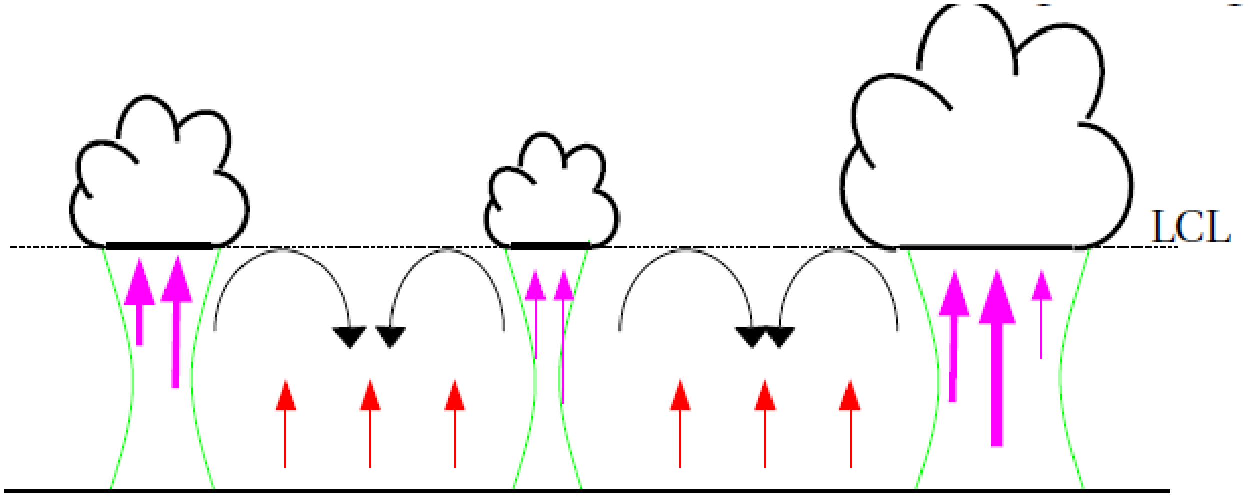
- Coupling between diffusion, thermals and wakes

Distinction of two environments:
inside/outside wakes
Should help to maintain longer both wakes and thermals outside wakes



- ALE and ALP computation

Consideration of “intra” and “inter” thermals fluctuations and of large scale convergence



Concluding remarks

- Moist thermals pre-condition deep convection
- Once activated, deep convection suppresses thermals, but
- if thermals are stronger than expected, they can weaken deep convection

How to handle the interactions between shallow and deep convection schemes?
What about unified schemes?

- Need of LES simulations to test hypothesis at the basis of parameterizations

- Deep convection schemes are often meant to represent shallow clouds:

Which one from the thermal plume model and the deep convection scheme is supposed to take care of the “congestus” phase?

- Be careful of differences between oceanic and continental conditions