Couplage des thermiques et des poches froides dans LMDZ

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Motivation

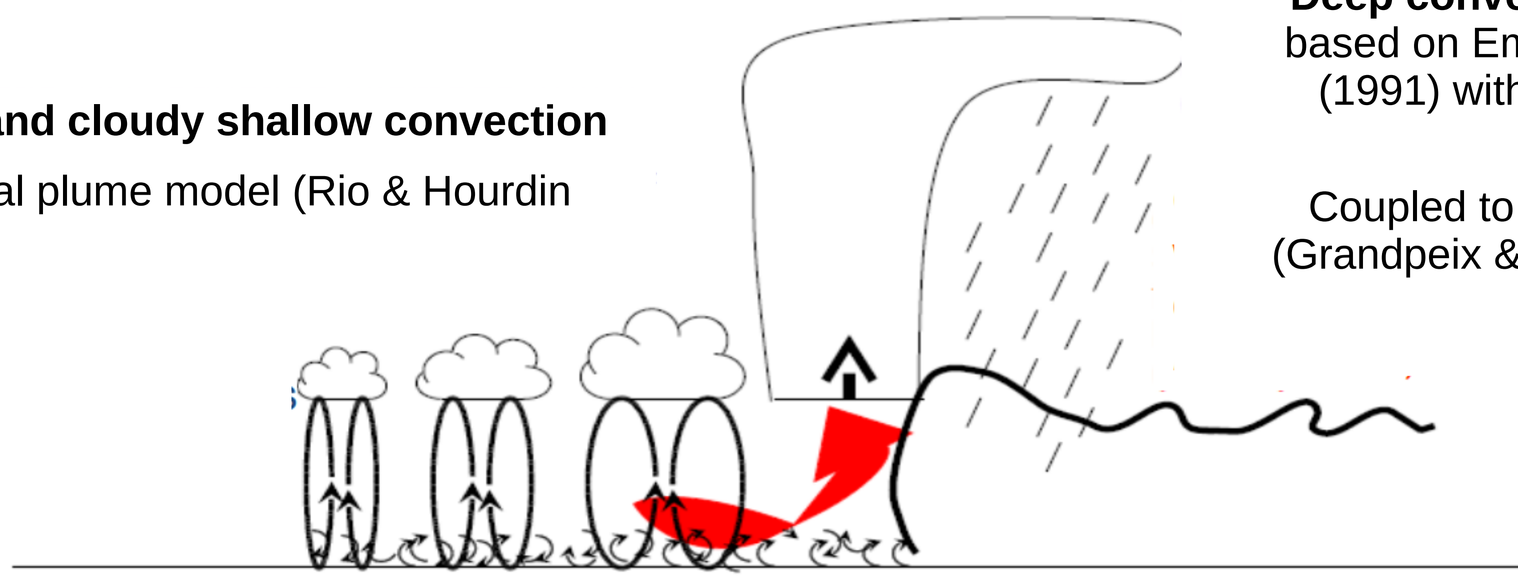
Two convective schemes in LMDZ6

- Emanuel's convective scheme, used to represent deep convection
- The thermal plume model (Rio and Hourdin 2008) to represent dry and cloudy shallow convection

→ cold pools are coupled with the deep convective scheme only

Dry and cloudy shallow convection

Thermal plume model (Rio & Hourdin 2008)



Deep convective scheme based on Emanuel scheme (1991) with ALP closure

Coupled to **cold pools** (Grandpeix & Lafore 2010)

In observations (especially in the trade wind region), presence of cold pools below shallow cumuli as well (Zuidema et al. 2012)

→ coupling cold pools with the shallow convective scheme

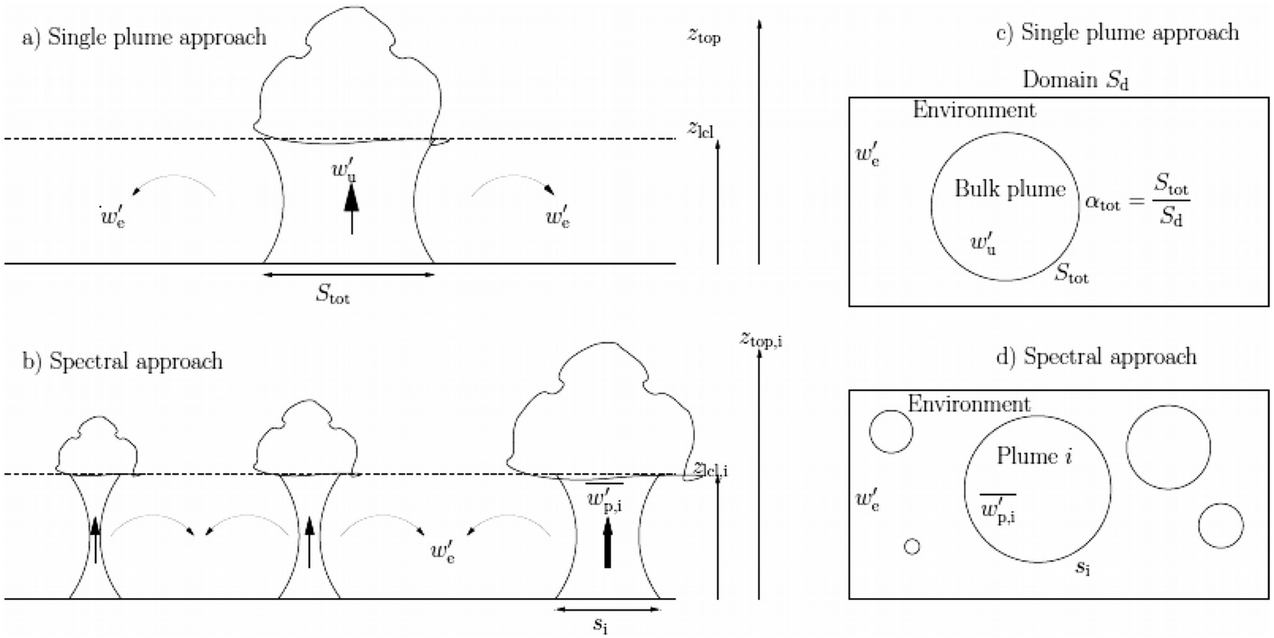
Coupling cold pools with the shallow convective scheme – original idea

Only the "**deepest shallow cumuli"** may precipitate and therefore create cold pools

=> use the cross-section spectrum of Rochetin 2012 to select only the shallow cumuli "deep enough"

$$\sqrt{s_2} = a(\langle z_{top}\rangle - \langle z_{lcl}\rangle) + b\langle z_{lcl}\rangle$$

$$P_2(s) = \frac{1}{s_2}\exp\left(\frac{-s}{s_2}\right)$$



Rochetin et al., JAS 2014

Assumptions:

1) clouds start to precipitate when $s > s_{trig} = 5\,km^2 \rightarrow s_{tot} = \int_{s_{trig}}^{\infty} \frac{N_2}{s_2}\exp(-s/s_2)$

2) The cooling and moistening due to the evaporation of precipitation is homogenized below cloud base

3) The thermals are present only outside cold pools

SCM Results – Rico case

I) Issues regarding the evaporation of precipitation

- Contrary to LES simulations and observations, no precipitation reach the ground => all precipitation is evaporated in clouds or just below
- <u>Explanation</u>
  - In fisrt, we proceed from top to bottom in the following order: 1. Reevaporation of rain 2. Formation of cloud 3. Formation of rain
  - Formula for the evaporation of rain from Sundqvist (1988)

$$\frac{\partial P}{\partial z} = \beta[1 - q/q_{sat}]\sqrt{P}$$

- In the original paper, this formula is applied only in the cloud free part, whereas in our model, since clouds are not formed at this stage, the formula is applied over the total grid cell → too much rain evaporation
- Currently in the model: it is not possible to saturate a domain larger than the largest cloud above

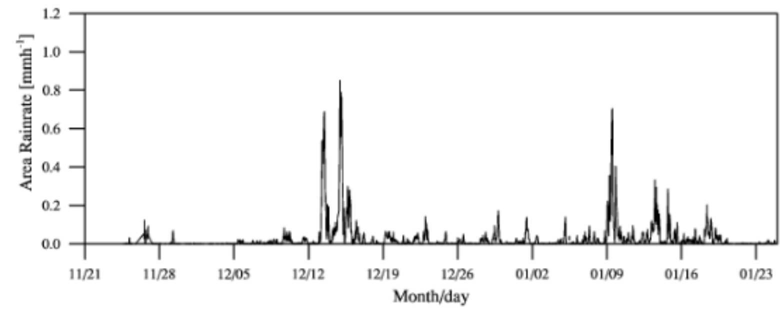
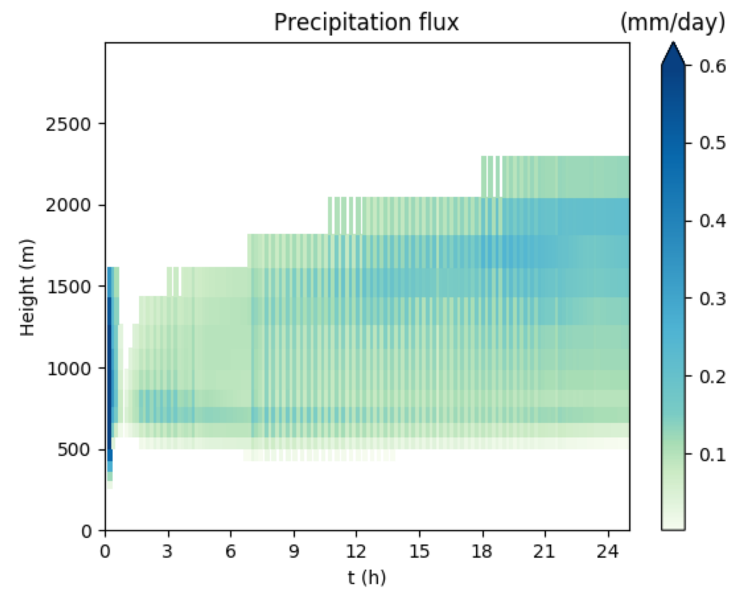
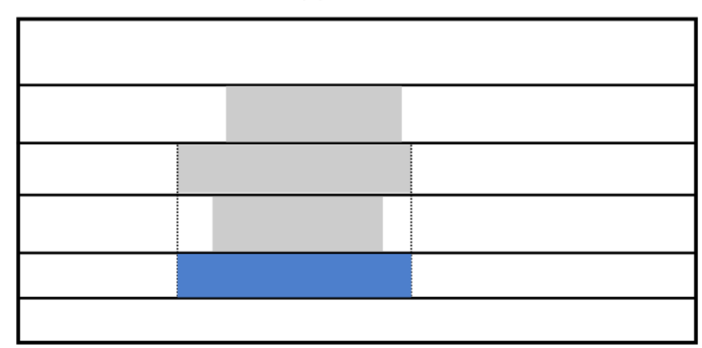


Figure 1. Time series of area rainfall during RICO, derived from SPol radar observations.





SCM Results – Rico case

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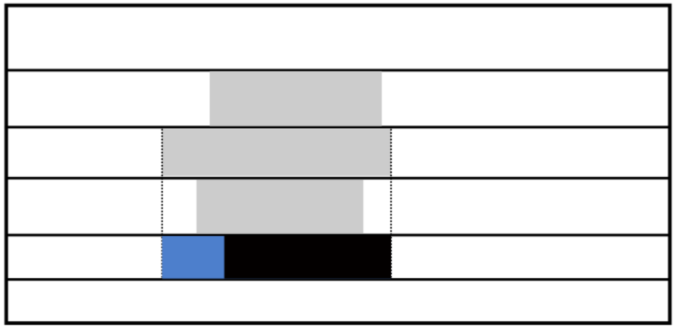
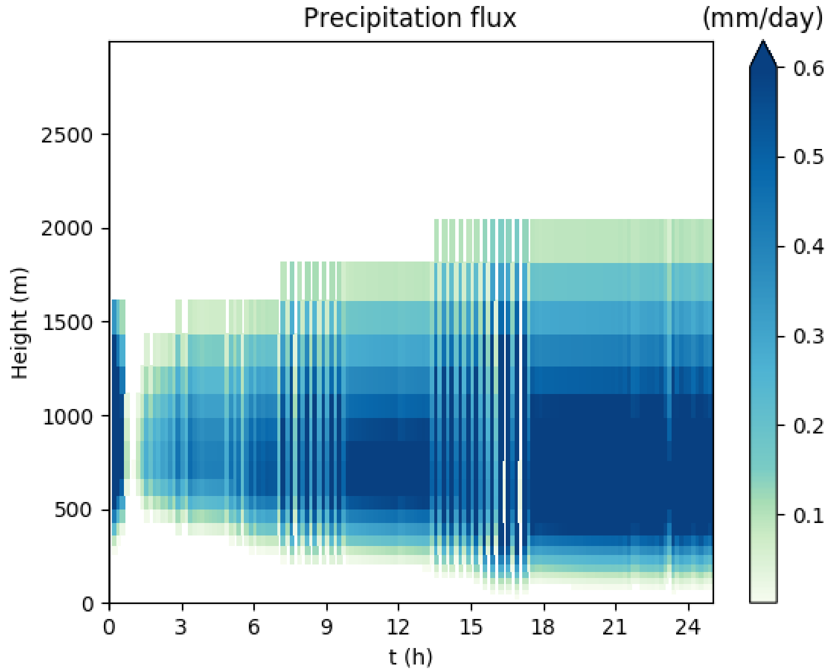


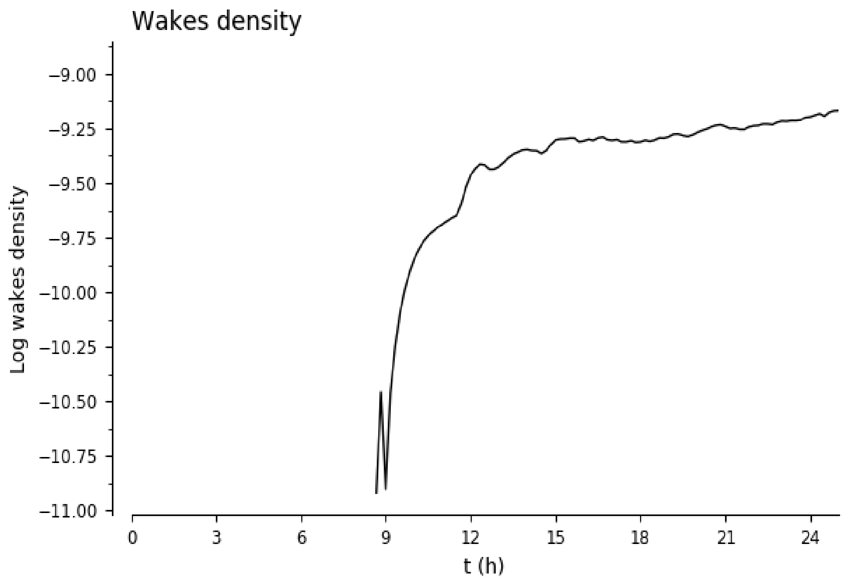
<u>Proposition</u>

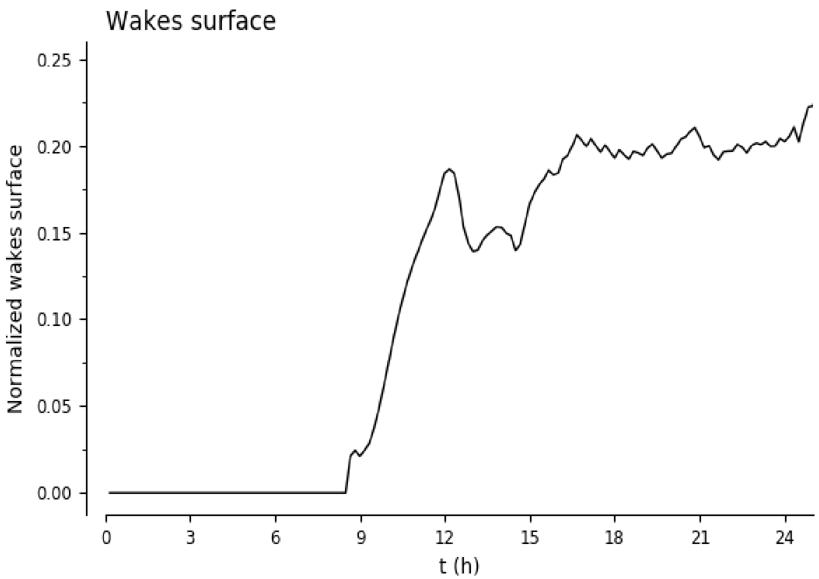
- At each level, in fisrt, before reevaporating the rain, we compute the cloud fraction by using cloudth in diagnostic mode.
- Then, we say that it is not possible to saturate a fraction greater than the non-overlapping fraction between the largest cloud above and the diagnosed cloud fraction (assuming a maximum overlap between clouds at different level)
- Precipitation flux more consistent with what we would expect with a maximum at cloud base and more precipitation reaching lower levels

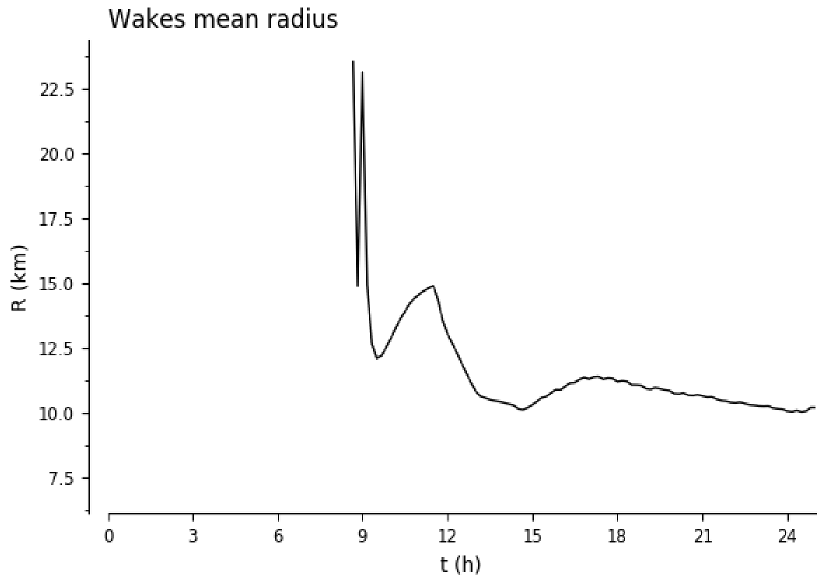


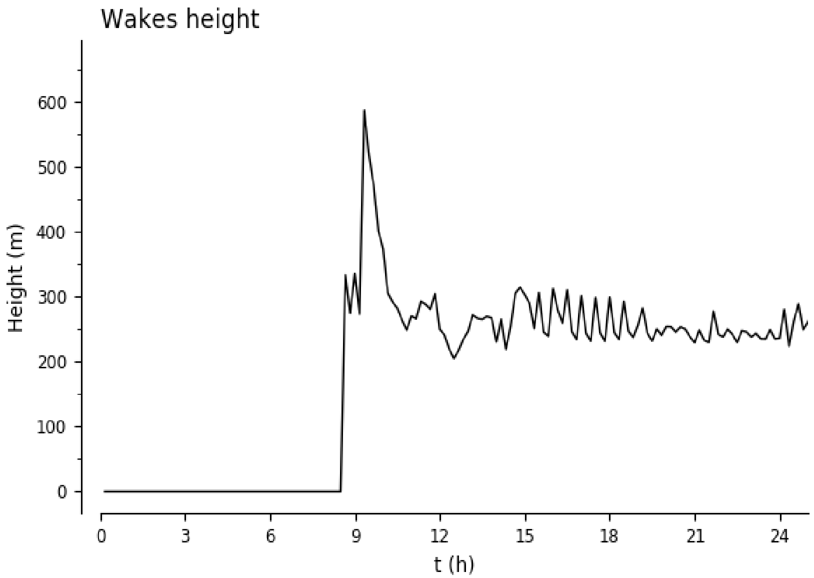
SCM preliminary results – Rico case

II) Wakes characteristics









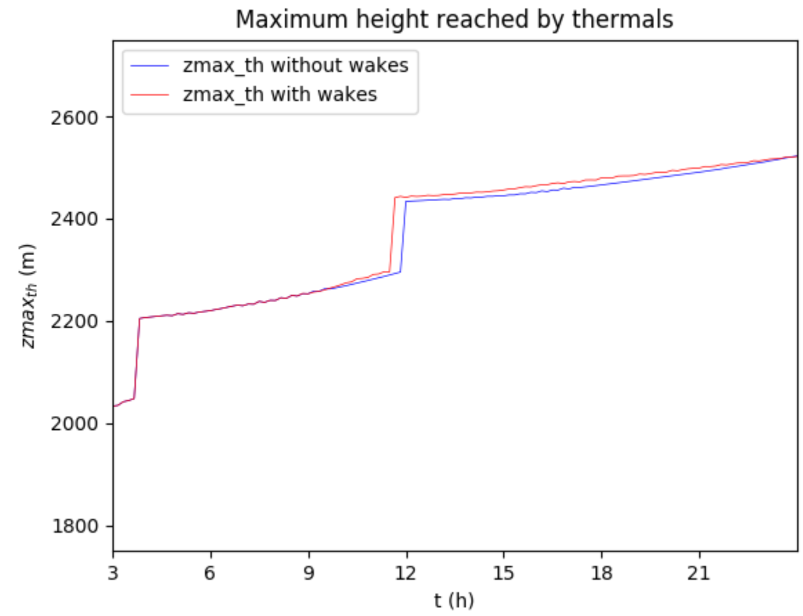
SCM preliminary results – Rico case

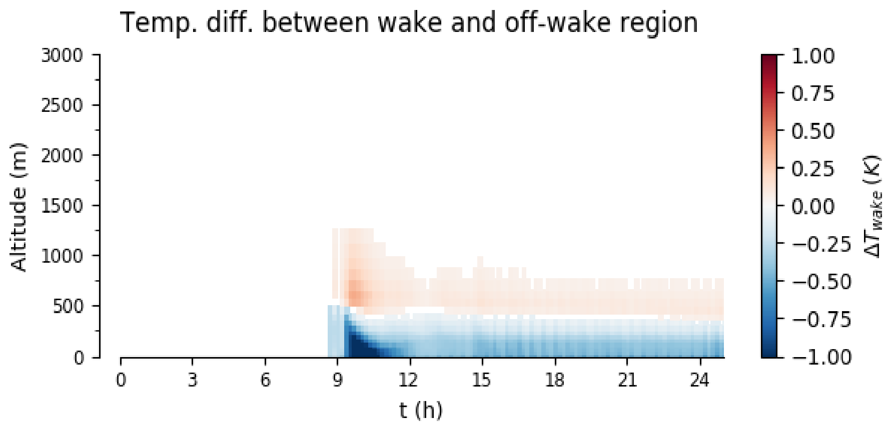
III) Wakes profile and tendencies

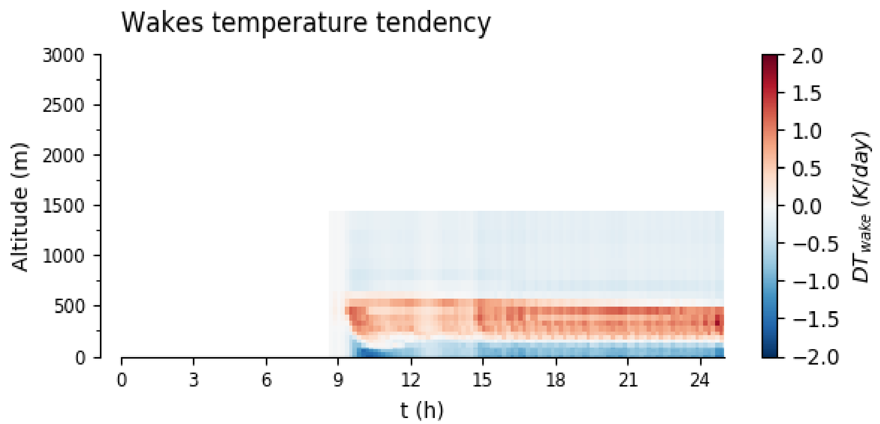
- Thermals are slightly enhanced by wakes, because they are initialized in the off-wake region (warmer than the mean grid cell)

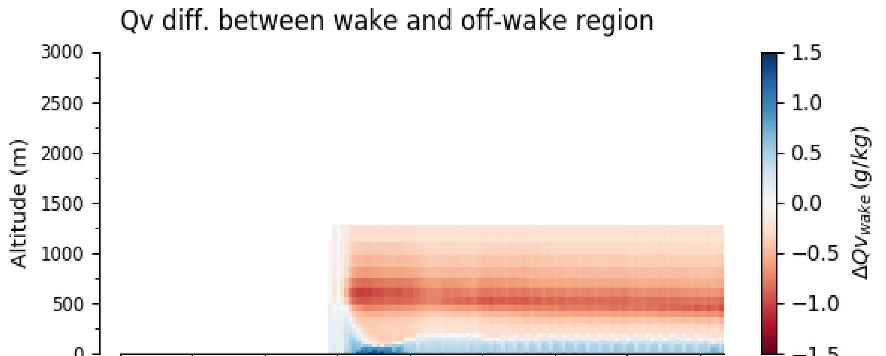
  → there is therefore a thermodynamic feedback from wakes on the thermals

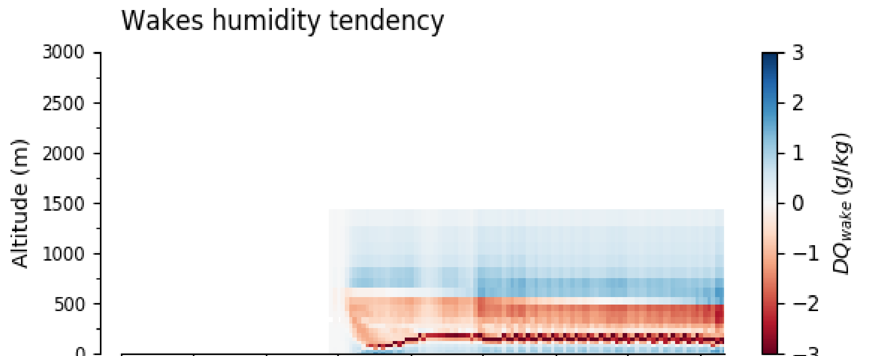
  → the dynamic feedback still has to be represented



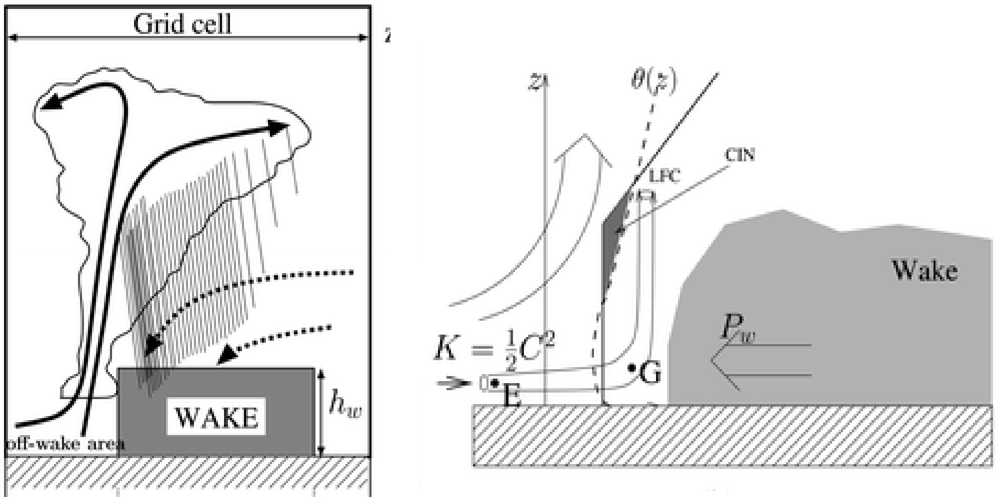








Perspectives – Parameterize the dynamical activation of thermals by cold pools



Grandpeix and Lafore., JAS 2010

In LMDZ, the parameterizations of triggering and closure of deep convection use an Available Lifting Energy (ALE) and an Available Lifting Power (ALP).

- <u>In the current version of the cold pool scheme:</u>

$$ALP \propto C_*^3 h_w$$

ALE calculated thanks to a Bernoulli equation

$$\frac{1}{2}v^2 + \frac{p'}{p} - \int_{z_0}^{z} B\,dz$$

applied to environment air entering at the relative speed C and reaching the LFC

$$\frac{1}{2}C^2 = p' = K_{LFC} + |CIN|$$

Condition for activation:

$$ALE = \frac{1}{2}C_{max}^2 = WAPE > |CIN|$$

→ no dependency of wake height

<u>Proposition to account for cold pool height:</u>

Calculate the distribution of field lines around the wake thanks to the velocity potential

$$\phi = Cx + \frac{C\,h_w}{\pi}\ln\sqrt{x^2+y^2}$$

(Prandtl theory of potentials – source + uniform flow)

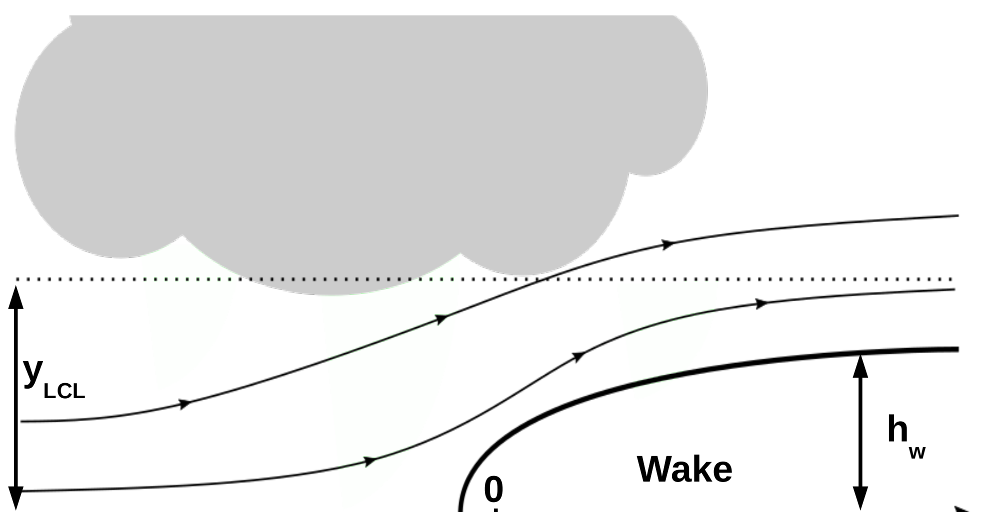
$$v = \frac{\partial\phi}{\partial y} = \frac{y\,C\,h_w}{\pi\sqrt{x^2+y^2}}$$

At cloud base

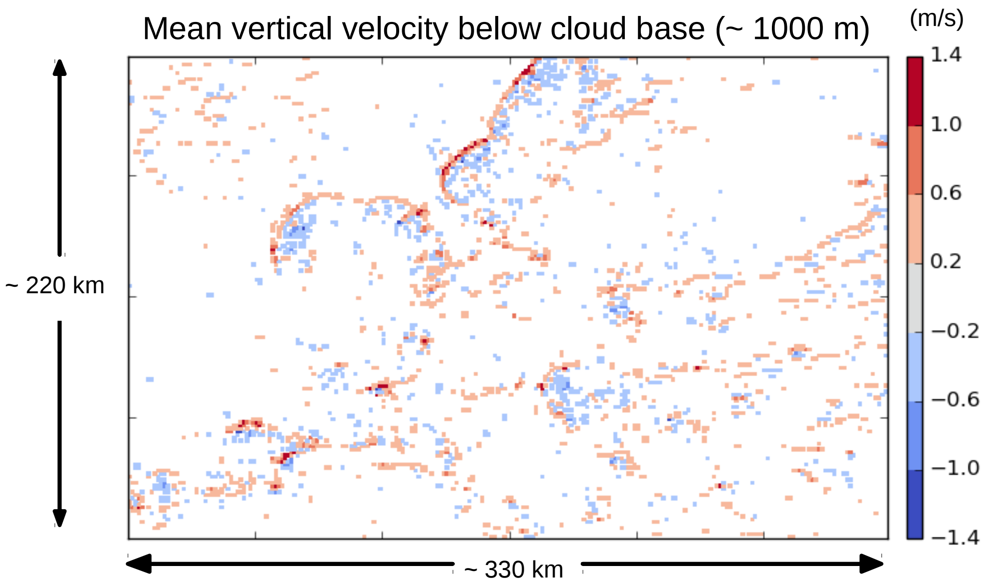
$$v_{max} = v(x=0, y=y_{LCL}) \propto \frac{C\,h_w}{y_{LCL}}$$

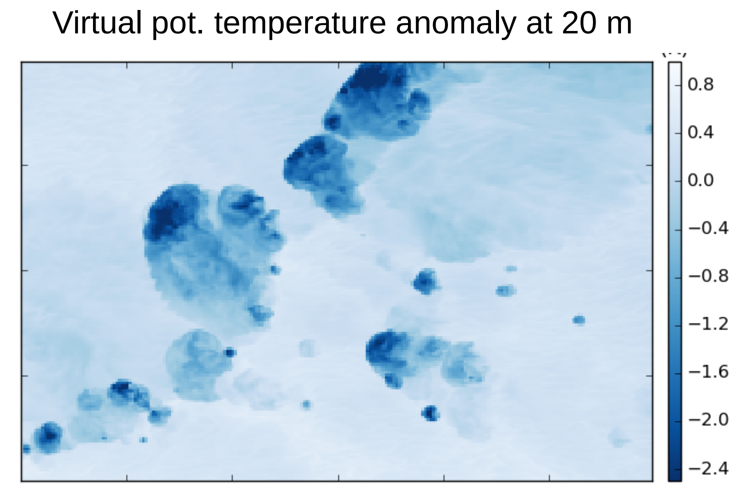
The condition becomes

$$ALE = k\frac{1}{2}C_{max}^2\left(\frac{h_w}{y_{LCL}}\right)^2 = k\,WAPE\left(\frac{h_w}{y_{LCL}}\right)^2 > |CIN|$$



Perspectives – Parameterize the dynamical activation of thermals by cold pools





How parametrize the dynamical activation of thermals by cold pools?

1) Use a closure similar to the one used for the deep convection scheme, with an ALP closure using $P_{lift}^{wk} \propto C_*^3 h_w D_{wk} 2\pi R_{wk}$
2) Change the existing closure of the thermal plume model:
   a. Increase the mass flux in the presence of cold pools
   b. Increase the maximum vertical velocity in the presence of cold pools