Lateral mixing in shallow convection: In theory and in practice

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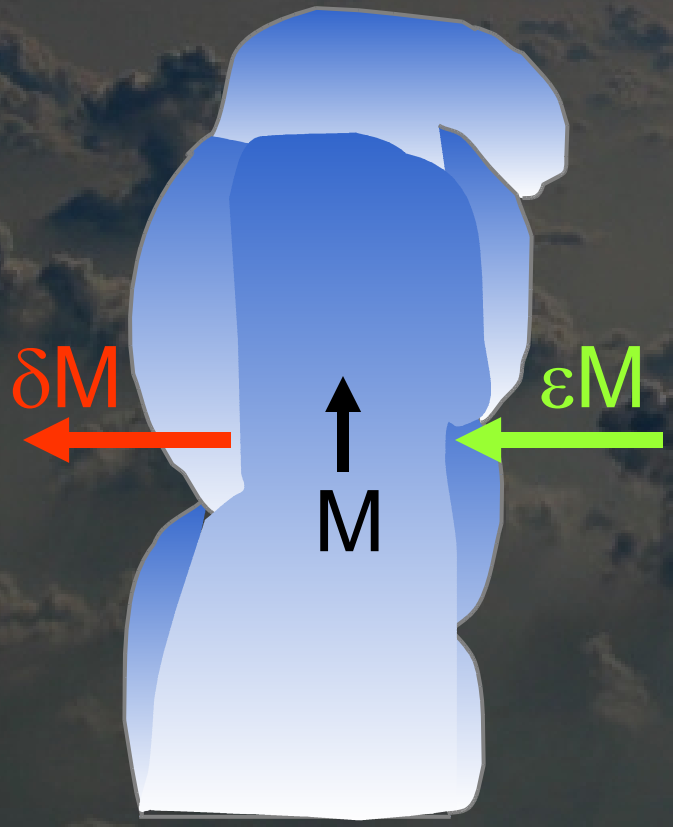
Outline

- ***Basics*** of convection schemes
- ***Expressions*** for lateral mixing from first principles
- ***Validation*** of the expressions
- ***Link*** to practical application
- ***Summary/Conclusions***

Convection is parameterized by a mass flux scheme

Key parameters in a mass flux scheme: ε and δ

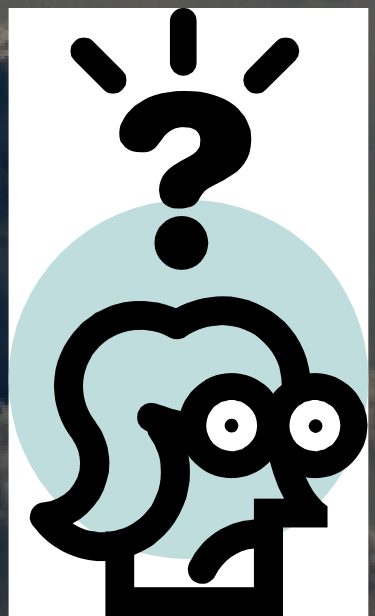


Different approaches for ε and δ:

- *Constant values*
- *Kain Fritsch (90, 04)*
- *De Rooy Siebesma (08)*

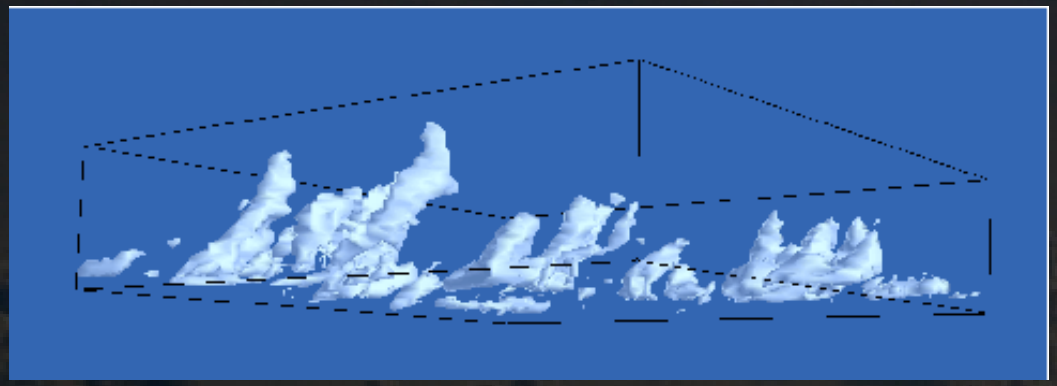
We need more insight into the behavior of ε and δ

For example: Why does δ varies so much more than ε ?



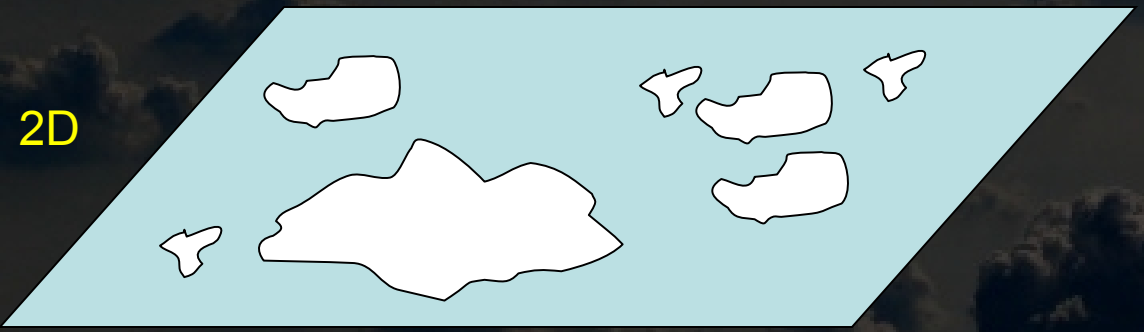
Expressions for ε and δ

3D



$$a_c = \frac{A_c}{A} \qquad \frac{\partial a_c}{\partial z} \neq 0$$

2D



$$\overline{\varphi_c} \equiv \varphi_c \equiv \frac{1}{A_c} \iint\limits_{\substack{cloudy \\ area}} \varphi dx dy$$

Starting point:

General equations for arbitrary in-cloud fields (Siebesma 98).

expressions

continuity equation
w_c equation
$q_{t,c}$ equation

Assumptions (literature)

$\Rightarrow$

Eliminate unknowns

q_t equation can be written as:

$$\frac{\partial q_{t,c}}{\partial z} = -\left(\frac{\alpha B}{w_c^2} - \frac{1}{w_c}\frac{\partial w_c}{\partial z}\right)\left(q_{t,c} - q_{t,e}\right)$$

Gregory(01)

An expression for δ

$$\varepsilon_{\exp} = \frac{\alpha B}{w_c^{\,2}} - \frac{1}{w_c}\frac{\partial w_c}{\partial z}$$

$$\frac{\partial M}{\partial z} = (\varepsilon - \delta) M$$

$$M = a_c w_c$$

$$\delta_{\exp} = \frac{\alpha B}{w_c^{\,2}} - \frac{2}{w_c^{\,2}}\frac{\partial w_c}{\partial z} - \frac{1}{a_c}\frac{\partial a_c}{\partial z}$$

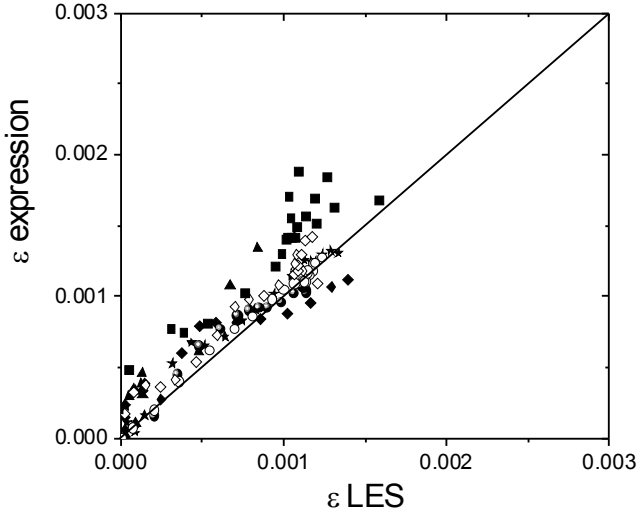
!

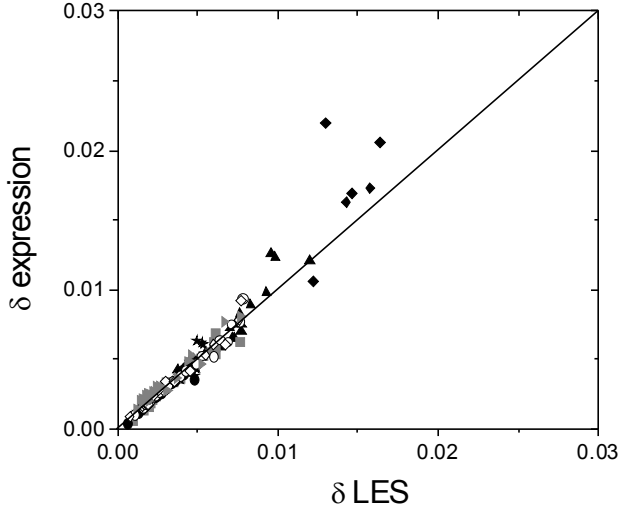
validation

ε

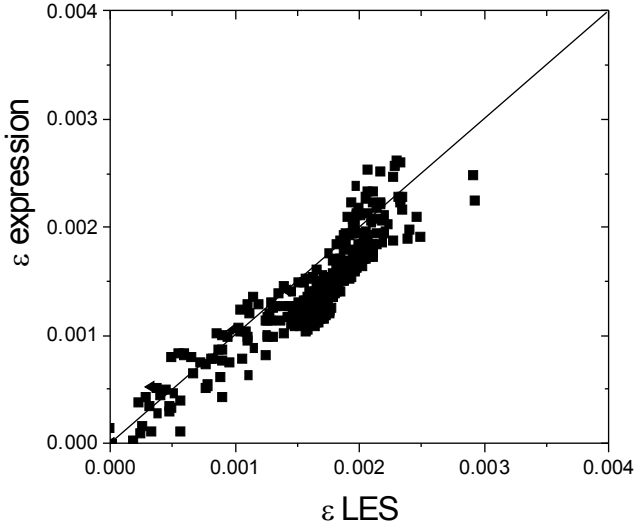
δ

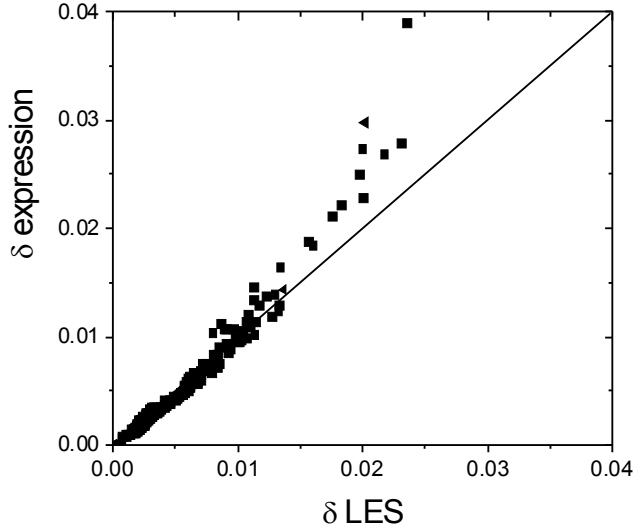
ARM





RICO





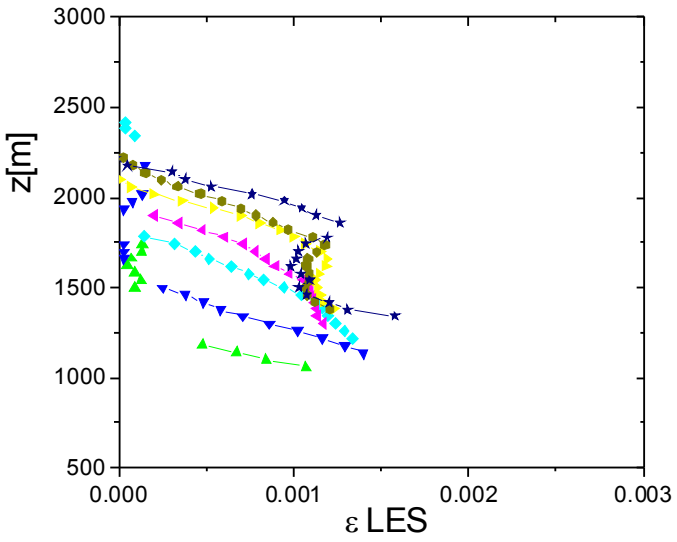
validation

ARM

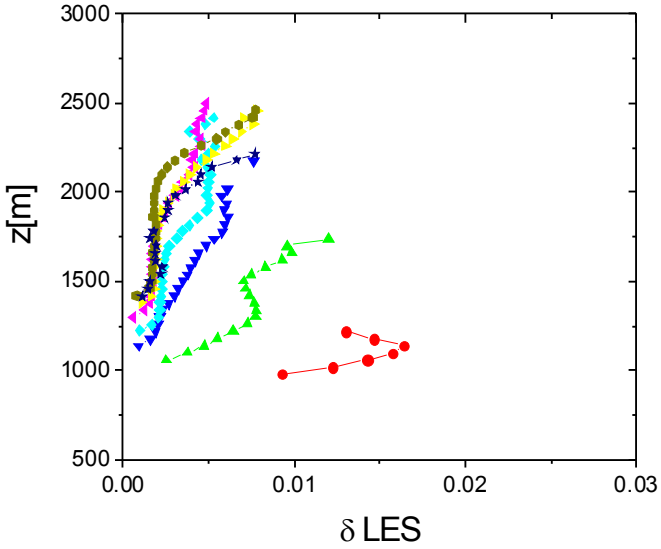
LES
(Best estimate)

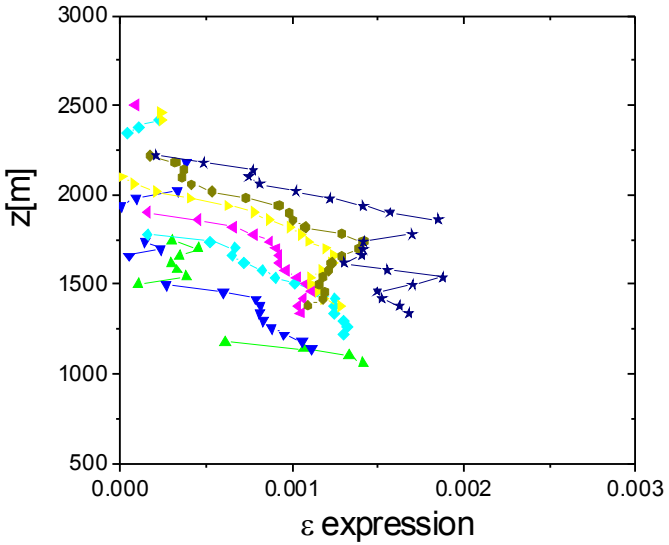
expression

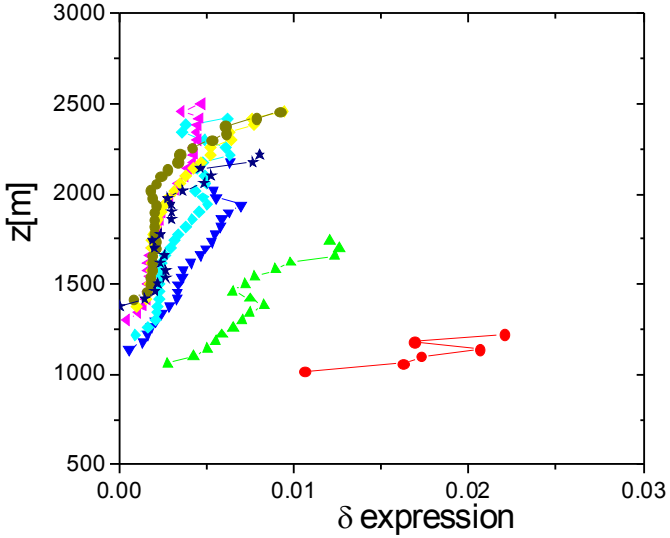
ε



δ







practice

What's the practical use of the expressions?

- Judge existing parameterizations:

-ε according to Gregory (01) misses essential term

-δ (with $\partial a_c/\partial z$) is closely linked to $\partial M/\partial z$ (via $M=a_c w_c$)

In Harmonie and Racmo: Variation in M-profile is determined by δ (de Rooy Siebesma 08)

- Inspiration for new parameterizations

Possible refinement for ε based on theoretical expressions

Summary/Conclusions

- Expressions from first principles and with a minimum of assumptions (e.g. no constant area fraction)
- Good correspondence with LES diagnosed values
- Gives insight into the behavior of ε and δ
- Helps to judge existing parameterizations
- Inspiration for further developments


Thank you
Questions?