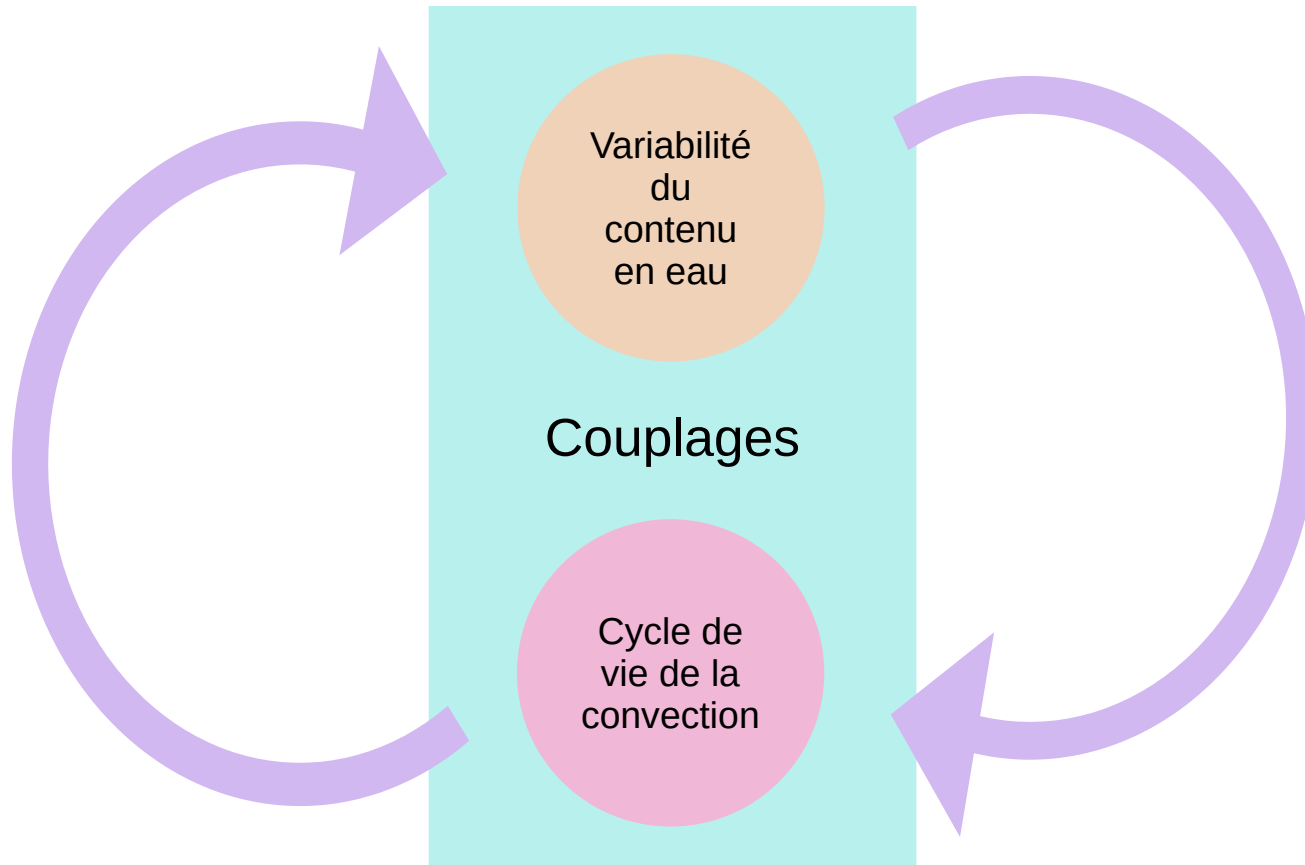


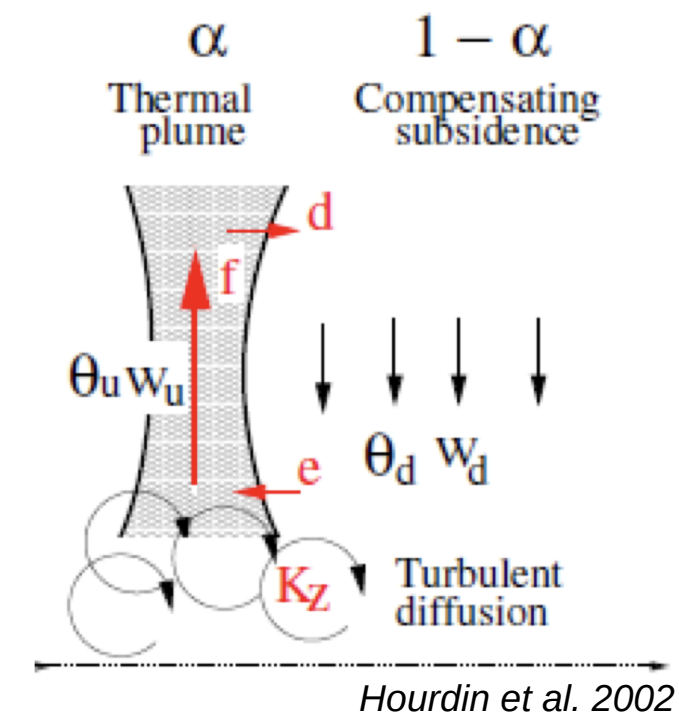
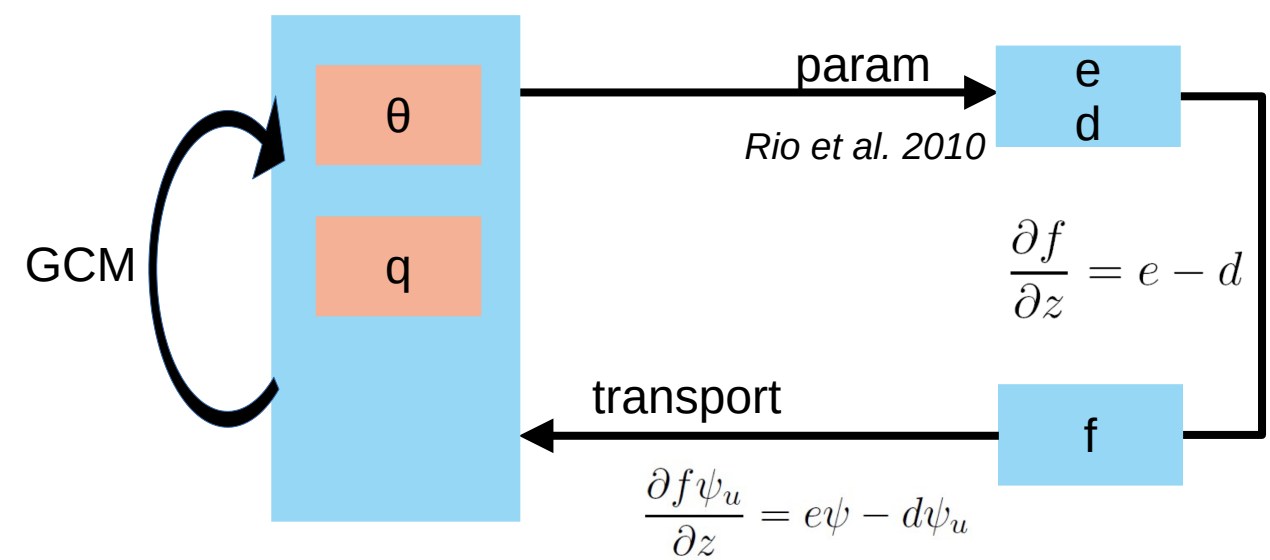
Transport de l'énergie cinétique turbulente par le modèle du thermique de LMDZ

Nicolas Nanou, Frédéric Hourdin, Catherine Rio

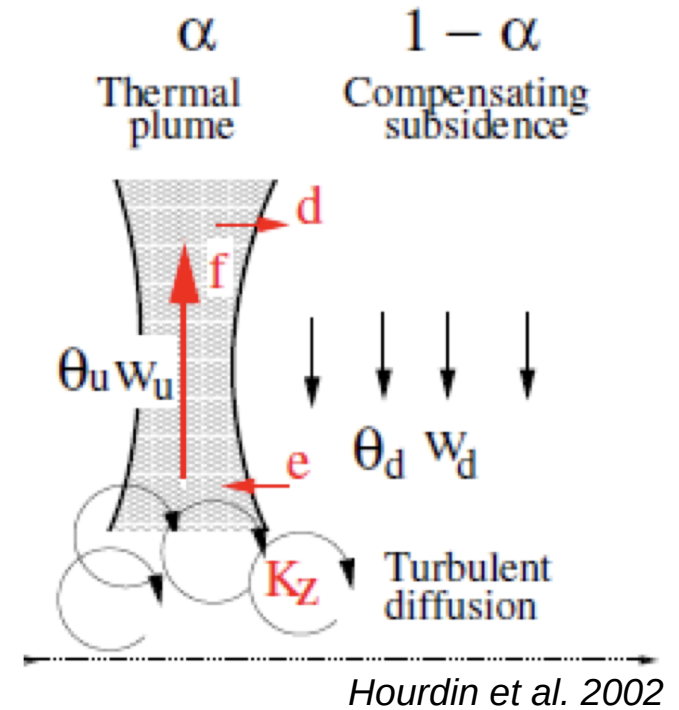
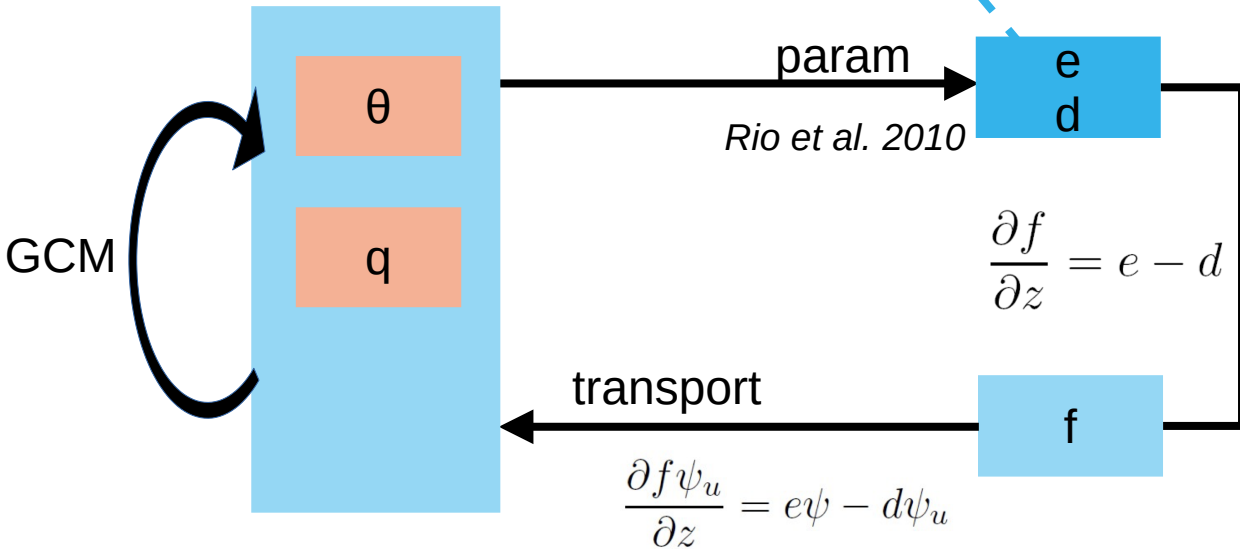
AMA 2026 : Session DEPHY

Motivations : sujet de thèse

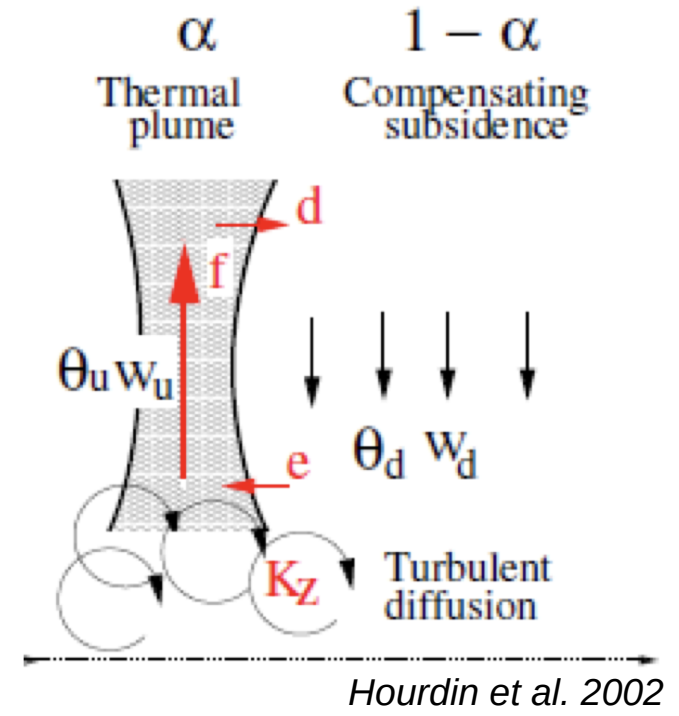
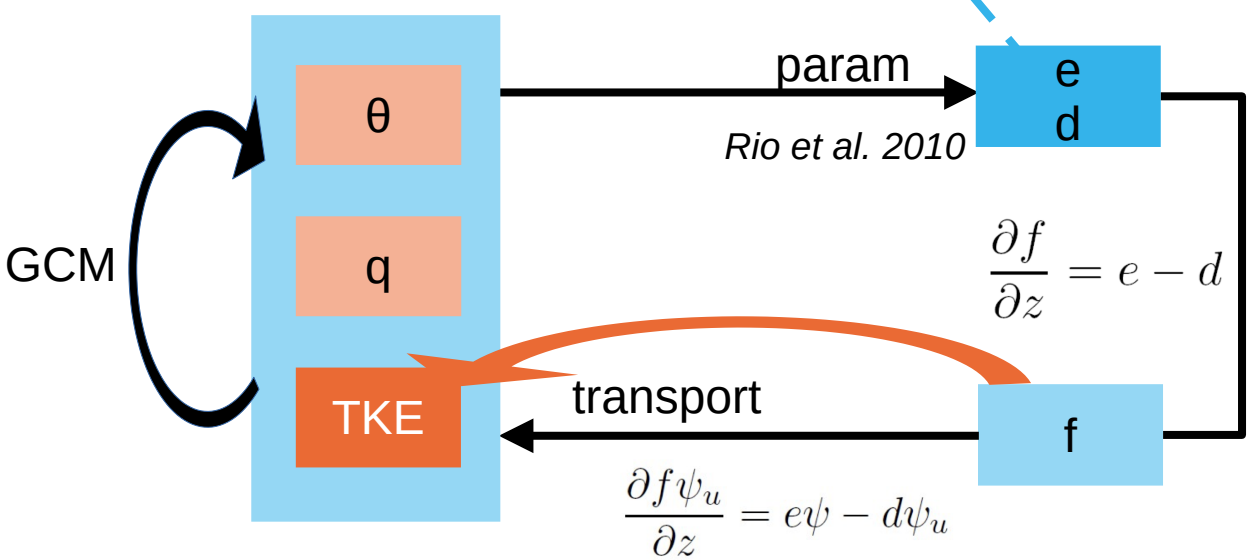




Paramétrisation du mélange sur les bords des thermiques



Paramétrisation du mélange sur les bords des thermiques ——— mélange de petite échelle = TKE dans les thermiques

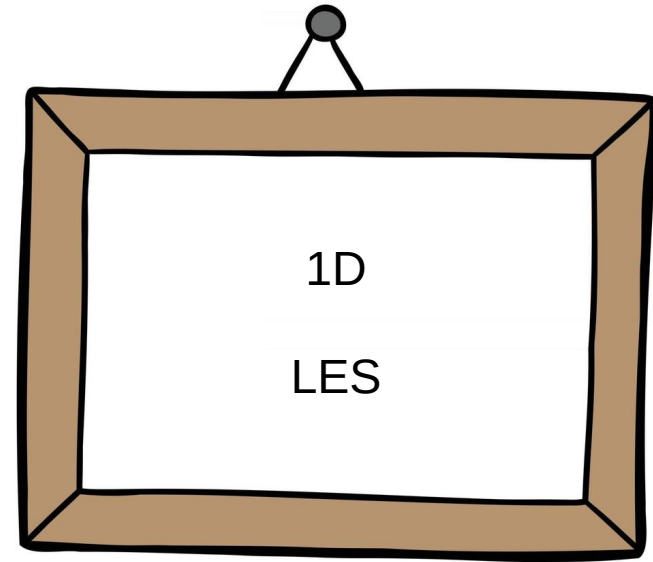


Problématique de l'exposé



I. Simulation : Analyse d'une LES

II. Modélisation : LMDZ

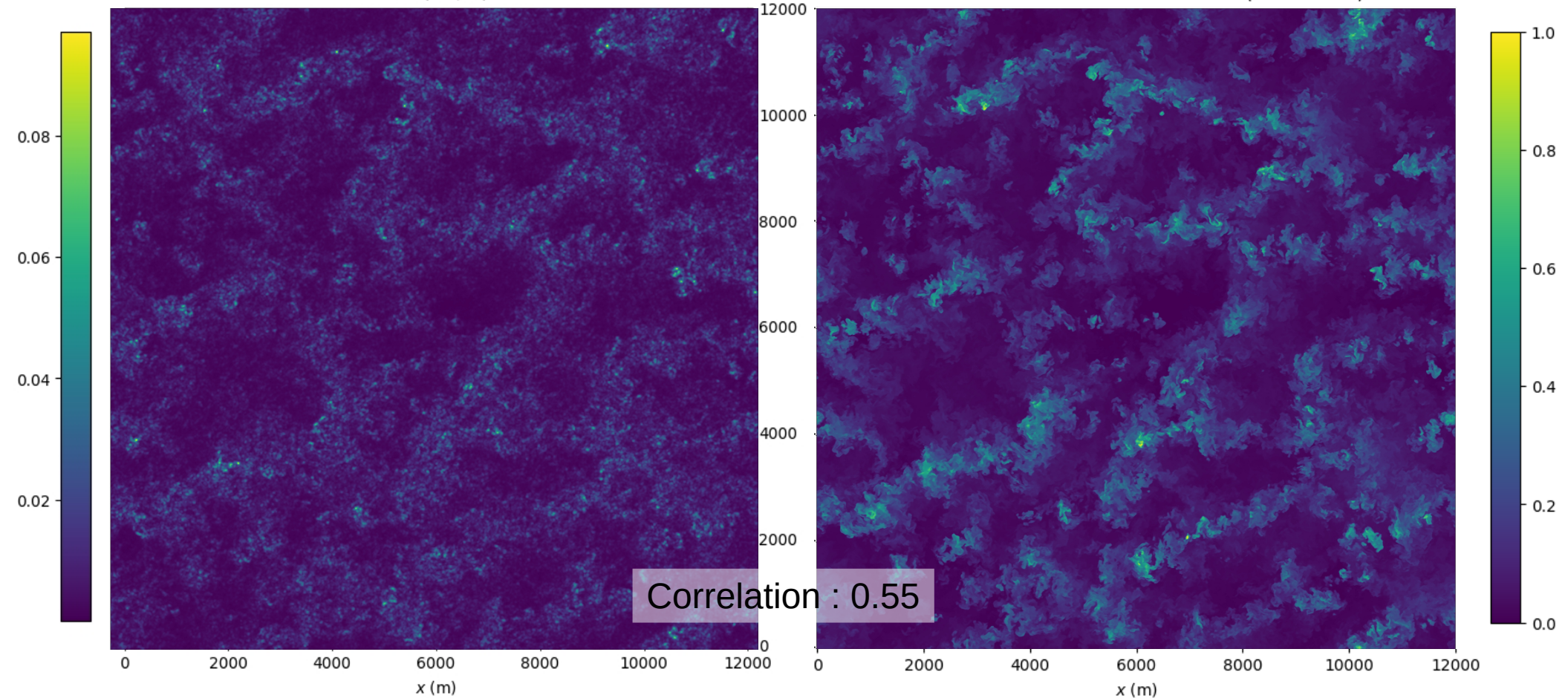


Z = 500 m

I – Simulation (LES)

Cas : ARMCU

Résolution : 8 mètres

TKE (m^2/s^2)Concentration en traceur radioactif (normalisée) *Couvreur et al. 2010*

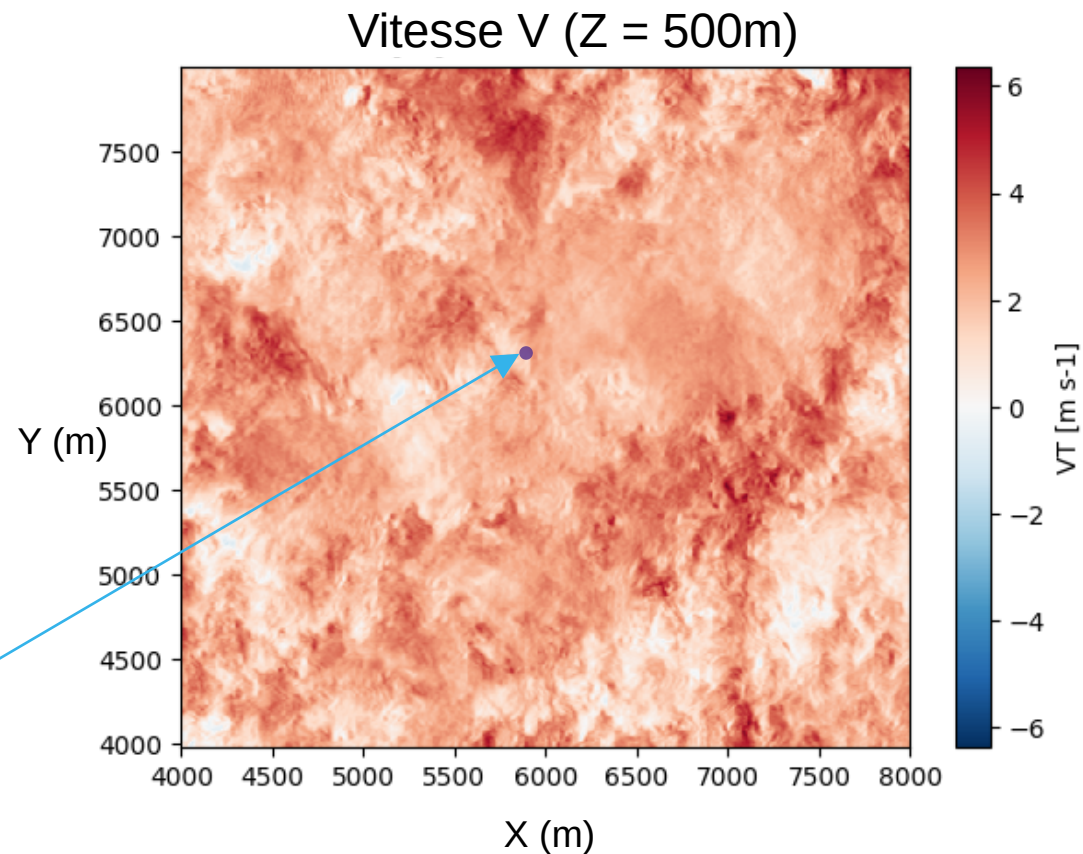
TKE : méthodologie de calcul

TKE qu'on cherche à caractériser :

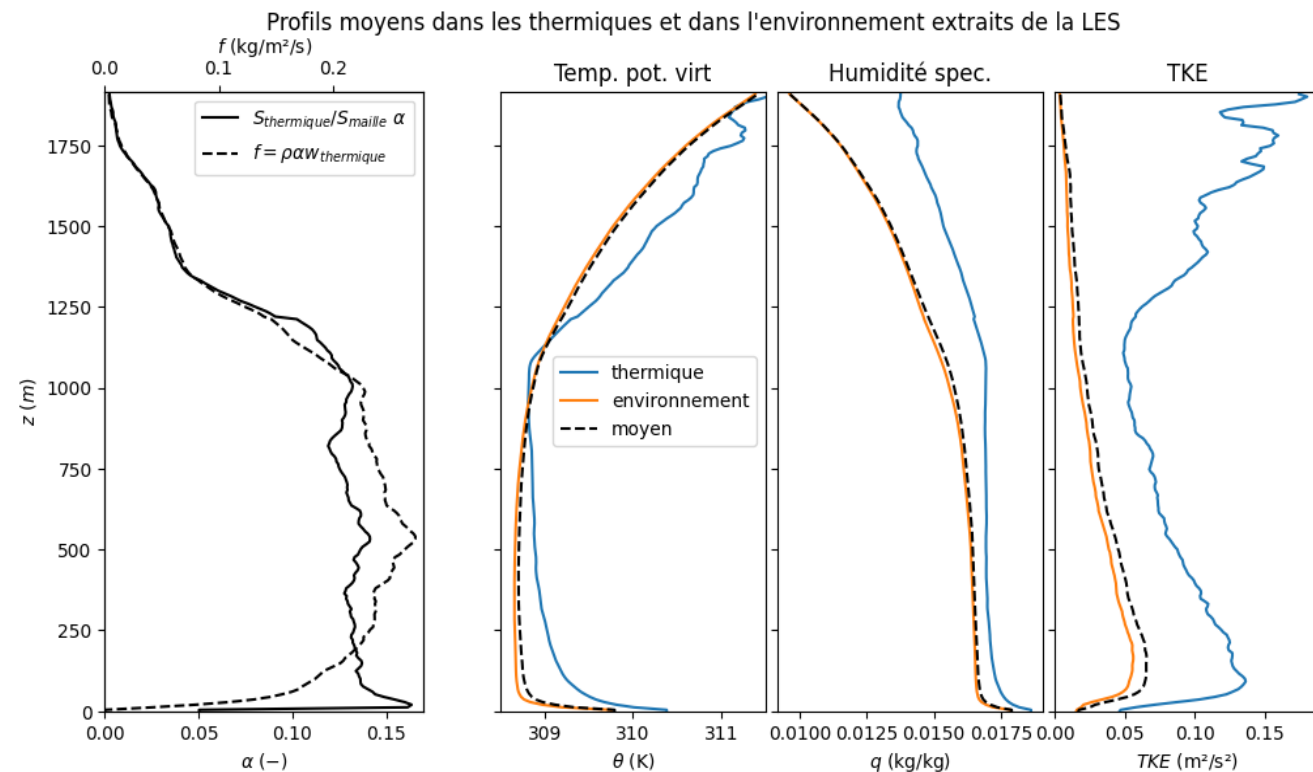
- énergie cinétique
- de petite échelle
- isotrope

Décomposition de Reynolds

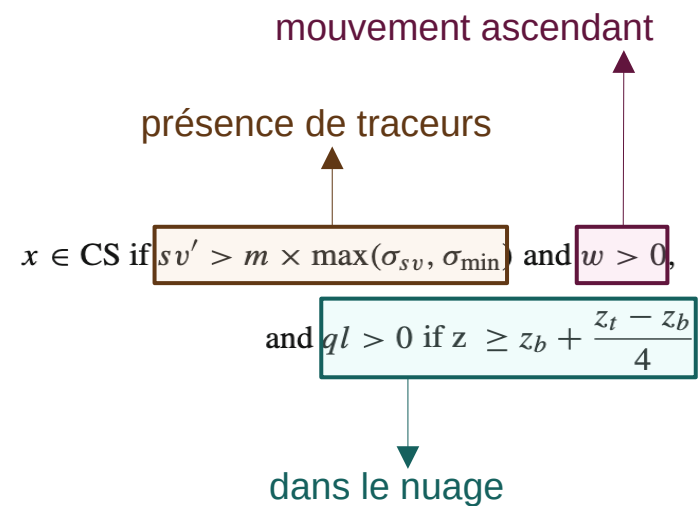
$$\text{TKE} = \frac{1}{2} \overline{[v - \bar{v}^{\text{loc}}]^2}^{\text{loc}}$$



Profils verticaux



Échantillonnage :

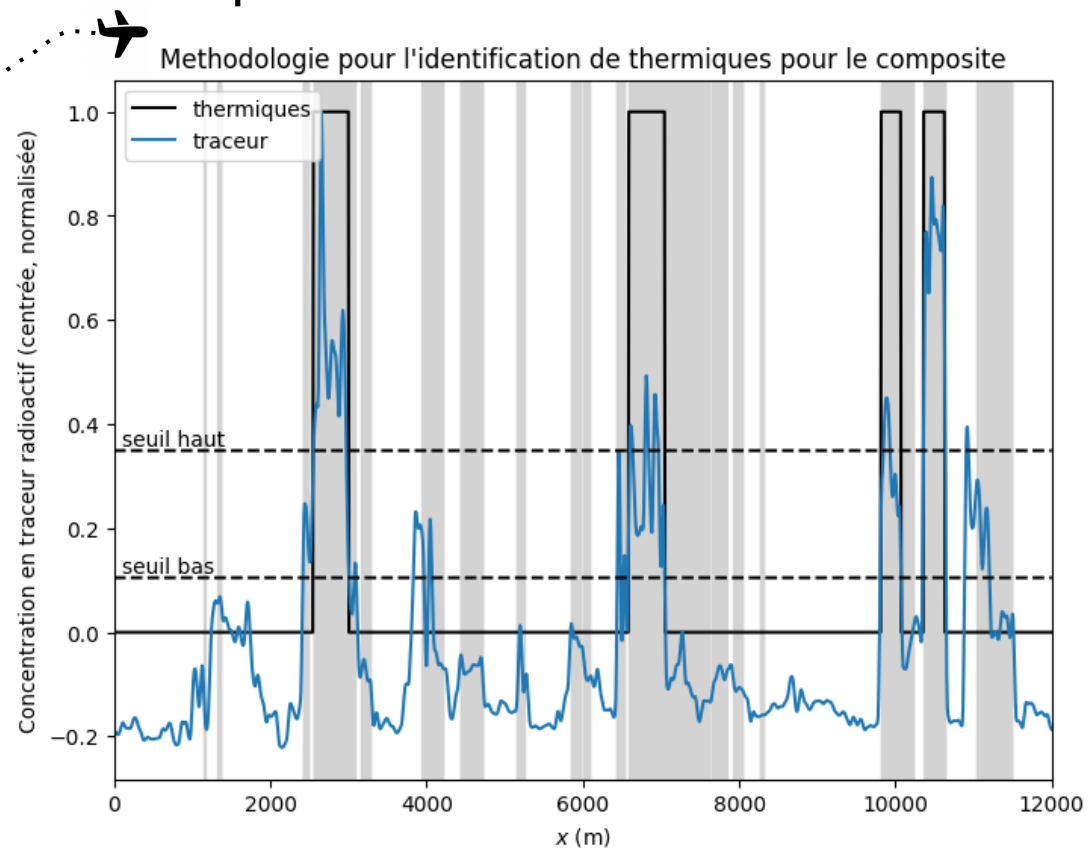
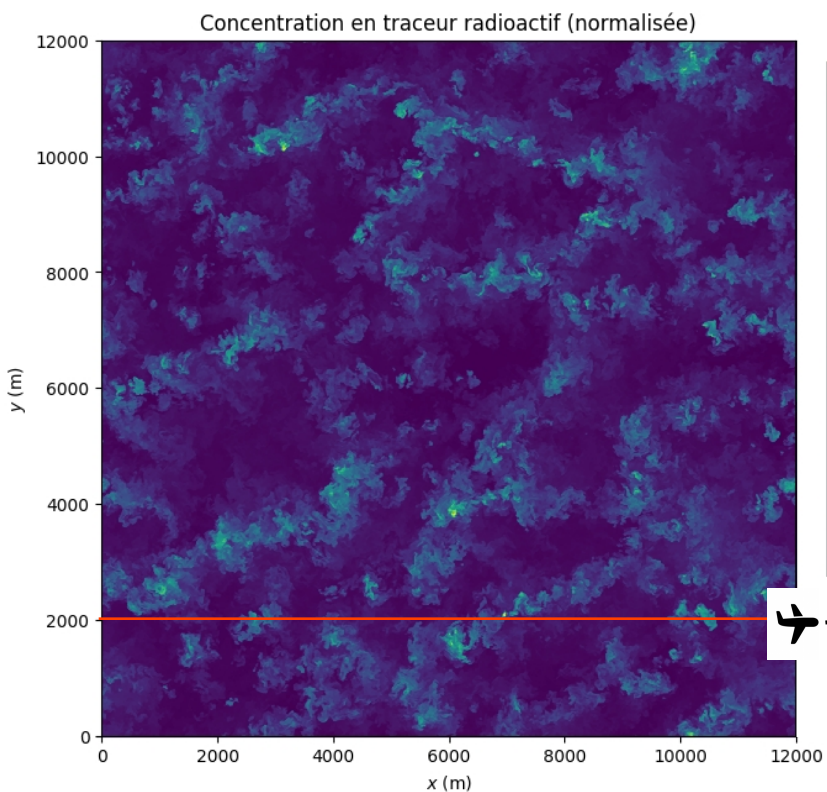


Couvreux et al. 2010

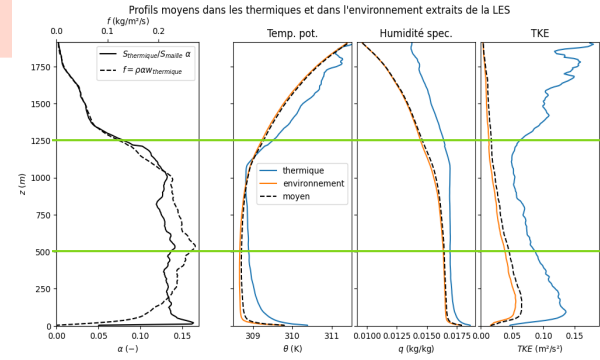
Structure des thermiques : fabrication de composites

Williams et Hacker 1993

On simule des vols d'avion dans les thermiques

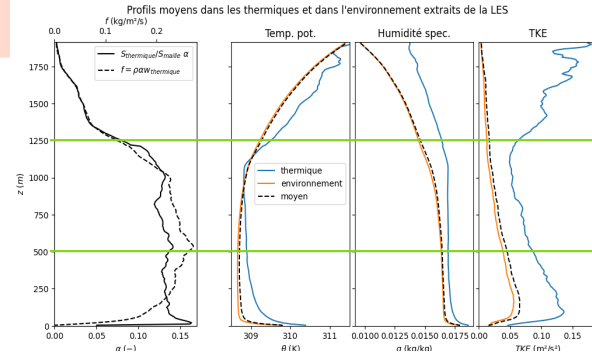


Structure des thermiques



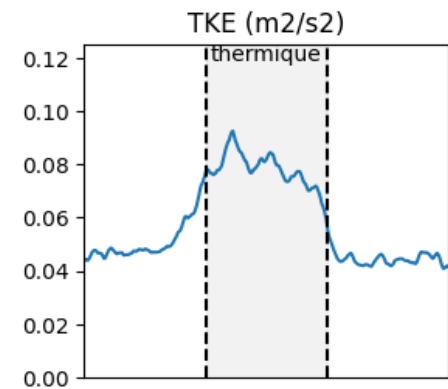
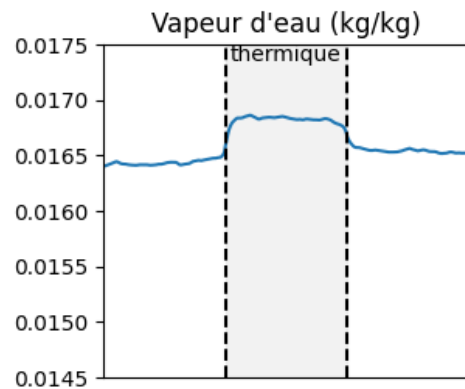
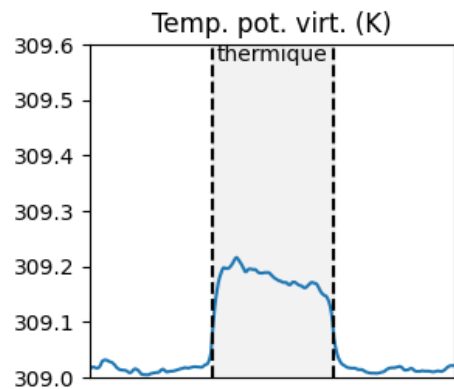
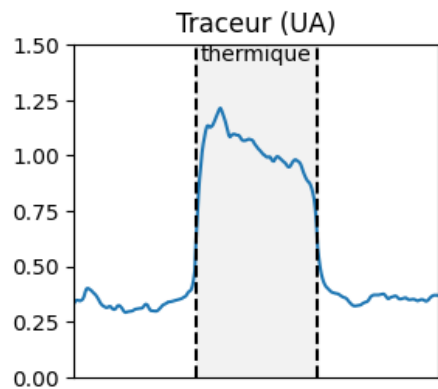
Structure des thermiques

50 vols



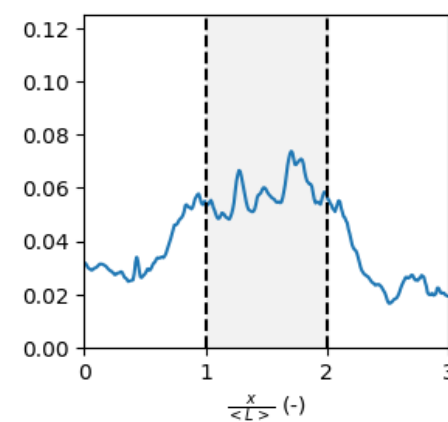
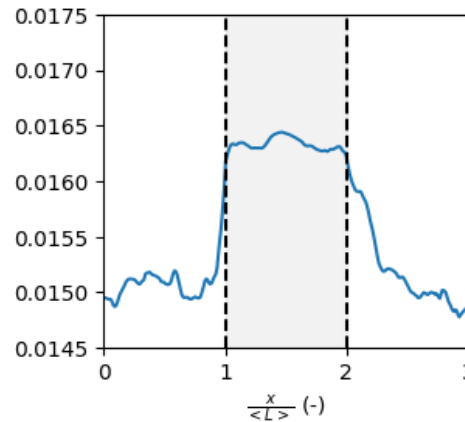
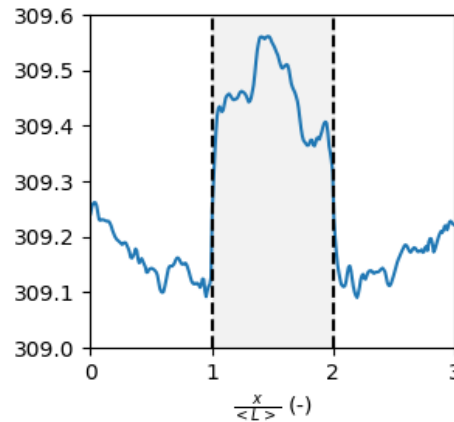
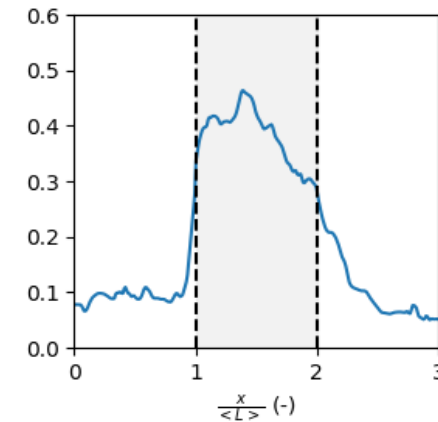
Z = 500 m

155 thermiques

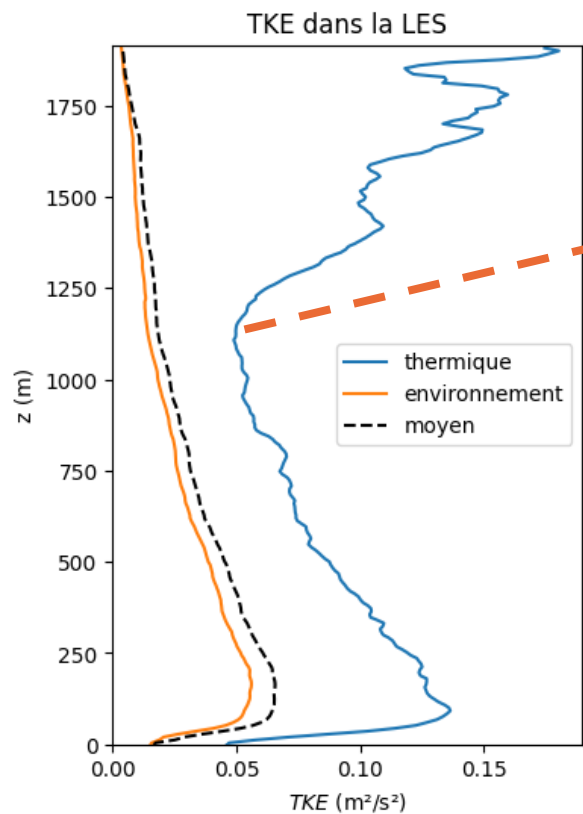


Z = 1250 m

80 thermiques



II – Modélisation (LMDZ)

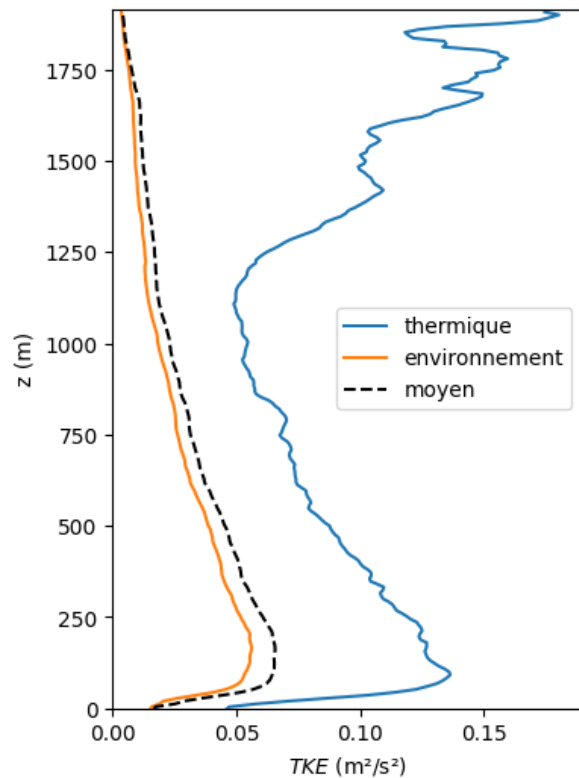


Changement de signe de la dérivée

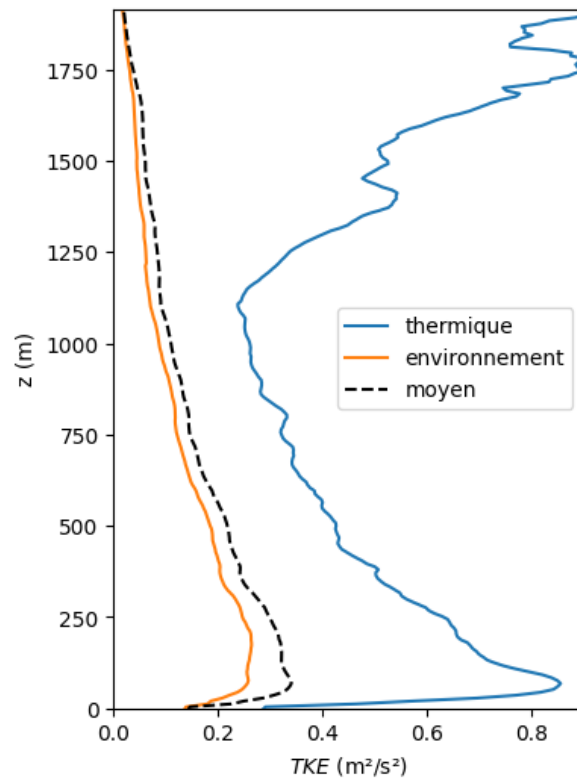
On veut comprendre la TKE dans les thermiques
=> on construit un modèle

Version 0 : pas de transport

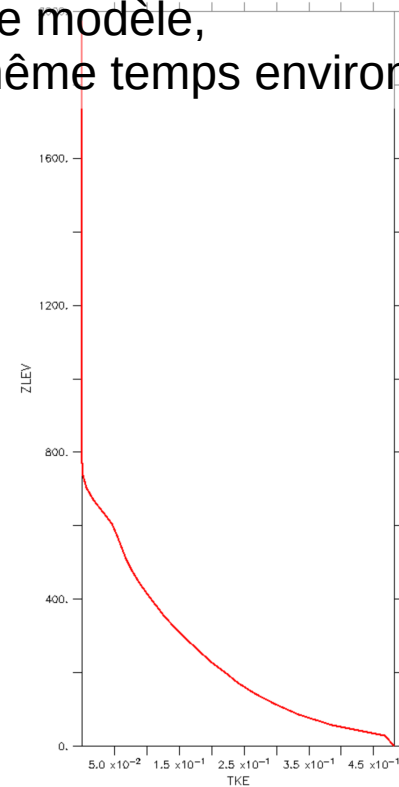
Coupure : 40 m



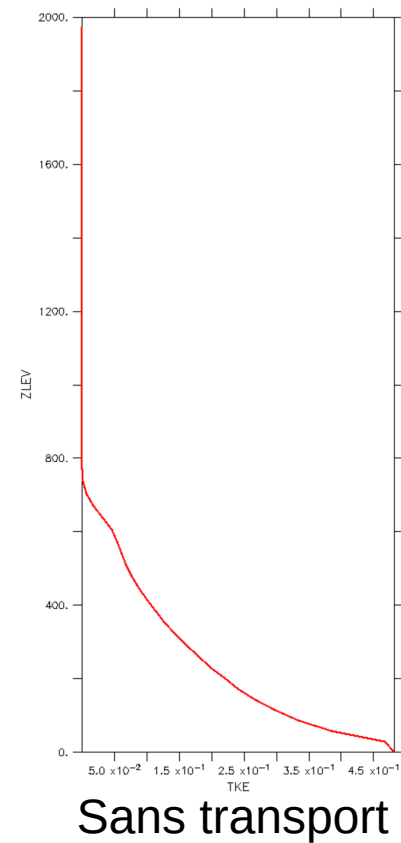
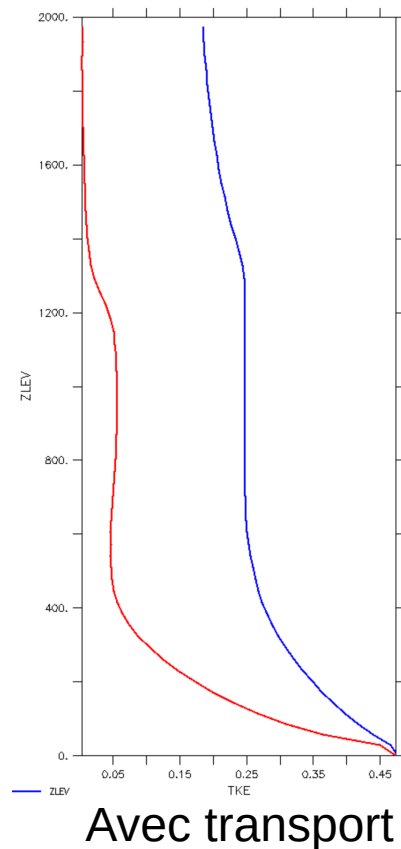
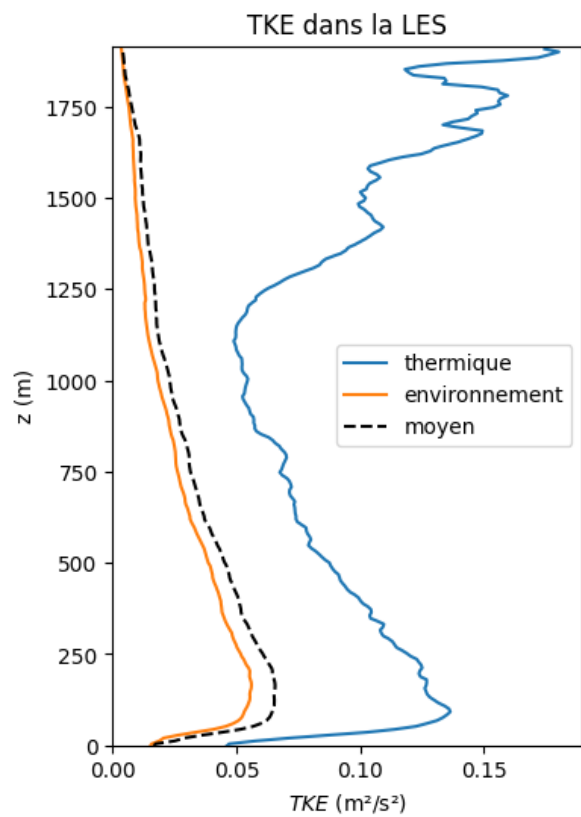
Coupure : 120 m



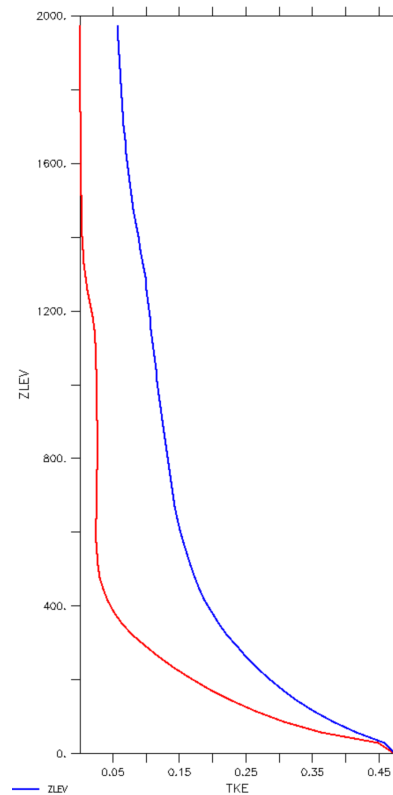
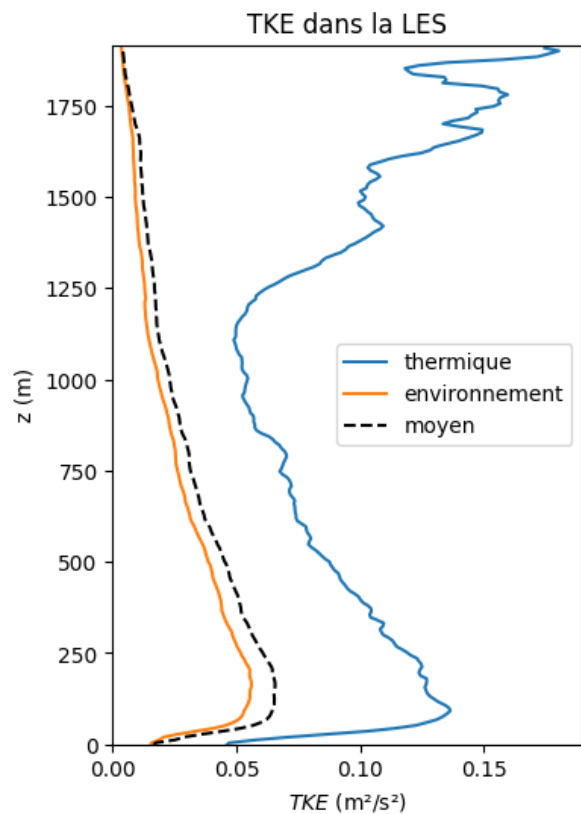
Sortie modèle,
au même temps environ que la LES



Version 1 : Transport seul

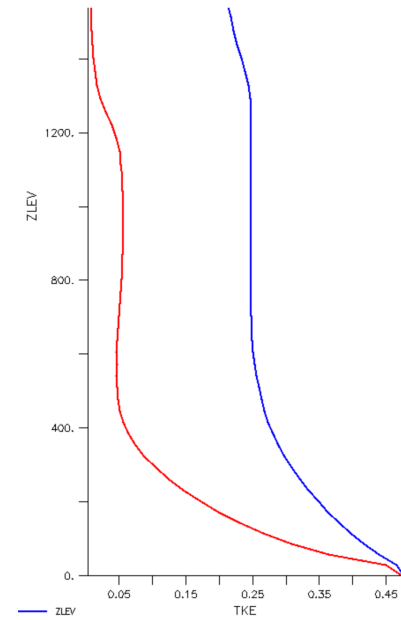


Version 2 : Transport $-\frac{\text{TKE}^{3/2}}{l_\epsilon}$



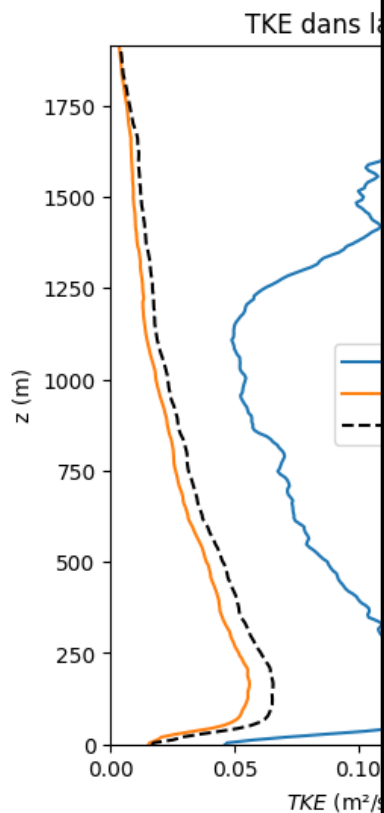
Avec puits

Entrainement (transport) :
mécanisme clé décroissance
TKE dans premières couches



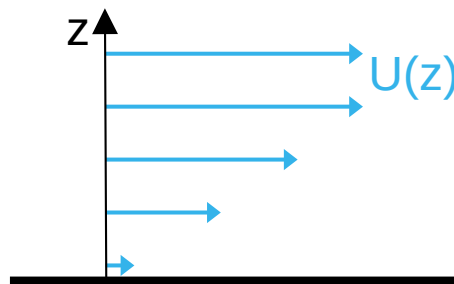
Transport seul

Version 3 : Transport $-\frac{\text{TKE}^{3/2}}{l_\epsilon} + \sqrt{2 \text{TKE}} \frac{w^2}{L}$



Schéma

Couche de surface idéalisée



Terme source

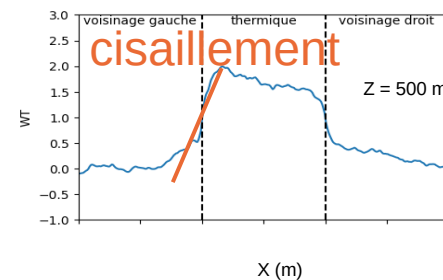
$$\overline{u'w'} \frac{\partial u}{\partial z}$$

Paramétrisation

$$K \left(\frac{\partial u}{\partial z} \right)^2$$

$$K \sim \sqrt{2 \text{TKE}} L$$

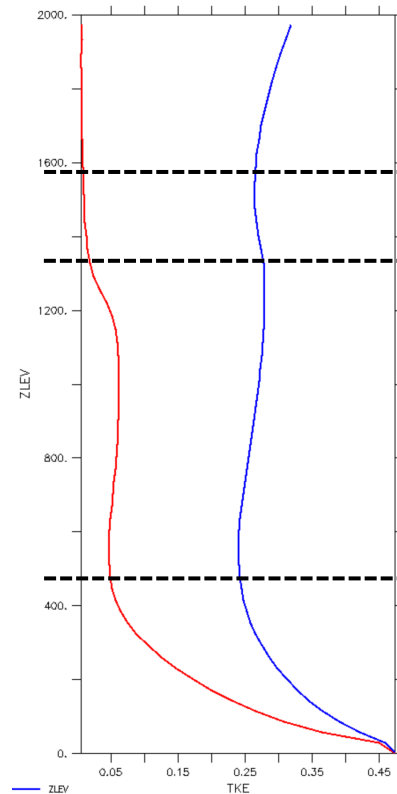
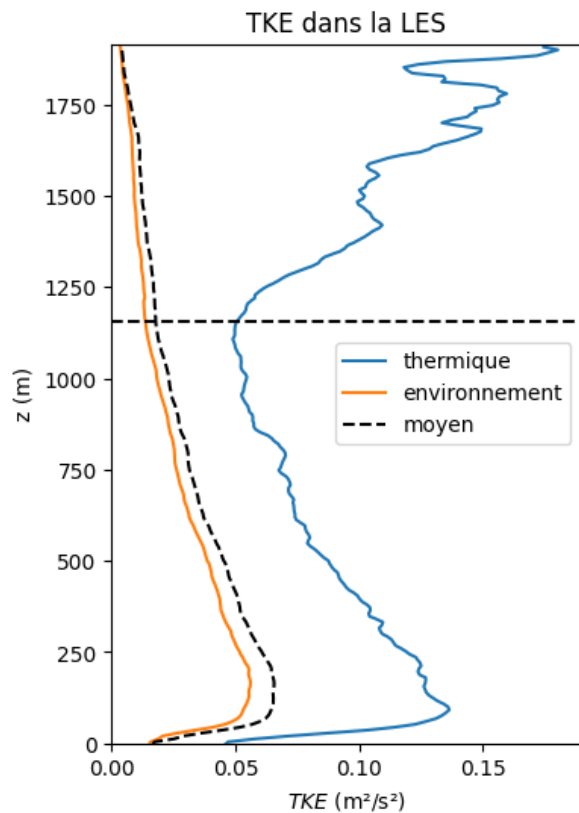
Thermique



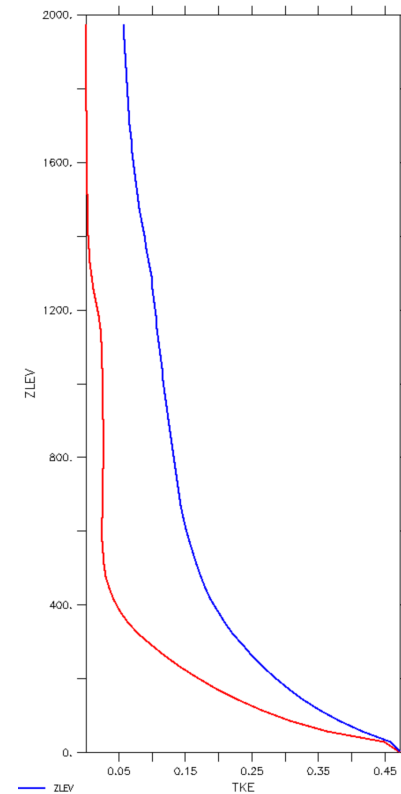
$$\overline{u'w'} \frac{\partial w}{\partial x}$$

$$K \left(\frac{\partial w}{\partial x} \right)^2$$

Version 3 : Transport $-\frac{\text{TKE}^{3/2}}{l_\epsilon} + \sqrt{2 \text{TKE}} \frac{w^2}{L}$

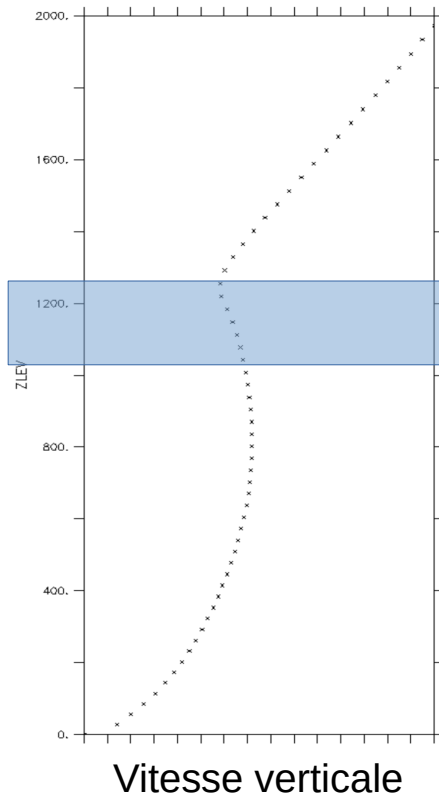
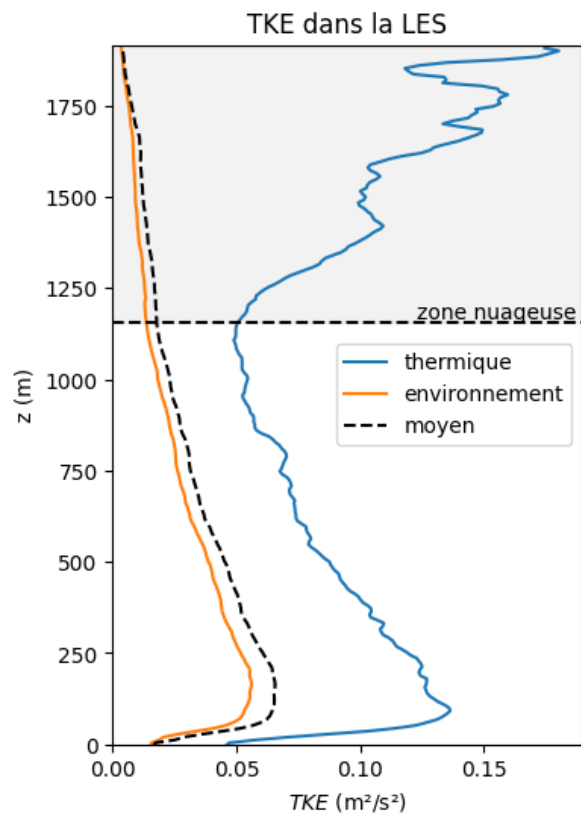


Avec source



Sans source

Version 3 : Transport $-\frac{\text{TKE}^{3/2}}{l_\epsilon} + \sqrt{2 \text{TKE}} \frac{w^2}{L}$



Zone d'inversion :
minimum local de vitesse verticale

Conclusions

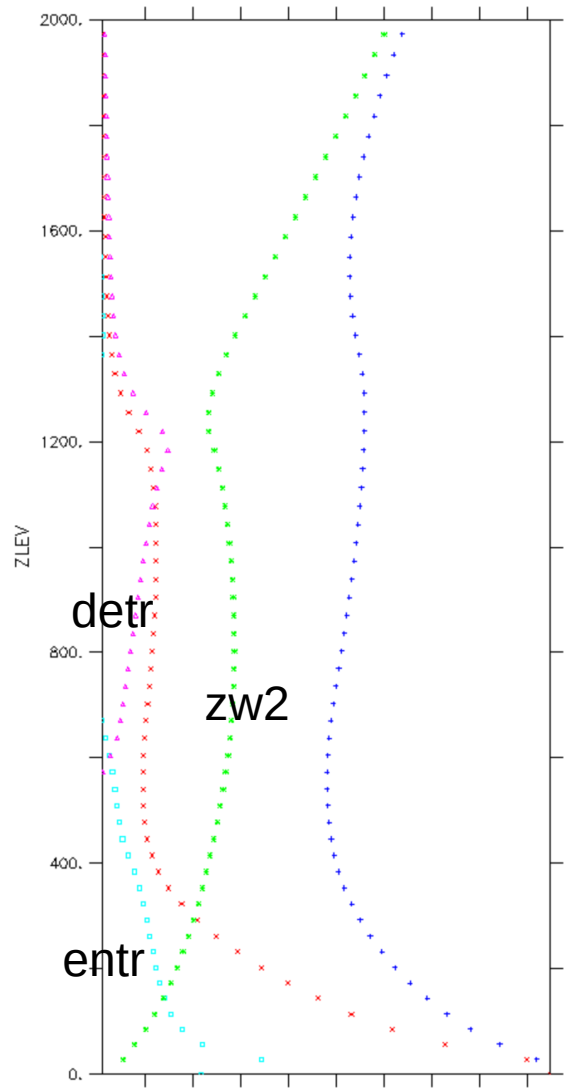
- TKE : variable d'état bien définie dans le thermique
- Il faut un terme source de turbulence dans le nuage => flottabilité

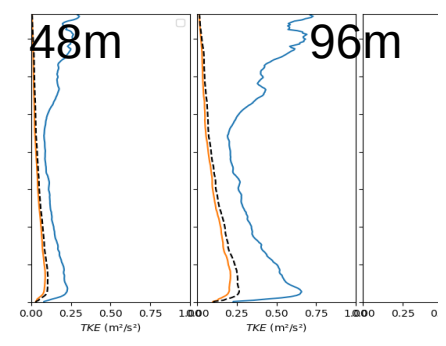
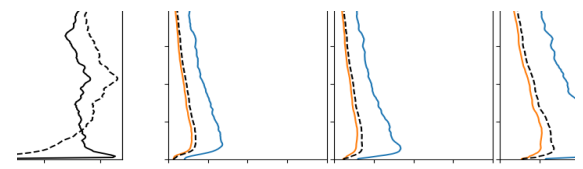
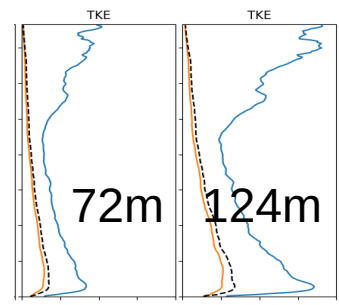
Conclusions

- TKE : variable d'état bien définie dans le thermique
- Il faut un terme source de turbulence dans le nuage => flottabilité

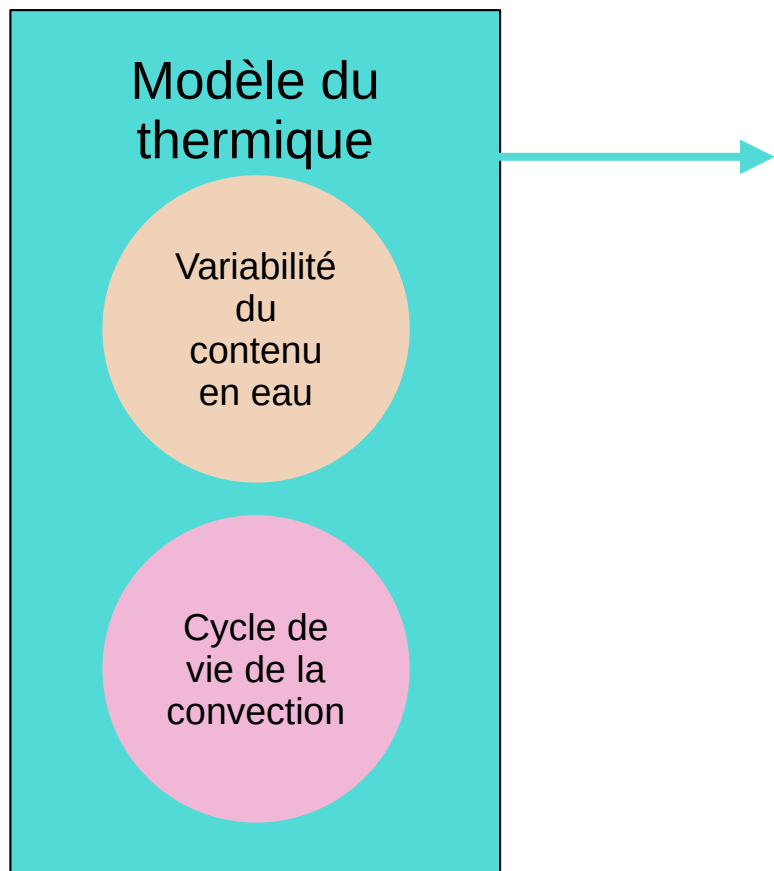
Perspectives

- Sources de TKE par flottabilité
- Paramétrisation de convection peu profonde



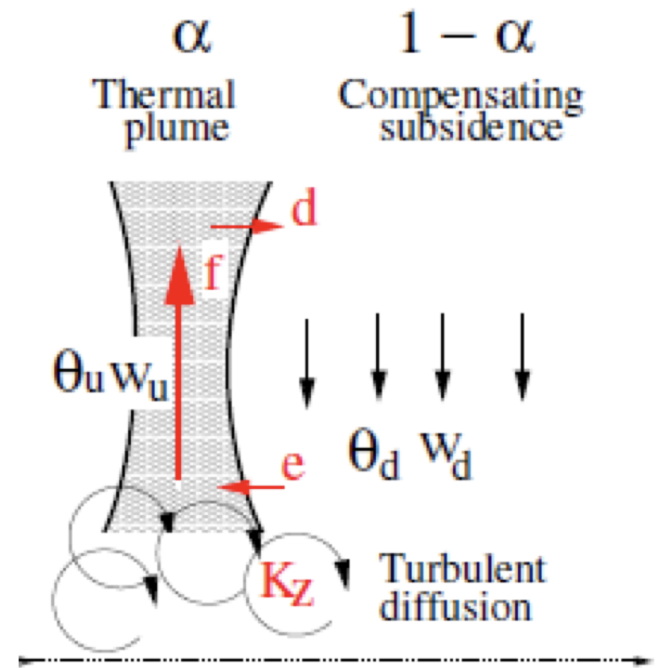


Pour la convection peu profonde, dans LMDZ



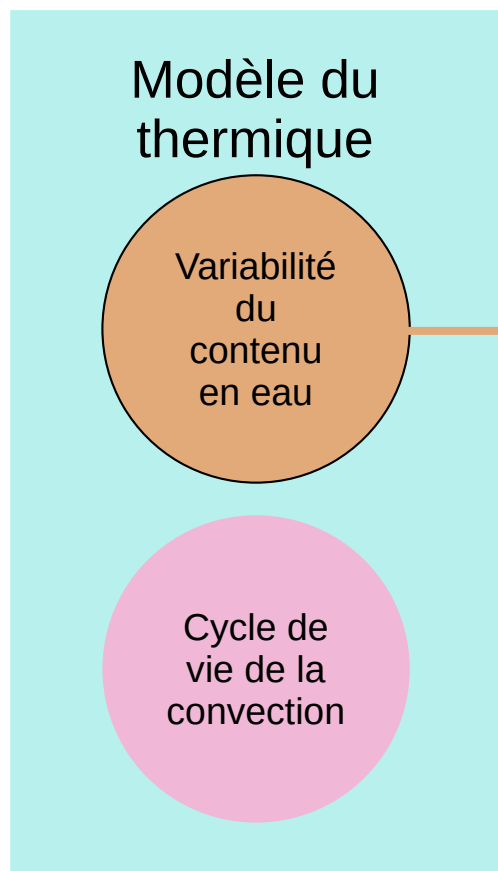
$$\frac{\partial f}{\partial z} = e - d$$

$$\frac{\partial f \psi_u}{\partial z} = e \psi - d \psi_u$$



Hourdin et al. 2002

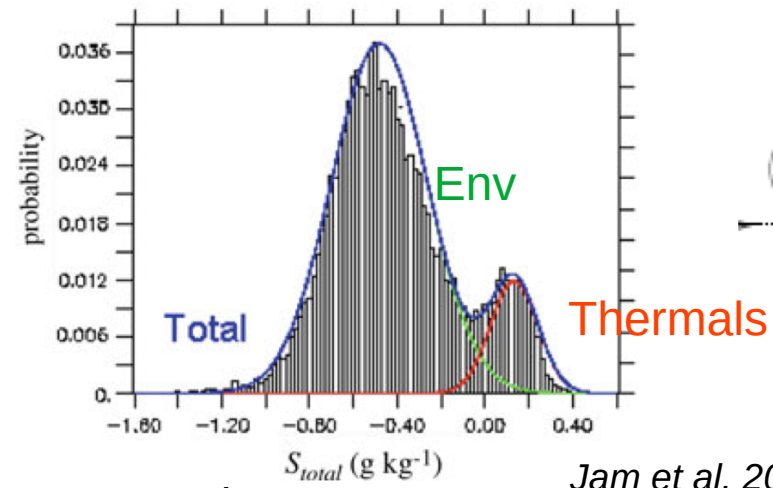
Pour la convection peu profonde, dans LMDZ



$$\frac{\partial f}{\partial z} = e - d$$

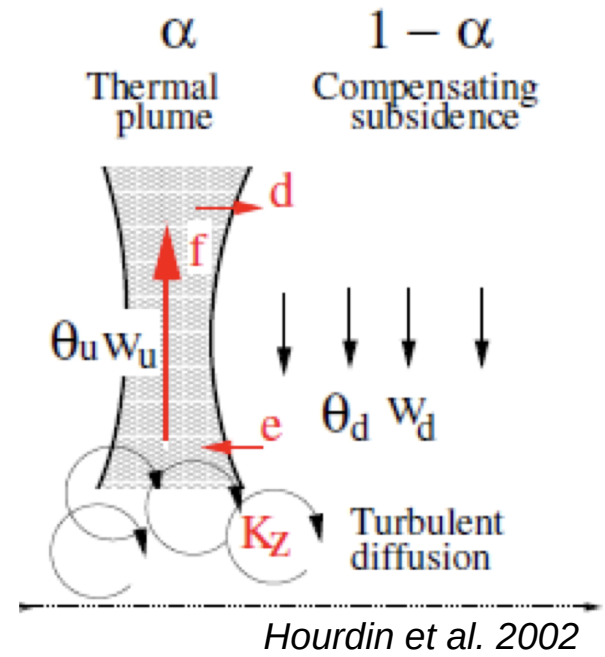
$$\frac{\partial f \psi_u}{\partial z} = e \psi - d \psi_u$$

cas ARM (heure 8)

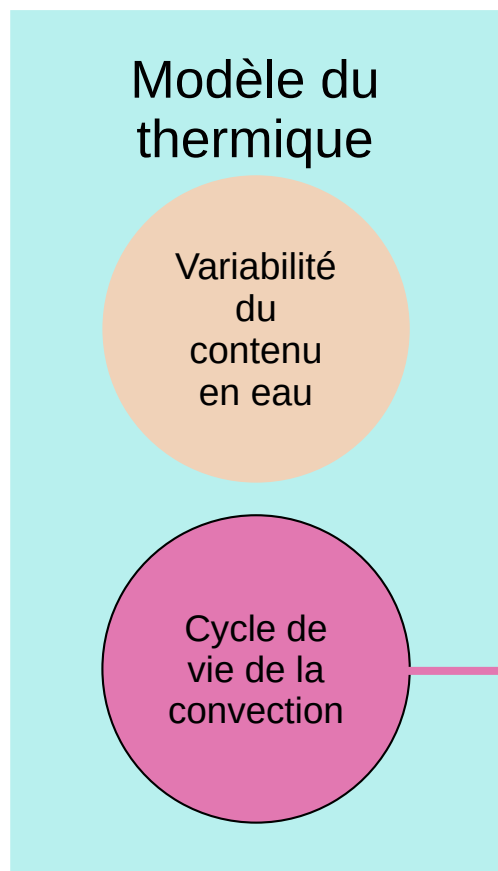


S : deficit à la saturation

Jam et al. 2013



Pour la convection peu profonde, dans LMDZ



$$\frac{\partial f}{\partial z} = e - d$$

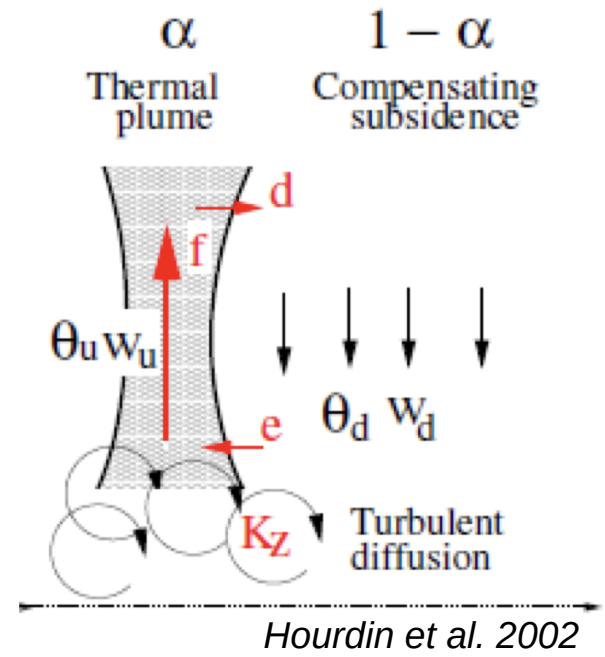
$$\frac{\partial f \psi_u}{\partial z} = e \psi - d \psi_u$$

Détraînement

$$d = d(\theta, q)$$

Tri par flottabilité : propriétés de parcelles d'air mélangées entre le thermique et l'environnement

Kain et Fritsch 1990



Idée
mélange de petite échelle = TKE
dans les thermiques dans les thermiques

Problématiques

1. Comment se fait le transport de la TKE par les thermiques ?
2. Comment le représenter dans LMDZ ?

