Impact of surface heterogeneity on the boundary-layer flow and near-surface turbulent exchanges LES analysis

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Context

-Need to explore L-A interactions (improve knowledge on involved processes + performance of the models).

- Already quite some work on the impact of surface heterogeneities but usually very idealized set up and in particular fixed fluxes (Rochetin et al 2017) or surface temperatures (Patton et al 2005)

=> go one step further with coupled LSM-LES

Until what level/scale the surface discontinuities influence the BL ?

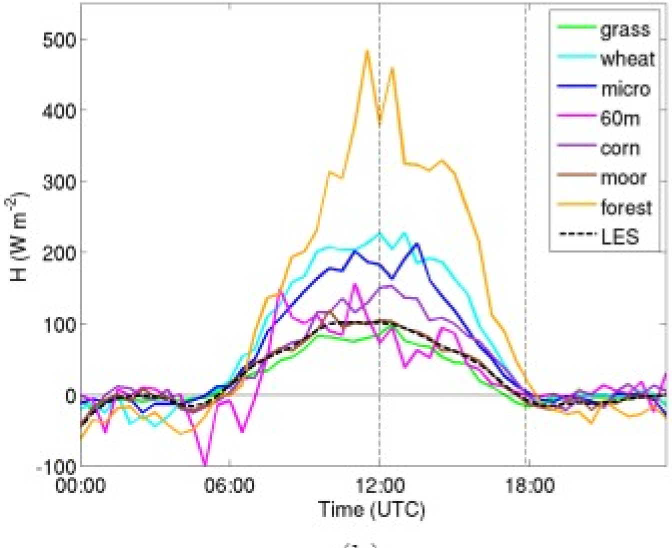
What complexity of the surface heterogeneities do we need to represent ?

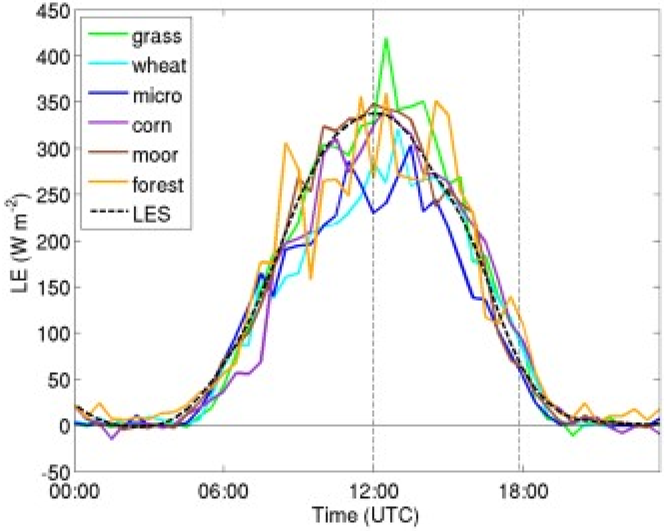
- Surface parameterization in LES uses bulk formulas based on the Monin Obukhov Similarity Theory (MOST) : Same formulas from climate to LES models.

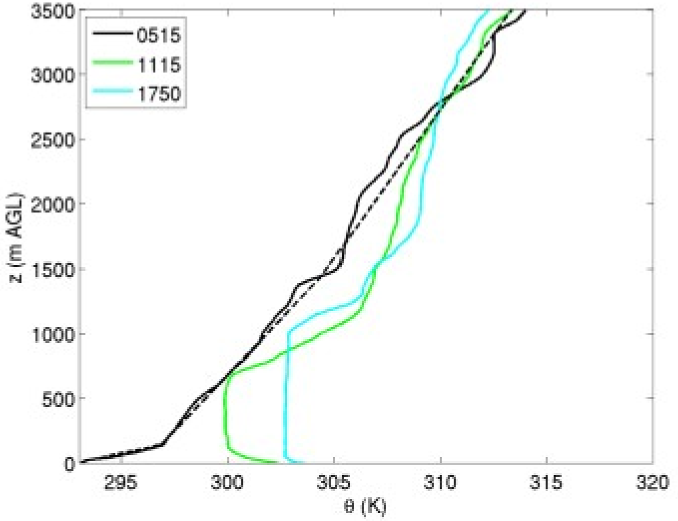
Only few LSM-LES but rather good results (Patton et al., 2005; Lohou et al., 2014b; Brilouet et al., 2020).

=> propose some work to highlight the sensitivity to this kind of setup

Method



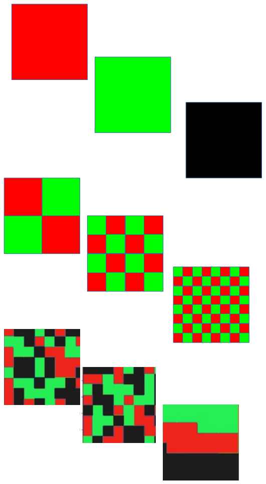




- Inspired by the case of Darbieu et al (BLLAST, 20/06/11)
But initial conditions from AROME (more complex profiles)
- Sensitivity to domain size (5, **10** ,25 km)
- Sensitivity to first level (5, 10, 25, 50 m) and grid size (strecthed, 25m , 50m)
-Sensitivity to humidity and temperature soil initialization

Method

- LES with surface-atmosphere coupled configuration (Meso-NH+SURFEX)
- 3 surfaces : grass, maize and forest + ECOCLIMAP database
- Homogeneous or Heterogeneous surfaces
- Same initial conditions and simulation set-up : Lx=10 km, Dx=50m, Lz=4km, Dz1=5m+stretched grid



Simulation	Grass cover %	Maize cover %	Forest cover %	z_0 (m)
GP	90	0	0	0.067
MP	0	65	0	0.24
FP	0	0	70	0.67
GM4P	45	32.5	0	0.127
GM16P	45	32.5	0	0.136
GM64P	45	32.5	0	0.140
GMF64P1	27	19.5	28	0.39
GMF64P2	27	19.5	28	0.38
GMF3P	27	19.5	28	0.44

On the influence of near-surface atmospheric variances on surface fluxes

Surface Flux Parameterization= bulk formula based on M-O similarity for climate → LES models

Pertinence for the LES simulations ? (Δt~1s, Δx~10m)

In LES simulations, large spatial variability of surface fluxes ?

What drive such variability ? Is it key ?

$$\overline{w'\theta'} = -C_H \left\| \overline{U}(z_l) \right\| \left(\overline{\theta}(z_l) - \overline{\theta}_s \right)$$

$$\overline{w'q'} = -C_Q \left\| \overline{U}(z_l) \right\| \left(\overline{q}(z_l) - \overline{q}_s \right)$$

$$\overline{u'w'} = -C_D \left\| \overline{U}(z_l) \right\| \overline{u}(z_l)$$

$$\overline{v'w'} = -C_D \left\| \overline{U}(z_l) \right\| \overline{v}(z_l)$$

$$\left\| \overline{U}(z_l) \right\| = \sqrt{\overline{u}^2(z_l) + \overline{v}^2(z_l)}$$

Tests on 3 types of surface (CMO Brilouet et al 2021, continental cases derived from BLLAST over Grass and Forest)

Spatial Homogeneization of 1st atmospheric level fields before computation of surface fluxes

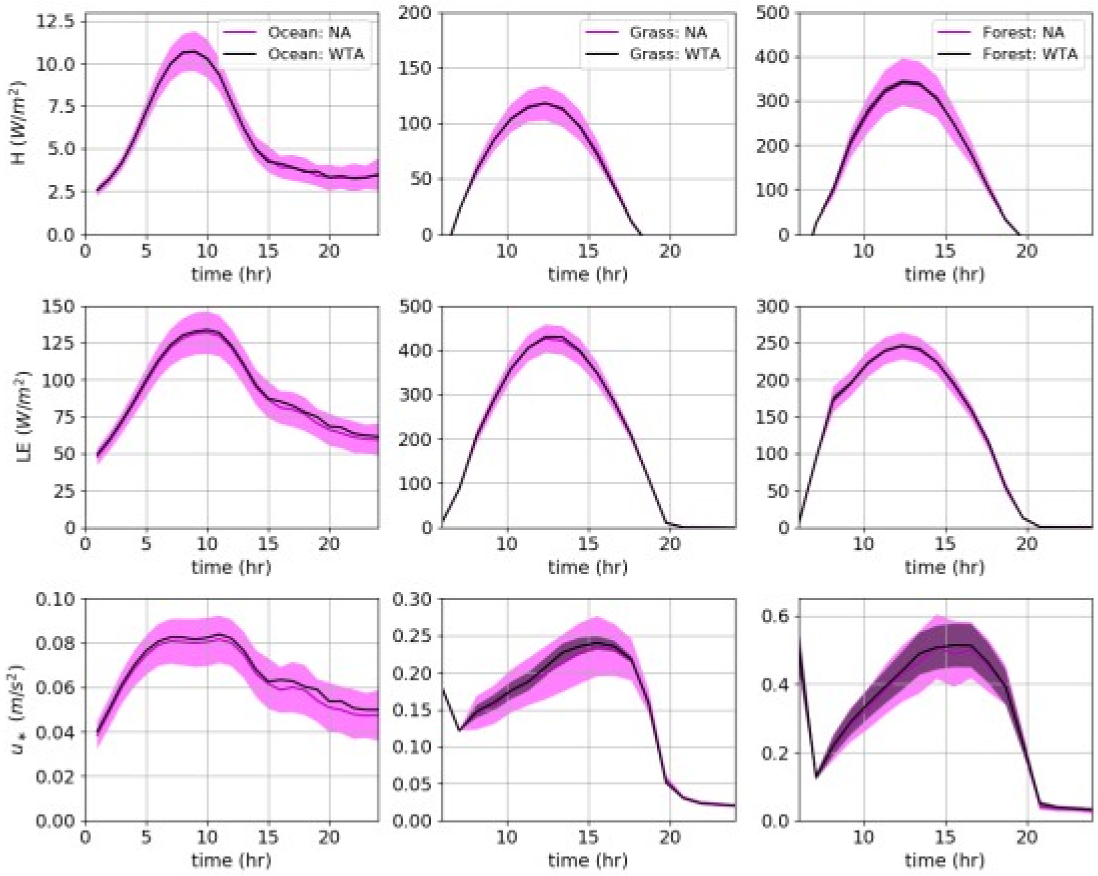
Experiment 1 (REF) — Experiment 2 — Experiment 3 — Experiment 4

$$H = -\rho \cdot C_{pa} \cdot C_H \cdot U \cdot (\theta_s - \theta_a) \sim -\rho \cdot C_{pa} \cdot C_H \cdot \overline{U} \cdot (\theta_s - \theta_a) \sim -\rho \cdot C_{pa} \cdot C_H \cdot U \cdot (\theta_s - \overline{\theta_a}) \sim -\rho \cdot C_{pa} \cdot C_H \cdot \overline{U} \cdot (\theta_s - \overline{\theta_a})$$

$$QE = -\rho \cdot C_{pa} \cdot C_H \cdot U \cdot (q_s - q_a) \sim -\rho \cdot C_{pa} \cdot C_H \cdot \overline{U} \cdot (q_s - q_a) \sim -\rho \cdot C_{pa} \cdot C_H \cdot U \cdot (q_s - \overline{q_a}) \sim -\rho \cdot C_{pa} \cdot C_H \cdot \overline{U} \cdot (q_s - \overline{q_a})$$

$$\tau = -\rho \cdot C_{pa} \cdot C_H \cdot U^2 \sim -\rho \cdot C_{pa} \cdot C_H \cdot \overline{U}^2 \sim -\rho \cdot C_{pa} \cdot C_H \cdot U^2 \sim -\rho \cdot C_{pa} \cdot C_H \cdot \overline{U}^2$$

On the influence of near-surface atmospheric variances on surface fluxes

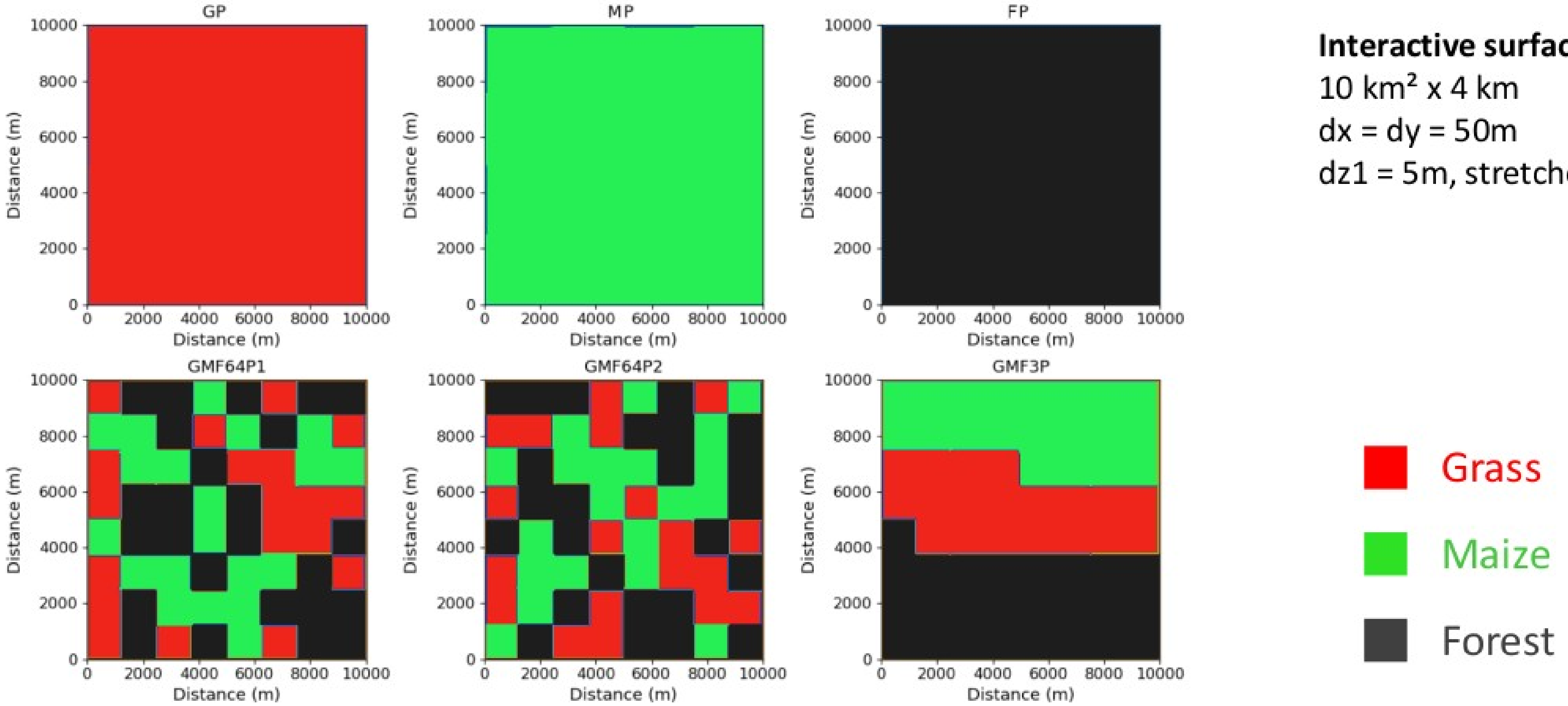


Spatial variability of surface fluxes controlled by the wind at first order

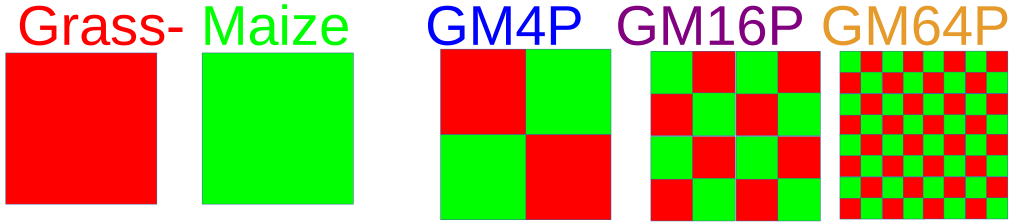
However no impact on the main characteristics of the BL except very close to the surface

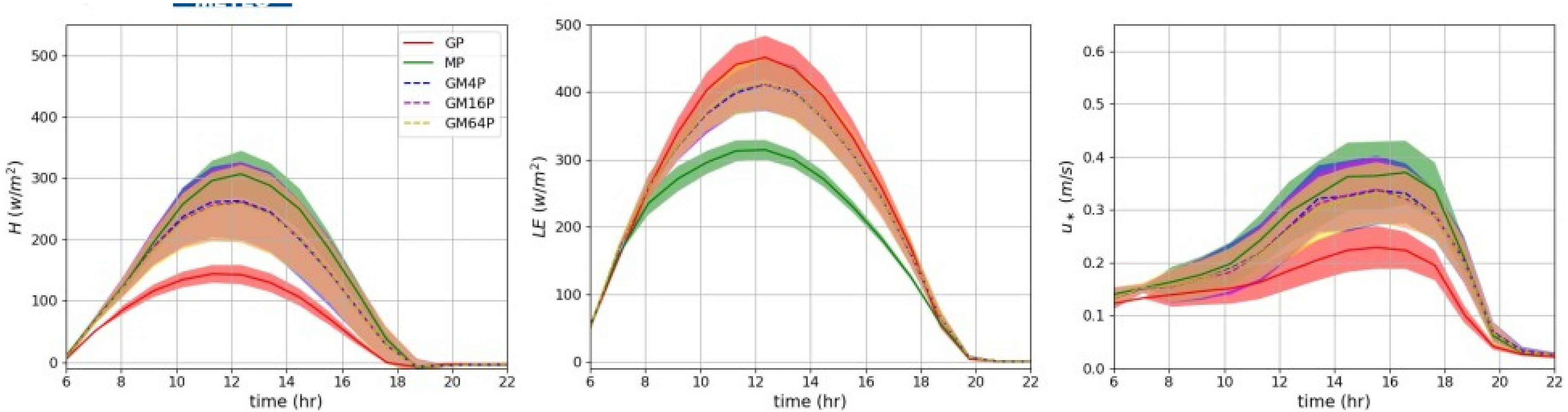
Large-eddy simulations with homogeneous or heterogeneous surface

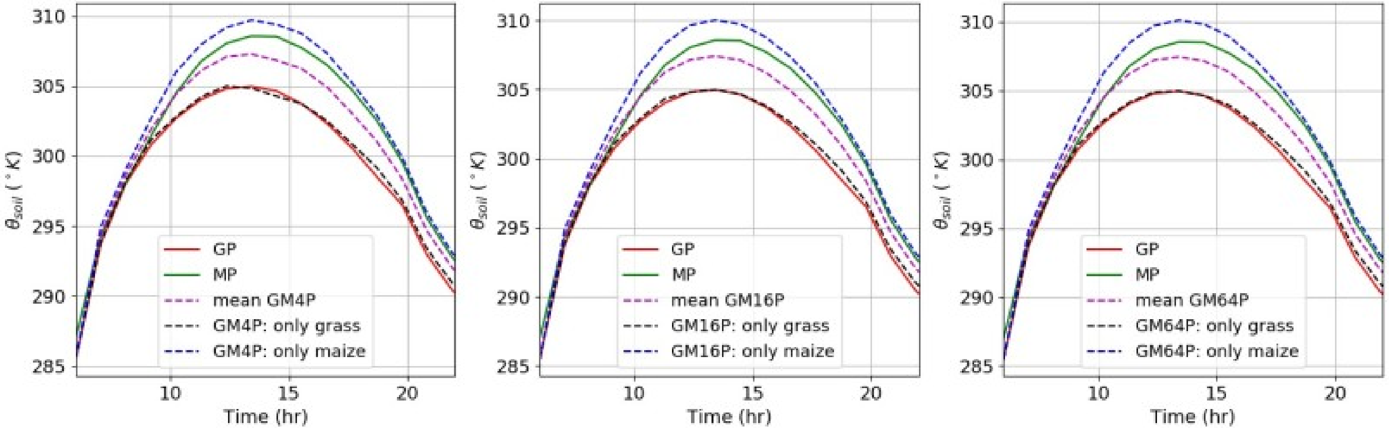
Interactive surface
10 km² x 4 km
dx = dy = 50m
dz1 = 5m, stretched grid



First results





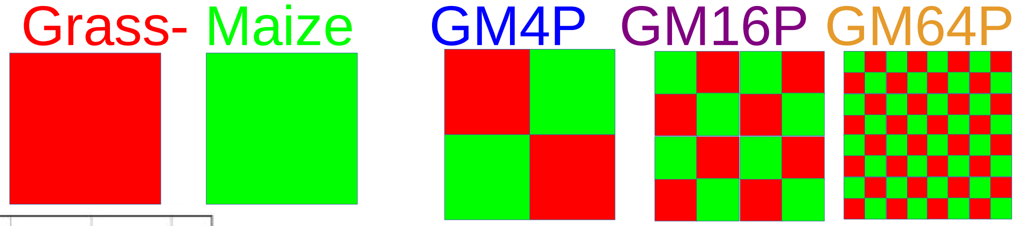


Mean flux controled by the fraction of each surface and not the size of patches

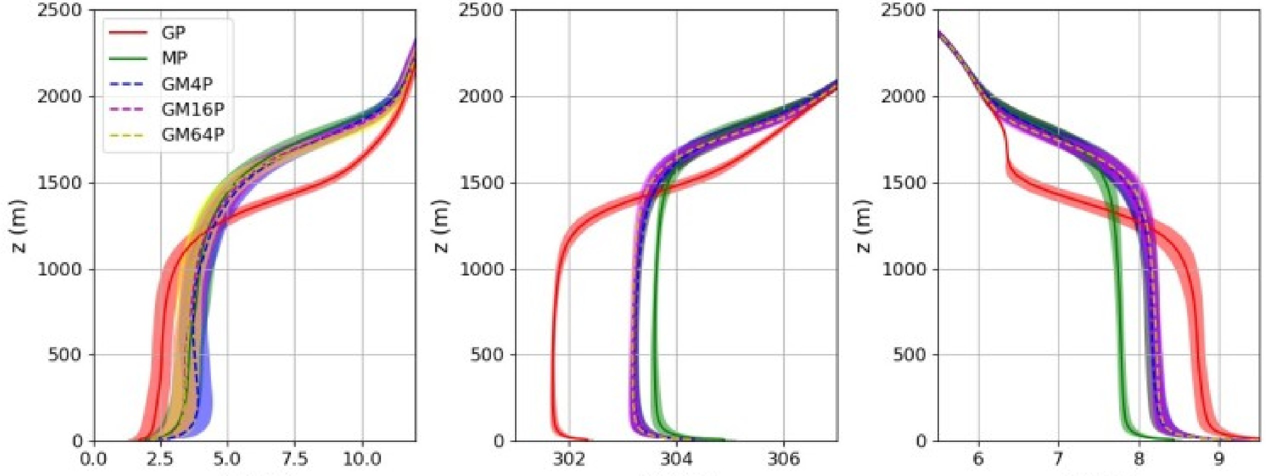
Larger variance for heterogenous simulations

Surface temperature over Grass modified by patches

First results



At 2pm

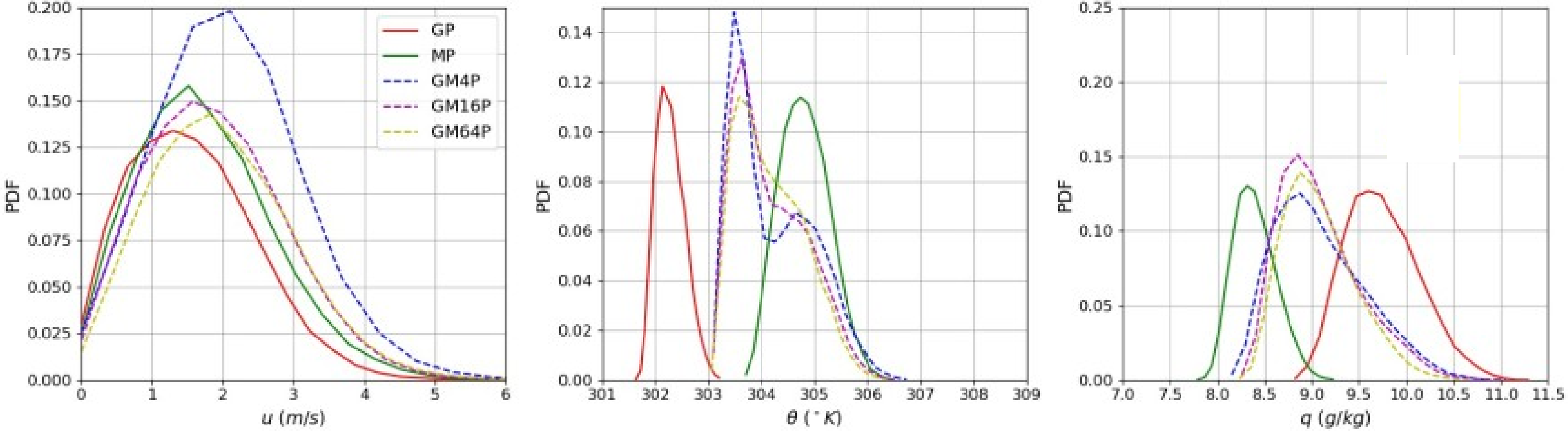


Heterogeneities lead to a generally higher boundary layer

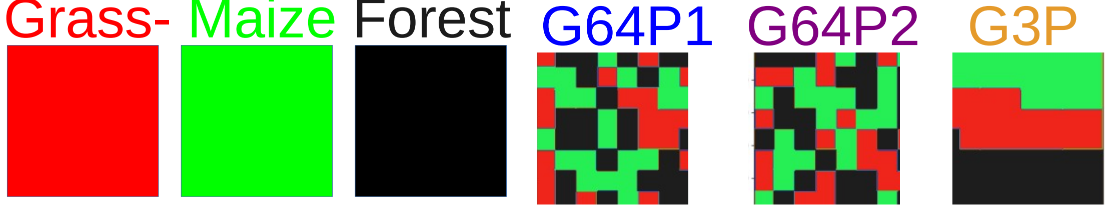
No impact of patch size except for wind (larger breeze for larger patch)

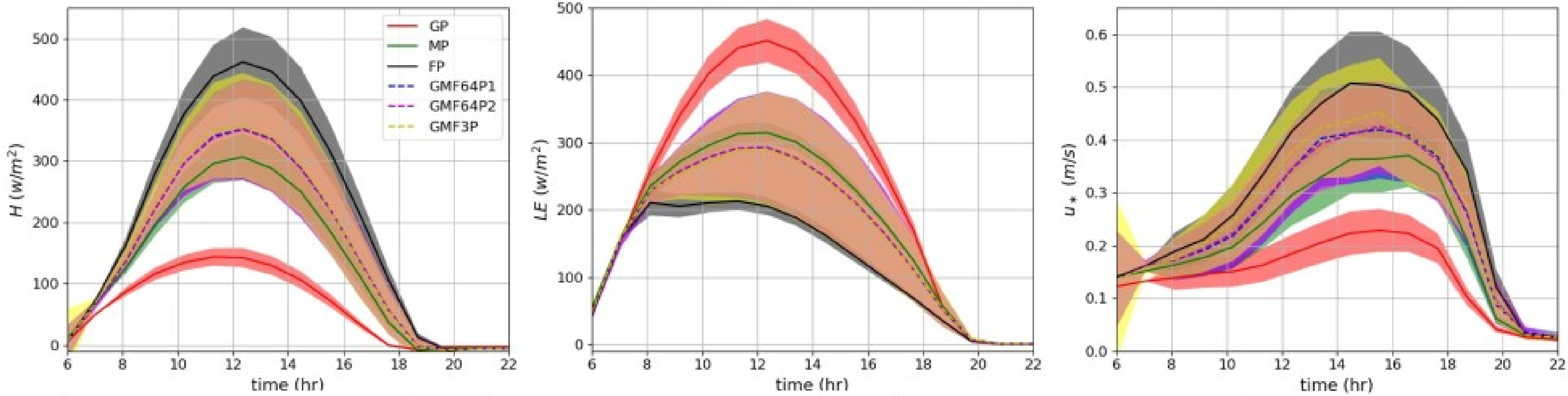
Surface temperature : bimodal for heterogeneous simulations

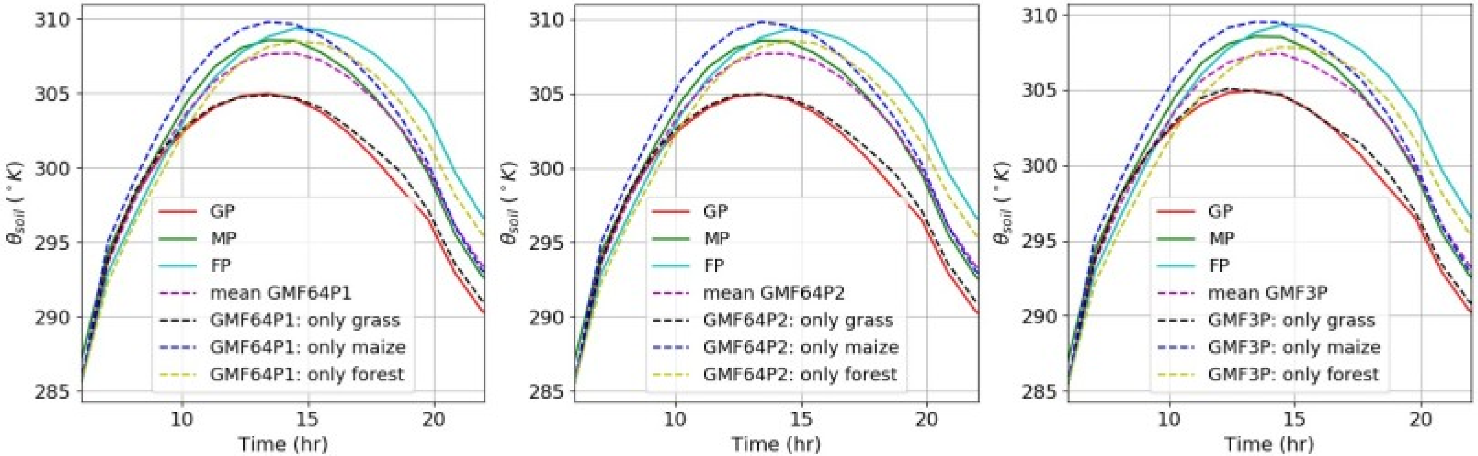
At 5 m



First results







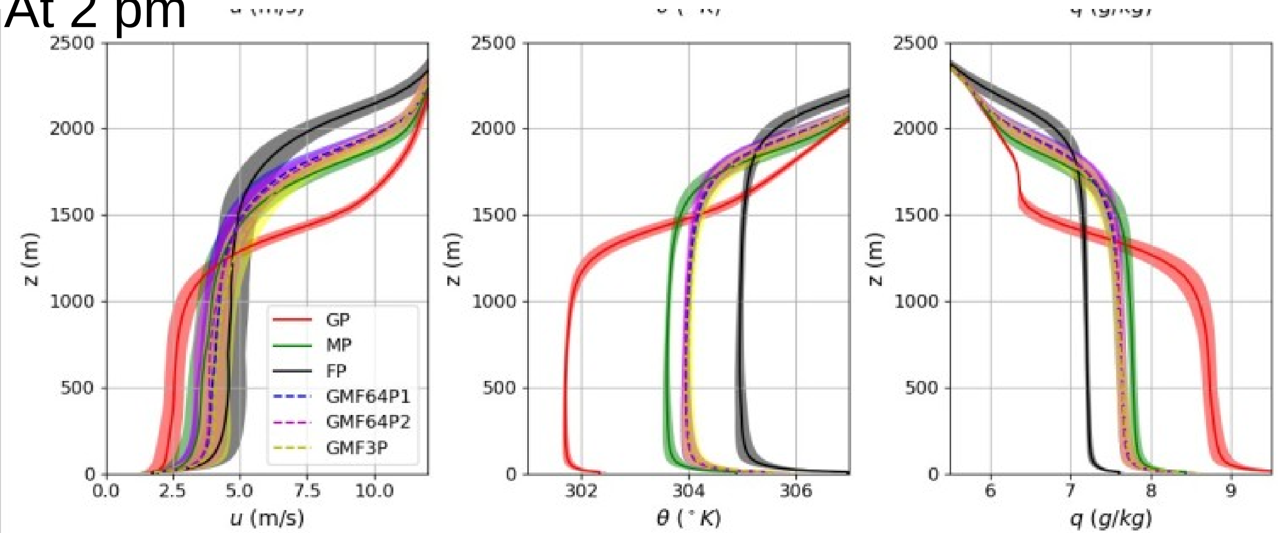
Same results for more complex heterogeneities

First results

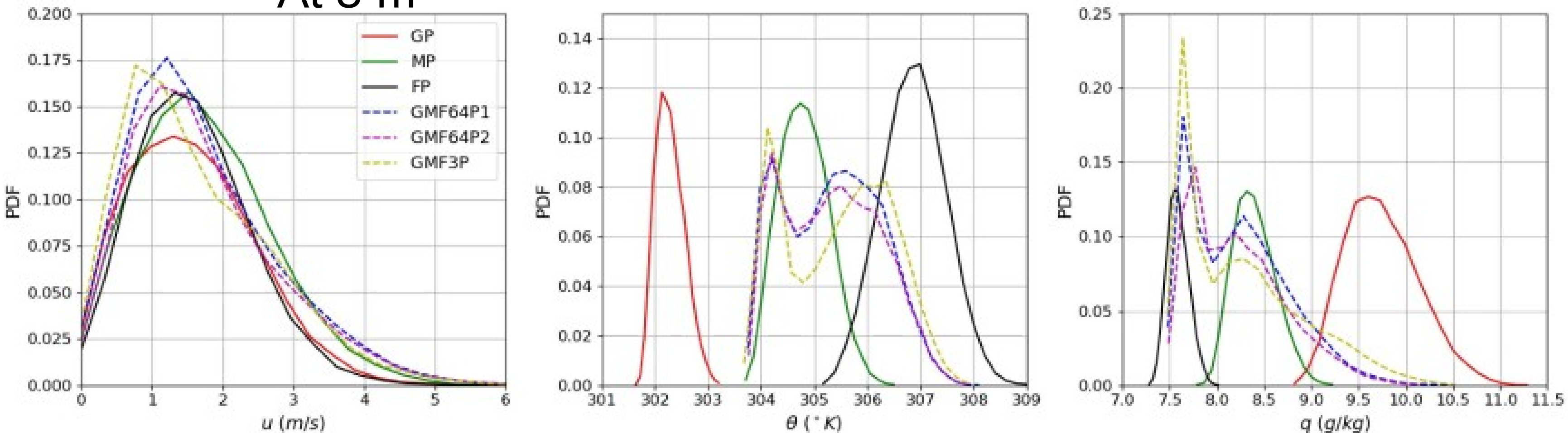
Heterogeneities slightly increase mean flux

However no impact on the main characteristics of the BL except very close to the surface

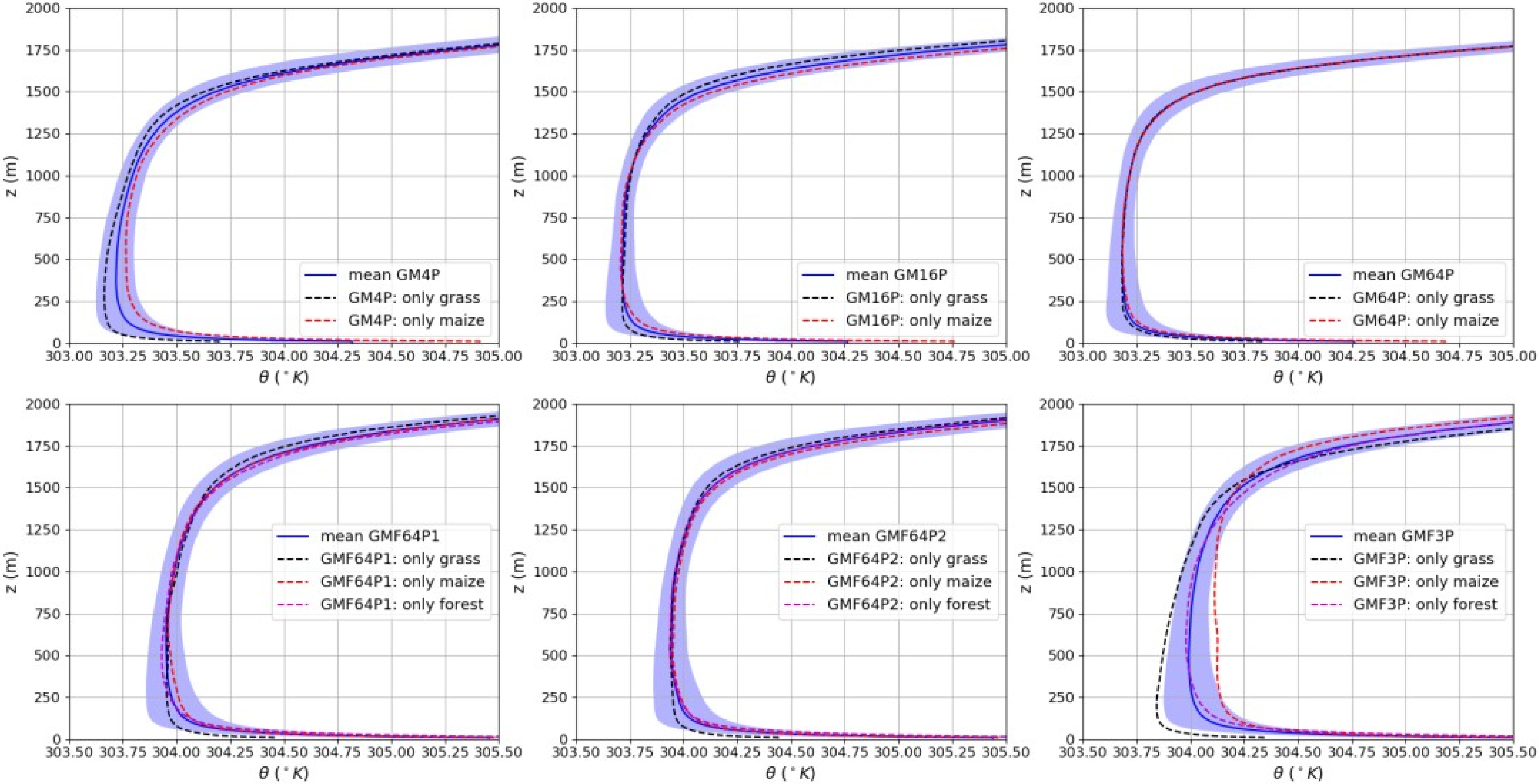
At 2 pm



At 5 m



First results



Conclusion

Coupled LES simulation with surface heterogeneities from very idealised to more realistic :
Following Emilie work => need to redo the simulations with improved albedo and root depth

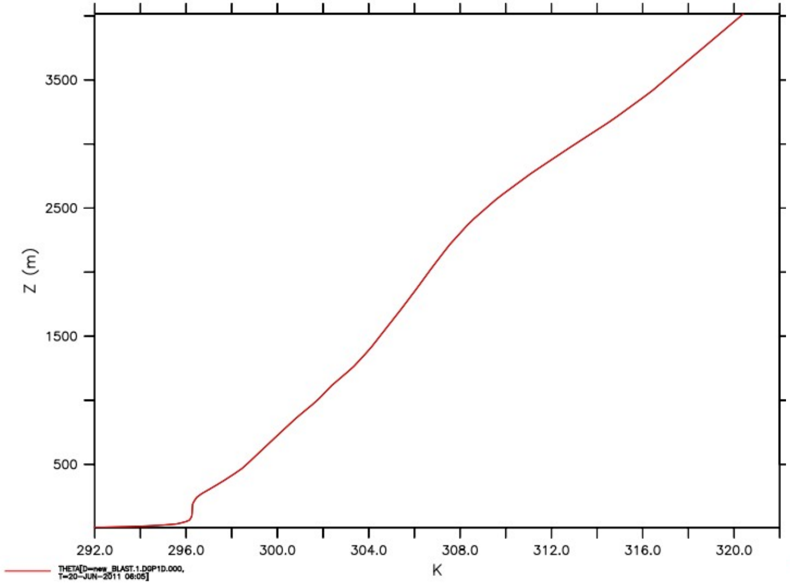
The realistic LES has to be completely analysed=> EMI stage proposed next year

LMD postdoc=> development of a simplified surface scheme and test for this ensemble of cases

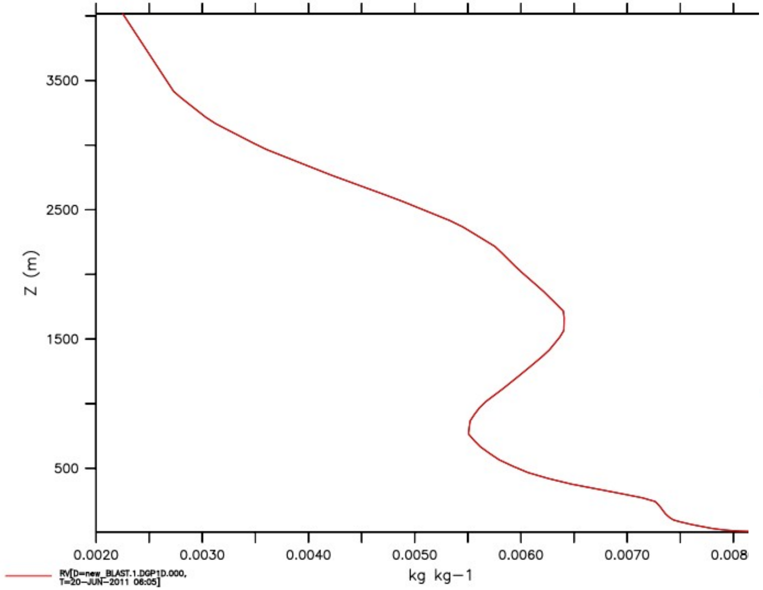
After the SOP at Lannemezan, possibility to do a LES and use the work of Myrtille and Sylvain Dupont to evaluate the resolution close to the surface at the border of the forest ?

Initial conditions and forcing (=0)

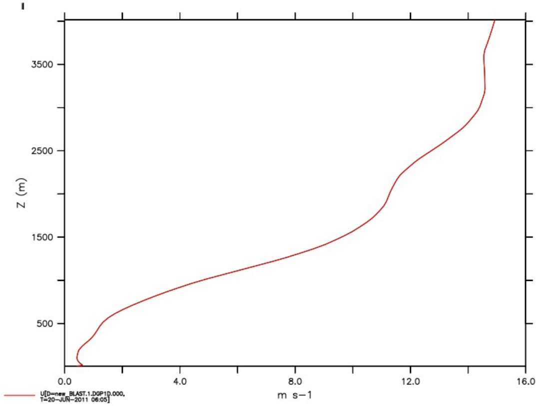
Simulations disponibles sous hendrix. fernandesr/MESONH/



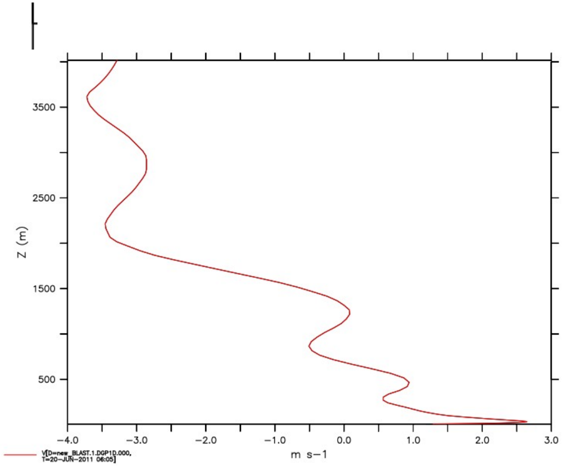
potential temperature



water vapor mixing ratio



zonal component wind



meridional component wind

Origine de ces profils initiaux => un radiosondage
Mais bcp de fluctuations ? On peut envisager
De refaire les simus LES avec des profils initiaux plus idéalisés.
Ca ne devrait pas chger bcp les résultats mais plus facile a
présenter pour un papier