Impact of the land surface forcing on land-atmosphere feedback in the convection permitting modeling

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1. Motivation and objectives

Predictive skill of an atmospheric model depends on the initial and boundary information that we use for its forcing. Besides the topography, **soil texture (ST)** and **land cover (LC) maps** are the two most relevant static information used for the model initialization.

In the Weather Research and Forecasting (WRF) model the default LC information are based on the Moderate Resolution Imaging Spectroradiometer (**MODIS**), and ST on the Food and Agricultural Organization (**FAO**) data. We created two alternative maps for WRF:

- A LC map based on the higher resolution and more up-to-date COoRdination of INformation on the Environment (**CORINE**) data for Europe,
- A ST map based on the Harmonized World Soil Database (**HWSD**, *Milovac et al. 2018*) and Bodenübersichtskarte (BÜK1000, *Milovac et al. 2014*) top ST data.

LC and ST characterize the land surface and control the hydraulic and dynamic properties of the soil, which have a strong impact on the energy partitioning at the land surface. The surface heat fluxes - calculated in a land surface model (LSM) or surface layer scheme, depending on the selected model configuration - represent the lower boundary condition for a Planetary Boundary Layer (PBL) scheme.

Within the CORDEX Flagship Pilot study (CORDEX-FPS) initiative on Convective Phenomena over Europe and Mediterranean (*Coppola et al. 2018*) an ensemble of convection permitting simulations is being produced, where all research groups running WRF use the two alternative (CORINE and HWSD) static maps. For the first time we do the basic validation of the impact of these maps on the model output using FLUXNET2015 data (Pastorello et al. 2017), and we investigate:

1. Sensitivity of WRF to changes in static maps
2. How the model sensitivity in (1) depends on the model configuration

2. Experimental design

- WRF model, version 3.8.1
- 2 model configurations **C1** and **C2**, different in the selection of the PBL schemes and LSMs
- 2 ensembles **ES1** and **ES2** created for 2 time lines: **ES1 for June 2009**, ES2 for October and first 7 days of November 2014. The two periods coincide with the climate mode experiments for the Austria and Foehn case studies described in *Coppola et al. 2018*.
- Each ensemble consists of 8 simulations, where 2 top soil texture, 2 land cover forcing maps (CH,CF,MH,MF), and 2 model configurations were combined → 16 simulations
- Results from ES1 presented here.

Conf.	C1	C2
PBL	YSU	MYNN 2.5
LSM	NOAH	NOAH-MP

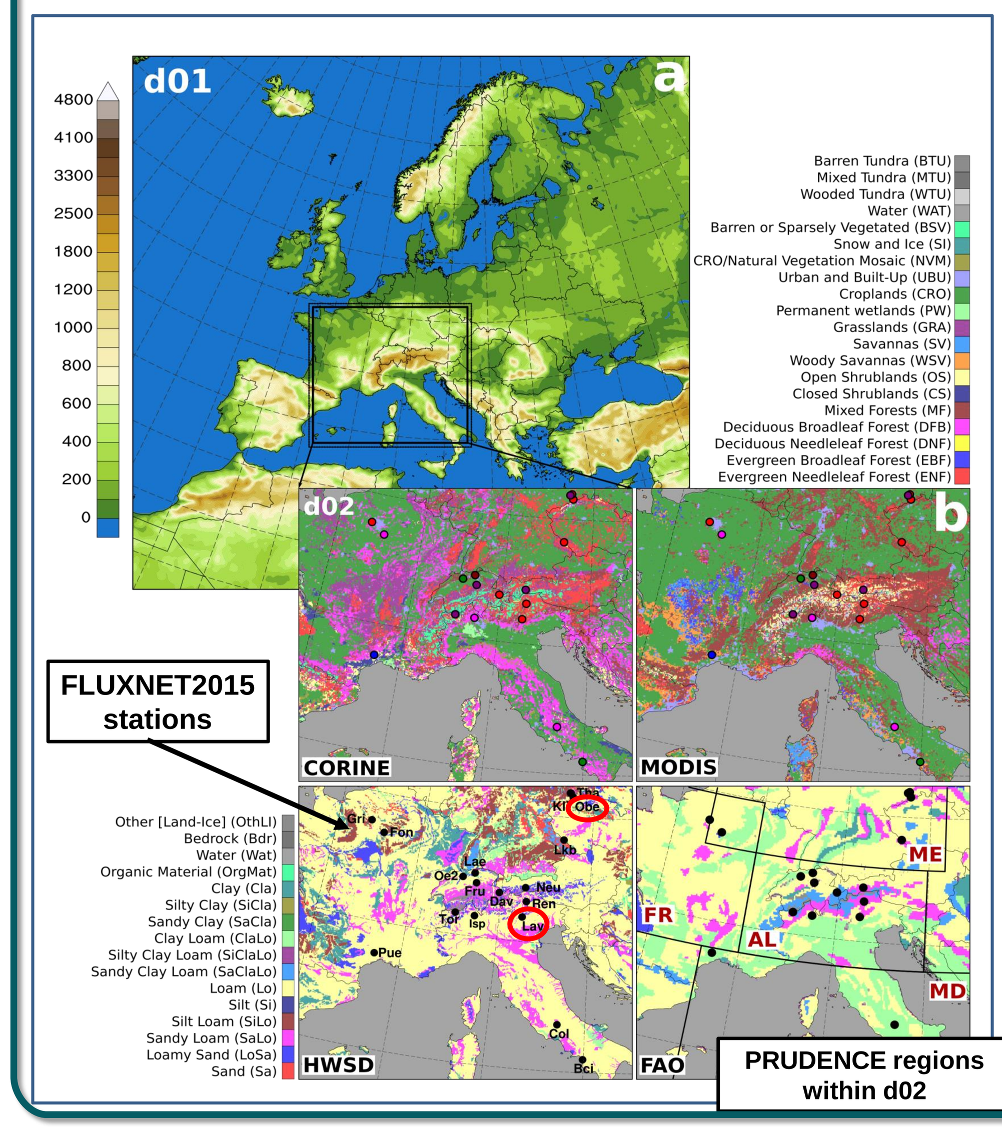


*Fig 1: The experimental domains coincide to the CORDEX-FPS domain setting. The convection permitting 3km domain (b) over the Alpine region (**d02: ALP-3**) nested into the 15 km domain (a) covering Europe (**d01: EUR-15**).*

Percentage of the grid cells over land affected with the change in the maps:

MODIS→CORINE 52.2%
MF→DBF 6.9%
MF→ENF 6.8%
CRO→GRA 6.2%
WS→ DBF 1.2 %
OS→ BSV 0.9 %
SV → GRA 0.7 %
FAO→HWSD 57.9%
ClaLo→Lo 19.5%
Lo→SaLo 5.5%
Lo→SiLo 5.2%
Lo→Cla 4%
ClaLo→Cla 2.1%
ClaLo→SaLo 2.1%

3. Methodology

- To investigate the impact of the land surface on the PBL evolution we use **the Mixing diagram approach** (Santanello et al. 2009).
- The diagram is basically a vector representation of the diurnal coevolution of 2m potential temperature and 2m mixing ratio (here we show from 6 to 16 UTC)
- Size of **Vsfc** equals the quantified impact of the surface (it is a model output or observed), and **Vatm** is the impact from the atmosphere on the PBL evolution (obtained from the diagram).

$$\beta_{sfc} = \frac{y_{sfc}}{x_{sfc}} \quad \beta_{atm} = \frac{y_{atm}}{x_{atm}} \quad A_{\lambda E} = \frac{x_{atm}}{x_{sfc}}$$

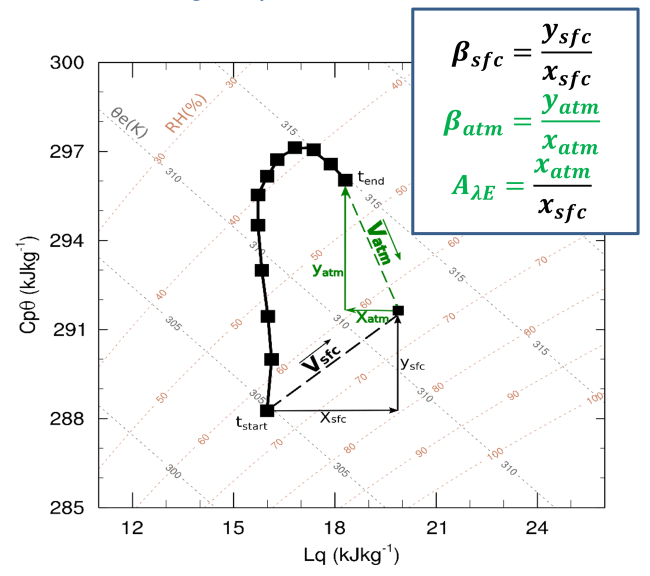


Fig 2: A scheme of a mixing diagram. Black part of the diagram show the data directly available from a model, or observations. The green part is calculated from the diagram.

4. Validation with FLUXNET2015 data

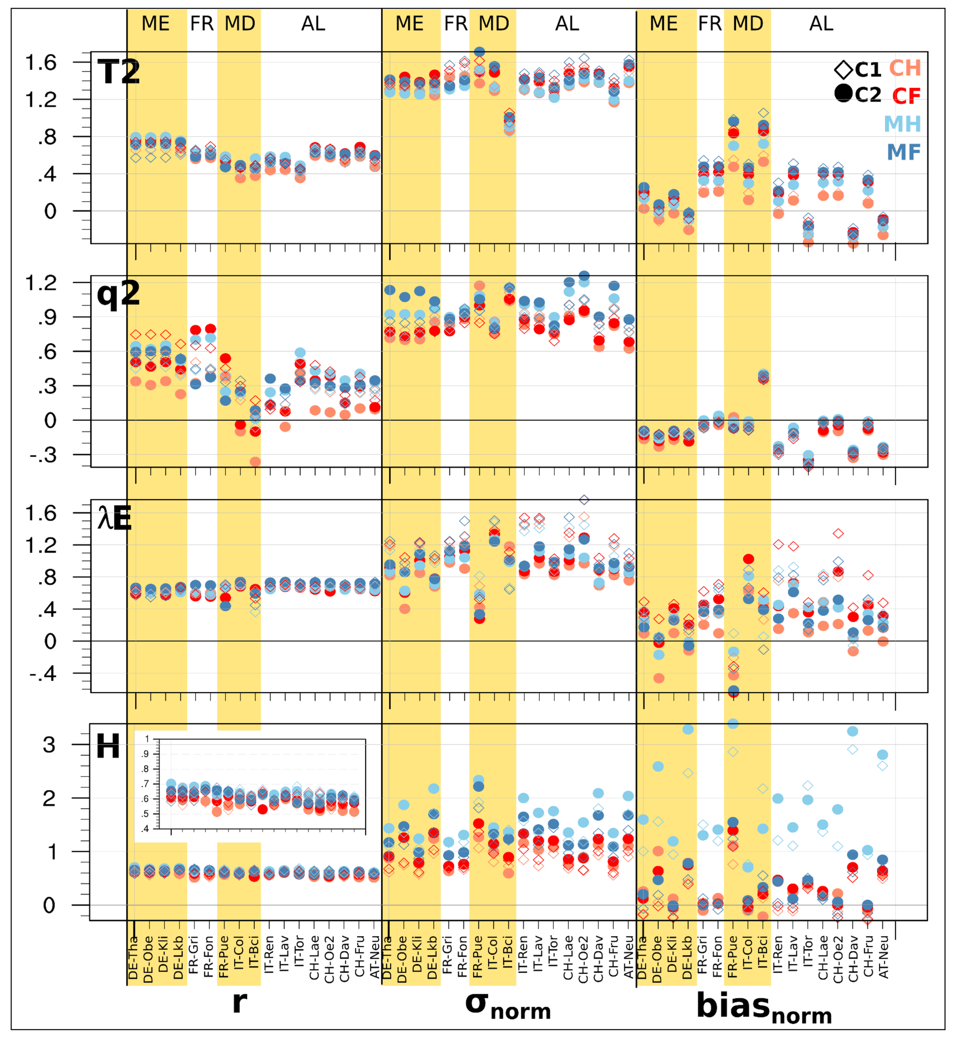
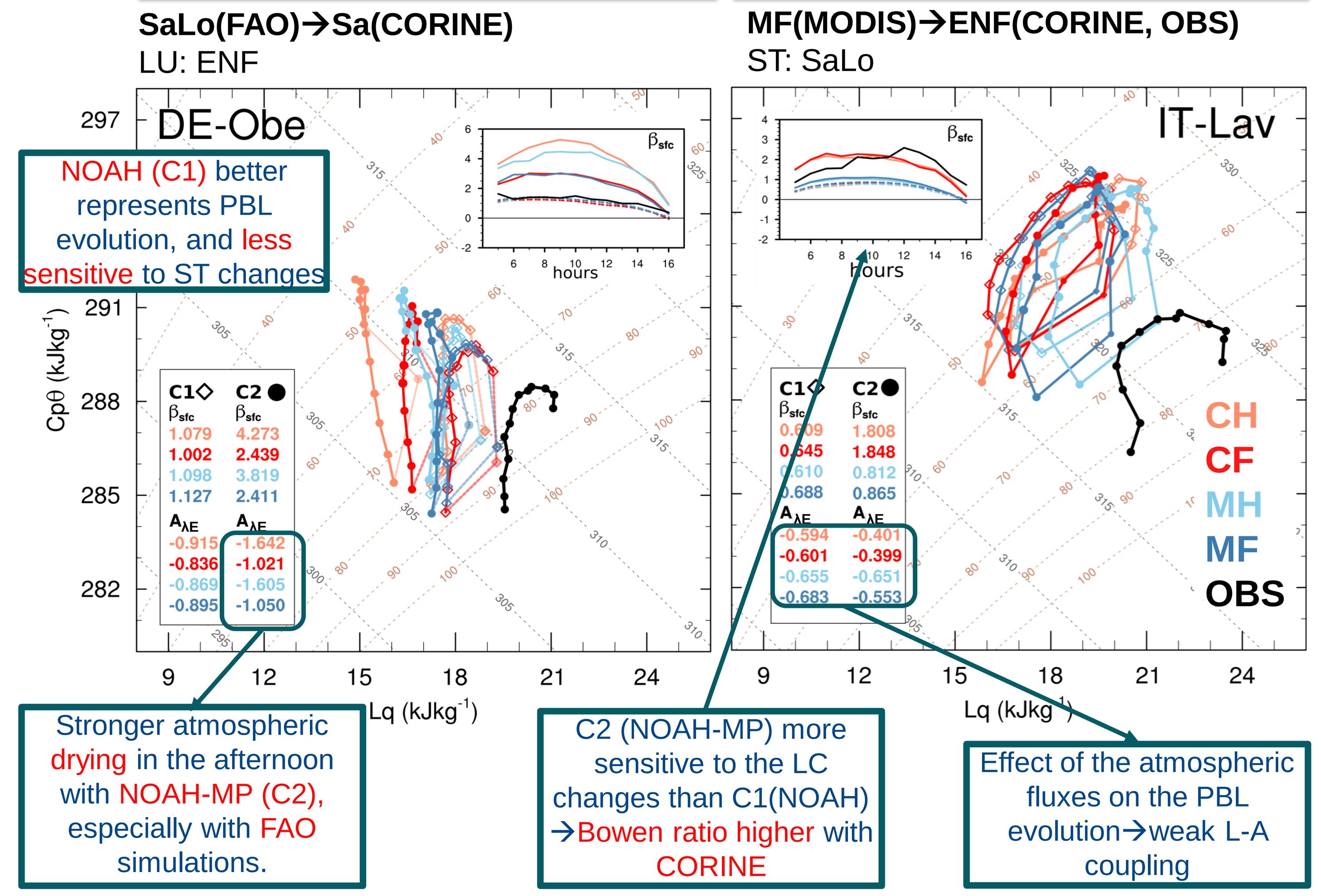


Fig 3: Pearson correlation (r), mean standard deviation (σ) normalized with σ observations, mean bias normalized with mean observations for 2m temperature (T2), 2m mixing ratio (q2), latent (λE) and sensible heat (H) fluxes - model vs FLUXNET2015 data.

- Lowest mean bias with **CH**.
- 20-40% higher σ at most stations for all runs
- The lowest ***r*** with **C2-CH**.
- **C1** & **C2** mostly too dry
- In ME and AL **CORINE** slightly drier than MODIS.
- **C1** higher mean ***σ*** than C2, especially for the stations in AL region.
- **C1-CH** the smallest mean bias for most stations.
- **MODIS** has higher r, but also higher σ.
- **C1** tend to produce smaller mean bias.
- The highest mean bias for C1 and C2 with **MH**.

Fig 4: Mixing diagrams at the locations of 2 FLUXNET2015 stations, DE-Obe and IT-Lav - model comparisons to observations. Panels within the plots show diurnal circle of mean surface Bowen ratio (βsfc) compared to observations (black lines).



5. Regional averages over dry days

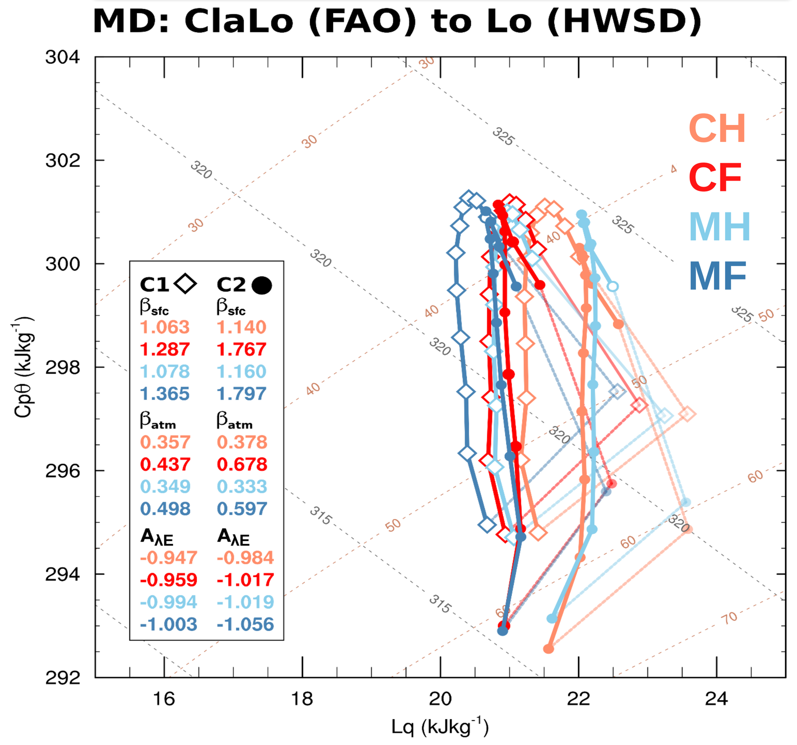


Fig 5: Mixing diagram averaged over grid cells within the Mediterranean (MD) region where Clay-Loam(Cla-Lo) in FAO is converted to Loam (Lo) in HWSD.

- In the Mediterranean (MD) region 46.9% of Clay Loam (ClaLo) grid cells in FAO is converted to Loam (Lo) in HWSD.
- This change results in an increase of moisture flux from the surface (lower βsfc), especially for the C2 (NOAH-MP) configuration.
- C2 more sensitive to this change→ higher differences at βsfc affect βatm more than C1(NOAH) simulations ($A_{\lambda E}$).

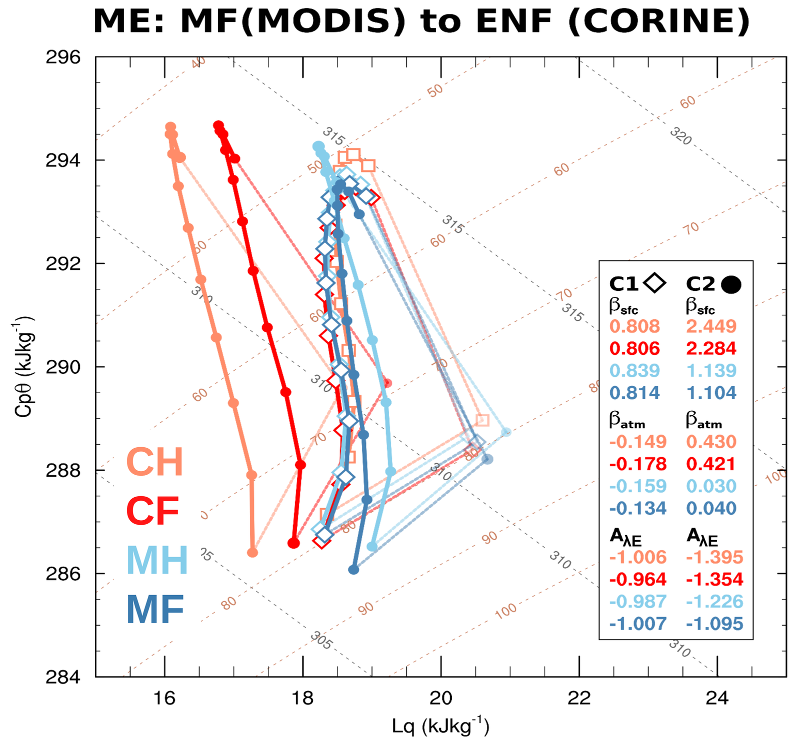


Fig 6: Mixing diagram averaged over grid cells within the Middle European (ME) region where Mixed Forrest (MF) is converted to Evergreen Needleleaf Forest (ENF).

- In the Middle European (ME) region 10% of Mixed Forest (MF) grid cells in MODIS is converted to Evergreen Needleleaf Forest (ENF) in CORINE.
- This change increases βsfc in C2 (NOAH-MP) simulations, but not in C1 (NOAH) simulations.
- Influence of the atmospheric drying in the afternoon PBL stronger in C2 than in C1 simulations ($A_{\lambda E}$) especially with CORINE simulations.

6. Atmospheric variables: LCL deficit

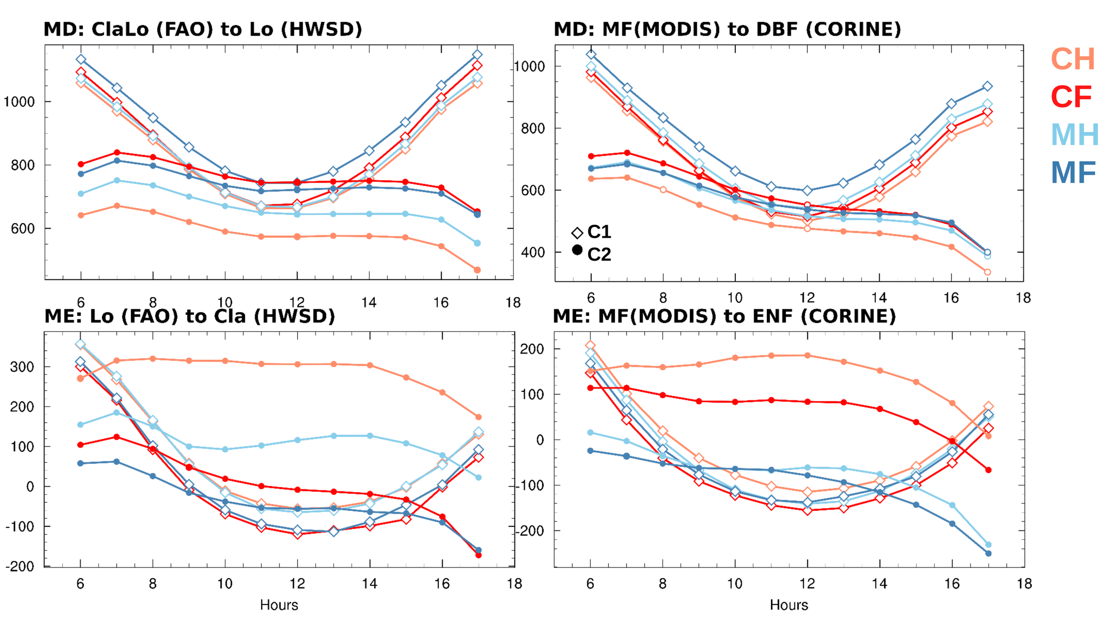


Fig 7: Mean diurnal cycle of the Lifting condensation Level (LCL) deficit calculated as difference between PBL (m) height and LCL (m). It shows the ability of PBL to reach the condensation level (Santanello et al. 2009).

- Changes of the static maps have an effect also on the PBL variables, such as PBL height and LCL.
- C2 (MYNN) simulations more sensitive to the changes than the C1 (YSU) simulations.
- C1 shows a strong diurnal cycle of the LCL deficit for all cases, with the minimum at midday; not evident in C2

- For these category changes in C2 simulations the impact is evident: higher/lower βsfc (i.e. less/more moisture enters PBL) produces higher/lower LCL deficit → this may lead to a conclusion that atmospheric impact on the PBL evolution stronger than the impact from the land surface.

7. Conclusions

- The comparison to the FLUXNET 2015 data shows WRF tendency to be drier and warmer than the observations. Higher variability of MODIS simulations for the moisture variables.
- NOAH-MP LSM and MYNN PBL scheme more sensitive to changes in land cover and top soil texture maps than NOAH LSM and YSU PBL scheme.
- The changes in the static maps have an impact on the surface variables and the PBL evolution, and the strength of the impact depends on the model configuration and a specific category change.

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Eddy covariance FLUXNET2015 data are acquired by the FLUXNET community (www.fluxnet.fluxdata.org).