The role of horizontal grid spacing on transport and mixing of passive tracers over complex terrain

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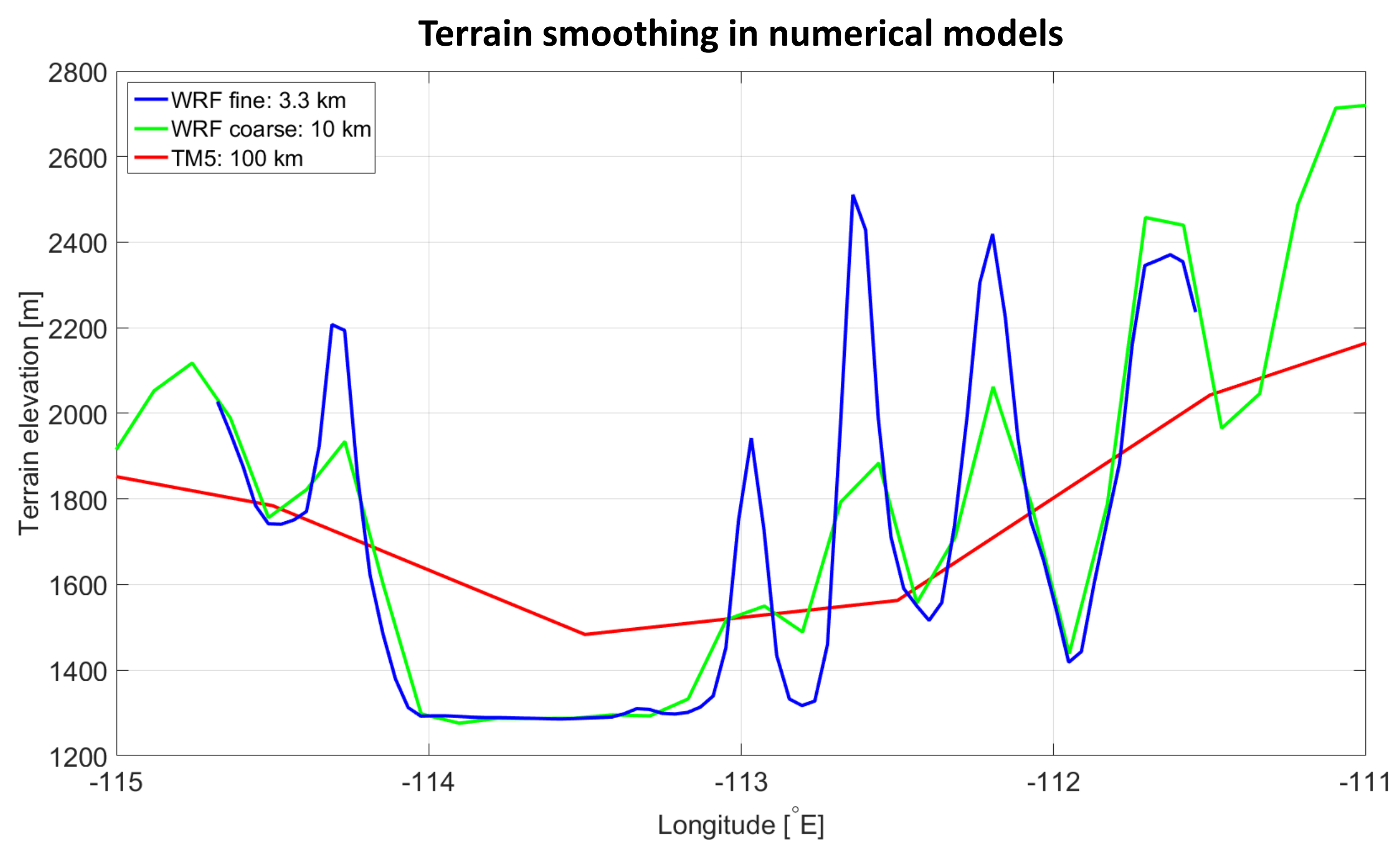
Motivation

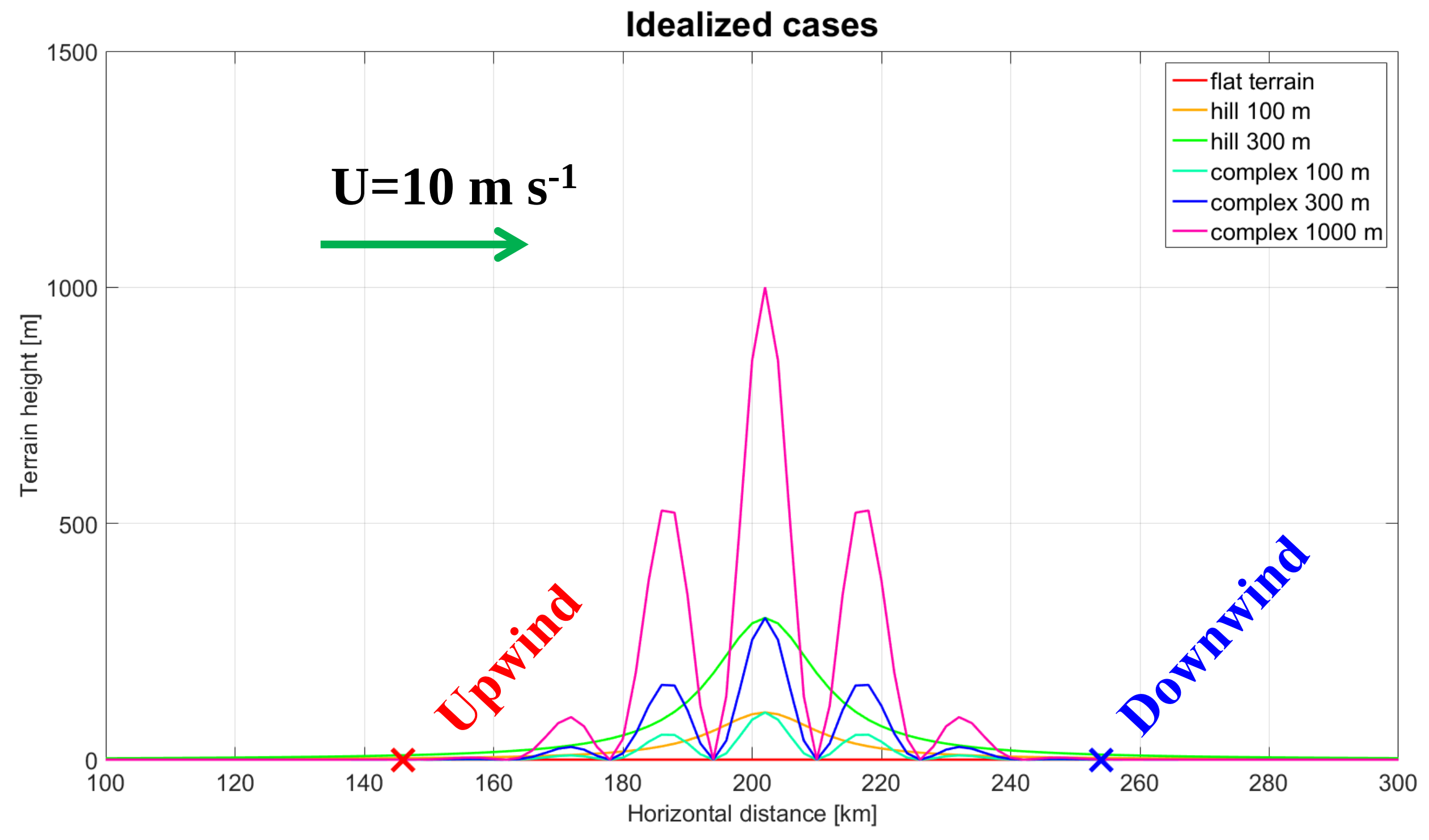
The estimation of greenhouse gas budgets, and the estimation of the terrestrial carbon uptake in particular, has many challenges from both modeling and observational perspectives. For example, on the one hand, the difficulty of modeling atmospheric transport and mixing processes introduces significant uncertainties in the fluxes estimated with inverse carbon transport models. Current offline global transport models used for carbon dioxide (CO2) flux estimations, such as TM5 for CarbonTracker, are typically run on very coarse grid spacing (around 100 km). Such models lack terrain variability (see **Fig. 1**), which leads to a poor representation of physical and dynamical processes associated, and the overestimation of PBL depths (Duine and De Wekker, 2017). This suggests that transport and mixing of trace gases are poorly simulated in complex terrain areas, which result in incorrect estimations of CO2 budgets.

On the other hand, from an experimental point of view, the comparison of an upwind and a downwind CO2 concentration profile using a mass budget approach is one of the most common strategies to derive terrestrial CO2 fluxes. Because of the difficulty to capture the variety of atmospheric processes by means of observations alone, this strategy is not the most obvious one to derive the sources of CO2 uptake or release. When dealing with mountainous terrain, this approach becomes even more challenging. In this poster, we use idealized modeling settings to mimic such an experimental setup, enabling to derive CO2 surface fluxes from simulated up- and downwind CO2 concentration profiles. By changing systematically the terrain complexity from flat to mountainous terrain (**Fig. 2**), we are able to assess how complex terrain influences carbon budget estimations from both the modeling and experimental viewpoints.

(1)

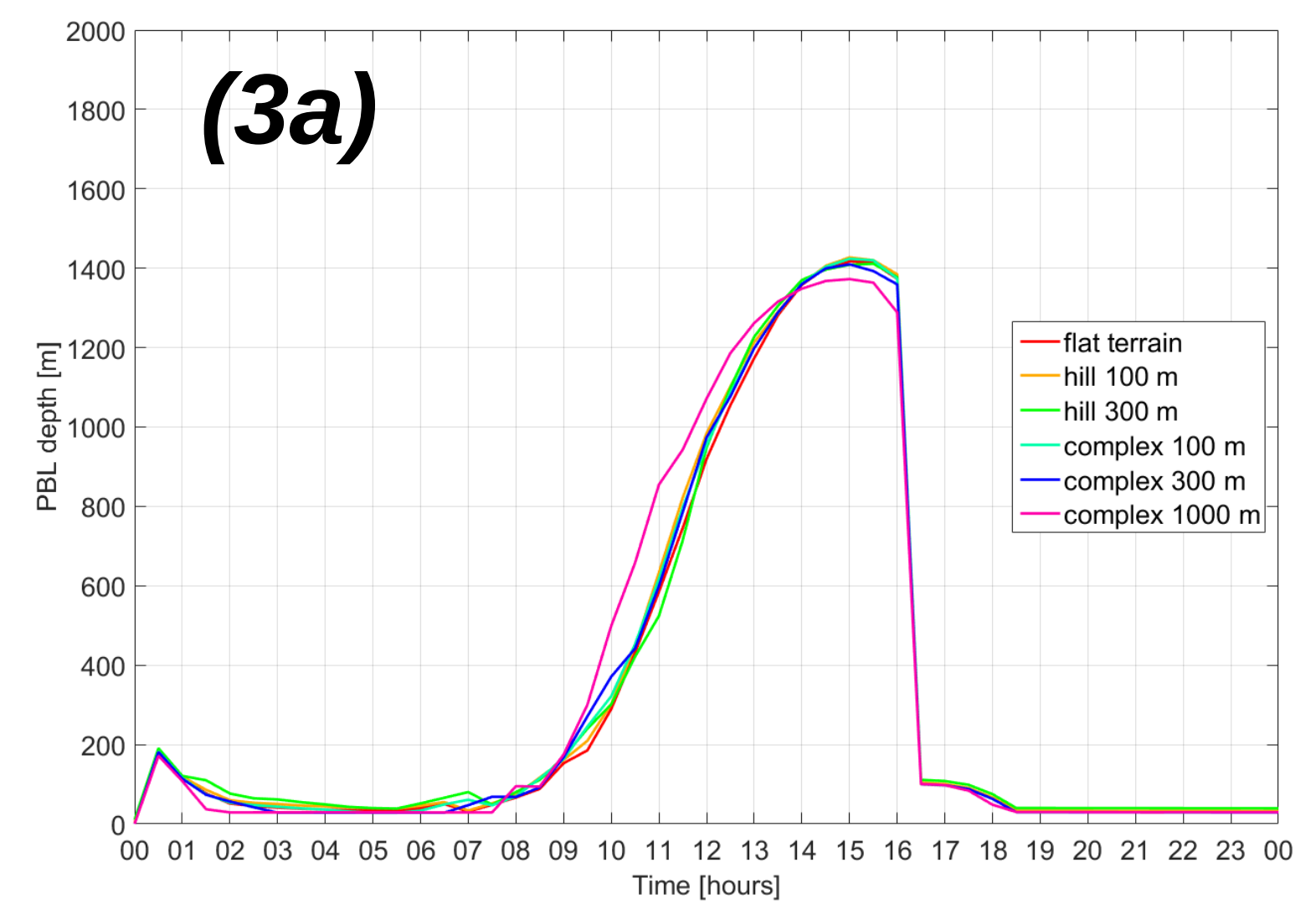


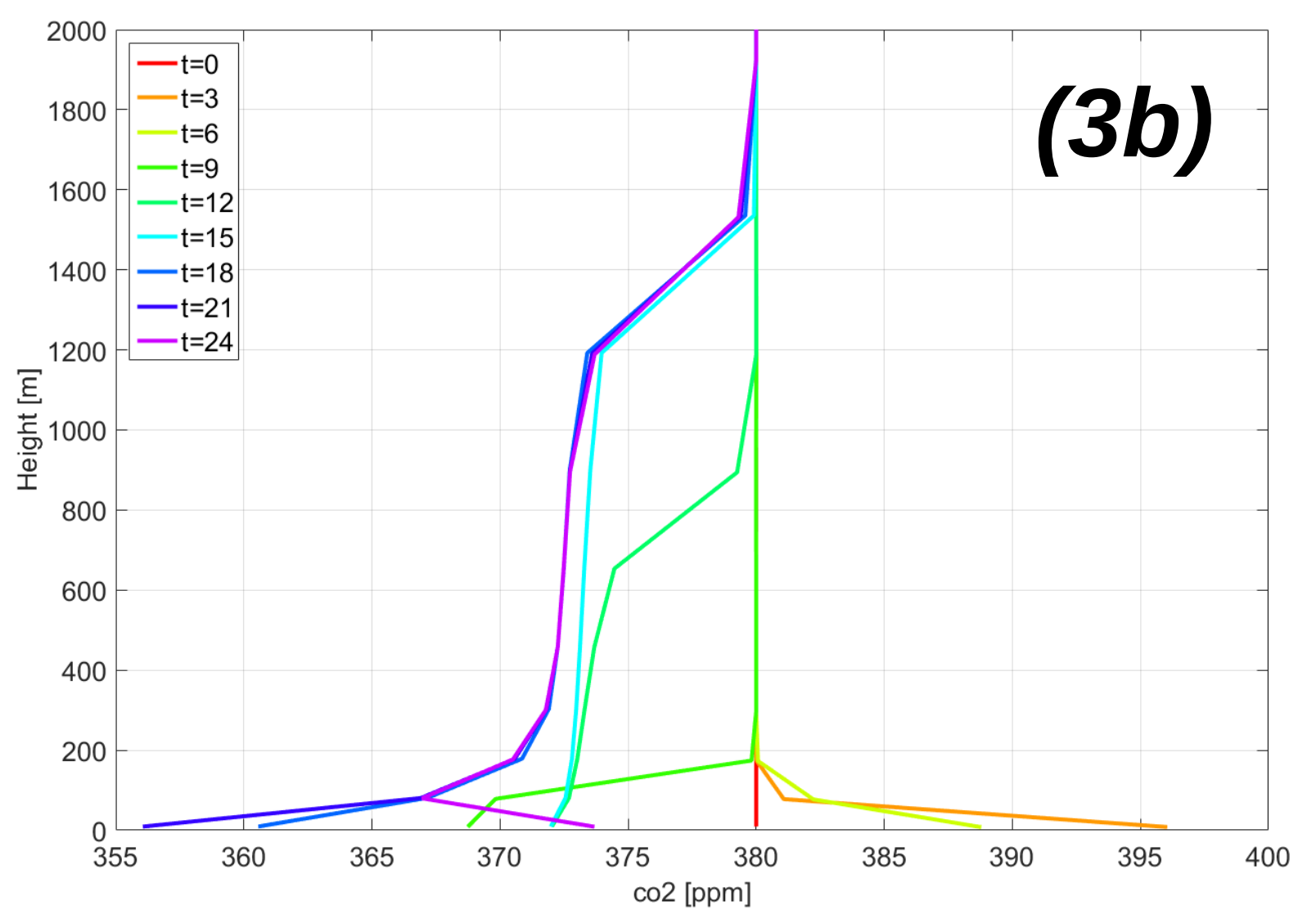
(2)



Idealized cases

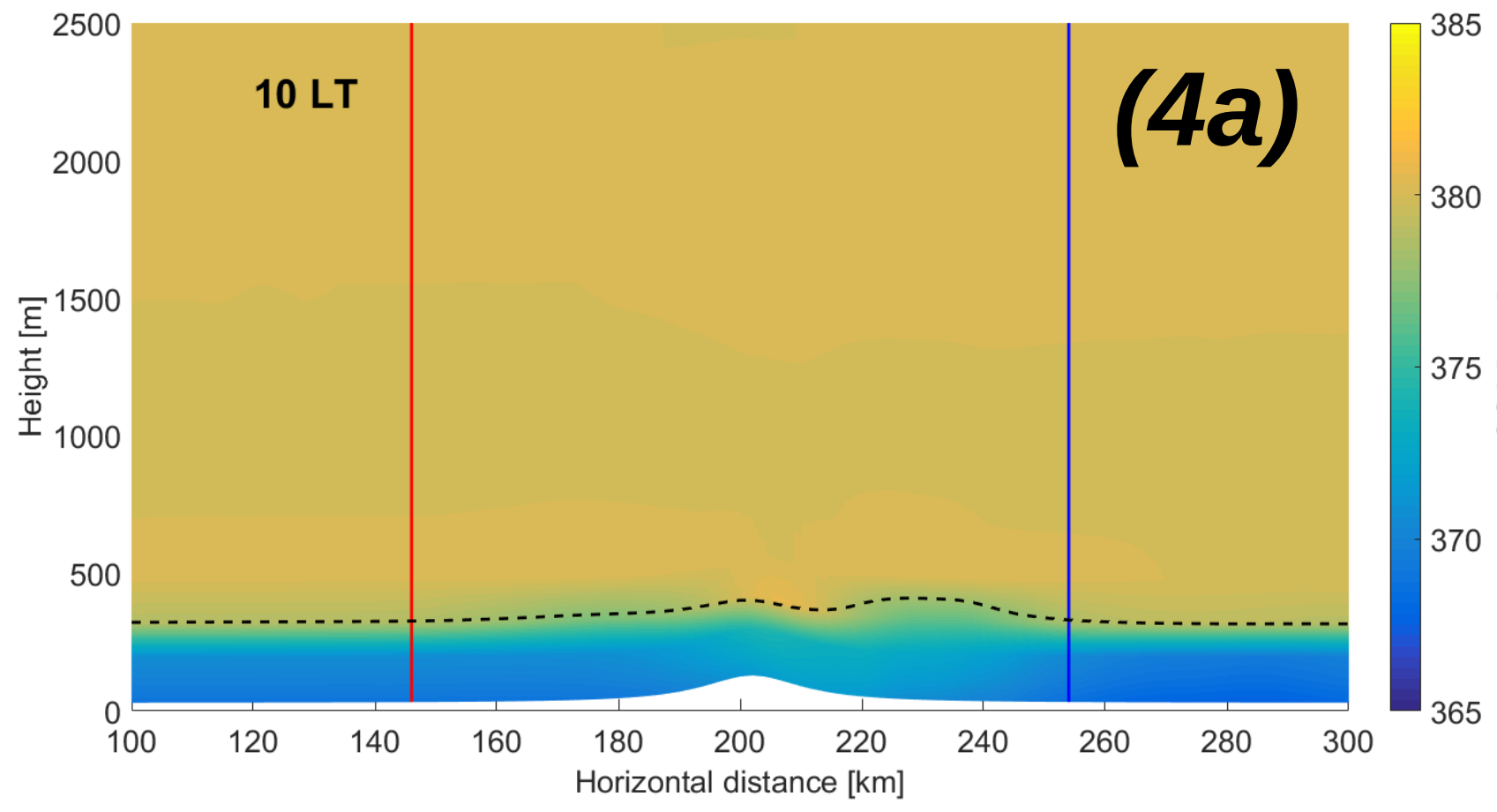
We use idealized settings in the Weather Research and Forecasting (WRF) model. Atmospheric CO2 and its transport are represented by implementing a passive tracer with a background concentration of 380 ppm, including a simplified representation for the diurnal uptake and release by vegetation (see black dashed line in **Fig. 5**). The simulations run for 24 hours (July 1st), with an homogeneous vertical wind profile of 10 m s^{-1}. We note a very general behavior for PBL depth evolution (see **Fig. 3a**).

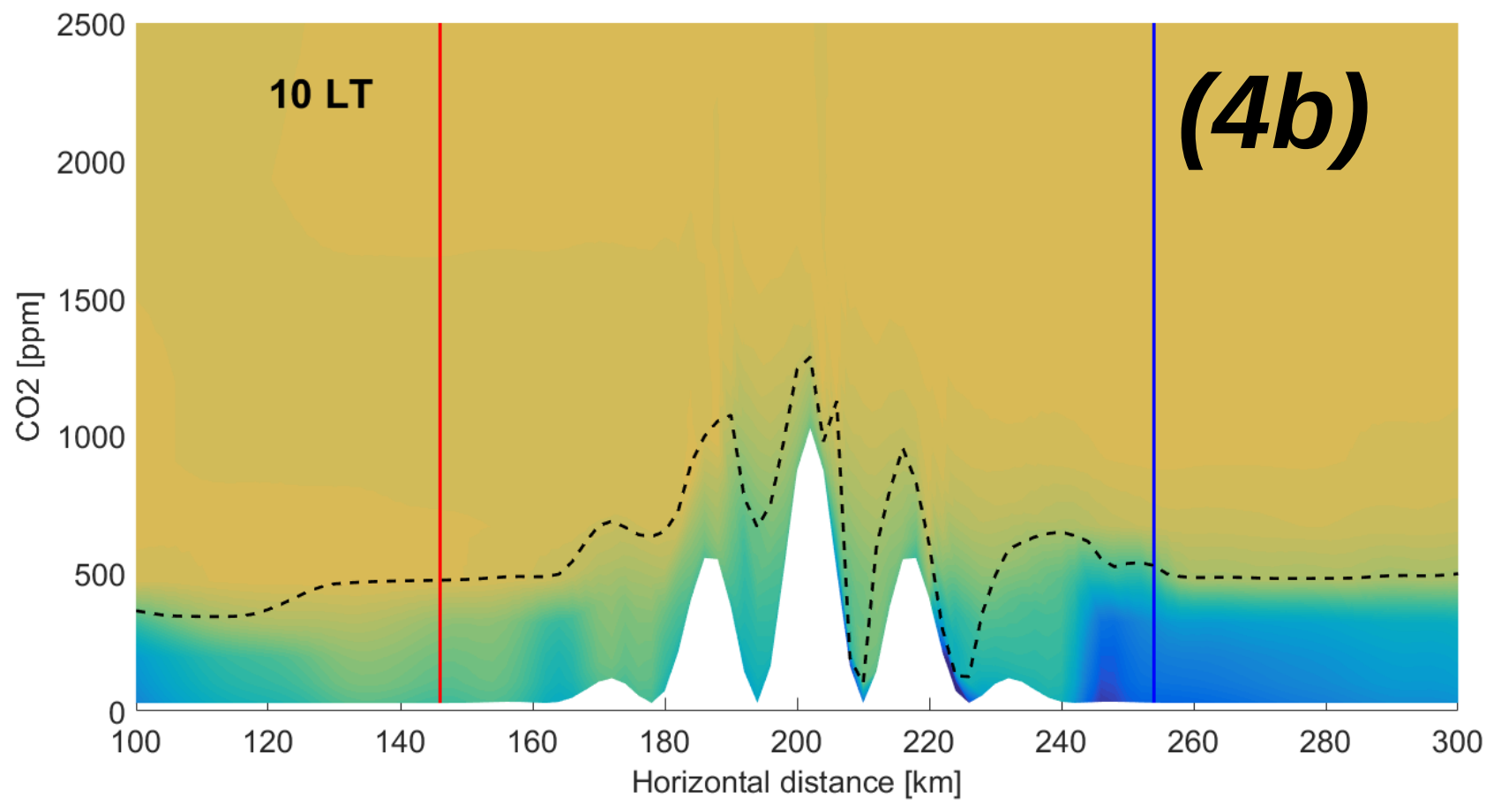


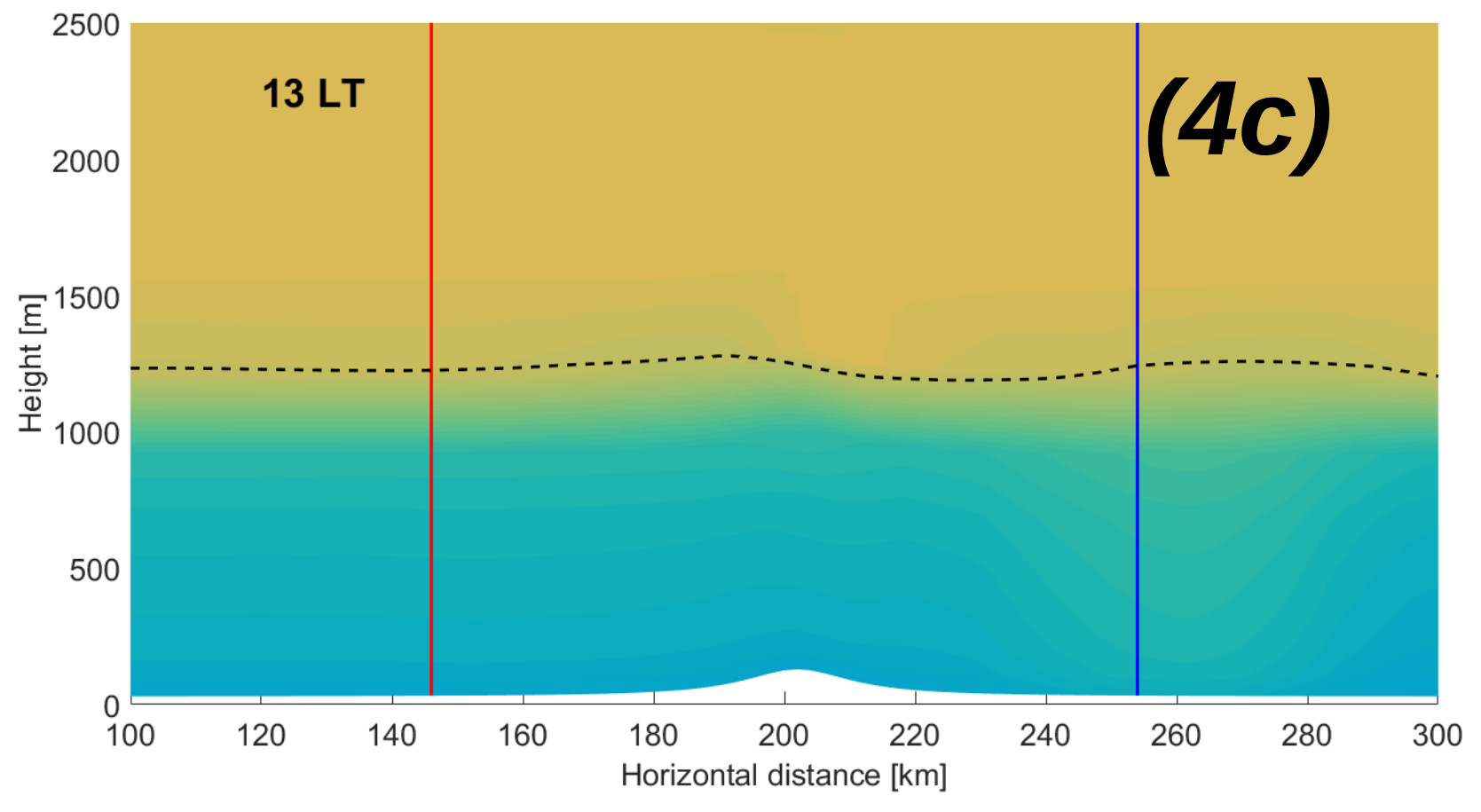


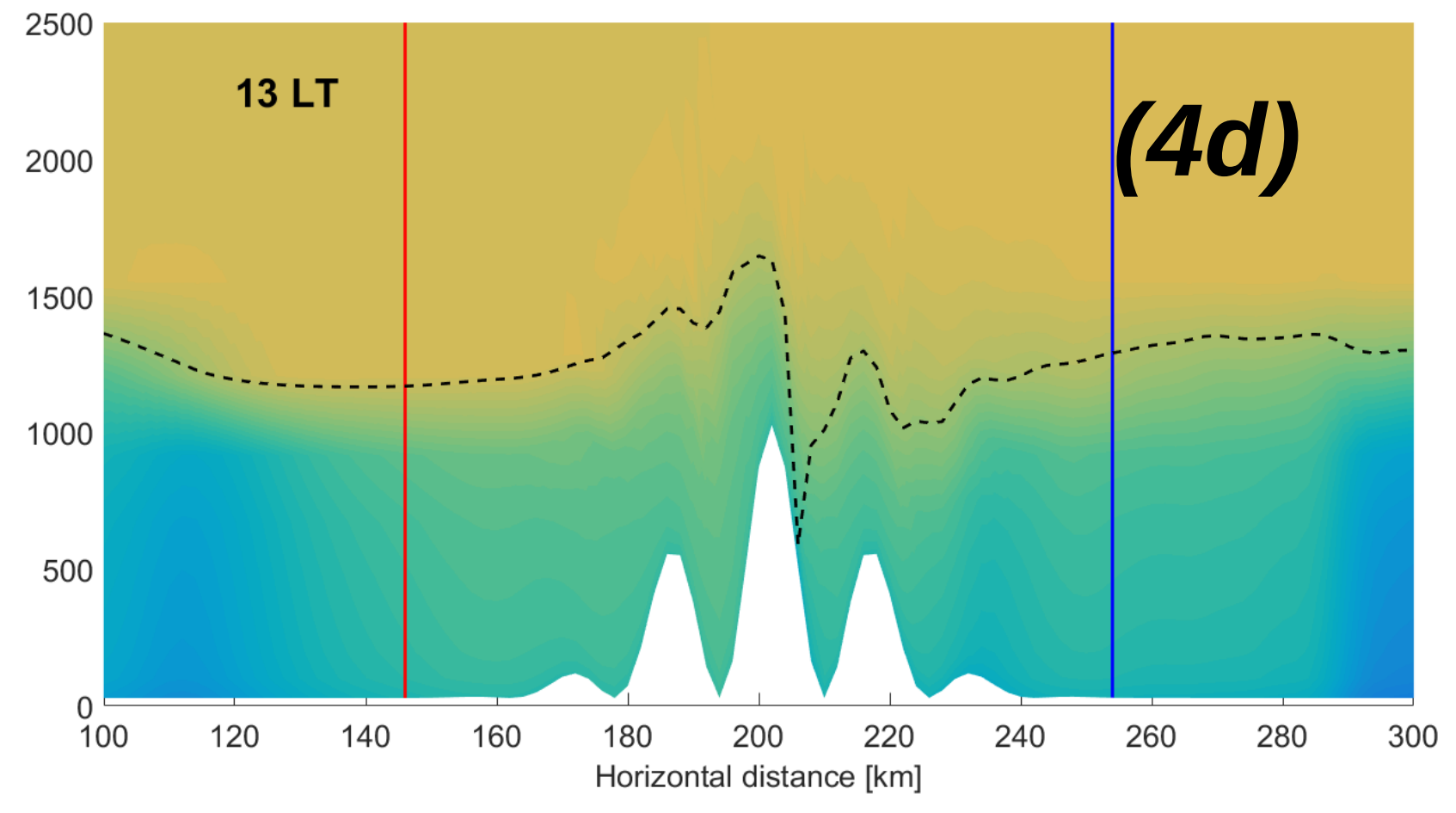
The diurnal uptake in combination with a shallow morning boundary layer clearly has an impact on the simulated profiles (see **Figs. 3b, 4a-b**). The low CO2 concentrations at the surface however get quickly diluted as the boundary layer rises (**Figs. 3b, 4c-d**) with on average the lowest mean profiles just before the convective PBL collapses (**Figs. 3b, 4e-f**).

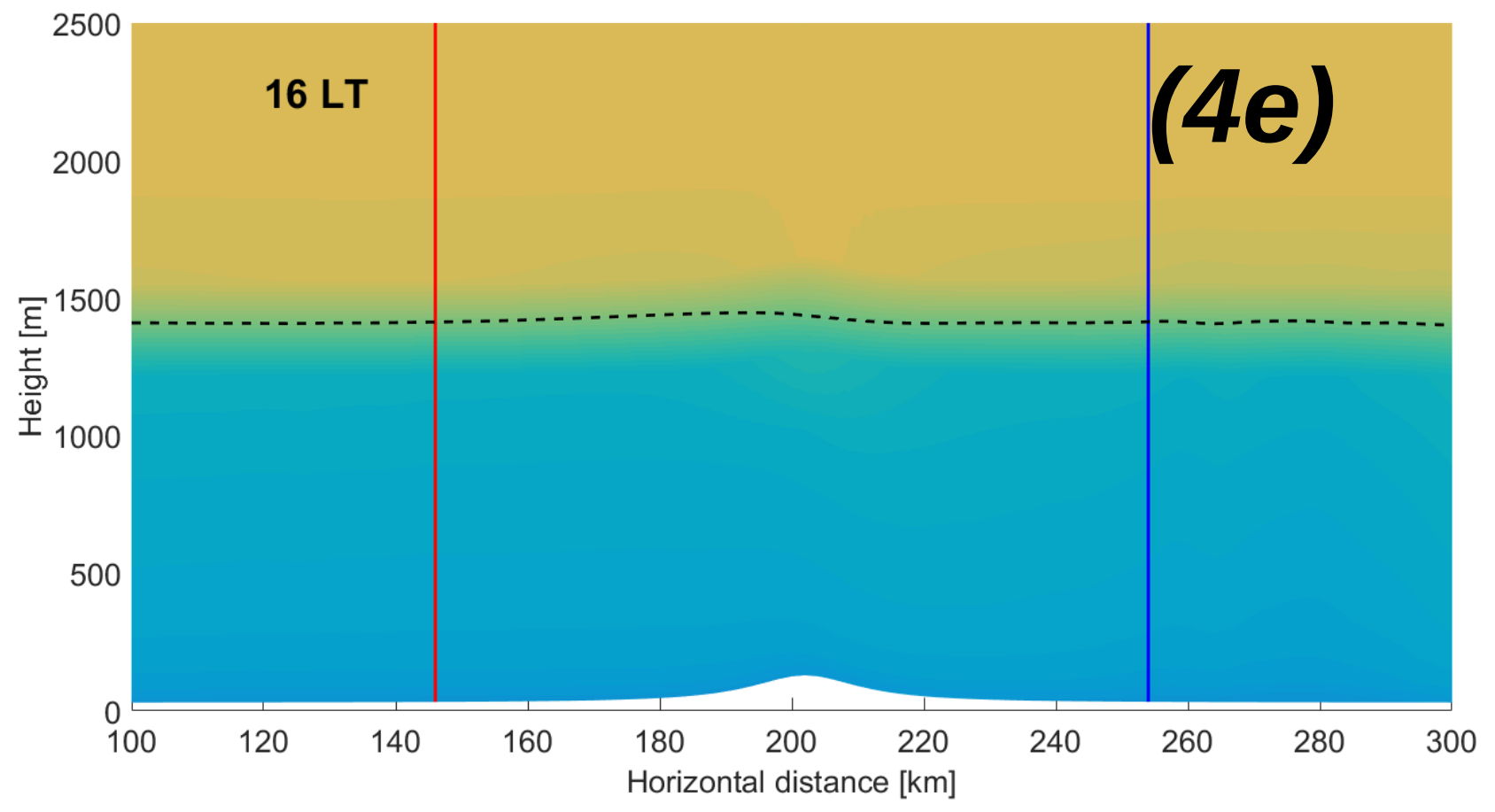
Low hill **Mountainous**

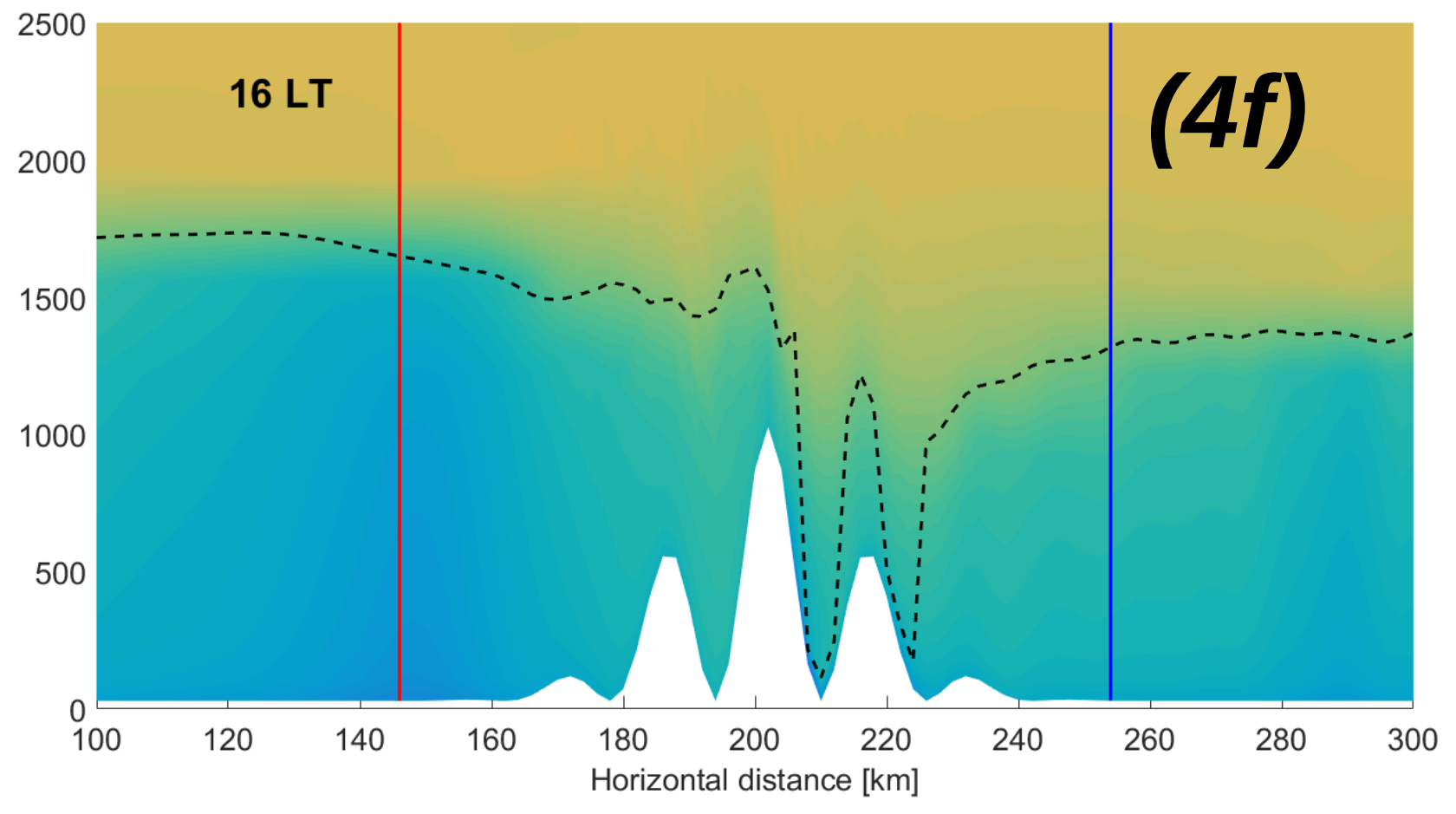












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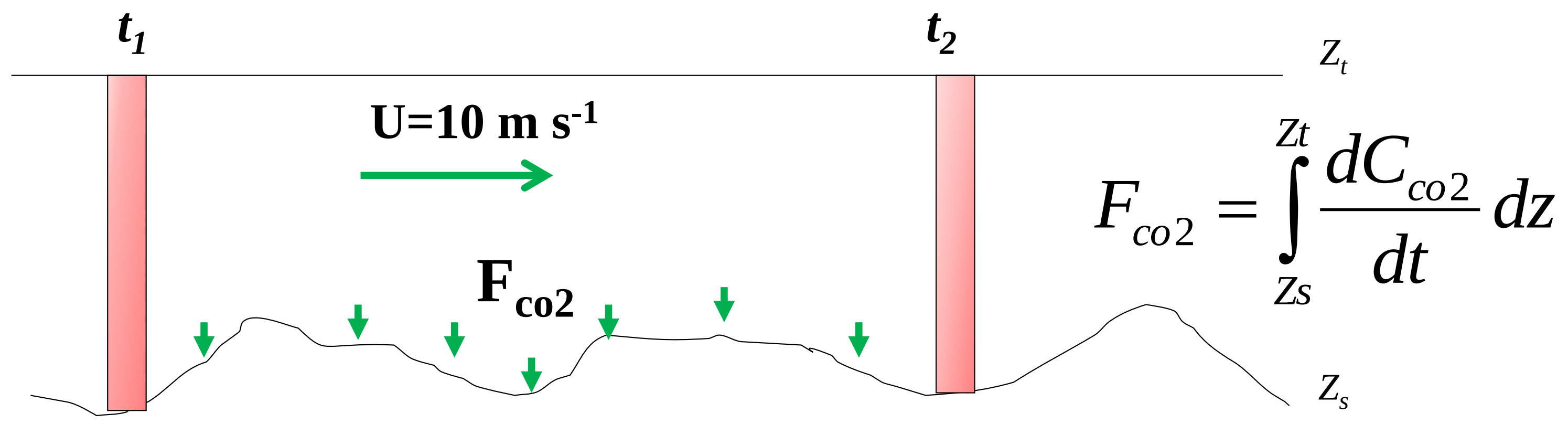
Derived CO2 fluxes

The estimation of CO2 surface flux are calculated by taking the difference in the downwind and upwind vertical profiles of CO2 at two different times (see **Fig. 5**). The time difference corresponds with the time it takes for the air to be transported from the upwind to the downwind location.

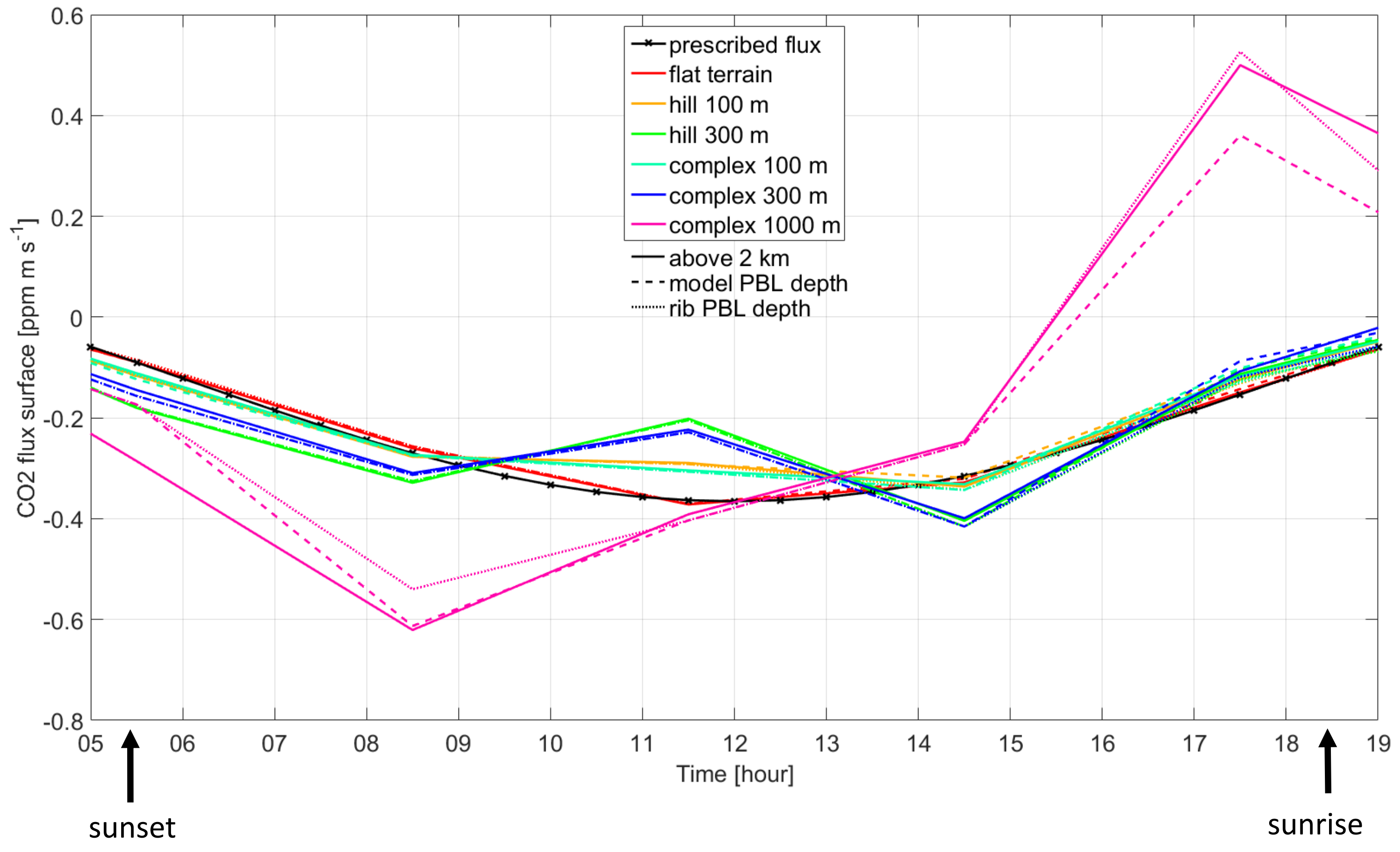
(5)



$$F_{co2} = \int_{Zs}^{Zt} \frac{dC_{co2}}{dt} dz$$

For flat terrain, the estimation of CO2 surface fluxes shows very good agreement with the prescribed surface flux (dashed line in **Fig. 6**). With increasing terrain complexity the differences with the flat terrain become larger. This is mostly a result from CO2 rich and CO2 poor air at the respective windward and leeward side of the hills (see **Fig. 4**). As long as the upper limit of the integration is taken above the maximum PBL depth, the results are not very sensitive to the simulated PBL depth.

(6)



Summary and outlook

By performing idealized simulations, we evaluated the performance of the mass budget approach to derive CO2 surface fluxes from up- and downwind vertical profiles. We find that the estimated CO2 fluxes diverges more from the prescribed fluxes over complex terrain than over flat terrain. Similarly, we expect that for models with coarse grid spacing, smoothing of the terrain leads to significant errors in deriving CO2 fluxes.

The results of this poster feed the development of a methodology to represent the effect of terrain smoothing on the estimation of CO2 budgets in large-scale models. A better understanding and representation of these terrain effects in coarse atmospheric models will lead to an improved quantification of North American and global carbon sources and sinks.

REFERENCES

Duine, G.J. and S.F.J. De Wekker, 2017. The effects of horizontal grid spacing on simulated PBL depths in an area of complex terrain in Utah, *Environ. Fluid Mech..*, in revision.