# Influence of subgrid terrain variability on simulated planetary boundary layer depths in large-scale transport models

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## *Motivation*

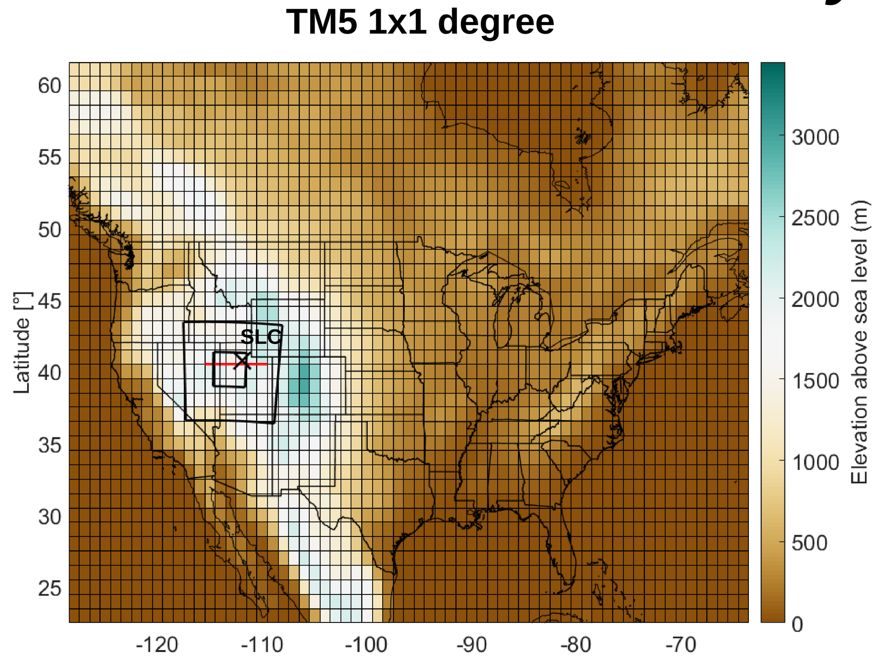
The difficulty of modeling atmospheric transport and mixing processes introduces significant uncertainties in the fluxes estimated with inverse carbon transport models. An important diagnostic for vertical transport and mixing is the planetary boundary layer (PBL) depth, the height above the surface up to which surface fluxes of heat, moisture, momentum, and trace gases such as CO2 are transported and mixed on a diurnal time scale. Current offline global transport models used for CO2-flux estimations, such as TM5 for CarbonTracker, are known to fail occasionally in reproducing daily cycles and absolute CO2 concentrations. These models are typically run on very coarse grid spacing (i.e. around 100 km), introducing uncertainties which may lead to incorrect estimations of PBL depths and, eventually, CO2-budgets. Important questions that we are trying to answer in an effort to understand and possibly reduce the uncertainty in these large-scale transport models in simulating PBL depths are:

1) How does missing subgrid-terrain information affect simulated PBL depths?
2) How can we best compare simulated PBL depths at various grid spacings with observed PBL depths at specific locations?

To determine the effects of subgrid variability, and to understand how we can compare observations to large-scale grids, we use two aggregation approaches with a coarse and a fine grid spacing domain from simulations using the Weather Research and Forecasting (WRF) model. We compare the two approaches and examine the influence of subgrid terrain variability on the PBL depth for one typical fair weather day in July 2013. For the analysis, we use WRF model output from the operational 4DWX forecast system developed by the NCAR Research Applications Laboratory, and TM5 model output. The study area is focused in and around the Salt Lake City valley, which comprises considerable terrain height variability. We use observations from radio soundings at SLC airport.

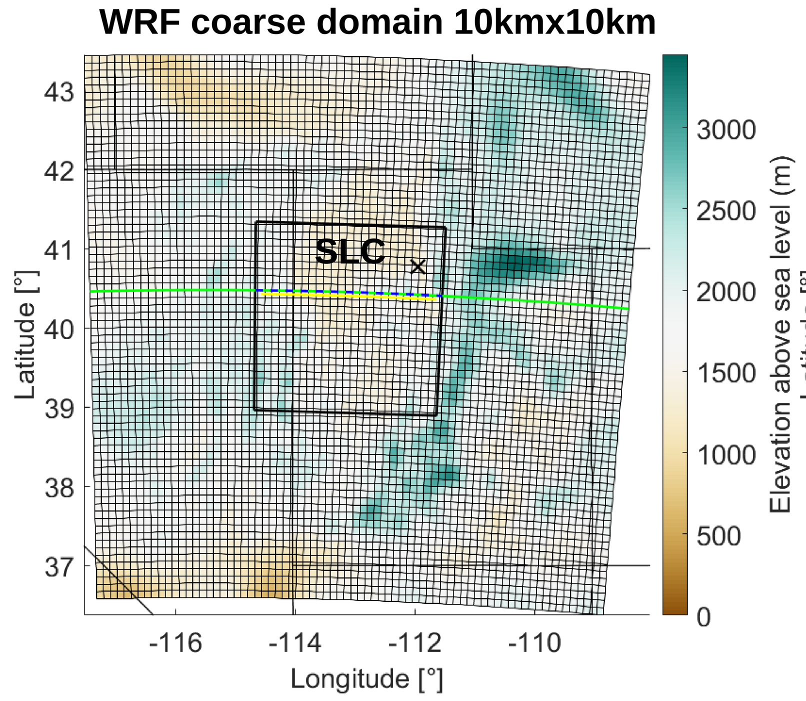
## *Study area*

TM5 1x1 degree

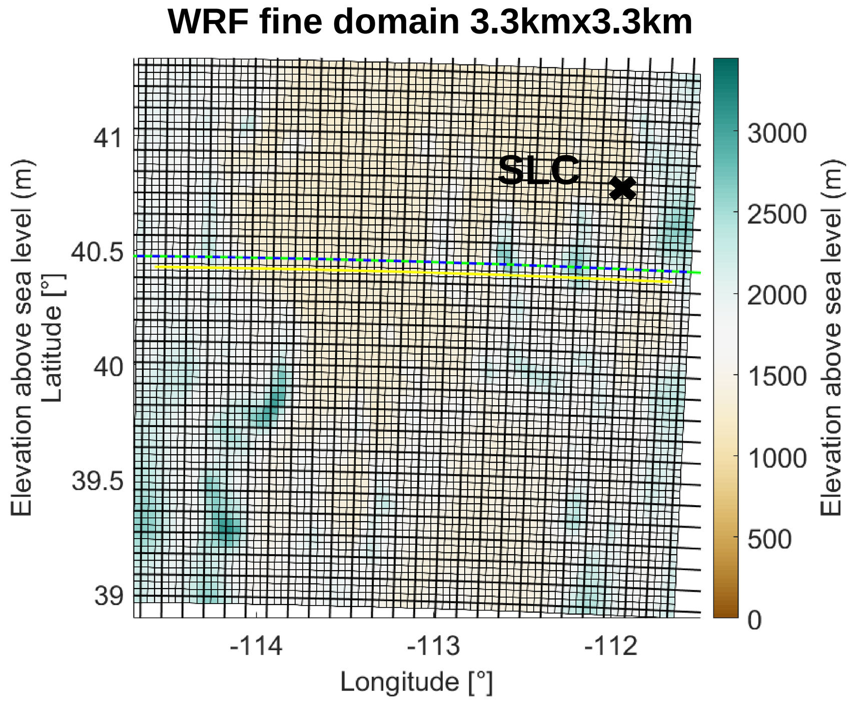


The study area (bottom right) and its terrain variability in the different models: TM5 (left), WRF coarse (bottom left) and WRF fine grid spacing (bottom right). SLC airport indicated by the x. Colored lines indicate cross section location.

WRF coarse domain 10kmx10km



WRF fine domain 3.3kmx3.3km



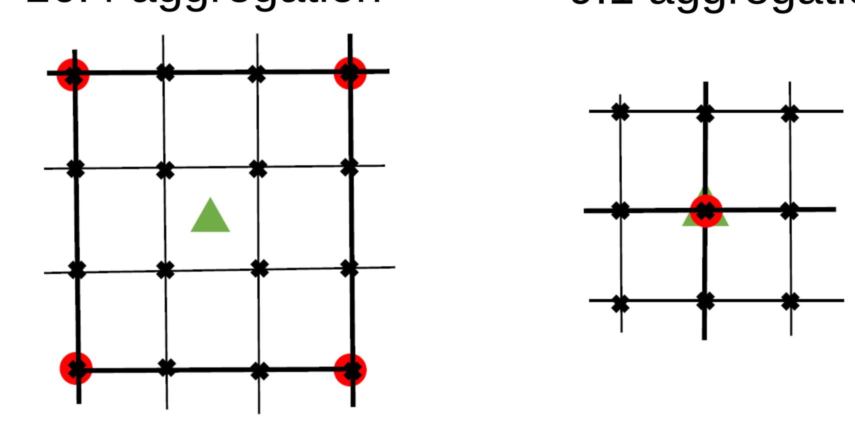
## *Simulations*

Simulations with WRF model are performed using 4 domains. We use output from domain 2 (WRF coarse) and from domain 3 (WRF fine) for our investigations. SLC airport is at 1288 m agl.

| *Model* | *Grid spacing* | *SLC terrain height agl [m]* |
|---|---|---|
| WRF fine | 3.3x3.3 km | 1287 |
| WRF coarse | 10x10 km | 1387 |
| TM5 | 1x1 degree | 2043 |

## *Aggregation: two different approaches*

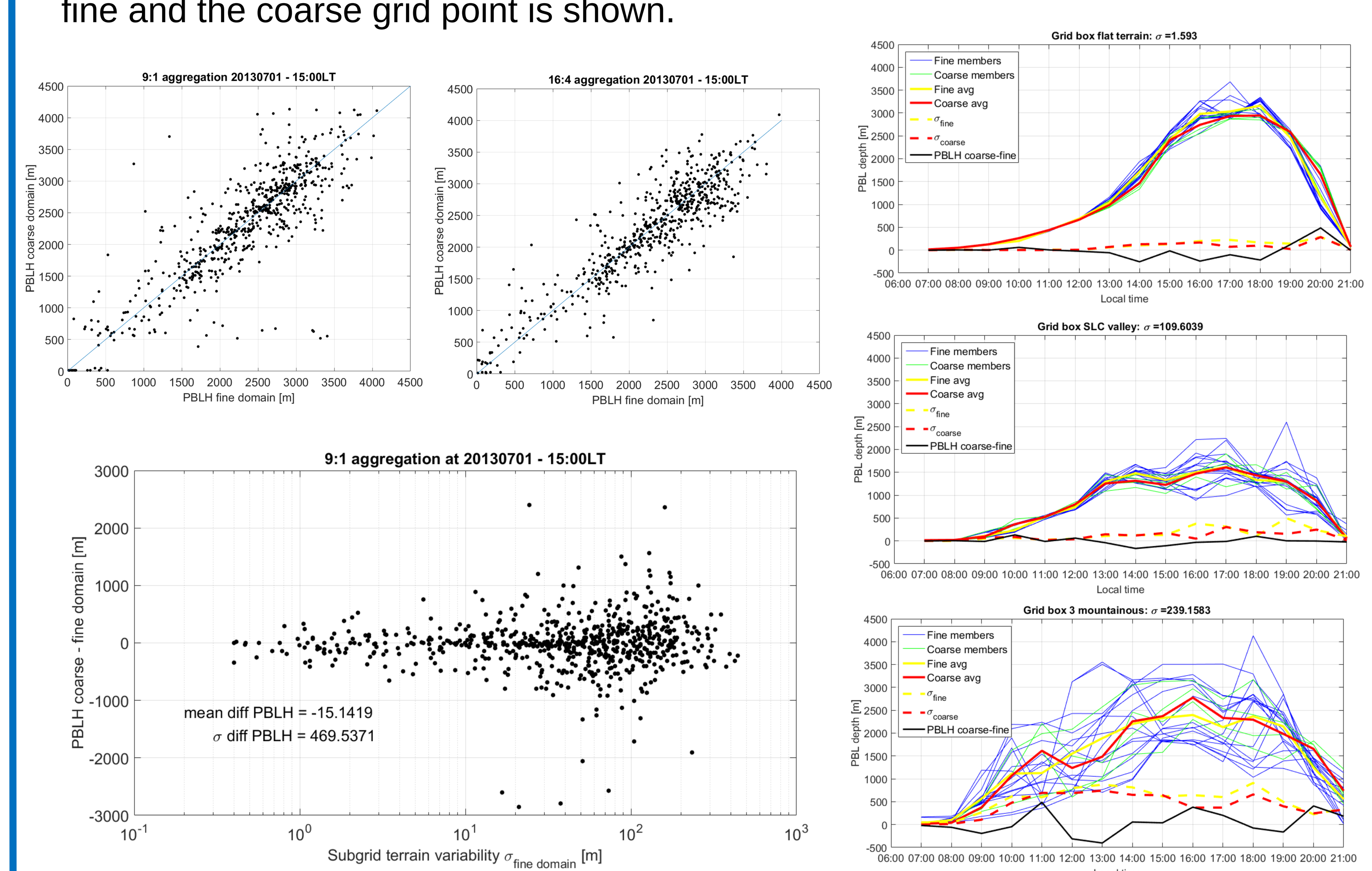
16:4 aggregation 9:1 aggregation



In both approaches the coarse (red circles) and fine (black crosses) grid points are aggregated (or: averaged) with the green triangle as a result.

## *Relation between PBL variability and subgrid terrain variability*

Subgrid terrain variability is determined by calculating the variance of the terrain height of the WRF fine grid points (9 or 16 points depending on aggregation approach). There is a small tendency for the coarse grid to underestimate the PBL depths. The 16:4 aggregation approach shows less PBL variability. With increasing terrain variability, an increased difference in PBL depth between the fine and the coarse grid point is shown.




## ACKNOWLEDGMENTS

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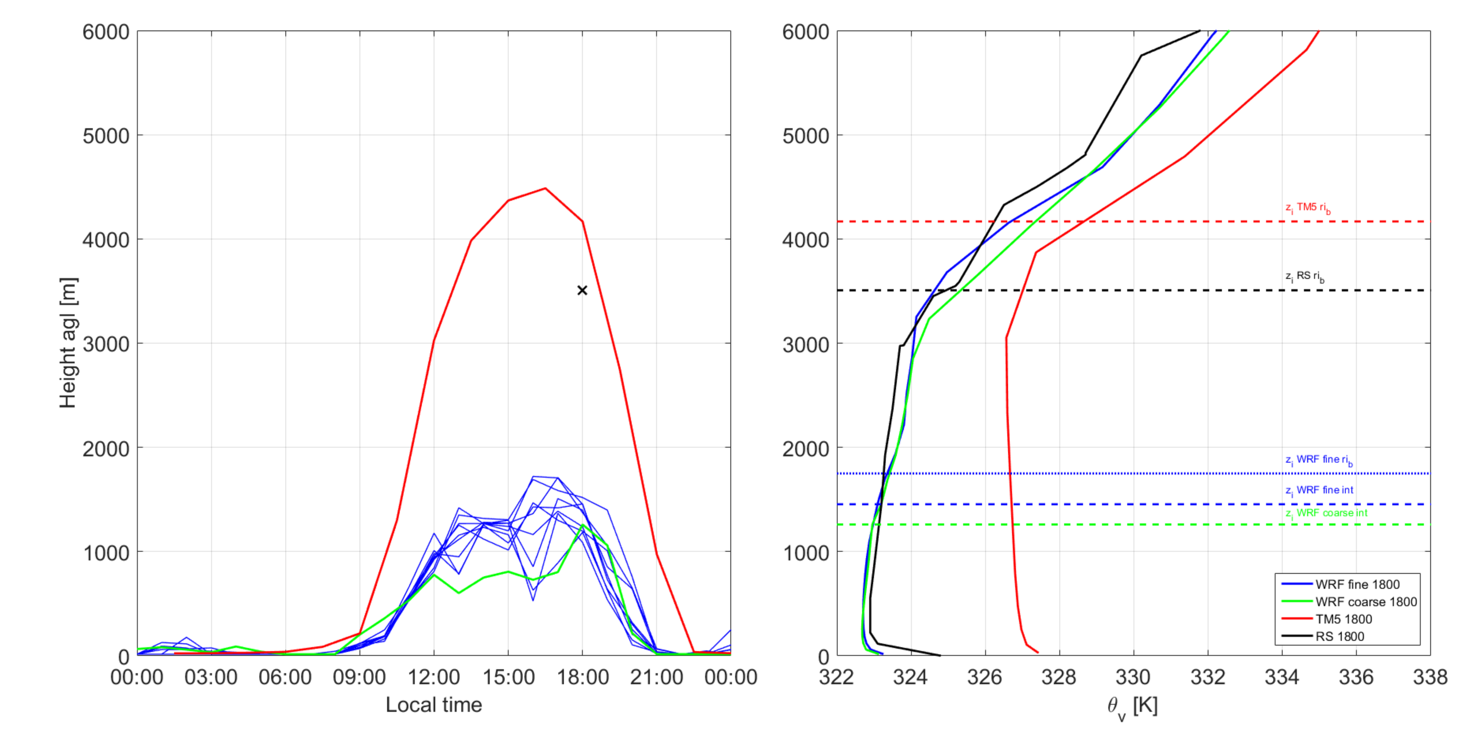
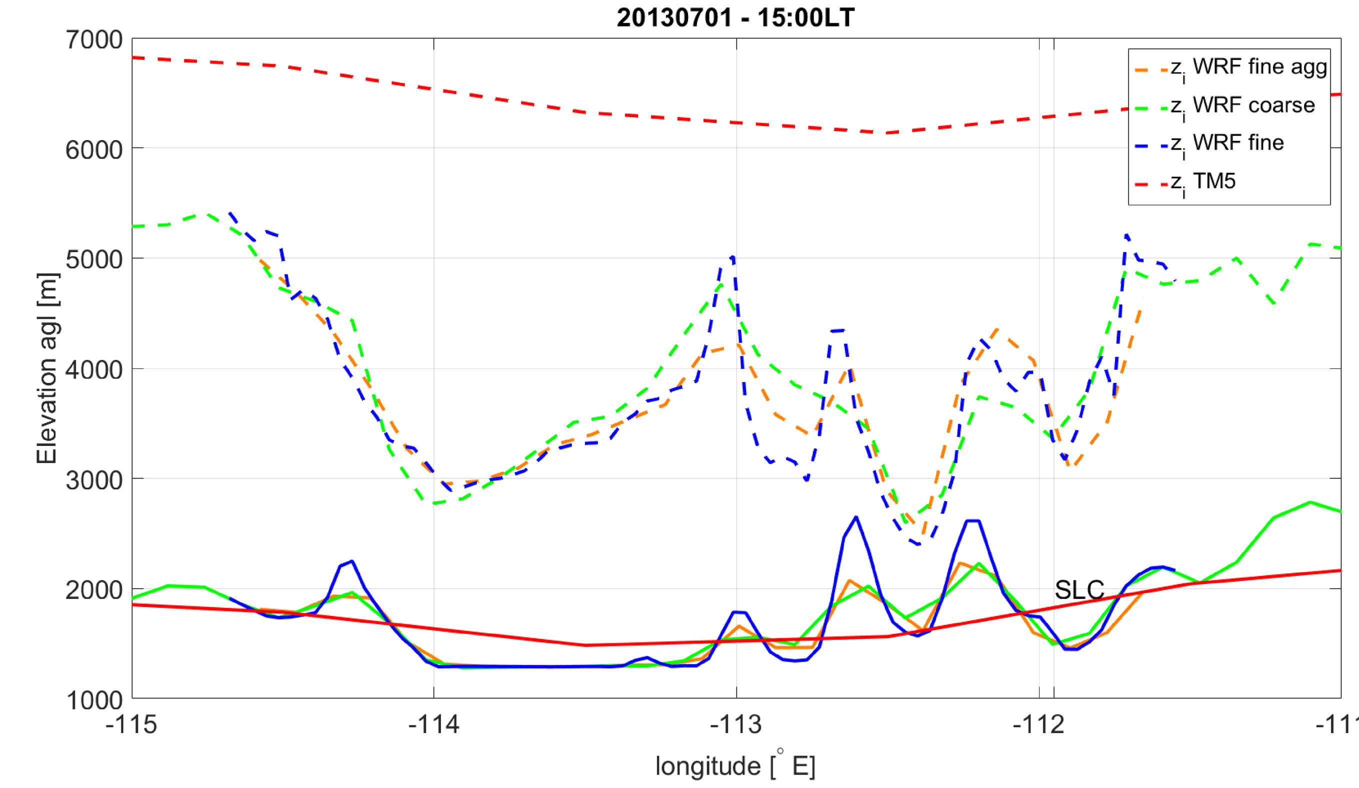
## *Case study*

For a particular case study (1 July 2013), large differences in the temporal evolution and spatial variability of PBL depth in WRF and TM5 are found. However, PBL depth in TM5 compares well with radiosonde observations, but this could be a fortuitous result. The spatial distribution of PBL depths is completely missed by the large-scale TM5 model.

### *Temporal evolution*



### *Spatial distribution*




## SUMMARY

In an effort to understand the uncertainty in large-scale transport models such as TM5 in simulating PBL depths, we are investigating the effect of subgrid terrain variability on afternoon PBL depths.
Increasing terrain variability increased PBL depth differences between an aggregated fine (3.3 km) and coarse (10 km) WRF model simulation. Large difference in PBL depths are found between WRF and TM5.

*Future work* The 1-day case study will be extended to a 2-year data period and with simulations (WRF) including CO2. We are planning to develop a methodology to represent the effects of sub-grid scale topography on PBL depths in large-scale transport models.