Lukas Pilz¹, Michal Galkowski², Joachim Fallmann³, Fei Chen⁴, Andre Butz¹, and Sanam N Vardag¹

¹Institute of Environmental Physics, Heidelberg University
²Max Planck Institute for Biogeochemistry, Biogeochemical Signals
³Office of Environmental Protection, City of Heidelberg
⁴National Center for Atmospheric Research, Research Applications Laboratory

February 9, 2023
Evaluation of WRF-Urban simulation setups for German urban GHG monitoring network design

Simulation domains with reference meteorological (blue) and radiosonde (red) stations.

Performance average of WRF simulations over spring, summer and autumn compared to ECMWF ERA5 and reference stations (average over all stations).

Performance of best WRF simulation vs ERA5 for all 4 seasons (left to right, top to bottom: spring, summer, autumn, winter).

Performance average of WRF simulations in winter compared to ECMWF ERA5 and reference stations (average over all stations).

Introduction

While urban areas are responsible for more than 70% of global CO2 emissions, reliable bottom-up information on (intra-)urban CO2 emissions is not readily available at high temporal and spatial resolution and with acceptable uncertainties. Urban monitoring networks can independently quantify anthropogenic CO2 emissions in cities and thus provide stakeholders with valuable information on (intra-)urban mitigation efforts. In the scope of the joint project ‘Integrated Greenhouse Gas Monitoring System for Germany’ (ITMS) we will analyze optimal network designs in German urban and metropolitan areas using the well-established WRF-Urban model. The first step in this task is to assess an accurate representation of atmospheric transport in our modeling framework, which we analyze in this study.

Methods

- 4x1 month simulation
- April, July, September, December 2020
- representative of seasons (phenomenological calendar)
- 3 hours GFDDA to ERA5 data, re-initialization every 7 days
- 3 domains (15, 5, 1km) focussing on Rhine-Neckar region
- 42 vertical layers, 14 layers below 1.5km
- BEP: lowest level (15m)
- UCM: lowest level (90m)
- high resolution input data (CORINE + LCZ landuse [Breuer, 2016; Demuzere, 2022], COP DEM topography)
- 16 combinations of parameters investigated:
  - PBL scheme (BouLac, MYJ, YSU)
  - LSM (Noah, Noah MP)
  - SL model (MO, MM5)
  - UCM/BEP parameterization
- Comparison with:
  - 19 German Weather Service (DWD) stations (5 urban, 14 rural)
  - 2 radiosonde stations

Results

- Higher ensemble spread in winter than in other seasons
- In winter, ERA5 performs better
- Average performance in rest of year better than ERA5
- 2m temperature:
  - best configuration: YSU, NMP, MM5, UCM
  - ERA5 performs better
- 10m wind velocity:
  - best configuration: MYJ, NMP, MO, UCM
  - WRF performs better
- PBL height:
  - best configuration: YSU, N, MM5, UCM
  - WRF performs better
- BEP underestimates diurnal variability in wind velocity
- UCP outperforms BEP in urban areas

Conclusions

- Even without 4DVar, WRF performs well compared to ERA5
- UCM generates better 10m wind velocity and PBL height
- Underestimation of diurnal winds by BEP probably due to overestimation of wind drag
- Optimize building height distribution in URBPARAM_LCZ.TBL

References


Acknowledgements

This work is part of the joint project ITMS, funded by the German BMBF under reference number 01LW1320C. This work used resources of the German Klimarechenzentrum (DKRZ) funded by the German BMBF under project 03E0511A. Furthermore, data of the German Weather Service was used.