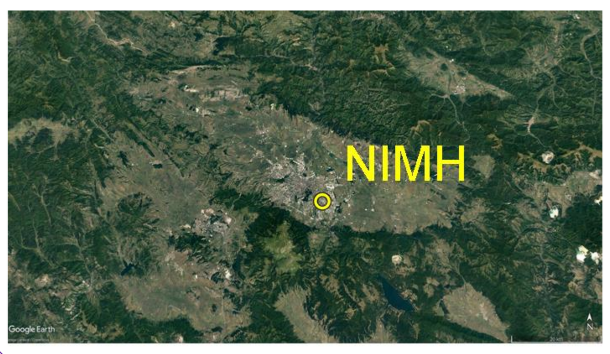
Validation of WRF with detailed topography over urban area in complex terrain

Hristina Kirova[1], Ekaterina Batchvarova[2], Reneta Dimitrova[3,4], Evgeni Vladimirov[3,]

[1]National Institute of Meteorology and Hydrology, [2]Climate, Atmosphere and Water Research Institute-Bulgarian Academy of Sciences (CAWRI-BAS), [3]Sofia University "St. Kliment Ohridski", [4]NIGGG-BAS,[5]BULATSA

Abstract *The urban convective atmospheric boundary layer (ABL) structure and its evolution were studied with Weather Research and Forecasting (WRF) model for the period of Sofia Experiment 2003. The experimental data of 2003 used for model validation encompass turbulent fluxes and profiles of temperature, humidity, wind speed and direction. Configuration using two datasets for topography (SRTM, NASA) and land cover (CORINE 2012) was implemented in WRF model. The spatial distribution of modelled maximal values of sensible and latent heat fluxes clearly indicated the location of big green areas in Sofia city, water bodies and mountain ridges. The model was able to reproduce sensible heat flux adequately for the entire period of the experiment with exception of September 30th when 2.6 mm rain was recorded. The model was able to capture the sharp jump in the latent heat flux after the rainfall, but with two hours delay. The model maximal values of friction velocity were overestimated compared to the measured ones.*

Sofia valley and surrounding mountains (Google Earth)



Sofia Experiment 2003

Data set with high spatial and temporal resolution was collected during the experimental campaign (Batchvarova and Rotach, 2005, Batchvarova et al., 2006) conducted in Sofia from September 27th to October 3rd, 2003.The experiment program contained measurements of turbulent fluxes and aerological observations tracking the development of the convective ABL in urban environment. Acoustic anemometers and fast hydrometer were mounted on the research tower at NIMH-BAS at height of 20 m and 40 m above the ground and they were set with 30-minutes averaging time. The radiosondes were launched every 2 h (from 04 to 16 GMT).

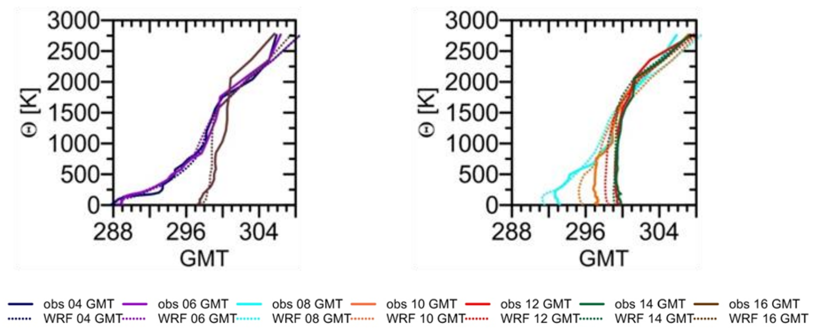
Parametrization of physical processes

Microphysics	2 = Lin et al
Longwave radiation	1 = RRTM
Shortwave radiation	2 = Dudhia
Surface layer	4 = QNSE
Land Surface	2 = Noah LSM
Planetary Boundary Layer	2 = QNSE
Cumulus parametrization	4 (D1&D2) = Arakawa - Schubert

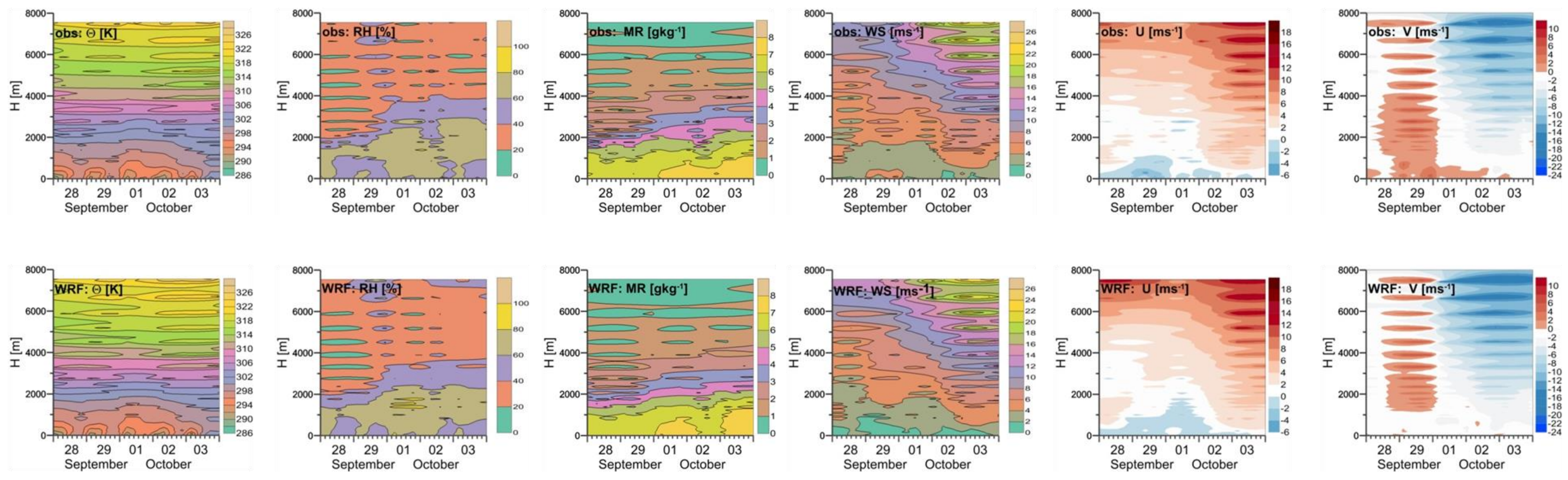
Model results validation

Summary statistics (using integrated data up to 8000 m)

	mean	*MB*	*SD*	*NRMSE*	*MAE*	*r*
T [K]	280.9	-0.9	1.2	0.0	1.2	0.998
Θ [K]	300.5	0.1	1.0	0.0	0.8	0.995
RH [%]	55.0	-0.2	10.4	0.2	7.3	0.890
MR [gкg^{-1}]	5.4	-0.2	0.6	0.1	0.5	0.970
WS[ms^{-1}]	4.4	-0.5	2.0	0.4	1.6	0.908

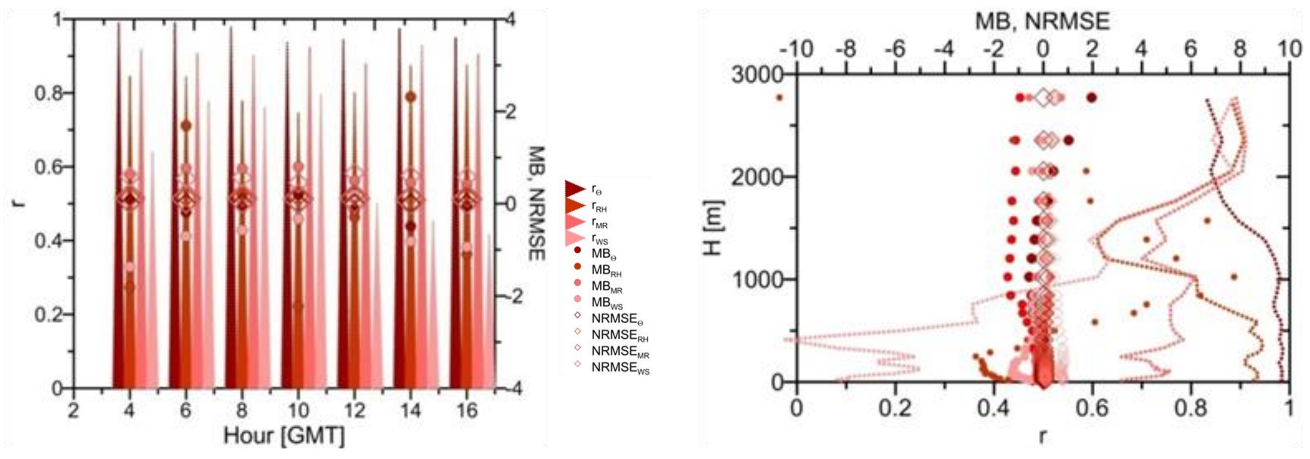


Comparison of model and measurements up to 3000 m -profiles of *Θ* on Sept., 29

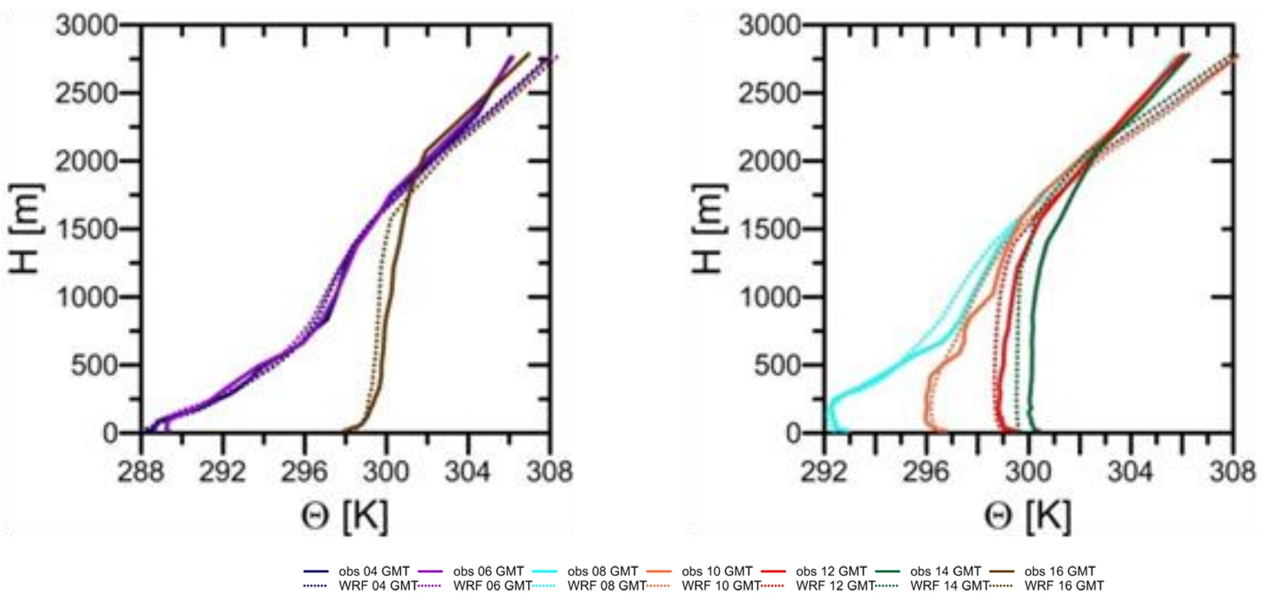


Vertical cross sections of observed and simulated *Q*, *RH*, *MR*, *WS*, *U* (zonal), *V* (meridional component of the wind speed) and *WD* up to 8000 m for „Sofia 2003" experiment hours with observations

The transition from stable to convective boundary layer in the morning hours is clearly displayed in both observed and modelled Θ profiles. Both profiles at 04 GMT show a stable layer approximately 250 m, residual convective layer between 900 m and 1800 m, and vast entrainment zone between them (250 m - 900 m). The convective layer (CL) starts to grow at 8 GMT. The simulated Θ is 2 K lower than observed at the ground at this time. The model results are in agreement with observations for the height of CL. It is approximately 750 m at 10 GMT, 1750 m at 12 GMT and 2000 m at 14 GMT. The model Θ values are lower close to the ground during the day, but the biases reduce with the CL development.



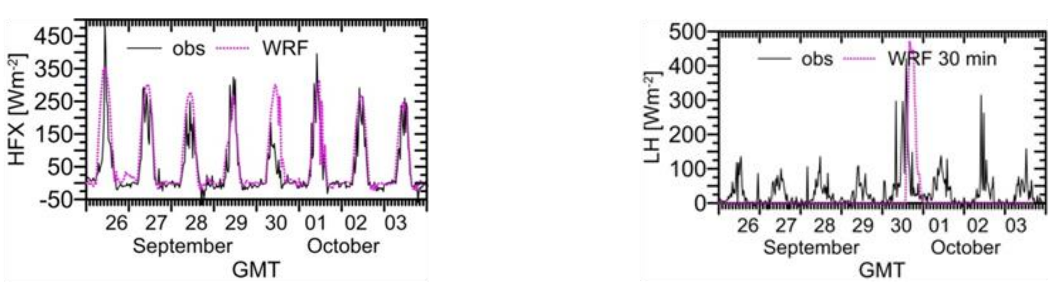
Statistical measures: *r*, *MB*, and *NRMSE* calculated at each observational time for all levels up to 3000 m (upper panel); *r*, *MB*, and *NRMSE* calculated at each model level using all observational times

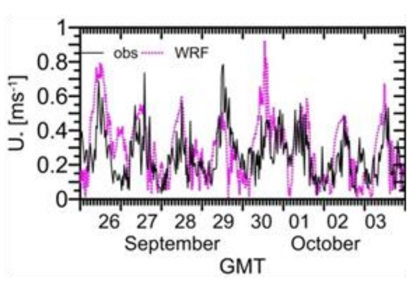


Hourly averaged profiles of *Θ* up to 3000 m

- ***The model successfully simulates the averaged state of the atmosphere over the studied period.***
- ***The modelled ABL heights are close to the observed ones.***
- ***The transition hours from convective to stable ABL and vice versa are well depicted by the model.***

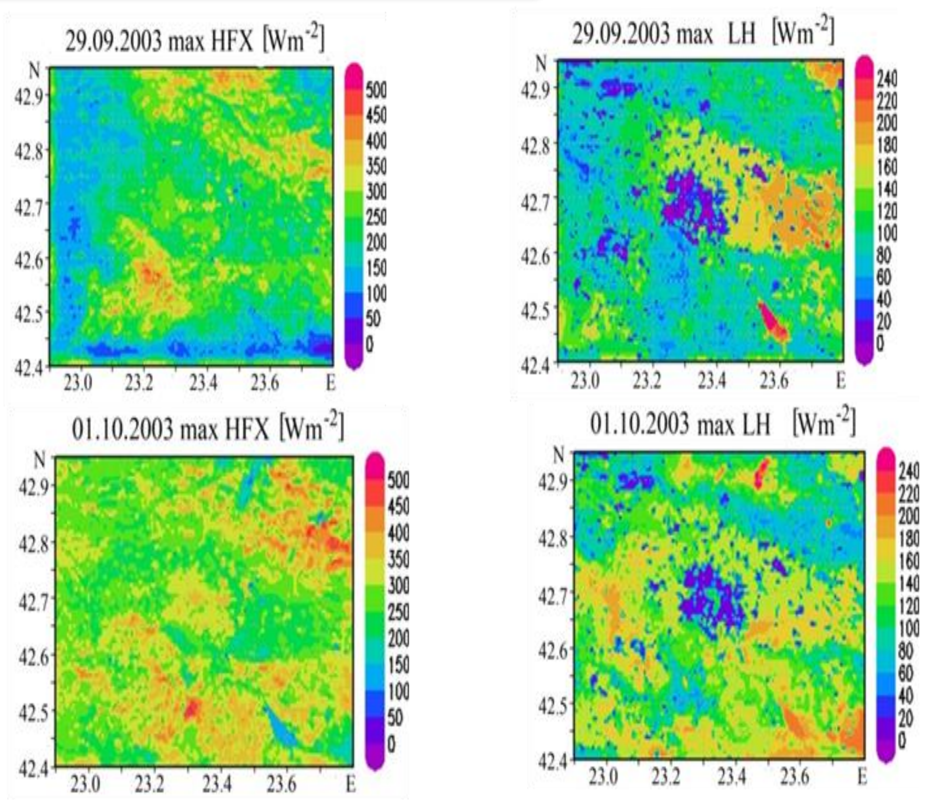
Turbulence





Sensible heat flux (HFX), latent heat flux(LH) and friction velocity (U*) validation

The model is able to reproduce adequately he HFX for the entire period, with exception of September 30th, when 2.6 mm rain was recorded. Simulated HFX is about 2 times larger than measured, but WRF is able to capture the sharp jump in LH after the rainfall.



Maximal simulated HFX and LH in D4 on 29.09.2003 and 01.10.2003

The spatial distribution of simulated maximal values of sensible (HFX) and latent (LH) heat fluxes clearly indicate the location of big green areas in Sofia city, water bodies and mountain ridges, due to implementation of new detailed CORINE land use in WRF. High values of LH are calculated for the water basins around the city and low for the built-up areas. High *HFX* values are calculated in the city and on the ridges of the mountains.

Model setup

Advanced Research WRF (ARW) Version 3.8. (http://www.mmm.ucar.edu/wrf/ users/docs) initialized with 0.25 degree NCEP Final Operational Analyses every 6 hours.

Four nested domains are used based on a Lambert Projection, centred at 42.68N and 23.36E with resolution of 32 km (D1), 8 km (D2), 2 km (D3) and 500 m (D4). Two new datasets for topography (SRTM, NASA) and land cover (CORINE 2012) were implemented in WRF. Four dimensional data assimilation (FDDA) is used for domain D1 at all vertical levels, and for domains D2, D3 only above the first 10 model levels. The FDDA option is not applied for D4.

Vertical structure of the atmosphere is presented through 50 levels going up to 50 hPa. A 48-hour simulation period with 24 hours spin-up period.

General Conclusions

The results of validation of WRF over Sofia urban area located in complex terrain show that the model adequately describes vertical profiles and turbulent fluxes with the selected parametrization of physical processes.

Acknowledgments

The work is supported by the project DN4/7 (Study of the PBL structure and dynamics over complex terrain and urban area), funded by the National Science Fund and partly by the National Science Program "Environmental Protection and Reduction of Risks of Adverse Events and Natural Disasters", approved by the Resolution of the Council of Ministers № 577/17.08.2018 and supported by the Ministry of Education and Science (MES) of Bulgaria (Agreement № D01-230/06.12.2018).

References

Batchvarova, E. andRotach, M.W., Bilateral co-operation on urban boundary layer studies. Turbulence measurements for urban boundary layer research in Sofia, Final Report COST Action715, 2005, ISBN: 978-954-9526-30-1, pp 185-188.

Batchvarova, E., Gryning, S-E., Rotach, M.W. and Christen, A. Comparison of modeled aggregated turbulent fluxes and measured turbulent fluxes at different heights in an urbanarea, in Borrego, C. and Norman, A. (Eds.): Air Pollution Modeling and its Application XVII,Kluwer Academic/Plenum Publishers, NATO Challenges of Modern Society,2007, pp.363–370.