MESOSCALE SIMULATION OF METEOROLOGICAL PROFILES DURING THE SOFIA EXPERIMENT 2003

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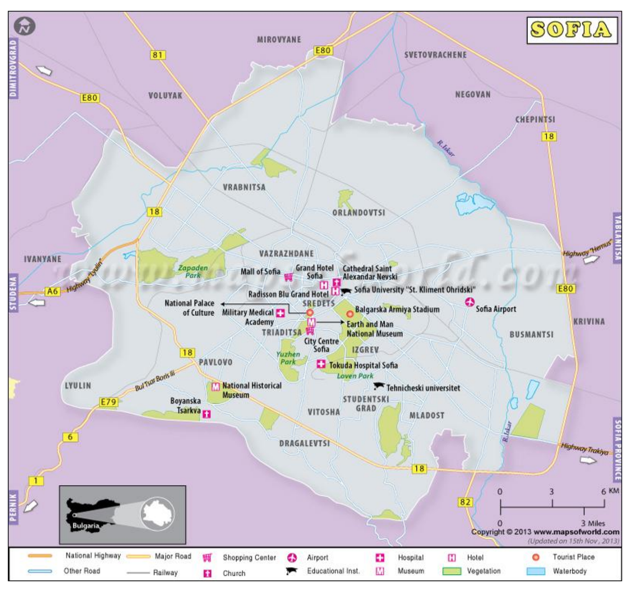
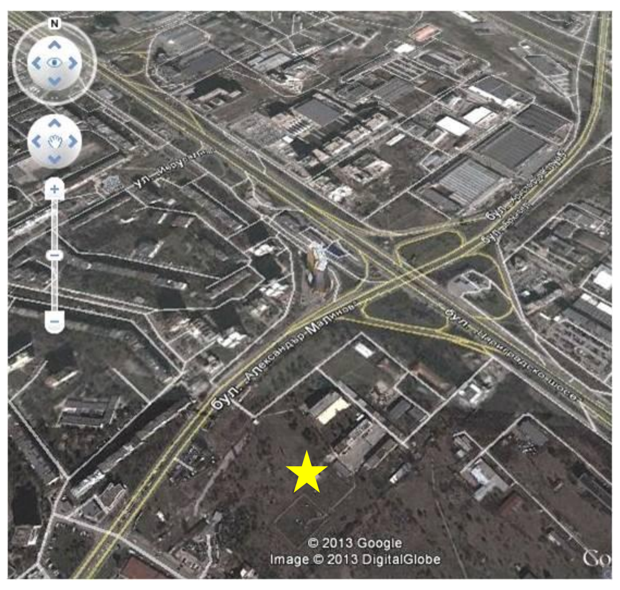
ABSTRACT

The 1,5-million-inhabitant city of Sofia is situated in a mountain valley, which creates significant air pollution problems in cases with shallow or stable boundary layer. Unfortunately, only one vertical sounding is operationally performed at noon, so the Sofia experiment 2003 is a unique data base for convective boundary-layer evolution. Here we present an evaluation of one configuration of the Weather Research and Forecasting (WRF) model against consecutive and high vertical resolution radiosounding data from Sofia Experiment 2003. The numerical simulations were performed with WRF version 3.3.1, initialized with the US National Center for Environmental Prediction Final Analyses (FNL). The model was set on 4 nested domains, with horizontal grid step of the finest domain 1.33 km covering Sofia and entirely the Vitosha mountain, and on 26 vertical levels (13 of which below 2 km). Mellor-Yamada-Janjic boundary-layer scheme was used.

Innovative statistical analysis was performed for all model levels and times of radiosoundings, as well as for some integral characteristics within the boundary layer. In order to examine the ability of presented configuration to simulate observed tropospheric profiles, a statistical comparison is performed between data from 35 radiosoundings and corresponding in time model results (the lowest 19 levels) up to 8000 m.

The vertical profiles of relative humidity, temperature, potential temperature and wind speed were reproduced well, while wind direction was poorly resolved in the lowest 1000 m. Statistical comparisons between modelled and measured parameters showed that WRF simulated most of the analysed parameters better in the transition periods than during convective conditions. The profiles of the coefficient of correlation for all parameters are analysed to illustrate the statistics of WRF performance in height. In general, this configuration of WRF was able to reproduce the complex structure of the profiles created by the combination of complex terrain, urban conditions and synoptic forcing.



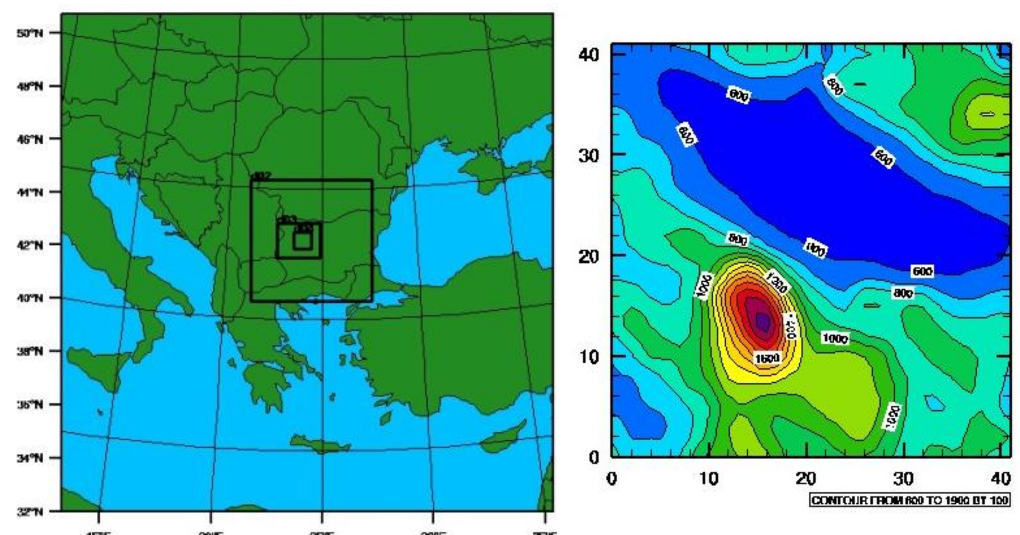


"SOFIA EXPERIMENT, 2003"

The "Sofia experiment 2003" field campaign was carried out in the early autumn of 2003, September 27 – October 3 in Sofia (Batchvarova et al, 2006). During the experimental campaign thirty five soundings were performed to document the convective boundary layer development. The sondes were launched from National Institute of Meteorology and Hydrology (starting at 7 a.m. ending at 19 a.m.). The soundings were performed with 2 hour temporal resolution and increased vertical resolution as the ascend velocity was kept about 3-4 ms^{-1} (two times slower than standard radio sounding). The collected data set of intensive observations comprises vertical profiles of air temperature and humidity, as well as wind speed and direction.

MODEL CONFIGURATION

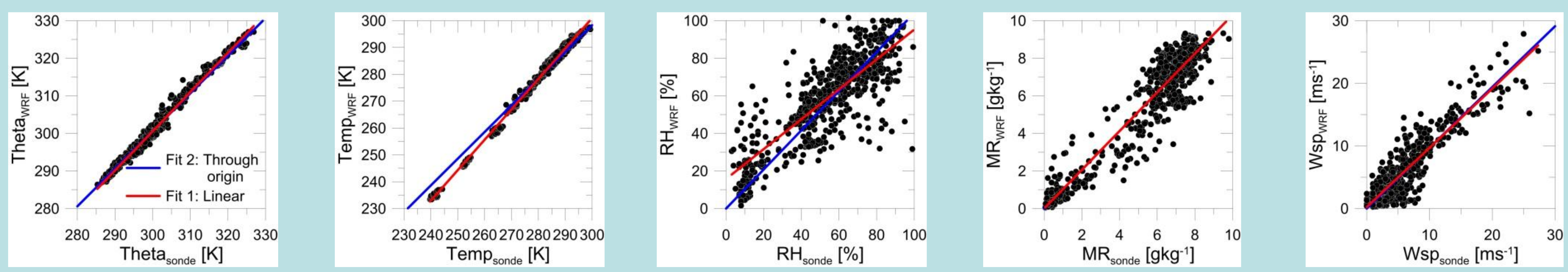
Numerical simulations were performed with the Weather Research and Forecasting (WRF) model (with ARW core), version 3.3.1 (Skamarock et al., 2008). The model was initialised with the US National Center for Environmental Prediction Final Analyses (FNL) with 1x1 degree spatial and 6 hours temporal resolution. WRF model was run with two-way nesting on 4 domains with horizontal grid step 36, 12, 4, 1.33 km and horizontal grid dimensions: 58x58 (D1), 43x43 (D2), 37x34 (D3), and 43x43 (D4) points, respectively (Fig.1) and 26 vertical levels up to 50 hPa. The parameterisations used were Thomson graupel (D3, D4) and WSM 5-class (D1, D2) scheme for cloud physics; RRTM for longwave and Goddard for shortwave radiation; Mellor-Yamada-Janjic TKE scheme for ABL with Noah LSM and Janjic-Eta surface layer. The new Grell cumulus parameterisation was used only for D1 and D2.

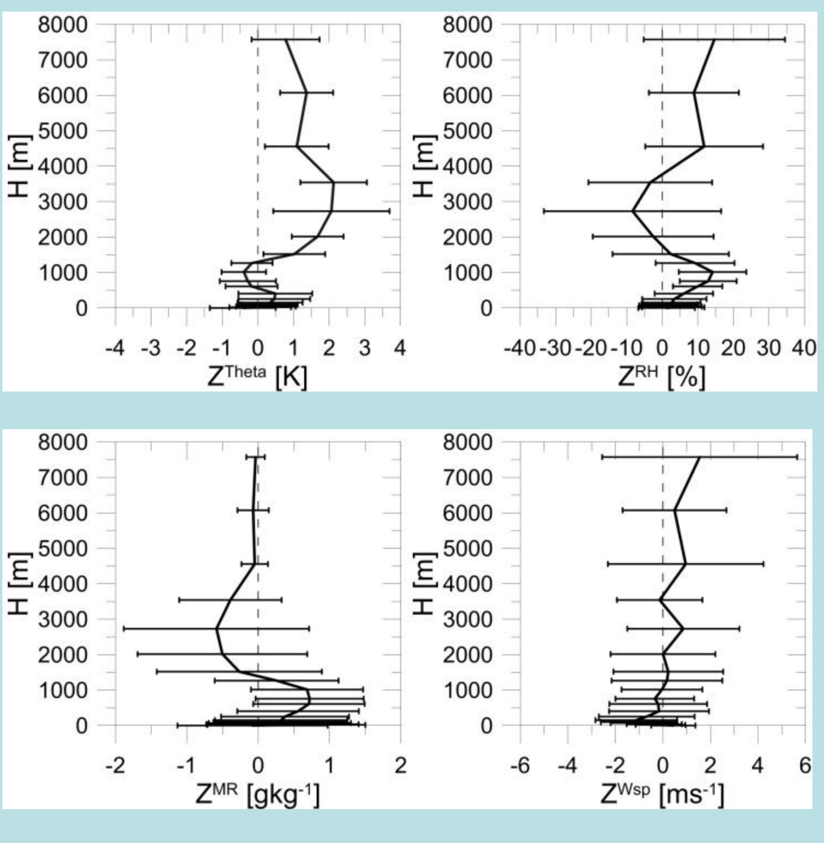


RESULTS

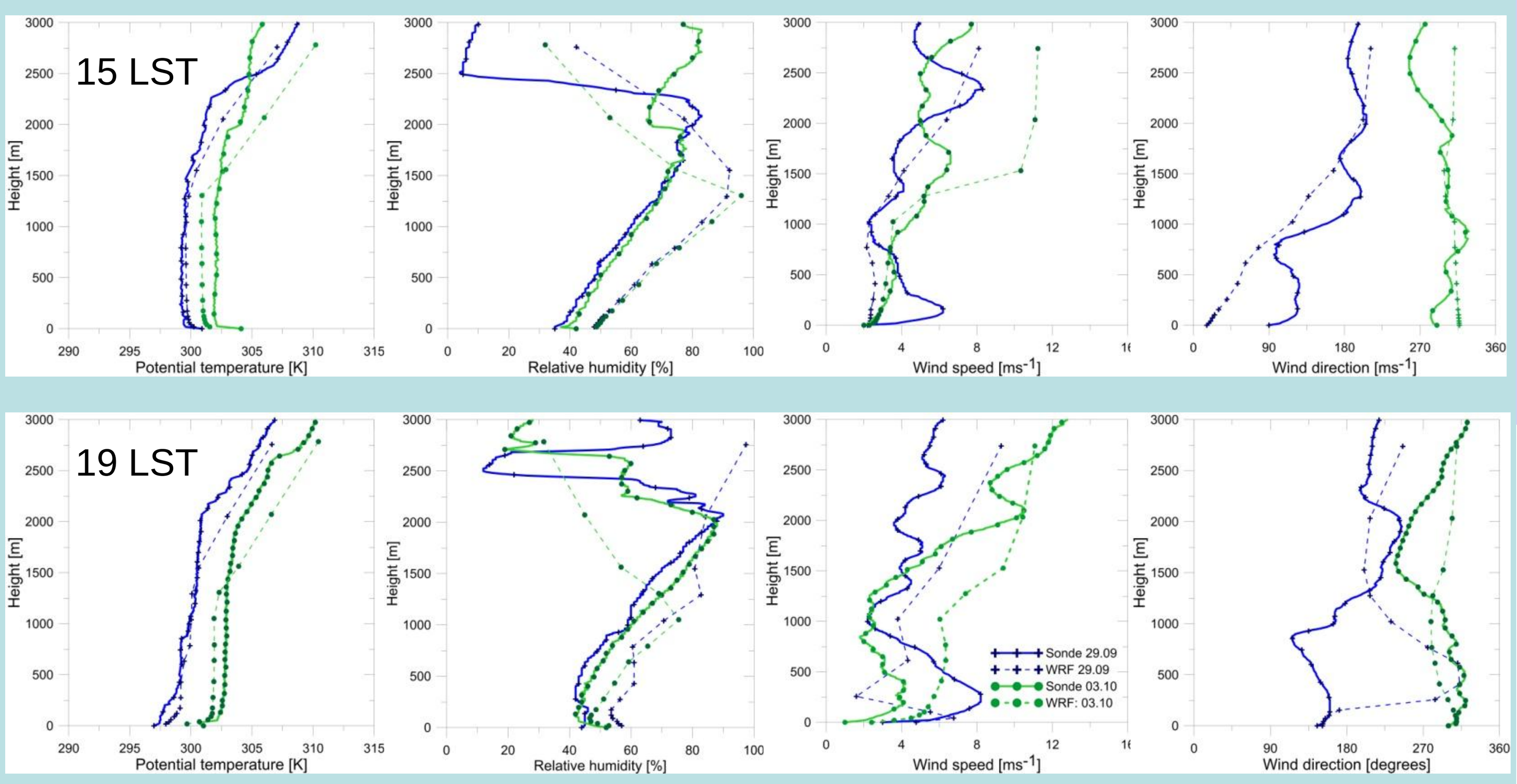
	Mean_WRF	Bias	RMSE	SD	r
Temp	277.9229	-1.7243	2.7704	2.1701	0.9971
Theta	302.6186	0.7356	1.3995	1.2204	0.9928
RH	58.6498	4.7696	14.7138	13.8942	0.8194
MR	5.3234	0.1749	0.9744	0.9584	0.9485
Wsp	5.3501	-0.0546	2.1795	2.1802	0.9037

Summary statistics (using integrated data on all radiosoundings and all model levels up to 8000 m)





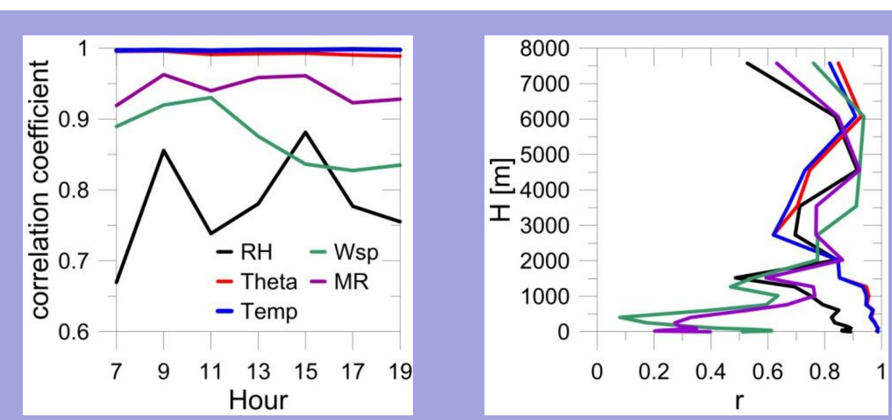
Averaged value of Z (Z = $Value^{WRF}$ - $Value^{Sonde}$) from all 35 soundings and its SD for each model level



Comparison between measured and modelled parameters at 15 (up) and 19 LST (down)

Summary statistics in transition (TH) and afternoon (AH) hours

	TH (07, 09, 19 LST)					*AH (11, 13, 15, 17 LST)*				
	Temp	**Theta**	**RH**	**MR**	**Wsp**	***Temp***	***Theta***	***RH***	***MR***	***Wsp***
Mean WRF	277,40	301,27	62,33	5,33	5,36	*279,04*	*303,12*	*55,99*	*5,48*	*5,09*
Bias	-1,56	0,75	3,32	0,04	-0,12	*-1,67*	*0,66*	*5,18*	*0,25*	*0,12*
RMSE	2,72	1,41	15,22	0,92	2,46	*2,78*	*1,52*	*14,88*	*1,09*	*1,94*
SD	2,43	1,20	14,87	0,92	2,46	*2,23*	*1,37*	*13,97*	*1,07*	*1,94*
r	0,997	0,994	0,823	0,950	0,879	*0,997*	*0,989*	*0,775*	*0,938*	*0,919*



Variation of correlation coefficient with time (left) and height (right)

CONCLUSIONS

The set up of WRF (with MYJ) simulated in a satisfactory way the vertical profiles of temperature, potential temperature and relative humidity, while the wind speed was reasonably resolved above 1500 m. The wind direction was poorly simulated in the lowest 1000 m. The overall performance of the model, based on data set formed by all WRF levels (up to 8000 m) and all time periods of radiosoudigs showed strong positive correlation (0.80-0.99) for Temp, Theta, RH, MR and Wsp.

The profile of the correlation coefficient (comparison between model and observations for all 35 soundings at each model) revealed low correlation for Wsp and MR in the first few hundred meters and higher correlation (> 0.80) above 2000 m, while for temperature stronger correlation was obtained below this height.

The temporal variations of the studied parameters, except the RH, were reconstructed with strong correlation.

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