Simulations of meso-scale phenomena under different large-scale conditions in Sofia region

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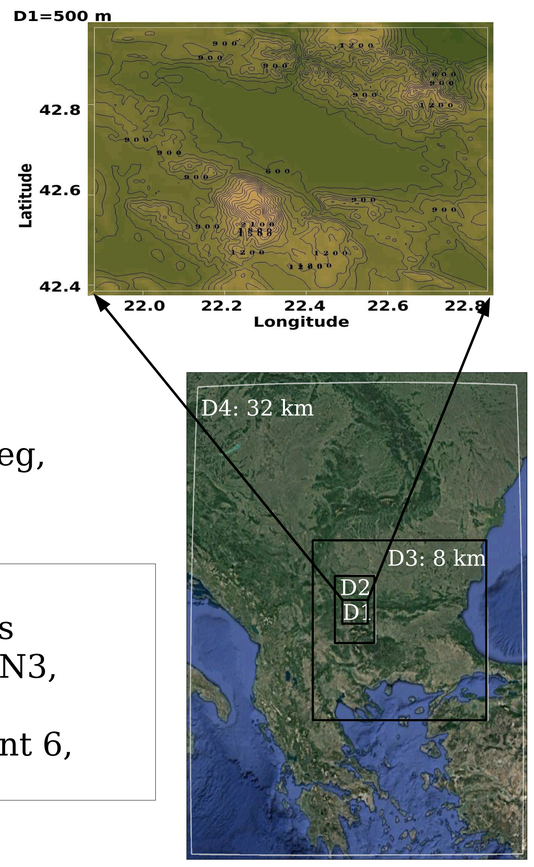
Abstract

Sofia city is located in a valley surrounded by mountain obstacles and in this complex terrain a large number of weather phenomena such as rain and snow, fog, frost, strong winds and foehn are observed. The complex terrain combined with the continuously growth of the urban area leads to various modifications on the weather conditions in the city compared to rural areas. The purpose of the numerical experiment is to determine some of the meso-meteorological phenomena which occur as a result of the modificated large-scale flows. Several meteorological cases typical for Sofia were selected so the model can be validated, and different model options were tested so the best configuration can be determined. The effect of the city on the surface fluxes and soil temperature are presented after a substitution of the urban area with most representative rural land use.

ARW-WRF v.3.8.1 model setup for the Sofia region

Configuration:
- Lambert projection (23.4°E, 42.68ºN)
- 4 nested domains with grid sizes of 32, 8, 2 and 0.5 kms
- Resolution of the inner domain: 157x129x51
- High terrain resolution 1 arcsec, https://lta.cr.usgs.gov/SRTM1Arc
- High land-use resolution 3 arcsec: Corine adopted to USGS classes, http://land.copernicus.eu/pan-european/corine-land-cover/clc-2012
- Input data: NCEP Final Analysis 0.25 deg, http://rda.ucar.edu/datasets/ds083.2/



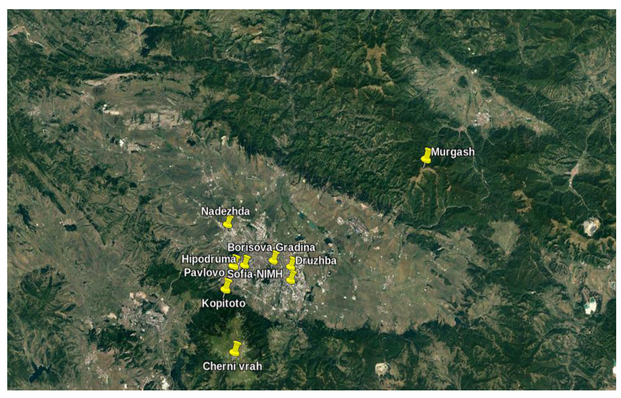
Model parametrization:
Radiation: RRTM and Dudhia schemes
PBL: YSU, ACM2, MYJ, MYNN2.5, MYNN3, QNSE, BouLac, UW;
Moisture: Lin et al., WRF Single-Moment 6, Goddard, Thompson;

Case study

Cases	Start (MDT)	End (MDT)	Start (UTC)	End (UTC)	Description	Wind speed
Case 1	**13/08/2016 22:00**	**15/08/2016 22:00**	**14/08/2016 00:00**	**16/08/2016 00:00**	**Quiescent**	**< 5m/s**
Case 2	03/01/2016 22:00	04/01/2016 22:00	04/01/2016 00:00	05/01/2016 00:00	Moderate SW wind	5 m/s – 10 m/s
Case 3	05/08/2015 22:00	06/08/2015 22:00	06/08/2015 00:00	07/08/2015 00:00	Moderate NE wind	5 m/s – 10 m/s
Case 4	10/11/2015 22:00	11/11/2015 22:00	11/11/2015 00:00	12/11/2015 00:00	Moderate NW wind	5 m/s – 10 m/s
Case 5	21/10/2015 22:00	22/10/2015 22:00	22/10/2015 00:00	23/10/2015 00:00	Moderate SE wind	5 m/s – 10 m/s
Case 6	24/05/2016 22:00	25/05/2016 22:00	25/05/2016 00:00	26/05/2016 00:00	Strong NW wind	> 10 m/s
Case 7	04/02/2016 22:00	05/02/2016 22:00	05/02/2016 00:00	06/02/2016 00:00	Strong NE wind	> 10 m/s
Case 8	**21/11/2015 22:00**	**22/11/2015 22:00**	**22/11/2015 00:00**	**23/11/2015 00:00**	**Strong SW wind**	**> 10 m/s**
Case 9	26/11/2015 22:00	27/11/2015 22:00	27/11/2015 00:00	28/11/2015 00:00	Strong SE wind	> 10 m/s

Observations

Surface observations (SYNOP): every 3 hours; National Institute of Meteorology and Hydrology (NIMH): Sofia-NIMH (552 m), Cherni Vrah (2286 m) and Murgash (1687 m). **Radiosonde:** at 12h UTC; NIMH aerological observatory. **Automatic stations:** hourly data: Borisova Gradina (577 m), Kopitoto (1321 m), Nadezhda (534 m), Pavlovo (615 m), Hipodruma (581 m), Druzhba (548 m).



Model validation for the Sofia region

Model data and in situ observations comparison

Comparison between model data and observations with 4 different PBL schemes: Table 1 and 2 - moderate and strong winds for 6 stations in Sofia city; Table 3 - for 2 mountain stations (Kopitoto and Murgash).

Table 1

6 Stations + 4 Cases	Mean	St. Dev.	MB	ME	RMSE	IA	r
Temperature – MODERATE WIND 5-10 m/s							
Observation	9.2	2.3					
Model data – QNSE	9.9	2.9	0.2	2.1	2.4	0.75	0.82
Model data – YSU	10.5	2.4	0.7	1.5	1.8	0.81	0.82
Model data – BouLAc	12.9	2.5	1.1	1.9	2.2	0.77	0.76
Model data – ACM2	10.5	2.7	0.7	1.9	2.1	0.79	0.82
Relative Humidity - MODERATE WIND 5-10 m/s							
Observation	71.4	8.1					
Model data – QNSE	72.5	10.1	-1.2	7.9	9.5	0.70	0.71
Model data – YSU	70.2	8.4	-4.3	7.2	8.2	0.77	0.83
Model data – BouLAc	67.4	8.1	-5.2	7.2	8.3	0.78	0.86
Model data – ACM2	70.9	8.7	-3.6	7.1	8.3	0.76	0.78

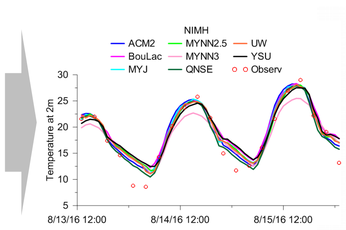
Table 2

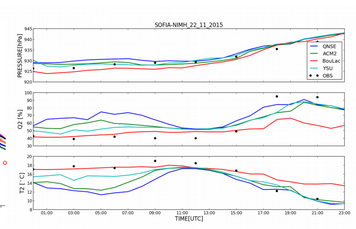
6 Stations + 4 Cases	Mean	St. Dev.	MB	ME	RMSE	IA	r
Temperature – STRONG WIND > 10 m/s							
Observation	7.4	1.6					
Model data – QNSE	8.2	1.8	0.3	1.6	1.9	0.74	0.68
Model data – YSU	11.8	2.0	-0.1	1.9	2.2	0.74	0.69
Model data – BouLAc	9.2	1.4	1.2	1.6	1.8	0.71	0.73
Model data – ACM2	8.6	1.7	0.7	1.6	1.8	0.71	0.69
Relative Humidity – STRONG WIND > 10 m/s							
Observation	75.2	9.1					
Model data – QNSE	75.9	9.1	-2.4	10.2	11.9	0.62	0.67
Model data – YSU	71.0	8.5	-3.7	9.2	10.4	0.64	0.71
Model data – BouLAc	70.9	7.6	-7.5	10.3	12.1	0.60	0.69
Model data – ACM2	73.4	9.3	-4.4	10.4	11.7	0.64	0.71

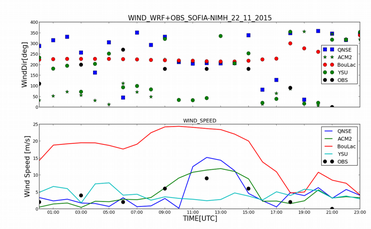
Table 3

2 Stations + 9 Cases	Mean	St. Dev.	MB	ME	RMSE	IA	r
Temperature							
Observation	6.6	1.6					
Model data – QNSE	5.6	1.6	-1.1	1.7	1.9	0.68	0.74
Model data – YSU	5.6	1.7	-1.0	1.6	1.8	0.71	0.76
Model data – BouLAc	5.9	1.7	-0.7	1.6	1.8	0.71	0.78
Model data – ACM2	5.6	1.8	-1.0	1.7	1.9	0.70	0.77
Relative Humidity							
Observation	72.9	7.1					
Model data – QNSE	77.6	6.1	4.7	10.0	11.4	0.49	0.40
Model data – YSU	77.8	5.8	4.9	9.7	10.9	0.51	0.45
Model data – BouLAc	77.2	5.4	4.3	9.7	11.1	0.48	0.40
Model data – ACM2	78.2	6.2	5.3	10.3	11.8	0.49	0.40

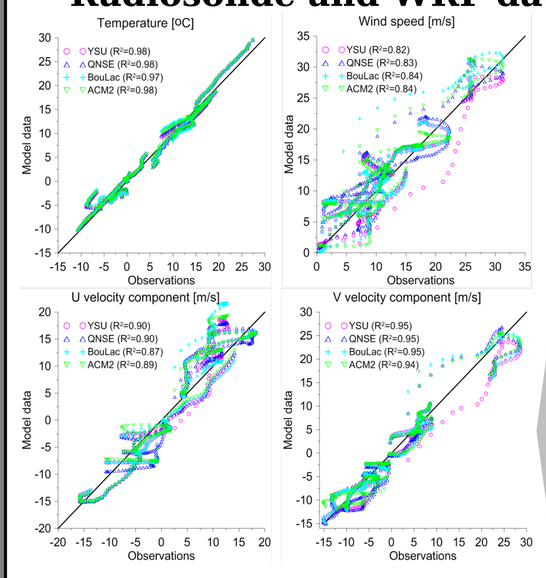
Comparison of diurnal surface temperature, pressure, relative humidity, wind speed and direction evaluation for different PBL schemes for case 8 and temperature for case 8.



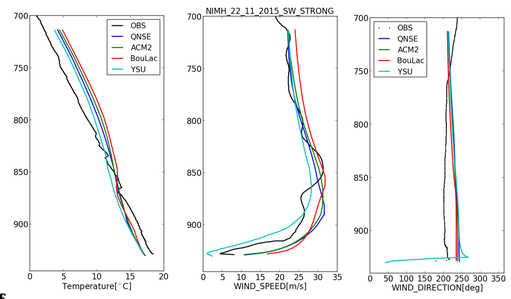




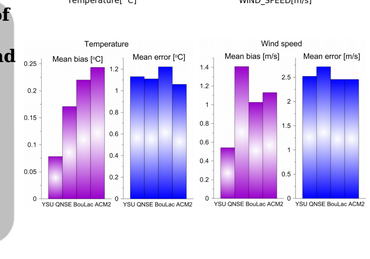
Radiosonde and WRF data comparison



Comparison of vertical profiles for different PBL schemes, 22.11.2015 at 12 UTC, NIMH site.

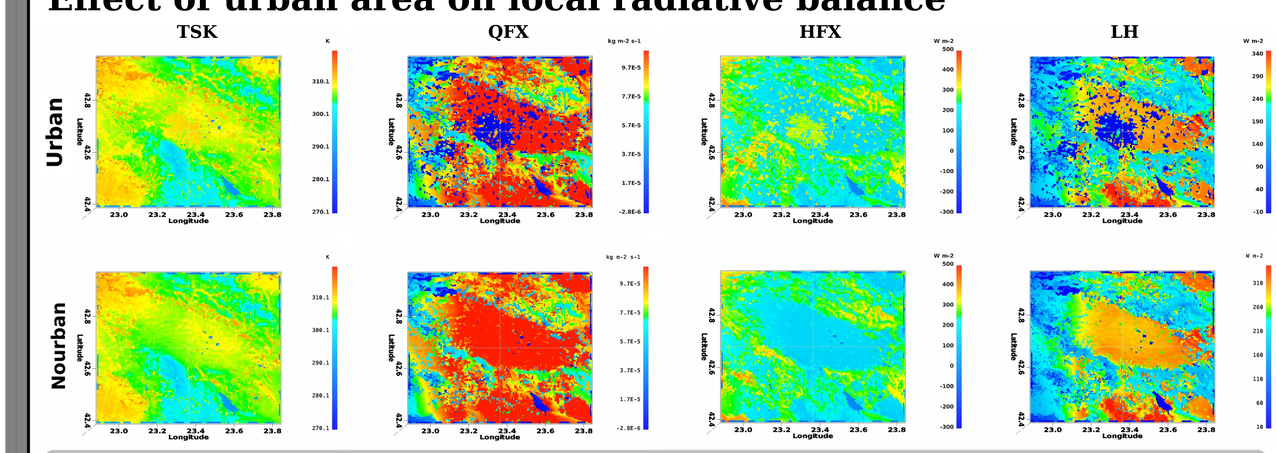


Scatter plots of interpolated observation and model data at the same vertical levels for 4 PBL schemes at 12 UTC, NIMH site; all cases are included.

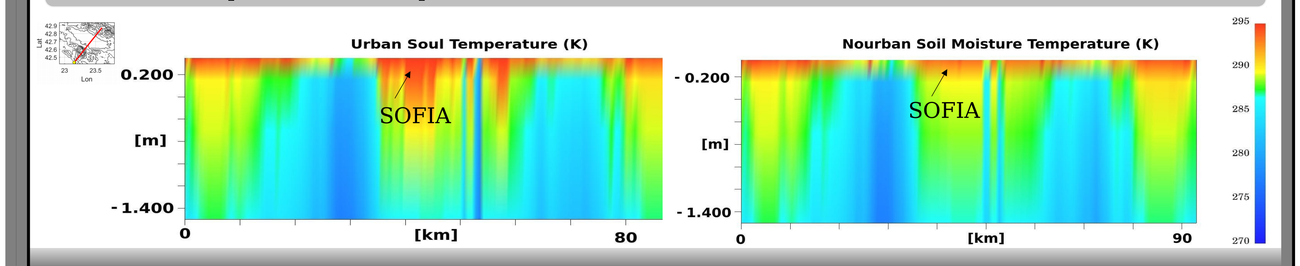


Mean bias and error of interpolated observation and model data at the same vertical levels for 4 PBL schemes at 12 UTC, NIMH site; all cases are included

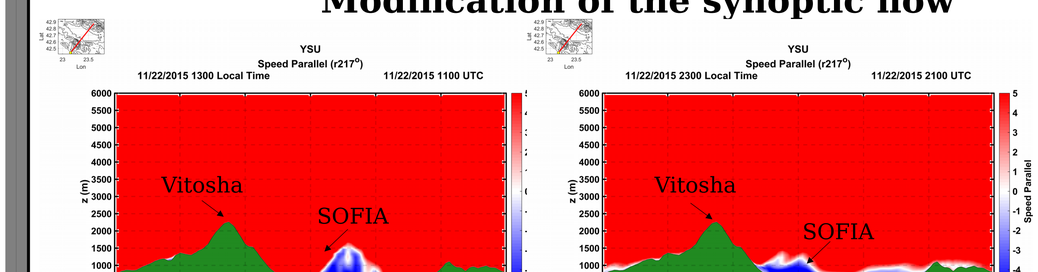
Effect of urban area on local radiative balance



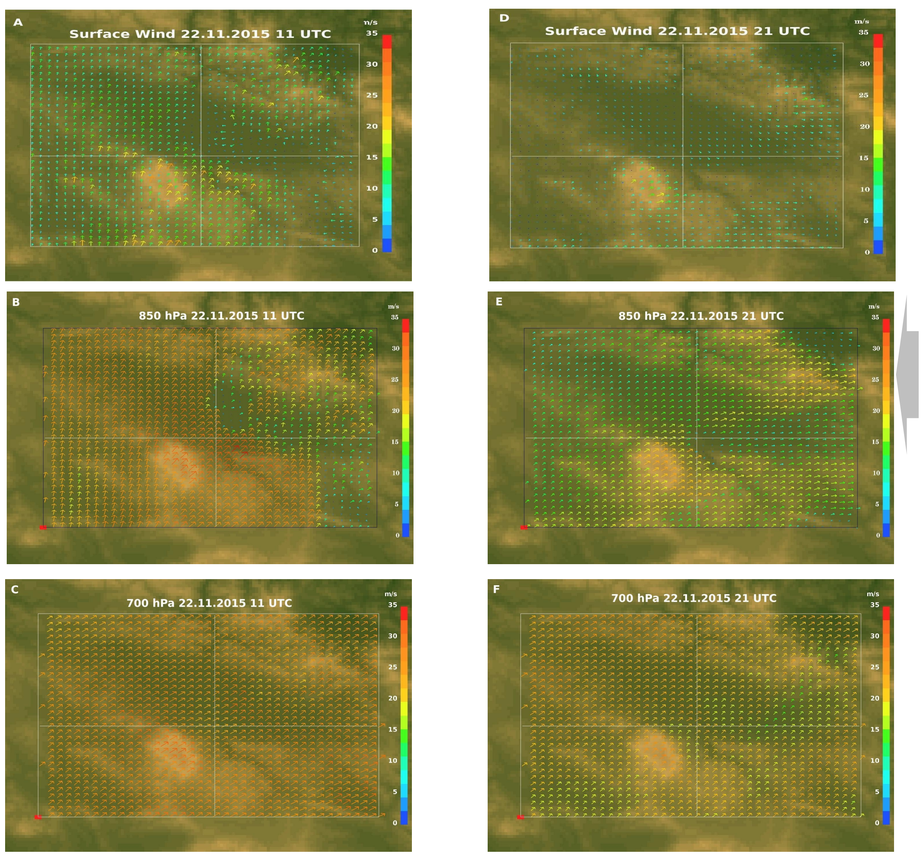
Comparison of skin temperature, moisture, heat, latent fluxes and soil temperature for Case 1 – 15.08.2016 12UTC. The urban area was replaced with most representative rural land use.



Modification of the synoptic flow



Cross-sections (perpendicular of Sofia valley axis) of strong (>10m/s) SW wind (case 8) at 11 UTC when the wind is strongest and 21UTC when it weakens.



Complex terrain leads to significant modification of the synoptic flow at surface and depending on the altitude of the obstacle at greater high. Surface wind (Panel 1) and wind at 850 hPa (Panel B) for case 8 are presented at 11 UTC. The wind weakens after it is influenced by the city at surface and at 850 hPa. The stable boundary layer formation can be seen at 21 UTC. The wind weakens at surface and at 850 hPa (Panel D and E), the effect of the city is negligible. At 700 hPa the flow remains unaffected (Panel C and F).

Conclusions

- Model validation of temperature, pressure, relative humidity, wind speed and direction showed good agreement for all cases. YSU schemes describes best surface and vertical parameters. The model performance is worse for the strong wind cases and mountain stations.
- Comparison between different microphysics schemes for one case shows that Lin schemes describe best surface parameters.
- The urban area plays significant role in modification of skin temperature, heat, moisture and latent fluxes. There is substantial increase of the heat flux and skin-surface temperature, and lack of moisture in the city area.
- Soil temperature in the upper layers around the city is higher in presence of urban area.
- The modification of the synoptic flow, due to the complex terrain in Sofia region, is significant. Reverse flows, vortices and areas with calm conditions over the city can be seen at 11 and 21 UTC.
- The presence of Vitosha mountain plays major role in modification of the flow at 850 hPa. At 700 hPa the flow remains unaffected.

Acknowledgements

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