VI-SEEM project

Bulgarian Climate Applications

https://vi-seem.eu

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TVRegCM

Methodology:

The simulation domain that was chosen is:

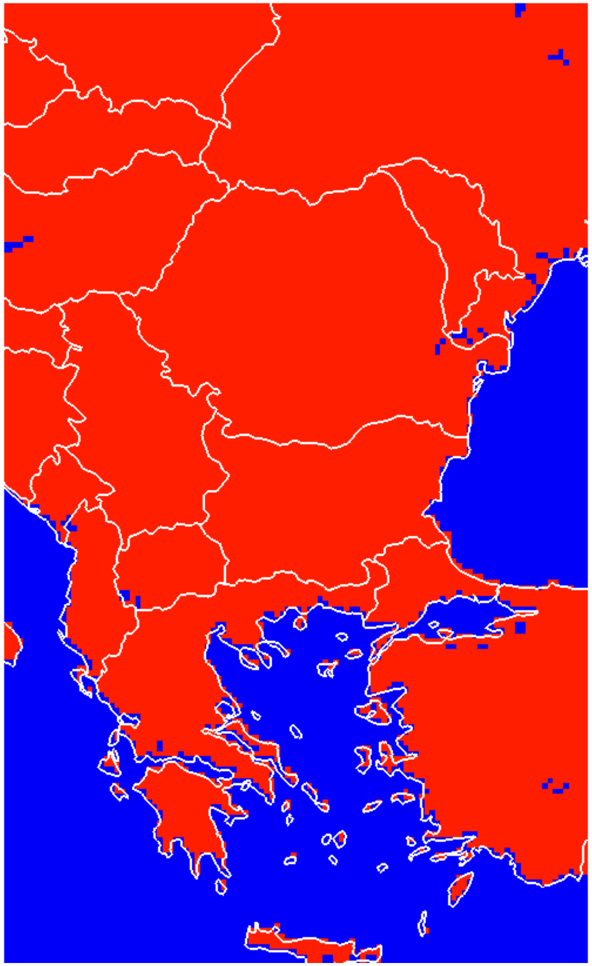
- with grid spacing 10km, and covers the South-East Europe;
- The model is set-up with 27 vertical levels (table 1);
- All the simulations are for 10 years period (from 01.12.1999 to 31.12.2009) and it is long enough for climate and statistical study;
- Land surface scheme – BATS

We will perform 40 different scenarios (table 2) which will be different combinations of:

- meteorological backgrounds;
- boundary conditions;
- PBL schemes;
- Moisture schemes;
- Cumulus schemes.

The produced results from these scenarios will be verified with the reanalysis and observation data sets.

The obtained results will be base for consequential simulation of the near and far future climate.



The results, concerning the average seasonal temperature and the seasonal precipitation sum from the runs of all successive model configurations, are projected onto the regular 0.125°x125° E-OBS grid and are evaluated with the newest E-OBS data-sets.

Vertical levels:

Vi-SEEM

We made some simulations with different dsmin and dsmax (minimum and maximum sigma spacing) to choose the best model configuration.

Table 1

#	4.50E-02	5.00E-03		4.00E-02	1.00E-02		5.00E-02	1.00E-02		5.00E-02	3.00E-02		4.00E-02	3.00E-02		5.00E-02	2.00E-02		4.00E-02	2.00E-02	
k	sigma	p(mb)	z(m)	sigma	p(mb)	z(m)	sigma	p(mb)	z(m)	sigma	p(mb)	z(m)	sigma	p(mb)	z(m)	sigma	p(mb)	z(m)	sigma	p(mb)	z(m)
28 / 01	1	1013.25	0	1	1013.25	0	1	1013.25	0	1	1013.25	0	1	1013.25	0	1	1013.25	0	1	1013.25	0
27 / 02	0.995	1008.43	40.28	0.99	1003.61	80.95	0.99	1003.61	80.95	0.97	984.35	247.61	0.97	984.35	247.62	0.98	993.98	163.48	0.98	993.99	163.47
26 / 03	0.989	1002.28	92.05	0.978	992.16	178.28	0.978	992.39	176.27	0.94	955.27	504.42	0.939	954.7	509.53	0.959	973.46	341.27	0.958	973.07	344.88
25 / 04	0.981	994.52	157.84	0.964	978.69	294.43	0.965	979.43	287.89	0.909	925.96	771.36	0.908	924.32	786.73	0.936	951.66	534.56	0.935	950.43	545.72
24 / 05	0.971	984.86	240.55	0.948	962.97	432.07	0.949	964.56	417.96	0.879	896.41	1049.48	0.875	893.23	1080.32	0.912	928.53	744.64	0.909	926.07	767.64
23 / 06	0.958	972.99	343.44	0.929	944.82	594.1	0.932	947.61	568.8	0.848	866.56	1339.97	0.842	861.45	1391.54	0.887	904.06	972.92	0.882	899.96	1012.39
22 / 07	0.943	958.59	470.17	0.907	924.06	783.61	0.912	928.44	742.94	0.816	836.4	1644.16	0.809	828.99	1721.78	0.86	878.23	1221.01	0.853	872.09	1281.87
21 / 08	0.925	941.34	624.76	0.883	900.53	1003.96	0.89	906.92	943.13	0.785	805.88	1963.6	0.774	795.89	2072.61	0.832	851.02	1490.68	0.823	842.5	1578.16
20 / 09	0.904	920.93	811.66	0.856	874.13	1258.72	0.865	882.92	1172.39	0.753	774.96	2300.07	0.739	762.16	2445.86	0.802	822.43	1783.96	0.79	811.2	1903.56
19 / 10	0.879	897.1	1035.69	0.825	844.78	1551.78	0.837	856.35	1434.04	0.72	743.62	2655.61	0.704	727.84	2843.57	0.771	792.44	2103.15	0.756	778.26	2260.6
18 / 11	0.851	869.63	1302.1	0.792	812.46	1887.29	0.807	827.16	1731.72	0.687	711.8	3032.61	0.667	692.96	3268.17	0.738	761.06	2450.89	0.72	743.73	2652.14
17 / 12	0.818	838.37	1616.62	0.755	777.21	2269.8	0.774	795.31	2069.51	0.653	679.47	3433.91	0.631	657.54	3722.44	0.704	728.3	2830.26	0.683	707.71	3081.42
16 / 13	0.782	803.25	1985.47	0.715	739.14	2704.29	0.738	760.81	2452.01	0.619	646.59	3862.85	0.593	621.63	4209.72	0.669	694.18	3244.85	0.644	670.3	3552.16
15 / 14	0.742	764.28	2415.49	0.673	698.4	3196.31	0.699	723.71	2884.44	0.585	613.11	4323.47	0.556	585.25	4733.96	0.632	658.72	3698.96	0.604	631.62	4068.69
14 / 15	0.697	721.61	2914.29	0.628	655.22	3752.12	0.658	684.09	3372.89	0.549	578.98	4820.65	0.517	548.45	5299.92	0.594	621.94	4197.73	0.562	591.81	4636.13
13 / 16	0.649	675.47	3490.46	0.581	609.9	4378.94	0.615	642.1	3924.52	0.513	544.16	5360.43	0.479	511.26	5913.45	0.554	583.89	4747.44	0.52	551.01	5260.66
12 / 17	0.598	626.21	4153.86	0.532	562.77	5085.26	0.569	597.9	4547.97	0.476	508.59	5950.35	0.44	473.73	6581.8	0.513	544.6	5355.92	0.477	509.39	5949.8
11 / 18	0.544	574.31	4916.19	0.482	514.24	5881.34	0.521	551.73	5253.9	0.438	472.22	6600.02	0.401	435.88	7314.14	0.471	504.13	6033.04	0.433	467.13	6712.99
10 / 19	0.488	520.3	5791.69	0.431	464.73	6779.93	0.471	503.83	6055.82	0.4	434.98	7321.96	0.361	397.77	8122.28	0.428	462.53	6791.57	0.389	424.39	7562.27
09 / 20	0.431	464.83	6798.32	0.379	414.7	7797.38	0.42	454.49	6971.36	0.36	396.83	8132.83	0.321	359.44	9021.87	0.384	419.87	7648.51	0.344	381.38	8513.45
08 / 21	0.372	408.57	7959.73	0.327	364.64	8955.44	0.368	404.05	8024.34	0.319	357.7	9055.6	0.281	320.92	10034.2	0.339	376.22	8627.09	0.299	338.29	9587.91
07 / 22	0.314	352.24	9308.48	0.275	315.01	10284.3	0.314	352.84	9248.4	0.278	317.52	10123.06	0.241	282.27	11189.1	0.292	331.66	9760.43	0.255	295.31	10815.7
06 / 23	0.256	296.57	10891.9	0.225	266.28	11827.7	0.261	301.24	10693.4	0.235	276.21	11384.44	0.201	243.52	12531	0.245	286.26	11098.1	0.21	252.62	12240.8
05 / 24	0.2	242.24	12783.8	0.175	218.89	13653.7	0.207	249.6	12438.4	0.191	233.7	12918.49	0.161	204.73	14129.1	0.197	240.12	12718.9	0.167	210.42	13932.2
04 / 25	0.145	189.89	15108.9	0.128	173.25	15876.2	0.154	198.3	14620.4	0.145	189.92	14863.03	0.12	165.94	16100.9	0.149	193.32	14760.6	0.123	168.9	16006.1
03 / 26	0.094	140.1	18106.4	0.083	129.69	18708.8	0.101	147.7	17509.6	0.098	144.77	17493.59	0.08	127.19	18670.5	0.1	145.97	17496.7	0.081	128.21	18682.6
02 / 27	0.045	93.35	22331.1	0.04	88.53	22630.4	0.05	98.16	21766.5	0.05	98.16	21498.35	0.04	88.53	22354	0.05	98.16	21604.7	0.04	88.53	22463.3
01 / 28	0	50	29643.2	0	50	29130.1	0	50	29891.2	0	50	29623	0	50	28853.8	0	50	29729.4	0	50	28963

Variations of model configurations

Number	Code	ICBC	PBL	M-scheme	CC
1	r11121	EIN15	Holtslag PBL	SUBEX	Grell 1
2	r11122	EIN15	Holtslag PBL	SUBEX	Grell 2
3	r11133	EIN15	Holtslag PBL	SUBEX	Emanuel
4	r11144	EIN15	Holtslag PBL	SUBEX	Tiedtke
5	r11155	EIN15	Holtslag PBL	SUBEX	Kain-Fritsch
6	r11221	EIN15	Holtslag PBL	Nogherotto/Tompkins	Grell 1
7	r11222	EIN15	Holtslag PBL	Nogherotto/Tompkins	Grell 2
8	r11233	EIN15	Holtslag PBL	Nogherotto/Tompkins	Emanuel
9	r11244	EIN15	Holtslag PBL	Nogherotto/Tompkins	Tiedtke
10	r11255	EIN15	Holtslag PBL	Nogherotto/Tompkins	Kain-Fritsch
11	r12121	EIN15	UW PBL	SUBEX	Grell 1
12	r12122	EIN15	UW PBL	SUBEX	Grell 2
13	r12133	EIN15	UW PBL	SUBEX	Emanuel
14	r12144	EIN15	UW PBL	SUBEX	Tiedtke
15	r12155	EIN15	UW PBL	SUBEX	Kain-Fritsch
16	r12221	EIN15	UW PBL	Nogherotto/Tompkins	Grell 1
17	r12222	EIN15	UW PBL	Nogherotto/Tompkins	Grell 2
18	r12233	EIN15	UW PBL	Nogherotto/Tompkins	Emanuel
19	r12244	EIN15	UW PBL	Nogherotto/Tompkins	Tiedtke
20	r12255	EIN15	UW PBL	Nogherotto/Tompkins	Kain-Fritsch
21	r21121	NNRP2	Holtslag PBL	SUBEX	Grell 1
22	r21122	NNRP2	Holtslag PBL	SUBEX	Grell 2
23	r21133	NNRP2	Holtslag PBL	SUBEX	Emanuel
24	r21144	NNRP2	Holtslag PBL	SUBEX	Tiedtke
25	r21155	NNRP2	Holtslag PBL	SUBEX	Kain-Fritsch
26	r21221	NNRP2	Holtslag PBL	Nogherotto/Tompkins	Grell 1
27	r21222	NNRP2	Holtslag PBL	Nogherotto/Tompkins	Grell 2
28	r21233	NNRP2	Holtslag PBL	Nogherotto/Tompkins	Emanuel
29	r21244	NNRP2	Holtslag PBL	Nogherotto/Tompkins	Tiedtke
30	r21255	NNRP2	Holtslag PBL	Nogherotto/Tompkins	Kain-Fritsch
31	r22121	NNRP2	UW PBL	SUBEX	Grell 1
32	r22122	NNRP2	UW PBL	SUBEX	Grell 2
33	r22133	NNRP2	UW PBL	SUBEX	Emanuel
34	r22144	NNRP2	UW PBL	SUBEX	Tiedtke
35	r22155	NNRP2	UW PBL	SUBEX	Kain-Fritsch
36	r22221	NNRP2	UW PBL	Nogherotto/Tompkins	Grell 1
37	r22222	NNRP2	UW PBL	Nogherotto/Tompkins	Grell 2
38	r22233	NNRP2	UW PBL	Nogherotto/Tompkins	Emanuel
39	r22244	NNRP2	UW PBL	Nogherotto/Tompkins	Tiedtke
40	r22255	NNRP2	UW PBL	Nogherotto/Tompkins	Kain-Fritsch

Table 2

We made some tests not only for chosen variation of the different combination of the selected schemes, but also to any other type of cumulus schemes (table 3).

It became clear that the Kuo scheme work in summer but doesn't work during the winter period for this resolution even if we reduce the time steps (table 4).

Ocean / Land	Kuo (0)	Grell (1)	Grell (2)	Emanuel (3)	Tiedtke (4)	Kain-Fritsch (5)
Kuo (0)	summer √ / winter -	-	-	-	-	-
Grell (1)	-	√	-	√	√	√
Grell (2)	-	-	√	√	√	√
Emanuel (3)	-	√	√	√	√	√
Tiedtke (4)	-	√	√	√	√	√
Kain-Fritsch (5)	-	√	√	√	√	√

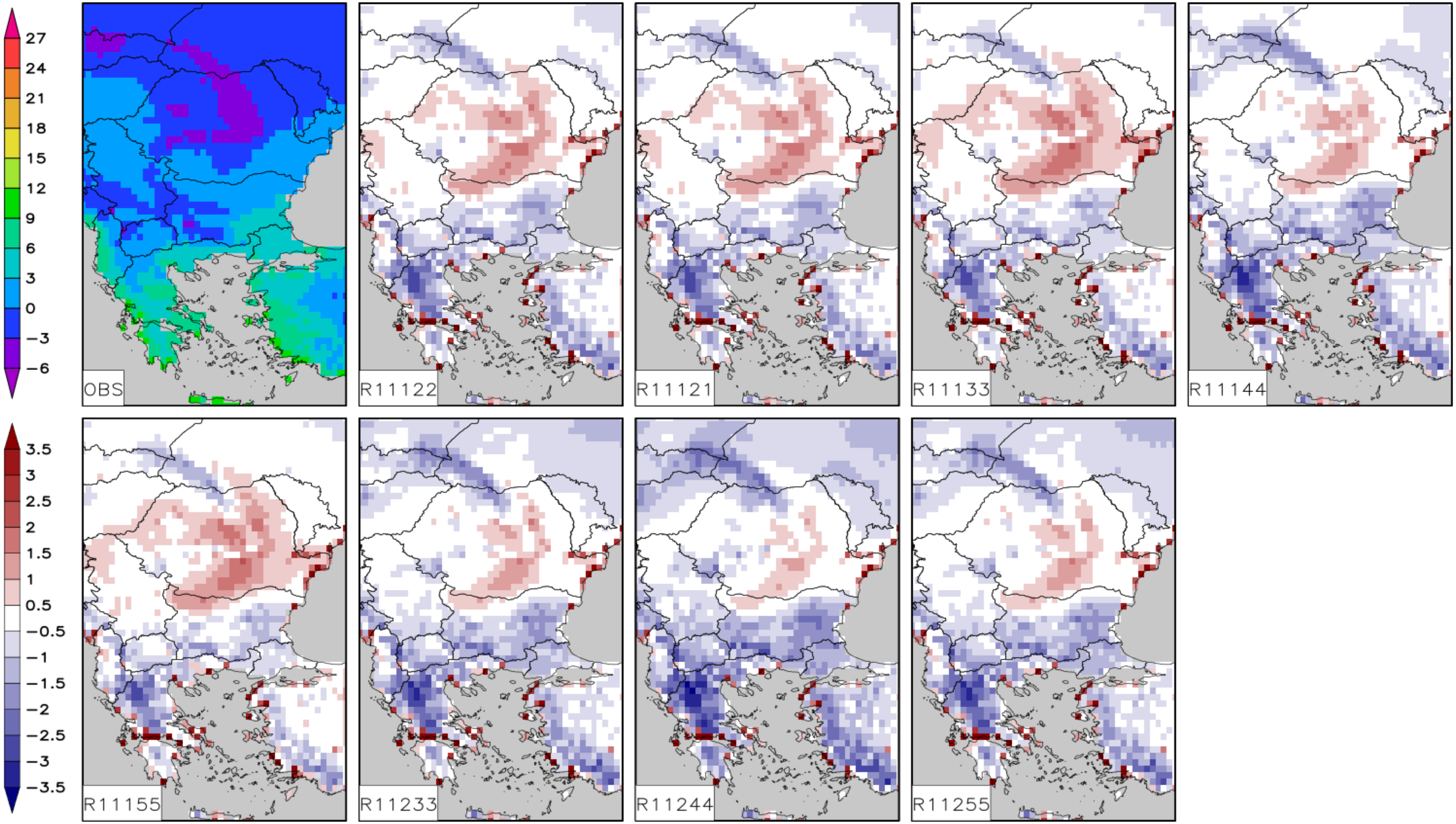
Table 3

We test the different horizontal resolution with different time steps, but the model implementation with the Kuo scheme get failed every time during the winter period for the selected domain.

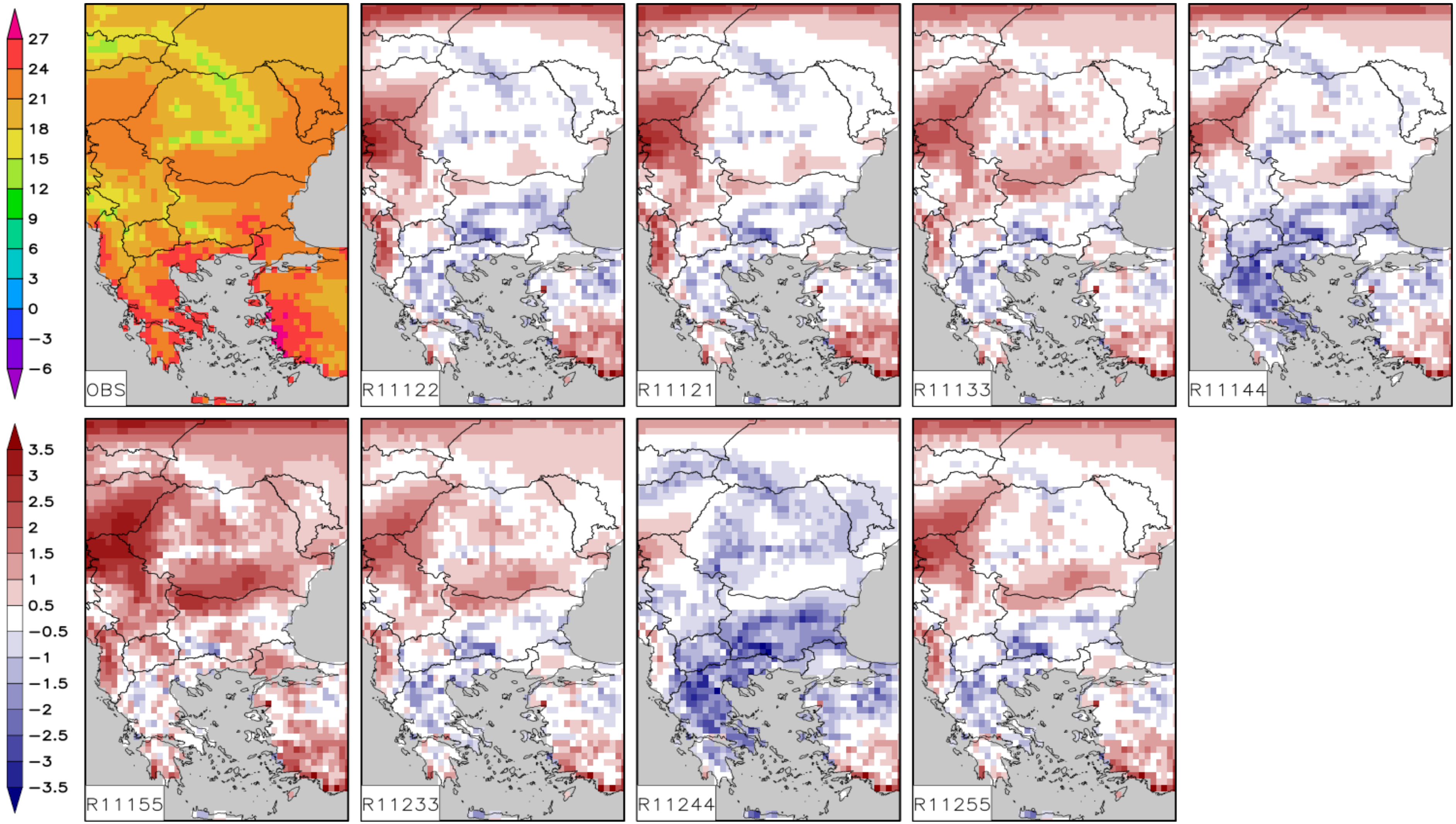
Kuo-Kuo	Winter			
dx dt	10s	20s	25s	30s
9km	-	-	-	-
10km	-	-	-	-
12km	-	-	-	-
Kuo-Kuo	Summer			
dx dt	25s			
9km	√			

Table 4

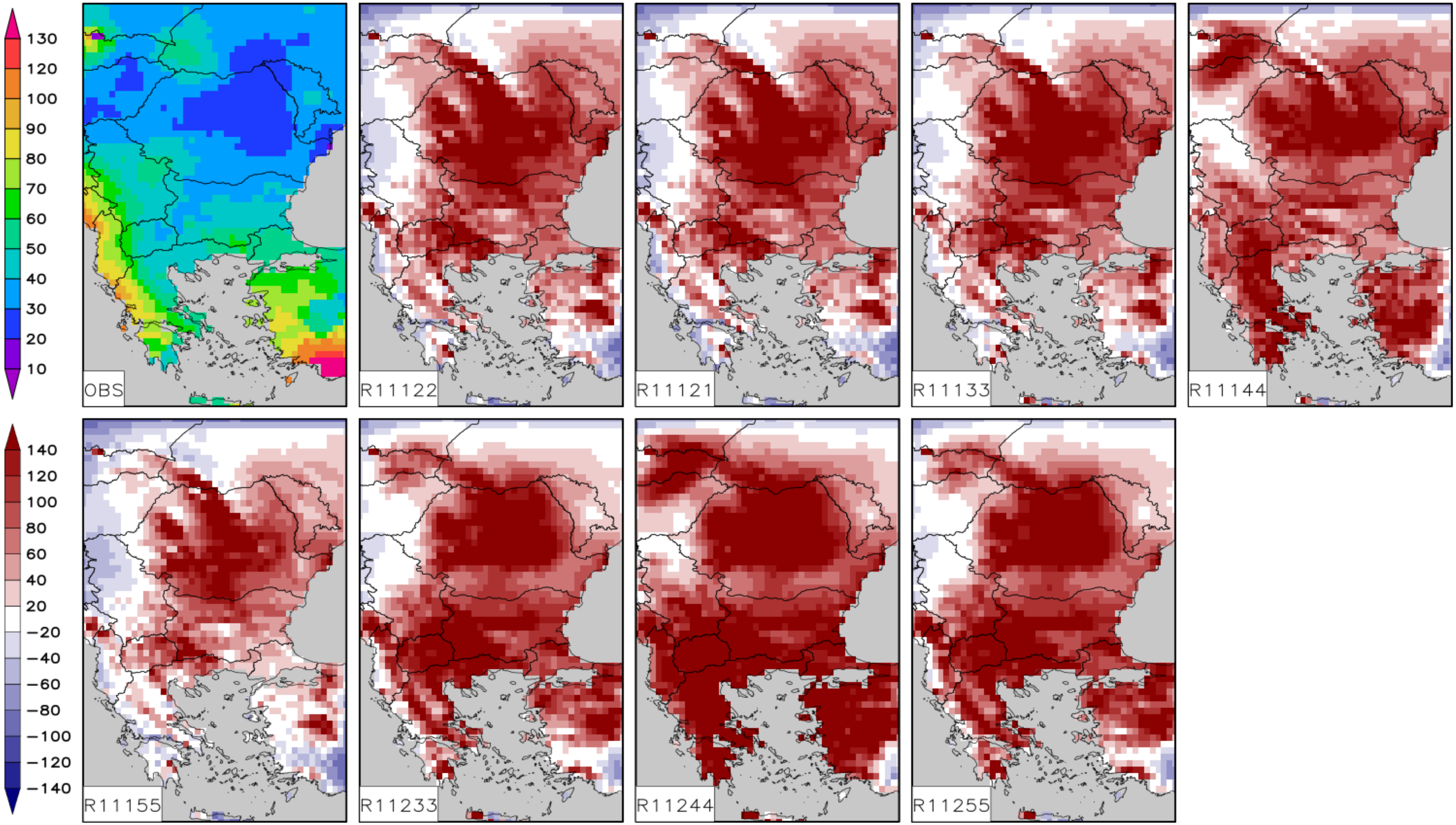
Results:



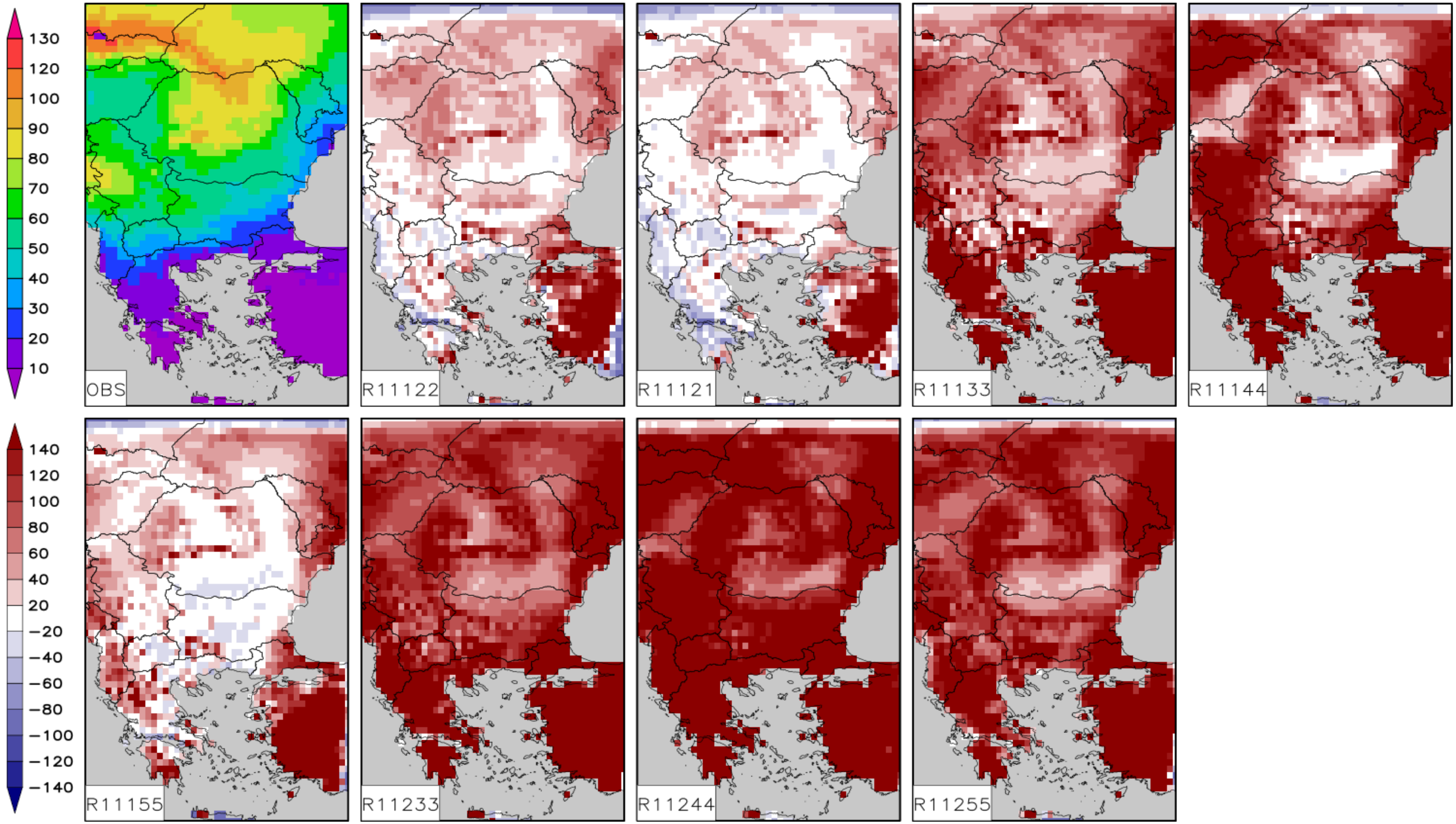
The BIAS of the Mean 2-meter temperature for the winter months (DJF)



The BIAS of the Mean 2-meter temperature for the summer months (JJA)



The relative BIAS of the Precipitation amount for the winter months (DJF)



The relative BIAS of the Precipitation amount for the summer months (JJA)

TVRegCM – Conclusions:

At this stage it could be conclude that the:

All of the model configurations mostly overestimate the temperature during the summer except with Tiedtke cumulus scheme (for both M-schemes).

The biases for the precipitation are more than 50 % over the whole domain during the winter for all of the scenarios.

The same conclusion could be made for the simulations with cumulus schemes of Emanuel, Tiedtke (for both M-schemes) and Kain-Fritsch with Nongherotto-Tompkins M-schemes during the summer.

To complete selected scenarios

To prepare more detailed and complex statistical assessment of the simulation results from different model configurations.

To provide high quality robust assessments of the Regional Climate and to conclude which of the scenarios are more reliable for the study of the Regional Climate in South-East Europe.

ACIQLife

Methodology

Modeling tools – US EPA Models-3 System:

WRF (Shamarock et al. 2007) used as meteorological pre-processor;

Meteorological data: NCEP Global Analysis Data with 1º×1º resolution in Grib2 format at every 6 hours.

SMOKE - the Sparse Matrix Operator Kernel Emissions Modelling System (CEP, 2003) – the emission pre-processor.

Emission data: The national emission inventory - for Bulgaria, outside the country - TNO with 0.25ºx0.125º in 10 SNAP categories. The biogenic emissions of VOC are estimated by the model SMOKE.

CMAQ - the Community Multiscale Air Quality System (Byun et al., 1998, Byun and Ching, 1999) - the Chemical Transport Model (CTM)

5 nested domains for WRF

D1 (Europe) – 81 x 81 km

D2 (Balkan peninsula) – 27 x 27 km

D3 (Bulgaria) – 9 x 9 km

D4 (Sofia municipality) – 3 x 3 km

D5 (Sofia city) – 1 x 1 km

4 nested domains for CMAQ

D2 (Balkan peninsula) – 27 x 27 km

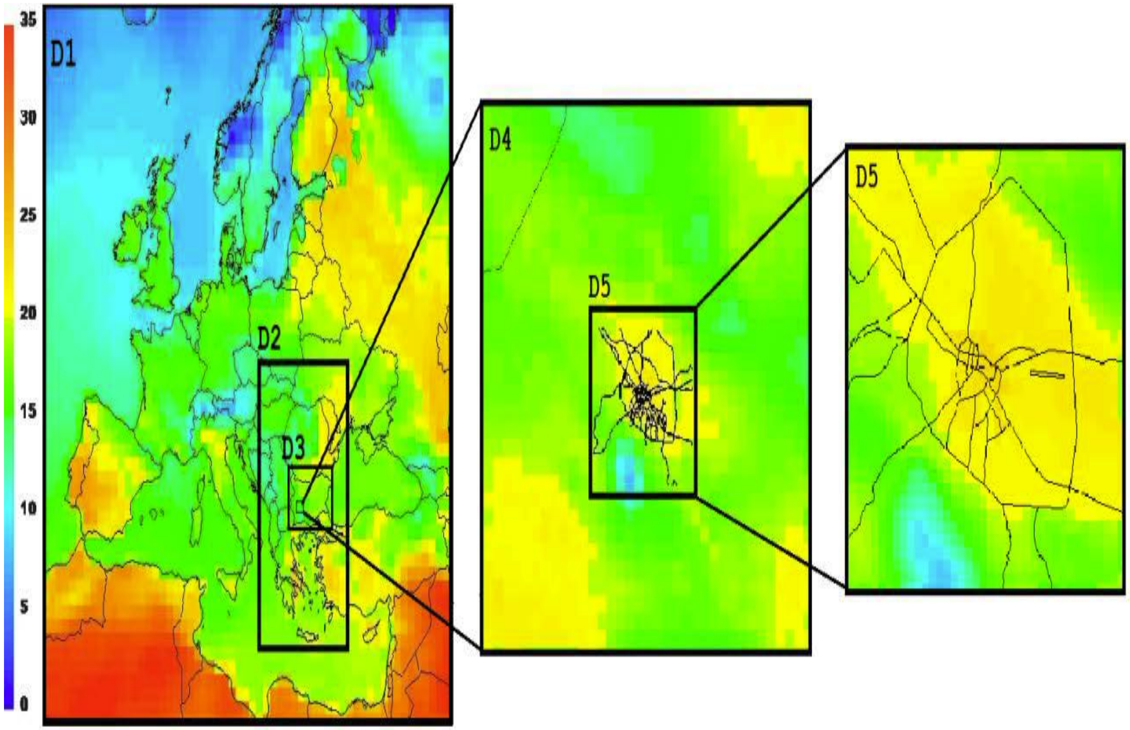
D3 (Bulgaria) – 9 x 9 km

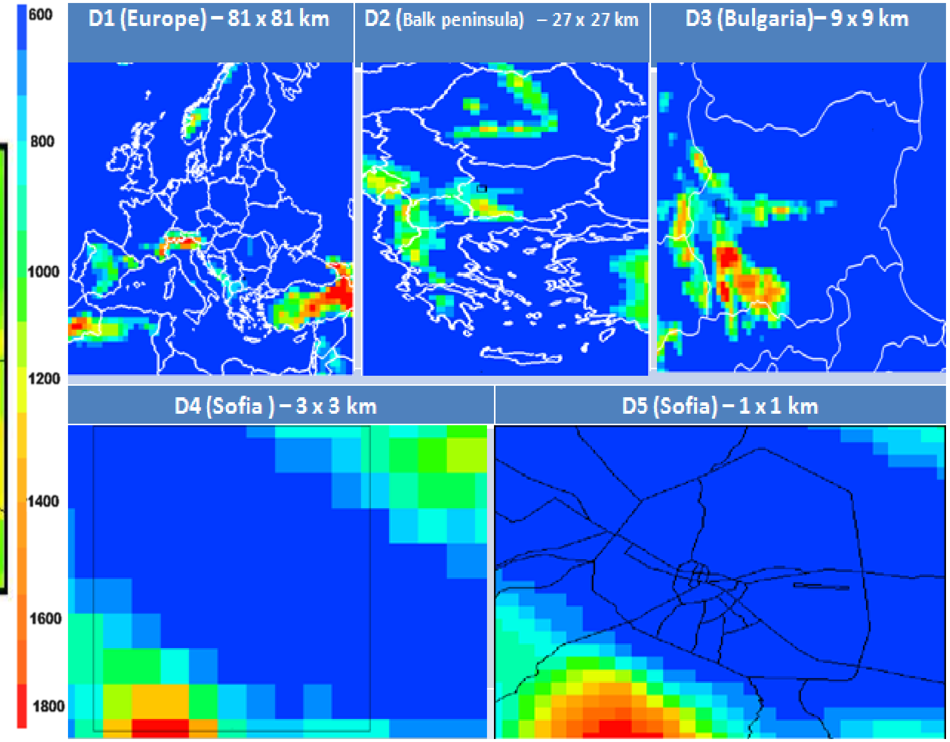
D4 (Sofia municipality) – 3 x 3 km

D5 (Sofia city) – 1 x 1 km

Downscaling effect

WRF and CMAQ nesting capabilities are applied for downscaling the simulations to a 1 km step for the innermost domain (Sofia).





The simulations were performed day by day for a period of 7 years – from 2008 to 2014 and then by averaging the typical fields of the compound surface concentrations were calculated for the 4 seasons and annually.

Air Quality Index

The AQI is an index for reporting air quality - how clean or polluted the air is, and what are the associated health effects for people. The AQI summaries the air quality state consisting of a complex mixture of a wide range of pollutants into one figure (expressed as a colored pictogram or as number).

Compute the AQI

✓requires air pollutant concentrations (monitoring or model)

✓defined in several segments, each of which is a linear function of the concentration of each the pollutant considered.

✓convert air pollutant concentration to index, which is defined for each pollutant in a different way

$$I = \frac{I_{high} - I_{low}}{C_{high} - C_{low}}(C - C_{low}) + I_{low}$$

I - the (Air Quality) index,

C - the pollutant concentration

C_{low} - the concentration breakpoint that is ≤ C,

C_{high} - the concentration breakpoint that is ≥ C,

I_{low} - the index breakpoint corresponding to C_{low}

I_{high} - the index breakpoint corresponding to C_{high}.

Air Quality Index

Converting the concentrations into a dimensionless scale associated with an intuitive color code (green to purple) and a linguistic description (Low to Very High) and health preposition.

Air Pollution Bandings and Index and the Impact on the Health of People who are Sensitive to Air Pollution

Banding	Value	Health Descriptor
Low	1–3	Effects are unlikely to be noticed even by individuals who know they are sensitive to air pollutants
Moderate	4–6	Mild effects, unlikely to require action, may be noticed amongst sensitive individuals.
High	7–9	Significant effects may be noticed by sensitive individuals and action to avoid or reduce these effects may be needed (e.g. reducing exposure by spending less time in polluted areas outdoors). Asthmatics will find that their 'reliever' inhaler is likely to reverse the effects on the lung.
Very High	10	The effects on sensitive individuals described for 'High' levels of pollution may worsen.

The reference levels used in the conversion are based on health-protection related limit, target values set by the EU or by the WHO.

Air Quality Index in Bulgaria

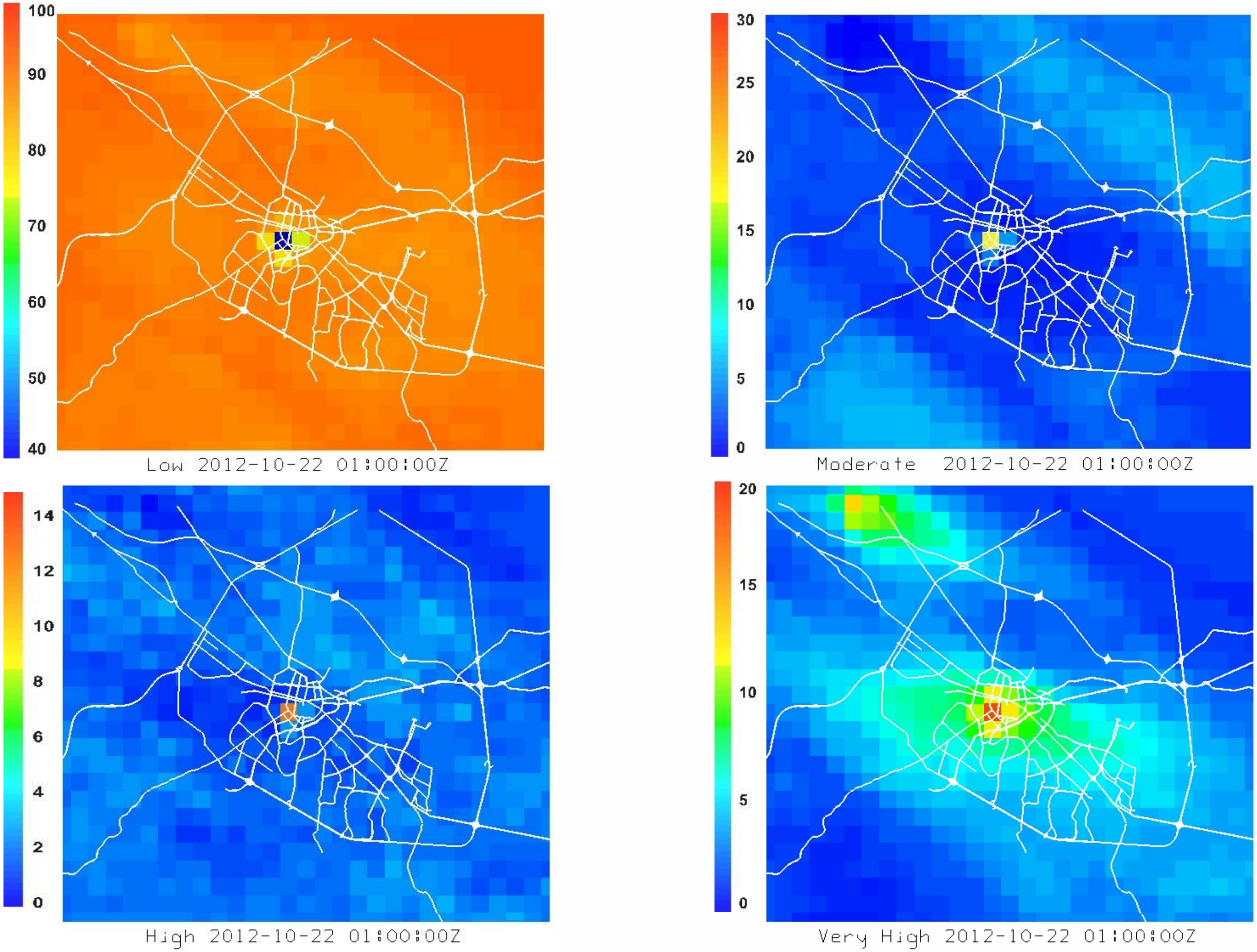
Boundaries Between Index Points for Each Pollutant

Index	O_3 Running 8 hourly mean (µg/m³)	NO_2 Hourly mean (µg/m³)	SO_2 15 minute mean (µg/m³)	PM10 Particles, 24 hour mean (µg/m³)	PM2.5 Particles, 24 hour mean (µg/m³)
1 (Low)	0-33	0-66	0-88	0-11	0-16
2 (Low)	34-65	67-133	89-176	12-23	17-33
3 (Low)	66-99	134-199	177-265	24-34	34-49
4 (Moderate)	100-120	200-267	266-354	35-41	50-58
5 (Moderate)	121-140	268-334	355-442	42-46	59-66
6 (Moderate)	141-159	335-399	443-531	47-52	67-74
7 (High)	160-187	400-467	530-708	53-58	75-83
8 (High)	188-213	468-534	709-886	59-64	84-91
9 (High)	214-239	535-599	887-1063	65-69	92-99
10 (Very High)	≥ 240	≥ 600	≥ 1064	≥ 70	≥ 100

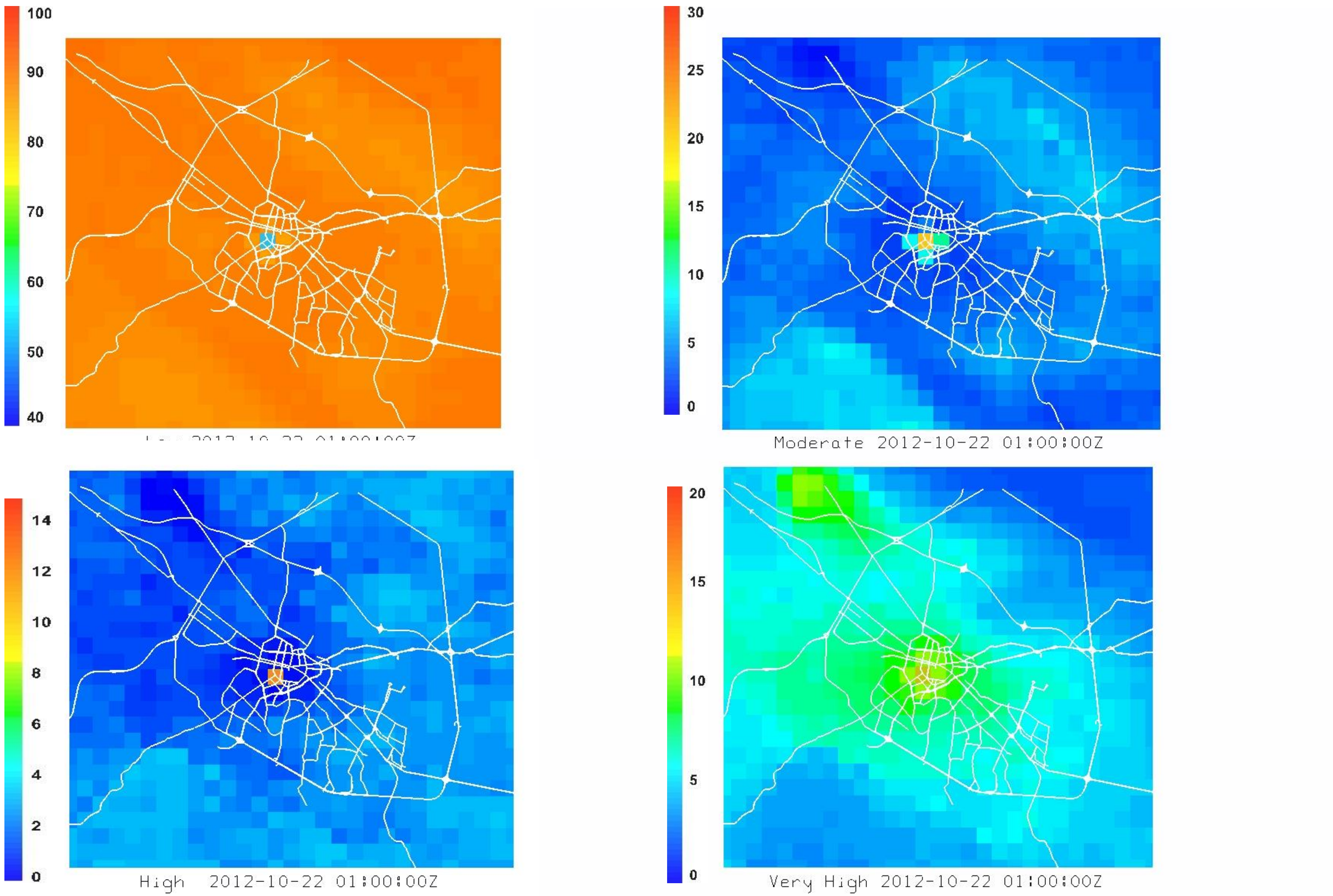
The AQI, calculated for Bulgaria follows the UK Air Quality Index.

- 10 categories from green to purple
- 4 bands: low, moderate, high and very high
- based on the concentrations of 5 pollutants: O3, NO2, SO2, PM2.5 and PM10
- The breakpoints between index values are defined for each pollutant separately and the overall index is defined as the maximum value of the index.
- Different averaging periods are used for different pollutants.

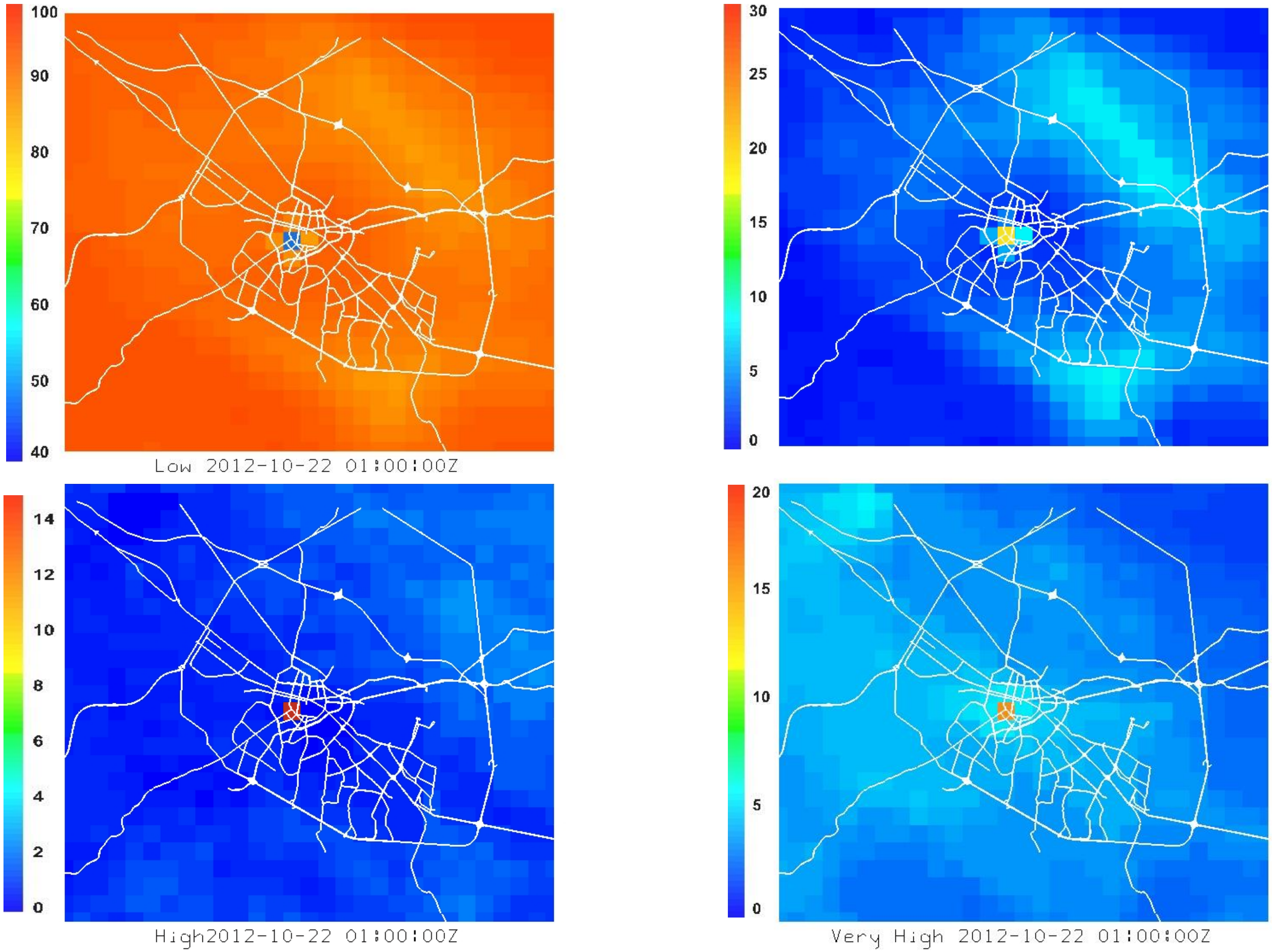
Spring plots of the percent recurrence of the AQI in the “Low”, “Moderate” ,“High” and “Very High” bands over Sofia



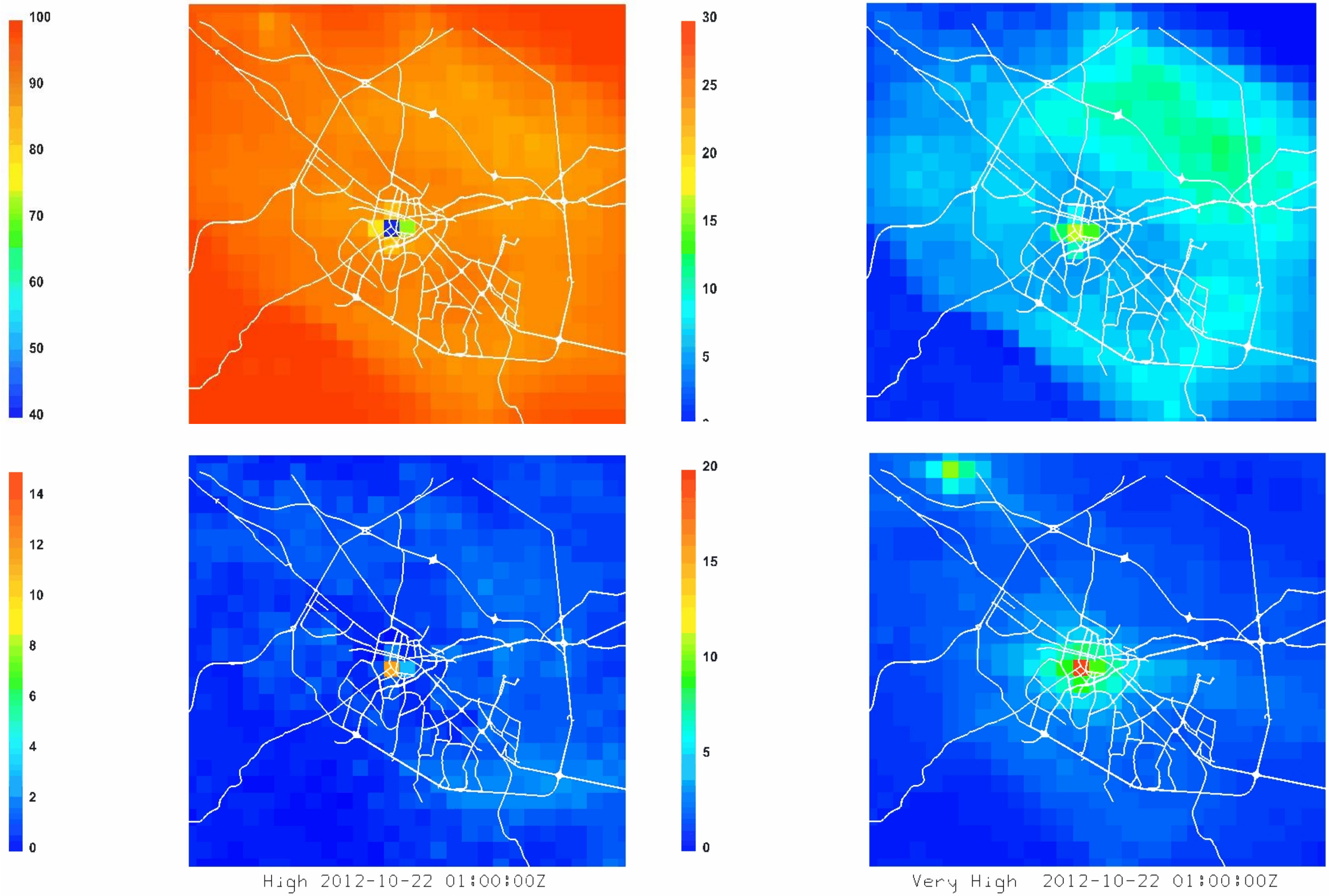
Summer plots of the percent recurrence of the AQI in the “Low”, “Moderate” ,“High” and “Very High” bands over Sofia



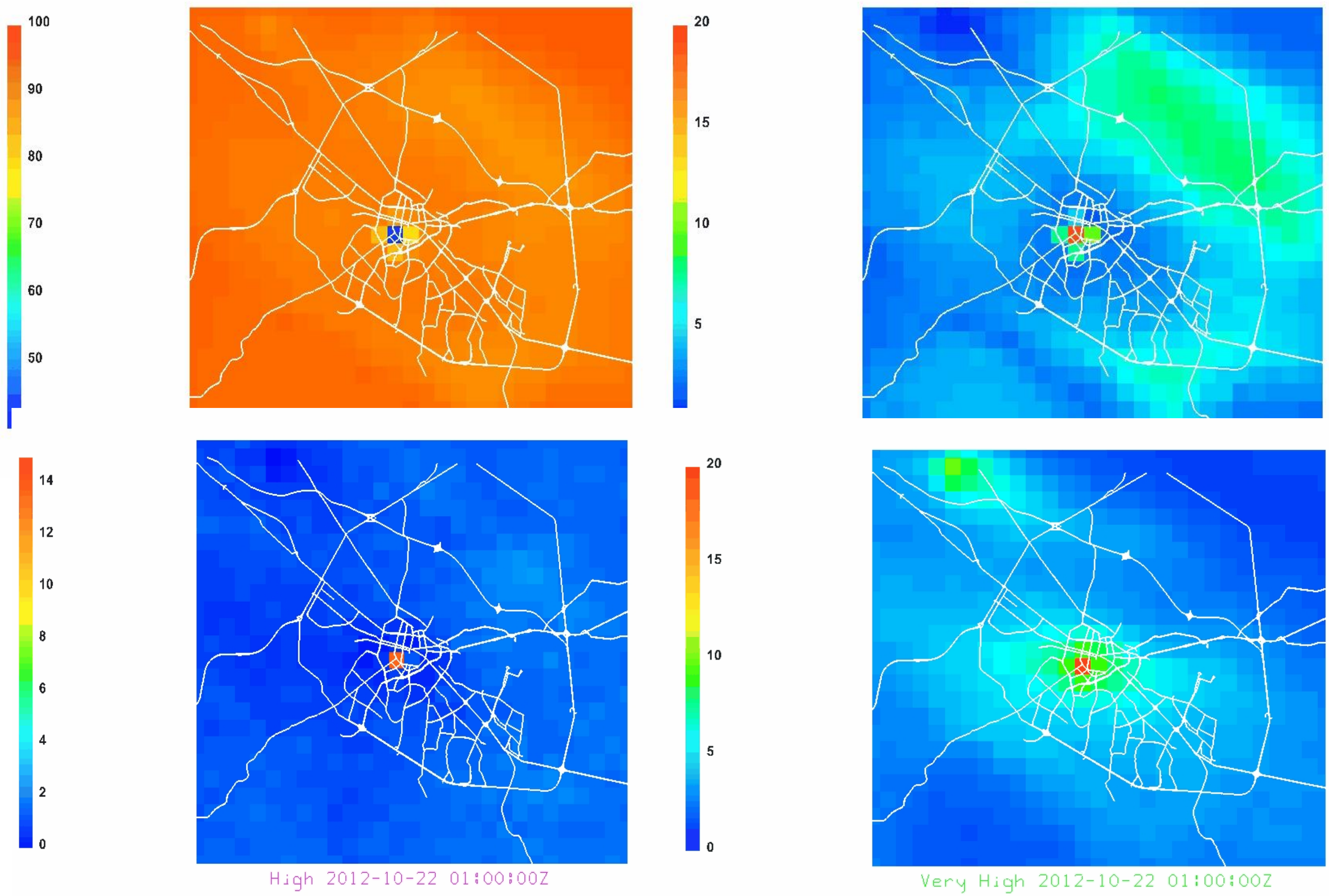
Autum nplots of the percent recurrence of the AQI in the “Low”, “Moderate” ,“High” and “Very High” bands over Sofia



Winter plots of the percent recurrence of the AQI in the “Low”, “Moderate” ,“High” and “Very High” ands over Sofia

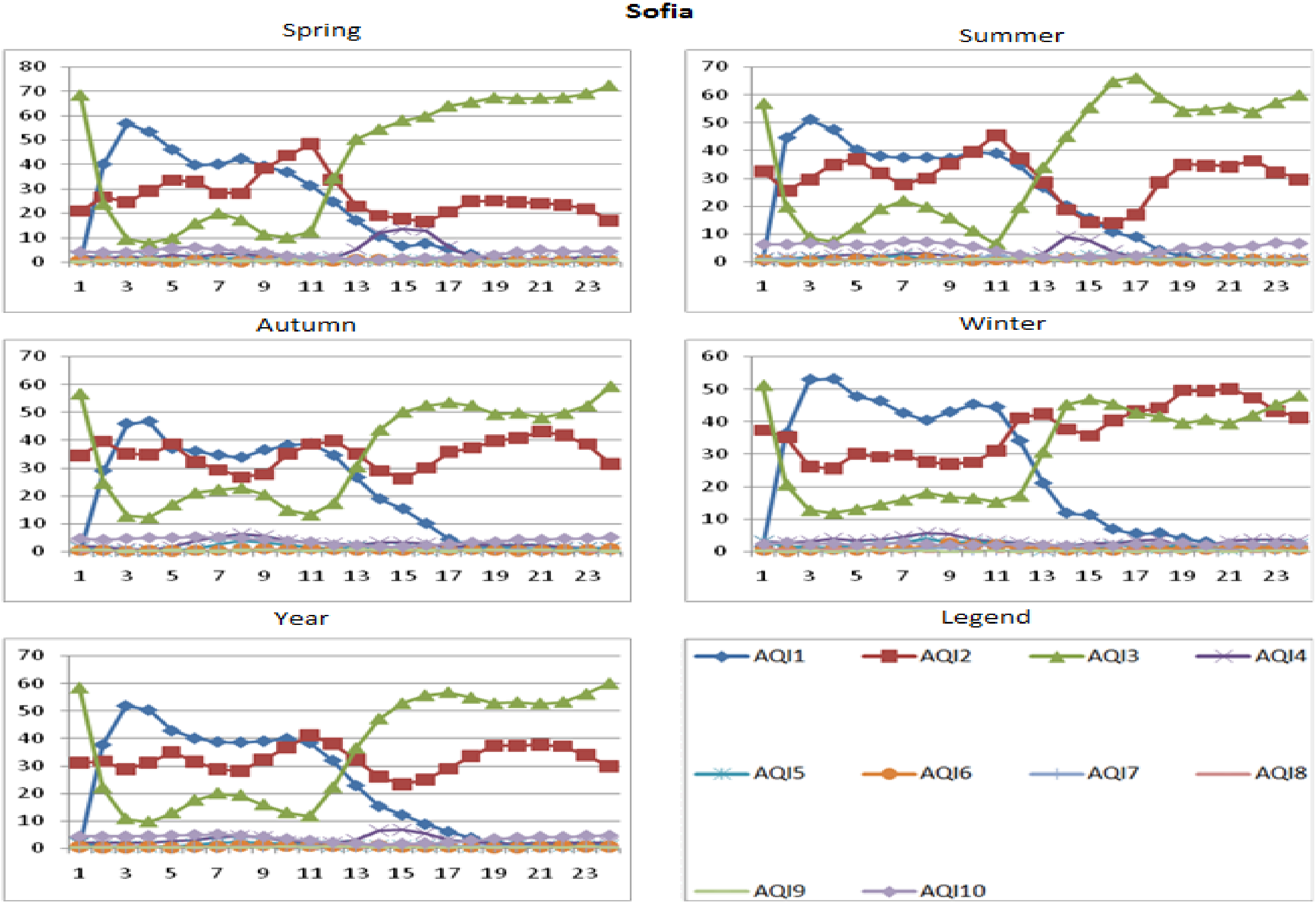


Annual plots of the percent recurrence of the AQI in the “Low”, “Moderate” ,“High” and “Very High” bands over Sofia



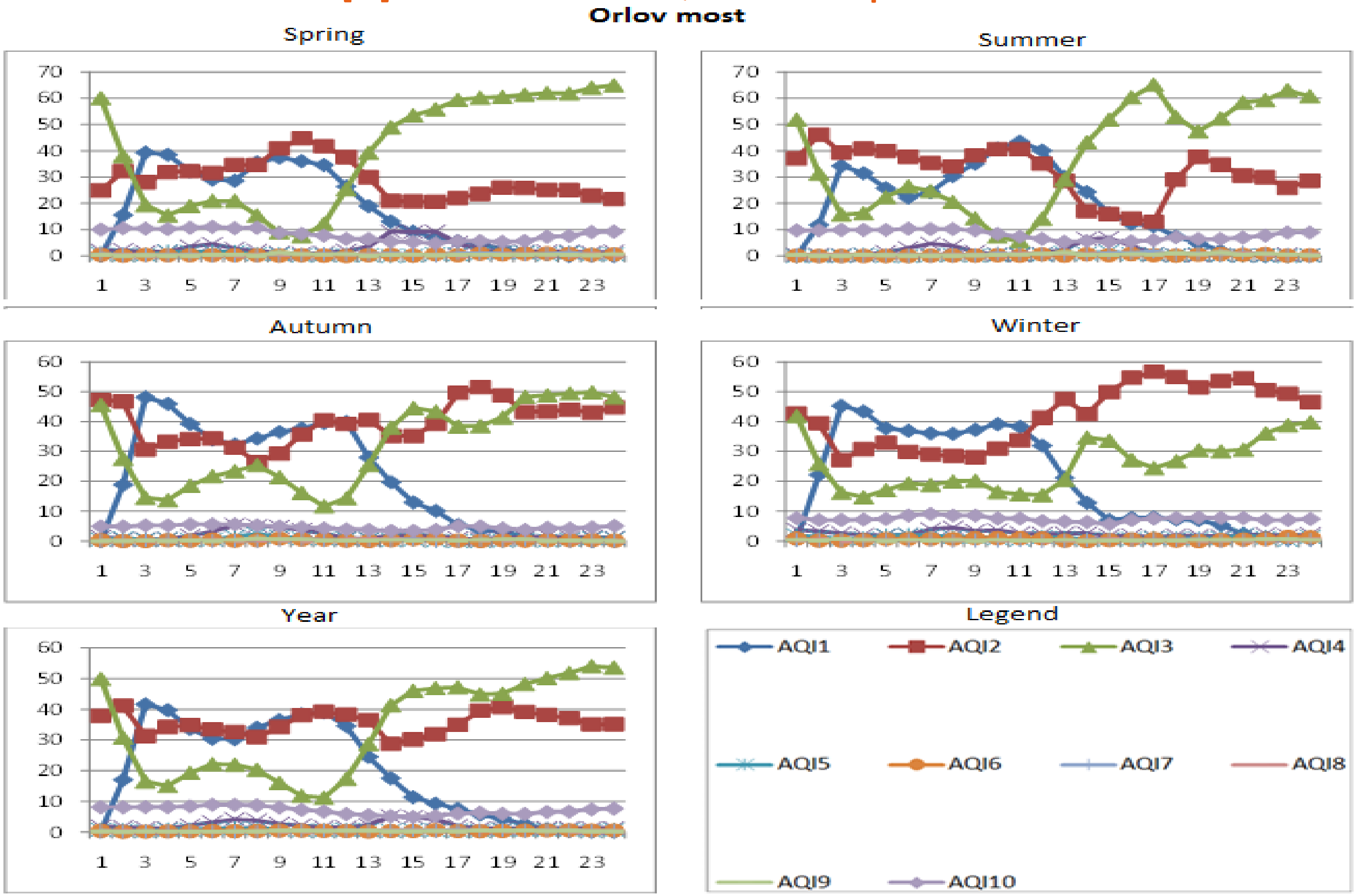
AQI spatial - temporal behavior

- **Diurnal and seasonal variations [%] of the different AQI for Sofia**



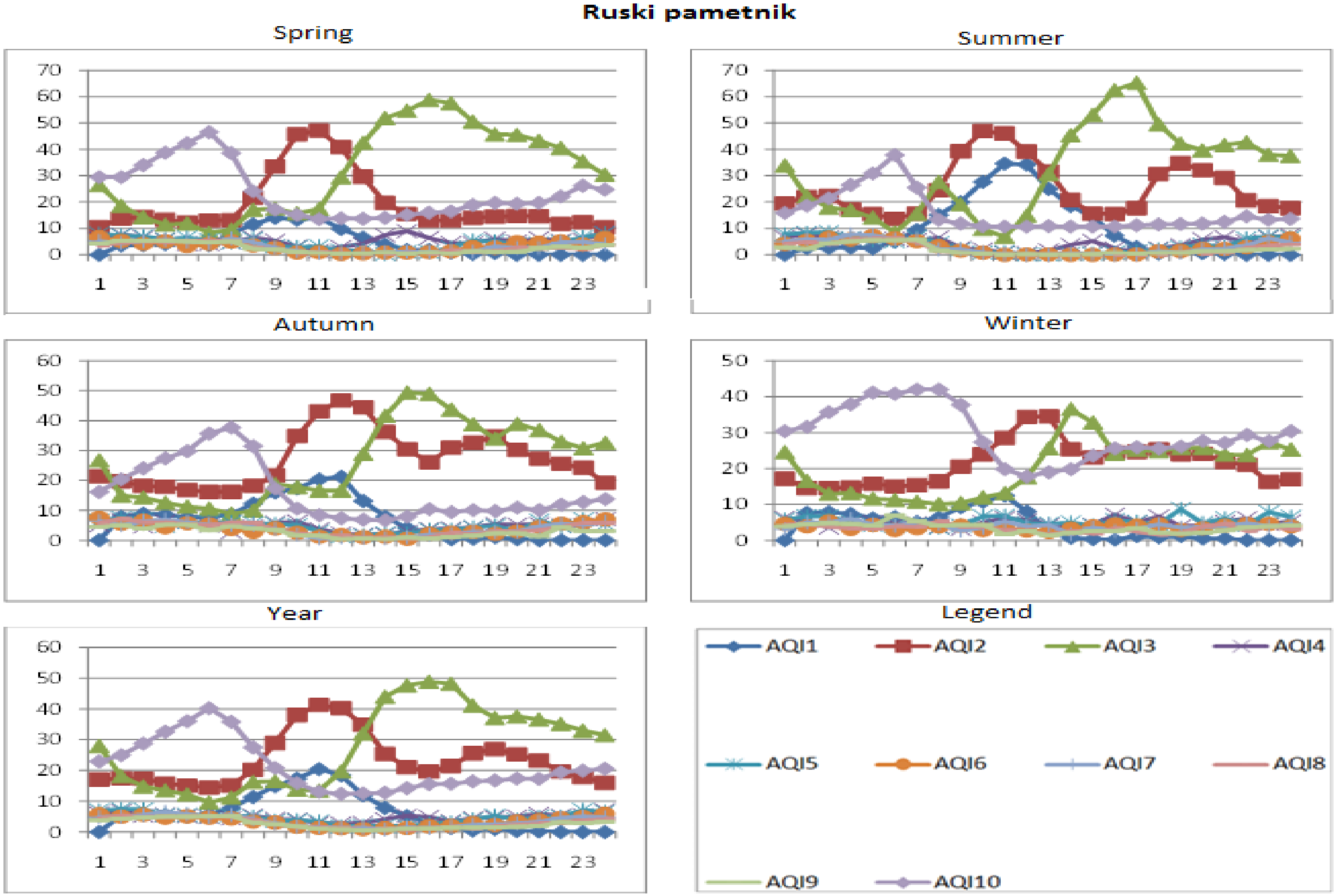
AQI spatial - temporal behavior

- Diurnal and seasonal variations [%] of the different AQI for central point



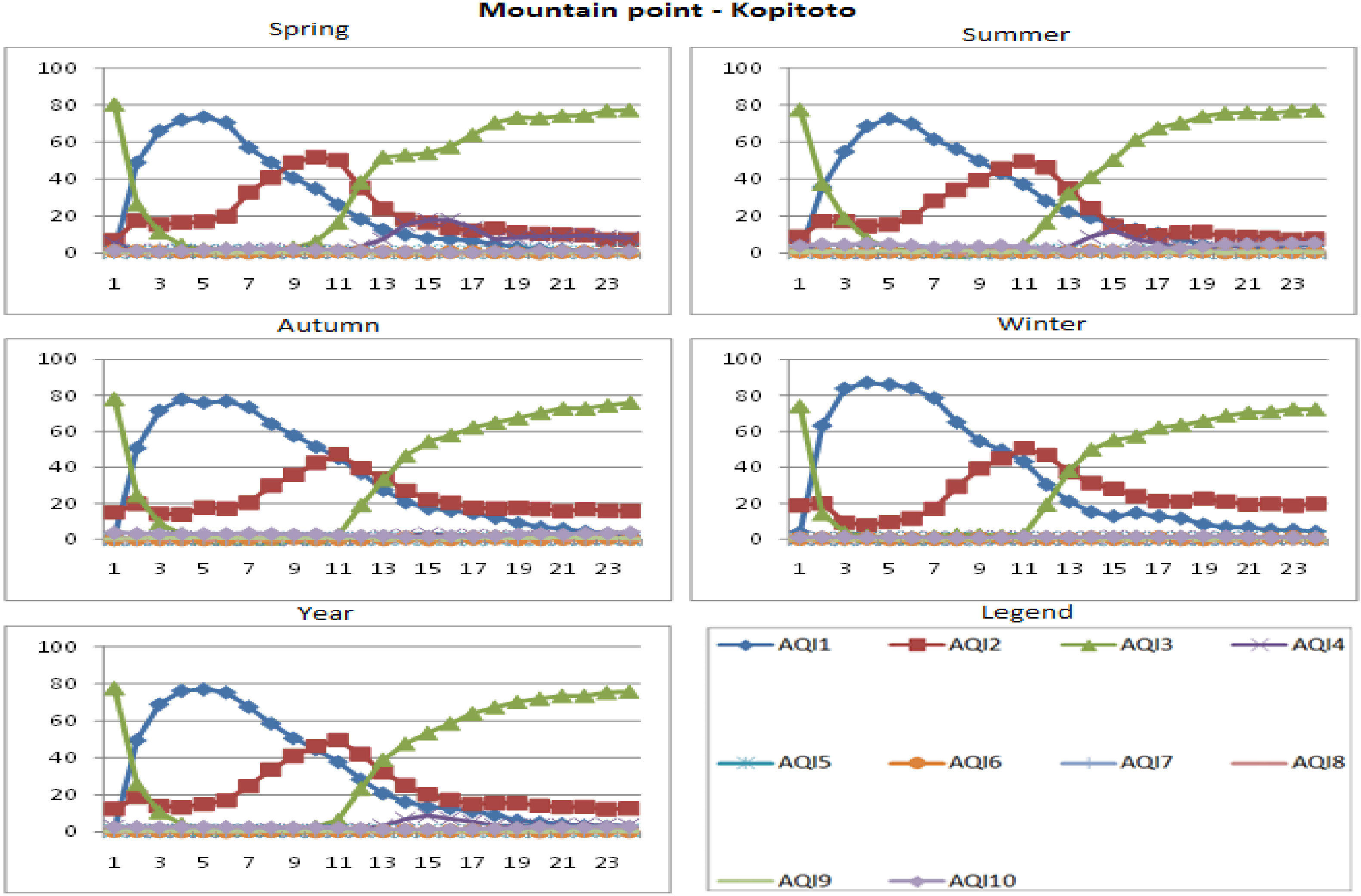
AQI spatial - temporal behavior

- **Diurnal and seasonal variations [%] of the different AQI for Ruski pametnik**



AQI spatial - temporal behavior

- Diurnal and seasonal variations [%] of the different AQI for mountain point



ACIQLife – Conclusions:

- The air quality status of Sofia is rather good (evaluated with a spatial resolution of 1km)
- AQI status falls mostly in "Low" and "Moderate" bands
- The recurrence of cases with Very High pollution is almost 20% mostly at the city centre.
- The pollution at the city probably due to the surface sources (road transport)

ACIQLife and TVRegCM resurses:

TVRegCM

16CPU	1 Month simulation	x120 Months	x40 Case
Time	6h	720h	28800h
HDD	6GB	720 GB	29TB

Every one job for TVRegCM is for 3 months

ACIQLife

1 Day simulation at 16CPU			
	WRF	CMAQ+SMOKE	Total
Time	3h	2h	5h
HDD	530MB	970MB	1.5GB

For ACIQLife the jobs are split to 2 jobs one for WRF and the other for CMAQ+SMOKE and every one of them is for 7 days

MM5 and RegCM

MM5

https://vre.vi-seem.eu/index.php/2-uncategorised/67-mm5

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MM5

The PSU/NCAR mesoscale model (known as MM5) is a limited-area, nonhydrostatic, terrain-following sigma-coordinate model designed to simulate or predict mesoscale atmospheric circulation. The model is supported by several pre- and post-processing programs, which are referred to collectively as the MM5 modeling system. The MM5 modeling system software is mostly written in Fortran, and has been developed at Penn State and NCAR as a community mesoscale model with contributions from users worldwide.

The MM5 modeling system software is freely provided and supported by the Mesoscale Prediction Group in the Mesoscale and Microscale Meteorology Division, NCAR.

HPC Resources supporting module				
Avitohol				

Details
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RegCM

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RegCM

The Regional Climate Model system RegCM , originally developed at the National Center for Atmospheric Research (NCAR), is maintained in the Earth System Physics (ESP) section of the ICTP. The first version of the model, RegCM1, was developed in 1989 and since then it has undergone major updates in 1993 (RegCM2), 1999 (RegCM2.5), 2006 (RegCM3) and most recently 2010 (RegCM4). The latest version of the model, RegCM4, is now fully supported by the ESP, while previous versions are no longer available. This version includes major upgrades in the structure of the code and its pre- and post- processors, along with the inclusion of some new physics parameterizations. The model is flexible, portable and easy to use. It can be applied to any region of the World, with grid spacing of up to about 10 km (hydrostatic limit), and for a wide range of studies, from process studies to paleoclimate and future climate simulation.

Model improvements currently under way include the development of a new microphysical cloud scheme (to be released by the end of 2014), coupling with a regional ocean model, inclusion of full gas-phase chemistry, upgrades of some physics schemes (convection, PBL, cloud microphysics) and development of a non-hydrostatic dynamical core.

ESP also supports the Regional Climate Research Network, or RegCNET. The objective of RegCNET is to expand and strengthen the network of model users and to develop collaborative research projects across the network to improve the understanding of climate change at the regional scale. The RegCNET also provides a forum for current and future model users to discuss relevant issues, exchange research experiences and formulate needs and priorities for further model development and dissemination.

HPC Resources supporting module				
ARIS	Avitohol			

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WRF and WRF-Chem

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WRF

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WRF

The **Weather Research and Forecasting** (**WRF**) Model is a numerical weather prediction (NWP) system designed to serve both atmospheric research and operational forecasting needs. NWP refers to the simulation and prediction of the atmosphere with a computer model, and WRF is a set of software for this. WRF features two dynamical (computational) cores (or *solvers*), a data assimilation system, and a software architecture allowing for parallel computation and system extensibility. The model serves a wide range of meteorological applications across scales ranging from meters to thousands of kilometers.

The effort to develop WRF began in the latter part of the 1990s and was a collaborative partnership principally among the US National Center for Atmospheric Research (NCAR), the US National Oceanic and Atmospheric Administration (represented by the National Centers for Environmental Prediction (NCEP) and the (then) Forecast Systems Laboratory (FSL)), the Air Force Weather Agency (AFWA), the Naval Research Laboratory (NRL), the University of Oklahoma (OU), and the Federal Aviation Administration (FAA). The bulk of the work on the model has been performed or supported by NCAR, NOAA, and AFWA.

WRF allows researchers to produce simulations reflecting either real data (observations, analyses) or idealized atmospheric conditions. WRF provides operational forecasting a flexible and robust platform, while offering advances in physics, numerics, and data assimilation contributed by the many research community developers. WRF is currently in operational use at NCEP and other forecasting centers internationally. WRF has grown to have a large worldwide community of users (over 23,000 registered users in over 150 countries), and workshops and tutorials are held each year at NCAR. WRF is used extensively for research and real-time forecasting throughout the world.

WRF offers two dynamical solvers for its computation of the atmospheric governing equations, and the variants of the model are known as WRF-ARW (Advanced Research WRF) and WRF-NMM (Nonhydrostatic Mesoscale Model). The Advanced Research WRF (ARW) is supported to the community by the NCAR Mesoscale and Microscale Meteorology Division. The WRF-NMM solver variant was based on the Eta Model, and later Nonhydrostatic Mesoscale Model, developed at NCEP. The WRF-NMM (NMM) is supported to the community by the Developmental Testbed Center (DTC).

HPC Resources supporting module				
ARIS	Armcluster	Avitohol	BA-HPC	Cy-Tera
ICAM BlueGene/P	InfraGRID	MK-03-FINKI	PARADOX	

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WRF-CHEM

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WRF-CHEM

WRF-Chem is the Weather Research and Forecasting (WRF) model coupled with Chemistry. The model simulates the emission, transport, mixing, and chemical transformation of trace gases and aerosols simultaneously with the meteorology. The model is used for investigation of regional-scale air quality, field program analysis, and cloud-scale interactions between clouds and chemistry.

The development of WRF-Chem is a collaborative effort among the community. NOAA/ESRL scientists are the leaders and caretakers of the code.

The Official WRF-Chem web page is located at the NOAA web site.

HPC Resources supporting module				
ARIS	Avitohol	Cy-Tera		

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