HPC simulations of Human Thermal stress

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ЕВРОПЕЙСКИ СТРУКТУРНИ И ИНВЕСТИЦИОННИ ФОНДОВЕ

ОПЕРАТИВНА ПРОГРАМА
НАУКА И ОБРАЗОВАНИЕ ЗА ИНТЕЛИГЕНТЕН РАСТЕЖ

Influence of the characteristics of the atmospheric environment on the human thermal stress

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Thermal Comfort indexes

Heat Index (high temperature conditions) – the apparent temperature at heat balance of the human body for a reference environment equal to that of the current air temperature and humidity at a height of 2 m

Heat Index (°C)	Category	Health risk
27 ÷ 32	Caution	Fatigue and cramps possible with prolonged exposure and activity.
32 ÷ 41	Extreme Caution	Cramps, heat exhaustion and heat stroke.
41 ÷ 54	Danger	Cramps, heat exhaustion are likely; heat stroke is probable.
Над 54	Extreme Danger	Heat stroke is imminent.

Wind chill Index (low temperature conditions) – the apparent temperature at a heat balance of the human body in no wind, equal to that at the current temperature at a height of 2 m and wind speed at a height of 10 m

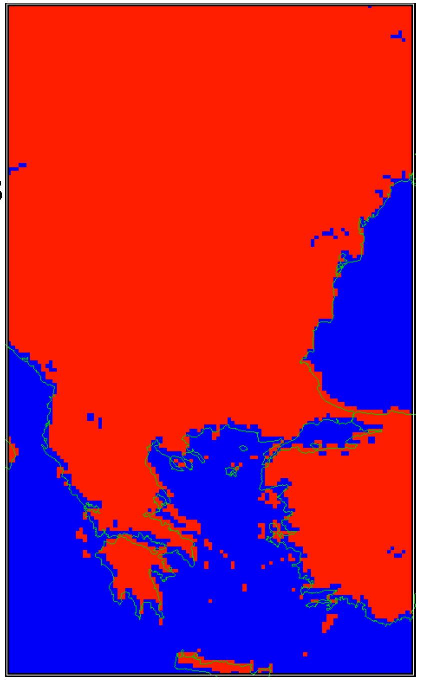
Wind Chill Index (°C)	Категория	Health risk
0 ÷ -9	Low Risk	Slight increase in discomfort
-10 ÷ -27	Moderate Risk	Increased discomfort, with risk of hypothermia and frostbite
-28 ÷ -39	High Risk	Exposed skin can freeze in 10–30 min
-40 ÷ -47	Very High Risk	Exposed skin can freeze in 5–10 min
-48 ÷ -54	Severe Risk	Exposed skin can freeze in 2–5 min
По-малко от -54	Extreme Risk	Exposed skin can freeze in less than 2 min.

RegCM4 numerical simulations

Index	Notation	ICBC	PBL-scheme	M-scheme	CC-scheme
1	r11111	EIN15	Holtslag	SUBEX	Grell/AS
2	r11112	EIN15	Holtslag	SUBEX	Grell/FC
3	r11133	EIN15	Holtslag	SUBEX	Emanuel
4	r11144	EIN15	Holtslag	SUBEX	Tiedtke
5	r11155	EIN15	Holtslag	SUBEX	Kain-Fritsch
6	r11221	EIN15	Holtslag	Nogherotto/Tompkins	Grell/AS
7	r11222	EIN15	Holtslag	Nogherotto/Tompkins	Grell/FC
8	r11233	EIN15	Holtslag	Nogherotto/Tompkins	Emanuel
9	r11244	EIN15	Holtslag	Nogherotto/Tompkins	Tiedtke
10	r11255	EIN15	Holtslag	Nogherotto/Tompkins	Kain-Fritsch
11	r12121	EIN15	UW	SUBEX	Grell/AS
12	r12122	EIN15	UW	SUBEX	Grell/FC
13	r12133	EIN15	UW	SUBEX	Emanuel
14	r12144	EIN15	UW	SUBEX	Tiedtke
15	r12155	EIN15	UW	SUBEX	Kain-Fritsch
16	r12221	EIN15	UW	Nogherotto/Tompkins	Grell/AS
17	r12222	EIN15	UW	Nogherotto/Tompkins	Grell/FC
18	r12233	EIN15	UW	Nogherotto/Tompkins	Emanuel
19	r12244	EIN15	UW	Nogherotto/Tompkins	Tiedtke
20	r12255	EIN15	UW	Nogherotto/Tompkins	Kain-Fritsch

rN1N2N3N4N5

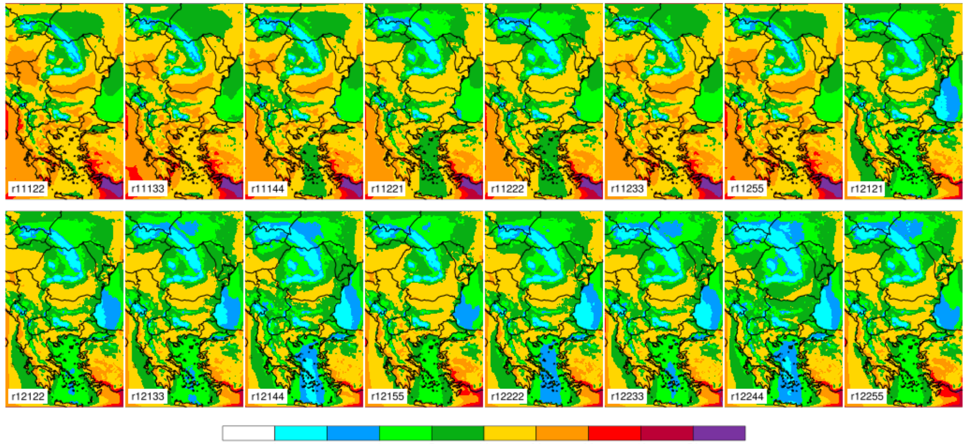
- Boundary conditions
- Boundary layer
- Microphysics
- Convection



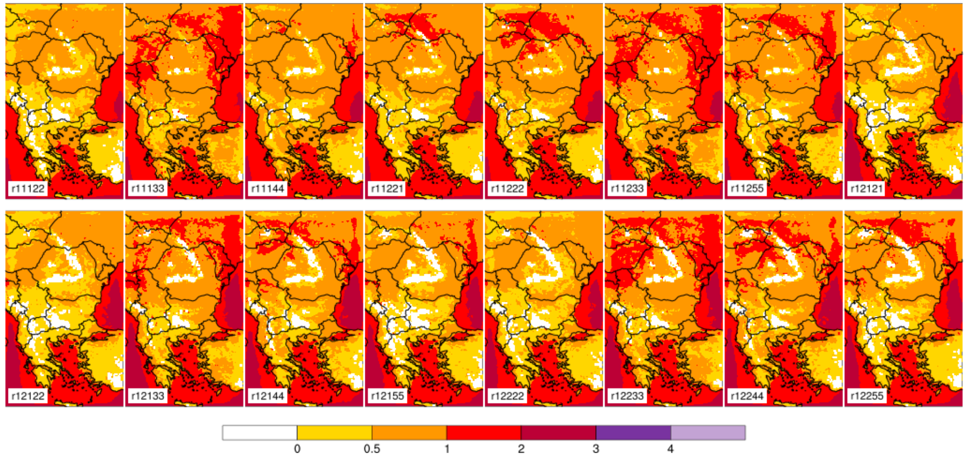
RegCM version 4
Hydrostatical core
Simulation period - 1999 ÷ 2009
Horizontal resolution - 10 km
Vertical levels - 27

Чувствителност на симулирания топлинен риск в Югоизточна Европа при различни конфигурации на модела RegCM

Frequency (%) for Caution Heat Index category under different model configurations.

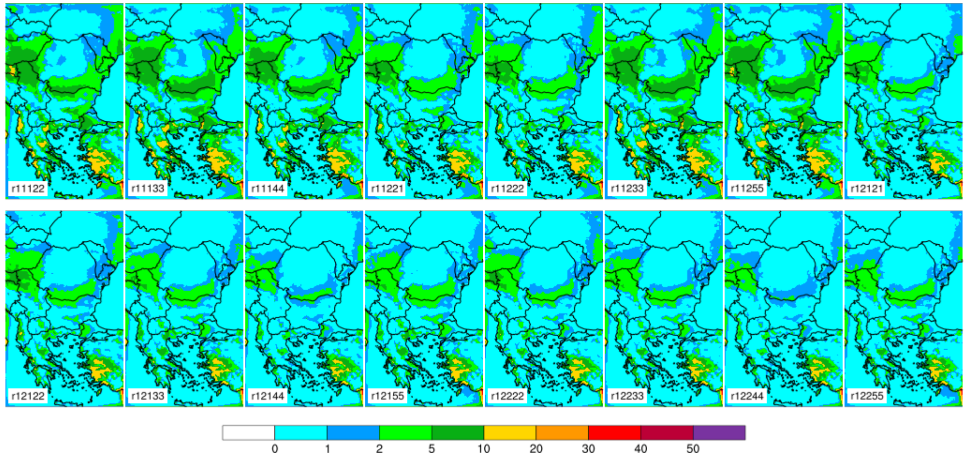


Frequency (%) for Extreme Caution Heat Index category under different model configurations.

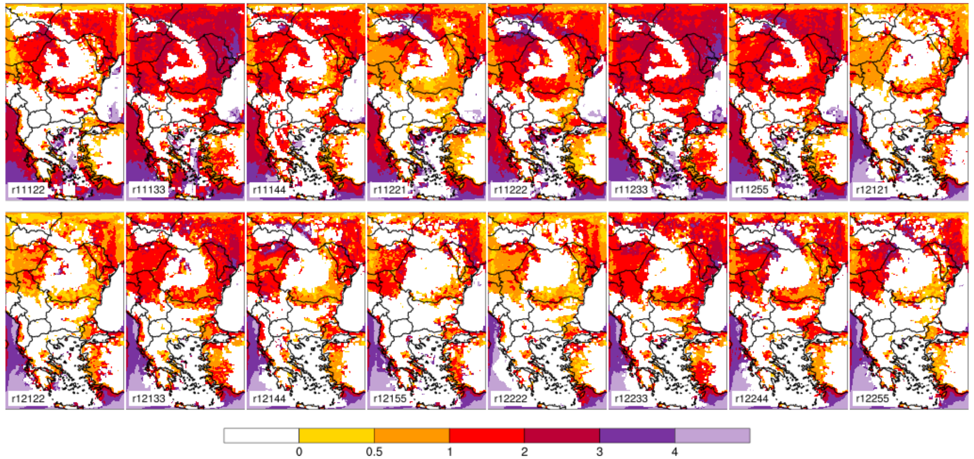


When the index falls under the "Caution" category, most of the Holtslag boundary layer scheme simulations produce the warmest conditions and the UW boundary layer scheme and Tiedtke convective scheme the coldest.

Average difference between Heat Index and surface air temperature for the Caution category.

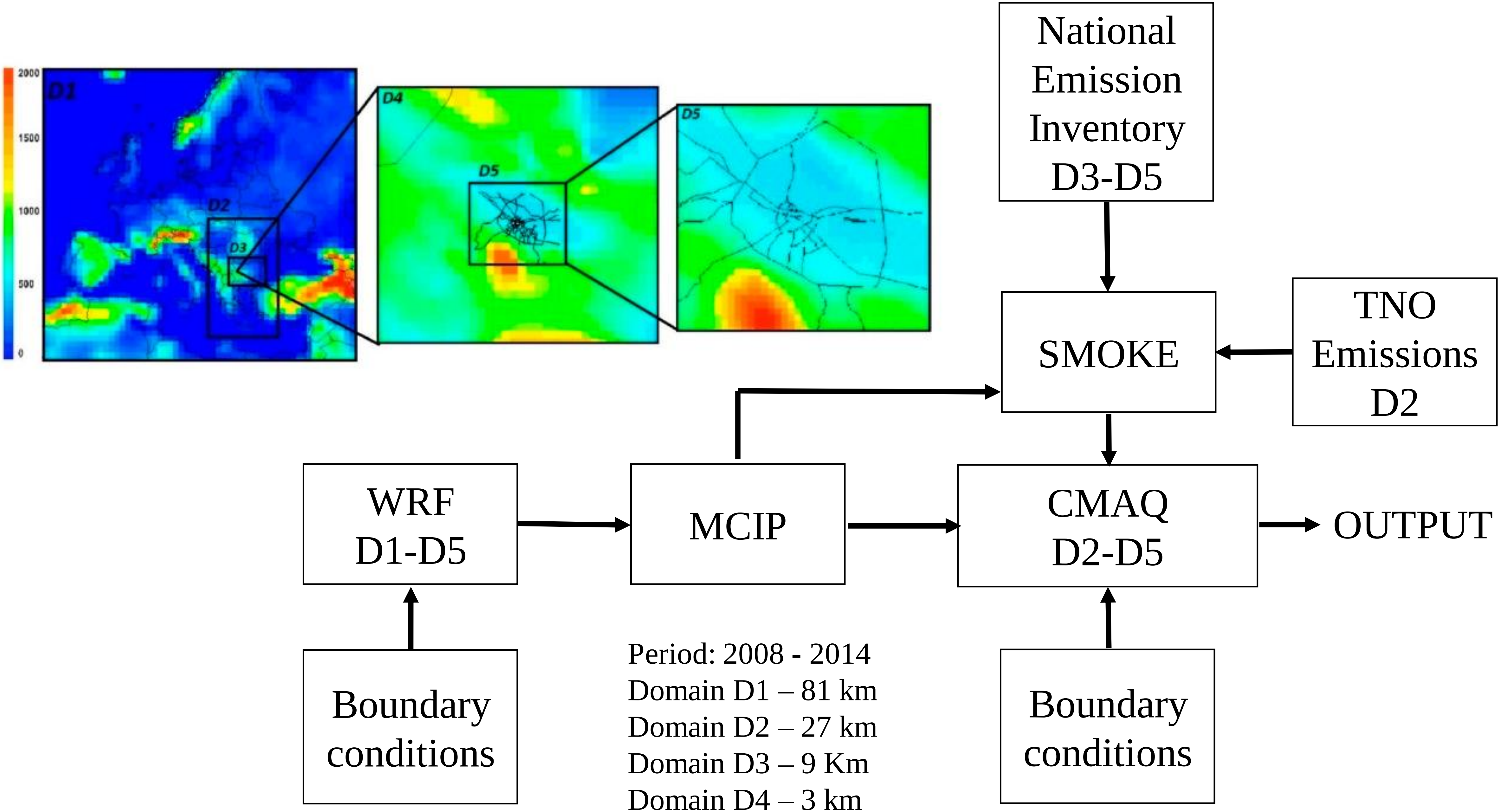


Average difference between Heat Index and surface air temperature for the Extreme Caution category.

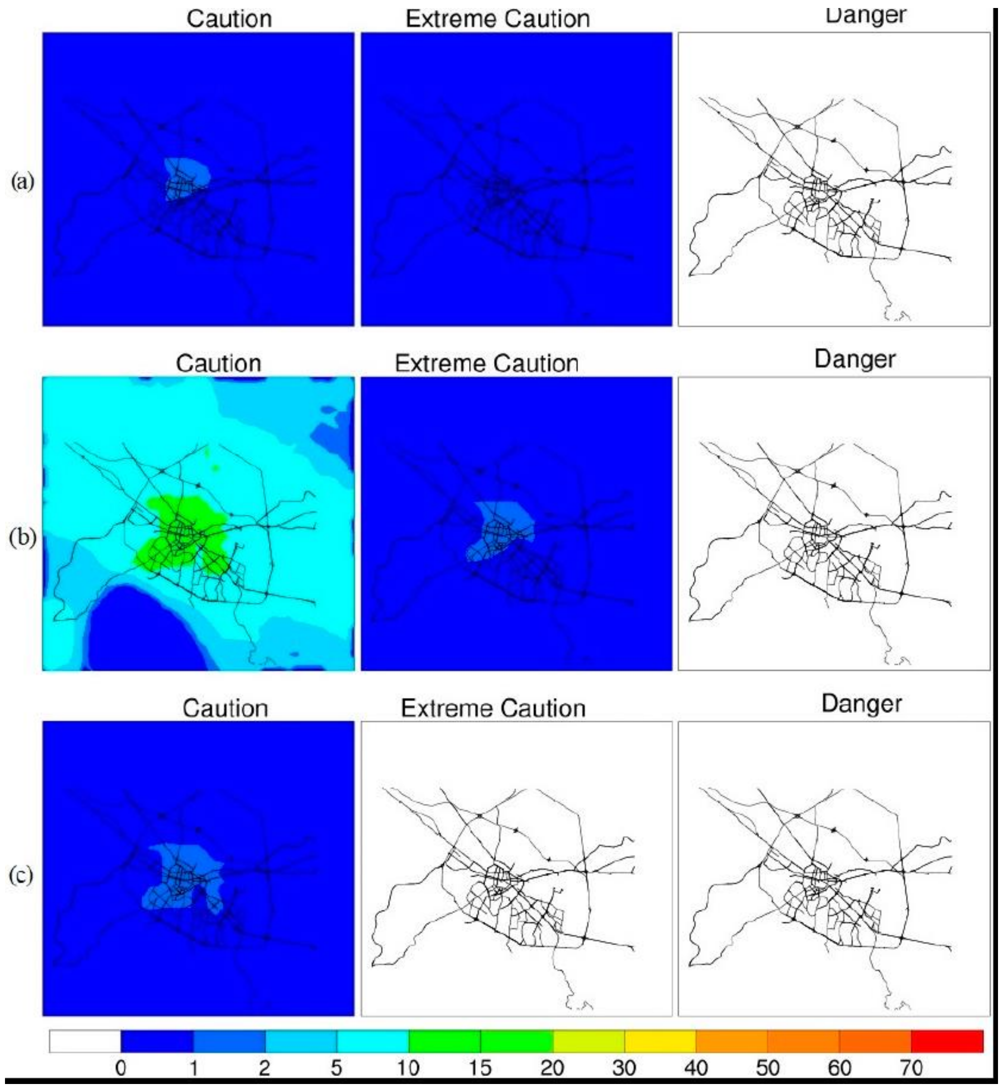


Changing the model configuration suggests a small effect of humidity on thermal discomfort at Caution cases. The Extreme Caution cases, however, are not so similar. Those with the largest humidity influence are the Holtslag boundary layer and Emanuel convective scheme simulations, and they are in the group of configurations with a positive precipitation bias. This is probably due to increased soil moisture due to the higher amount of precipitation in the periods preceding these high index values.

Computer Simulations of Air Quality and Bio-Climatic Indices for the City of Sofia

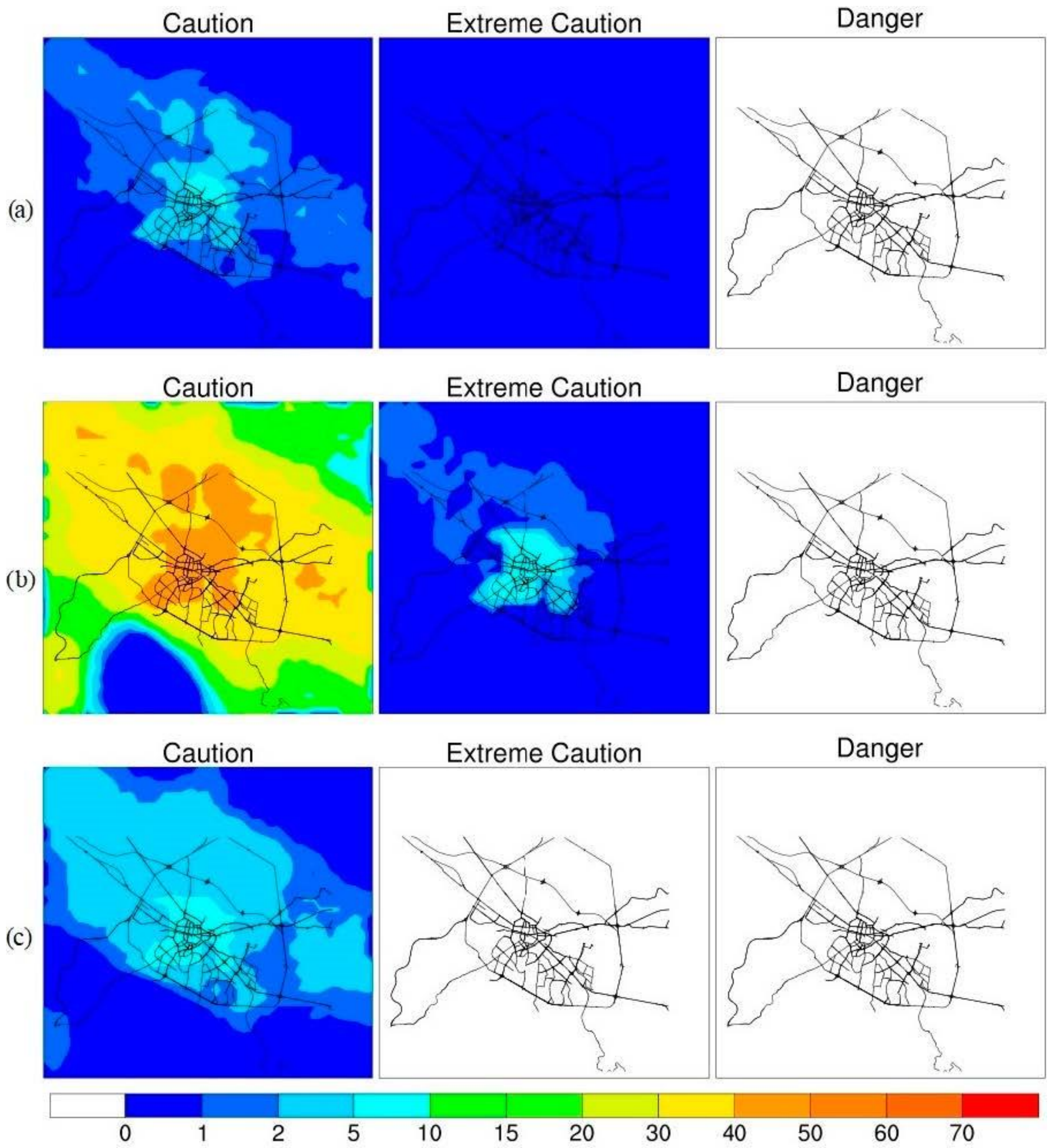


Frequency (in %) for (**a**) spring, (**b**) summer, and (**c**) autumn of the Heat index categories in the Sofia region during the spring (first row), summer (second row), and autumn (third row)



Heat Index (°C)	Category	Health issues
27 ÷ 32	Caution	Fatigue and cramps possible with prolonged exposure and activity.
32 ÷ 41	Extreme Caution	Cramps, heat exhaustion and heat stroke.
41 ÷ 54	Danger	Cramps, heat exhaustion are likely; heat stroke is probable.

Frequency (in %) for (**a**) spring, (**b**) summer, and (**c**) autumn of the Heat index categories "Caution" (first column), "Extreme caution" (second column), and "Danger" (third column) in the Sofia region at 12 UTC during the spring (first row), summer (second row), and autumn (third row)



Heat Index (°C)	Category	Health issues
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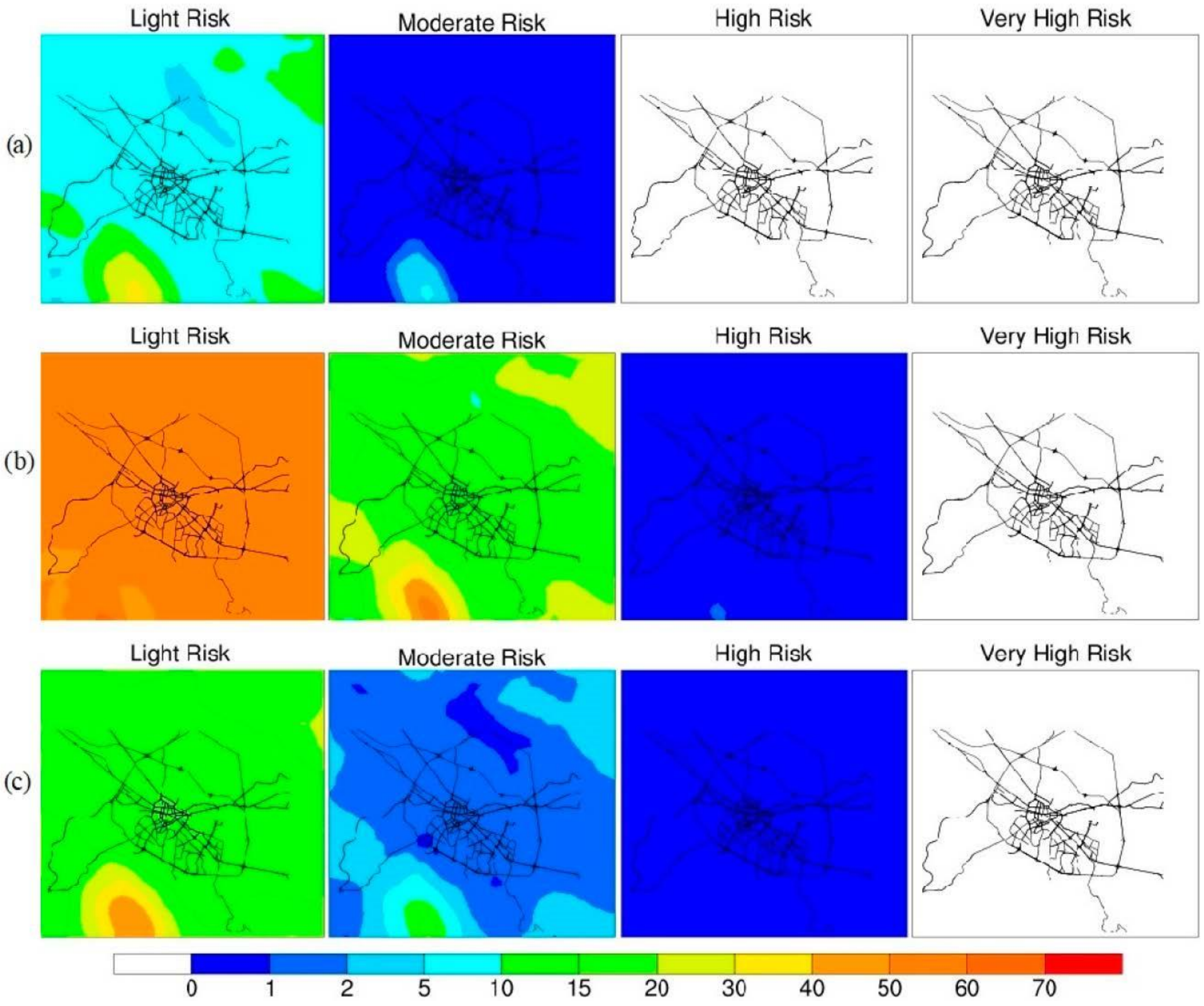
Frequency (in %) for (**a**) spring, (**b**) summer, and (**c**) autumn of the Wind Chill Index categories in the Sofia region during the autumn (first row), winter (second row), and spring (third row)



Wind Chill Index (°C)	Category	Health issues
0 ÷ -9	Low Risk	Slight increase in discomfort
-10 ÷ -27	Moderate Risk	Increased discomfort, with risk of hypothermia and frostbite
-28 ÷ -39	High Risk	Exposed skin can freeze in 10–30 min
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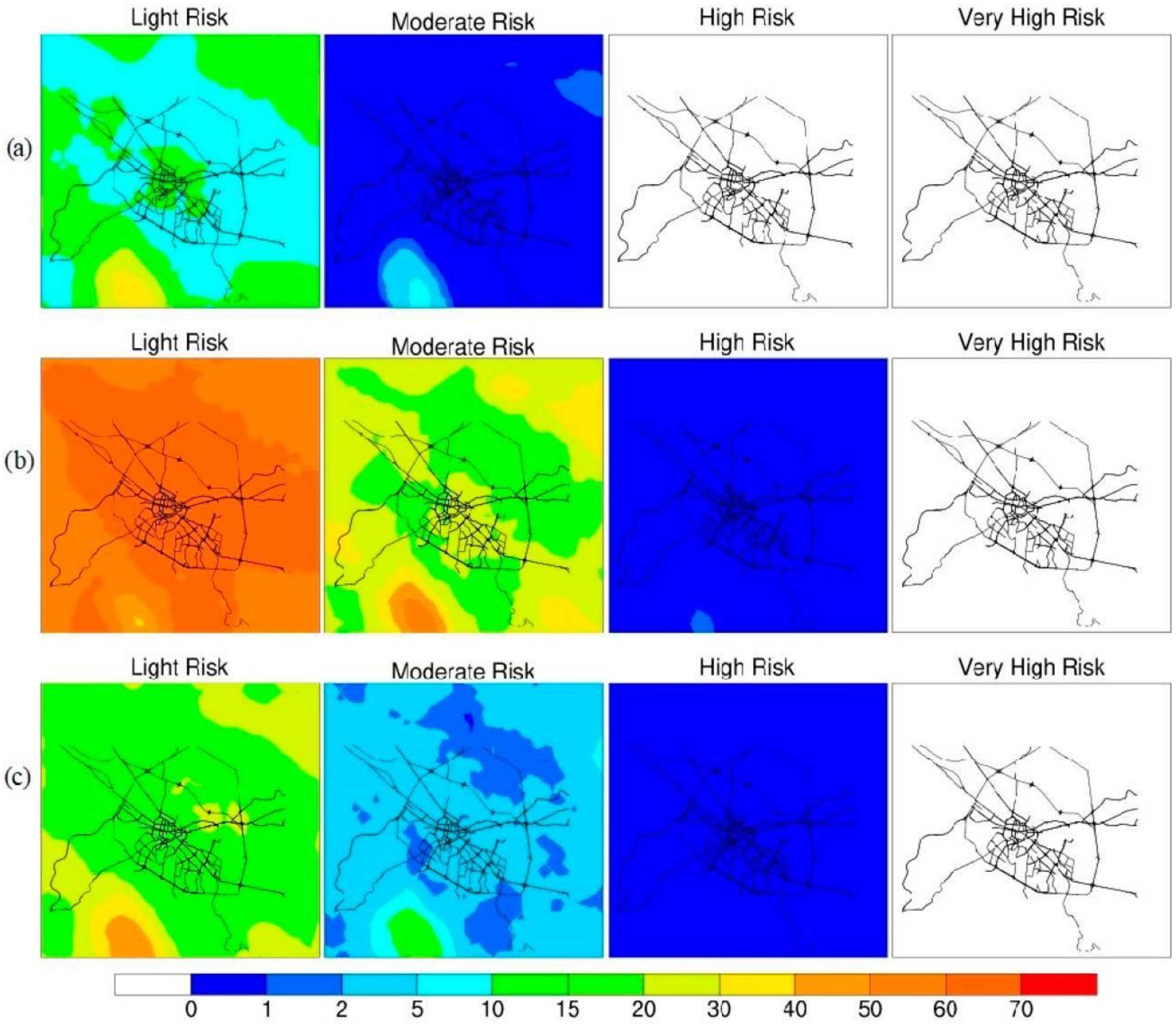
-54 ÷	Extreme Risk	Exposed skin can freeze in less than 2 min.

Frequency (in %) for (**a**) spring, (**b**) summer, and (**c**) autumn of the Wind Chill Index categories at 06 UTC in the Sofia region during the autumn (first row), winter (second row), and spring (third row)



Wind Chill Index (°C)	Category	Health issues
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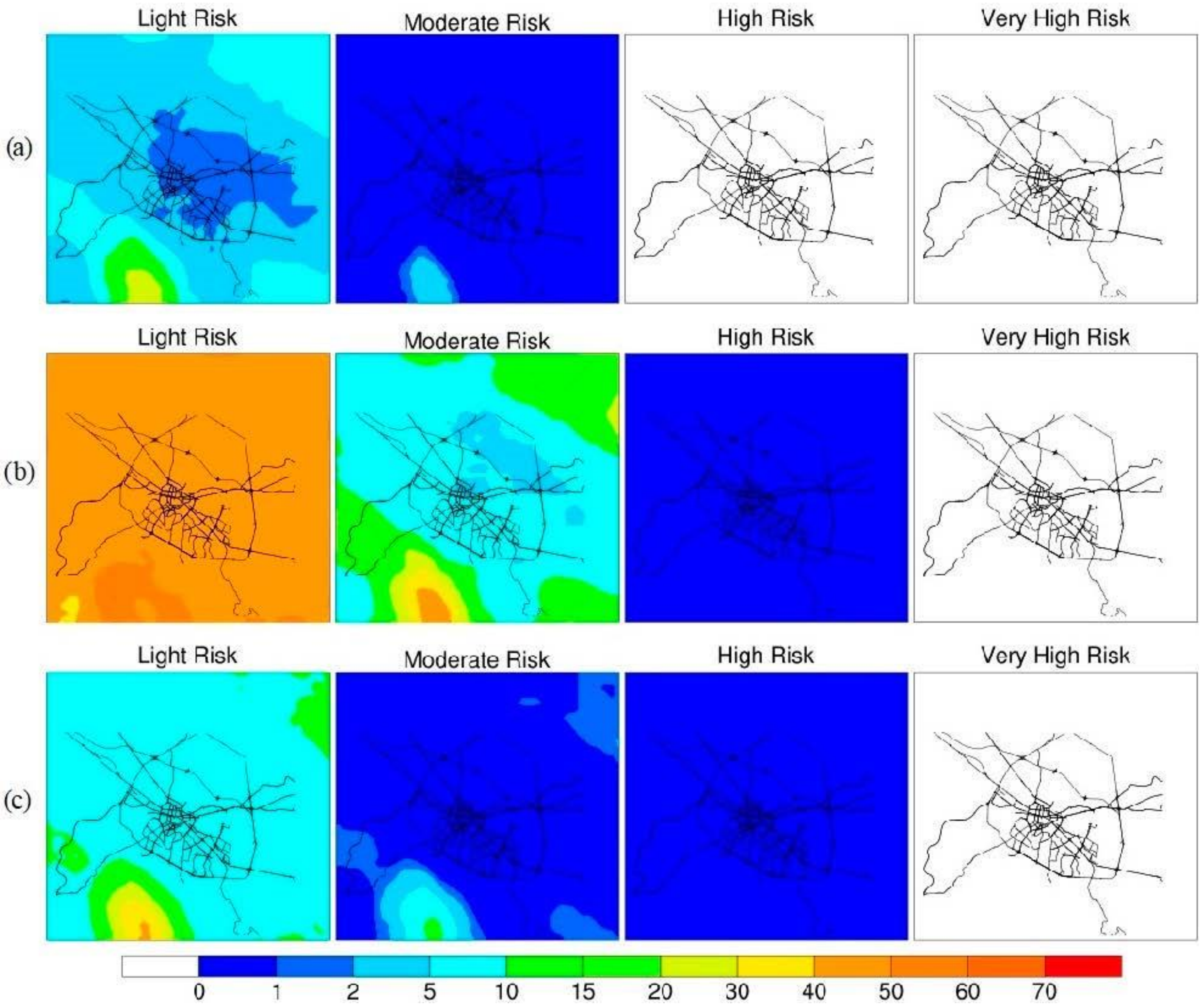
-54 ÷	Extreme Risk	Exposed skin can freeze in less than 2 min.

Frequency (in %) for (**a**) spring, (**b**) summer, and (**c**) autumn of the Wind Chill Index categories at 15 UTC in the Sofia region during the autumn (first row), winter (second row), and spring (third row).



Wind Chill Index (°C)	Category	Health issues
0 ÷ -9	Low Risk	Slight increase in discomfort
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High Performance Computing resources for simulation with the numerical models RegCM4 и WRF-CMAQ on the supercomputer „Avitohol”

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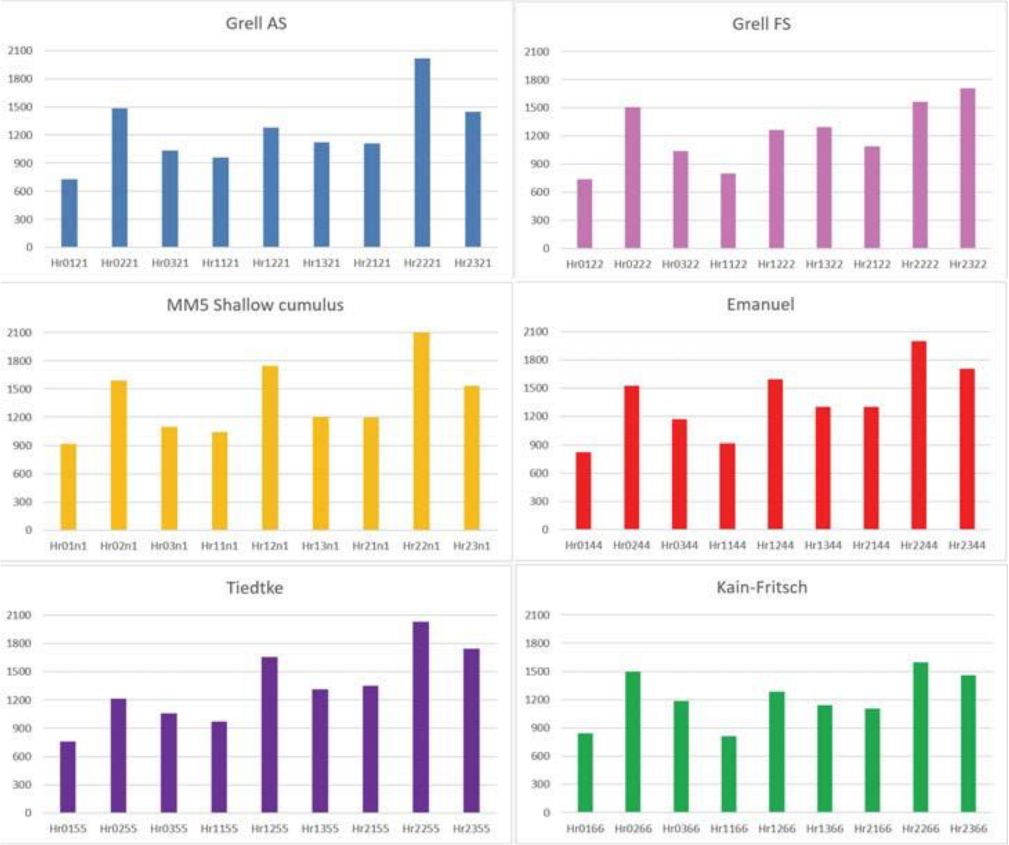
High performance simulations with the regional climate model RegCM4 with different model configurations

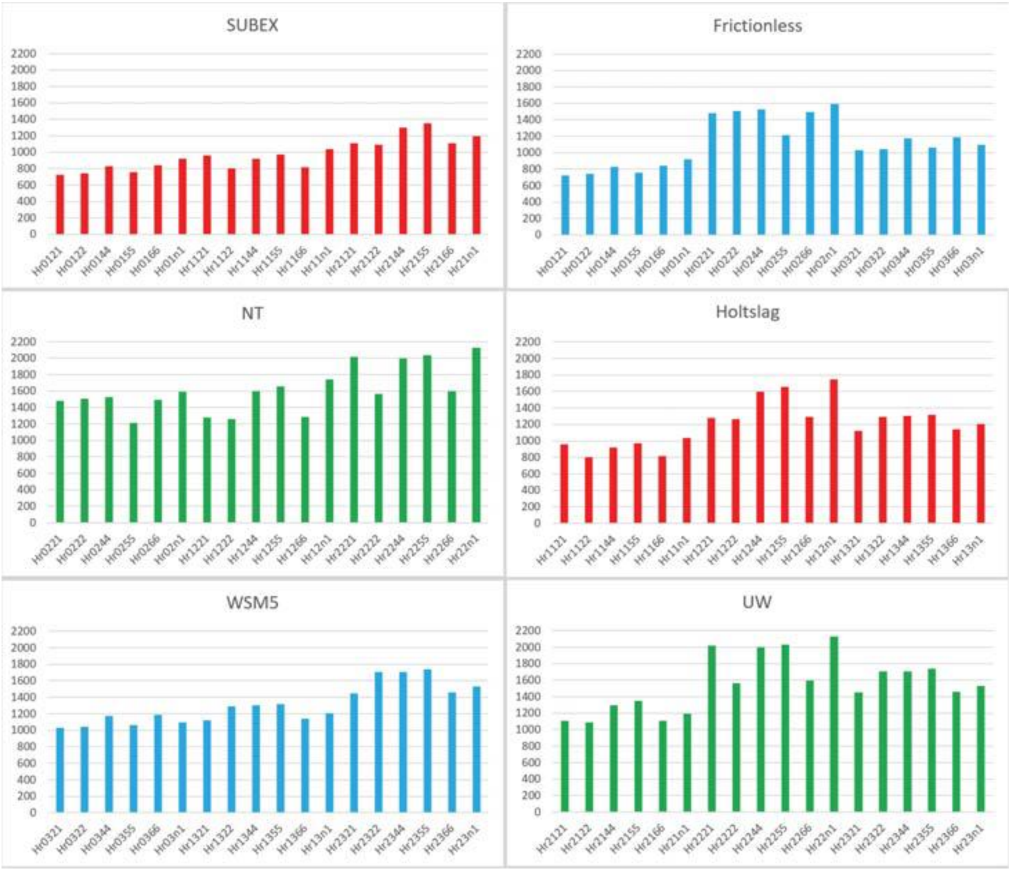
- RegCM version 4
- Hydrostatric/Non-Hydrostatic core
- Horizontal resolution – 10 km
- Size - 128 x 96
- Vertical levels - 18
- 1 month

PBL	Moisture	Cumulus Convection	Notation	PBL	Moisture	Cumulus Convection	Notation
Frictionless	SUBEX	Grell AS	Hr0121	Holtslag	Nogherotto/ Tompkins	Tiedtke	Hr1255
Frictionless	SUBEX	Grell FC	Hr0122	Holtslag	Nogherotto/ Tompkins	Kain-Fritsch	Hr1266
Frictionless	SUBEX	Emanuel	Hr0144	Holtslag	Nogherotto/ Tompkins	MM5 Shallow	Hr12n1
Frictionless	SUBEX	Tiedtke	Hr0155	Holtslag	WSM5	Grell AS	Hr1321
Frictionless	SUBEX	Kain-Fritsch	Hr0166	Holtslag	WSM5	Grell FC	Hr1322
Frictionless	SUBEX	MM5 Shallow	Hr01n1	Holtslag	WSM5	Emanuel	Hr1344
Frictionless	Nogherotto/ Tompkins	Grell AS	Hr0221	Holtslag	WSM5	Tiedtke	Hr1355
Frictionless	Nogherotto/ Tompkins	Grell FC	Hr0222	Holtslag	WSM5	Kain-Fritsch	Hr1366
Frictionless	Nogherotto/ Tompkins	Emanuel	Hr0244	Holtslag	WSM5	MM5 Shallow	Hr13n1
Frictionless	Nogherotto/ Tompkins	Tiedtke	Hr0255	UW	SUBEX	Grell AS	Hr2121
Frictionless	Nogherotto/ Tompkins	Kain-Fritsch	Hr0266	UW	SUBEX	Grell FC	Hr2122
Frictionless	Nogherotto/ Tompkins	MM5 Shallow	Hr02n1	UW	SUBEX	Emanuel	Hr2144
Frictionless	WSM5	Grell AS	Hr0321	UW	SUBEX	Tiedtke	Hr2155
Frictionless	WSM5	Grell FC	Hr0322	UW	SUBEX	Kain-Fritsch	Hr2166
Frictionless	WSM5	Emanuel	Hr0344	UW	SUBEX	MM5 Shallow	Hr21n1
Frictionless	WSM5	Tiedtke	Hr0355	UW	Nogherotto/ Tompkins	Grell AS	Hr2221
Frictionless	WSM5	Kain-Fritsch	Hr0366	UW	Nogherotto/ Tompkins	Grell FC	Hr2222
Frictionless	WSM5	MM5 Shallow	Hr03n1	UW	Nogherotto/ Tompkins	Emanuel	Hr2244
Holtslag	SUBEX	Grell AS	Hr1121	UW	Nogherotto/ Tompkins	Tiedtke	Hr2255
Holtslag	SUBEX	Grell FC	Hr1122	UW	Nogherotto/ Tompkins	Kain-Fritsch	Hr2266
Holtslag	SUBEX	Emanuel	Hr1144	UW	Nogherotto/ Tompkins	MM5 Shallow	Hr22n1
Holtslag	SUBEX	Tiedtke	Hr1155	UW	WSM5	Grell AS	Hr2321
Holtslag	SUBEX	Kain-Fritsch	Hr1166	UW	WSM5	Grell FC	Hr2322
Holtslag	SUBEX	MM5 Shallow	Hr11n1	UW	WSM5	Emanuel	Hr2344
Holtslag	Nogherotto/ Tompkins	Grell AS	Hr1221	UW	WSM5	Tiedtke	Hr2355
Holtslag	Nogherotto/ Tompkins	Grell FC	Hr1222	UW	WSM5	Kain-Fritsch	Hr2366
Holtslag	Nogherotto/ Tompkins	Emanuel	Hr1244	UW	WSM5	MM5 Shallow	Hr23n1

Model simulation times for each of the convective parameterization schemes.

Model simulation times for each of the microphysical parameterization schemes (left plots) and planetary boundary layer parameterization schemes (right plots)

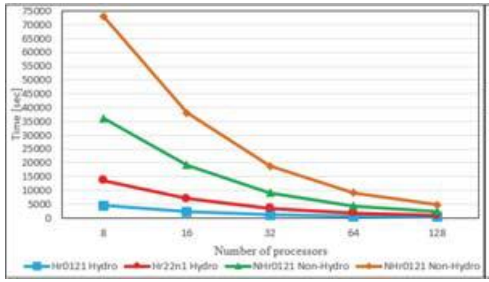


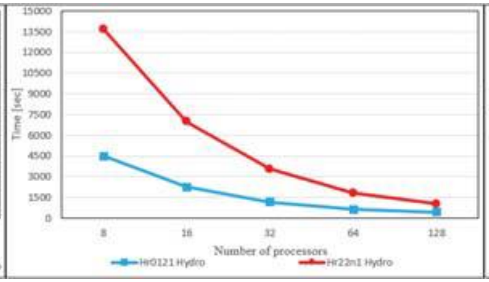


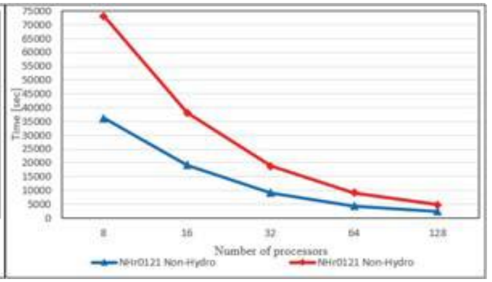
RegCM4 model simulation times with „Avitohol“ for different dynamical cores

- RegCM version 4
- Hydrostatric (Hr) core
- Non-Hydrostatic (NHr) core
- Horizontal resolution – 10 km
- Size - 256 x 192
- Vertical levels - 23
- 2 weeks

Simulation times of the fastest and slowest schemes for the model with hydrostatic and non-hydrostatic options







Hr0121 -
Hr22n1 -
NHr0121 -
NHr22n1 -

Hr0121 -
Hr22n1 -

NHr0121 -
NHr22n1 -

High- performance computing resources for numerical simulations with RegCM4 и WRF-SMOKE-CMAQ model systems in the supercomputer „Avitohol“

RegCM version 4
Hydrostatical core
Simulation Period - 1999 ÷ 2009
Horizontal resolution - 10 km
Domain - 177 x 107
Vertical levels - 27
HPC resources - 16 CPU

	Month	Year
Time	6h	72h
Data [GB]	6	720

RegCM версия 4
Hydrostatical core
Simulation Period - 1974 ÷ 2004
Horizontal resolution - 20 km
Домейн - 125 x 93
Vertical levels - 18
HPC resources - 128 CPU

	Month	30 years
Time	0.22h	79.2h (285120)
Output data [GB]	1.9	684
Input data [GB]	1.1	397

- WRF version 3.4
- Simulation Period - 2008 ÷ 2014
- Horizontal resolution:
  - D1 - 81km (WRF-60x54)
  - D2 - 27km (WRF-42x69 CMAQ-34x57)
  - D3 - 9km (WRF-84x63 CMAQ-68x47)
  - D4 - 3km (WRF-36x33 CMAQ-20x19)
  - D5 - 1km (WRF-39x36 CMAQ-29x26)
- Vertical levels – 35
- HPC resources - 16 CPU

	Day	
	WRF	CMAQ и SMOKE
Време	3h	2h
Данни [MB]	530	970

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Acknowledgments

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