Assessment of precipitation statistics with non-hydrostatic regional climate model RegCM4.7.1 at regional and convection-permitting scales over Bulgaria

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1. Motivation

In the last ten years, the development of high-performance computing systems and regional climate models has allowed long-term, very high-resolution (1-4 km) simulations, called "convection-permitting" (CP) simulations. The Convection-Permitting Regional Climate Models (CP-RCMs), allow the explicit representation of deep convective processes without the use of parametrization schemes which is considered to be a major source of model errors and uncertainty [1].

The Regional Climate Model version 4 (RegCM4) developed at the Abdus Salam International Centre for Theoretical Physics ICTP [2, 3] has been upgraded with the non-hydrostatic dynamic core based on MM5, which can be used for high - resolution applications [3, 5]. The Non-hydrostatic RegCM contributes to several large projects at km-scale such as European Climate Prediction System (EUCP), Coordinated Regional Climate Downscaling Experiment Flagship Pilot Studies on Convective phenomena [4], and is used by a large modelling community all over the world

Recent studies using decade-long CP-regional climate simulations show that increasing the resolution reduces the present day biases in precipitation [6, 7]. The results confirm the improved performance of the convection-permitting models with respect to coarser-resolution ones in simulating important characteristics of daily and hourly precipitation and extreme events [7].

2. Overview

The aim of this study is to present an initial assessment of precipitation, simulated with the non-hydrostatic regional climate model RegCM4.7.1 at a regional and convection-permitting (CP) scale for a decade-long period (2000-2010) over Bulgaria. The simulations use a horizontal grid spacing of 3 km and are driven by the ERA-Interim reanalysis (0.75° x 0.75°) through an intermediate driving RegCM4 simulation at 15 km grid spacing using parametrized deep convection. The km-scale simulation is evaluated against daily E-OBS (0.1° x 0.1°) and CHIRPS (0.05° x 0.05°) datasets (tab. 2) and is compared with the coarser-resolution driving simulation. We focus on different precipitation statistics such as seasonal mean daily precipitation, seasonal wet-day intensity, seasonal wet-day frequency, and seasonal heavy precipitation. The simulations are carried out on the **HPC Discoverer supercomputer,** located in Sofia Tech Park in Sofia, Bulgaria.

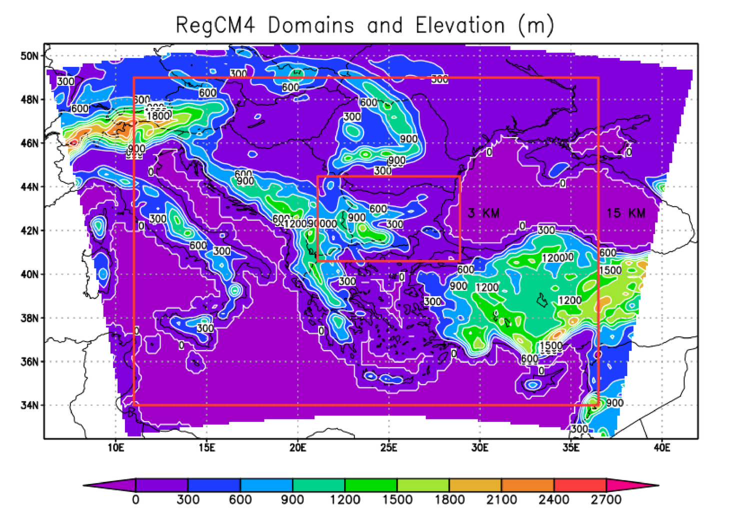

Fig. 1. Simulated domains with non-hydrostatic RegCM4.7.1 - intermediate domain with 15 km grid size (6.08 ºE – 41.96 ºE, 32.47 ºN – 50.54 ºN) and nested domain with 3 km grid size (19.91 ºE – 30.09 ºE, 39.76 ºN – 45.32 ºN) after removing the buffer zone (red lines) from 15 and 30 grid points from each side, respectively.

3. Model, data and methods

Several statistical indices are used, defined in Table 1, to assess the model ability to reproduce the precipitation climatology. The indices are calculated as seasonal values for winter (December–January–February), spring (March–April–May), summer (June–July–August) and autumn (September–October–November). The observational datasets are remapped onto a 3 km grid for the evaluation of the CP-RegCM simulation, and onto the 15 km grid for the evaluation of RegCM simulation.

Both 10-year simulations (15 km and 3 km) use the non-hydrostatic dynamic core of the RegCM4 model, Holtslag planetary boundary scheme, SUBEX moisture scheme, BATS landuse scheme and Zeng ocean flux scheme. For the intermediate simulations we use Kain-Fritch cumulus convection scheme. For the convection permitting (CP) simulations we use MM5 shallow convection.

Table 2. *Observational datasets*

	Spatial resolution	Temporal resolution
E-OBS	0.1° x 0.1°	daily
CHIRPS	0.05° x 0.05°	daily

Table 1. *Statistical indices for precipitation*

Statistical indices	**Index definition**	**Unit**
Mean Precipitation	Mean daily precipitation	(mm/day)
Frequency	Wet day frequency, defined as a percentage of the number of wet days per season. Wet day is a day with precipitation >= 1mm.	(%)
Intensity	Wet day intensity. Wet day is a day with precipitation >= 1mm	(mm/day)
Heavy Precipitation (p99)	Defined as the 99th percentile of all daily precipitation events (wet and dry)	(mm/day)
Mean Bias	(RegCM-Observation)	(mm/day) or (%)

Table 3: *Area average mean and biases*

		CHIRPS	E-OBS	RCM3	RCM15	RCM3-CHIRPS	RCM3-E-OBS	RCM15-CHIRPS	RCM15 -E-OBS
MEAN PRECIPTATION (mm/d)									
	MAM	1.9	1.5	3.2	1.8	1.3	1.9	0.1	0.4
	JJA	1.8	1.6	3.5	2.1	1.7	2.2	0.3	0.7
	SON	2.0	1.8	2.5	1.5	0.5	0.8	-0.5	-0.3
	DJF	2.0	1.6	2.5	1.7	0.5	1.0	-0.4	0.1
INTENSITY (mm/d)									
	MAM	8.6	6.0	8.4	5.6	-0.1	2.6	-2.9	-0.3
	JJA	15.4	7.8	11.7	6.9	-3.7	4.2	-8.9	-0.9
	SON	12.5	7.9	8.0	6.1	-4.6	0.1	-6.5	-1.7
	DJF	7.4	5.9	6.8	5.1	-0.6	0.9	-2.3	-0.8
FRQUENCY (%)									
	MAM	21.6	25.2	35.1	29.3	13.8	11.9	8.1	5.9
	JJA	11.4	20.1	28.0	29.1	16.9	9.7	18.2	11.6
	SON	16.2	23.1	29.6	22.3	13.6	0.1	6.1	0.2
	DJF	27.3	27.8	34.7	30.5	7.5	0.9	3.3	3.4
HEAVY PRECIPITATION P99 (mm/d)									
	MAM	22.1	15.0	39.0	20.4	17.2	26.3	-1.5	6.5
	JJA	33.6	18.2	55.0	24.7	22.0	40.4	-8.5	8.1
	SON	32.0	20.3	36.5	20.8	4.8	17.6	-11.2	1.2
	DJF	20.1	14.8	29.2	18.4	9.1	15	-1.8	3.6

4. Results: seasonal mean 2000-2010

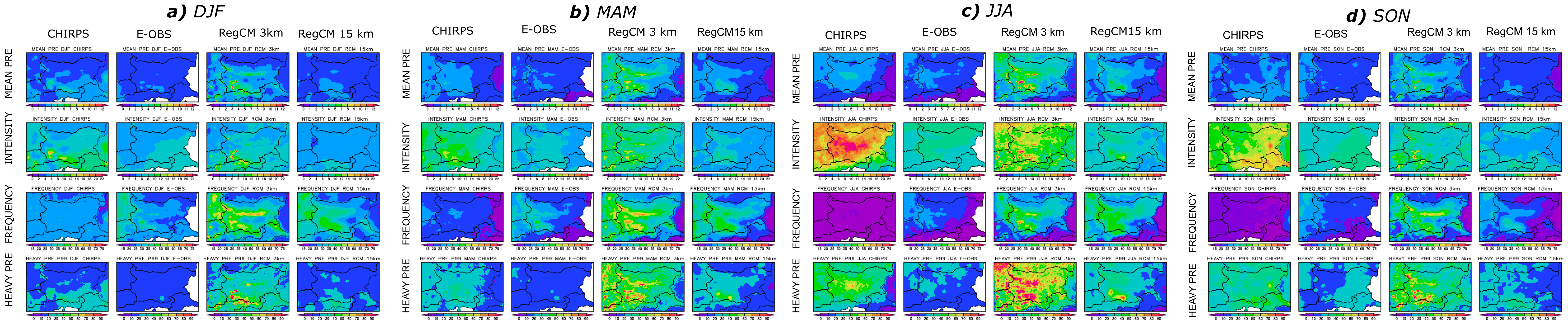

***Fig. 2**. Spatial distribution of seasonal mean of analysed indeces: from top to bottom (mean precipitation, precipitation intensity, precipitation frequency and heavy precipitation from observations: CHIRPS (first column) and E-OBS (second column) and simulations: RegCM 3 km (third column), and RegCM 15 km (last column) for the a) winter (DJF), b) spring (MAM), c) summer (JJA) and d) autumn (SON) seasons.*

5) Results: seasonal mean biases 2000-2010

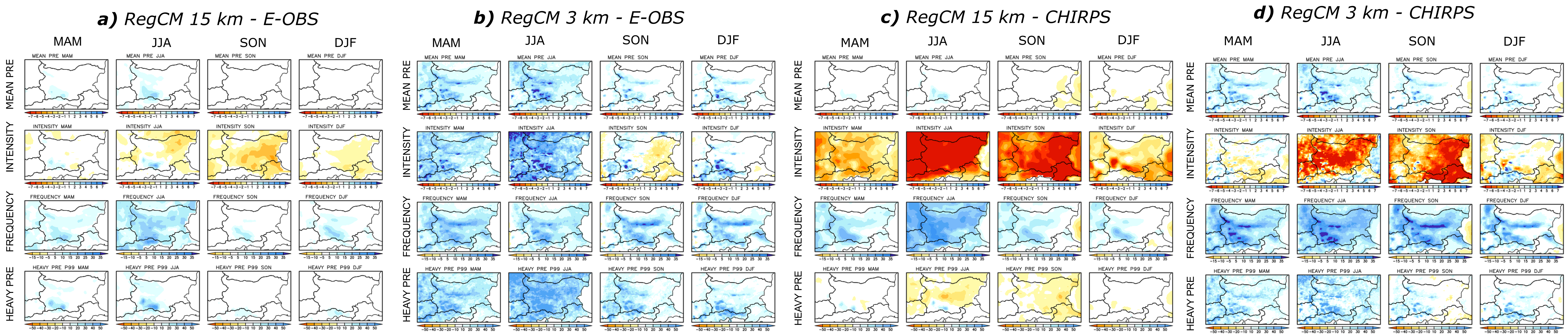

***Fig. 3**. Spatial maps of seasonal mean biases of daily precipitation (first row), precipitation intensity (second row), precipitation frequency (third row) and heavy precipitation (fourth row) between a) RegCM 15 km and E-OBS, b) RegCM 3 km and E-OBS, c) RegCM 15 km and CHIRPS, d) RegCM 3 km and CHIRPS.*

Conclusion

Overall, the model represents well the spatial distribution of mean precipitation at regional and km-scale for the territory of Bulgaria. However, CP-RegCM model produces too much precipitation over the mountains (fig. 2). The most significant improvements in CP-RegCM simulations were found for intensity when compared with CHIRPS data in summer and autumn seasons and in autumn season when compared with E-OBS observational dataset.

Observational datasets, CHIRPS and E-OBS, show similar distribution for mean precipitation, but CHIRPS dataset shows extremely high precipitation intensities, especially in summer and autumn (fig. 2c, 2d). Also, CHIRPS dataset underestimates precipitation frequency compared to E-OBS data in summer and autumn and overestimates heavy precipitation in summer.

In winter, RCM3 overestimates mean precipitation, precipitation intensity and heavy precipitation over mountains. Both, RCM3 and RCM15, overestimate precipitation frequency (fig. 2a). In summer, RCM3 overestimates precipitation mean, frequency and heavy precipitation (fig. 2c). RCM3 underestimates intensity compared with CHIRPS and overestimates when compared with E-OBS. We find significant differences between CHIRPS and E-OBS precipitation intensity. In spring, RCM15 captures well the spatial distribution of mean precipitation, precipitation intensity, frequency and heavy precipitation, RCM3 overestimates all indices over mountains (fig. 2b). In autumn, RCM3 also overestimates all indices over mountains (fig. 2d). CHIRPS underestimates precipitation frequency and overestimates precipitation intensity in summer and autumn compared with E-OBS dataset (fig. 2c, 2d).

Overall, RCM3 overestimates mean precipitation, frequency and heavy precipitation in all seasons, underestimates precipitation intensity when compared with CHIRPS data in JJA and SON and overestimates it when compared with E-OBS, especially in JJA (fig. 3b, 3d, tab. 3). RCM15 underestimates precipitation intensity and overestimates precipitation frequency in all seasons. RCM15 underestimates heavy precipitation when compared with CHIRPS in JJA and SON and overestimates it when compared with E-OBS in MAM and JJA (fig. 3a, 3c).

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Photography encouraged

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