Russian Supercomputing Days 2019

Validation of the regional climate model for the South of Russia

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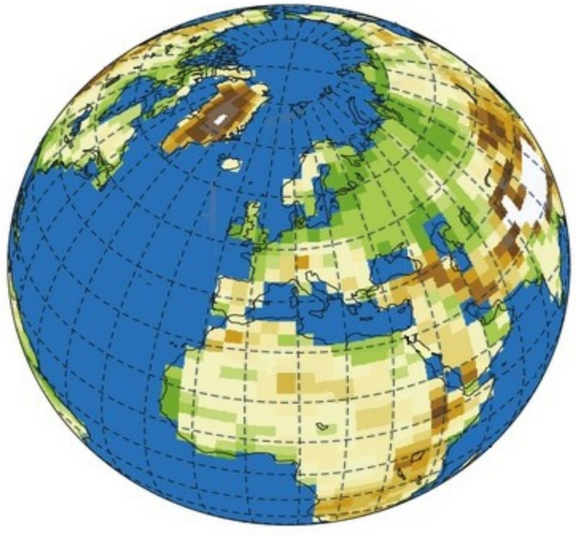
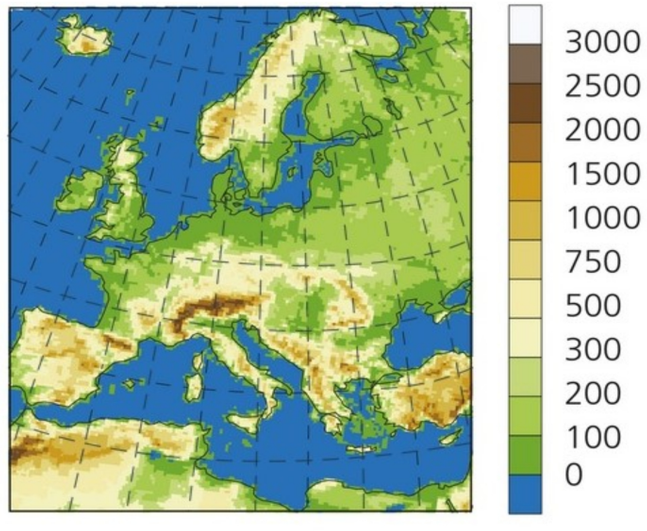
Downscaling climate models

General Circulation Models



Regional climate models

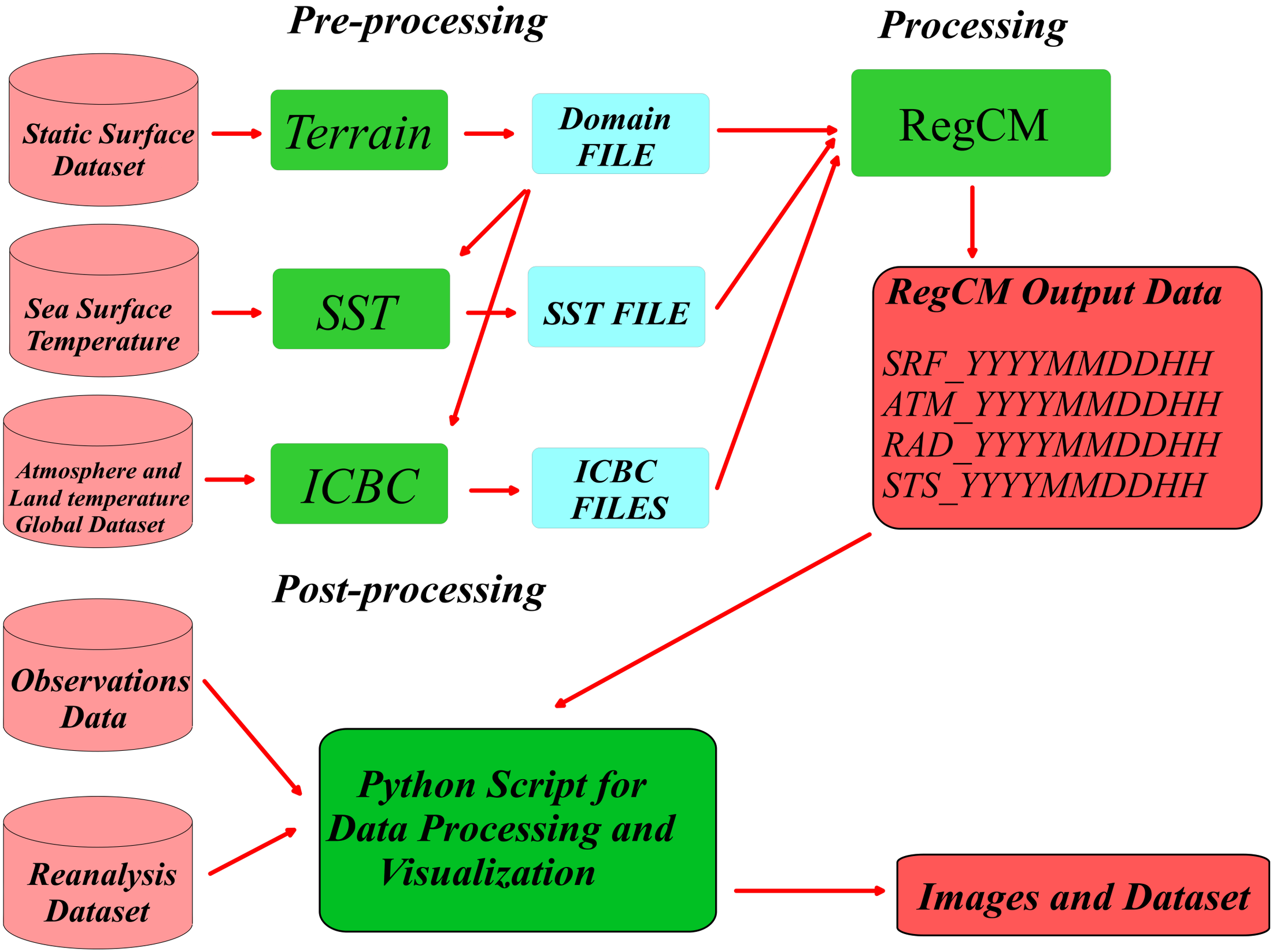


Local impact models

The Regional Climate Model (RegCM) is a 3-dimensional, sigma-coordinate, primitive equation regional climate model:

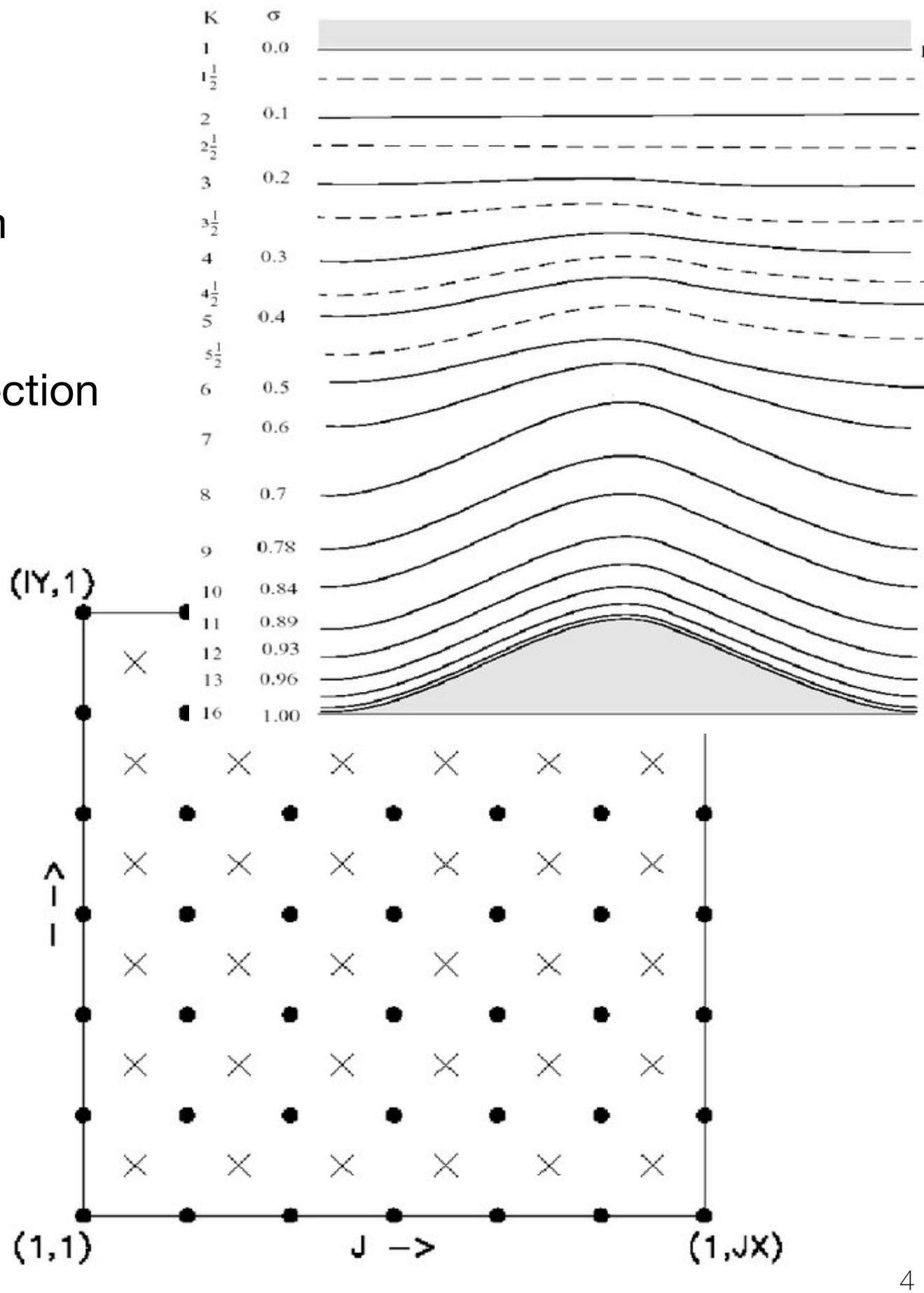
- Developed in the late 1980s, and it was the first limited area model applied to climate studies
- Supported by International Center for Theoretical Physics
- Flexible and versatile system which can be used for different regions of the world and for a wide range of applications

RegCM Architecture Model



Parameters

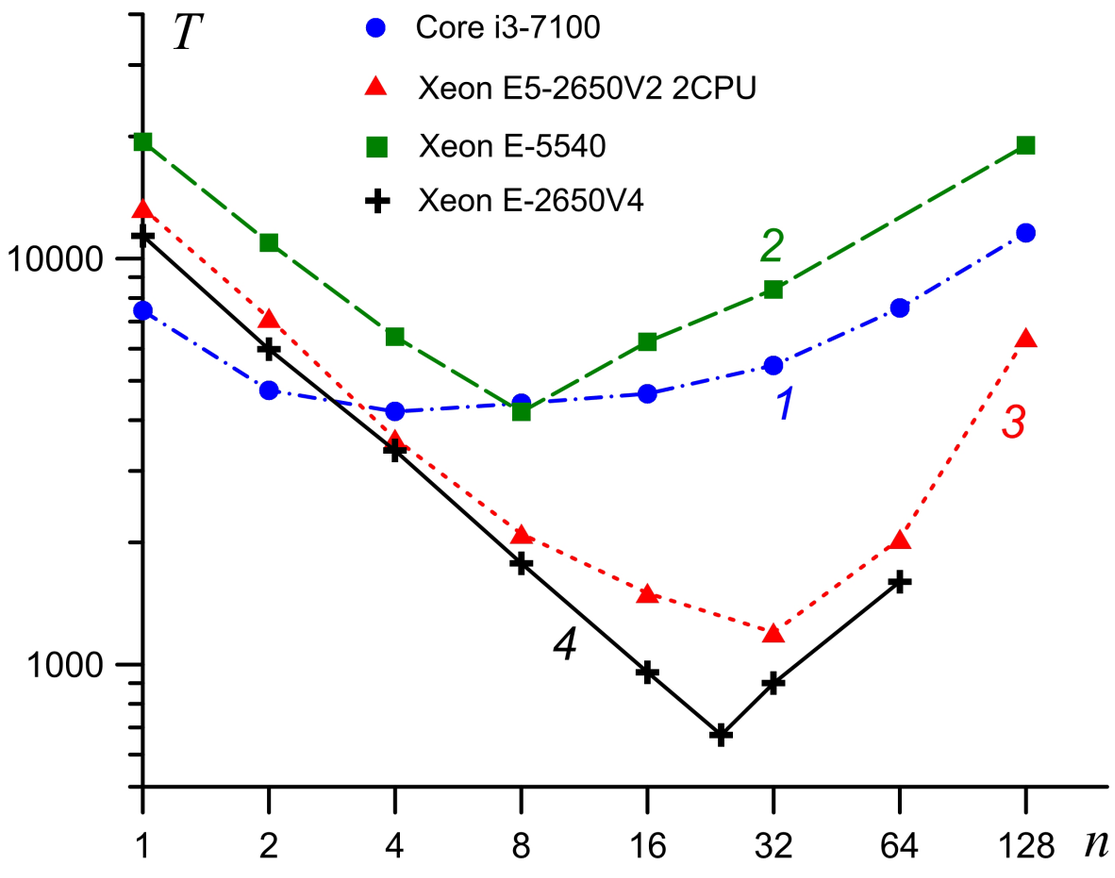
- Grid resolution (hydrostatic)— 20 km
- Grid resolution (nonhydrostatic)— 5 km
- Vertical σ–levels — 21
- Projection — Mercator conformal projection
- Reanalysis data — EIN15
- Topographic data — GTOPO
- Sea surface temperature - OISST



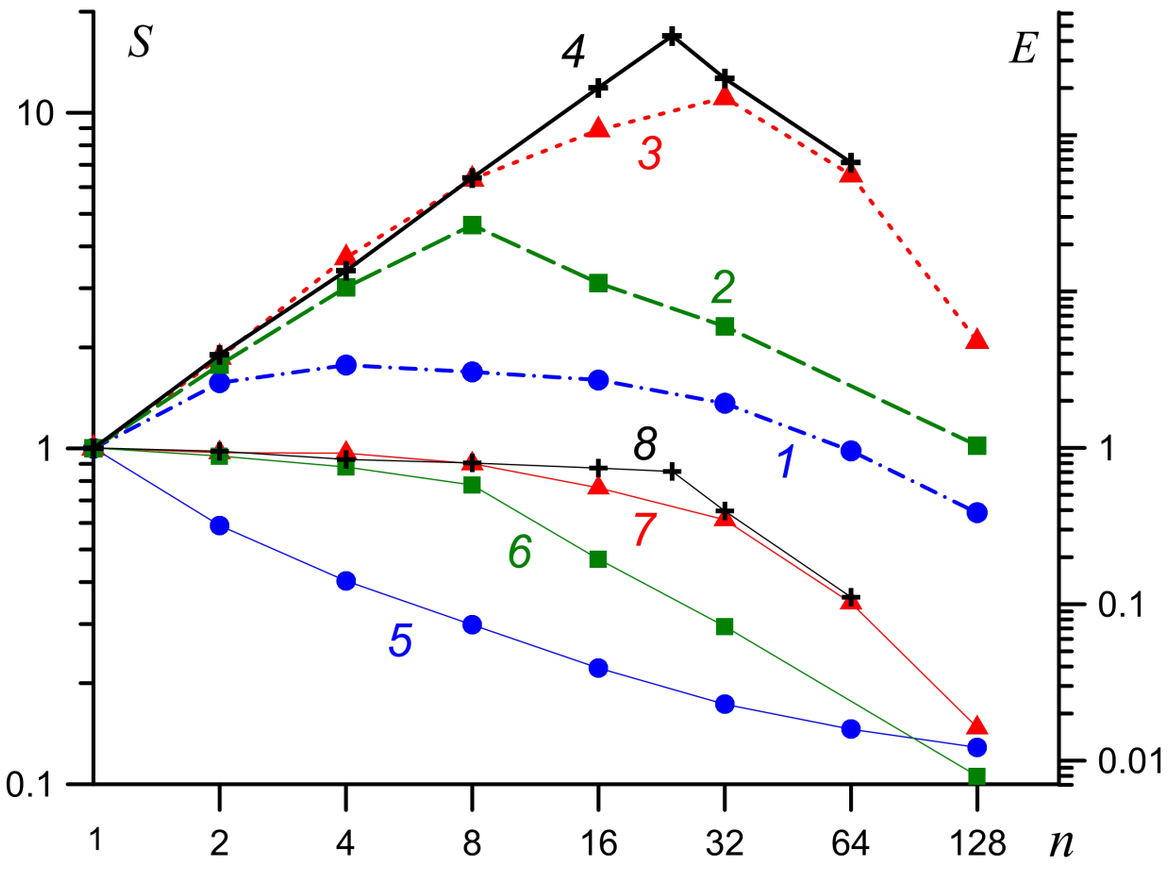
- EIN15 — ERA-Interim is a global atmospheric reanalysis from 1979 and will continue to be extended forward in time until 31 August 2019.
- GTOPO — global digital elevation model (DEM) with a horizontal grid spacing of 30 arc seconds
- OISST — Optimum Interpolation Sea Surface Temperature

Hardware and Parallelization Result

#1	Core i3 — 7100	3.9 GHz	4 cores	8 Gb
#2	Xeon E5-2650 V2	2.6 GHz	16 cores	256 Gb
#3	Xeon E5540	2.53 GHz	8 cores	64 Gb
#4	Xeon E5 — 2650 V4	2.9 GHz	12 cores	64 Gb



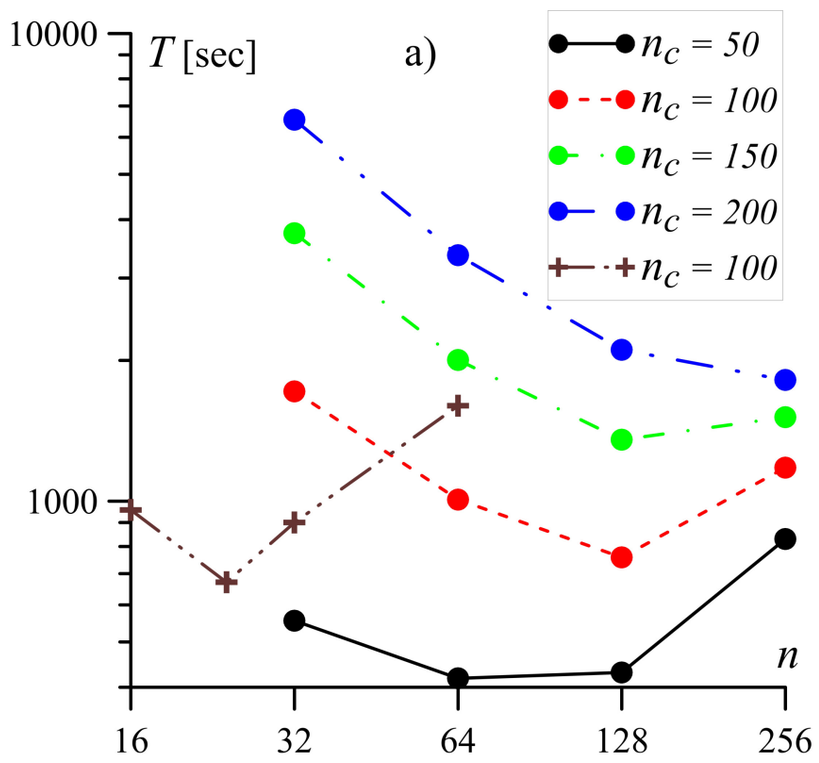
T — Time

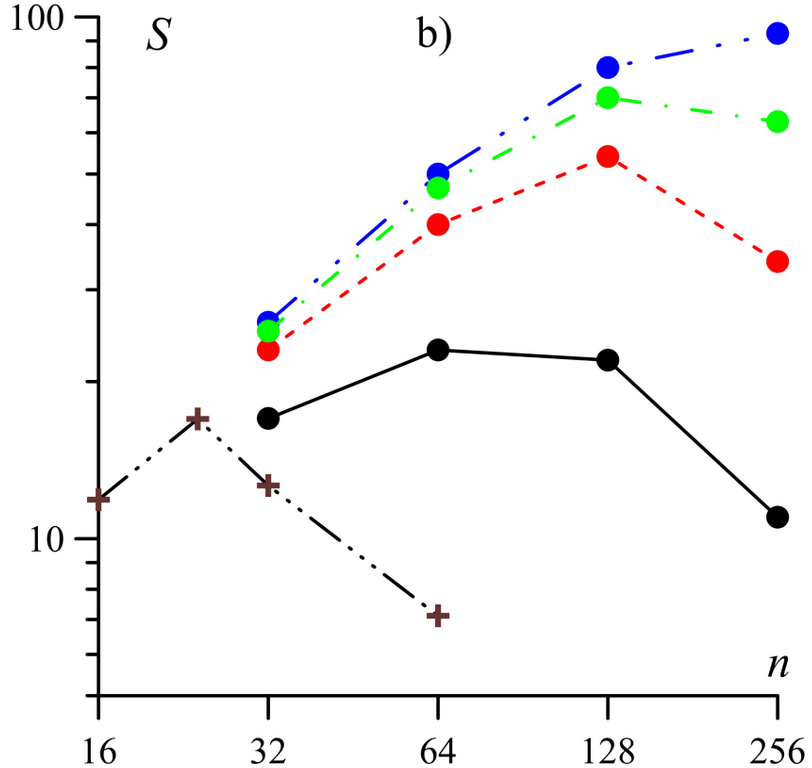


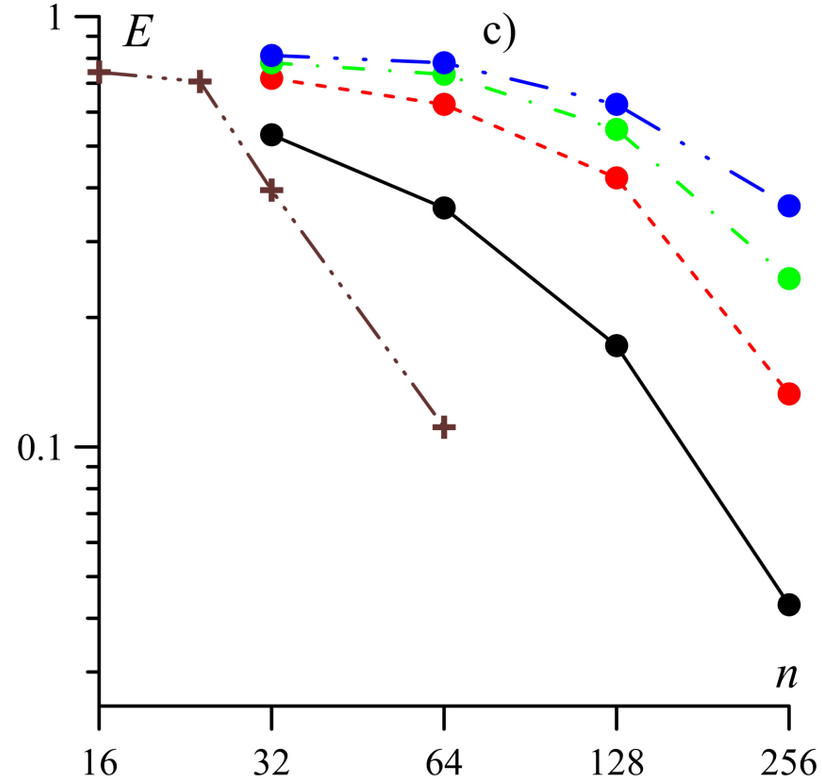
S — Parallel speedup (curves 1–4)

E — Parallelization efficiency (curves 5–8)

Parallelization Result. HPC computing resources at Lomonosov







T — Time

S — Parallel speedup

$$S = T(1)/T(N)$$

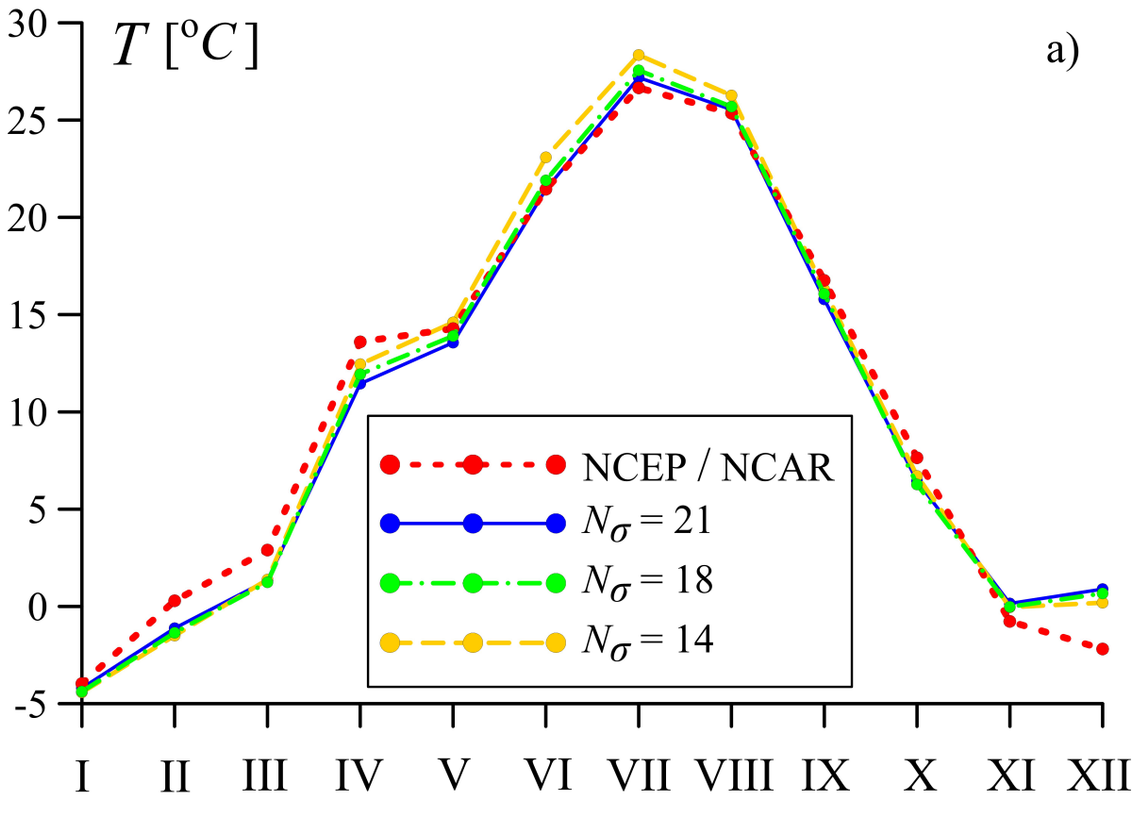
E — Efficiency

$$E = S/n$$

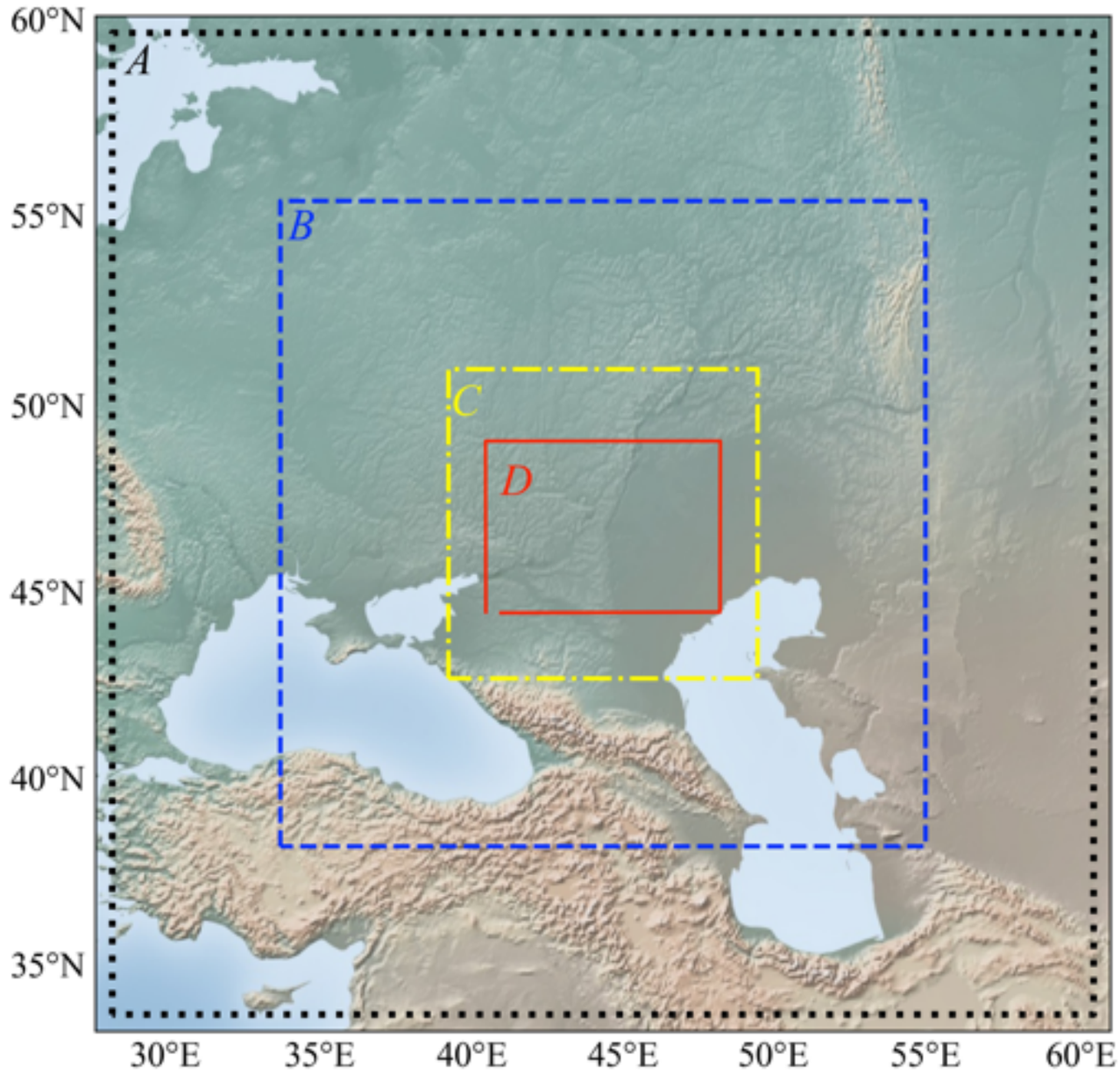
	5 km	10 km	20 km
Model Input Data	285 Gb / year	71 Gb / year	5.5 Gb / year
Model Output Data	1.2 Tb / year	290 Gb / year	28 Gb / year

The boundaries of computational domains

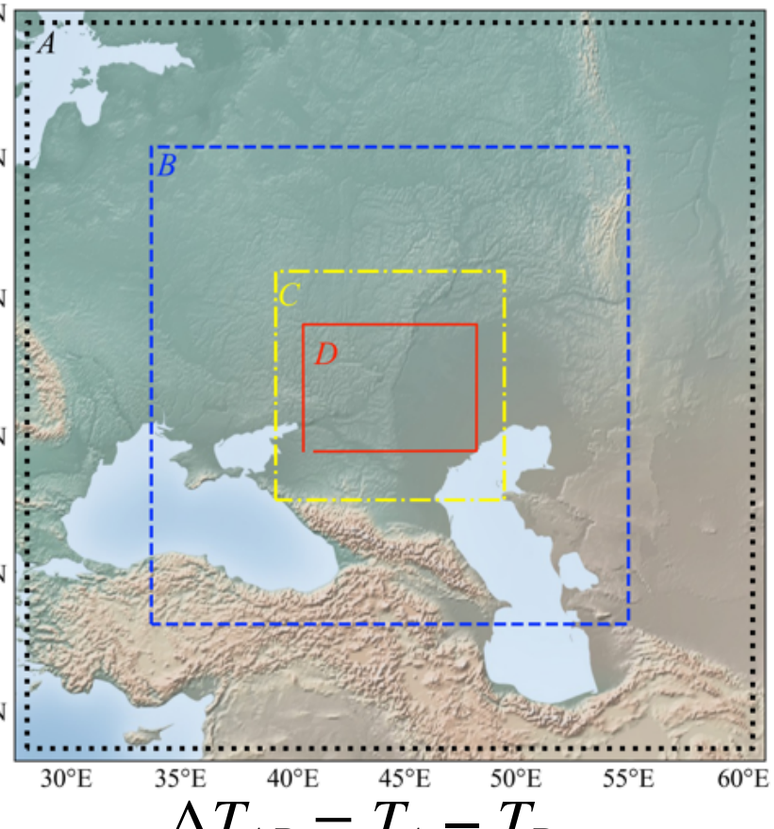
A – 3000 **km** × 3000 **km**
B – 2000 **km** × 2000 **km**
C – 1000 **km** × 1000 **km**



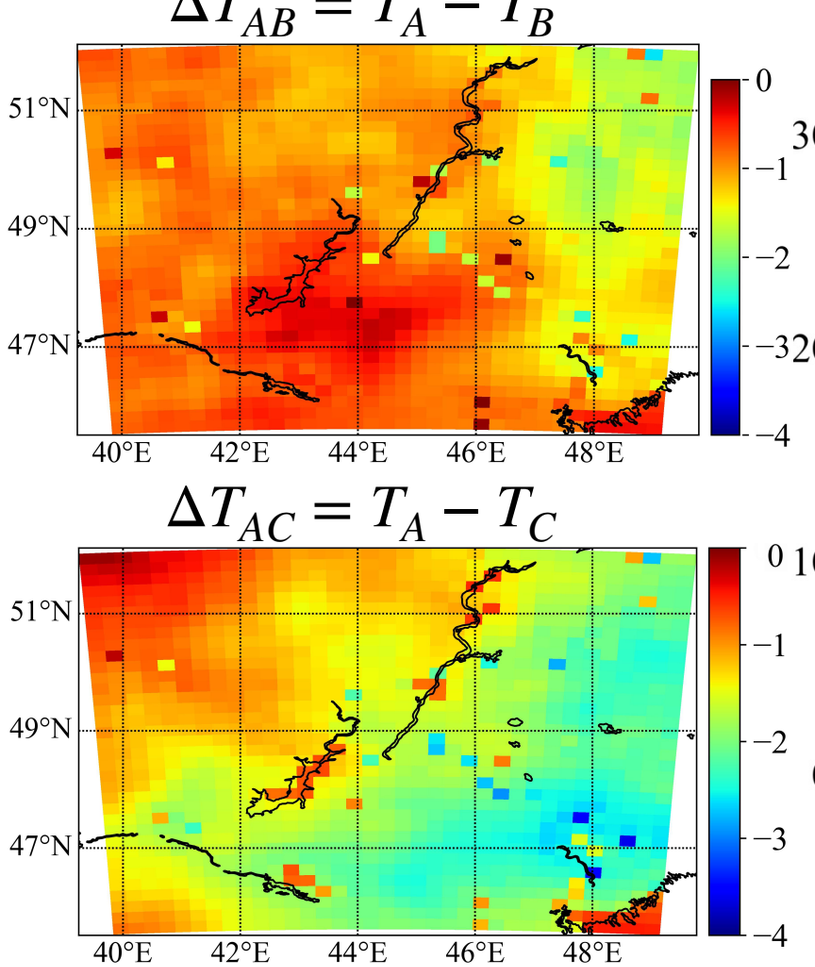
a)



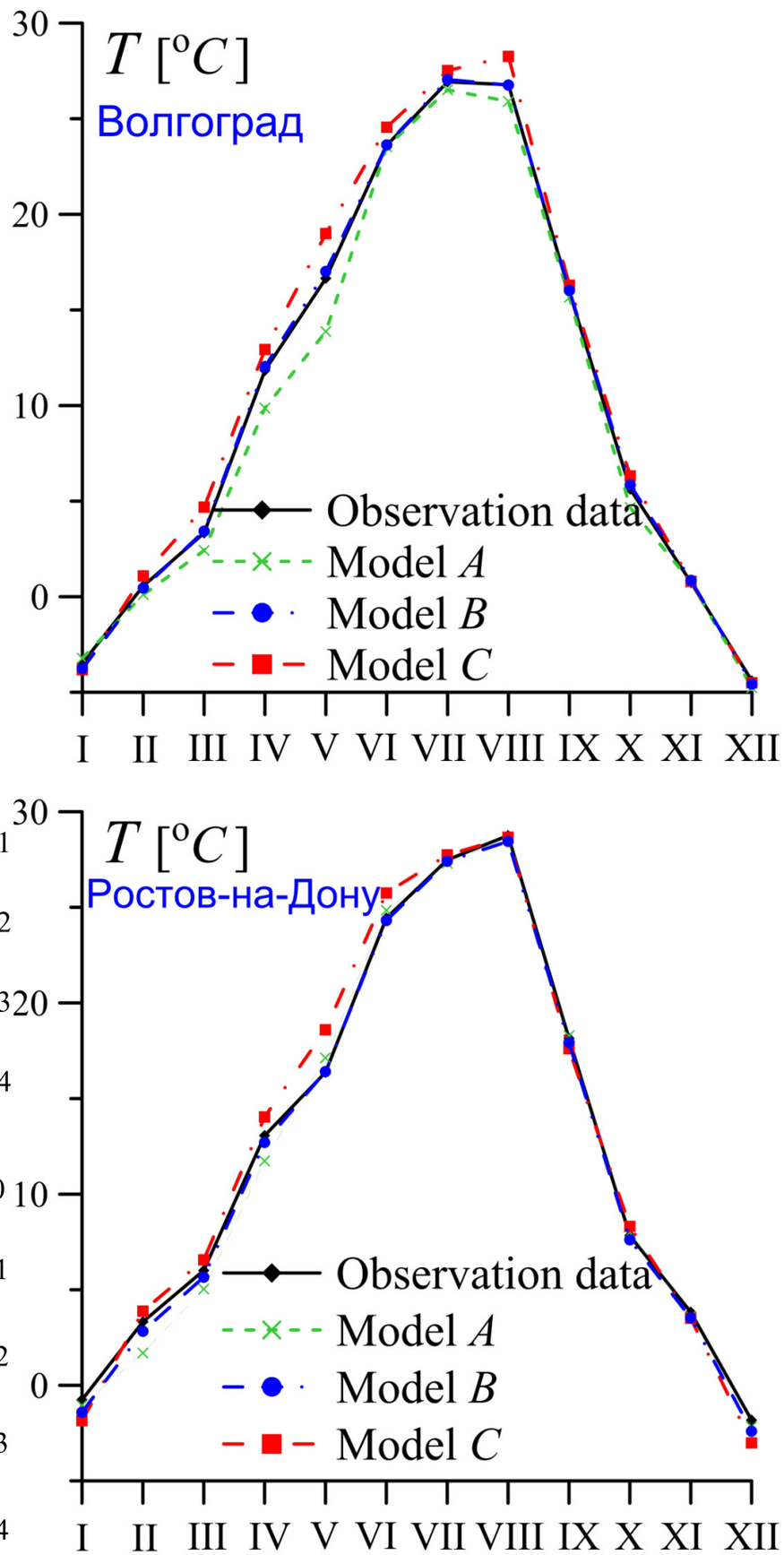
The average monthly temperature at two meters high

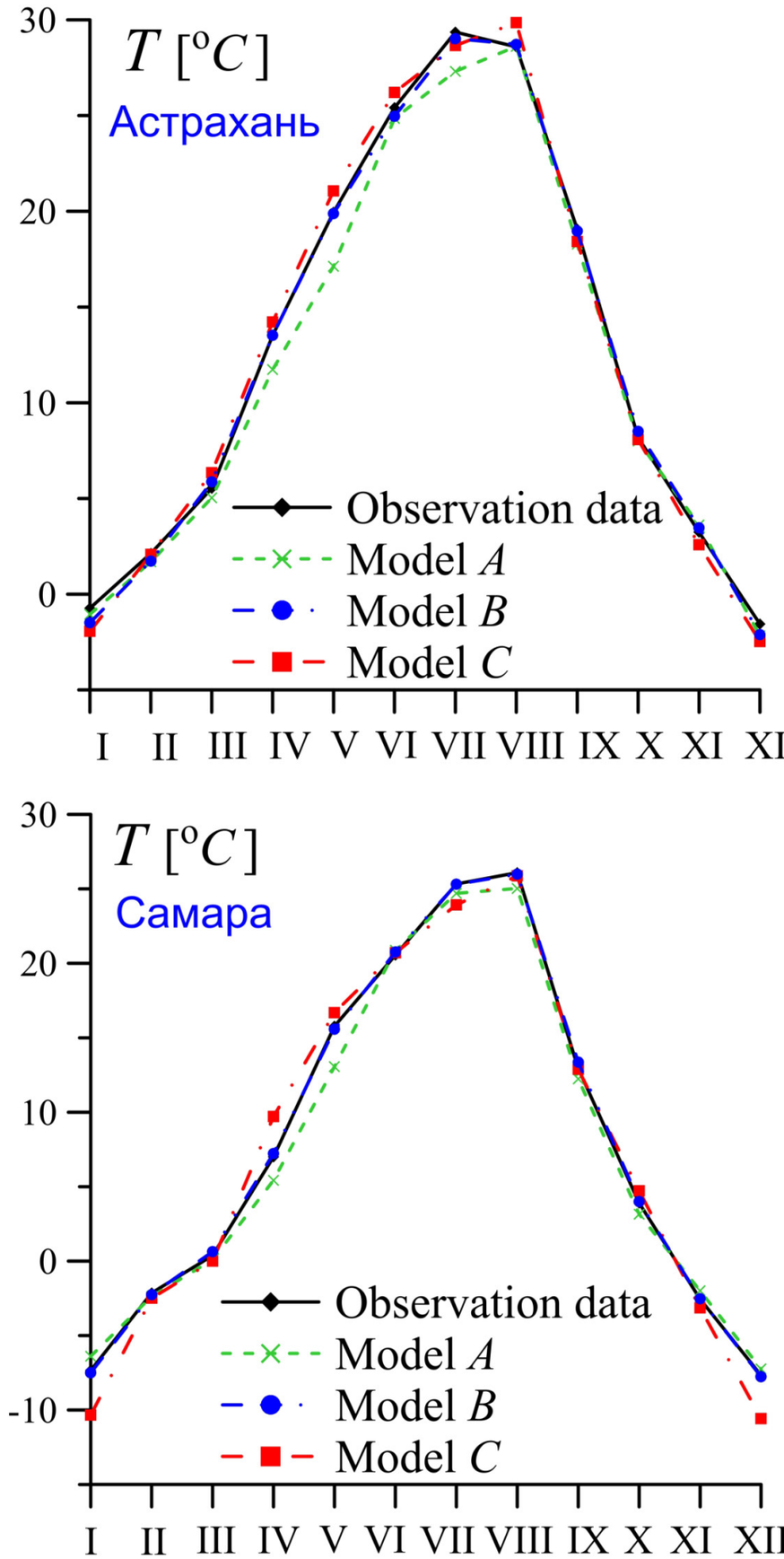


$$\Delta T_{AB} = T_A - T_B$$

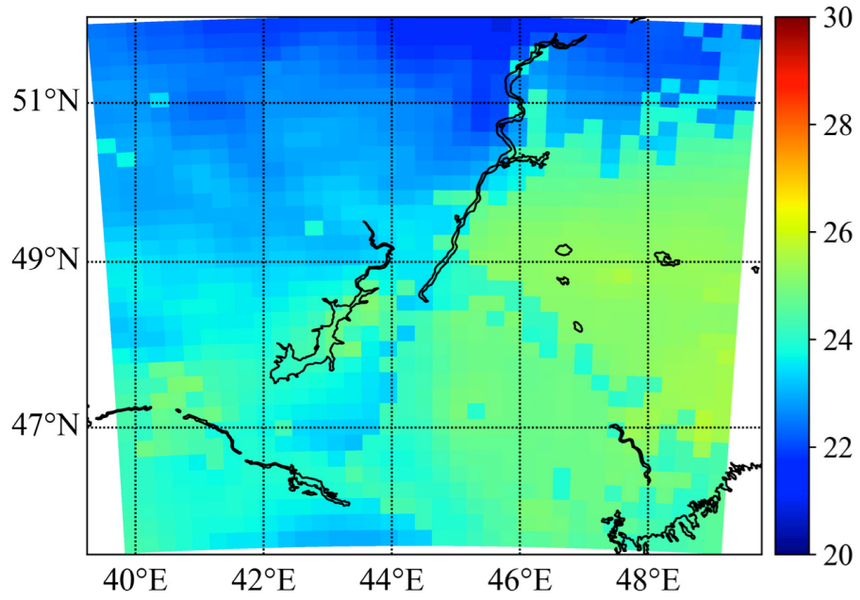


$$\Delta T_{AC} = T_A - T_C$$

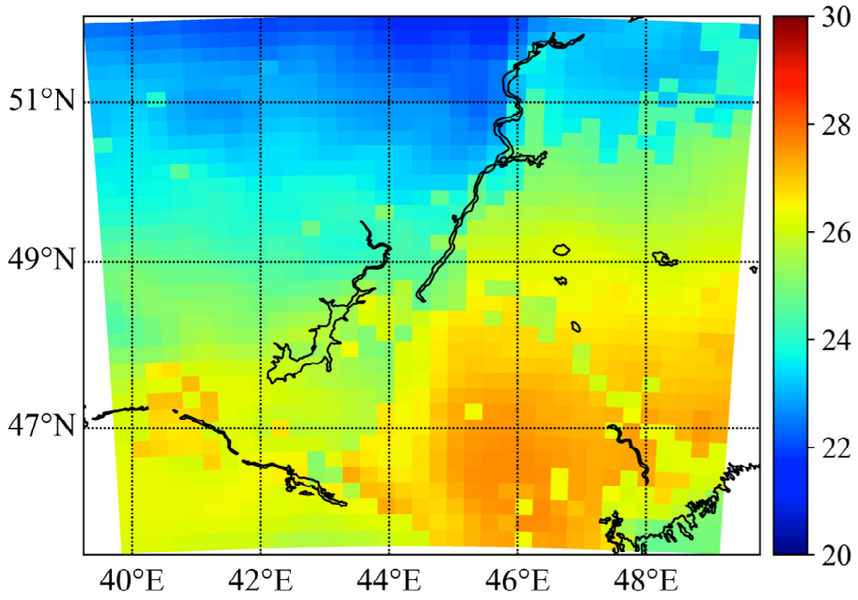




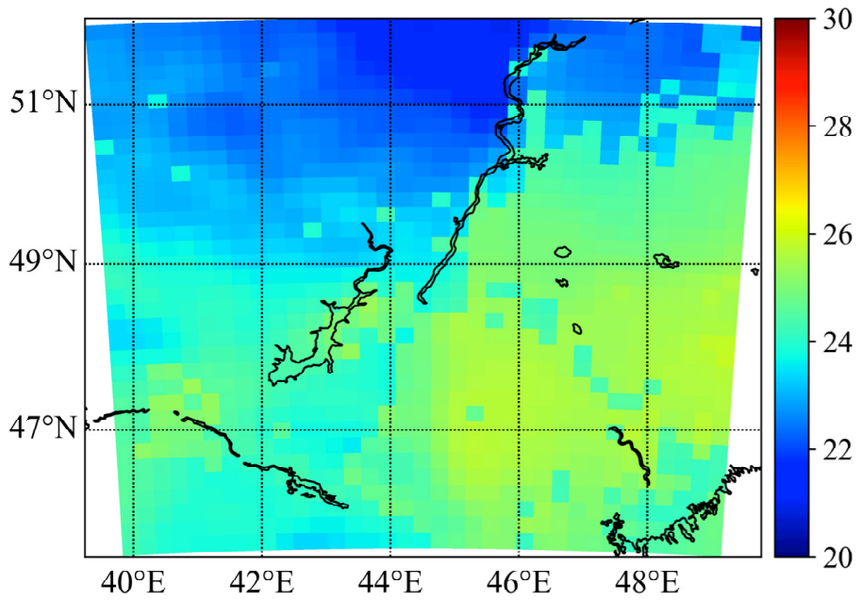
Cooling effect from the Volga-Akhtuba floodplain (VAF)



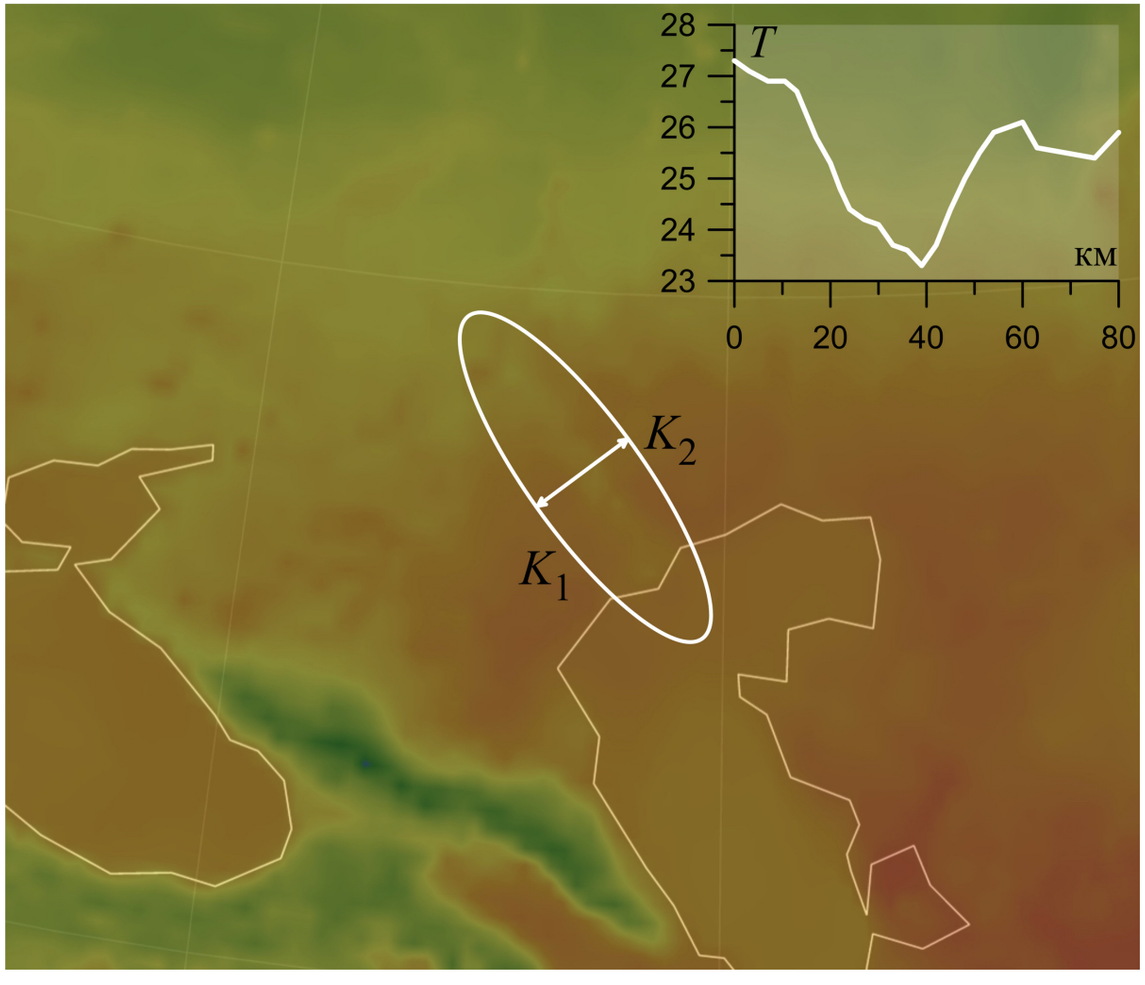
a) Model A

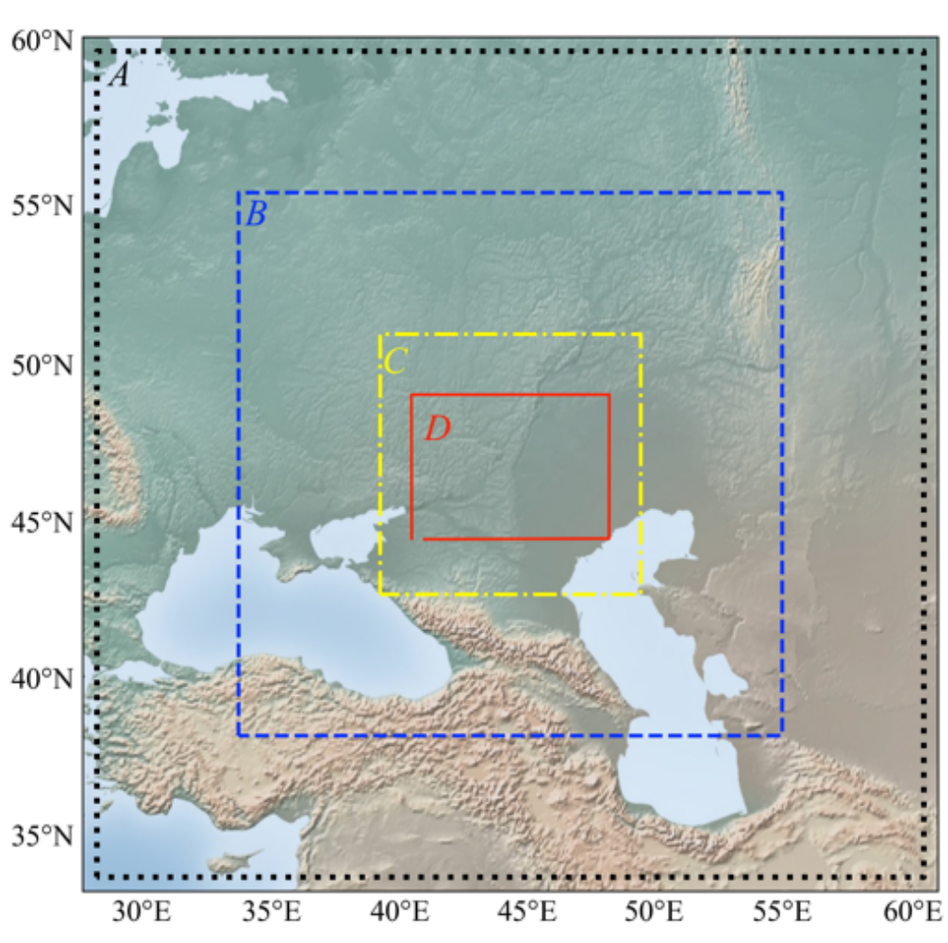


b) Model B

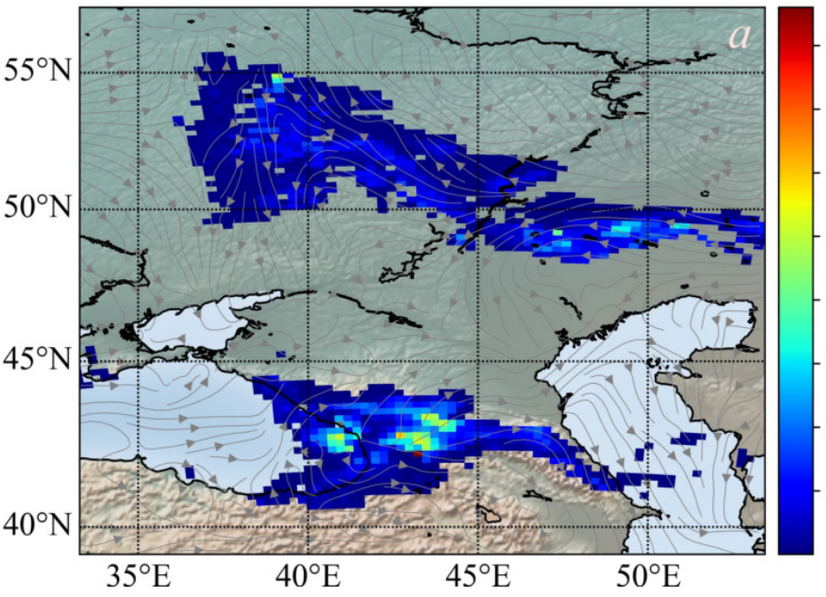


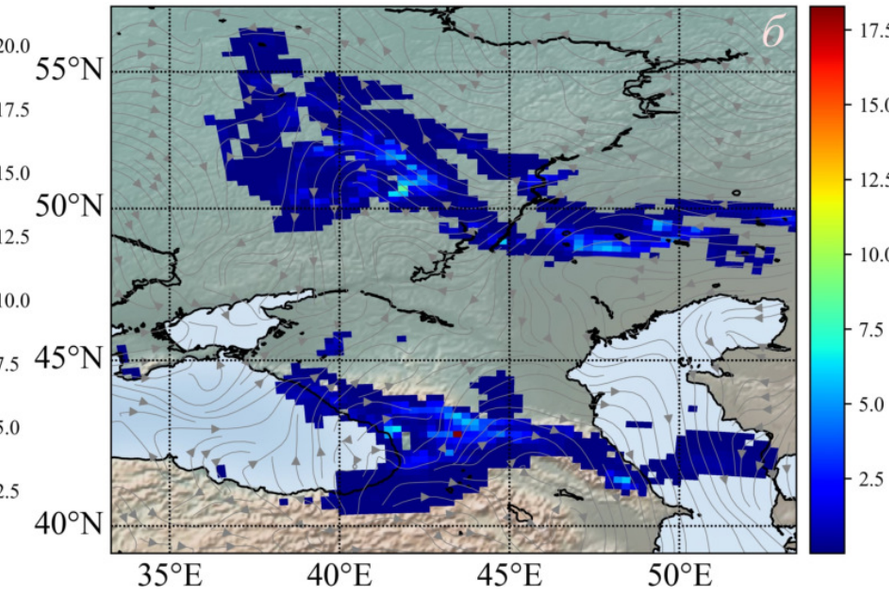
c) Model C

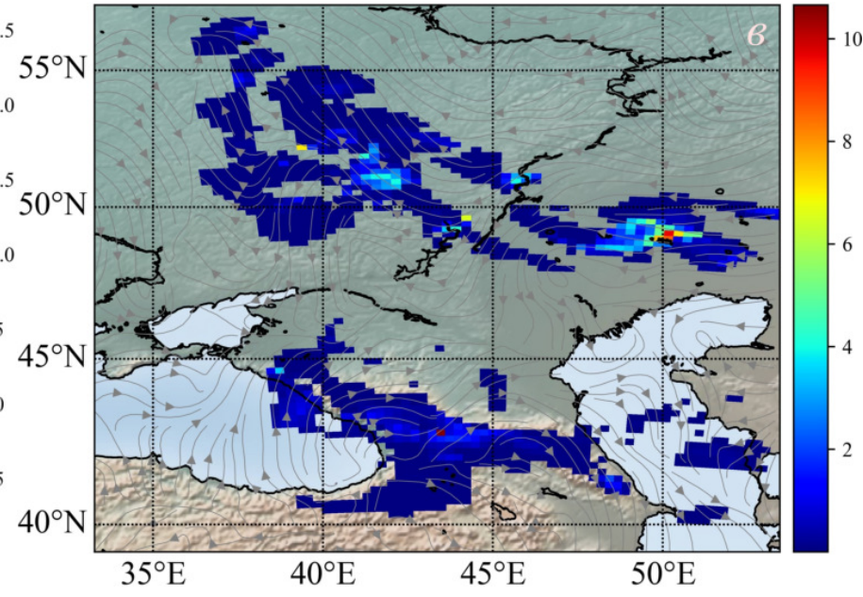


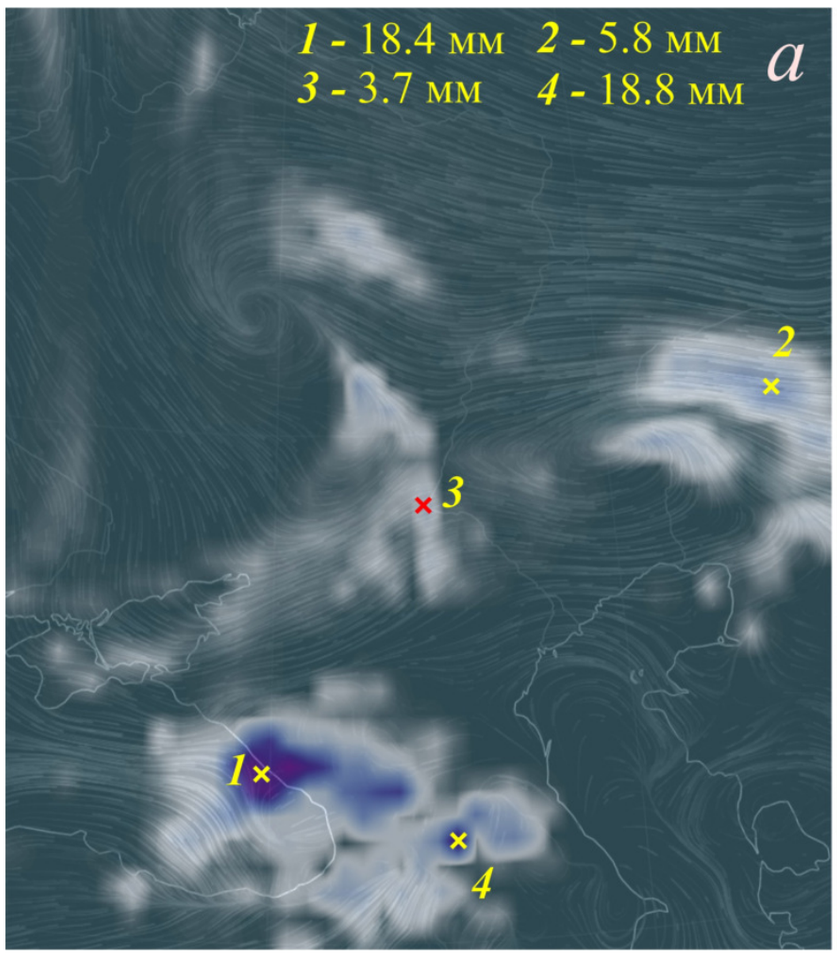


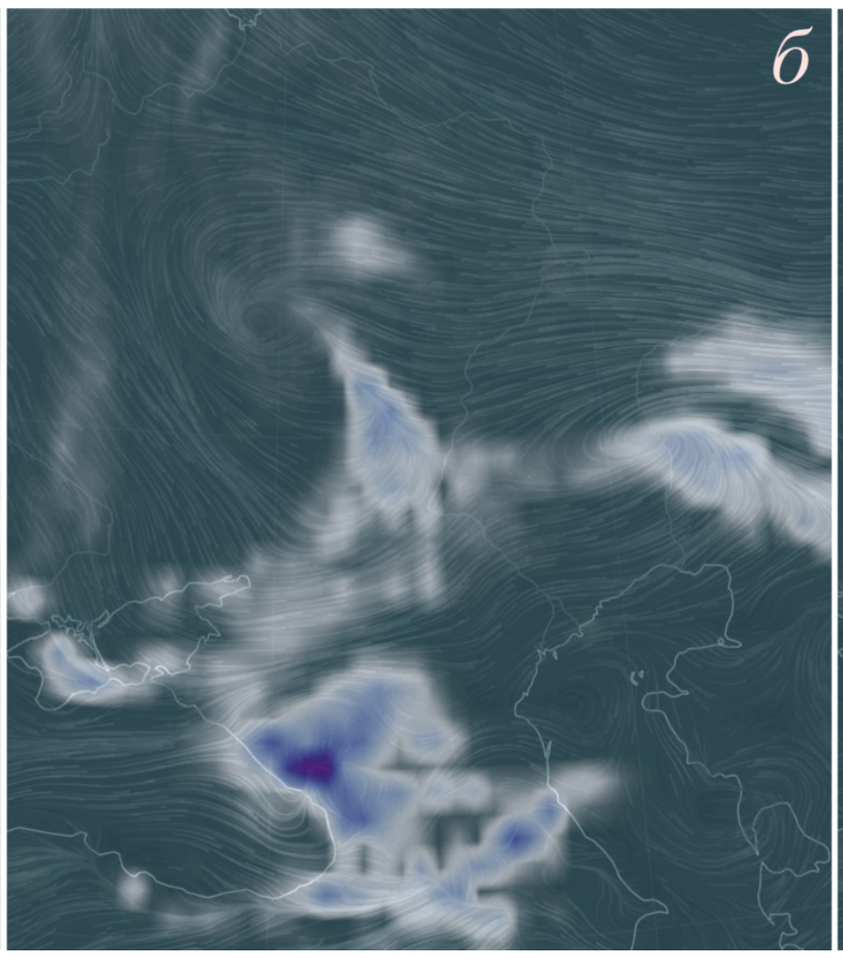
Rainfall distributions

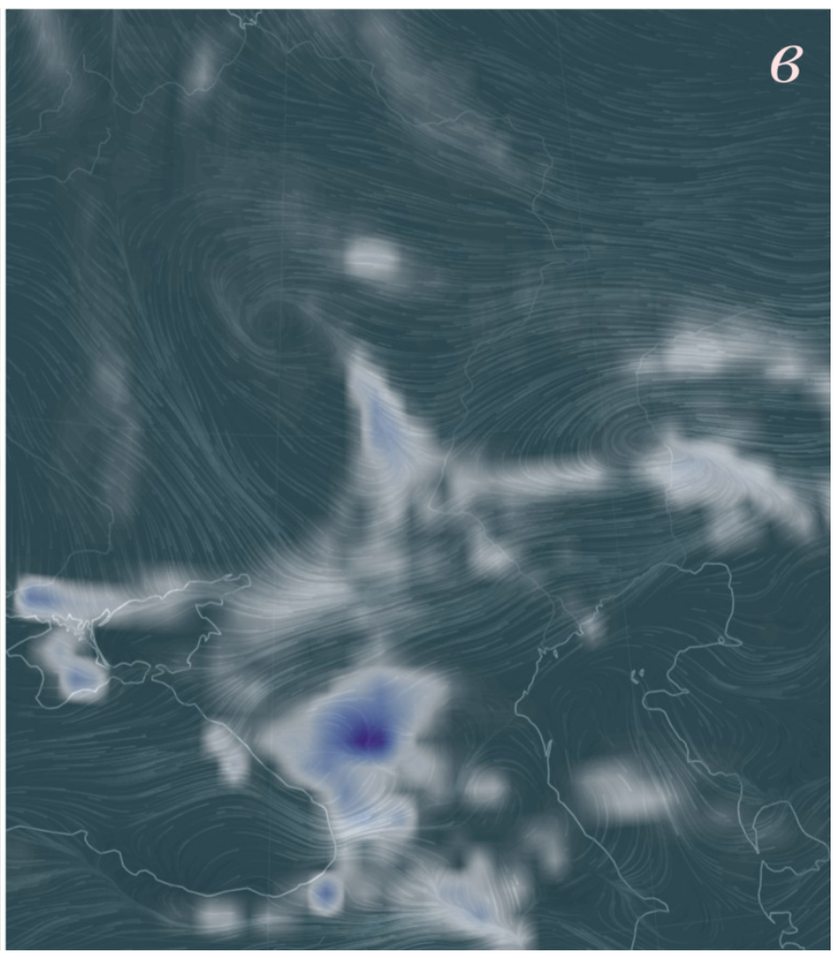




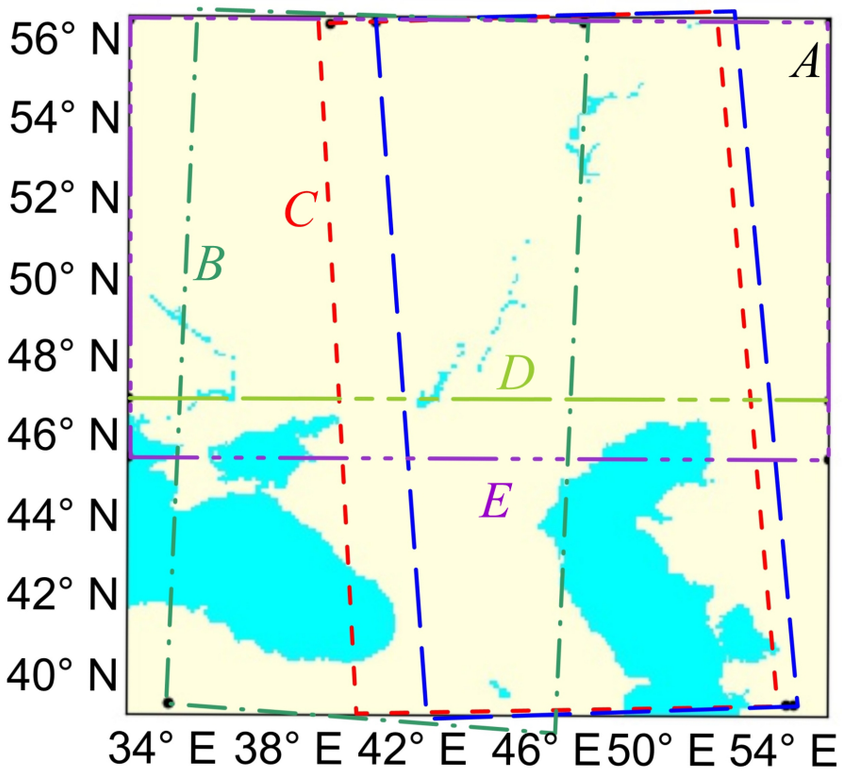








Influence of the computational domain choice on the forecast of rainfall distribution



Types of events:

- **Very weak rainfall**

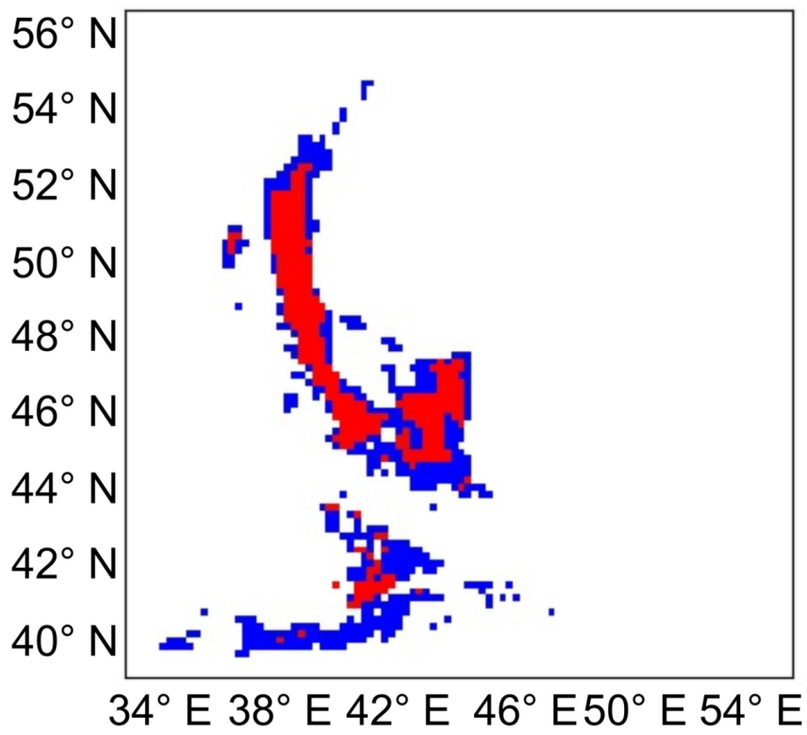
  Symbol $0\ I < 10^{-5}\ kgm^{-2}s^{-1}$

- **Weak or moderate rainfall**

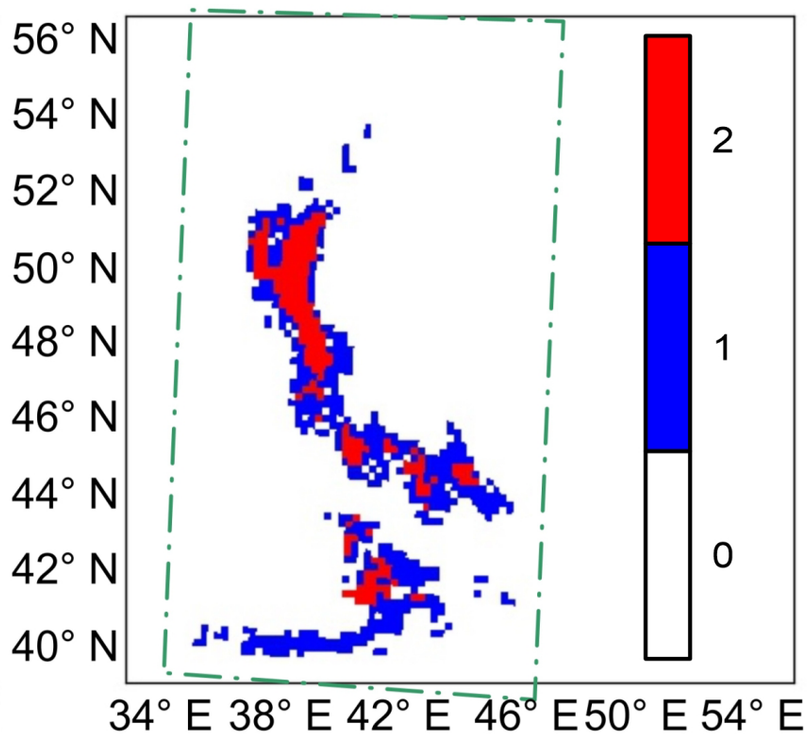
  Symbol 1

- **Heavy rainfall**

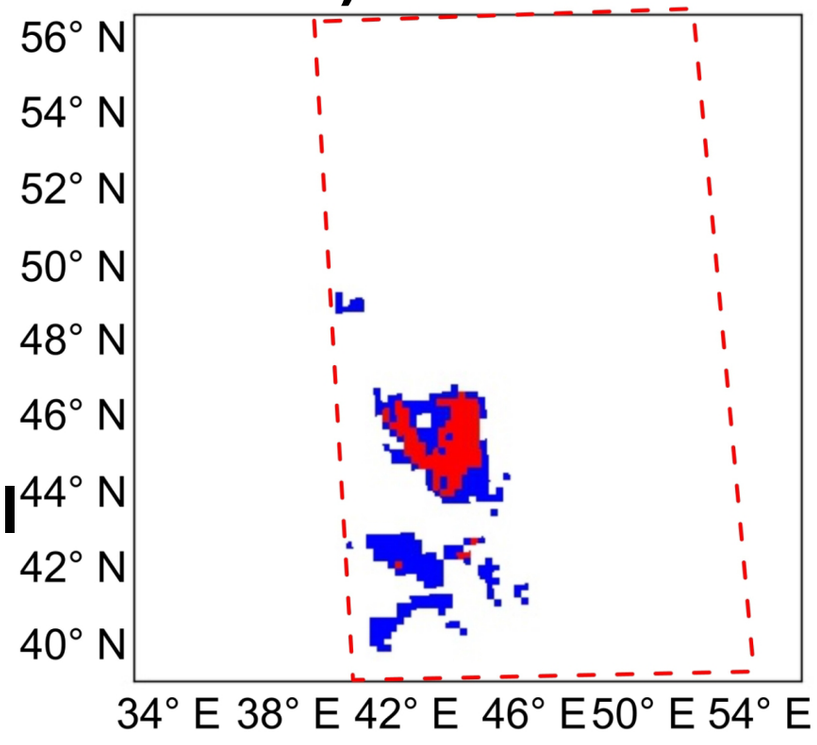
  Symbol $2\ I > 0.28 \times 10^{-3}\ kgm^{-2}s^{-1}$



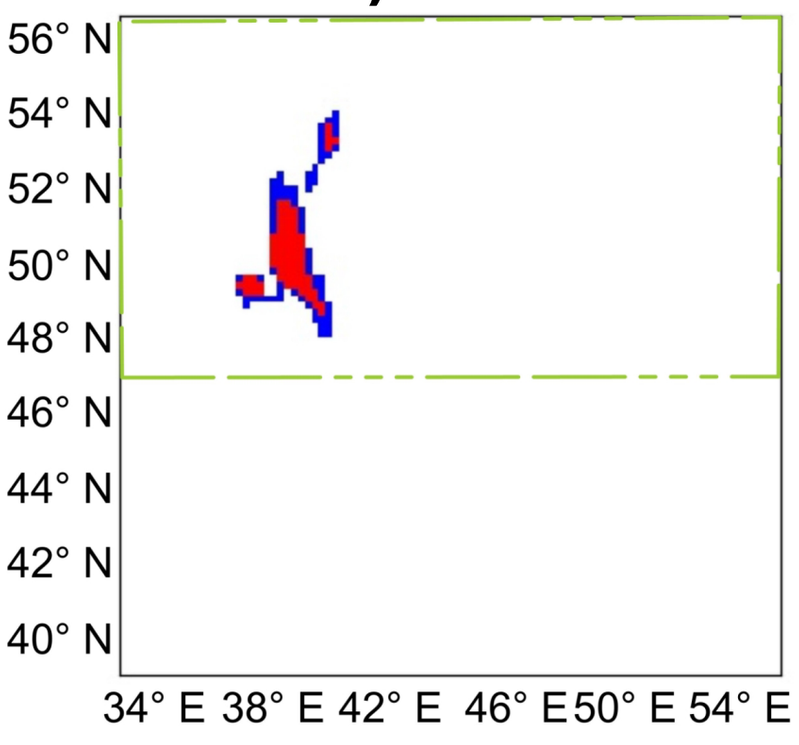
a) Model A



b) Model B



c) Model C



d) Model D

Conclusion

- We describe the first stage of the deployment of the regional climate model for Southern Russia based on RegCM 4.5

- We demonstrated the influence of the computational domain choice on the forecast of rainfall distribution in the numerical model

- We demonstrated analyzing the choice of the computing area, determining the accuracy of the vertical profiles of parameters, comparing temperature fields using observational data.

- We found that for small-scale features driven by the presence of large water bodies (Volgograd, Tsimlyansk reservoirs) and Volga-Akhtuba Floodplain (VAF) it is necessary to adopt an extra subgrid parametrization and hydrostatic equilibrium should be revisited by using high-resolution models of 1-5 km to further accommodate the climate model with a hydrological model of the VAF

Conclusion

- Calculation time non-monotonically varies with a number of cores n and the location of the minimum $n^{(min)}$ depends strongly on the spatial resolution adopted in the model. The reason for such a puzzling characteristic is the features of parallelization adopted in RegCM

- Main limiting factor for regional climate simulations is the amount of output data and the limits of the bandwidth for the data transfer from/to supercomputer

- We conclude that the radiation transfer routine in RegCM 4.5 provides a typical error of $1 Wm^{-2}$ in climate conditions of the South of Russia, but for tropics, the error can be significantly larger

•The research is carried out using the equipment of the shared research facilities of HPC computing resources at Lomonosov Moscow State University supported by project RFMEFI62117X0011