Scientific Conference on Climate Change in the Caspian Sea Region, 2021

Моделирование уровня Каспийского моря в различных климатических условиях с использованием океанической модели INMIO-CICE и климатической модели INMCM

Simulation of the Caspian Sea level fluctuations in different climatic conditions within ocean model INMIO-CICE and climate model INMCM

Morozova P.A. [1,*], Ushakov K.V.[2], Volodin E.M.[3], Semenov V.A.[1,4,5]

[1] *Institute of Geography, Russian Academy of Sciences, Moscow, Russia*

[2]*Shirshov Institute of Oceanology Russian Academy of Sciences, Moscow, Russia*

[3]*Marchuk Institute of Numerical Mathematics of the Russian Academy of Sciences, Moscow, Russia*

[4] *Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences, Moscow, Russia*

[5] *Water Problems Institute, Russian Academy of Sciences, Moscow, Russia*

**e-mail: morozova_polina@mail*

Motivation and methods

- Today there is no consensus on the genesis, scales and dating of the Caspian sea level fluctuations during the Late Pleistocene and the Holocene

- The study of relationships between Caspian Sea level, climatic conditions and water budget components using eddy-resolving ocean model

Climate model INMCM48 (CMIP6 version)

Atmosphere: 2x1.5 degrees in latitude and longitude, 21 levels in vertical, the uppermost level at 30 km

Ocean: 1.0x0.5°, 40 levels

Model includes also:

- aerosol block;
- carbon cycle

Experiments:

- Last Glacial Maximum, (LGM, 21 ka BP);
- preindustrial (PI,1850 CE)

More detail in [Volodin et al.,2018]

Atmospheric forcing from INMCM48 for INMIO-CICE: precipitation, surface SW and LW radiation fluxes, air temperature and humidity, wind speed and direction

Ocean model INMIO-CICE

Resolution: 0.27° over the longitude and 0.2° over the latitude (the size of a cell of ~22 km); 28 horizons with a step from 6 m in the top layer to 125 m in the depth.

Time step: 20 min.

Experiments: Caspian sea levels –60, –45, –30, and –15 m a.s.l. for PI and LGM climatic conditions

Paleoclimate Modelling

PMIP3

Intercomparison Project

Paleoclimate Modelling

PMIP4

Intercomparison Project

Experimental design

Geosci. Model Dev., 10, 4035–4055, 2017
https://doi.org/10.5194/gmd-10-4035-2017
© Author(s) 2017. This work is distributed under
the Creative Commons Attribution 3.0 License.

Geoscientific Model Development
Open Access
EGU

The PMIP4 contribution to CMIP6 – Part 4: Scientific objectives and experimental design of the PMIP4-CMIP6 Last Glacial Maximum experiments and PMIP4 sensitivity experiments

Masa Kageyama[1], Samuel Albani[1], Pascale Braconnot[1], Sandy P. Harrison[2], Peter O. Hopcroft[3], Ruza F. Ivanovic[4], Fabrice Lambert[5], Olivier Marti[1], W. Richard Peltier[6], Jean-Yves Peterschmitt[1], Didier M. Roche[1,7], Lev Tarasov[8], Xu Zhang[9], Esther C. Brady[10], Alan M. Haywood[4], Allegra N. LeGrande[11], Daniel J. Lunt[3], Natalie M. Mahowald[12], Uwe Mikolajewicz[13], Kerim H. Nisancioglu[14,15], Bette L. Otto-Bliesner[10], Hans Renssen[7,16], Robert A. Tomas[10], Qiong Zhang[17], Ayako Abe-Ouchi[18], Patrick J. Bartlein[19], Jian Cao[20], Qiang Li[17], Gerrit Lohmann[9], Rumi Ohgaito[18,21], Xiaoxu Shi[9], Evgeny Volodin[22], Kohei Yoshida[23], Xiao Zhang[24,25], and Weipeng Zheng[26]

First results

Clim. Past, 17, 1065–1089, 2021
https://doi.org/10.5194/cp-17-1065-2021
© Author(s) 2021. This work is distributed under
the Creative Commons Attribution 4.0 License.

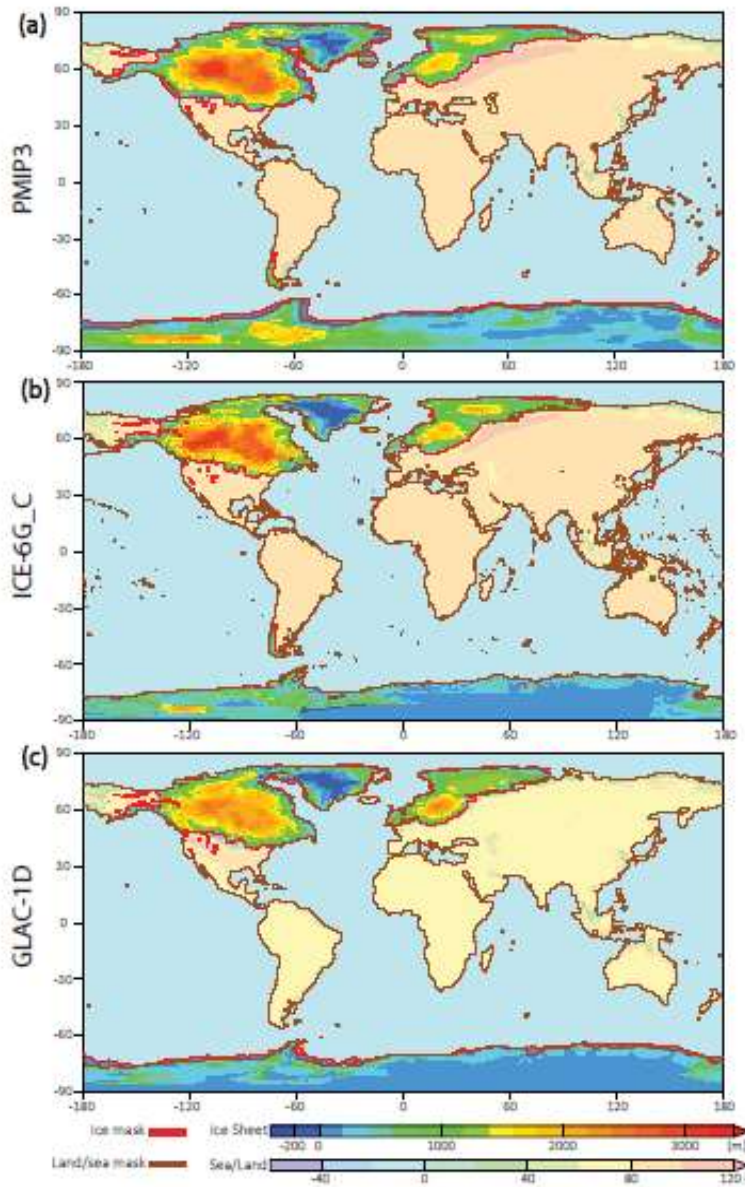
Climate of the Past
Open Access
EGU

The PMIP4 Last Glacial Maximum experiments: preliminary results and comparison with the PMIP3 simulations

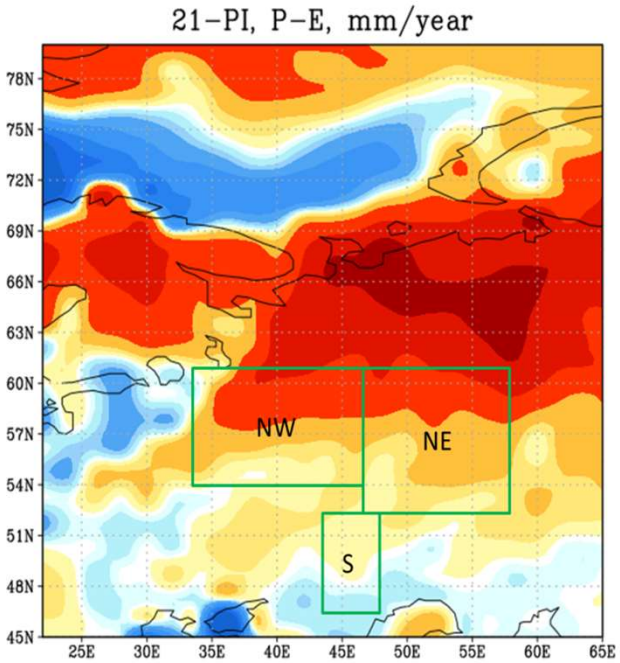
Masa Kageyama[1], Sandy P. Harrison[2], Marie-L. Kapsch[3], Marcus Lofverstrom[4], Juan M. Lora[5], Uwe Mikolajewicz[3], Sam Sherriff-Tadano[6], Tristan Vadsaria[6], Ayako Abe-Ouchi[6], Nathaelle Bouttes[1], Deepak Chandan[7], Lauren J. Gregoire[8], Ruza F. Ivanovic[8], Kenji Izumi[9], Allegra N. LeGrande[10], Fanny Lhardy[1], Gerrit Lohmann[11], Polina A. Morozova[12], Rumi Ohgaito[13], André Paul[14], W. Richard Peltier[7], Christopher J. Poulsen[15], Aurélien Quiquet[1], Didier M. Roche[1,16], Xiaoxu Shi[10], Jessica E. Tierney[4], Paul J. Valdes[9], Evgeny Volodin[17], and Jiang Zhu[18]

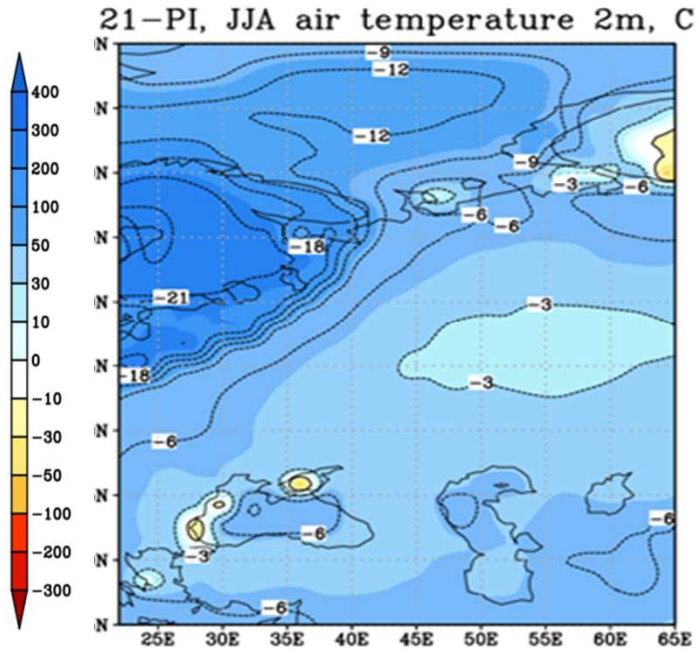
Summary of the forcings and boundary conditions for the CMIP6-PMIP4 LGM experiment

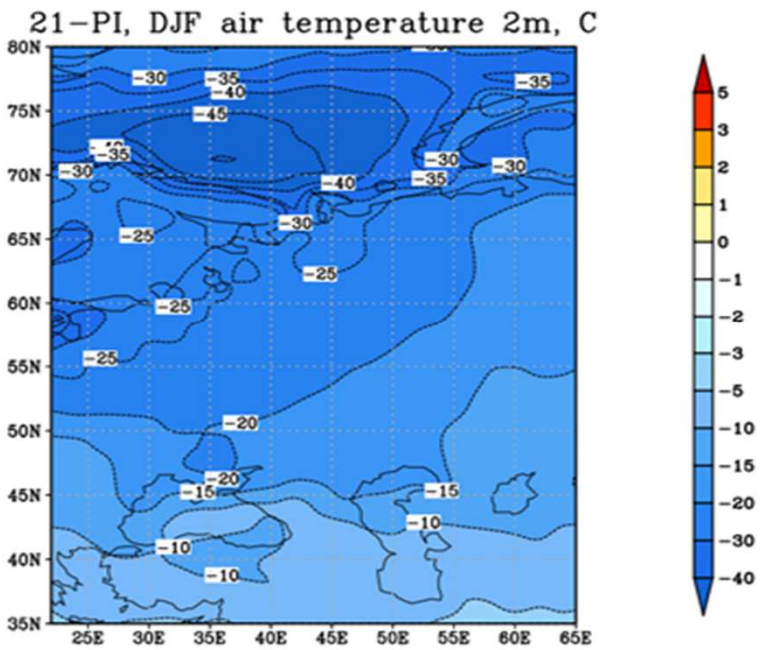
Forcings or boundary conditions	**21 ka (LGM)**
Insolation	eccentricity 0.018994, obliquity 22.949 perihelion-180=114.42
Atmosperic trace gases	**CO_2** = 185 ppm ; **CH_4** = 350 ppb; **N_2O** = 200 ppb; **CFC** = 0; **O_3** = same as in PI
Ice sheets, topography and coastlines	Reconstructions: GLAC-1D (Tarasov et al., 2012; Briggs et al., 2014; Ivanovic et al., 2016), ICE_6G-C (Peltier et al., 2015; Argus et al., 2014),
Global freshwater budget	Should be closed to avoid drifts Rivers should get to ocean; snow should not be allowed to accumulate indefinitely over ice sheets
Ocean salinity	+ 1 psu higher than PI



LGM climate



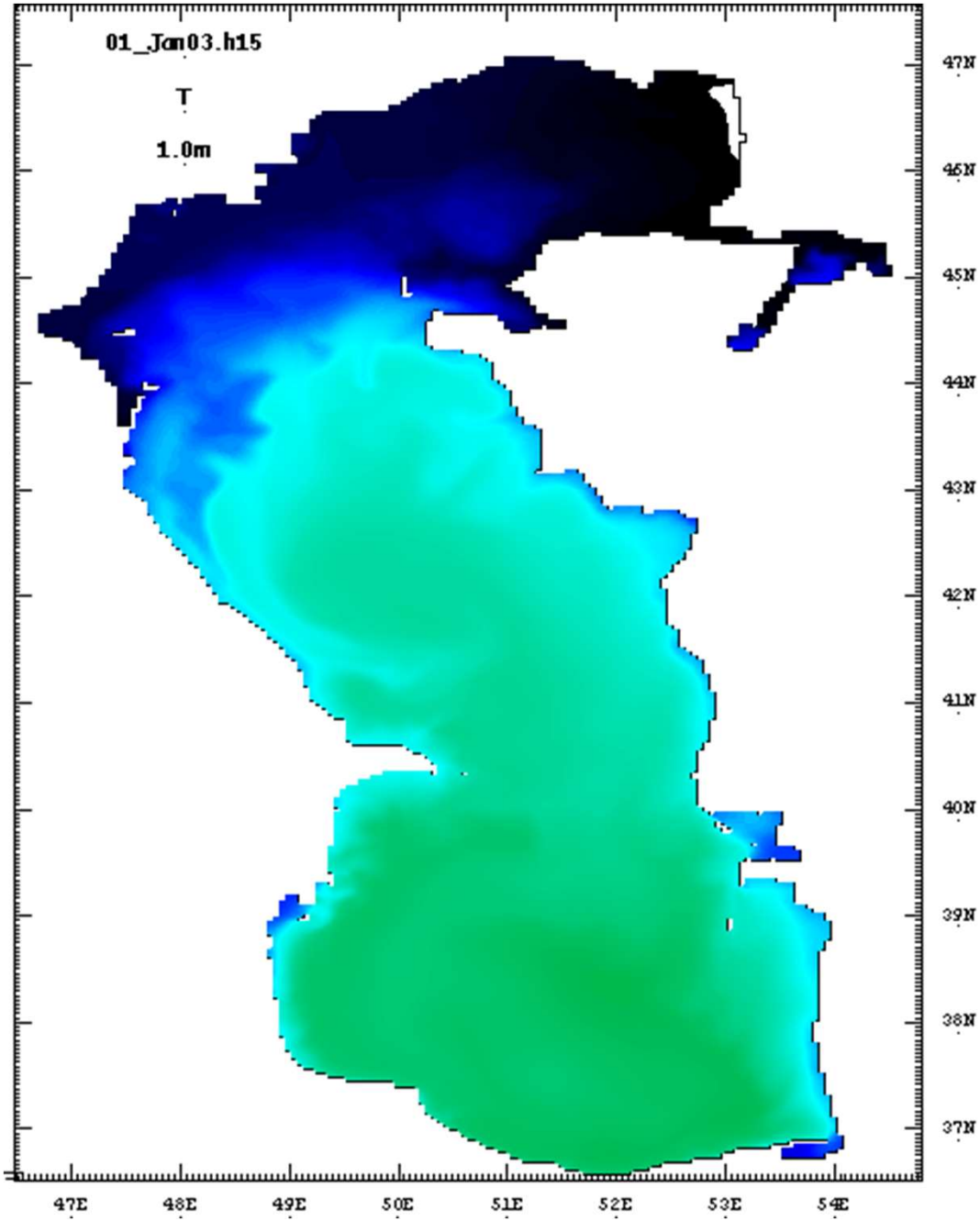




Caspian Sea		INM-CM48		MIROC		MPI	
		PI	LGM	PI	LGM	PI	LGM
Precipitation, mm/year		248	204	438	356	249	241
Evaporation, mm/year		1044	1022	836	673	1114	936
Air temperature at 2m*, °C	annual	12,2	5,4	15,7	9,6	15,2	11,1
	DJF	0,4	-9,6	4,1	-3,5	3,9	-1,8
	JJA	25,2	20,7	28,1	22,9	27,2	24,9

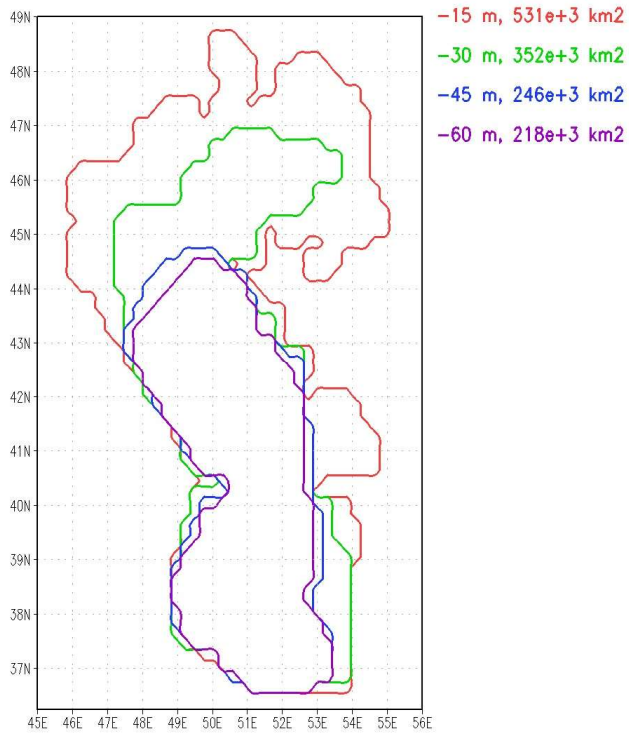
Ocean model INMIO-CICE

- Eddy-resolving oceanic model (INMIO) coupled with sea ice model CICE. The model of ice dynamics and thermodynamics CICE in zero-layer approximation is used on the grid with the same resolution and the same time step as the oceanic model. The structure of the INMIO-CICE model is described in [Fadeev et al.,2018].
- The INMIO model approximates a system of three-dimensional equations of oceanic dynamics and thermodynamics in Boussinesq approximation, hydrostatics, and water incompressibility by finite volume method on a grid of *B* type in vertical *z*-coordinates. The numerical implementation of the model is described in [Ushakov and Ibraev, 2018]. The horizontal exchanges are described with the use of a biharmonic operator for the momentum and Laplace operator for the temperature and salinity with nominal (equatorial) coefficients of - 1.5×10^{11} m^4/s and 300 m^2/s, respectively.
- The evaporation and surface turbulent fluxes of heat and momentum are calculated based on the values of the air temperature, specific humidity and wind speed with the use of bulk formulas. The boundary conditions also include the precipitation and the fluxes of incoming long-wave and short-wave radiation



Sea surface temperature annual cycle (*Ibrayev et al., 2010)*

Experimental design



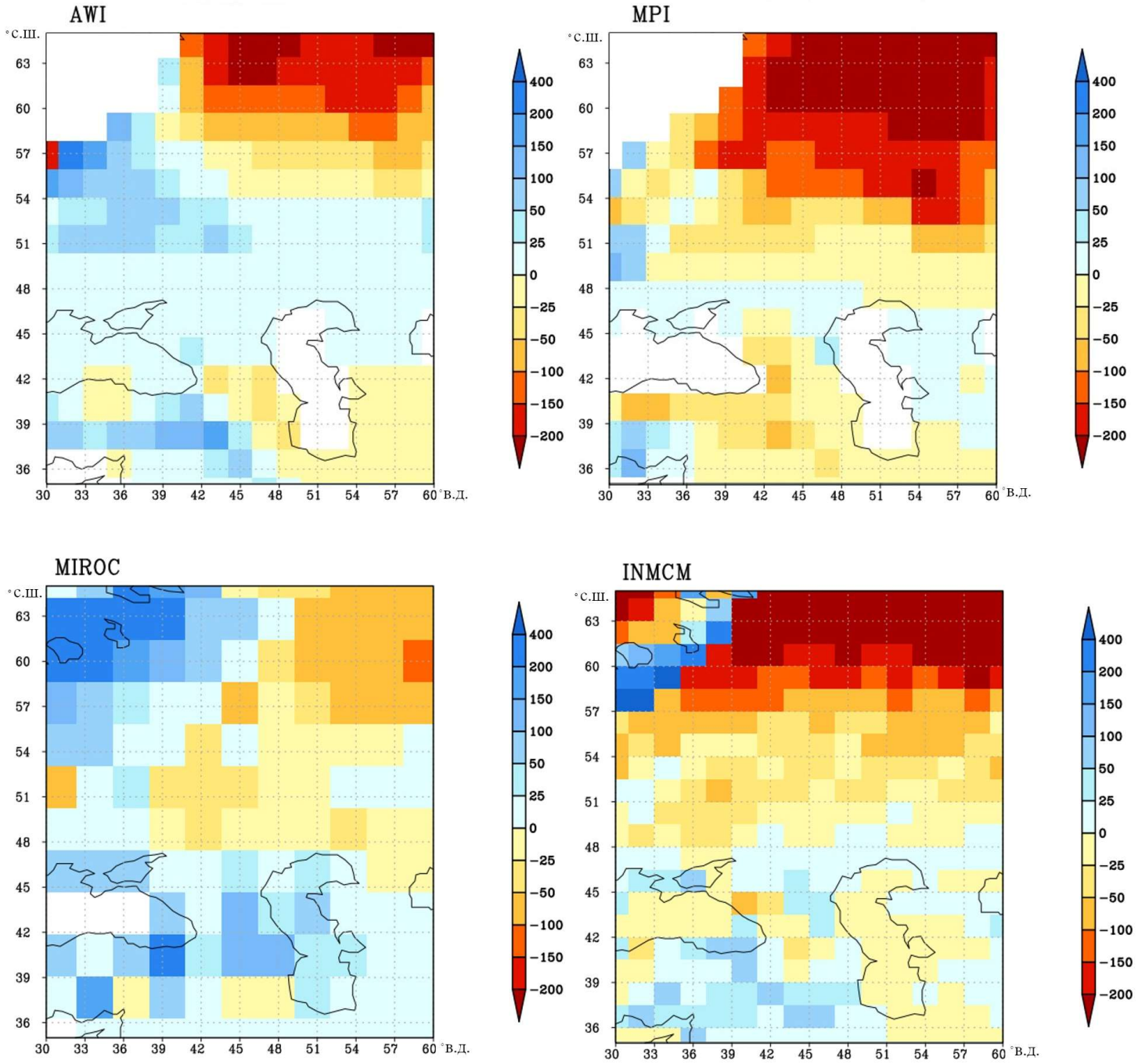
- The calculations were made for different Caspian levels: –60, –45, –30, and –15 m above sea level (m a.s.l.). The meteorological forcing data were taken from experiments with INMCM model for reproduction of preindustrial climate and LGM climate with a daily resolution.
- Resolution: 0.27° x 0.2°, 20 minutes
- The experiment was organized as follows:

at each lake level, an initial approximation was specified for the value of river runoff as an empirical linear function of the water area. Next, for a period of 20 years, calculations were made of data of climate modeling INMCM (experiments PI, LGM) to evaluate water disbalance averaged over years 6–20. Next, the volume of river runoff was corrected by the disbalance value, and the calculations continued for 30 years more under the conditions of a balanced state of the Caspian sea. Finally, analysis was made of the obtained evaporation fields averaged over the last 20 years

Precipitation and evaporation over Caspian sea by simulation and observation data

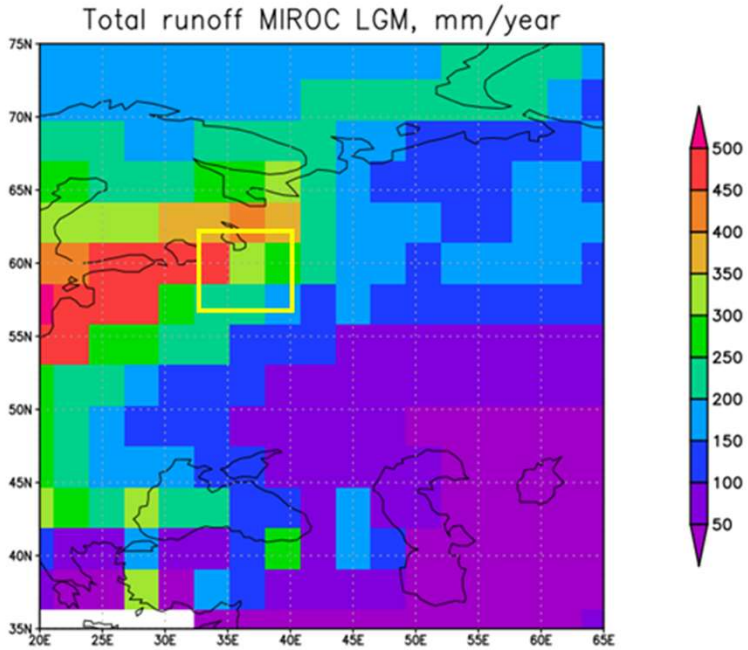
Data	Experiment	Precipitation, mm/year	Evaporation, mm/year
AWI	PI	188	1124
	LGM	178	1065
INMCM	PI	248	1044
	LGM	204	1022
MIROC	PI	438	836
	LGM	356	673
MPI	PI	249	1114
	LGM	241	936
INMIO-CICE + INMCM	PI	248 (INM-CM48)	918
	LGM	204 (INM-CM48)	760
Observations	–	215±50	980±20

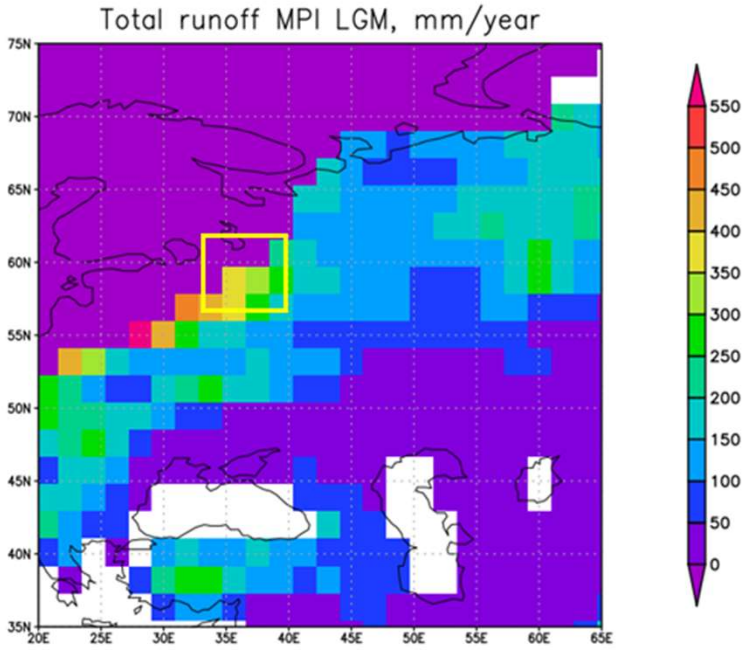
Variations of river runoff (mm/year) in LGM compared with the PI experiment by PMIP4 models



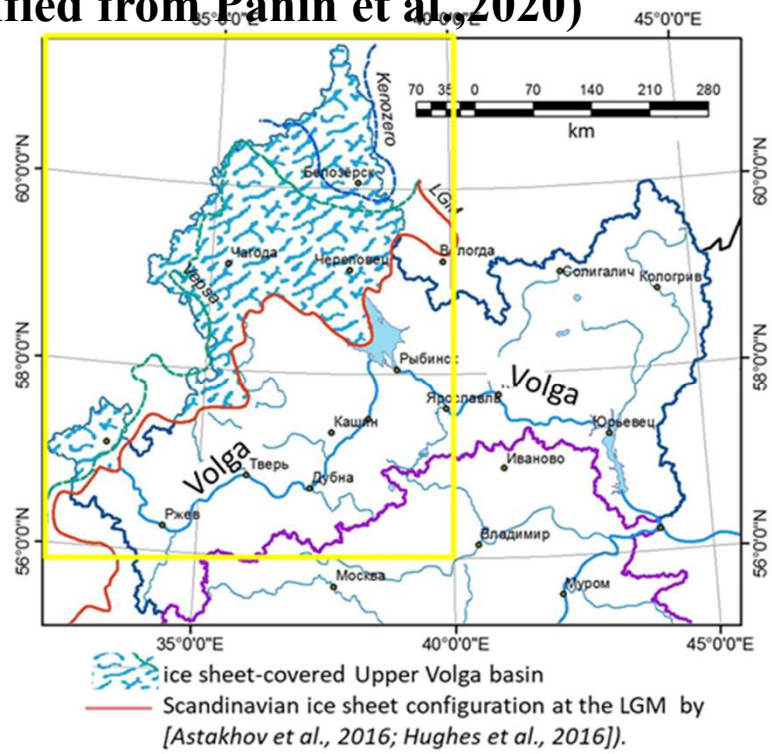
Variations of Volga runoff components by data of observations and PMIP4 simulation (mm –mm in the layer, % compared with the PI experiment)

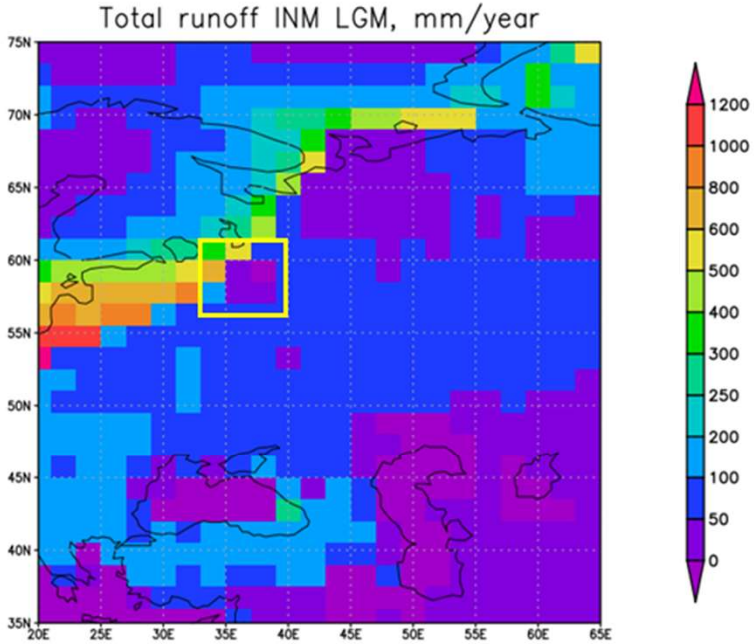
Data source		Precipitation, km^3/year	Evaporation, km^3/year	Volga runoff, km^3/year	S runoff, km^2
Observations		873 (642 mm)**	621 (457 mm)	252(185 mm)	1 380 000
AWI	PI LGM LGM-PI	1028 (602 mm) 839 (491 mm) -189 (-18%)*	850 (497 mm) 670 (392 mm) -180 (-21%)	175 (103 mm) 166 (97 mm) -9 (5%)	1 708 500
INMCM	PI LGM LGM-PI	1009 (568 mm) 495 (278 mm) -514 (-50%)	748 (421 mm) 367 (206 mm) -381 (-50%)	262 (147 mm) 138 (78 mm) -123 (-47%)	1 776 670
MIROC	PI LGM LGM-PI	1099 (650 mm) 776 (459 mm) -323 (-29%)	874(517 mm) 562 (332 mm) -312 (-36%)	222 (131 mm) 210 (125 mm) -12 (-5%)	1 692 000
MPI	PI LGM LGM-PI	1293 (767 mm) 828 (491 mm) -465 (-36%)	963 (571 mm) 674 (400 mm) -289 (-30%)	328 (194 mm) 151 (90 mm) -147 (-44%)	1 686 000



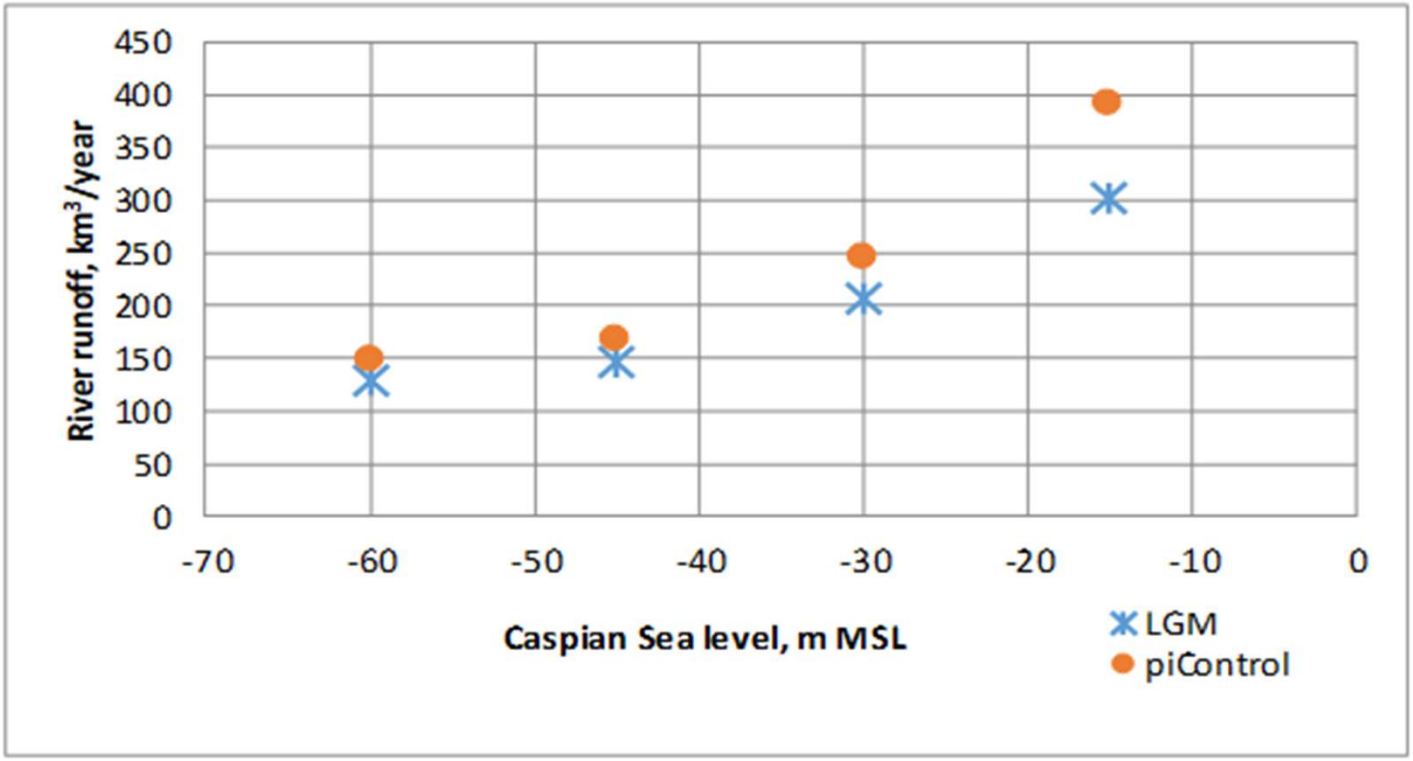


Upper Volga basin at the LGM (modified from Panin et al. 2020)





River runoff volume required for the equilibrium state of the Caspian Sea at different levels for preindustrial period and LGM climate by data of INMIO-CICE and INMCM



Total runoff into the Caspian Sea in LGM:

- Volga (140 – 210 km^3/year);
- Caucasian rivers (the Sulak, Kura, and Terek) (25-30 km^3/year);
- “meltwater” component (50 km^3/year - ?)

Conclusions

- The small number of models and the considerable scatter of the values of Caspian water balance components between the models make it impossible to determine what was the phase of the Caspian Sea in LGM period—transgressive or regressive. However, the obtained results very likely exclude the deep regression of the Caspian Sea.
- The volumes of equilibrium river runoff differ considerably for the modern climate and LGM climate, especially, for the Caspian level higher than the present one. In the future, additional experiments are planned for the Caspian levels below—15 m a.s.l.
- The volumes of evaporation and river flow required to maintain the equilibrium state of the Caspian Sea at different levels and under different climate conditions, obtained with the use of a high-resolution oceanic model, reproducing three-dimensional circulation in the water body and ice dynamics, can be of use for estimating model results and paleogeographic reconstructions.

Acknowledgment

The study was supported by the Russian Science Foundation, project no. 19-17-00215 (assessing the results of PMIP4 Project), IG RAS State assignment project no. 0148-2019-0009 (modeling LGM climate with the use of INMCM model); IO RAS State assignment project no. 0128-2021-0003 (version of INMIO-CICE model for the Caspian Sea and atmospheric data INMCM).