Experimental forecast of sea ice characteristics at the Hydrometcenter of Russia based on the INM RAS climate model

V. V. Vorobyeva[1,2] , M. A. Tarasevich[1,2,3] , E. M. Volodin[1,2] , A. S. Gritsun[1]

[1] Marchuk Institute of Numerical Mathematics, Russian Academy of Sciences

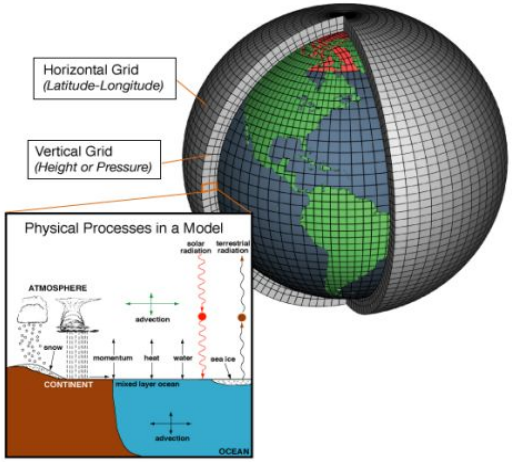
[2] Hydrometeorological Research Center of Russian Federation (Hydrometcenter of Russia)

[3] Moscow Institute of Physics and Technology (National Research University)

ACF
Arctic Climate Forum

INMCM5 climate model

- **Atmosphere:** 2 ˚x 1.5 ˚in longitude and latitude,
  73 levels (the uppermost level at 60 km)
- **Ocean:** 0.5 ˚x 0.25 ˚in longitude and latitude,
  40 levels
- **Aerosol block:** predictive equations are calculated for the concentration of 10 substances. The same resolution as in the atmospheric block.
- **Sea-ice evolution block:**
  Sea ice block uses generalized spherical coordinates similar to oceanic block.
  North Pole is at 60N, 100E, South Pole coincides with geographical South Pole.
  Resolution is 0.5 ˚x0.25 ˚degrees. Single category is used for ice thickness.
  Linear temperature profile in the ice is assumed.



Model is used for:

1. Present day climate simulations, past climate simulations and scenario runs for future up to 2100 (CMIP6)
2. Seasonal hindcasts

Possibility of NAO, PNA, ENSO, QBO, SSW seasonal prediction was shown:

Vorobyeva, V. and Volodin, E., 2021 Evaluation of the INM RAS climate model skill in climate indices and stratospheric anomalies on seasonal timescale. Tellus A: Dynamic Meteorology and Oceanography, 73(1), p.1892435.
DOI: http://doi.org/10.1080/16000870.2021.1892435

3. Validation of ice parameters (Arcic sea ice area and concentration) for 1991-2020 winter seasons with SMMR/SSM/I-SSMIS satellite data and ORAS5 reanalysis
4. Decadal predictions
5. Studies of potential predictability and mechanisms of natural decadal climate oscillations

Volodin, E.M., Mortikov, E.V., Kostrykin, S.V. et al. Simulation of the present-day climate with the climate model INMCM5. Clim Dyn 49, 3715–3734 (2017).
DOI: https://doi.org/10.1007/s00382-017-3539-7

Generation of initial data

- Atmosphere, soil and land reanalysis data (ERA-Interim/ ERA5)
- Ocean and sea ice reanalysis data (SODA3.4.2)

Model climatology

Technique of model bias eliminating:

$$W_{1OCT\,2022} = \overline{W_{M_{1OCT}}} + \left(W_{R_{1OCT\,2022}} - \overline{W_{R_{1OCT}}}\right)$$

INMCM5

Seasonal predictions (hindcasts + experimental forecast)

Experiments are initialised on the **October 1, 1991-2020; 2022**

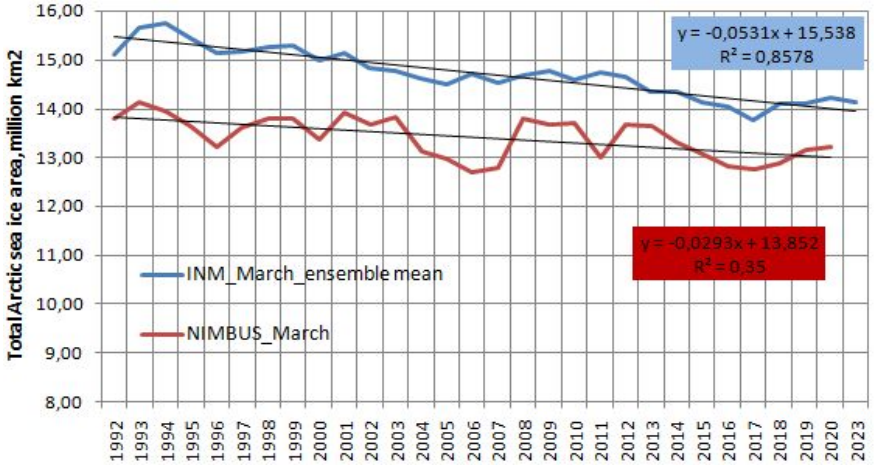
Duration of each experiment – **6 months**

20 ensemble members

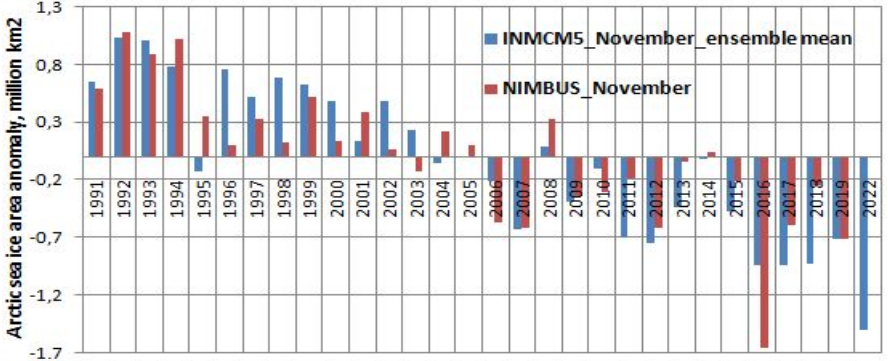
Arctic sea ice

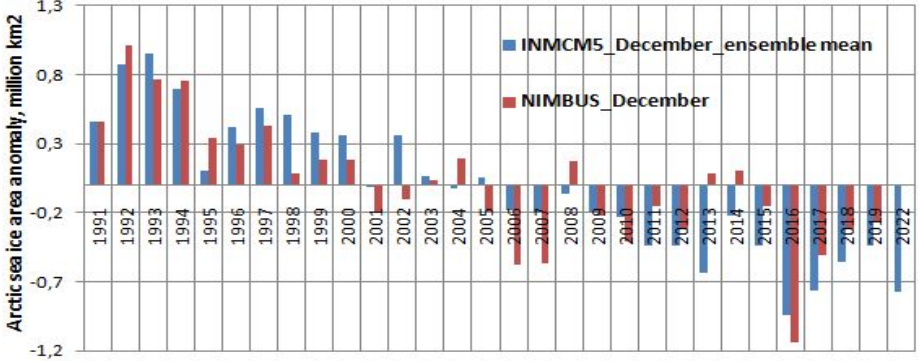
	Month				
	November	December	January	February	March
σ INMCM5	0,613	0,491	0,429	0,461	0,501
σ NIMBUS obs.	0,573	0,455	0,404	0,467	0,422
Mean bias	1,231	1,082	1,159	1,167	1,323
MSE	1,636	1,244	1,392	1,444	1,873
ACC	0,826	0,833	0,856	0,806	0,711
signal/noise	0,973	0,919	0,880	0,846	0,835

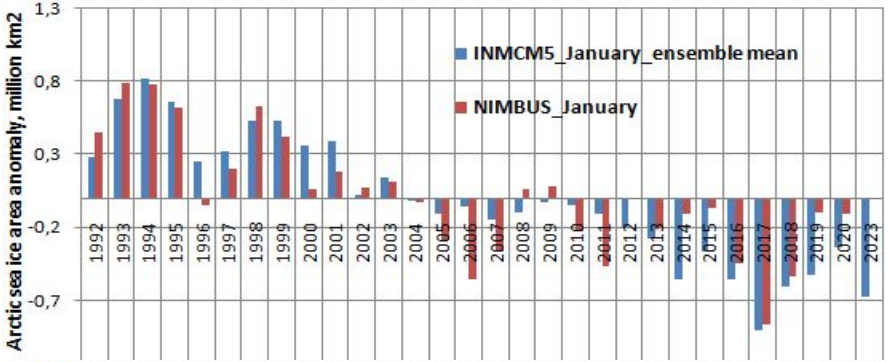
1991-2020 scores from INMCM5 and SMMR/SSM/I-SSMIS Passive Microwave Data, Version 1 satellite data (recalculated from concentration).

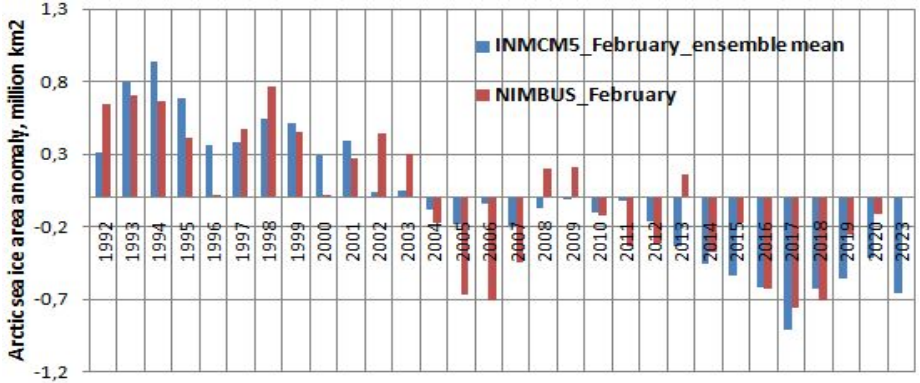


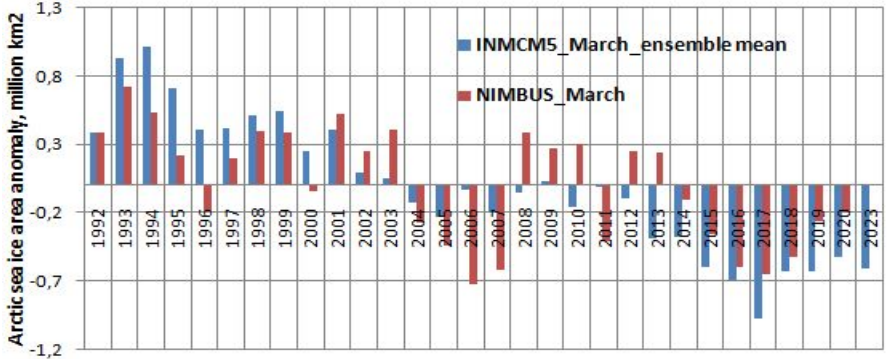
Arctic sea ice area, million km2 : variability of March ice area data based on the INMCM5 data and SMMR/SSM/I-SSMIS satellite data.







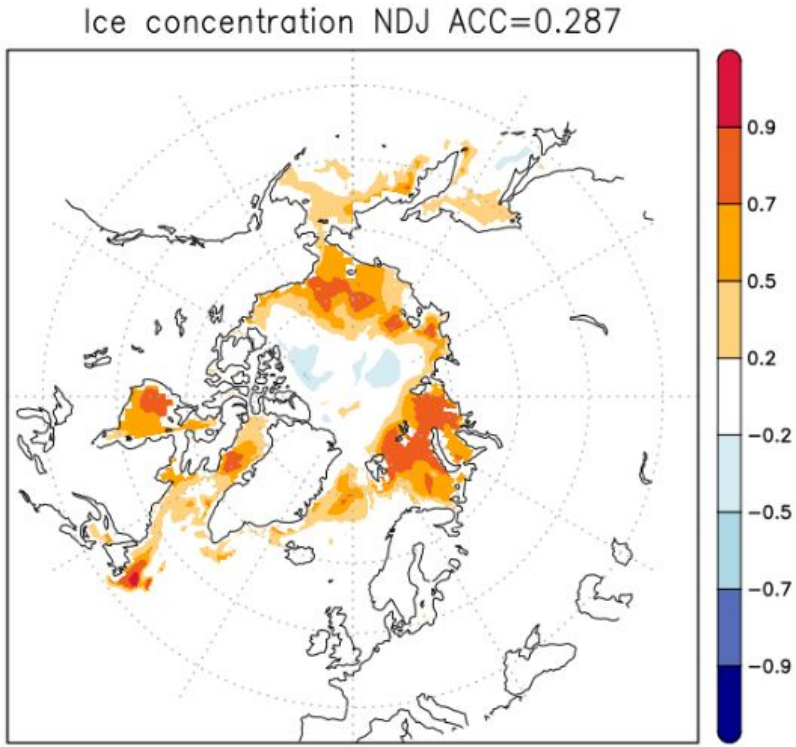


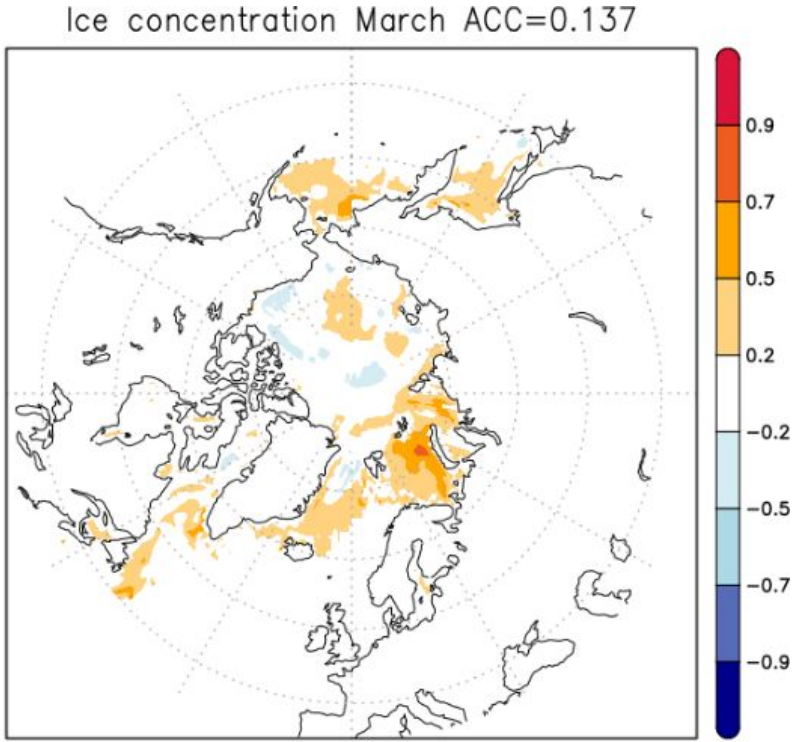


Arctic sea ice area anomaly relative to 1991-2020 period based on the INMCM5 data, million km2.

	Winter season 2022/23	
	Total Arctic sea ice area, million km2	Arctic sea ice area anomaly based on the 1991-2020 reference period, million km2
November	8,35	-1,50
December	11,09	-0,78
January	12,83	-0,67
February	13,76	-0,66
March	14,12	-0,61

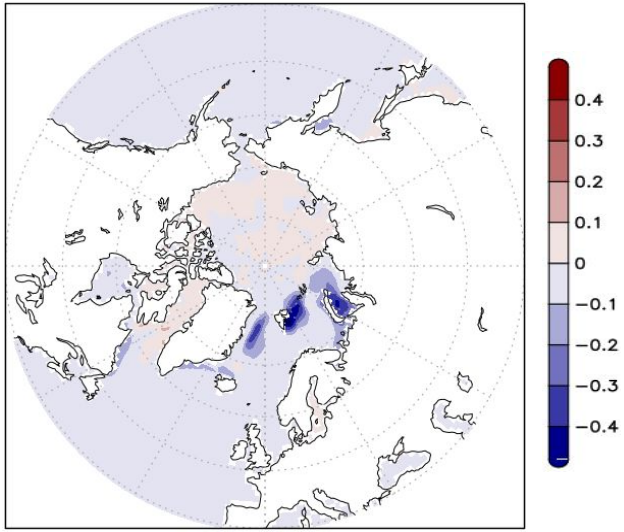
Arctic sea ice. Hindcasts

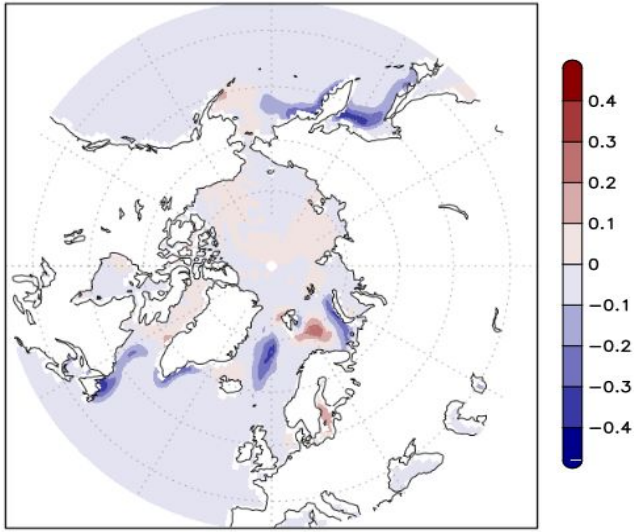




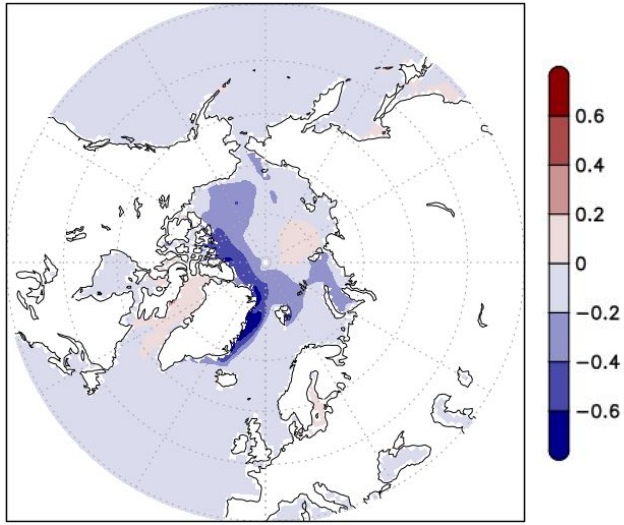
Anomaly correlation coefficients of ice concentration in November-December-January(NDJ) **(left)** and March **(right)** relative to 1991-2020 period based on the INMCM5 and ORAS5 reanalysis data.

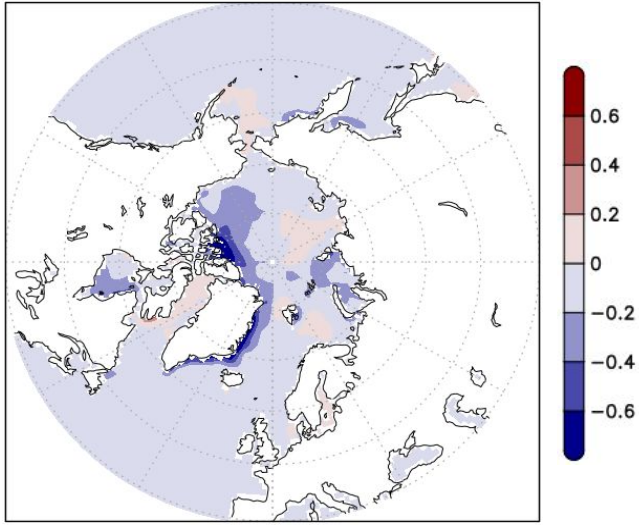
Arctic sea ice
Experimental forecast





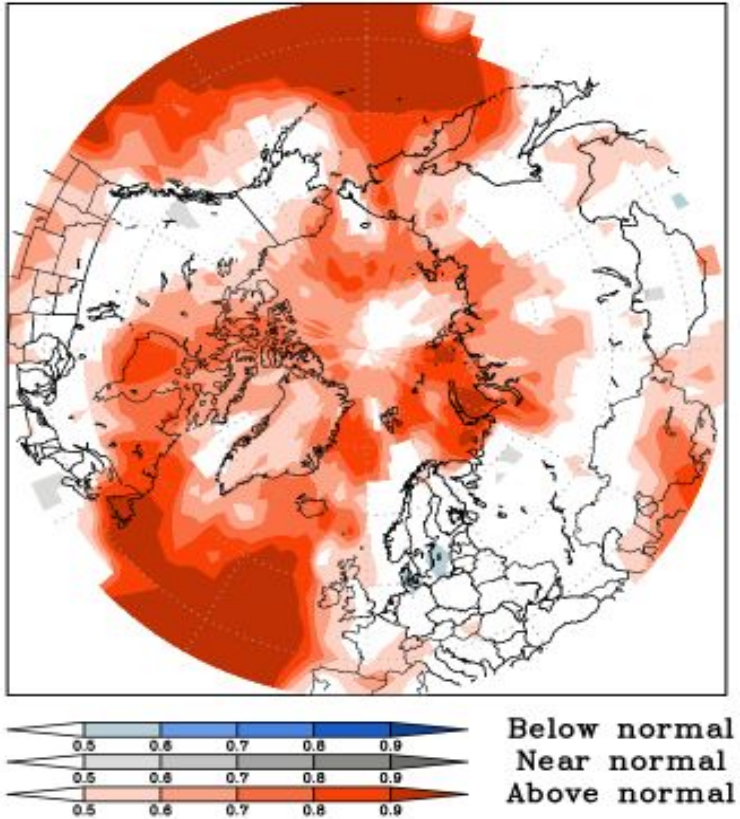
Arctic sea ice concentration anomaly in November-December-January(NDJ) **(left)** and March **(right)** for 2022/23 winter season relative to 1991-2020 period based on the INMCM5 data.



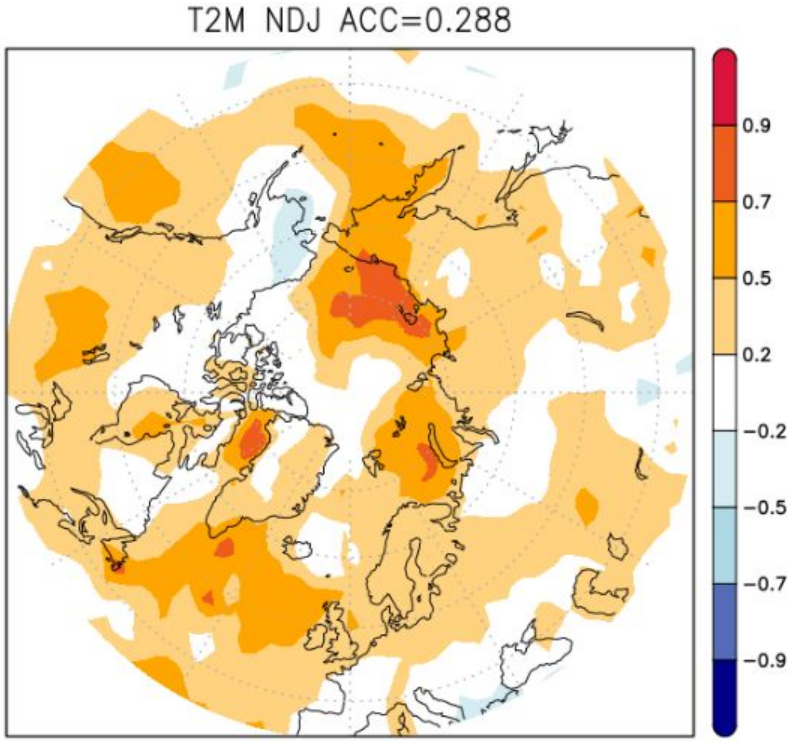


Arctic sea ice thickness anomaly in November-December-January(NDJ) **(left)** and March **(right)** for 2022/23 winter season relative to the 1991-2020 period based on the INMCM5 data, m.

Probabilistic forecast for November-December-January (NDJ) 2-m air temperature (T2m) anomalies in 2022/23 winter season based on the INMCM5 experimental forecast.



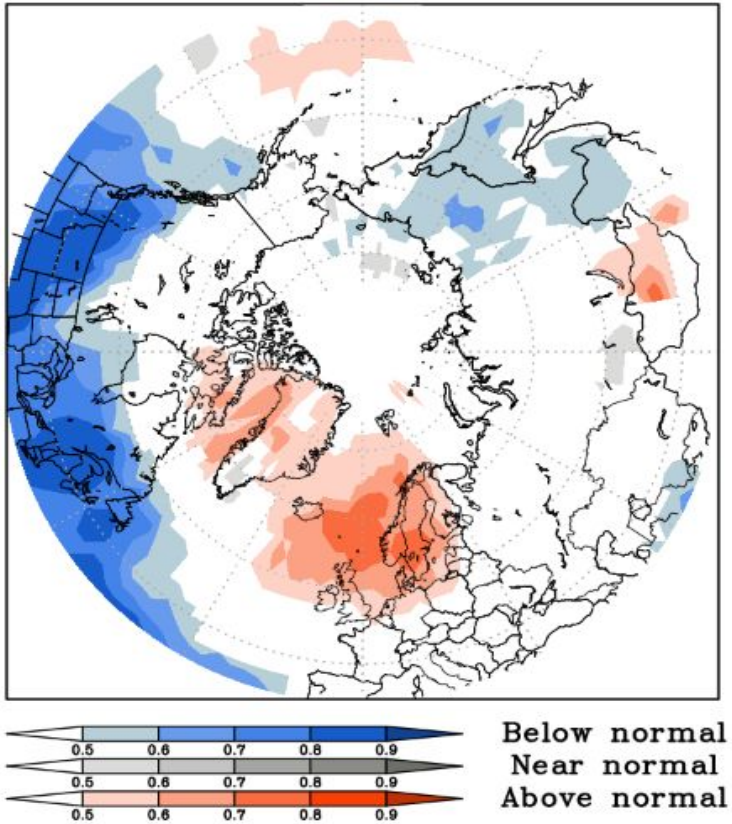
November-December-January (NDJ) anomaly correlation coefficients of the 2-m air temperature (T2m) based on the INMCM5 1993-2009 winter hindcasts and ERA5 reanalysis data.



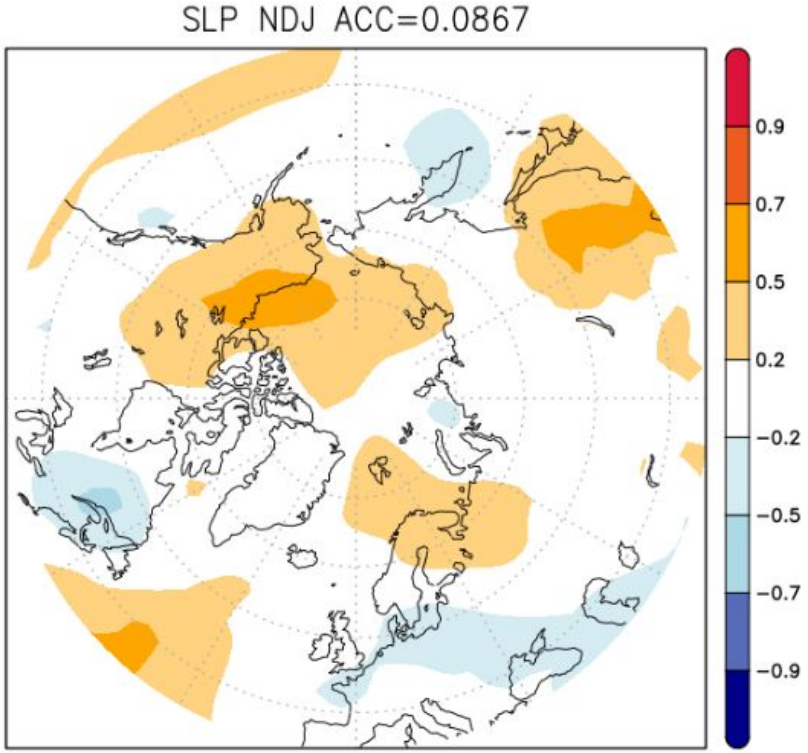
ACC=0.311 for 1993-2009 WMO multi-model ensemble

WMO LRF MME: https://wmolc.org/seasonVrfyHindDmmeUI/plot_VrfyHIND_DMME#

Probabilistic forecast for November-December-January (NDJ) sea level pressure (SLP) anomalies in 2022/23 winter season based on the INMCM5 experimental forecast.



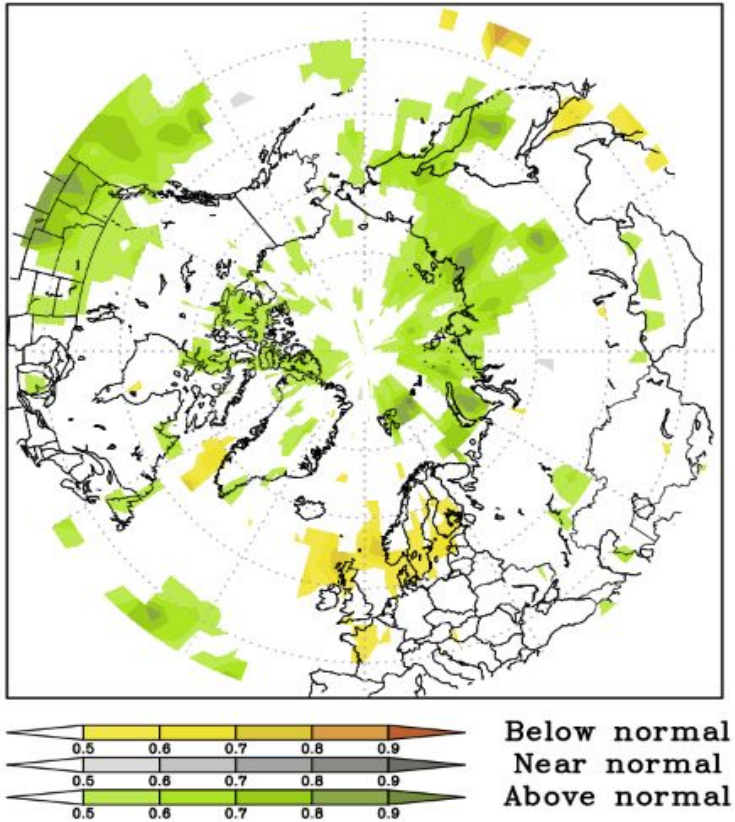
November-December-January (NDJ) anomaly correlation coefficients of the sea level pressure (SLP) anomalies based on the INMCM5 1993-2009 winter hindcasts and ERA5 reanalysis data.



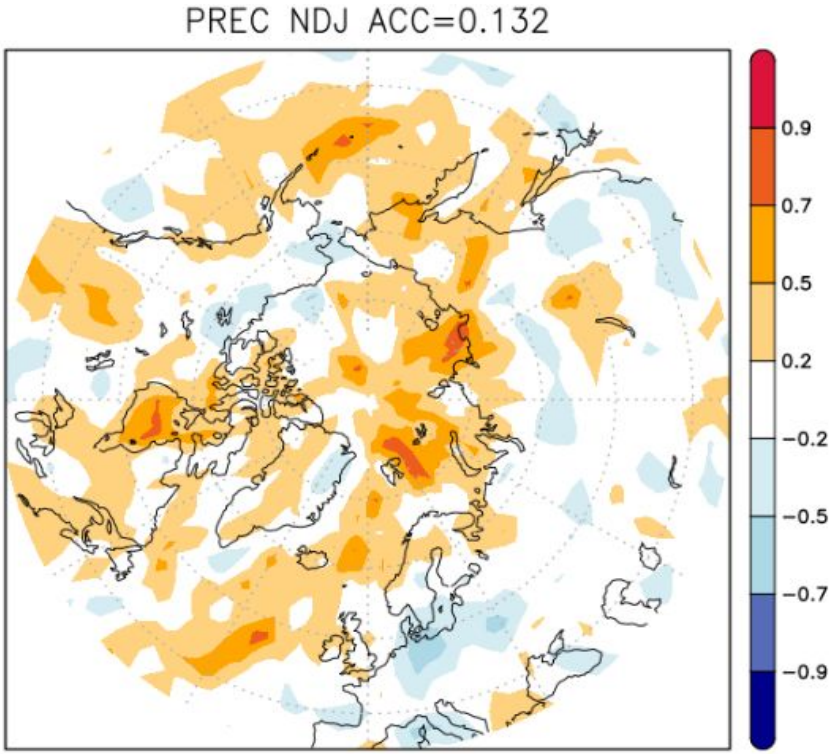
ACC=0.126 for 1993-2009 WMO multi-model ensemble

WMO LRF MME: https://wmolc.org/seasonVrfyHindDmmeUI/plot_VrfyHIND_DMME#

Probabilistic forecast for November-December-January (NDJ) precipitation anomalies in 2022/23 winter season based on the INMCM5 experimental forecast.



November-December-January (NDJ) anomaly correlation coefficients of precipitation anomalies based on the INMCM5 1993-2009 winter hindcasts and ERA5 reanalysis data.



ACC=0.141 for 1993-2009 WMO multi-model ensemble

WMO LRF MME: https://wmolc.org/seasonVrfyHindDmmeUI/plot_VrfyHIND_DMME#

Conclusion

- The INMCM5 climate model shows good skill in Arctic sea ice area and concentration winter seasonal hindcasts.

- November-December-January (NDJ) anomaly correlation coefficients of 2m air temperature, sea level pressure, precipitation anomalies based on the INMCM5 1993-2009 winter hindcasts and ERA5 reanalysis data are in good agreement with the WMO LRF MME.

- Experimental forecast of sea ice characteristics shows the ice freezing up lag at the beginning of the 2022/2023 winter season, which is consistent with the positive 2-m air temperature forecast anomalies in November-December-January.

- High probability of positive NDJ sea level pressure (SLP) anomalies according to the INMCM5 experimental forecast are expected in the Norwegian Sea and Baffin Bay.

- The INMCM5 climate model predicts a high probability of above normal NDJ precipitation anomalies in the Kara Sea, in the Laptev Sea, to the east of Spitzbergen and over the Canadian Arctic Archipelago.

- Forecasts based on the INM RAS climate model currently are calculated in experimental mode within the framework of scientific research. It is planned to test the forecasts at the Roshydromet Central Methodological Committee for Hydrometeorological and Heliogeophysical Forecasts level. In the future, steps may be taken towards offering an atmospheric forecast to the WMO LRF MME and ice characteristics forecast to the Arctic Regional Climate Centre.

Thank you!

E-Mail:

vasilisa.vorobyeva@phystech.edu
mashatarasevich@gmail.com
volodinev@gmail.com

This study was supported by Russian Fund for Basic Research (grant №20-05-00673)