Northern Hemisphere snow cover sensitivity to temperature changes in the CMIP6 model ensemble

Arzhanov M.M.[1], Mokhov I.I.[1,2], Parfenova M.R.[1]

[1]A.M. Obukhov Institute of Atmospheric Physics, RAS, 119017, Moscow, Russia
[2]Lomonosov Moscow State University, 119991, Moscow, Russia
arzhanov@ifaran.ru

Estimates of changes in the area of snow cover (SCE) in the Northern Hemisphere in the late 20th - early 21st centuries were obtained using the results of simulations with the ensemble of global climate models CMIP6. Monthly average values of the proportion of snow coverage and surface air temperature of the model grid cells were obtained based on the results of calculations with global climate models (CanESM5, CNRM-ESM2-1, IPSL-CM6A-LR, NorESM2-LM, UKESM1-0-LL) of the international project CMIP6 (https: //esgf-node.llnl.gov/search/cmip6/). For the period 1980-2014, the historical scenario was chosen and for the period 2015-2019, the anthropogenic impacts SSP2-4.5, realization of r1i1p1f1 (in its absence, r1i1p1f2) [1, 2] scenario was used. The SCE used for the calculations for the Northern Hemisphere did not include Greenland SCE.

Figure 1 shows the changes in the SCE depending on the surface air temperature of the Northern Hemisphere for the period 1980-2019 according to calculations with an ensemble of climatic models. The parameter of the sensitivity of the SCE to the changes in the surface air temperature, characterized by the coefficient of the corresponding linear regression, is estimated to be $-3.2(\pm 0.1)\times 10^6$ km^2 K^{-1}.

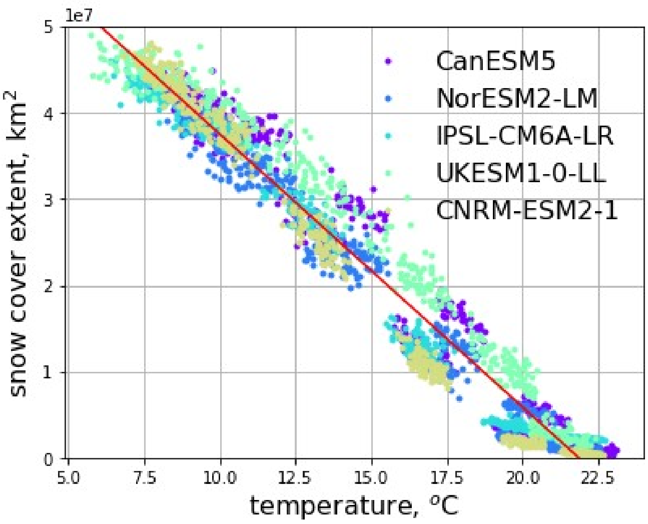

Fig.1. Relationship between the total SCE in the Northern Hemisphere and hemispheric surface air temperature for the period 1980-2019 according to calculations with a climatic models ensemble.

This is close to a similar estimate of the SCE sensitivity parameter to changes in the surface air temperature of -3.6×10^6 km^2 K^{-1} obtained in [3] using the NSIDC (https://www.ncdc.noaa.gov/) and GSL (https://climate.rutgers.edu/) data for the chosen period.

Estimates of changes in SCE in Eurasia and North America for different months depending on the surface air temperature for the two periods 1980-2019 and 2015-2030 are given in Table 1. The highest absolute values were obtained for spring and autumn seasons. The standard deviations of the regression coefficients are maximum in the autumn period and increase from 1980-2019 period to 2015-2030 period.

Table 1. Values of the linear regression coefficient and standard deviation for the snow cover extent S_s in Eurasia and North America for each month depending on the surface air temperature T_a in Eurasia and North America.

dS_s / dT_a, $\times 10^6$ km^2 / K				
Months	1980–2019		2015-203	
	Eurasia	North America	Eurasia	North America
January	-0.54 (±0.04)	-0.29 (±0.02)	-0.61 (±0.07)	-0.35 (±0.04)
February	-0.63 (±0.04)	-0.29 (±0.02)	-0.67 (±0.08)	-0.40 (±0.05)
March	-0.98 (±0.07)	-0.46 (±0.03)	-1.00 (±0.11)	-0.50 (±0.06)
April	-1.24 (±0.09)	-0.56 (±0.04)	-1.01 (±0.11)	-0.41 (±0.05)
May	-0.99 (±0.07)	-0.52 (±0.04)	-0.58 (±0.07)	-0.18 (±0.02)
June	-1.22 (±0.09)	-0.58 (±0.04)	-0.95 (±0.11)	-0.40 (±0.05)
July	-0.27 (±0.02)	-0.20 (±0.01)	-0.27 (±0.03)	-0.25 (±0.03)
August	-0.40 (±0.03)	-0.24 (±0.02)	-0.39 (±0.04)	-0.16 (±0.02)
September	-1.35 (±0.10)	-0.79 (±0.06)	-1.83 (±0.21)	-0.91 (±0.10)
October	-1.37 (±0.10)	-0.83 (±0.06)	-1.20 (±0.14)	-1.06 (±0.12)
November	-1.09 (±0.08)	-0.72 (±0.05)	-1.36 (±0.15)	-0.92 (±0.10)
December	-0.76 (±0.05)	-0.44 (±0.03)	-0.92 (±0.10)	-0.64 (±0.07)

Linear SCE trend values in the Northern Hemisphere for 1980-2019 according to calculations with an ensemble of models for the winter and spring periods exceed -50×10^3 km^2 yr^{-1}. The results obtained agree well with the estimates obtained in [1]. Analysis of the results of numerical experiments with the ensemble of climate models of the CMIP5 project also showed a decrease in SCE for all seasons for the period 1967–2018. [2].

This work is supported by the Russian Foundation for Basic Research (19-05-00409, 19-35-90118). Regional features of snow cover variability were analyzed within the framework of the Russian Science Foundation project 19-17-00240.

References

[1] Mudryk L., Santolaria-Otin M., Krinner G., Menegos M., Derksen C., Brutel-Vuilmet C., Brady M., Essery R. Historical Northern Hemisphere snow cover trends and projected changes in the CMIP6 multi-model ensemble. *The Cryosphere.* 2020, **14**: 2495-2514.

[2] Connolly R., Connolly M., Soon W., Legates D.R., Cionco R.G., Herrera V.M.V. Northern Hemisphere snow-cover trends (1967–2018): A comparison between climate models and observations. *Geosciences.* 2019, **9** (135): 1-23.

[3] Mokhov I.I., Parfenova M.R. Changes of the sea ice and snow cover extent associated with temperature changes in the Northern and Southern Hemispheres in recent decades. *IOP Conf. Series: Earth and Environmental Science.* 2021. (In press).