Atmospheric centers of action in the Northern and Southern Hemispheres: Tendencies of change in the 21st century from model simulations

Mokhov I.I.[1,2], Chernokulsky A.V.[1], Osipov A.M.[2]

[1]A.M. Obukhov Institute of Atmospheric Physics RAS

[2]Lomonosov Moscow State University

mokhov@ifaran.ru

The key large-scale structures in the atmosphere of the Earth climate system are atmospheric centers of action (CoA). CoA are clearly manifested in monthly and seasonal distributions of surface air pressure and characterize features of general atmospheric circulation [1,2]. Here, we estimate possible changes of CoA associated with global climate changes using simulations with the CMIP5 ensemble of climate models under various RCP scenarios of anthropogenic forcing in the 21st century, including the RCP4.5 and RCP8.5 scenarios.

Table 1 presents the estimates of changes in the intensity of various CoA by the end of the 21st century from simulations of monthly-mean surface pressure with INM-CM4, IPSL-CM5A-MR, MPI-ESM-MR climate models under the scenario RCP4.5. The CoA intensity was characterized by the extremal surface pressure Pextr and mean surface pressure Pmean for the corresponding CoA region (see [1,2]). Table 1 shows changes in the intensity of CoA (in hPa) for the period 2070–2099 relative to 1976–2005 in winter and summer.

Table. Changes in the intensity of CoA (hPa) for the period 2070-2099 relative to 1976–2005 in different seasons from simulations with three climate models under the RCP4.5 scenario with moderate anthropogenic forcing in the 21st century. Statistically significant changes at the 0.1, 0.05, and 0.01 significance levels are shown in italic, bold italic, and bold type, respectively. The blue color characterizes the strengthening (deepening) of the lows, red color shows the strengthening of the highs, the green color displays the weakening of the CoA.

CoA	INM-CM4		IPSL-CM5A-MR		MPI-ESM-MR	
	P mean	P extr	P mean	P extr	P mean	P extr
Southern Hemisphere						
Winter (June-August)						
Minima						
Indian	**-1.7**	**-1.5**	**-3.1**	**-2.7**	**-2.1**	**-2.1**
South Atlantic	**-0.9**	***-0.8***	**-2.6**	**-2.0**	**-2.2**	**-2.3**
South Pacific	***-1.0***	***-1.0***	**-3.0**	**-3.6**	*0.6*	**-2.0**
Maxima						
Antarctic	**-2.5**	**-2.8**	**-6.1**	**-6.2**	**-2.6**	**-2.8**
Mascarene	0.3	0.4	**1.2**	**1.2**	**0.8**	*0.5*
South Atlantic	0.3	0.3	0.3	0.3	***0.6***	**0.9**
South Pacific	**0.7**	**0.7**	**1.5**	**1.2**	*0.6*	***0.6***
Summer (December-February)						
Minima						
Indian	0.0	0.3	**-1.6**	**-1.4**	**-1.4**	**-1.4**
South Atlantic	0.0	0.2	**-2.1**	**-1.9**	**-1.5**	**-1.6**
South Pacific	0.5	*0.7*	**-4.7**	**-4.4**	**-2.0**	**-1.9**
Maxima						
Antarctic	-0.6	***-0.9***	**-7.3**	**-7.2**	**-2.8**	**-2.9**
Mascarene	-0.1	0.0	***0.5***	**0.7**	0.3	0.4
South Atlantic	0.0	0.0	***0.5***	***0.5***	0.1	0.2
South Pacific	-0.1	0.0	**0.9**	**0.6**	0.3	0.2

CoA	INM-CM4		IPSL-CM5A-MR		MPI-ESM-MR	
	P mean	P extr	P mean	P extr	P mean	P extr
Northern Hemisphere						
Winter (December-February)						
Minima						
Aleutian	***-0.8***	**-1.2**	-0.5	0.1	-0.4	*-0.7*
Islandic	**-1.7**	**-2.1**	*-0.9*	*-1.0*	-0.5	*-0.9*
Maxima						
Azores	***0.6***	**1.0**	-0.3	-0.4	*0.5*	***0.8***
Arctic	**-1.7**	**-1.8**	**-2.2**	**-2.7**	**-2.0**	**-1.9**
North Pacific	-0.5	0.1	0.1	***-0.7***	0.4	0.0
Greenland	**-1.9**	**-1.7**	0.0	0.5	***-1.2***	-0.8
North American	***-0.7***	*-0.6*	***-0.8***	-0.6	***-0.6***	-0.4
Siberian	*-0.5*	***-0.7***	***-0.7***	**-1.3**	*-0.6*	-0.4
Summer (June-August)						
Minima						
Asian	**-0.6**	**-0.7**	**-0.6**	***-0.4***	-0.1	0.0
Aleutian	**0.6**	-0.1	***-0.5***	*-0.4*	***-0.6***	***-0.5***
Islandic	**-0.9**	**-1.3**	**-1.2**	**-1.0**	0.3	0.2
	0.0	-0.1	***-0.4***	**-0.5**	**0.9**	**0.9**
Maxima						
Azores	-0.2	*0.4*	**-0.6**	0.0	0.1	0.3
Arctic	-0.4	-0.3	**-1.1**	**-1.6**	-0.1	-0.2
North Pacific	***0.3***	**0.5**	*-0.4*	0.1	-0.3	-0.4
Greenland	**-1.0**	***-0.9***	**-1.9**	**-2.6**	-0.3	-0.5

Results of model simulations in Table 1 under the RCP 4.5 scenario show general strengthening (deepening) of cyclonic CoAs (both year-round and seasonal) in both hemispheres for the last 30 years of the 21st century, relative to the current regime (1976–2005). At the same time, different trends appear for the North American summer minimum (low) for different models. For anticyclonic CoAs in the Northern Hemisphere, a general weakening of winter continental CoA prevails, the development of which is associated with surface cooling in the cold season. The most significant weakening was noted for the Greenland High. An increase in the intensity (stronger in winter) of oceanic subtropical maxima (highs), in particular in the Southern Hemisphere, can be associated with the expansion of the Hadley cell during global warming. In the Northern Hemisphere, for different models, differently directed tendencies of changes for the Azores and Hawaiian maxima (highs) were revealed. Weakening of the polar highs (Arctic and Antarctic) is noted, which is more pronounced in winter. This is associated with the poleward shift of the trajectories of extratropical cyclones. A more significant weakening is manifested under the RCP-8.5 scenario with stronger anthropogenic forcing in the 21st century.

This work was supported by the Russian Science Foundation project 19-17-00240.

References

[1] Mokhov I.I., Chernokulsky A.V., Osipov A.M. Changes in the characteristics of atmospheric centers of action. In: *Intense Atmospheric Vortices and Their Dynamics.* Ed. By I.I. Mokhov, M.V. Kurgansky, O.G. Chkhetiani. Moscow, GEOS, 482 pp. (In Russian)

[2] Mokhov I.I., Chernokulsky A.V., Osipov A.M. Atmospheric centers of action in the Northern and Southern Hemispheres: Features and variability. *Russ. Meteorol. Hydrol.*, 2020, **45** (10): 749-761.