Extreme precipitation and features of their precipitation in the territory of Perm region

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Introduction

This paper is devoted to the study of the formation of extreme precipitation in Perm region. Attention is paid to the spatial and temporal features of the distribution of cases with heavy precipitation, vertical motions of the atmosphere, synoptic situation, as well as the thermodynamic state of the atmosphere during heavy precipitation. The study was based on the use of information about the dates when extreme precipitation was observed in the period from 1979 to 2018, data from the reanalysis of the CFS model (Climate Forecasting System) at the time of 0, 6, 12, 18 hours of UTC, the archive of synoptic maps in the software complex «GIS Meteo» and data from weather stations about the observed phenomena and their duration.

Extreme precipitation, according to regulatory documents, can be divided into two groups: **heavy shower** and **very heavy rain**.

The criterion for **heavy shower** is the amount of precipitation more than 30 mm for a period of less than 1 hour; very heavy rain is the amount of precipitation over 50 mm (in rain-prone areas more than 30 mm) for a period of less than 12 hours.

In the Perm region, 5 weather stations out of 25 are located in rain-prone areas: Vaya, Gubakha, Biser, Kungur and Kyn.

Results and its discussion

A total of 134 reports of extreme precipitation were transmitted by weather stations in the Perm region during the period 1979-2018. At the same time, 13 times the hazardous phenomenon was recorded at two stations. Thus, during the study period, 121 cases of extreme rain were observed: 11 with heavy shower and 110 with very heavy rain.

Analysis of the temporal distribution of the number of cases with heavy rains revealed some periodicity (Fig. 1). Currently, there is a tendency to reduce the number of cases with heavy precipitation or to keep them at a low level.

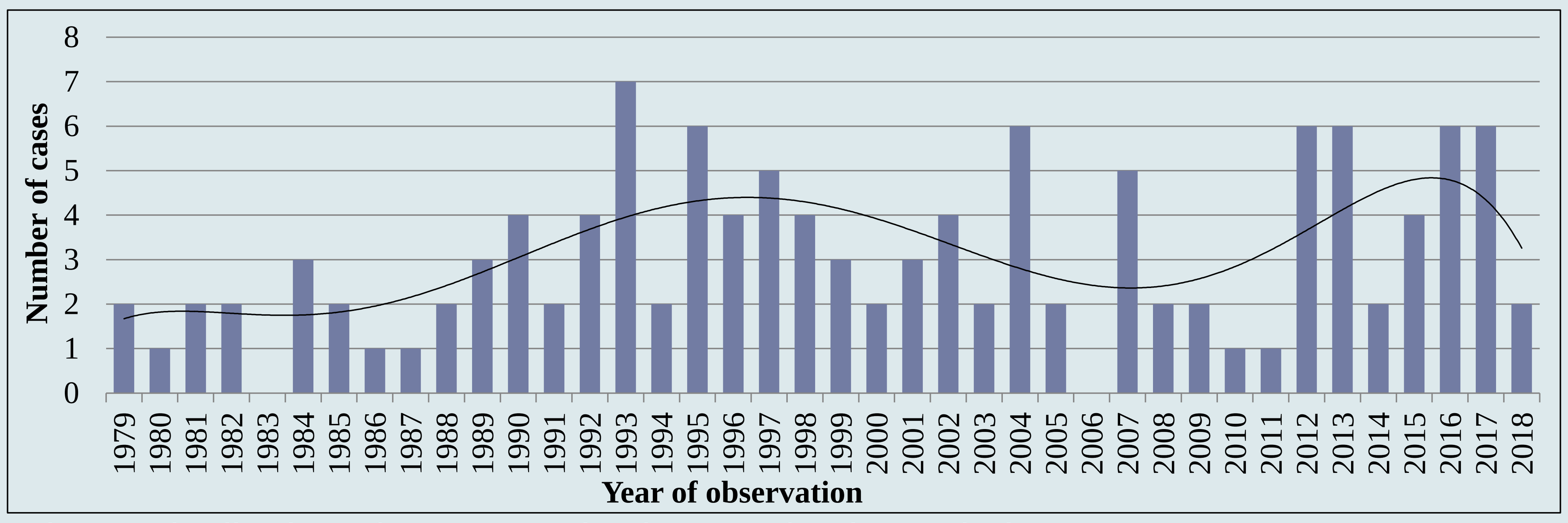

Fig. 1. Distribution of extreme rains by year for the period 1979-2018.

Analysis of the spatial distribution of cases with extreme precipitation on the territory of the Perm region showed that it has a meridional character (Fig. 2). Moreover, the frequency of cases with heavy precipitation increases from west to east.

The Ural Mountains play a special role in the distribution of heavy precipitation. As a natural barrier, they delay cyclones and their fronts over the Perm region, which contributes to longer and more intense precipitation.

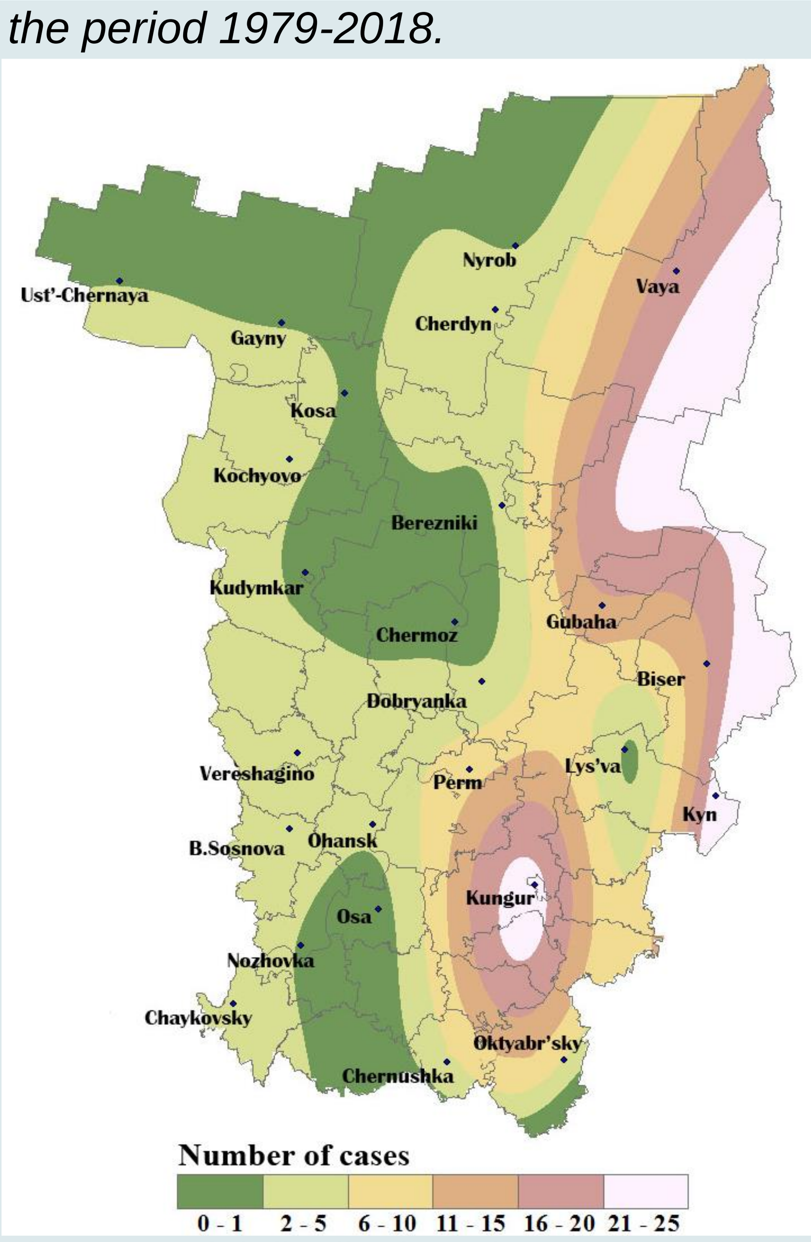

Fig. 2. Spatial distribution of extreme precipitation on the territory of the Perm region.

The study of vertical motions showed that the intensity of vertical motions depends on the stage of development of cyclones. The highest speed values are observed at the stage of a young cyclone (table 1). The lowest values of the speed of vertical motions are observed when heavy precipitation is not associated with cyclonic activity.

Tab. 1. Average values of vertical motions speed during heavy precipitation depending on the cyclone development

Stage of development of the cyclone	Height of the isobaric surface, hPa		
	850	700	500
Wave stage	–0,445	–0,651	–0,609
Young cyclone	–0,574	–0,776	–0,697
Maximum development	–0,399	–0,425	–0,468
Stage of filling up	–0,416	–0,501	–0,506
Intra-mass	–0,212	–0,219	–0,201

The most intense upward motions are observed with heavy precipitation associated with the frontal sections. (table 2). At the same time, the difference between the speed of updrafts on different fronts is insignificant. Intra-mass precipitation is formed at a lower speed of vertical motions.

Tab. 2. Average values of vertical motions speed during heavy precipitation depending on the synoptic situation

Height of the isobaric surface, hPa	Statistical characteristic	Synoptic situation				
		Cold front	Warm front	Occlusion front	A wave disturbance on an inactive front	Intra-mass
850	Max.	–0,059	–0,150	-0,160	-0,252	–0,048
	Min	–1,439	–1,176	–1,077	–0,717	–0,336
	Average	–0,471	–0,462	–0,457	–0,474	–0,204
	Median	–0,444	–0,445	–0,430	–0,476	–0,203
700	Max.	–0,006	–0,148	–0,165	–0,156	–0,040
	Min	–1,310	–1,668	–1,472	–1,328	–0,387
	Average	–0,533	–0,533	–0,580	–0,673	–0,205
	Median	–0,448	–0,541	–0,518	–0,667	–0,221
500	Max.	–0,071	0,007	–0,060	–0,189	0,004
	Min	–0,941	–1,528	–1,885	–1,629	–0,486
	Average	–0,490	–0,558	–0,592	–0,641	–0,187
	Median	–0,453	–0,422	–0,586	–0,509	–0,178

An important issue is the identification of synoptic conditions under which heavy precipitation occurs. In addition, the state of the atmosphere during heavy precipitation is of interest. For this, instability indices are used, which characterize the temperature and humidity state of the atmosphere (CAPE, LI, CIN, K, Fateev index, TQ Index, DCI, TI).

Most cases of extreme precipitation in Perm region are associated with the passage of occlusion fronts (33%) and cold fronts (23%). Less often, heavy precipitation is formed on warm fronts (13%). At the same time, cold fronts are characterized by higher values of instability indices than occlusion fronts (table 3).

Tab. 3. Values of instability parameters depending on the frontal system

Index	Characteristic	Cold front	Warm front	Occlusion front	A wave disturbance on an inactive front	Intra-mass
CAPE, J/kg	Median	479	146	212	287	1295
	Average	991	538	512	574	1258
CIN, J/kg	Median	0	0	0	0	0
	Average	–3	0	–1	–1	–2
DCI, °C	Median	23	17	20	23	25
	Average	23	18	17	21	26
Fateev index, °C	Median	22	20	22	22	16
	Average	20	18	21	20	15
K Index, °C	Median	35	33	33	35	34
	Average	35	33	32	35	34
LI, °C	Median	–2,0	–0,1	–0,2	–0,8	–4,1
	Average	–2,2	0,4	0,3	–0,3	–3,8
TI, °C	Median	37	34	34	37	37
	Average	36	34	33	36	37
TQ Index, °C	Median	20	18	18	20	20
	Average	19	18	18	19	20

Heavy precipitation, which have reached the criterion of a dangerous phenomenon are mainly of a shower-type (61%) and mixed type (32%) precipitation. The percentage of widespread precipitation is very small (7%).

Shower-type precipitation are most often formed on cold fronts and during intra-mass processes, while widespread and mixed rains are mainly associated with occlusion fronts (table 4).

Tab. 4. The frequency of occurrence of precipitation types depending on the synoptic situation (%)

Precipitation type	Cold front	Warm front	Occlusion front	Intra-mass	A wave disturbance on an inactive front
Shower-type	28	9	11	29	23
Widespread	20	20	60	–	–
Mixed	24	8	48	–	20

Tab. 5. Values of instability parameters depending on precipitation types

Index	Characteristic	Precipitation type		
		Shower-type	Widespread	Mixed
CAPE, J/kg	Max	3017	198	509
	Min	0	0	0
	Average	966	52	141
CIN, J/kg	Max	0	0	0
	Min	–19	–1	–2
	Average	–1	0	0
DCI, °C	Max	38	15	24
	Min	13	–3	–6
	Average	25	10	12
Fateev index, °C	Max	25	25	25
	Min	–26	19	0
	Average	16	22	21
K Index, °C	Max	42	36	37
	Min	21	22	19
	Average	35	30	31
LI, °C	Max	3,3	9,4	14,0
	Min	–8,1	0,2	–1,5
	Average	–2,7	3,4	3,0
TI, °C	Max	46	39	37
	Min	20	18	12
	Average	37	29	29
TQ Index, °C	Max	24	20	21
	Min	14	10	8
	Average	20	17	17

For different types of precipitation, differences in the values of instability indices are observed. This difference is most evident in the indices that characterize the instability of the atmosphere (CAPE, LI), and to a lesser extent is characteristic of the indices that characterize the conditions of humidification (K, Fateev index, TQ Index, DCI, TI), which indicates that the formation of heavy precipitation of stormwater, widespread and mixed types is characterized by almost identical temperature and humidity characteristics (table 5).

Extreme rains most often have a duration of precipitation from 4 to 6 hours. For widespread rains, the duration of precipitation is 10-12 hours. At the same time, there is a fairly strong feedback between the duration of precipitation and the values of instability indices. The higher the values of the instability indices, the shorter the duration is observed.