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Atmospheric Circulation Patterns and Flood Events in the South of Eastern Siberia (Based on the 2001 Flood)

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Abstract: The paper presents the findings of characteristics of atmospheric circulation and extreme floods in the Baikal region in July 2001. During the flood in July 2001, precipitation at the meteorological stations of the study area was significantly higher than normal. In July, the Inga station reported an impressive maximum precipitation of 311 mm, a remarkable 278% of the long-term average for the month. Historical maximums of daily precipitation were recorded at four meteorological stations. A comprehensive synoptic analysis was conducted to identify the main causes of the extremely high precipitation values that caused a rise in water levels on the left-bank tributaries of the Angara, the upper Lena, and on the rivers of South Baikal in July 2001. Synoptic processes were classified according to the Jenkinson and Collison weather types. For July 2001, eight weather types were identified, two of which – cyclonic and advective types with northern components – emerged prominently during the flood period. The directions of air mass transfer were determined based on the analysis of five-day backward trajectories of HYSPLIT. The following were found to be the primary determinants of the devastating flood's intensity: (1) active process of southern cyclogenesis; (2) development of blocking processes; (3) high content of precipitable water content over the study area.

Keywords: extreme rainfall floods, synoptic processes, atmospheric precipitation, HYSPLIT backward trajectories, south of Eastern Siberia

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Review

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1. Introduction

The most dangerous of all floods in the South of Eastern Siberia are rainfall floods. They have the highest frequency, and the largest flooding areas and severity of impact and are characterized by the greatest damage and by the largest number of victims and evacuated people [*Kichigina*, 2020; *Kichigina*, 2018]. The ridges and foothills of the Eastern Sayan Mountains in the basins of the left tributaries of the Angara River, as well as the mountain rivers of the Khamar-Daban, are the most flood-prone areas. The largest number of populated areas prone to flooding are located here, including the cities of Tulun, Nizhneudinsk, Irkutsk, Zima, and Angarsk. Damage to populated areas, agricultural and industrial enterprises in these densely populated and well-developed areas can be severe. The northern districts of the Irkutsk Region in the Lena River basin – Kachugsky, Kazachinsko-Lensky, Ust-Kutsky, and Kirensky districts – are also highly vulnerable. Despite the relatively sparse population density of these areas, most of the settlements are located along river banks and have long suffered from flooding, including Zhigalovo, Ust-Kut, Kirensk, and others.

It is advisable to consider the synoptic situations with prolonged precipitation rather than individual short-duration rainfall to estimate the maximum of possible precipitation which is needed to assess maximum of floods [*Bolgov et al.*, 2017]. Intense precipitation, which happens under specific atmospheric conditions, is the main cause of rainfall floods. Extreme precipitation is determined by the prevailing atmospheric circulation conditions in the area. Identifying the characteristics and patterns of atmospheric circulation during catastrophic, large-scale floods allows us to better understand the mechanisms underlying their formation and forecast such events.

The atmospheric circulation system will eventually need to be restructured as a result of the continuous climate changes. The frequency of catastrophic hydrometeorological events with substantial damage and frequent fatalities increases as a result. Here, flooding is a major problem, which happens everywhere and constantly, particularly in Russia. In recent decades, severe floods have occurred in the Amur and Ob river basins, as well as on the rivers of the South of Eastern Siberia. Atmospheric circulation played a leading role in their formation [*Antokhina et al.*, 2018; *Kononova*, 2014a,b; *Semenov et al.*, 2014; *Vasilevskaya et al.*, 2020].

The southern Baikal region recently experienced a devastating flood in 2019. Human deaths and significant material damage resulted from the devastating rainfall flood that affected the western and central Irkutsk oblast at the end of June 2019 along the Iya, Uda, Oka, and Biryusa rivers, which are left-bank tributaries of the Angara. Eight districts of Irkutsk oblast were affected. More than 109 communities, hundreds of kilometers of roads, crops, 22 bridges, more than 11,000 home plots, 10,890 residential buildings, and 86 socially significant facilities were destroyed or damaged. Twenty-six people died, five went missing, and 42,762 were injured. The town of Tulun, which was submerged in water to a depth of several meters, received the bore the brunt of the flood. Entire streets of wooden houses were carried away by the water flow, and multi-story buildings were submerged up to the third floor. In the town of Nizhneudinsk, 16,932 people and 3,798 homes were within the flood zone, while 10,739 people, 3,056 homes, and 290 hectares of buildings were in Tulun. The damage is estimated at 31.2 billion rubles. The second flood happened at the end of July 2019. The area that was flooded included seven districts. 3,207 home plots, 1,984 residential buildings, 5,424 persons, and 58 communities were impacted. An estimated 35.152 billion rubles have been damaged by the two floods, of which over 20 billion have been damaged in administrative and infrastructure facilities, 10.8 billion have been lost as a result of housing loss, and 420 million rubles have been lost in the agricultural complex [*Interfax-Russia.ru*, 2019].

Experts questioned whether the 2019 flood was a unique event. Among other events, the region experienced an exceptionally high amount of precipitation due to the peculiar state of air circulation. The flood of 2019 received a lot of attention from specialists [*Bolgov et al.*, 2020; *Makarieva et al.*, 2020; *Shalikovsky*, 2019; *Shalikovsky et al.*, 2019]. However, identical events happened here before. The last incident occurred in 2001 and was comparable in scale and devastation. Several areas of Irkutsk oblast experienced damage by the overflow of the Kitoy, Irkut, Belaya, Iya, and Oka rivers and their tributaries during the July 7–12, 2001 flash flood. Eleven people died and 12,000 were evacuated while more than 150 settlements with a total population of 460,000, including seven towns, became flooded and submerged. The estimated damage resulting from the recent flood is approximately 1.75 billion rubles. This unfortunate event was primarily caused by heavy rainfall in the Baikal region, which exceeded the monthly average for several consecutive days. The situation was particularly severe in the Ziminskii district of Irkutsk oblast, where several thousand homes were affected by flooding. Both 2001 and 2019 were marked by exceptionally heavy precipitation in the days leading up to the floods (3–5 days prior to the peak), with many meteorological stations reporting daily precipitation maxima that were unprecedented within the entire observation period.

The aim of this study was to evaluate the characteristics of atmospheric circulation that contributed to the occurrence of extreme floods in the river basins of southern Eastern Siberia in July 2001.

2. Materials and Methods

The paper considers the extreme flooding events that occurred in the rivers of southern Eastern Siberia in 2001. The focus of the study includes the basins of the left tributaries of the Angara River – specifically the Irkut, Kitoy, Belaya, Oka, Iya, Uda and Biryusa – as well as the upper reaches of the Lena River and the rivers surrounding Southern Baikal. Data from Roshydromet regarding water levels at hydrological posts [*Rosvodresursy*, 2019] and precipitation measurements from meteorological stations (available at https://meteo.ru) were utilized for this analysis. The study determined the exceedance of critical water levels (H_{cr}) at hydrological posts, indicating the onset of flooding [*Resources…*, 1972; *Resources…*, 1973]. Furthermore, an analysis of precipitation was conducted, which included a review of annual rainfall as well as precipitation during the warmer months (May to September) in relation to long-term averages. This analysis also encompassed precipitation data for one and two months prior to the flooding events, which helped characterize the preceding wetting of the catchment area; daily maxima for the entire observation period and the dates of their occurrence, as well as daily precipitation in years with floods. In addition, an analysis of daily precipitation on the eve of the flood and its sum before the peak of the flood was performed. The locations of hydrological posts and meteorological stations is shown in Figure 1. Sea level pressure fields, geopotential height maps (H_{850}, H_{700}, H_{500}), fields of precipitable water (PW) and vertical movements were used for synoptic analysis. Composite maps were created for different periods. The analysis of the directions of air mass transfer entering the study area was performed using the HYSPLIT model (Hybrid Single Particle Lagrangian Integrated Trajectory) [*Rolph et al.*, 2017; *Stein et al.*, 2015]. The HYSPLIT model is a complete system for calculating simple airflow trajectories, as well as complex transport, dispersion, chemical transformation, and deposition modeling. In this paper, the model is used to analyze backward trajectories of air masses. 120-hour back trajectories were constructed for three levels corresponding to the surface layer – 0 m, the lower troposphere – 2,000 m, and the middle troposphere – 5,500 m. This choice of altitudes reflects the expected altitudes from which the air mass begins to move. This takes into account moisture-bearing air flows both in the ground layer and at mid-tropospheric level. Points with coordinates corresponding to the centers of the study area were selected as initial points. NCEP/NCAR reanalysis data were used as a meteorological archive of the model [*Kalnay et al.*, 1996]. The NCEP/NCAR reanalysis incorporates satellite data in addition to observational data to provide a more accurate picture of cyclone movements.

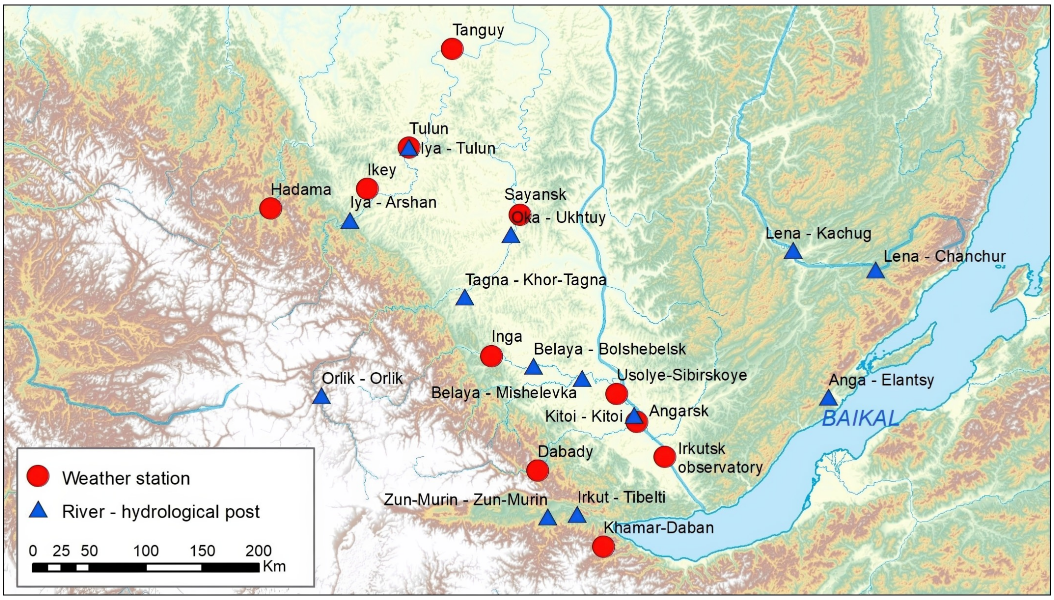


Figure 1. The layout of hydrological posts and meteorological stations.

To identify weather types, we utilized the objective classification system developed by Jenkinson and Collison [*Jenkinson and Collison*, 1977], which offers advantages of objectivity and compatibility with reanalysis data. The classification includes 27 weather types grouped into three categories, cyclonic (CYC), anticyclonic (ANT), and advective (ADV), and unclassified type U representing a baric field with weak gradients. This classification has been validated for the southern region of Eastern Siberia [*Osipova and Osipov*, 2022]. The synoptic type classification is based on calculating air flow parameters at 16 evenly spaced points, specifically between latitudes 47.5 and 67.5° N and longitudes 102.5 and 132.5° E, centered over flood-affected areas. The initial data comprised daily NCEP/NCAR reanalysis data for June and July 2001.

3. Results and Discussion

3.1. Peculiarities of the Synoptic Situation from July 4 to 12, 2001

The primary baric formations responsible for the moisture inflow to the Baikal region during the summer months are Mongolian cyclones. Notably, the severe flooding experienced in the Baikal region's rivers in 1971 was attributed to southern cyclogenesis occurring in the atmospheric boundary layer [*Osipova and Kichigina*, 2024]. Similarly, during the flooding of the southern Irkutsk oblast's rivers in July 2001, we observed active cyclogenesis linked to the emergence of a Mongolian cyclone. In contrast, the floods of June and July 2019 presented a different and somewhat atypical synoptic situation. In that instance, precipitation was predominantly frontal and associated with a high-altitude cyclone and blocking processes, characterized by a low-mobility high-altitude meridional ridge over Eastern Siberia [*Osipova*, 2020].

The weather conditions in the southern Irkutsk oblast on July 4 were mainly influenced by the high-pressure baric field with weak gradients, associated with an isolated anticyclone. Meanwhile, the northern areas of the region were under the influence of a cyclone (with a pressure in the center of 995 hPa). On that day, a high-altitude trough extended from a large cyclone situated south of the Ob bay toward the Irkutsk oblast, where the study area was affected by the front part of the baric trough. A baric ridge extended from Mongolia to Transbaikalia. On the isobaric surface of H_{850} on July 4, the study area was located within a zone of thermal gradients resulting from the interaction of a warm air mass over Mongolia and a cold trough extending from the Krasnoyarsk Territory. On July 6, an independent cyclonic circulation center formed over Lake Khovsgol in the front part of the baric trough, which was also evident at the H_{500} level. By July 5–6, the cyclone center shifted from southern Mongolia to its central regions, and on July 6, the study area was influenced by the northern periphery of this cyclone. By July 7, the center of the high-altitude cyclone had moved to the southeastern shore of Lake Baikal, and the study areas were under the influence of the rear part of the cyclone, which facilitated the influx of cold and moist air masses into the region (Figure 2).

In the lower layers of the troposphere (H_{850}), the southern region of Transbaikalia was influenced by a cyclone that had originated from the areas of China and Mongolia (Figure 3). The southern part of Irkutsk region found itself in the rear sector of the cyclone, experiencing the effects of northeastern and northern air currents. These air currents were oriented nearly at right angles to the Eastern Sayan mountain range, which led to forced convection as they ascended the mountain slopes. The weather conditions at the surface in the study area from July 7 to 9 were shaped by the interaction between the rear section of the Mongolian cyclone (with a minimum pressure of 996 hPa) and a center situated over Transbaikalia, along with the eastern edge of a baric ridge extending from the west (Figure 4). The study area was located in a region characterized by heightened thermal and baric gradients. A baric ridge over the western Pacific coast hindered the further eastward movement of the cyclone. The cyclone's intensity was supported by dual temperature advection, involving the inflow of warm air from China at the front and cold air advection from the rear. In the middle troposphere, the rear section of the high-altitude cyclone centered over Transbaikalia and the Far East influenced the pressure field across

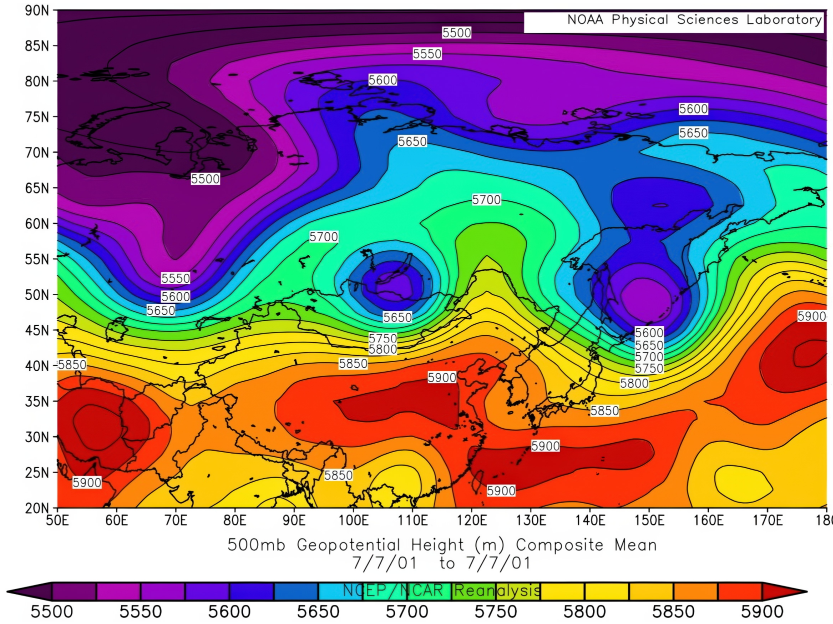


Figure 2. 500 mb geopotential height at 00:00 UTC (July 7, 2001).

the central and southern parts of the Irkutsk oblast. This convergence of surface and high-altitude cyclonic fields resulted in the formation of a center with significant upward vertical movements. At H_{850}, the thermal field was characterized by a trough. Convective instability is crucial for precipitation formation, and favorable conditions for this process were present specifically in the centers of the tropospheric cold, as observed in the study area. Additionally, a center with a high precipitable water (PW) values developed over the study area, which, when combined with the ascending vertical movements, resulted in heavy precipitation.

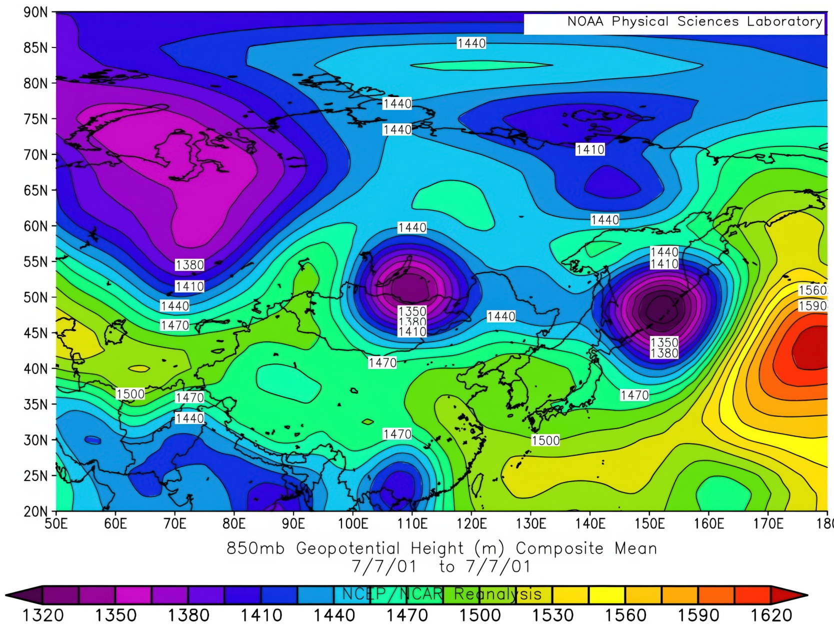


Figure 3. 850 mb geopotential height at 00:00 UTC (July 7, 2001).

From July 10, the cyclone center transitioned to the Far East and China, while a baric ridge spread from Mongolia to southern and western regions of the Irkutsk oblast and further to Yakutia.

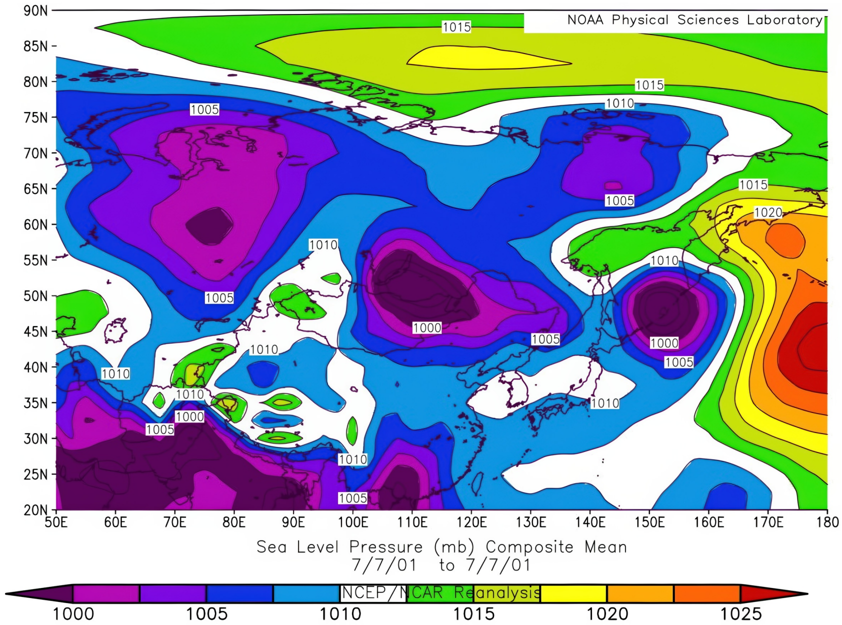


Figure 4. Sea level pressure field at 00:00 UTC (July 7, 2001).

3.1.1. Synoptic Classification

In July 2001, according to the Jenkinson and Collison classification, eight weather types were recorded. The highest frequency was noted for U-types (weak gradient pressure field) over 12 days (39%), followed by anticyclonic types (A, AS, AN, AE) over 11 days (35%), advective types (N, NE) for 4 days (16%), and cyclonic types (C) for 3 days (10%). Notably, a cyclone (type C) was present during the rain flood period from July 7 to 9, 2001. This distribution of weather types aligns with the catalog of weather types compiled for Eastern Siberia [*Shalikovsky et al.*, 2019]. Cyclonic and advective types with an eastern component are associated with humid weather conditions, with cyclonic types contributing significantly to annual precipitation (CYC). In summer, types with a northern component (N and NW) make a large contribution to the amount of precipitation.

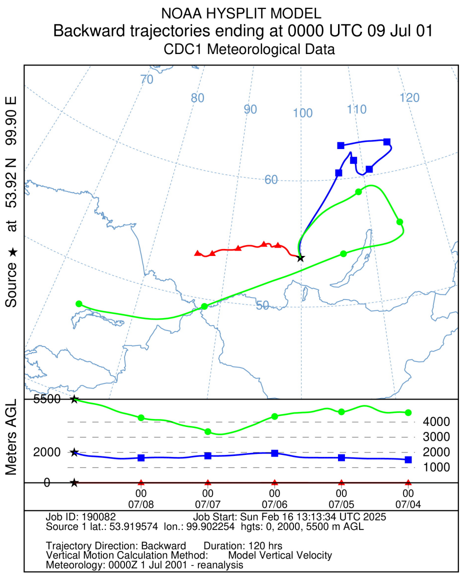
3.2. The HYSPLIT Backtracking Model

HYSPLIT was employed to analyze the trajectories of air mass transport related to the air masses entering the study area. The model facilitated the construction of 120-hour backtracks corresponding to the centers of the study areas at three levels: the surface layer (0 m), lower troposphere (2,000 m), and middle troposphere (5,500 m) (Figure 5).

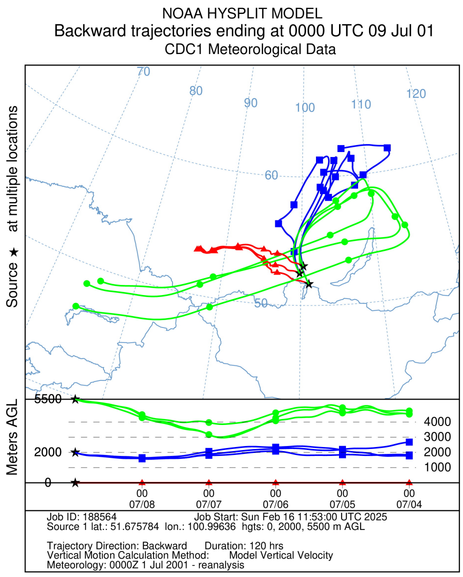
The backward trajectories of airflows for the Iya basin (Figure 5a), the Irkut, Kitoy, and Oka basins (Figure 5b), and the Southern Baikal river basins (including Snezhnaya, Utulik, and Khara-Murin) (Figure 5c) exhibit similarities in both the surface layer and the lower troposphere. In the five days leading up to July 9, 2001, air masses moved from the southern regions of Western Siberia in the surface layer, while in the lower troposphere, they originated from Yakutia. A significant southwesterly transport was noted in the middle troposphere within the basins of the left-bank tributaries of the Angara (Iya, Irkut, Kitoy, and Oka), as depicted in Figures 5a and 5b, resulting in air masses arriving from the eastern regions of Kazakhstan. In contrast, air masses flowing into the rivers of South Baikal (Figure 5c) originated from the eastern areas of China.

3.3. Precipitation and River Water Levels During the Flood on July 7–12, 2001

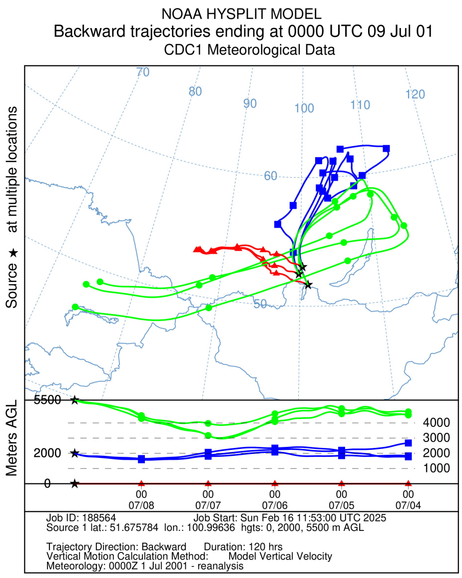
During the outstanding floods of July 7–12, 2001, many areas of the Irkutsk Region suffered from the overflow of the Kitoy, Irkut, Belaya, Iya, and Oka rivers and their tributaries. More than 150 settlements, with a total population of approximately 460,000, including seven cities, were affected within the Angara basin. Tragically, 11 lives were



(a)



(b)



(c)

Figure 5. (a) July 09, 2001, Iya basin; (b) July 09, 2001, Irkut, Kitoy and Oka basins; (c) July 09, 2001, Southern Baikal river basins.

lost, and 12,000 individuals were evacuated. Damage from the flood was estimated to be around 1.75 billion rubles. The main cause was heavy rainfall in the Baikal region, which exceeded the monthly normal for several days. The situation was particularly dire in the Ziminskii district of Irkutsk oblast, where several thousand homes were inundated.

In 2001, critical levels of H_{cr} (beginning of the flood) were exceeded at hydroposts in July 6–13 on rivers in the Angara, Upper Lena and southwestern parts of Lake Baikal basins (Table 1).

In 2001, the annual precipitation was noted to be somewhat above the average long-term values, ranging from 111% to 147% of the long-term norm at the analyzed meteorological stations. However, the high-mountain meteorological station Khamar-Daban recorded lower precipitation, only 88% of the norm. In the Iya basin (Tanguy, Tulun, and Ikei meteorological stations), precipitation values were close to the norm.

During the warm period (May to September) of 2001, precipitation again exceeded the average long-term values, measuring between 111% and 159%, with the exception of the Khamar-Daban station. The highest precipitation amounts for the year and the warm

Table 1. Maximum exceedances of H_{cr} on rivers during the flood of July 7–12, 2001

River – hydropost	Date of maximum	Duration of H_{cr} excess / number of days	H_{max}, cm	H_{cr}, cm	Weather type
Upper Lena Basin					
Lena – Kachug	12.07	12–13.07 / 2 days	263	240	N
Lena – Chanchur	10.07	1 day	283	280	N
Lake Baikal Basin					
Anga – Elantsy	16.07	15–21.07 / 7 days	375	320	U
Snezhnaya – Vydrino	08.07	1 day	440	390	C
Angara Basin					
Irkut – Tibelti	08.07	1 day	644	600	C
Zun-Murin – Zun-Murin	07.07	1 day	285	150	C
Kitoy – Razdolye	07.07	1 day	330	280	C
Kitoy – Kitoy	09.07	1 day	622	550	C
Belaya – Mishelevka	09.07	1 day	822	800	C
Belaya – Bolshebelsk	08.07	1 day	827	680	C
Oka – Ukhtuy	09.07	1 day	662	400	C
Orlik – Orlik	07.07	1 day	187	190	C
Tagna – Khor-Tagna	08.07	1 day	507	460	C
Iya – Tulun	10.07	1 day	752	700	N
Iya – Arshan	08.07	1 day	445	400	C

period were observed at the Inga meteorological station (Belaya River basin) with 159% and at Khadama (Uda and Iya River basins) with 156%.

The precipitation in June 2001 indicates an initial moistening of the area. At a number of stations, precipitation in June was significantly below normal. The lowest amounts were observed at the Khamar-Daban station (43%), Dabady (Kitoy River basin) (55%), and the Irkutsk observatory (Irkut and Olkha basins) (73% of the norm). Conversely, the greatest precipitation was recorded at the Orlik (Kitoy, Irkut, and Oka) weather station with 194%, Tanguy (Iya basin) with 189%, and Khadama (Uda and Iya basins) with 166% of the norm. Overall, the daily maximums for June 2001 were considerably lower than the average long-term values.

In July, precipitation at most weather stations significantly surpassed the long-term averages, reaching almost twice the normal value. The most notable deviations were observed at the Inga (Belaya) weather station, which recorded 278% (311 mm), the Irkutsk observatory (Irkut and Olkha basins) at 254% (264 mm), and Angarsk (Kitoy) at 196% (202 mm). In the Iya basin, the precipitation values at the Ikei, Tanguy, and Tulun weather stations were close to the long-term average.

Daily maxima for July ranged between 29 mm and 185 mm, exceeding the average long-term daily maxima at the Angarsk weather station (128 mm, 376%), Usolye-Sibirskoye (97 mm, 323%), Irkutsk observatory (93 mm, 321%), and Inga (111 mm, 358%). At these four weather stations, the daily maximum recorded on July 7, 2001, was the highest for the entire observation period up to 2006.

The river levels experienced a significant rise between July 6 and July 8, reaching their maximum values 2 to 5 days later, on July 8–12. Following this period, the levels decreased sharply over the course of two days, after which they continued to decline gradually, returning to pre-flood levels in some rivers, while other rivers recorded levels above their pre-flood values. Continuous precipitation began on July 3 and 4, persisting almost uninterrupted across all meteorological stations reviewed (Table 4) until July 9. The highest precipitation amounts were observed at the Khamar-Daban meteorological station, with 314 mm, followed by Inga with 220 mm, and the Irkutsk observatory with 129 mm.

Table 2. Characteristics of precipitation for 2001 in comparison with the entire observation period

Weather station (river basin)	Observation period	Annual precipitation		Precipitation per warm period (V–IX)		Amount of precipitation per month			
						June		July	
		2001 year / average for the whole period	% of average	Warm period of 2001 / average for the whole period	% of average	June / average for the whole period	% of average	July / average for the whole period	% of average
Dabady (Kitoy)	1966–2006	no data / 770	–	no data / 630	–	65/118	55	204/203	100
Angarsk (Kitoy)	1935–2006	495/426	116	364/326	111	51/64	80	202/102	196
Usolye-Sibirskoye (Kitoy, Belaya)	1974–2006	434/391	111	353/304	116	83/62	134	163/87	187
Irkutsk observatory (Irkut, Olkha)	1891–2006	578/470	123	451/352	128	53/73	73	264/104	254
Khamar-Daban (Irkut)	1936–2006	1237/1399	88	859/1000	86	85/196	43	430/288	149
Inga (Belaya)	1936–2006	793/538	147	623/391	159	83/80	103	311/112	278
Sayansk (Oka)	1987–2006	628/449	140	491/312	157	91/70	130	177/81	220
Ikey (Iya)	1936–2006	439/485	90	343/370	93	74/69	107	123/111	111
Tanguy (Iya)	1936–2006	396/399	99	290/284	102	104/55	189	89/82	108
Tulun (Iya)	1908–2006	398/421	95	304/313	97	87/60	145	79/93	85
Khadama (Uda, Iya)	1940–2006	636/556	143	540/466	156	159/96	166	182/136	134

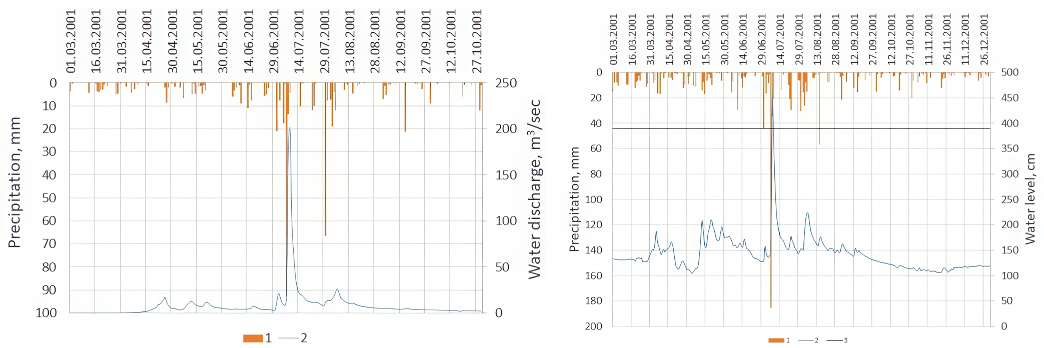
Conversely, the lowest amounts were recorded at the Tulun meteorological station with 33 mm and Khomutovo with 14 mm. Notably, after the daily maximum precipitation on July 7, 2001, the peak of the flood in the rivers occurred 1 to 2 days later (Figure 6).

Table 3. Characteristics of daily maximum precipitation for June and July 2001 in comparison with the entire observation period

Weather station (river basin)	Observation period	June	July	
		June 2001 / avg. for obs. period / % of average	July 2001 / avg. for obs. period / % of average	Max for July for all years / date
Dabady (Kitoy)	1966–2006	16/28/57	42/49/86	102/1987
Angarsk (Kitoy)	1935–2006	12/21.4/56	128/34.4/376	128/07.07.2001
Usolye-Sibirskoye (Kitoy, Belaya)	1974–2006	22/20/110	97/30/323	97/07.07.2001
Irkutsk observatory (Irkut, Olkha)	1891–2006	11/23/48	93/29/321	93/07.07.2001
Khamar-Daban (Irkut)	1936–2006	29/54/54	185/76/243	260/26.07.1971
Inga (Belaya)	1936–2006	20/22/91	111/31/358	111/07.07.2001
Sayansk (Oka)	1987–2006	27/24	70/28	89/01.07.2006
Ikey (Iya)	1936–2006	16/19/84	32/31/103	93/08.07.1961
Tanguy (Iya)	1936–2006	29/17/170	20/26/77	90/10.07.1941
Tulun (Iya)	1908–2006	25/17/147	18/27/67	101/10.07.1919
Khadama (Uda, Iya)	1940–2006	23/21/109	24/30/80	100/30.07.1980

Table 4. Atmospheric precipitation and water level during the flood of July 7–12, 2001

Date	Precipitation at weather stations							Water level at the hydroposts, cm		
	Orlik	Tulun	Inga	Irkutsk observatory	Tunka	Khamar-Daban	Kazachinskoe	Olkha-Olkha	Snezhnaya – Vydrino	Lena – Kachug
30.06.01	19.1	0.0	0.0	0.0	2.9	2.9	0.1	3.28	128	47
01.07.01	8.8	0.0	2.2	21.0	20.2	43.8	2.7	11.1	130	48
02.07.01	0.0	0.0	0.0	0.0	0.0	0.0	0	21.3	158	48
03.07.01	1.1	6.2	18.0	7.7	16.5	16.4	30.9	18.5	144	50
04.07.01	9.6	1.1	0.8	0.0	0.1	1.6	9.3	12.2	138	55
05.07.01	0.0	0.0	24.8	17.4	7.0	8.2	5.8	10	137	55
06.07.01	29.7	3.7	44.3	0.5	3.5	1.1	0	8.74	141	64
07.07.01	24.5	3.5	111.4	92.8	36.3	185.2	1	17.8	202	73
08.07.01	0.3	0.3	4.9	13.6	0.3	34.3	4.4	186	440	104
09.07.01	0.0	18.2	15.5	4.3	0.0	20.6	0	201	364	152
10.07.01	0.4	0.1	0.0	0.0	0.0	0.0	19	101	286	192
11.07.01	0.3	0.0	0.0	0.0	0.0	0.0	3.5	66.4	232	235
12.07.01	0.0	0.0	0.0	0.0	0.0	0.0	0.1	43.5	206	262



(a) **(b)**

Figure 6. Atmospheric precipitation at weather stations and water levels at hydroposts during the flood of 2001. (a) Irkutsk weather station observatory (1) and water discharge hydrograph at the hydropost Olkha – Olkha (2); (b) Khamar-Daban weather station (1), water level hydrograph at the hydropost Snezhnaya – Vydrino (2), critical level H_{cr} (3).

4. Conclusions

During the July 2001 flood, most meteorological stations in the study area recorded precipitation amounts that were almost twice as high as the long-term average. A comprehensive synoptic analysis helped to identify the main causes of the extremely high precipitation amounts that caused a rise in water levels on the left-bank tributaries of the Angara River, the upper reaches of the Lena River, and the rivers of Southern Baikal in July 2001. The main factors that determined the intensity of catastrophic flood were: active cyclogenesis from the south (Mongolian cyclone, weather type C according to the Jenkinson and Collison classification); a sharp increase in meridional cold and warm air flows and the development of blocking processes; convective instability; a high content of potentially accumulated moisture; ascending vertical air movements and forced convection in the foothills; local orographic conditions.

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