

Field survey of the 2025 Kamchatsk Tsunami on coasts of the Northern Kurilis, Russia (2d Kuril Strait)

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Abstract

On July 29, 2025, a strong earthquake near Kamchatka (Russia) generated the tsunami that spread across the entire Pacific Ocean. The tsunami had its strongest impact on the coast of the northern Kuril Islands (Paramushir and Shumshu), causing great destruction. During the first days after the earthquake, the field survey of tsunami traces on these islands was conducted in the area of the Second Kuril Strait (that divides these islands), and the boundary of land inundation by tsunami waves was outlined using GPS. Runup heights were determined using GEBCO_2019 (grid with 15 arc-second resolution) topographic maps installed into Google Earth. The observation results are summarized in this paper.

1. Introduction

The catastrophic earthquake with the magnitude of 8.8 occurred at 23:24:52 UTC on July 29, 2025, or at 11:24:52 on July 30, local Kamchatka time. The characteristics of the earthquake, now called the Kamchatka earthquake, are given in the paper [Benz et al, 2025]. The epicenter was located at the point with coordinates: 52.5°N, 160.3°E, at the depth of 30 km, but the focus itself extended to the south for the distance of 500 km. This mega-earthquake is among the ten strongest earthquakes in the entire history of observations. It led to local destruction in populated Kamchatka areas: the wall of a kindergarten collapsed, cracks appeared in houses, chimneys were destroyed, but fortunately there were no human casualties. The earthquake caused the tsunami that spread across the entire Pacific Ocean. Tsunami alerts were announced in almost all Pacific Ocean countries, including Russia. Tsunami waves of up to 4 m were registered in Kamchatka (we should note that water level fluctuations were also observed in the inland Kuril Lake), but they did not cause any particular consequences. The tsunami had its strongest impact on the city of Severo-Kurilsk (Paramushir Island, Russia). The water reached the Alaid fish processing factory. The Severo-Kurilsk port and the fishing enterprise were flooded by the tsunami. The tsunami caused ships to be torn off in the port and carried into the Second Kuril Strait (between the islands of Paramushir and Shumshu). Fortunately, the city itself has been rebuilt on higher ground over the years, therefore, there turned out to be neither human deaths nor casualties. On the neighboring island of Shumshu, a tent camp was flooded by the tsunami waves, but its inhabitants got saved on a higher ground. Just a few hours after the tsunami waves arrived, videos were distributed on the Internet showing the coastline flooding by tsunami waves on the islands of Paramushir and Shumshu (the Northern Kuril Islands). The geographic region map with the tsunami epicenter indicated is shown in Fig. 1.

We conducted a field survey of tsunami traces on these islands in the area of the Second Kuril Strait, which separates these islands, and analyzed the data obtained. The survey of tsunami traces in the city of Severo-Kurilsk (Paramushir Island) was made one day after the tsunami - on August 1, and on Shumshu Island (former settlements of Baikovo and Kozyrevsky) two days later - on August 2

2. Methodology for measuring the flood zone

The aim of the measurements was to trace the tsunami wave splash line on the coast. This line is clearly visible by the various object ejection (garbage, boards, ropes, etc.) and the strong grass flattening. The coordinates of the splash line points were measured using a GPS navigator (Garmin GPSmap 65S). Then, using the General Bathymetric Chart of the Oceans (GEBCO_2019, grid with 15 arc-second resolution), which is installed into Google Earth, the height of these points above the sea level (the zero level in the Baltic system) and the distance of the splash line from the water edge were determined. We would like to note that the tsunami occurred at low tide. Thus, according to the tide table, the sea level dropped from 1.6 m at 10:00 to 1.2 m at 12:00, and then to 1 m at 14:00 Kamchatka time (let us recall that the earthquake occurred at 11:24 local time). Therefore, the measured heights of the place on the topographic map correspond to the actual wave heights above low tide, which are 1.2 m higher. However, below we will provide the height data according to the topographic map without making the tide correction.

This mapping method has been recommended in the ITST-Post-Tsunami Survey Field Guide (ITST, 2014) and already partially used during the the 2018 tsunami survey in Sulawesi Island (Indonesia) [Omira et al, 2019].

3. The coastal zone survey of Severo-Kurilsk, Paramushir Island

The coastal zone map of Severo-Kurilsk is shown in Fig. 2. The red line on it shows the line of coast flooding by tsunami waves, outlined during the survey. Here are also the numbers of the points for which we will give more detailed information about the flooding.

First of all, we will mention several flooding shots of the Severo-Kurilsk port taken from various video clips which appeared in large numbers on the Internet (Fig. 3). The characteristic points from these clips have been transferred onto the map (top left). Let us note that all the objects (hangars, barrels), which allowed us to determine the position of these shots on the map, are clearly visible in the shots.

Point 1 (50.683516°, 156.124325°) - Fig. 4

The height of this point relative to the sea level according to the topographic map is about 5m, the distance to the water edge is 450 m. The grass flattened by water and the garbage lane brought by water are observed in this place. The last line where the garbage was carried by the wave is clearly visible. It is worth noting that the road running parallel to the coast became an obstacle for the tsunami. The wave crossed it only in a few places where the road passes through streams.

Point 2 (50.677960°, 156.126235°) – Fig. 5

The height of this place relative to the sea level according to the topographic map is about 5m, the distance to the water edge is 550 m. The grass, flattened by water, is observed in this place. It is important to note that the river, along which the wave passed more than 650 m deep into the land, flows in this place. Visually, the width of the stream bed after the tsunami increased three-to-four times.

Point 6 (50.675025°, 156.131761°) – Fig. 6

The height of this point relative to the sea level according to the topographic map is about 6m, the distance to the water edge is 550 m. The grass flattened by water and the garbage lane are observed in this place. The narrow tongue-like coastal flooding is clearly visible. The water did not reach the buildings by about 20 m.

The summary picture of the Severo-Kurilsk flooding line is shown in Fig. 7 with the red line. The splash heights along this line are also shown here. As one can see, the maximum splash height was about 10 m. This place is shown in Fig. 7 with the vertical arrow and in more detail in Fig. 8. The coordinates of the place are: 50.675669°N, 156.14124°E and the distance from the shore is 260 m. Outside this place, the splash height is almost constant along the coast and on the left side of the port is 5 m. To the right of the port, the splash heights are higher and reach 7 m. The riverbed can be seen on the right side of the map. It is difficult to tell visually how far the wave traveled along the river, but garbage traces are visible at a distance of 100 m from the sea.

4. The tsunami trace survey on Shumshu Island (former Baikovo and Kozyrevsky settlements)

The settlement of Baikovo (currently uninhabited) is located on the coast of the Second Kuril Strait between the islands of Paramushir and Shumshu. The work was carried out on August 2, 2025, two days after the event. The measurement method is the same as during the survey of Severo-Kurilsk.

The video showing how the tsunami almost completely flooded the diesel power plant has been distributed on the Internet (shown by the arrow in Fig. 9). Let us note that the plant height is about 3 m, and it is located at an altitude of 3 m above the sea level. According to eyewitnesses, when the wave arrived, the diesel power plant was not completely hidden under the water. Therefore, the maximum height is estimated to be slightly less than 6 m.

The same figure shows the maximum splash line in the area of Baikovo settlement (the red line). The maximum height reached 15 m at the point with the coordinates: 50.716564°, 156.199945°, and the distance of this point from the water edge was 500 m in a straight line.

In Fig. 9a wide tongue-like area where the wave passed far along the shore can be seen; see also Fig. 10. The Nikolaevka River, about 2m wide flows in the lowland here. The water spread to the width of about 150m, maximum 170m.

Below we will provide several photos of the flooded areas taken during the survey. The point numbers are shown in Fig. 10.

Point 1 (50.719872°, 156.194949°) – Fig. 11

The height of this point relative to the sea level according to the topographic map is about 10m, the distance from the edge is 110 m. In this place, the grass flattened by water is observed, and the flood line is clearly visible.

Point 2 (50.718680°, 156.194824°) – Fig. 12

The height of this place is about 8m, the distance from the edge is 80 m. In this place, the grass flattened by water and pieces of wood brought by water, are observed. The flood line is clearly mapped.

Point 3 (50.716590°, 156.196533°) – Fig. 13

Its height relative to the sea level is about 8m, the distance from the cut is 290 m. In this place, the lane of the garbage, brought by water, tracing the flooding line is clearly visible,.

Point 4 (50.716541° 156.199888°) – Fig. 14

The farthest point of the wave approach ends with a metal container brought by the tsunami from the coast. Flattened grass is also visible. This point height is about 15 m, the distance from the water edge is 500 m.

Similar measurements were made in the area of Kozyrevsky settlement (also currently uninhabited). The survey was conducted in the area of this settlement ledge into the strait (see Fig. 1 on the right). The flooding coast line along the ledge is shown in Fig. 15. The maximum wave height here reached 15 m at a distance of 250 m from the shore (this point is shown by the arrow in the figure). In the figure, between the cape and the greatest splash point, a lowland area is visible, where the wave penetrated far to the shore.

Point (50.703663° 156.178119°) – Fig. 16

The wave entry point along the creek-bed ends with the debris lane brought by the tsunami. Flattened grass is also visible. This point height is about 4 m, the distance from the water edge is 85 m.

Point (50.707642° 156.174656°) – Fig. 17

The run-up line along the coast is clearly visible. The grass is dry and flattened, and small washouts are also visible. This point height is about 2 m, the distance from the shore is 55 m.

Point (50.707920° 156.177052°) – Fig. 18

At this point, the run-up line is visible, it is marked by the lane of the garbage brought. This point height is about 7 m, the distance from the shore is 165 m.

5. Conclusion

The results of the field survey of tsunami traces on the Paramushir and Shumshu islands in the Second Kuril Strait area (the Northern Kuril Islands, Russia) that occurred as a result of a catastrophic earthquake with the magnitude of 8.8 on July 29, 2025 near the Kamchatka Peninsula are presented. The survey of tsunami traces was made during the first two days after the tsunami, and then it was refined by examining individual points in more detail.

The coordinates of the splash line points were measured using a GPS navigator. Then, using the General Bathymetric Chart of the Oceans, which is installed into Google Earth, the height of these points above the sea level (the zero level in the Baltic system) and the distance of the splash line from the water edge were determined. The maximum splash height in the area of the city of Severo-Kurilsk (Paramushir Island) was about 10 m, apparently as a result of the focusing of water flows between two hills behind the port facilities. The wave moved most strongly along the riverbed by about 650 m. The maximum splash height in the area of the former Baikovo settlement (Shumshu Island) reached 15 m when the wave moved along the riverbed. A similar splash height was also in the area of the former Kozyrevsky settlement, located near the Baikovo settlement. The measured GPS tracks of the flood zone on the islands of Paramushir and Shumshu are available on the resource (<https://skbsami.ru/tsunamisurvey>)

It should be noted that, in fact, in the same place on November 5, 1952, the worst disaster in the Russian Far East in the last 100 years occurred after the earthquake with the magnitude of 9.0, when as a result of tsunami waves reaching the northern Kuril Islands, the city of Severo-Kurilsk, as well as many coastal settlements, were almost completely destroyed (Savarensky et al., 1958; Soloviev, 1978; Zayakin, 1996; Kaistrenko and Sedaeva, 2001; Levin and Nosov, 2009; Shevchenko et al., 2012; Gusiakov, 2016). The distribution of wave heights along the islands of Paramushir and Shumshu is shown in Fig. 19, taken from (Kaistrenko and Sedaeva, 2001). The maximum wave height exceeded 18m, and the number of civilian victims from the tsunami, according to the official data, was 2336 people. At that time, there was no tsunami warning system, that led to a large number of victims. This year, thanks to the competent and skillful actions of all services, it was possible to avoid human casualties.

Let us also compare the wave heights during the catastrophic tsunami of 2025 with the predicted values in the tsunami zoning scheme for the Russian Far East. In the first scheme (Go et al, 1988), on the basis of very scarce historical data available, the predicted wave height for 100 years in the Severo-Kurilsk and Baikovo area is 17–18 m, and in the Kozyrevsky area – 11 m. In the Regional tsunami hazard maps for the Far East coast of the Russian Federation built in the framework of the PTHA methodology (Gusakov et al, 2019), the predicted wave height in the area of Shumshu and Paramushir islands exceeds 6m for the period of 50 years with the probability of 5%, which corresponds to the recurrence rate of once every 975 years. The 2025 earthquake is the sixth strongest event on record, and the observed tsunami wave heights are in line with predicted figures: 5-7m on average with maximums up to 15m.

Declarations

Author Contribution

The tsunami field survey was conducted by Mark Kotenko, and data processing and research coordination were carried out by Andrey Zaytsev and Efim Pelinovsky

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Figures

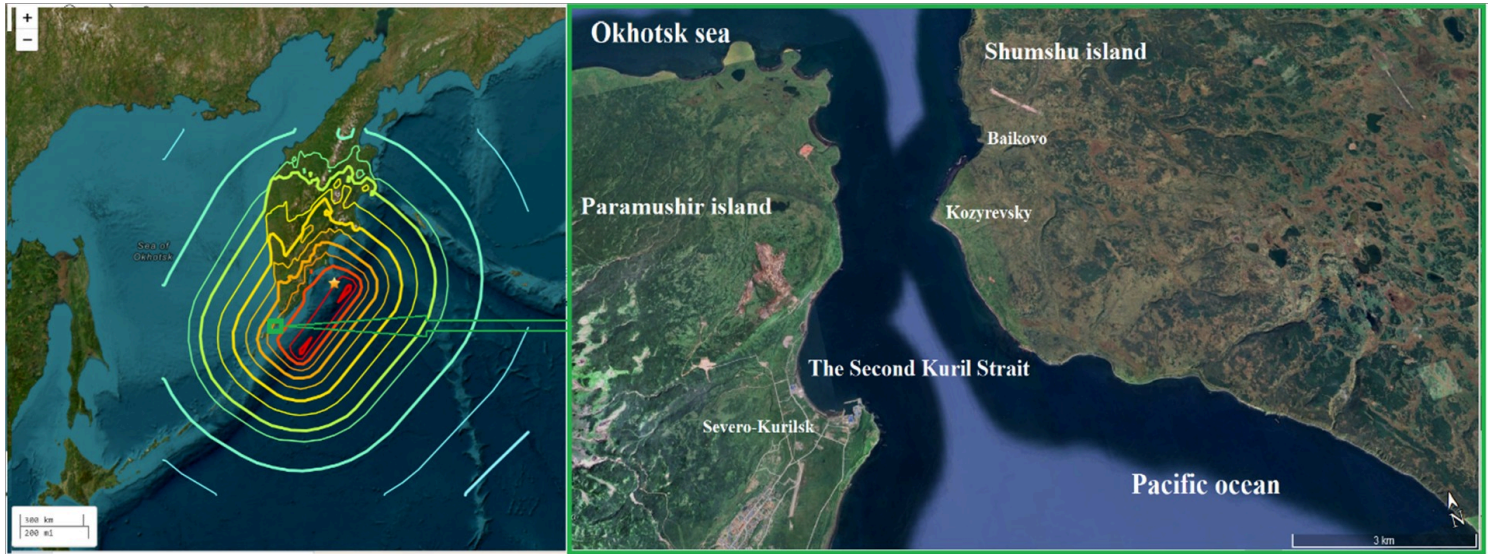


Figure 1

The geographical region map indicating the tsunami epicenter.



Figure 2

Severo-Kurilsk coastal zone. The red line shows the maximum splash line



Figure 3

The flooding zone of the Severo-Kurilsk port according to video clips [GR RAS (Kamchatka branch)]



Figure 4

Point 1 (50.683516°, 156.124325°)



Figure 5

Point (50.677960°, 156.126235°)



Figure 6

Point 3 (50.675025°, 156.131761°)

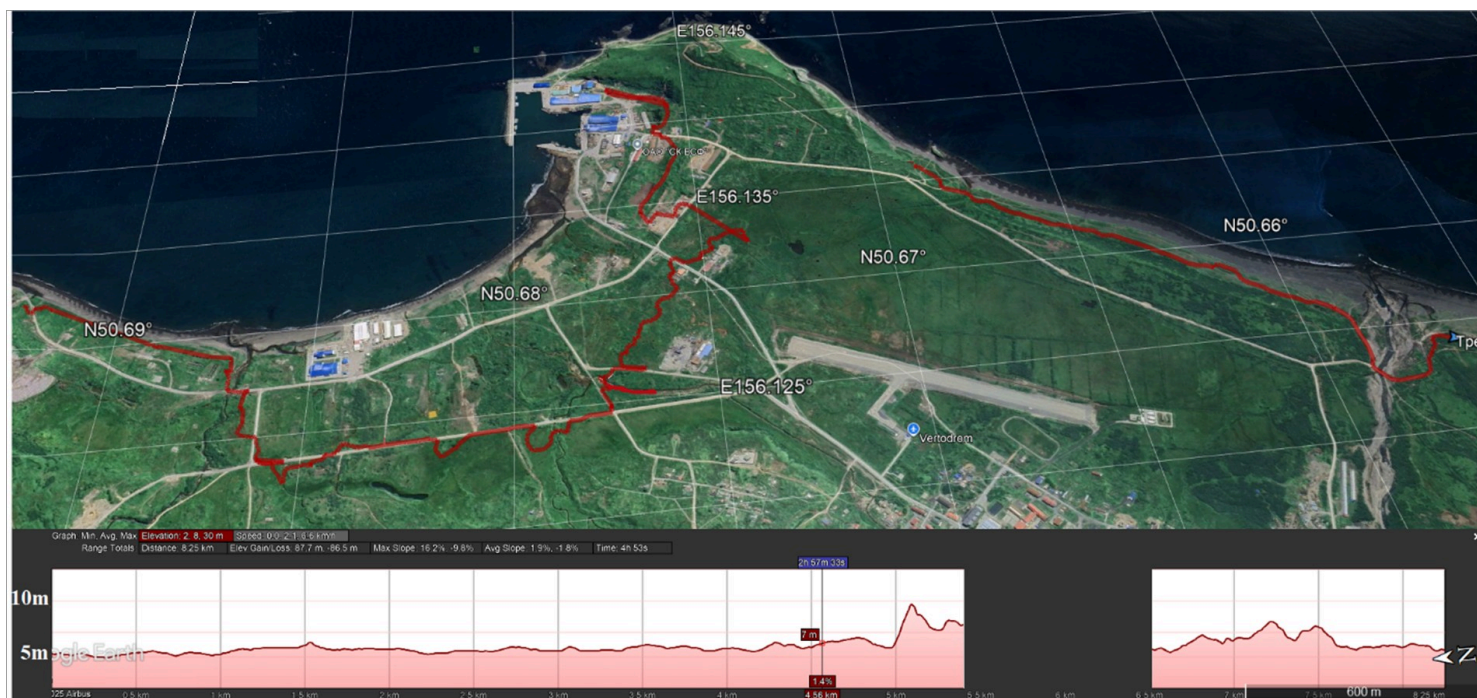


Figure 7

The coastal flood line (the red line) and the heights of these places above the sea level on the coast in the area of the Severo-Kurilsk port (Paramushir Island). The splash line and the height coordinates are also given in the appendix (<https://skbsami.ru/tsunamisurvey>)



Figure 8

The view of the point with the extreme 10m splash height. In the middle is the view from the sea, and on the right is the view towards the sea.

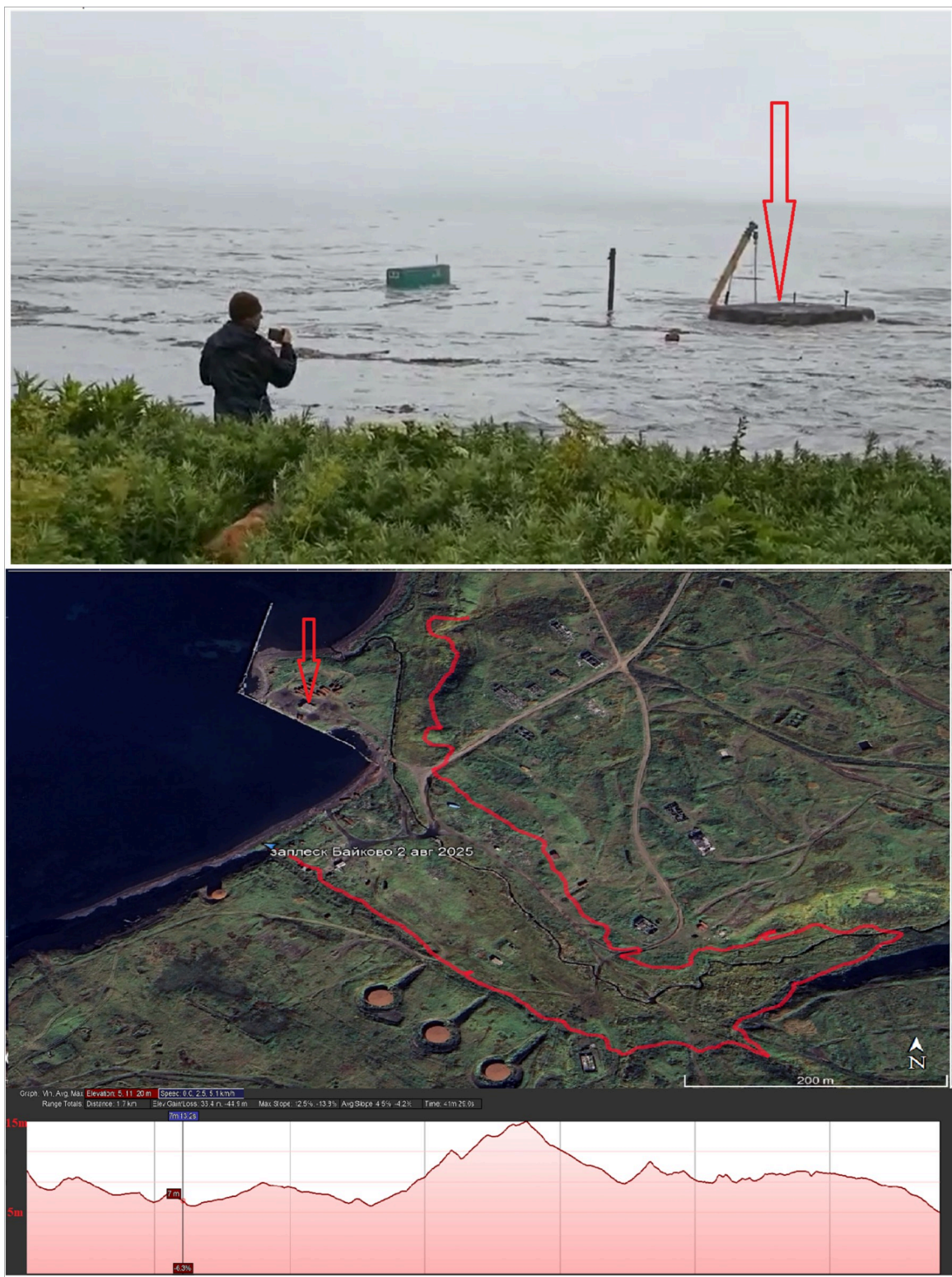


Figure 9

The flooding line track (the blue line) of the tsunami in the area of Baikovo settlement and the distribution of the heights of these places along it. The arrow on the map indicates the diesel plant location, the flooding pattern of which is shown in the upper part of the figure.



Figure 10

The area of the coast flooding in the area of the Nikolaevka River (see Fig. 9)



Figure 11

Point 1 (50.719872°, 156.194949°)



Figure 12

Point 2 (50.718680°, 156.194824°)



Figure 13

Point 3 (50.716590°, 156.196533°)

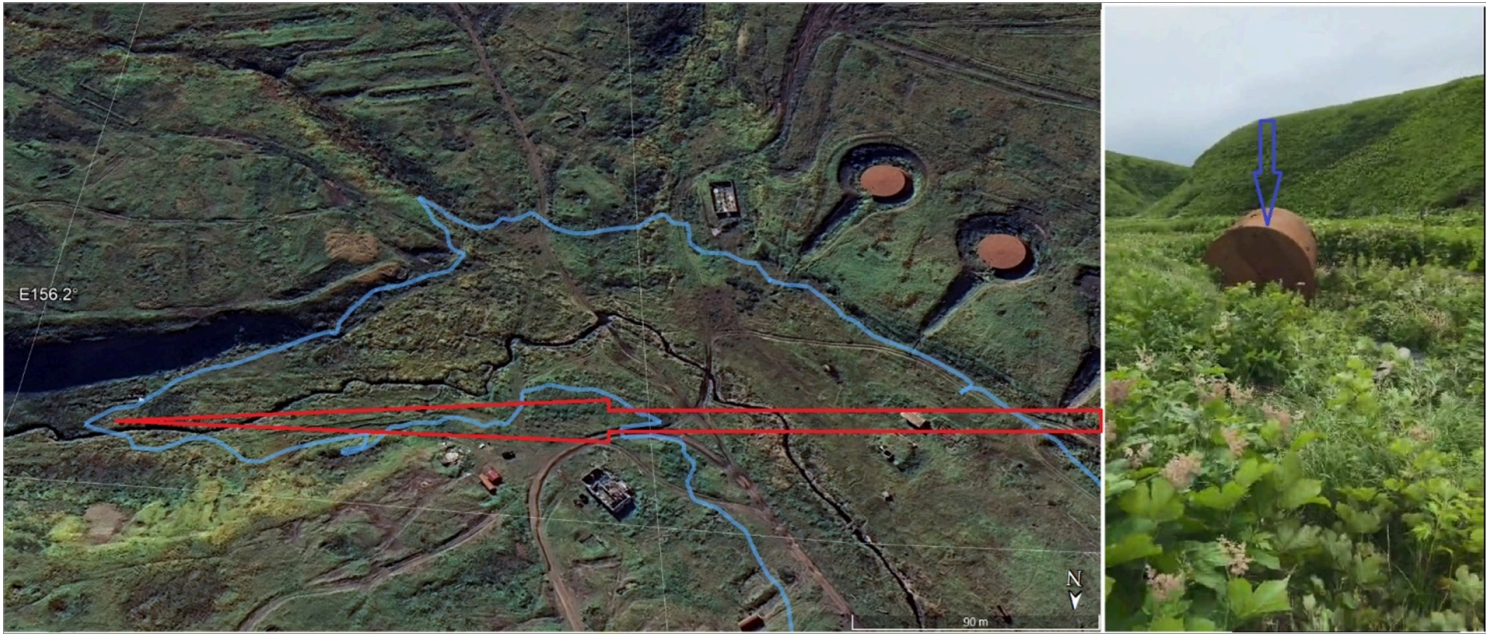


Figure 14

Point 4 (50.716541° 156.199888°)



Figure 15

The track of the tsunami flood line (the blue line) in the area of Kozyrevsky settlement and distribution of splash heights along it.



Figure 16

Point 5 (50.703663° 156.178119°)



Figure 17

Point (50.707642° 156.178119°)

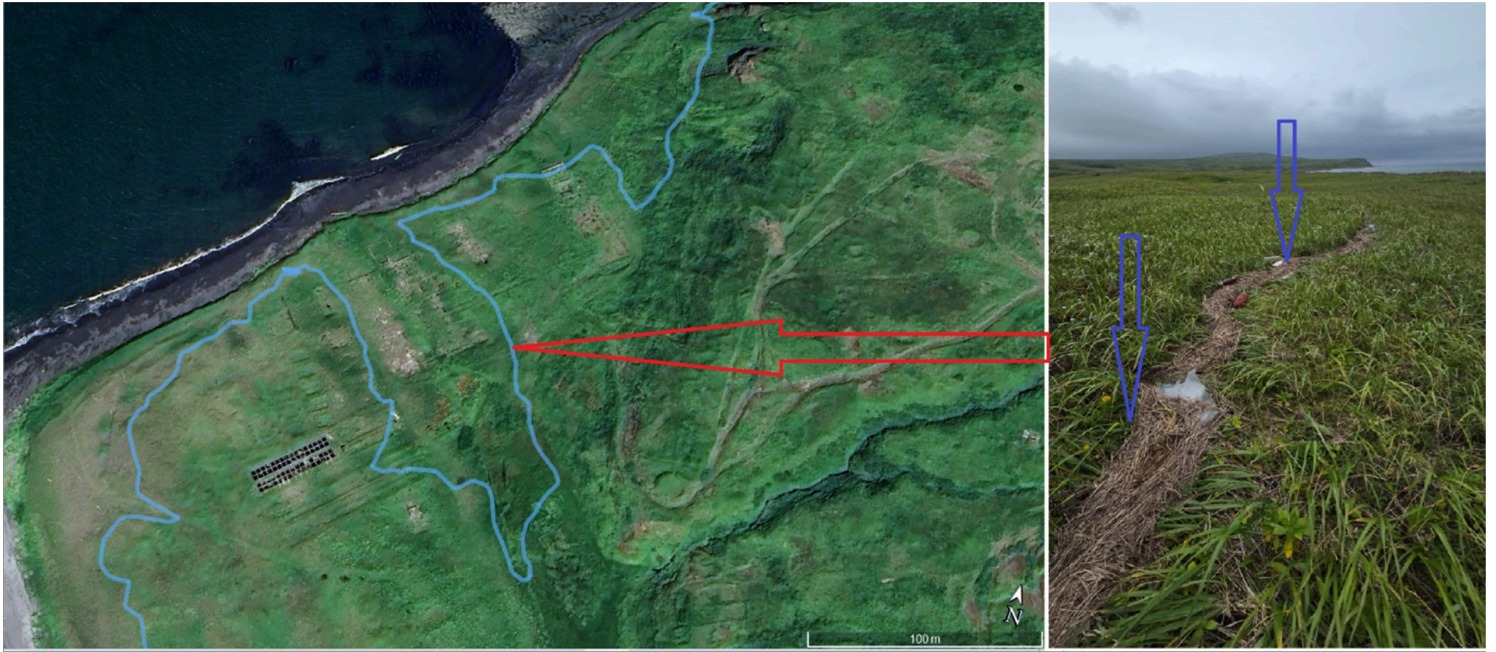


Figure 18

Point (50.707920° 156.177052°)

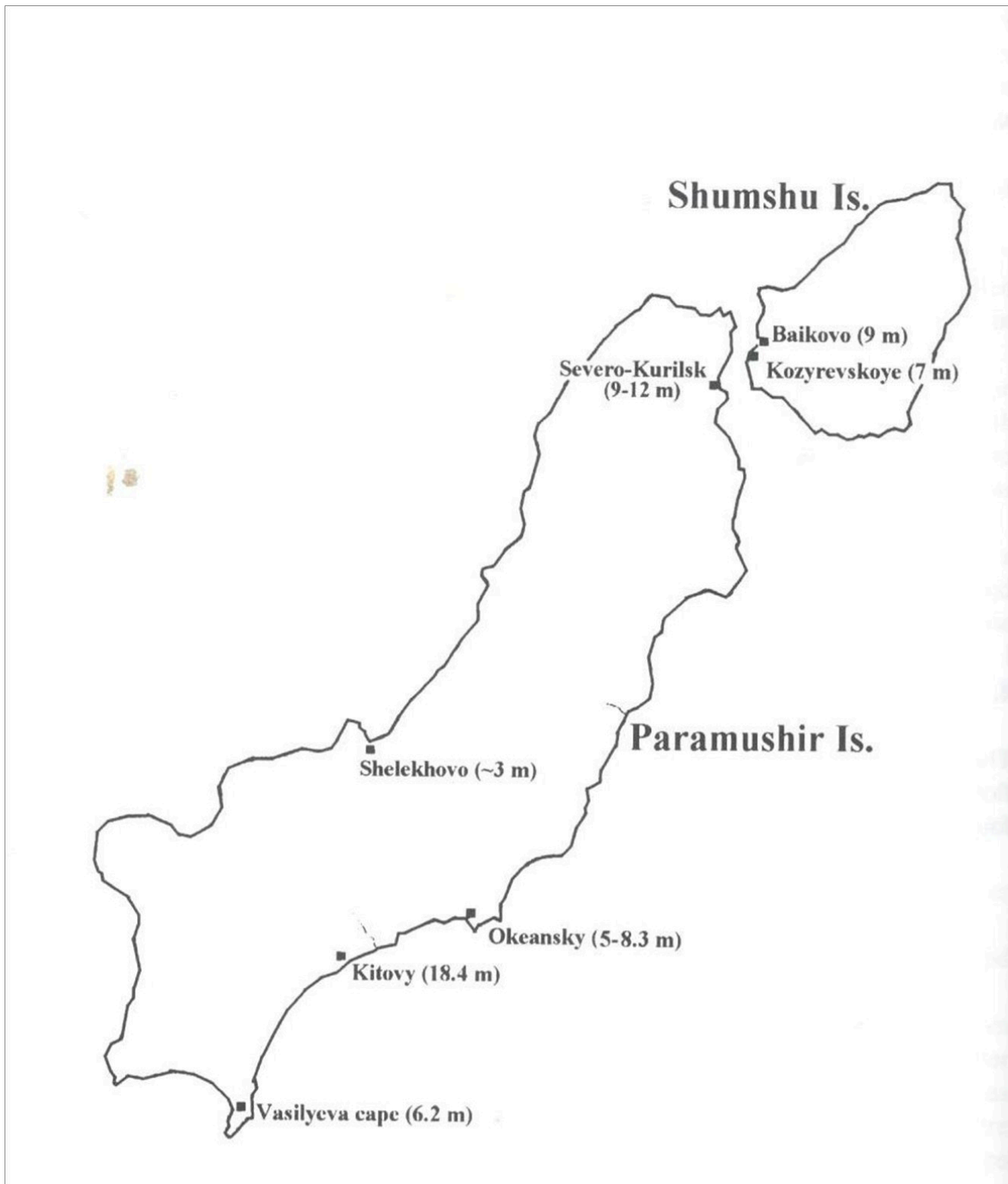


Figure 19

The distribution of wave heights along the islands of Paramushir and Shumshu during the 1952 tsunami (Kaistrenko and Sedaeva, 2001)