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Expert tsunami database for the Kuril–Kamchatka region*

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As a result of a feasibility study, a concept and prototype of the Expert Tsunami Data Base (ETDB) was developed at the Tsunami Laboratory of the Novosibirsk Computing Center, Russian Academy of Sciences. The ETDB contains in the digital form all available information on regional earthquakes and tsunamis (source parameters, observed heights, original historical descriptions, etc.) as well as basic reference information on regional seismic and mareograph networks, regional geography, geology and tectonics. Additionally, it includes some software blocks for tsunami simulation (e.g. calculation of travel time charts, calculation of initial bottom displacements) and some standardized tools for data processing and plotting. A specially developed graphic shell provides the possibility to manipulate maps, models and data in the convenient and efficient manner.

The ETDB currently exists for the Kuril–Kamchatka region, however, the supporting software can be easily adapted to any other tsunamigenic region of the Pacific and elsewhere, after that the actual data compiling from the available tsunami catalogs, original reports and other sources of data can be made in relatively short time.

1. Introduction

Historically, data on tsunami occurrence and coastal manifestation have been compiled and published in the form of tsunami catalogs for the whole Pacific and for its particular regions [1–8]. The collection and refinement of primary data scattered in numerous sources is of great deal of efforts and the importance of published catalogs for tsunami research and investigation cannot be overestimated. However, the data in the paper catalogs become obsolete rather quickly because they cannot be easily edited and updated. In addition, they have a fixed predetermined format which makes their retrieval and handling rather a complicated and time consuming process.

The modern information technology demands organization of data in the form of databases, where data are in the computer readable and active form and their handling can be interactively made in the fast and efficient

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manner. Database technology has been significantly developed in the last two decades for all kinds of computers including PCs and power workstations. However, this development was mainly in response to commercial data processing needs, which are characterized by large, record-oriented, fairly homogeneous data sets mostly retrieved in response to relatively simple (point, interval or range) queries. However, today database research and practice are increasingly concerned with other applications, such as management of spacial data that stretch the conventional DB technology to its limit and beyond. One of the main features of these data is that are embedded in space and are typically accessed through their position in space.

In response to these needs, a new class of the supporting software – Geographic Information Systems (GISs) has been developed in the last decade and offered on the market. GISs provide an enhanced environment for spacial data storage, retrieval and processing. In the past, the GISs have concentrated mostly on retrieval and display problems, but now they are beginning to develop the analytical and modeling tools. Today some of GISs can provide a very sophisticated and enhanced environment for spacial data handling and processing. The ability of GISs to handle and analyze spatially referenced data may be seen as a major characteristic which distinguishes GIS from information systems developed to serve the needs of business data processing as well as from CAD systems or other system whose primary objective is map production.

However, being the universal, multipurpose systems, GISs turned out to be not very flexible and cost effective systems for the number of specific applications especially in the field of geophysical data compilation, storage and processing. Their price and computer requirements are usually much higher than the standard DBMS software. Besides, in the most of existing GISs, the compiled data are related to socio-economic phenomena and are often organized in an administrative hierarchy, so that all further data queries should strictly follow this hierarchy. That is why the development of the inexpensive PC-based software oriented to the handling of geophysical, seismological or hydrographical observational data, is still the matter of interest.

Recent advancements in the development of PC-based DBMS and mapping software along with declining prices of personal computers provide an excellent opportunity to bring all observational tsunami data to a desk of the researcher who wishes to have all available information at hand. It is highly desirable to make all regional and Pacific-wide tsunami catalogs readily available for individual researchers and to provide them with a specialized software environment which can be easily used to manipulate with this type of data. Direct access to historical tsunami databases in a standardized format along with some mathematical models and efficient processing tools opens new possibilities for investigations related to many aspects of the tsunami problem.

As a result of a feasibility study, a concept and prototype of the Expert Tsunami Database (ETDB) was developed at the Tsunami Laboratory of the Novosibirsk Computing Center, Russian Academy of Sciences. In this concept, the ideas about the development of seismological databanks based on the Hypertext approach [9] were essentially used. The ETDB contains in the digital form all available earthquake and tsunami information for a particular region (source parameters, observed heights, original historical descriptions, etc.) as well as basic reference information on regional seismic and mareograph networks, regional geography, geology and tectonics. Additionally, it includes some software blocks for tsunami simulation and some standardized tools for data processing and plotting. A specially developed graphic shell provides the possibility to manipulate maps, models and data in the convenient and efficient manner.

2. ETDB requirements

In elaborating the ETDB we are to meet the following basic requirements:

1. the system should include all available historical earthquake and tsunami data for a particular region along with basic reference information on regional geography, geology and tectonics;
2. the system should have a module structure allowing flexibility and adjustment to a particular application and be an open system providing the potential of growth to keep abreast of research advancement;
3. the system should have a built-in computer mapping subsystem providing the ability to display spatial data on the actual geographical bases;
4. the system should have a built-in glossary of tsunami related terms accessible in sequential and browsing mode;
5. the system should have a set of built-in standardized tools for data analysis and processing;
6. the system should have a friendly user's interface based on the menu-driven approach.

3. ETDB conception

According to our concept, the Expert Tsunami Database should exist in two forms which can be called conventionally as the parents' form and the user's form. The database in its parents' form should exist at a regional warning center or specialized data center on some dedicated hardware and be provided with some continuing qualified maintenance, that is, to have the database administrator who is authorized and responsible for routine updating, editing and refinement of data as well as for further development and improvement of the system.

In its user's form, the ETDB exists as an automated tsunami catalog embedded inside a specialized graphic shell that is a user's interface and provides possibilities for fast and convenient retrieval, visualization and handling of data. In this relation, the user's database represents an electronic analog of conventional tsunami catalogs, however, it considerably surpasses them in its efficiency and convenience. It can operate sufficiently independent of the parents' database, but is still compatible enough with it to allow exchange and updating. The user's database is also provided with some tools for data editing and further data compiling that makes it possible to use it as a basement for development of the personal database containing all meaningful information related to needs of the individual researcher.

4. EDTB prototype

The demonstration version of the ETDB has been developed at the Tsunami Laboratory of Novosibirsk Computing Center on the basis of the historical tsunami database for the Kuril–Kamchatka region [10].

Currently, the ETDB contains all available information on tsunami sources and their coastal manifestation in the Kuril–Kamchatka region (within 41° to 64° N and 130° to 168° E). It consists of four main parts: the earthquake database, the tsunami database, a specially developed graphic shell providing the ability for fast search, retrieval and mapping of data, and the standardized built-in software for data processing. Two additional databases contain some basic reference information on the existing regional seismic and mareograph networks. The geographical database includes geographical contours within the region, isolines of underwater and land topography, state and administrative boundaries, main rivers and cities.

The earthquake database contains the source data of almost 42000 events that occurred within the region from 1089 to 1990. Source information includes date, time, coordinates of an epicenter, depth, magnitude, and seismic intensity followed by indexing to data sources.

The tsunami database covers the period from 1640 to 1991 and contains 129 events with 115 of them having regional and 14 distant sources. The criterion for including a historical event into the database was the position of its source within the area between 41°30′ and 64°00′ N and 130°00′ and 168°00′ E for regional events or the presence of at least one coastal observation within this area (except Hokkaido Island) for distant events.

The data set consists of four main blocks: detailed source data of tsunamigenic events, coastal observation of wave heights, historical descriptions of tsunamis and bibliographical data. The data can be retrieved by area, date, tsunami intensity and source magnitude (in the submenu PARAMETERS).

The source data of tsunamigenic events are cross referenced to the earthquake database but contain the extended set of parameters including moment-magnitude Mw, tsunami-magnitude Mt, seismic moment Mo, moment-tensor and source mechanism (where available), tsunami intensity I (according to Soloviev–Imamura scale), maximum run-up height, position of tsunami source, validity of event, warning status and some other complementary information.

The coastal observations of tsunami, that consist mainly of tsunami run-up heights, were taken from existing tsunami catalogs, various reports and publications. During the compilation, we tried to determine the original sources of the data and to collect a most reliable set of tsunami wave heights that can be given. They all were provided with geographical coordinates of observational sites, that is why they can be easily retrieved and displayed on shoreline maps of Kamchatka and Kuril Islands.

The third part of the tsunami database, which is still in the process of compilation, contains the full original descriptions of tsunami events, collected from the original reports and records, scattered in numerous publications of very different nature. Its main destination is to bring to the researcher the full initial descriptions of all events, and especially of the old ones, some of them can be reinterpreted from a contemporary point of view. It is provided with the glossary of some specific terms and geographical points mentioned in the textual descriptions.

And the last, but not the least component of the tsunami data set is the bibliographical information collected as a comprehensive list of publications related to the regional tsunami events. It is cross correlated to the earthquake and tsunami data sets and contains the standard bibliographical references necessary for locating a publication. The bibliographical data can be independently retrieved by an author, a year and preliminary selected key words related to the subject of publication.

5. ETDB graphic shell

The ETDB is being developed for the user who may be unfamiliar with the modern DBMSs, numerical methods or computer graphics software. This has predetermined the elaboration of the easy-to-learn and easy-to-use interface based on the menu-driven approach and having on-screen buttons for process management and on-screen windows for input and output of information. A specially elaborated graphic shell provides an ability to manipulate maps, models, data and results of computation in an efficient and convenient manner. Some examples of screen outputs produced by the graphic shell are shown in Figures 1–10.

The background map of the region and the submenu panel of the mapping subsystem are shown in Figure 1. Using the rubber screen window one can select a rectangular area within the region for further data retrieval and visualization and then build its contour map with the necessary amount of topographical details using on-screen buttons on the right panel.

Figure 2 visualizes the full Kuril–Kamchatka seismic catalog for the period from 1089 to 1990 (about 48 000 events). This data set is the result of combination of three regional catalogs provided by different institutions: Kamchatka Institute of Volcanology, Sakhalin Institute of Marine Geology and Geophysics and Japan Meteorological Agency. One can clearly see the difference in the accuracy of source coordinates for Kamchatka, Kuril and Japan regions as a result of the difference in the network density and configuration as well as in numerical algorithms used for data processing.

As an example of other possibilities of data processing and visualization unit in the earthquake database, Figure 3 shows the vertical cross-section through the south of Kamchatka as looking to the north-east through the volume indicated by the solid rectangular in Figure 2. The concentration of earthquake sources along the dipping oceanic plate is clearly seen.

Figure 4 displays all tsunamigenic earthquakes occurred within the region during 1737–1990. Using a small jumping arrow, the user can point out to any particular event on the map or select it from the list of condensed source data, which is displayed upon pressing the LIST button, and then obtain all data on this event available in the database.

As an example, Figure 5 displays all the basic information on the Kamchatka tsunami of November 4, 1952. It shows the positions of shock of this earthquake, a set of one-year aftershocks, estimated position of the tsunami source according to [11], and distribution of observed tsunami wave heights along the coast. The histogram of the wave heights of this tsunami observed along Kamchatka and North Kuriles coast is show in Figure 6. The abscissa is expressed in terms of numbers of observations, and the ordinate is in logarithmic scale of the observed value h, normalized by the logarithmic mean value $h^\wedge$.

A fragment of the original historical description of the 1737 Great Kamchatka tsunami taken from [12] is shown in Figure 7.

The next three figures demonstrate some examples of application of the built-in analyzing and modeling software.

Figure 8 gives an example of the built-in software for calculation of tsunami travel times and their application for the estimation of a tsunami source position. For the case of Iturup tsunami of October 13, 1963, the reverse isochrons are calculated for three points with available observed travel times. They outline a possible position of tsunami source which roughly coincides with one-week aftershocks of this event. This software is based on the algorithm of tsunami travel times calculation described in [13] which provides a fast and efficient calculation and plotting of travel time charts.

Figure 9 shows the tsunami occurrence versus time. This type of a diagram can be used for evaluation of the completeness of the catalog. It strongly depends on the historical period and reflects, first of all, the quality of the observational network and for older times – the density of population and the level of economic development of the territory.

Figure 10 shows the histogram of accumulated (over the whole period from 1737 to 1990) wave heights within separate tectonics blocks. This type of a diagram can provide a basement for the preliminary evaluation of tsunami risk for a particular coast.

6. Conclusion

The ultimate goal of the ETDB Project is to develop a comprehensive database on tsunami and related geophysical phenomena which would contain a complete set of original, uninterpreted information available to anyone who wishes to revise estimates, to make his own interpretation, to raise questions or to propose improvements. The final product could be used not only as a comprehensive tsunami database, but also as a convenient electronic textbook and reference book on tsunami topics as well as a computer-aided device for investigation of different issues of tsunami problem.

Although the ETDB currently exists only for the Kuril–Kamchatka region, the supporting software can be easily adapted to any other tsunamigenic region of the Pacific and elsewhere, after that the actual data compiling from the existing tsunami catalogs, original reports and other sources of data can be made in a relatively short time.

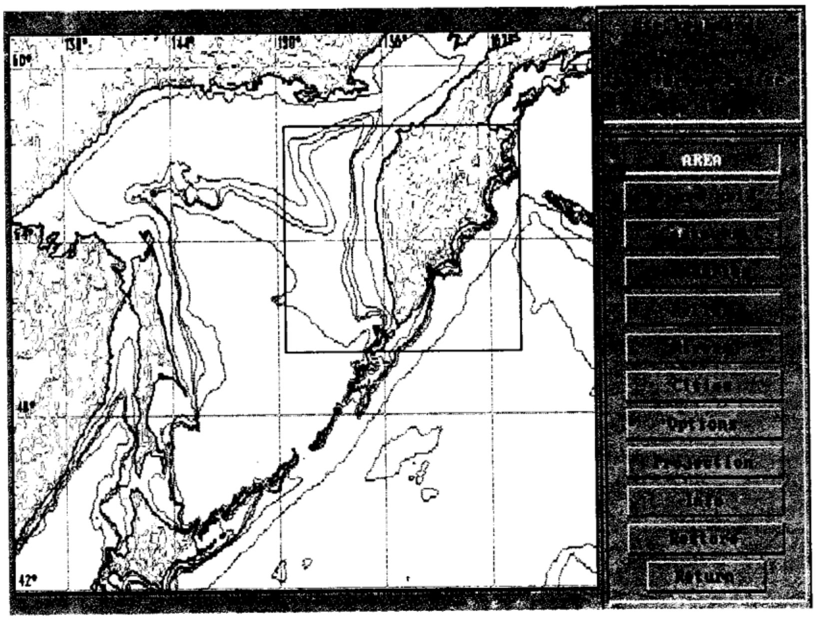


Figure 1. An example of the screen output provided by the ETDB graphic shell. The contour map of the Kuril–Kamchatka region is shown in the left screen window. On the right is the submenu of the second level operating with the mapping subsystem.

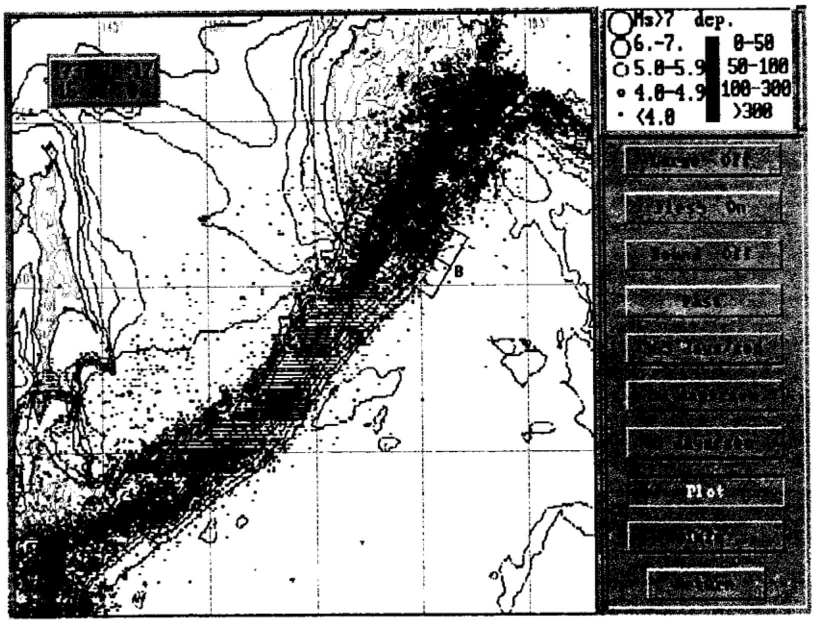


Figure 2. Visualization of the combined Kuril–Kamchatka seismic catalog for the period from 1640 to 1990 (about 48 000 events). Solid rectangular confines the area for which the vertical cross-section is shown in Figure 3.

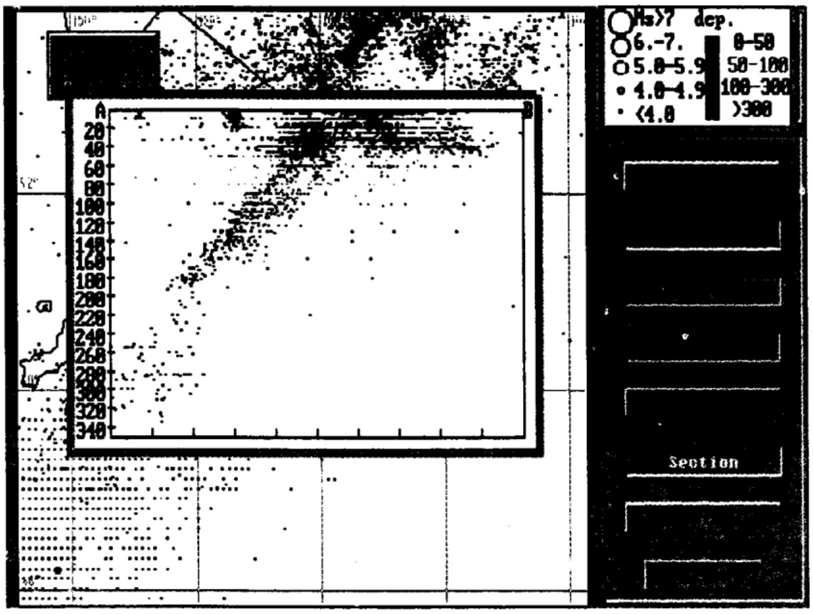


Figure 3. Vertical cross-section through the south of Kamchatka as looking to the north-east through the volume indicated by the solid rectangular in Figure 2.

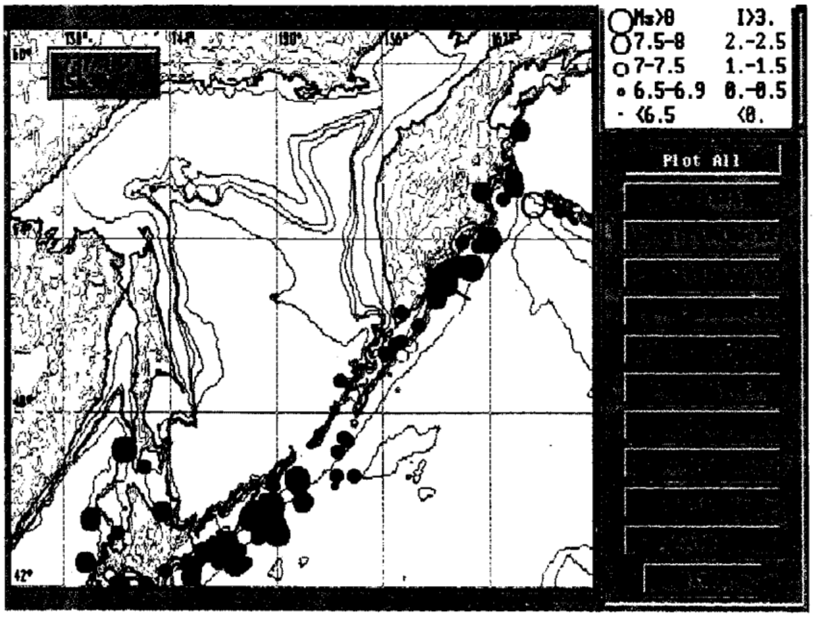


Figure 4. Map of epicenters tsunamigenic earthquakes occurred during 1737–1990 within the Kuril–Kamchatka region. The size of circles represents the event magnitude, the density of black tone – the tsunami intensity.

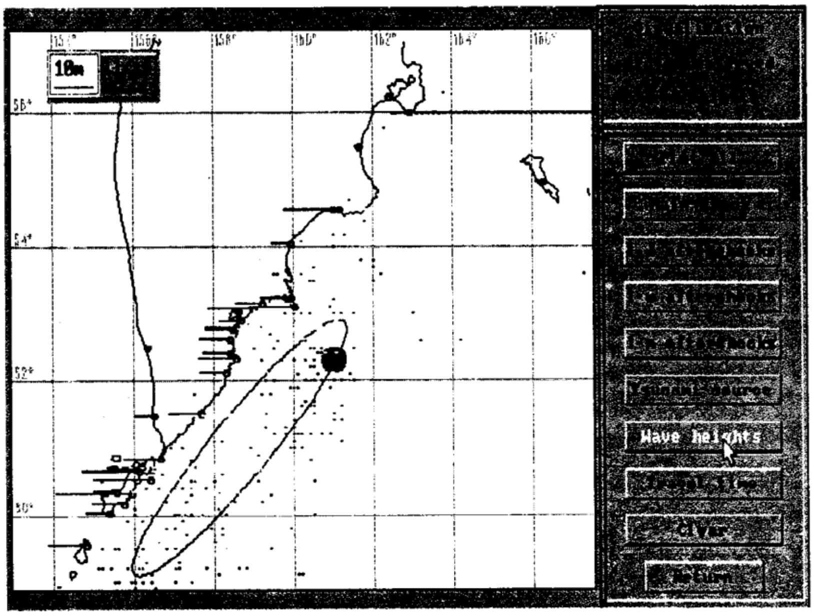


Figure 5. Source area (solid ellipse), first-year atershocks (small dots), run-up heights and observed travel times (sections of black lines and digits near them, respectively) of the of November 4, 1952 Kamchatka tsunami.

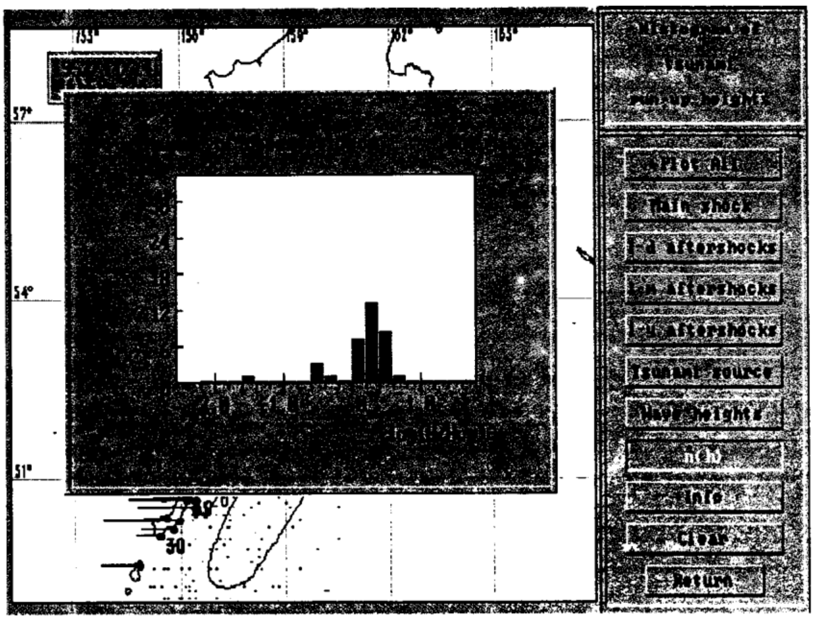
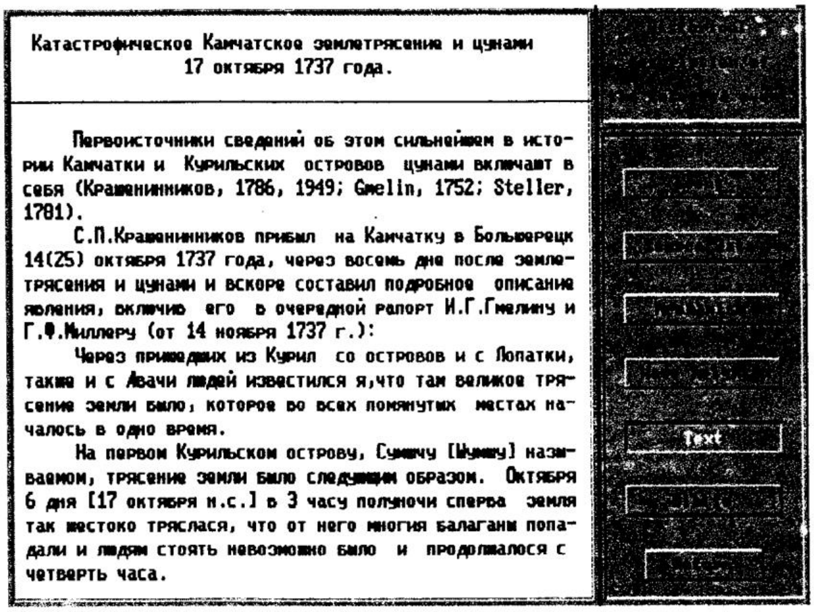


Figure 6. The histogram of the November 4, 1952 tsunami wave heights observed along the cost of the North Kuriles and Kamchatka.



Катастрофическое Камчатское землетрясение и цунами
17 октября 1737 года.

Первоисточники сведений об этом сильнейшем в истории Камчатки и Курильских островов цунами включают в себя (Крашенинников, 1786, 1949; Gmelin, 1752; Steller, 1781).

С.П.Крашенинников прибыл на Камчатку в Большерецк 14(25) октября 1737 года, через восемь дне после землетрясения и цунами и вскоре составил подробное описание явления, включив его в очередной рапорт И.Г.Гмелину и Г.Ф.Миллеру (от 14 ноября 1737 г.):

Через пришедших из Курил со островов и с Лопатки, также и с Авачи людей известился я,что там великое трясение земли было, которое во всех помянутых местах началось в одно время.

На первом Курильском острову, Сумчу [Шумшу] называемом, трясение земли было следующим образом. Октября 6 дня [17 октября н.с.] в 3 часу полуночи сперва земля так жестоко тряслася, что от него многия балаганы попадали и людям стоять невозможно было и продолжалося с четверть часа.

Figure 7. A fragment of the original historical description (in Russian) of the October 17, 1737 Great Kamchatka tsunami taken from [5].

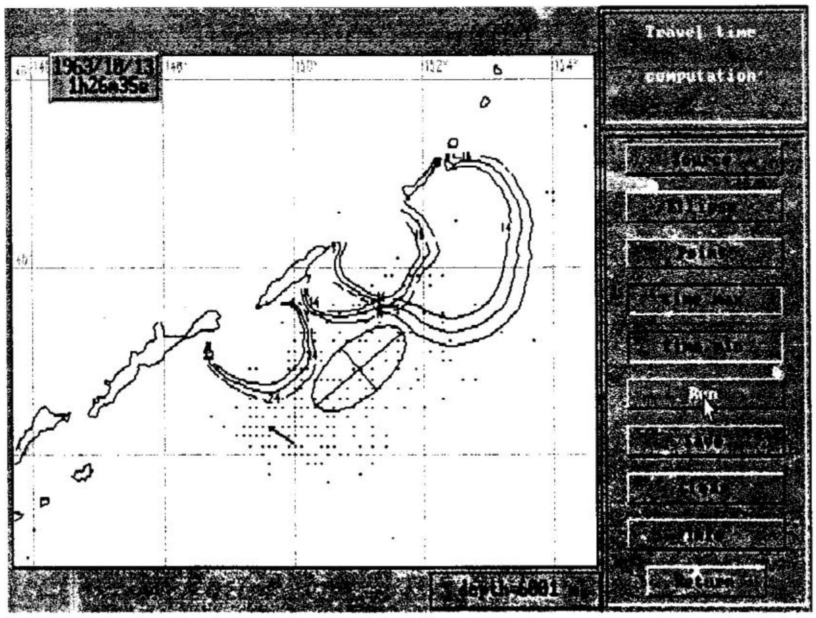


Figure 8. An example of application of the built-in modeling software – map of inverse isochrons for the event of October 13, 1963, calculated and plotted for three coastal points where observed travel times of this tsunami are available. Small black circles represent the first-week aftershocks.

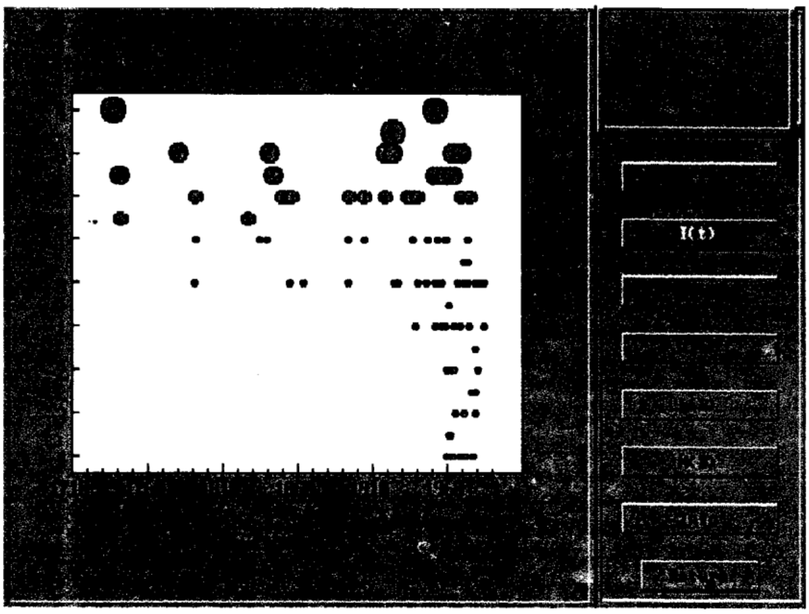


Figure 9. An example of application of the built-in analyzing software – tsunami occurrence depending on a year. The size of circles is proportional to the tsunami intensity.

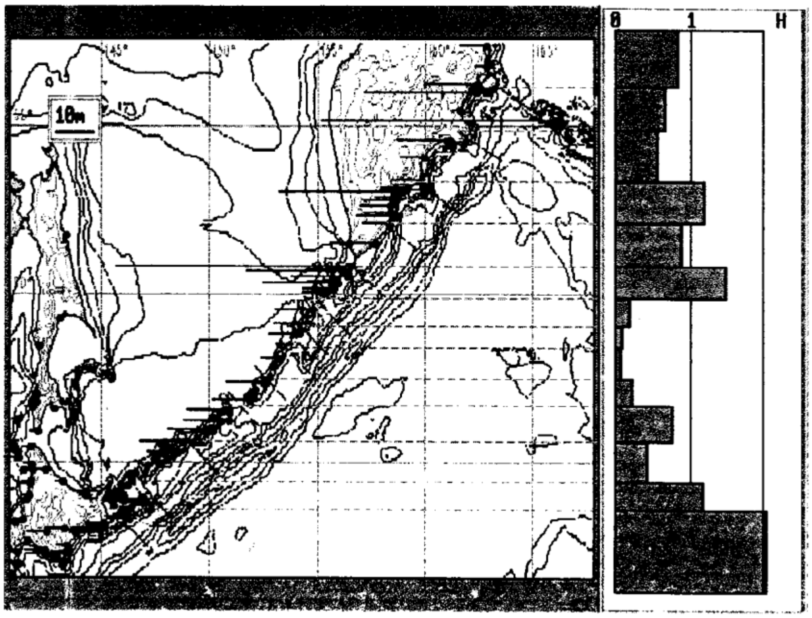


Figure 10. An example of the application of the built-in data processing software – the diagram of accumulated tsunami wave heights during 1737–1990 within separate tectonic blocks distinguished within the region by some seismotectonic evidences.

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