

Basic Pacific tsunami catalog and database, 47 BC–2000 AD: Results of the first stage of the project

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Abstract. A comprehensive Historical Tsunami Database for the Pacific region has been compiled as a result of the joint IUGG Tsunami Commission and ICG/ITSU Project “Basic Pacific Tsunami Catalog and Database.” The project is directed to improve the situation with catalogization of historical tsunamis in the Pacific by means of organizing them in the form of a parametric tsunami catalog and database. Its final product will be the multimedia CD-ROM “Tsunamis in the Pacific, 47 BC–2000 AD,” containing all the meaningful historical tsunami data along with additional reference information related to the tsunami problem in the Pacific. The main purpose of the first stage of the HTDB project was the initial collection of parametric data from all the available published tsunami catalogs and the original publications. This has been done at the Novosibirsk Tsunami Laboratory within the relational databases dBASEVI, Access, and MS SQL Server. The current version of the catalog contains 1453 tsunamigenic events that occurred in the Pacific from 47 BC to 2000 AD, with 1348 of them having a validity index equal to or greater than 1. The basic set of parametric data collected within the database (the catalog of the Pacific tsunamigenic events and the catalog of the observed wave heights) is available on the dedicated web site at <http://tsun.sssc.ru/htdbpac/>. The full version of the database, provided with DOS-based and Windows-based graphic shells for easy data manipulation, visualization, and handling, is distributed on a CD-ROM.

1. Introduction

The compilation of historical data on tsunami occurrence and coastal manifestation is an important part of tsunami research and mitigation. Historically, observational data on tsunamis have been compiled and published in the form of tsunami catalogs for the whole Pacific and for its particular regions (Cox and Pararas-Carayannis, 1976; Pararas-Carayannis, 1977; Soloviev, 1972; Soloviev and Go, 1984a, 1984b; Iida, 1984; Lander and Lockridge, 1989; Lander *et al.*, 1993; Lander, 1996). Collection and refinement of the primary data scattered in numerous sources required a great deal of effort and the importance of the published catalogs for tsunami research and mitigation cannot be overestimated.

However, some of these catalogs are more than 10 years old, and a lot of new information is now available, especially for recent events; many of them have been investigated in detail by the International Post Tsunami Survey Teams. Besides, all the historical catalogs have been compiled and published in the form of a descriptive plain text in different styles, formats, and approaches. The quantitative data in these catalogs are scattered over the text and they are not easy to retrieve and handle, thus limiting to some extent their further application in tsunami research. To keep abreast of present-day information technology, the observational data should be organized in the

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form of a computerized database, where data are kept in a constantly updated and active form and are readily accessible. The information from the database can be quickly retrieved in many different ways and formats, and can be easily transferred to other relational databases and data processing and visualization programs.

The Historical Tsunami Database for the Pacific (HTDB/PAC) Project was initiated by the IUGG Tsunami Commission (IUGG/TC) in 1995 under the leadership of the Tsunami Laboratory of the Institute of Computational Mathematics and Mathematical Geophysics (TL/ICMMG), Novosibirsk, Russia. By that time, the TL/ICMMG had the basic parametric tsunami catalog for the whole Pacific compiled from a variety of sources and provided with the specialized graphic shell written in Turbo-Pascal. At the XVII Session of the International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU) held in Lima, Peru in 1997, the HTDB/PAC project was adopted as the joint IUGG/TC-ICG/ITSU project with its final goal to develop by the year 2001 the multimedia CD-ROM "Tsunamis in the Pacific, 47 BC–2000 AD."

In its present form, the HTDB/PAC data subsystem represents the most complete historical tsunami data set for the Pacific available in digital domain. The primary part of the database contains parametric source data on the 1453 historical events that occurred in the Pacific from 47 BC to 2000 AD, with nearly 8000 coastal observations provided with geographical coordinates of sites. The secondary part of the database consists of the textual descriptions of tsunami manifestations, a set of tsunami photographs, and some additional reference information related to the tsunami problem (bibliographical references, a list of tsunamigenic regions, a list of mareograph stations, a list of active volcanoes, a list of coastal populated places, etc.). These datasets are embedded into a specially developed graphic shell (GIS-type mapping subsystem) for easy data retrieval, visualization, and handling.

2. Basic Content of the Database

The primary collection of historical earthquake and tsunami data was made within the relational databases dBASEIV and MS Access that were established and are being maintained at the TL/ICMMG since 1993. For the HTDB/PAC system, the basic content of the databases was exported in the form of several data files in the standardized ASCII formats. The main advantage of the ASCII data files is that they allow the further editing and correction of tsunami parameters without using any database management system.

A set of the historical data files embedded inside the HTDB/PAC system consists of the basic seismic catalog, tsunami event and run-up catalogs, textual description of tsunami manifestations, and several auxiliary files containing additional reference information (a list of inhabited places, a list of active volcanoes, a list of mareograph stations). A brief description of each part of the database is given below.

2.1 Earthquake catalog

In the HTDB/PAC system, the built-in historical earthquake catalog has an auxiliary function and is used mainly for the identification of tsunami-prone areas in the Pacific. The catalog was created on the basis of combining the three world-wide seismic catalogs: “The catalog of significant earthquakes” (Dunbar *et al.*, 1992), the catalog of the International Seismological Center (ISS/ISC), and the PDE catalog of the National Earthquake Information Center (PDE/NEIC). These three world-wide catalogs were merged into a single data file based on the following time windows:

- Catalog of significant earthquakes—for 2150 B.C to 1913
- ISS/ISC catalog—for 1914 to 1963
- PDE/NEIC catalog—for 1964 to 2000

This basic catalog was extended by adding several regional catalogs (the JMA catalog, the Kuril-Kamchatka and the Hawaiian catalogs) using some simple criteria (coincidence within specific time and space windows) for deleting duplicates.

A list of the source parameters includes date, time, source coordinates, source depth, and magnitude (basically M_s). Inside the HTDB/PAC graphic shells the earthquake catalog is kept in binary format to reduce its size (comparative to ASCII format) and speeds up data search and retrieval.

The combined earthquake catalog for the Pacific contains nearly 226,000 events and covers the time period from 186 BC to 31 December 2000. The completeness and the minimum magnitude threshold of this catalog vary in space and time depending on the quality of the world-wide and the regional catalogs from which the data have been taken. For recent years, on the Pacific-wide scale the catalog is complete for magnitudes greater than 5.0. However, for some local areas (for instance, near Kamchatka or Japan) the minimum magnitude threshold can be as low as 2.0.

It is important to stress that all the events from the earthquake catalogs with the reported tsunami effect (even with validity 1) are included in the tsunami event catalog. Their source parameters, however, can differ from those listed in the earthquake catalog, because they can be taken from different sources.

2.2 Tsunami catalogs

The historical tsunami catalog for the Pacific, developed under the HTDB/PAC project, summarizes the long-term efforts of several research groups and individuals in collecting, refining, and editing the historical tsunami data for the Pacific region. The data have been assembled from a wide variety of published and unpublished sources including the NGDC/NOAA world-wide tsunami database, the main published regional, national, and Pacific-wide tsunami catalogs, and the original reports, publications, Tsunami Newsletters, and messages distributed in 1992–2000 through the electronic Tsunami Bulletin Board). To the end of year 2000, the collected data represent the

most complete historical tsunami data set for this area available in the digital domain.

The Pacific tsunami catalog consists of three separate parts that are stored in different files: the tsunami event catalog, the tsunami run-up catalog, and the textual descriptions of tsunami manifestation. Within the HTDB/PAC system, the interaction between these three catalogs is made through the event identification number that is a 15-digit code consisting of the date (year, month, day) and time (hour, minutes, seconds) of an event.

The tsunami event catalog contains comprehensive lists of the tsunamigenic events with their basic source parameters followed by a set of integral parameters describing the tsunami effect. Within the catalogs, the tsunamigenic events are arranged in the order of their date and time. In its present form, the tsunami event catalog covers the period from 47 BC to December 31, 2000 and contains 1453 historical events with 1348 of them having the a validity index equal to or greater than 1. (We keep 105 events with validity 0 as false entries to prevent their re-entry in the database, because the information on these events in any way presents in the tsunami literature).

For each event, a set of parameters includes the full date (year, month, day) and time (hour, minutes, seconds), source position (latitude, longitude), a source depth, the basic set of source magnitudes (m_b , M_s , M_w , M_t), tsunami intensity (on the Soloviev-Imamura scale), tsunami magnitude (on the Imamura-Iida scale), the maximum observed run-up value, the number of available run-up observations, damage code, the number of fatalities due to tsunamis, the type of tsunami source, validity of an event, warning status (for the events since the beginning of the 60s), tsunamigenic region code, the basic reference for an event (a published catalog or a primary publication), and a brief description of the source region. In the event data table, a blank in a column means that the value of this parameter is unavailable for this particular event. The minimum set of parameters of a tsunamigenic event to be included in the event catalog is the date (at least, a year), a source position, validity, the basic reference for an event, a source region code, and a descriptive indication to the tsunami source area.

The run-up catalog contains listings of the observed tsunami wave heights provided with names and geographical coordinates of observation sites. Through the event identification number, they are linked to the tsunami events catalogs. For each record, a set of parameters includes a 3-level name of the site (region name, area name, and site name), geographical coordinates of an observational site, the type of measurement (tide-gauge or on-land vertical run-up), a measured run-up height or double amplitude (in meters), and, where available, additional parameters characterizing tsunami manifestation at a particular site (horizontal inundation (in meters), direction of the first motion, and the leading wave period).

The textual descriptions of tsunamigenic events are stored in the database to provide the users with non-parametric information on tsunami manifestation. They are kept in HTML format, which allows hyperlinks, photos, and even pieces of video to be included in the text. Currently, textual descriptions are available for 225 historical events in the Pacific. They were retrieved from a variety of sources with the main volume of the texts taken

from three published tsunami catalogs (Lander and Lockridge, 1989; Lander *et al.*, 1993; Lander, 1996).

2.3 Geographical data

The built-in geographical database consists of the three main layers represented by raster data (land and bottom relief of different resolutions), vectorized data (geographical contours, state boundaries, rivers and lakes, plate boundaries) and point data (populated places, active volcanoes, mareograph stations). In the HTDB/PAC system, the digitized geographical data are used for construction of the user-made background maps that can be done in a variety of options.

The raster data in the HTDB/PAC system are represented by the digital elevation and bathymetry models (DEBM) of different resolutions. As low-resolution data, we use the ETOPO5 array that is the global DEBM of the Earth relief on a 5-min grid. The medium resolution data are represented by 1-min DEBM for the Pacific region obtained from the Global Sea Floor Topography from Satellite Altimetry on 2-min resolution (Smith and Sandwell, 1997) and the USGS Digital Elevation Models (GTOPO30 and DEM 250). Smith and Sandwell's 2-min global bathymetric array has been recalculated to a 1-min grid using the linear interpolation procedure. In the resulting array, the land surface elevations were replaced with their values taken from GTOPO30 (30-sec resolution) array. Finally, we have obtained a 1-min DEBM array covering the Pacific and the adjacent regions (between 65°S–65°N and 80°E–50°W).

The HTDB/PAC mapping subsystem automatically determines the necessary level of resolution (based on the spatial scale of the user-made map) and makes the search and retrieval of the raster data related to the selected geographical area.

The vectorized data are used for representing the geographical contours, state boundaries, rivers and lakes, as well as tectonic plate boundaries. The Global Relief CD-ROM Data Set (NGDC Product 1093A27001, Boulder, Colorado, 1993) was used as the main source of these types of geographical data (except the plate boundaries that were provided by the NEIC).

3. HTDB/PAC Graphic Shells

The data set collected within the HTDB/PAC Project is embedded into a specially developed graphic shell, built as a GIS-type mapping system that provides the enhanced environment for easy and efficient manipulation of historical tsunami data. The HTDB/PAC graphic shell exists in two versions—DOS-based (written in Watcom C++) and Windows-based (written in MS Visual C++). Both versions have a standardized user's interface with similar menu options and provide the following basic functions:

- selection of a working area on the Pacific background map and zooming it to the full screen size;

- construction of a raster (the 3D shaded relief) and/or a vector (land contours, main rivers and lakes, state borders) map of a selected area;
- overlay of additional information on the resulting map (geographical grid, plate boundaries, populated places, mareograph stations, active volcanoes, etc.);
- search and retrieval of pertinent seismic and tsunami data for the current geographical area by complex criteria and their listing and display in a variety of options on the user-made map;
- search and retrieval of historical tsunami data in the “New Event” mode where the data search is made within the current geographical area for the run-up heights produced by historical events from the circular area centered on a new event;
- saving the resulting user-made map in standard graphical formats (GIF, BMP) for use in the next working session and for further editing and printing from commercial graphic editors;
- providing a user with a glossary for the explanation of the basic tsunami-related terms and with built-in help on the options of HTDB/PAC graphic shells;
- some additional functions provided by the HTDB/PAC shells, include reading the geographical coordinates and elevation/depth values at any point of a working area, calculation of a distance between two geographical points, calculation and plotting of the vertical cross-sections of the sea bottom and the land surface along an arbitrary broken contour.

Two examples of the screen outputs provided by the DOS-based HTDB/PAC shell are shown in Figs. 1–2. Examples of the screen outputs of the Windows-based shell are shown in Figs. 3–4.

4. Data Processing System

The HTDB/PAC graphic shell has several built-in procedures for data processing that allow one to make some standard operations for analysis of catalog completeness (histograms of event occurrence, magnitude-time, and intensity-time charts), relations between tsunami intensity and source magnitudes, tsunami event occurrence for different areas, and run-up frequency occurrence for any coastal point. Two examples of outputs provided by these options are shown in Figs. 5–6.

Acknowledgments. In the implementation of the HTDB/PAC Project, the main volume of programming for the HTDB/PAC graphic shells was done by Katherine Chernykh, Denis Ivaikin, and Eugene Popov from the College of Informatics of the State University of Novosibirsk. The primary collection of historical earthquake and tsunami data was made Mrs. Anna Osipova, administrator of the Expert Tsunami Database for the Pacific that has been maintained by the TL/ICMMG since

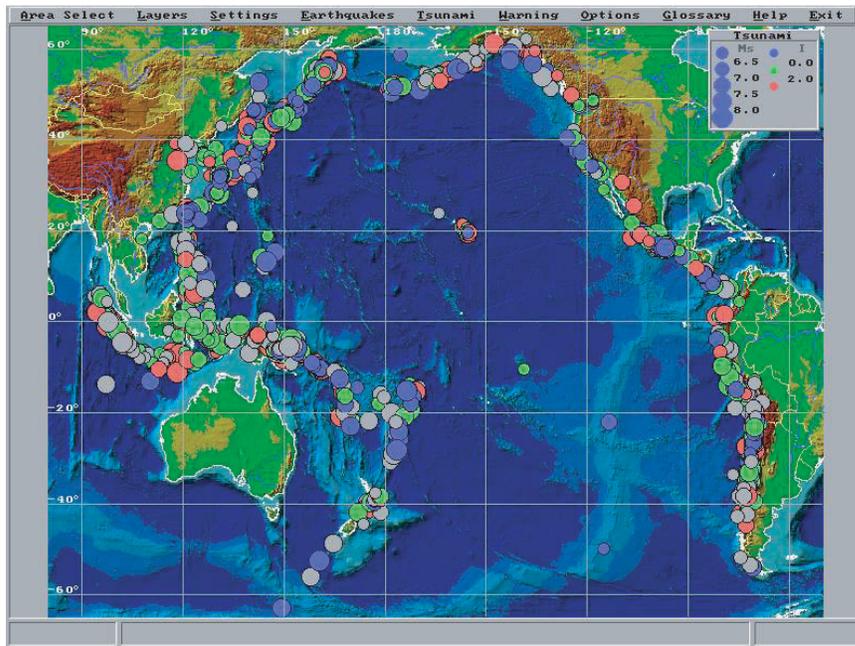


Figure 1: An example of the screen output provided by the DOS-based HDTB/PAC graphic shell—the map of historical tsunamigenic events in the Pacific. The size of circles is proportional to the event magnitude, while the color is defined by tsunami intensity.

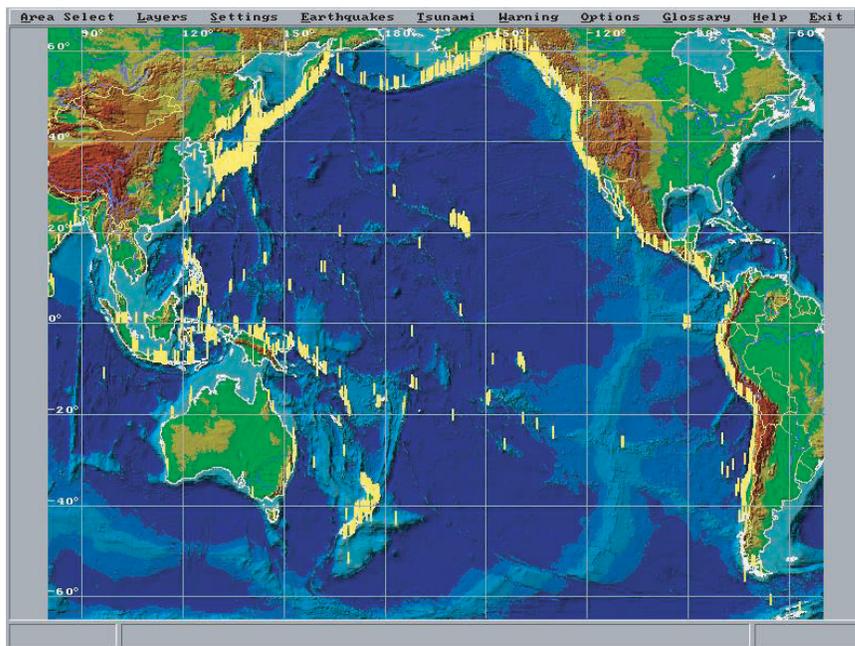


Figure 2: An example of the screen output provided by the DOS-based HDTB/PAC graphic shell—visualization of the historical run-up catalog for the Pacific.

HTDB -

File Area Select Map Earthquakes Tsunami Warning Options Glossary View Window Help

HTDB1

[HTDB1] Tsunami Event List (1183 Events)

Year	Mon	Day	Hour	Min	Sec	Lat	Lon	De...	mb	Ms	M...	Mt	l	m	Hmax	
1958	7	10	6	16	0,2	58,51	-136,13	27		7,9	7,7	8,0	3,5	9,0	525,00	
1936	10	27	6	50		58,60	-137,60	0					3,5	7,0	150,00	
1853						58,60	-137,50						3,5	7,0	120,00	
1741	8	29				41,60	139,40			6,9			2,5	3,0	90,00	
1788	8	6				55,00	-161,00			8,0			4,0		88,00	
1771	4	24				24,00	124,30			7,4			5,0	4,0	85,40	
1674	2	17				-3,70	127,70			8,0			4,0	6,0	80,00	
1964	3	28	3	36	12,8	61,02	-147,65	7	6,2	8,4	9,0	9,0	4,5	4,5	67,09	
1737	10	17	15	30		52,50	159,50	40		8,3			4,0	4,5	63,00	
1899	9	10	21	30		60,00	-142,00	25		8,5			3,5	3,0	60,00	
1792	5	1				32,00	128,00						2,5		55,00	
1896	6	15	10	33		39,60	144,20	30		7,4	8,5	8,5	3,7	4,0	38,20	
1883	8	27	2	59		-6,10	105,40						4,5		35,00	
1905	7	4				59,50	-139,80						2,5	5,0	35,00	
1946	4	1	12	28	56,0	52,75	-163,50	50		7,4	8,5	9,3	4,0	5,0	35,00	
1993	7	12	13	17	12,6	42,90	139,24	12	6,7	7,5	7,7	8,0	3,1		30,60	
1605	1	31	10	11		34,30	140,40			7,9			4,0	5,0	30,00	
1946	6	23	17	13		49,80	-124,50	33		7,2	7,5		3,0	5,0	30,00	
1933	3	2	17	30		56,7	39,27	144,60	4		8,3	8,0	8,3	3,5	3,0	29,30
1854	12	23				34,10	137,80			8,3			8,1	3,0	4,0	28,00
1997	12	12	5	29	28,6	-8,50	121,84	33	6,7	7,5	7,7		2,7		26,17	

For Help, press F1

Lat 43,1861 Lon -53,8450 Depth -3794

Figure 3: An example of the screen output provided by the Windows-based HTDB/PAC graphic shell—the listing of the historical tsunamigenic events in the Pacific sorted in order of their maximum run-up value.

HTDB

File Area Select Map Earthquakes Tsunami Warning Options Glossary View Window Help

HTDB1

Tsunami Description

1994, October 4 tsunami.

Quake

A magnitude 8.1 submarine earthquake hit the southern Kurils and northern Hokkaido on Tuesday October 5, 1994 at 00:23 local time (October 4 at 13:23 GMT). It was a sudden event, without any short-term precursors or foreshocks. The epicenter was located 80 km east southeast of Shikotan Island, the biggest island in the Small Kuril (Habomai) group of islands. The earthquake was largest shallow event in the Pacific since the 1989 Macquarie Ridge earthquake. It was felt over a large area from Severo-Kurilsk, Paramushir Island (about 1200 km north of the epicenter) to Tokyo, Honshu Island (about 800 km to the south). The source parameters of the main shock as determined by different seismological agencies and tsunami warning centers are shown in Table 1.

Table 1. List of source parameters as determined by different seismological agencies and operational centers

Time, UTC	Lat. N	Long. E	Depth, km	Magn.	Source
13:23:58	43.66	147.38	28	7.9	ISC, Newbury, UK
13:22:56	43.77	147.32	14	8.1	NEIC, Golden, USA
13:23:00	43.22	147.40	30	8.1	JMA, Tokyo, Japan
13:23:05	43.39	147.08	46	8.1	RCEP, Hokk. Univ., Japan
13:22:56	44.81	147.60	33	7.6	CSEM, Bruyeres, France

For Help, press F1

Lat 42,7542 Lon -65,1136 Depth -43

Figure 4: An example of textual description of the selected event—4 October 1994 Shikotan earthquake and tsunami.

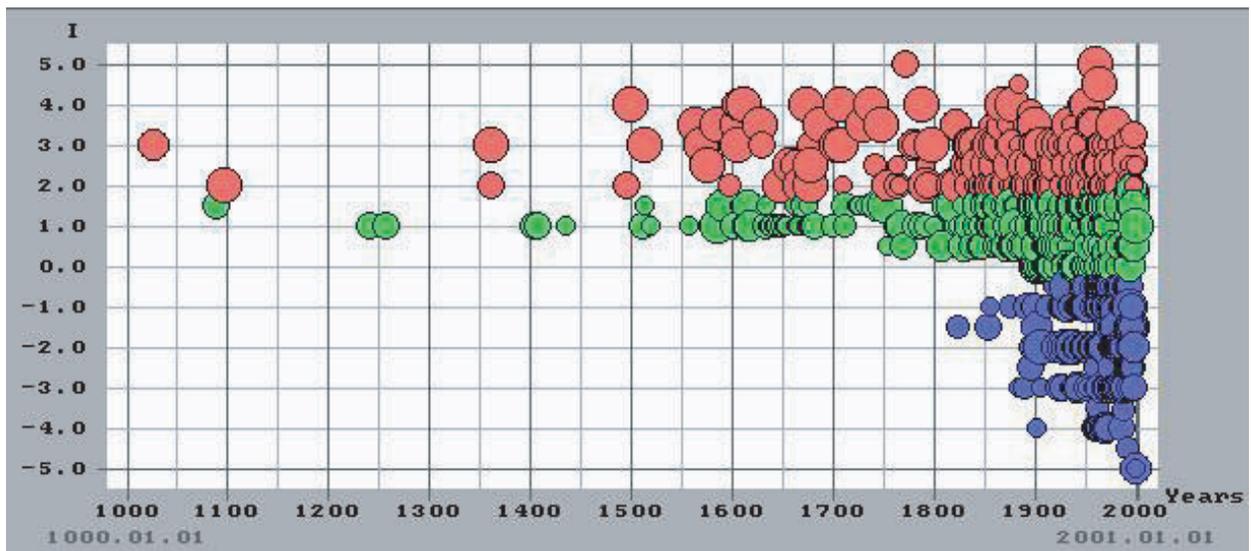


Figure 5: An example of the built-in processing software of the HTDB/PAC graphic shells—tsunami occurrence in the Pacific for the period from 1000 to 2000. The size of the circles corresponds to the source magnitude. Note the increased number of small tsunamis detected since the beginning of the 20th century due to the extension of the Pacific mareograph network.

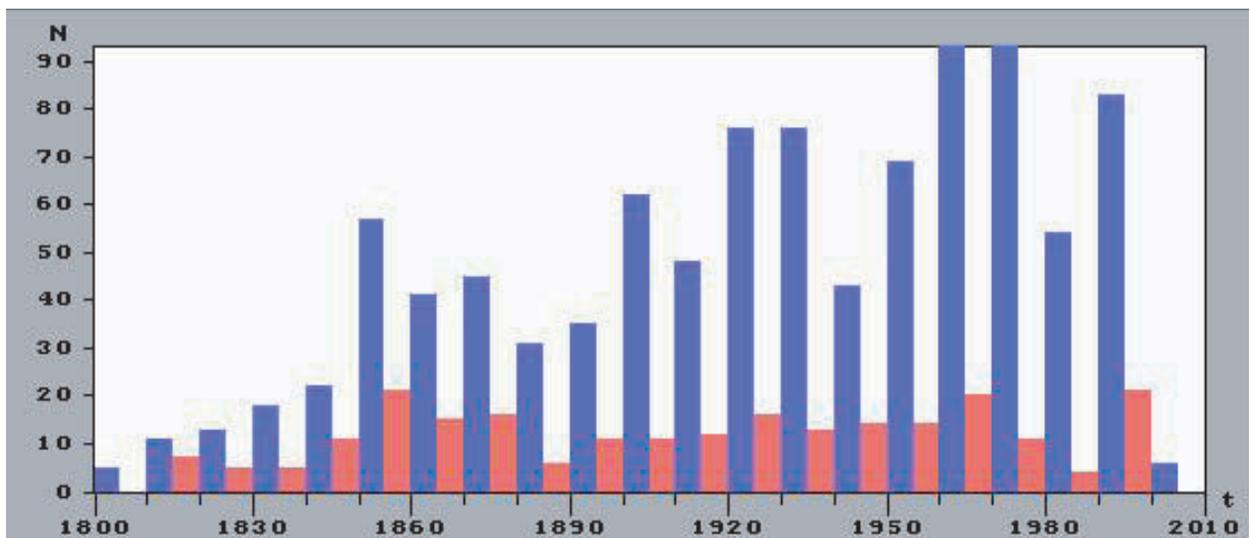


Figure 6: An example of the built-in processing software of the HTDB/PAC graphic shells—histogram of tsunami occurrence in the Pacific for the period from 1800 to 2000 (as the number of events within 10-year intervals). Blue color represent all tsunamigenic events; red color—events with tsunami intensity $I > 0$. In terms of major tsunamis, the Pacific catalog is complete since the middle of the 19th century. Note the deficiency of major tsunamis during the 1980–1989 decade.

1993. Dr. Andrey Marchuk, a senior researcher of the TL/ICMMG, collected the basic volume of the digital geographical data used by the HTDB/PAC mapping subsystem. Mr. Jim Lander of NGDC/NOAA (Boulder, Colorado) kindly provided us with the textual descriptions of tsunami manifestations at the U.S. coast in computer readable form. Dr. Emilio Lorca from University of Chile in Santiago, Chile, the HTDB/PAC regional coordinator for South America, greatly contributed to the improvement of quality of the tsunami event catalog for this area. The HTDB/PAC Project was supported by the IOC/UNESCO Contracts SC-207.557.0, and RFBR Grant 01-07-90199.

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