Vol. 5, No. 4 ● June 1995

EARTH SYSTEM MONITOR

NGDC monitors frequency of recent destructive tsunami events

Scientists examine possible recent increase in the occurrence of tsunamis

A guide to NOAA's data and information services

INSIDE

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The last three years have seen an unusual apparent increase in the frequency of destructive tsunami events. First, a group of three very destructive tsunamis occurred in the months between September 1992 and July 1993 (Figure 1), resulting in more than 1300 deaths. After an eleven-month period, a second series of five destructive tsunamis began in June 1994. No other 2.3 year period since the turn of century has had eight destructive tsunamis. The following is a brief description of each event between September 1992 and December 1994, and a comparison of the period with previous periods of tsunami activity.

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The September 1992 tsunami in Nicaragua

This event and the Skagway event in November of 1994 were the only two tsunamis of the eight (in this time period) to occur in the eastern Pacific. At 7:16 P.M. local time on September 1, 1992, an earthquake with a surface wave magnitude of 7.2 generated a tsunami with waves between 8 and 15 m high that struck 26 towns along 250 km of Nicaragua's Pacific coast. More than 40,000 people were affected by the loss of their homes or means of income. The waves left 170 dead, and another 500 injured. A tsunami inundation of 1000 m was reported at Masachapa, where at least 15 people were killed.

The tsunami caused an estimated U.S. $25 million in damage and losses. Fifty-three percent of this damage occurred to housing. Low income people suffered the most, incurring losses of homes, fishing boats, and income. The tsunami occurred in the evening when the fishing boats were docked, and many of them were lost or

– continued on page 2

▲ **Figure 1.** The Hokkaido Nansei-Oki (Sea of Japan) earthquake of July 12, 1993, produced one of the largest tsunamis in Japan's history. It also impacted the coasts of Russia, the Republic of Korea, and the Democratic People's Republic of Korea, causing varying degrees of damage. The photograph depicts a fishing boat beached by the tsunami near a damaged fire truck at Aone, Okushiri Island, Japan.

U.S. DEPARTMENT OF COMMERCE
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Tsunamis, *from page 1*

damaged by the waves. Several tourist centers were damaged, and two schools were destroyed; in addition, water supplies, waste disposal, electricity, and port infrastructure were affected. The ecology of the coastal area was injured as the waves and high salinity seawater destroyed plants, fish, turtles, and fish and turtle eggs.

The earthquake epicenter was located about 120 km west-southwest of the city of Managua. The earthquake was caused by the interaction of the Cocos and Caribbean tectonic plates, and occurred within a seismic gap located along the intersection of this event. This may have included a slow earthquake recently modeled by Jordan and Imhle (1995). Several aftershocks of decreasing magnitude followed.

The unusual wave height and destruction from the tsunami resulted from the relatively shallow earthquake depth and a subterranean landslide. The tsunami moved rapidly toward the Nicaragua coast, arriving at some coastal locations just twenty minutes after the earthquake.

The December 1992 tsunami in Indonesia

Of the eight events described in this article, the December 1992 tsunami in Indonesia was the most devastating. On December 12, 1992, at 05:29 UT a 7.5 magnitude (Ms) earthquake occurred in the Flores region of Indonesia, about 1800 east of Jakarta. The death toll as a result of the combined earthquake and tsunami effects was 2800, including 1,490 at Maumere and 700 on Babi Island. More than 500 were seriously injured, and 90,000 were left homeless. In addition, 28,118 houses, 785 schools, 307 mosques, and 493 commercial buildings were damaged or destroyed.

On Kalaota, 19 people were killed and 130 houses were destroyed. Severe damage occurred at Maumere, with 90 percent of the buildings destroyed by the earthquake and tsunami; damage also occurred on Sumba and Alar. Tsunami inundations of 300 m with wave heights of nearly 30 m were reported on Flores Island, along with landslides and ground cracks at several locations around the island.

The maximum tsunami runup height of 26.2 m was measured at Riangkroko, where 163 people lost their lives. Severe coastal erosion occurred during the tsunami, exposing eroded coral complexes and lowering coastal island surfaces. Coastline areas were characterized by the deposition of extensive and continuous sediment sheets of up to a meter in thickness. Wave reflection off Flores Island may have been partially responsible for the devastation on Babi Island.

The Hokkaido Nansei-Oki tsunami of July 12, 1993

On July 12, 1993, at 22:17 local time (1317 GMT), an earthquake with a surface wave magnitude of 7.6 occurred off the west coast of Hokkaido and the small offshore island of Okushiri in the Sea of Japan. In two to five minutes the tsunami engulfed the coastline of Okushiri Island and the central west coast of Hokkaido. More than 330 fatalities were associated with the event, with more than half attributed to the tsunami. The death toll on Okushiri Island alone was at least 165.

This July 12, 1993 earthquake filled a previously identified seismic gap. The resulting 30 m tsunami caused spectacular localized damage, especially on the southwestern shores of Hokkaido and on Okushiri Island. A runup height of nearly one meter was recorded at Aomori, Honshu, where one person was killed on a fishing boat.

The tsunami reached Russian shores in 30 minutes, with runup heights of one to four meters. The tsunami affected much of the southeastern coast of Russia, and also caused damage to a factory at Kamenka, Sakhalin Island. Three people from the southeast coast of Russia were missing after the tsunami. About 50-70 minutes after the earthquake, the first waves arrived in Prymoric, Russia. Three main waves were registered, but at some points up to eighteen minor waves were reported. In enclosed bays, sea level oscillations (seiches) were observed until noon.

Ninety minutes after the earthquake, the tsunami struck the coast of the Republic of Korea, where a maximum tsunami height runup height of two meters was recorded. Approximately 600 fishing boats were damaged

– continued on page 4

EARTH SYSTEM MONITOR

The *Earth System Monitor* (ISSN 1068-2678) is published quarterly by the NOAA Environmental Information Services office. Questions, comments, or suggestions for articles should be directed to the Editor, Richard J. Abram. Requests for subscriptions and changes of address should be directed to the Assistant Editor, Nancy O'Donnell.

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Workshop scheduled on remote sensing algorithms in hydrology

The IAHS/IMAS Session Jw1 workshop, "Remote Sensing Algorithms in Hydrology" will be held in conjunction with the XXI General Assembly of the International Union of Geodesy and Geophysics on July 3-14, 1995, at the University of Colorado in Boulder, CO. This workshop will present a valuable opportunity to convene a group of international scientists from multiple disciplines to share experiences regarding the development, application, and validation of various remote sensing algorithms in hydrology. One full day will be devoted to each of the following topics:

- Soil moisture - July 3
- Evapotranspiration - July 4
- Snow cover - July 5

Each session will be conducted in a true workshop format, which will provide an informal and interactive forum for the exchange of ideas, methods, and the presentation of specific problems and solutions. Each session will begin with one or two brief invited papers which will describe the history of algorithm development, offer examples of real applications, evaluate overall success, and identify specific problem areas.

Short presentations will then be made by a panel of selected researchers who are actively working with a particular algorithm, describing their specific successes, problems, and proposed solutions. The remainder of each topic session will be devoted to general discussions of: 1) an improved understanding of the physical basis for the particular problems identified, 2) possible techniques to reduce or eliminate the errors, and 3) suggestions for future research.

General audience participation will be encouraged during and after the panel presentations. All participants are encouraged to come prepared with a few key examples of their research to be presented in the general discussion.

For further information on any of the workshop topics, please contact the appropriate chairperson:

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News briefs

NGDC obtains new data in cooperative efforts with other agencies

The National Geophysical Data Center (NGDC) has received aeromagnetic data from the Indian Ocean, collected north and west of the island of Diego Garcia. The U.S. Naval Research Laboratory and the University of Wisconsin were joint investigators in this effort. Airborne magnetic data over the Central Indian and Carlesberg ridges were of primary concern. Aeromagnetic data in this area are of interest since little or no data are presently held by the NGDC. The collection is 23.5 megabytes and spans 38,668 nautical miles.

NGDC has also obtained 30 megabytes of uncorrected strong motion data from the U.S. Geological Survey for the Northridge, California earthquake of January 17, 1994. The magnitude 6.8 earthquake caused $30 billion worth of damage, with maximum horizontal ground accelerations exceeding 1 g at several stations in the epicentral area.

NCDC supports Global Climate Observing System (GCOS) project

The National Climatic Data Center's Senior Scientist, Tom Karl, provided an overview of the GCOS long-term climate monitoring meeting (held in Asheville, N.C.) to the GCOS Data Management Panel Meeting. Several action items resulted from the meeting, including a draft of an article which provides guidance on GCOS requirements for database documentation. Mr. Karl will be working with NESDIS's Chris Miller and other international scientists on this activity.

A call for putting CLICOM on CD-ROM will be part of the GCOS management plan. NCDC will be asked to lead in this effort. A report of the meeting is now available through the Joint Planning Office.

NGDC aids in improving data availability on the World Wide Web

NGDC has carried out a cooperative project with scientists in NESDIS and NOAA's Pacific Marine Environmental Laboratory to apply the most advanced World Wide Web interactive visualization techniques available to an important NOAA Pathfinder data set. This collaboration provides the capability to view monthly climate data from the TIROS operational Vertical Sounder (TOVS) instrument for the Pathfinder benchmark period along any horizontal or vertical plane, as well as examining time histories from any grid cell or as latitude/longitude/time images and series. All of this can be done interactively over the World Wide Web. The results of this revolutionary work are available on the World Wide Web at URL: *http://ferret.wrc.noaa.gov/ferret/main-menu.html*.

Conference scheduled on sustainable development and climate change

"Sustainable Development and Global Climate Change: Conflicts and Connections," a conference sponsored by the Center for Environmental Information, will take place December 4-5, 1995, at the Doubletree Hotel, Arlington, VA. The keynote speaker will be Bert Bolin, chairman of the Intergovernmental Panel on Climate Change. For information on this conference, please contact:

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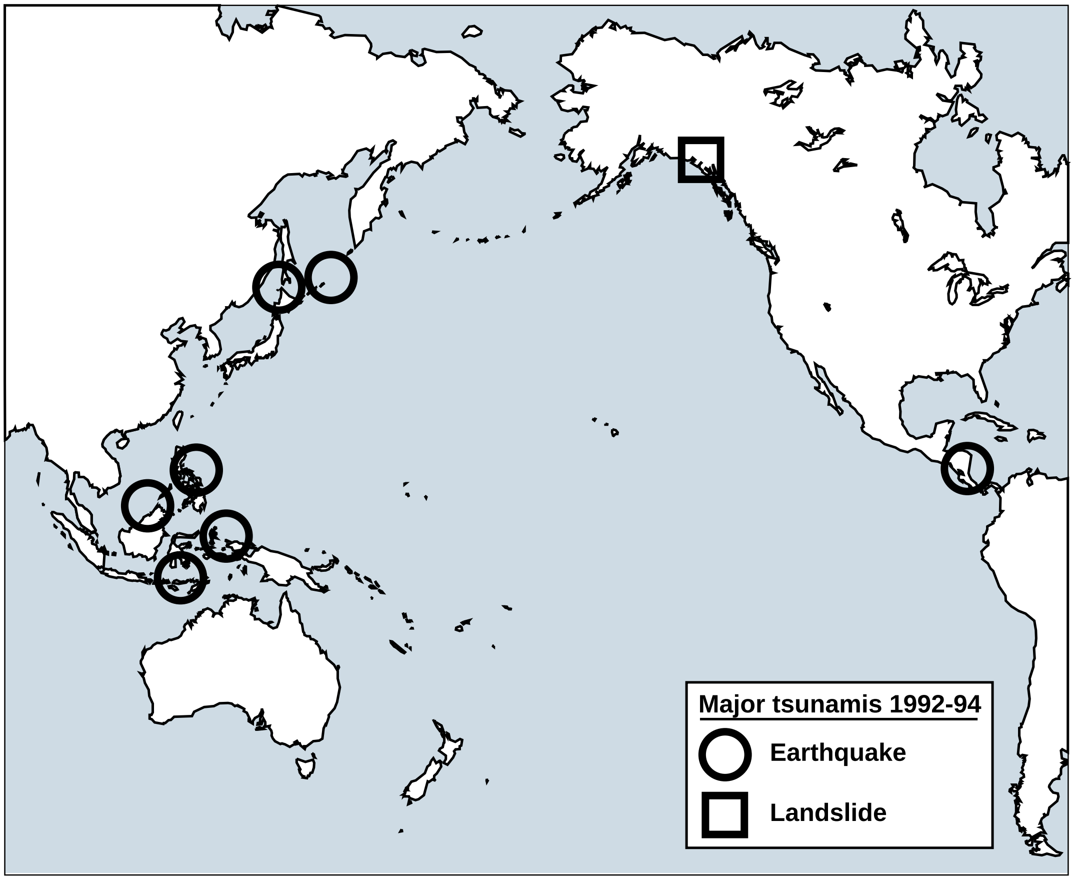

▲ **Figure 2** Locations of destructive tsunami events that occurred during September 1992 to November 1994. The maximum runup height was 26 meters. No other 2.3-year period since the turn of the century has had eight destructive tsunamis. Collectively, the eight tsunamis caused 2,000 deaths and over $50 million in property damage.

Tsunamis, *from page 2*

or lost off western Japan, southeastern Russia, and the People's Republic of Korea.

At almost all coastal points in eastern Russia that reported tsunami activity, the wave was preceded by a booming sound coming from the sea, and arrived as a very high tide. The maximum tsunami wave height was registered at Point Valentina and Rudnaya Pristan Bay (4 m). Damage resulting from the tsunami waves in Russia is estimated at $10 million. The maximum tsunami height was 30.6 m at southwest Okushiri Island.

The June 1994 tsunami in Indonesia

A destructive earthquake and tsunami occurred in Indonesia on June 3 causing extensive damage and numerous casualties along the Indian Ocean coastline of Java Island. Tsunami runup height was measured at more than eleven meters in some areas. The earthquake, with a surface magnitude of 7.2 and a moment magnitude of 7.8 occurred in the Java Trench—about 225 km south-southeast of Malang. Researchers are drawing similarities between this earthquake-tsunami event and the one that occurred in Nicaragua in 1992. The focal mechanism for this event indicates a thrust–type earthquake with a shallow dip angle.

The tsunami hit coastal areas in the Banyugwangi district and killed 250 people, and injured 440. Total monetary losses were estimated at $2.2 million. Survivors of the tsunami said waves hit unexpectedly, but were accompanied by a roaring sound as the tsunami swept inland as much as 300 m. More than 1,500 homes were destroyed, and numerous small boats either sank or were severely damaged.

This same tsunami reached the Australian coastline three to four hours later, and was recorded on tide gauges at Broome, Onslow, and Carnarvon. Several vessels operating close to shore were affected by the tsunami. A liquid natural gas ship experienced heavy loading on its mooring lines, and petroleum transfer between two vessels was disrupted, causing an oil spill. Near Northwest Cape, a gap in the offshore reef allowed the tsunami to reach the beach and a parking lot. A surge of about 3.5 m in height carried hundreds of fish, crayfish, rocks, and coral inland two or three hundred meters.

The area was deserted at the time of inundation, however, the tsunami was heard by residents of nearby camping areas who described the noise as like the "roar of a train." Inundation also occurred in other areas further south where gaps in the reef exposed the shoreline to the surge of the tsunami.

The October 1994 tsunami in the Kuril Islands

An 8.1 magnitude (Ms) earthquake occurred in the Kuril Islands on October 4, 1994. The earthquake epicenter was in deep water 1000 km north of Tokyo, and 165 miles east northeast of Kushiro, a city on Hokkaido Island (the northernmost island in the Japanese chain). The tsunami was first recorded in Japan with a 1.75 meter runup height at Nemuro, on the eastern tip of Hokkaido. Tsunamis of less than one meter in height came in at about thirty minute intervals along the Pacific coast of Hokkaido, Japan. The National Weather Service's Tsunami Warning Center reported tsunami waves of 3.46 m at Hanaskai, Japan, 1.62 m at Chichijima, Japan, 1.44 m in Miyako, Japan, and 1.3 m at Hachinohe, Japan.

The destructive tsunami had waves with heights nine meters or more in the Kuril Islands, Russia. At least ten people were killed by the tsunami that also produced a great deal of damage on Shikotan and on other small islands in the Kurils.

The event was called the first "great" earthquake of 1994 by the U.S. Geological Survey. The agency said that on the average only one great earthquake occurs worldwide each year.

Thousands of people from coastal areas of Hawaii were evacuated in anticipation of the arrival of the tsunami. Canada's west coast was also put on alert for waves caused by the quake. A warning bulletin was issued for the west coast of Vancouver Island, the Queen Charlotte Islands, and the northern half of British Columbia extending to Alaska. The main population centers of Vancouver and Victoria were not effected. A small tsunami was recorded as far away as Tahiti and Chile.

The October 1994 tsunami in Indonesia

A 6.8 magnitude earthquake occurred in the Obi Strait, south of Halmahera Island, Indonesia, on October 6, 1994. The earthquake generated a tsunami that caused localized damage on Obi Island. Six villages on Obi Island reported casualties and damage to houses and public facilities from the 3 m tsunami. The tsunami resulted in one death, 12 injured, and severe damage to 113 houses.

The November 1994 tsunami in Alaska

The Skagway tsunami is unique in this group because it is the only tsunami that had a landslide as its triggering mechanism. The other seven tsunamis were triggered by earthquakes. At about 7:10 P.M. on November 1, 1994, a landslide into the harbor at Skagway, Alaska, destroyed the southern 244 m of the White Pass Company railway dock, claiming the life of one construction worker. Loose alluvial sediment, ten to twenty-four meters deep, had accumulated along the eastern edge of the harbor at an average angle of about 35 degrees. A 0.9 to 1.2 m drop in the tide triggered the landslide, which was parallel to 300 m of shoreline, and slid west 125-200 m into the harbor.

Roughly one third of the land mass involved was initially above water, including over 10,000 metric tons of riprap (stone sustaining wall) stacked on a similar mass of fill along the shore next to the southern half of the dock. There was evidence that the wave resulting from the landslide reached 9-11 m in height at the shore.

The damage from this event included one million dollars to the ferry dock, one hundred thousand dollars to the small boat harbor, and replacement costs of between fifteen and twenty million dollars to the railroad dock. This event illustrates the fact that land-generated tsunamis, while less frequent than earthquake-generated tsunamis, can present a serious hazard. The threat from such events is increased by the fact that such landslide generated tsunamis give little or no natural warning.

The November 1994 tsunami in the Philippines

On November 14, 119, a tsunami generated by a 7.0 magnitude earthquake in the strait between Luzon and Mindoro Islands in the Philippines killed 62 people and injured more than 250. The tsunami struck Calapan City, Malaylay, Baco Town, and Puerto Galera. A wave height of 10 to 15 m was reported, however, the maximum measured runup height was 7.15 m in the southwestern coast of Baco Island.

The devastated areas were mostly restricted to the north of Mindoro Island, with inlets suffering the heaviest impact. Communications, power, and water supplies were severely disrupted, and damage to roads was estimated at $2.6 million. In addition, numerous buildings and bridges were destroyed. The tsunami reportedly reached the shore within as little as two to three minutes of the earthquake, leaving little time for coastal residents to attain high ground.

At Barangay Malaylay (a small low-lying island adjacent to the north coast of Mindoro Island), the tsunami reached a height of 6 m. With 24 dead and four missing, the island incurred the most casualties and damage from the tsunami. Both Nipa houses (made from palm fronds) and several houses with concrete walls and foundations were totally destroyed.

The tsunami at Barangay Wawa left much destruction and six dead. Nipa houses were dragged several meters inland, although concrete and masonry houses in this area appear to have incurred much less damage.

Tsunami earthquakes

Many of the events that occurred in the interval from 1992 through 1994 were generated by unusually small earthquakes. An earthquake that generates a tsunami much larger than is expected from the surface wave magnitude or the moment magnitude of the earthquake is known as a "tsunami earthquake." "Since the amplitude of a traveling tsunami in the near field is half the wave height of the initial tsunami, the sea bed must rise twice the value of the amplitude of the near field traveling tsunami" (Furumoto, 1993).

In a "tsunami earthquake" the sea bed rise required to generate the observed tsunami is larger than the vertical component of the slip derived from seismological calculations of the actual event. The events that were produced by tsunami earthquakes include: the September 1992 Nicaragua tsunami, the December 1992 Indonesia tsunami, the July 1993 Japan Sea tsunami, the June 1994 Indonesia tsunami, the November 1994 tsunami in the Philippines, and perhaps the October 1994 tsunami in Indonesia (Figure 2).

Back arc thrust fault earthquakes

Several of the tsunamigenic earthquakes were also back arc thrust fault earthquakes. "This type of earthquake belongs to the class of subduction earthquakes but occurs less frequently than the conventional subduction earthquakes associated with oceanic trenches" (Furumoto, 1993).

On the right of the island arc where an ocean (i.e., the Pacific or the Indian Ocean) is located, the oceanic lithospheric plate thrusts under the island arc, because the oceanic plate is denser than the island arc (usually a fragment of an ancient continent). On the continent side of the island arc system is a marginal sea, which is sometimes referred to as the back arc basin. The crust beneath the marginal sea also subducts under the island arc from the back side because the marine crust is denser than island arc crust.

The December 1992 earthquake in Indonesia, the July 1993 earthquake in the Japan Sea, the June 1994 earthquake in Indonesia, and the November 1994 earthquake in the Philippines all appear to be back arc earthquakes. "Within the last few decades, back arc earthquakes have occurred more frequently than in previous decades and have become noted for the destructive tsunamis that accompany them" (Jordan and Imhle, 1995).

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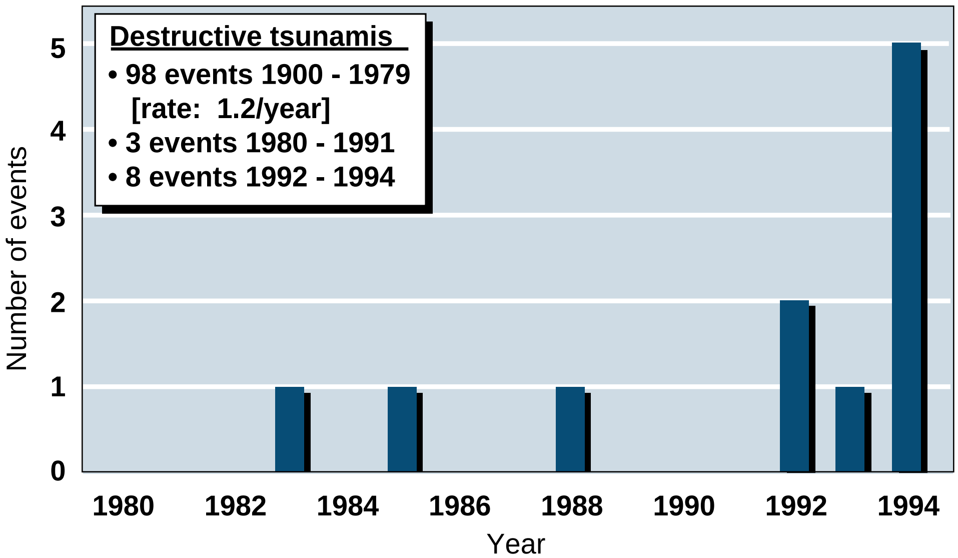

▲ **Figure 3.** Number of destructive tsunami events since 1980. Tsunamis occurred more frequently in the six-month period from June 1994 to November 1994 than in any period in this century. However, these tsunamis have tended to be local in their effects.

Tsunamis, *from page 5*

Tsunami rate of occurrence

Throughout most of this century. destructive tsunamis have occurred at the rate of 1.2 per year. During the twelve years between December 1979 and December 1991, there was on the average one destructive tsunami every year. This was only one-third of the normal rate for this century.

Then three destructive tsunamis occurred in the ten-month period from September 1992 to July 1993. There followed an eleven-month period with no destructive tsunamis. Then, in the six-month period from June 1994 to November 1994, five destructive tsunamis occurred. Tsunamis have occurred more frequently in this six-month period in 1994 than in any period in this century (Figure 3).

However, these tsunamis have all been rather local in their effects and impact as compared to the five great tsunamis of this century. We have not experienced a repeat of the Pacific Basin tsunami events that occurred from 1946 through 1964. During that eighteen-year period, five events occurred that caused damage in major portions of the Pacific Basin:

• The first of these events was the 1946 tsunami generated in the East Aleutian Islands, which caused major damage in the Hawaiian Islands and some damage on the west coast of the United States.

• The second great tsunami was the 1952 Kamchatka event. This event also caused major damage in the Hawaiian Islands.

• The third Pacific basin event was generated in the Central Aleutian Islands, and like the 1946 event also caused damage in the Hawaiian Islands.

• The fourth event was a huge tsunami generated off the coast of Chile in 1960 that caused damage throughout the Pacific, including major damage in Hawaii and Japan.

• The last major Pacific-wide tsunami was generated in the Gulf of Alaska in 1964. This event caused major damage in Alaska and on the west coast of the United States.

The eight tsunamis of the last three years have been much more limited in their scope, although some like the December event in Indonesia have had death tolls higher than any of the five "great" tsunamis (Table 1). The clustering of these event dates in the current decade and in the forties, fifties, and sixties illustrate both the random occurrence and the sporadic temporal spacing of tsunami events.

Table 1. Destructive tsunamis 1992-1994

Date	Eq Mag (Ms)	Location	Runup height (m)	Tsunami damage	Deaths
Sep '92	7.2	Nicaragua	9.7	Extensive	170
Dec '92	7.5	Indonesia	26.0	Extreme	1000
Jul '93	7.6	Japan Sea	19.7	$1.5x10^9$	330
Jun '94	7.2	Indonesia	3.0	$2.2x10^6$	250
Oct '94	8.1	Kuril Islands	9.0	Some	11
Oct '94	6.8	Indonesia		Local	1
Nov '94	Landslide	Alaska	10.0	$21x10^6$	1
Nov '94	7.0	Philippines	10.0	$25x10^6$	62

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The tsunami bulletin board.

The Tsunami Newsletter, Vol. XXVII, No. 1, International Tsunami Information Center, Honolulu, HI, January 1995.

The Tsunami Newsletter, Vol. XXVI, No. 1, International Tsunami Information Center, Honolulu, HI, July 1994. ■

The Spitak Earthquake Database: integrated online and desktop access to natural hazards information

International effort produces complete database from 1988 Armenian earthquake studies

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The Spitak, Armenia, earthquake of December 7, 1988, caused widespread damage to land and property, and resulted in tens of thousands of deaths. Research groups from France, Japan, the former U.S.S.R., and the U.S. studied the earthquake. NOAA's National Geophysical Data Center (NGDC), in cooperation with the Russian Academy of Sciences and the International Decade of Natural Disaster Reduction (IDNDR) Commission of the International Association of the Earth's Interior (IASPEI), has created the 1988 Spitak Earthquake Database in order to make the enormous amount of data obtained by the research groups available to the global scientific community.

The *Spitak Earthquake CD-ROM* represents an exciting new way to view and understand catastrophic phenomena. The Database has the following subdivisions: Geology, Geophysics, Mainshock, Aftershocks, Impact (epicentral area, towns, buildings), Elements of Prediction, and Seismic Wave Forms. Almost 2,000 files and 170 megabytes of data are contained on a CD-ROM.

The majority of the data consists of descriptive text files and maps, charts, photos, and other graphic images as .PCX format files [all photographs in this article were downloaded from the CD-ROM]. The set contains textual and graphical information about the earthquake, and a User Manual which discusses the data and explains how to use the access software to display and obtain desired information. The Database can be accessed using DOS, Windows, UNIX, or the World Wide Web (WWW).

Understanding seismic events requires the collection of large amounts of data concerning aspects of the natu-

– continued on page 8

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▲ Spitak, Armenia, and the surrounding region was the site of a severely destructive earthquake which was studied by an international group of scientists. Data obtained by researchers is being made available through the Spitak Earthquake Database.

▲ A five-story communications building in Spitak destroyed by the earthquake and the resulting fires. Image files such as this and accompanying detailed descriptions are part of the data available from the new *Spitak Earthquake CD-ROM.*

▲ Partial destruction of a five-story stone masonry bearing-wall building in Spitak.

Spitak earthquake, *from page 7*

ral environment, the performance of man-made structures, and data from the earthquake itself. The Spitak Earthquake Database contains almost all material relevant to the Spitak earthquake and its aftereffects, and also the geological/geophysical information collected during the years prior to the event. This database may be the first which contains such a complete integrated description of a catastrophic earthquake and offers such diverse access paths.

A vast amount of information is also needed in order to develop strategies for mitigating impacts of catastrophic earthquakes and other natural disasters. *The Spitak Earthquake CD-ROM* brings together one of the most complete collections of such information for a destructive earthquake. In addition to extensive material on the destructive effects of the earthquake, the database includes information on variations of numerous geophysical parameters prior to the earthquake. This information may prove helpful in forecasting or predicting similar events in the future.

This project involved a number of diverse geophysical and computer science challenges. The information in the Database was assembled by Russian scientists. The information (the majority of which was stored as images in .PCX format) was sent to the NGDC on numerous floppy discs. Natural hazards experts at the NGDC reviewed hundreds of pages of text in these files, clarifying the English and ensuring proper scientific usage. The relationship of the descriptive text to the images was also reviewed, and text was added where we felt it was necessary to improve understanding.

Two types of software, Spitak Data Base Software (SDBS) and GeoVu, provide access to the Database. The SDBS was specifically developed for accessing the .PCX images, the descriptive text which accompanies them, and other data on the CD-ROM. This software runs under DOS on IBM-PC compatibles. As with any specialized software, SDBS provides quick and logically reasonable access to information.

GeoVu was created at the NGDC as a general tool for access to many interdisciplinary data collections created at the NGDC or other data centers. The database, "Spitak Earthquake of 1988," is one such collection. GeoVu can be used to examine the Database under Microsoft Windows or on several UNIX workstations (SUN and SGI at present). GeoVu can read .PCX format, allowing access to the existing files without reformatting or translation. This broadens the potential user community for this CD-ROM and enables users to access the information on the CD using their platform of choice.

Data access experts at NGDC developed the support files needed to view the Database using GeoVu. One such file, termed a GeoVu menu file, includes a detailed hierarchical description of the database structure and its

– continued on page 12

▲ View of the right-lateral strike-slip motion along the fault southwest of Spitak. Note offset of sugar beet rows. Damage to agriculture in this region was more than $13.3 billion.

NDBC develops advanced electronic bulletin board system

New graphical user interface eases access to high-quality marine data

David B. Gilhousen
National Data Buoy Center
NOAA/NWS

The National Data Buoy Center (NDBC) has developed an advanced electronic bulletin board system (BBS) called SeaBoard (Figure 1). SeaBoard is one of the first government BBS's to support a "point and click" graphical user interface either through direct dial or the Internet (Figure 2). It was created to give engineers and scientists easier access to NDBC's marine observations. NDBC's 114 moored buoys and Coastal-Marine Automated Network (C-MAN) stations transmit hourly weather and oceanographic reports via the Geostationary Operational Environmental Satellite (GOES).

▲ **Figure 1.** The SeaBoard bulletin board's welcome screen as it appears to Remote Imaging Protocol (RIP) users. A free shareware program is available to provide graphical interface capability for modem access.

Purpose

SeaBoard's primary purpose is to provide high-quality data within a few days of observation. Though observations are transmitted to the NWS weather forecasters within minutes of their collection, the BBS data set is more thorough and has gone through more extensive quality control. Besides the observations, climatic summary tables of previous reports help users get an historical perspective.

A data inventory shows detailed station history, and status reports show what is being measured currently at each station. Data are kept online for three months; older data are available through the National Oceanographic Data Center's home page or CD-ROMs.

NDBC stations typically measure sea level pressure, winds, waves, air and sea surface temperature. Some buoys measure directional wave data, humidity, and a profile of currents with depth. Some C-MAN stations measure visibility, humidity, and water levels.

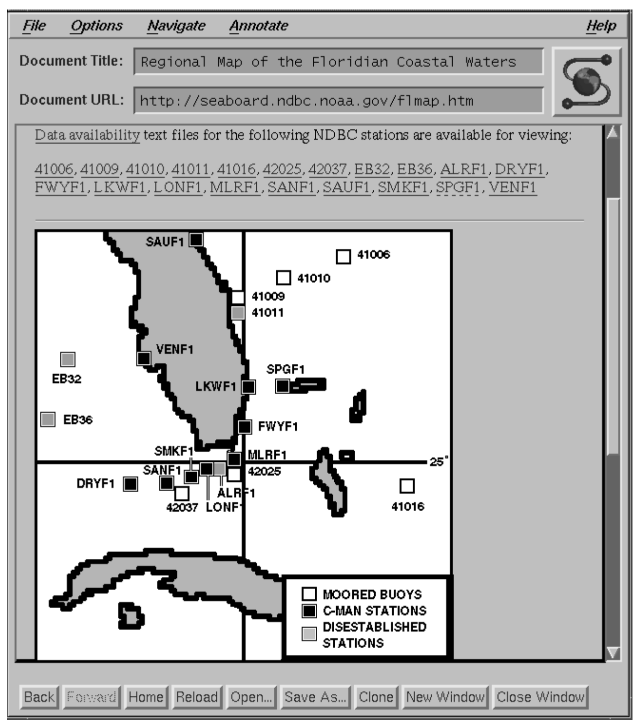
National Data Buoy Center
NOAA/NWS
John C. Stennis Space Center, MS 39529
E-mail: dgilhousen@ndbc.noaa.gov

Usage

Though most of the stations are funded to support weather forecasting, many other uses have been found. Engineers use measurements taken during storms when designing breakwaters to withstand huge waves or buildings to withstand hurricane force winds. Geologists relate these measurements to beach erosion, and biologists relate water temperatures and winds to fish populations. Similarly, physicists calibrating remotely-sensed winds and waves from spacecraft are big data users. Over 50 such users expressed an interest in SeaBoard before its completion.

"Recent wind reports from a buoy posted on SeaBoard helped forecast the movement of an oil spill. The spill occurred 60 miles southwest of Houston, Texas and SeaBoard was a great way to recover past wind reports," said Mr. Jesse Uzzell of Morris Environmental.

– continued on page 10



▲ **Figure 2.** A regional map accessible through the Internet that is part of Seaboard's innovative "point and click" graphical user interface.

SeaBoard, from page 9

Technical Details

SeaBoard supports many users simultaneously either through direct dial via a modem or over the Internet. Internet users have their choice of Telnet, FTP, and World-Wide Web access methods. Amazingly, the system was developed on a Pentium PC running DOS using Galacticomm's Major BBS software. SeaBoard graphics include location maps which help users get to information without having to know where the stations are located.

SeaBoard's graphical "point and click" interface is supported through the Remote Imaging Protocol (RIP). Figure 2 shows what the first screen will look like with RIP. A free shareware communications program, RipTerm, can be downloaded to provide this capability for modem access. Smartcom, a Windows communications program developed by Hayes, can provide this same interface through the Internet.

A BBS that combines dial-in and Internet access gives the user several advantages. According to system designer David Gilhousen, "A Web browser is a great way to get information about our stations and measurements (Figure 3), including buoy and station photographs. The RIP interface is best for the novice dial-in user. FTP is excellent for transferring large files, yet users can fall back to dialing in if the Internet bogs down." Dial-in capability was a requirement because some NWS field offices lack an Internet connection.

Access Information

Phone number: (601) 688-7938
Modem settings: 8 data bits, no parity, and 1 stop bit
Modem Speeds: Up to 28.8 Kbps
Telnet and FTP Host Name:
Seaboard.ndbc.noaa.gov
FTP Login: *anonymous* and give e-mail address as the password
Home Page Address:
http://seaboard.ndbc.noaa.gov

Acknowledgements

SeaBoard was funded as part of NOAA's Earth Systems Data Information and Management program. The National Climatic Data Center produced the climatic summary tables which will also be available on CD-ROM. ■

Evidence for radiative effects of anthropogenic sulfate aerosols in the observed climate record

Evidence for anthropogenic sulfate aerosol influence on surface air temperature is supported by a new analysis of daily surface air temperatures, cloud amount, and SO_x emissions in North America. The complete study is being published in *Aerosol Forcing of Climate*, edited by R. Charlson and J. Heintzenberg. The following synopsis overviews the principal results of this investigation.

Within the contiguous U.S., SO_x increased by about 8 Tg between 1950 and 1970, and decreased by a similar amount from 1970 to 1990. The daily surface air temperature maxima under both clear sky and overcast conditions cooled by about 0.9°C from 1950 to 1970, and warmed by a similar amount thereafter. These results are consistent with the expected direct and indirect impact of SO_x emissions on surface air temperature.

The research indicates that the change in SO_x emissions in the U.S. have led to a variation of the mean daily temperature, under both completely clear and fully overcast skies of up to about 0.45°C. However, there was no net change of temperature since 1950 during average weather conditions.

Assuming that the sulfate-induced cooling effect is quantitatively similar for all sky conditions, the total depression of the mean annual surface air temperature due to SOx emissions of 20.5 Tg (in 1990) is estimated to be approximately 1.0°C.

The results of several other detection studies on a hemispheric scale support the hypothesis that sulfur-based industrial aerosols have influenced surface temperature since at least the 1940's. Regions of high and/or increasing rates of SO_x emissions in the Northern Hemisphere tend to coincide with areas of relative cooling.

However, aspects of the seasonal temperature trends, as well as other temperature analyses of data prior to the 1940's do not readily conform to the expected sulfate aerosol forcing. A more complete understanding of the climatic causes and consequences of aerosol formation and transport, aerosol interaction with clouds, and the role of natural variations of atmospheric and oceanic circulation with respect to aerosol forcing will all require more research.

References

Charlson, R. and J. Heintzenberg (eds.), 1994. *Aerosol Forcing of Climate*. John Wiley and Sons, Ltd., Dahlem Konferenzen, in press.

—Thomas Karl and Richard W. Knight
NOAA/NESDIS
National Climatic Data Center
151 Patton Ave.
Asheville, NC 20081-5001

—George Kukla and Joyce Gavin
Lamont Doherty Earth Observatory
Columbia University
P.O. Box 1000/Rt 9W
Palisades, NY 10964-8000 ■

Views of the globe hemispheric color relief images

Fourteen images of hemispheric global relief have been computer-generated from NGDC's digital elevation data, and combined into a 24" x 24" full-color poster. Views are spaced every 90° of longitude and 45° of latitude. An arbitrary color scheme was chosen to give a natural look to the continents and oceans, and the colors were assigned according to elevation. The resolution of the gridded data used varies from true 5-minute for the ocean floors, the United States, Europe, Japan, and Australia, to 1 degree in the data-deficient parts of Asia, South America, northern Canada, and the Arabian subcontinent.

The poster is available for viewing in a miniature form on the Internet at the home page address: *http://www.ngdc.noaa.gov/mgg/mggd/html*.
Contact: NGDC

Worldwide marine geophysical trackline data

The NGDC announces an update to its GEophysical DAta System (GEODAS) CD-ROM set of underway marine geophysical data. GEODAS software, developed to manage marine geophysical trackline data, has been enhanced, allowing application to other types of data: GEODAS/TRKDAS for marine geophysical trackline data, GEODAS/HYDDAS for hydrographic (bathymetric) survey data, and GEODAS/ARODAS for aeromagnetic data.

The GEODAS/TRKDAS CD-ROM Version 3.1 data set contains all of NGDC's digital, marine geophysical trackline data, including new data which have been acquired and assimilated by NGDC during 1994. The total amount of new data covers 591,000 nautical miles of bathymetry, magnetics, and gravity from 184 cruises, and includes over 2.9 million additional digital records. Vertical beam data from 388 multibeam bathymetry surveys have been included on the GEODAS/TRKDAS CD-ROM Version 3.1 data set. This CD-ROM set allows inventory searches for multibeam bathymetry and analog data, which are also available from NGDC.

NGDC has made GEODAS/TRKDAS available using a World Wide Web browser. Users can search the inventory, create Postscript® plot files and download the newest MGD77 data that are not yet available on CD-ROM. To try out GEODAS online, run a World Wide Web browser (such as Mosaic) and open URL: *http://www.ngdc.noaa.gov/mgg/gdas/gd_sys.html*.
Contact: NGDC

Data products and services

NCDC announces the availability of ISMCS Version 3 CD-ROM

The NCDC announces the availability of the International Station Meteorological Climate Summary (ISMCS) Verion 3 CD-ROM. This CD-ROM is the third in a series produced at the Federal Climate Complex in Asheville, NC, as a joint product of NCDC, the U.S. Navy, and the U.S. Air Force. It contains detailed climatological summaries for about 2200 international locations, along with brief summaries for about 5000 other locations.

The software is IBM-compatible and allows the user to view, print, export, and even graph (histograms of selected tables, wind roses, etc.) the data. The user can select the station or region in a number of ways, such as the World Meteorological Organization (WMO) station number, individual country, alphabetical sort, latitude/longitude area, or mouse-click on a user-defined map.

This upgrade from Version 2 includes 1100 additional non-U.S. locations with detailed summaries, several additional tables and narratives, and new graphical plots of selected tables. The package contains 38 different climatic tables/summaries, including:

- A one-page climate summary for the station with monthly averages and extremes of temperature, precipitation (amount and/or frequency), cloudiness, humidity, winds, and occurrence of various weather phenomena (e.g., fog, thunderstorms).
- Frequency distribution of daily maximum and minimum temperatures by month.
- Bivarate distribution of dry vs. wet bulb temperatures.
- Frequency distribution of wind direction vs. wind speed by month-hour.

Contact: NCDC

CONTACT POINTS

National Climatic Data Center (NCDC)
Climate Services:
704-271-4682
Fax: 704-271-4876
E-mail: orders@ncdc.noaa.gov

Satellite Services:
301-763-8399
Fax: 301-763-8443
E-mail: sdsdreq@ncdc.noaa.gov

National Geophysical Data Center (NGDC)
303-497-6958
Fax: 303-497-6513
E-mail: info@ngdc.noaa.gov

National Oceanographic Data Center (NODC)
202-606-4549
Fax: 202-606-4586
E-mail: services@nodc.noaa.gov

NOAA Environmental Services Data Directory
202-606-5012
(Gerry Barton)
Fax: 202-606-5012
E-mail: barton@esdim.noaa.gov

NOAA Central Library
Reference Services:
301-713-2600
Fax: 301-713-4599
E-mail: noaalib@libmail.lib.noaa.gov

Aurora Australis (Southern Lights) slide set

The NGDC's Division of Solar-Terrestrial Physics presents a unique set of twenty spectacular slides taken by David Miller from Kangaroo Island in southern Australia showing the southern lights (aurora australis) during disturbed geomagnetic times—similar in nature to the northern lights (aurora borealis). The displays are presented in full color and show the form of the aurorae framed against background stars and landscapes.

In addition, the NGDC offers a set of 52 black-and-white slides illustrating auroral variability and other nocturnal lights viewed from space. Each frame was prepared with no retouching from an extensive 35 mm archive of satellite auroral imagery—nighttime images taken between 1973 and 1977 by Defence Meteorological Satellite Program (DMSP) satellites. Both Northern and Southern Hemisphere auroras are included.

A Zurich sunspot slide set is also offered. The seven fully captioned slides illustrate different sunspot-related phenomena. The set is designed to illustrate the importance of solar phenomena in studies of the Earths's "energy budget."
Contact: NGDC

▲ Granary in a flour mill complex east of Spitak (grain can be seen spilling out of the collapsed concrete shear-wall structures in the foreground). This image from the *Spitak Earthquake CD-ROM* is available for viewing online through the WWW.

Spitak earthquake, *from page 9*

contents. This menu file can be examined on the WWW using browsers such as Mosaic or Netscape and the NGDC Hierarchical Metadata Server (which works with the WWW server at NGDC. This allows Internet users to interactively view all of the descriptive material in the Database (metadata).

We recently added the capability to view the .PCX files in the Database, making most of the information and images in the Database available online. The WWW implementation features Hypertext Markup Language (HTML) pages, which include a thumbnail rendition of each .PCX file and the caption for that file. These pages are created dynamically in response to user requests, avoiding the need to create and maintain hundreds of HTMLs at the NGDC. This same capability is being used to make the NGDC's collections of Natural Hazards Photographs available online. Look for both of these on the "What's New" page at *http://www.ngdc.noaa.gov* or at *http://www.ngdc.noaa.gov/seg/mainmeta.html*

The NGDC is interested in applying this technology to other diverse collections of data related to any earth science. Please contact Ted Habermann (*haber@ngdc.noaa.gov*) if you would like more information on such collaborative projects. This project was funded in part by the NOAA Pioneer Fund.

Briefly, system requirements for utilizing the *Spitak Earthquake CD-ROM* are:

- DOS: requires 800 Kb hard disc space and 560 KB of memory;
- Microsoft Windows: requires 570 Kb hard disk space for the access software.

The *Spitak Earthquake CD-ROM is* available from the NGDC at:

National Geophysical Data Center
NOAA/Code E/GC1
325 Broadway, Dept. 958
Boulder, CO 80303
Phone: 303-497-6277
Fax: 303-497-6513
TDD: 303-497-6958
E-mail: *info@ngdc.noaa.gov* ■

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