Chapter 4

Data and Information Collection

The collection of data and information from locally maintained and international earth data observation networks is a crucial function of National Tsunami Warning Centers (NTWC) and Regional Tsunami Watch Providers (RTWP). NTWCs and RTWPs have three basic data and information collection requirements. These requirements are:

- Collect seismic and sea-level observational data
- Receive event impact reports from national, state, and local agencies and the public
- Share data and information with other NTWCs and RTWPs

This chapter describes data and information collection requirements, in particular the communications systems for collecting seismic and sea level data needed to detect the occurrence of a tsunami (Figure 4-1).

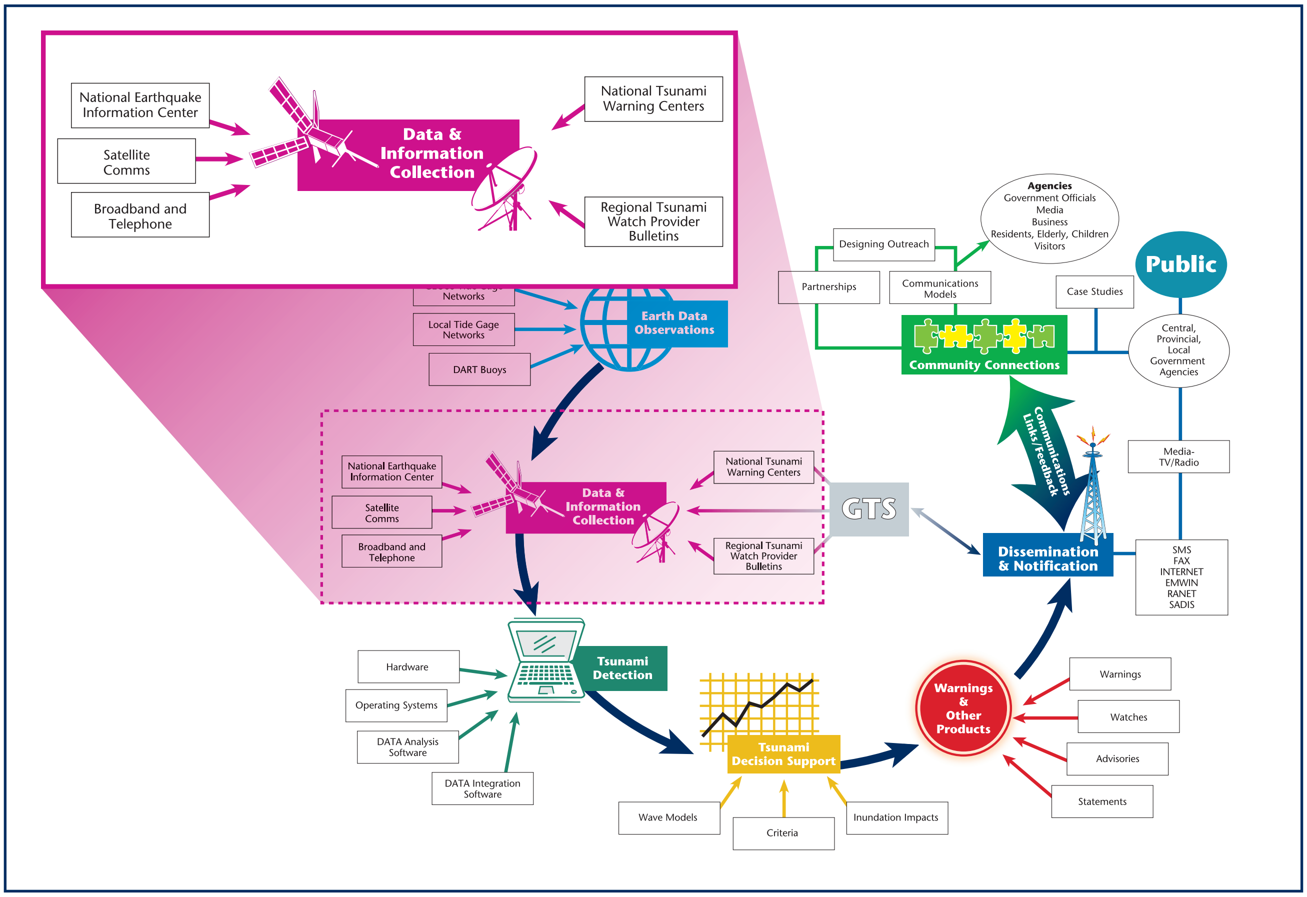


Figure 4-1. Components of a Tsunami Warning Center's Data and Information Collection Requirements

Several telecommunications connections are required to collect data and information needed to detect a tsunami. Some data, especially seismic and sea level data from international networks, are available in real time through the internet and satellite downlinks. Data from locally maintained networks often require alternate communications paths such as land lines, wireless telephone, or radio. This chapter should be read by persons who need to understand the types of communications methods necessary to collect and share data and information, and the importance of maintaining these communications programs and their backups.

How Do Data and Information Collection Fit into an End-to-End Tsunami Warning System?

Data and information collection systems are part of the hazard detection and forecast component of an end-to-end tsunami warning system. The rapid detection and characterization of tsunami-generating earthquakes provides the first indication of a potential tsunami in an end-to-end tsunami warning system. Initial seismic-based warnings based on data from networks of seismic gages are subsequently refined by the detection of tsunami-generated changes in sea level measured by tide gages and buoys. In both cases these data must be received at a center with as little delay as possible. Critical seismic and sea level data must be received rapidly at tsunami warning centers to be of any use in the warning process. Thus, data collection communications systems are crucial to the success of the warning system. Use of backup networks and backup communications paths are needed to ensure a robust program.

What Is in this Chapter?

This chapter contains sections that discuss the following topics:

- **Primary data and information collection through the Global Telecommunications System (GTS):** This section describes the World Meteorological Organization's (WMO) GTS, the primary earth data collection system, including general message formats, and the Message Switching System.
- **Other data and information collection communications channels:** This section briefly discusses methods other than GTS for retrieving earth observation data, including internet, telephone dial-up, etc.
- **Accessing international seismic networks:** This section discusses methods for accessing the Global Seismic Network and local seismic networks.
- **Accessing international tide gage networks:** This section discusses communications requirements for NTWCs and RTWPs to access the Global Sea Level Observing System, an international sea-level monitoring network.
- **Backup communications for data and information collection:** This section discusses the communications connections with other centers, and the importance of backup communications channels.
- **Data collection formats:** Tide gage data, Deep Ocean Assessment and Reporting of Tsunami (DART™) buoy, and seismic data formats are discussed in this section.

What Are the Most Important Points to Remember about Data and Information Collection for NTWCs and RTWPs?

- Critical seismic and sea level data must be received rapidly at tsunami warning centers to be of any use in the warning process.
- Seismic and sea level data from international networks are available in real time through the internet and satellite downlinks.
- Data from locally maintained networks often require alternate communications paths such as land lines, wireless telephone, or radio.
- Backup networks and backup communications paths are needed to ensure a robust program.

Primary Data and Information Collection through the Global Telecommunications System

The primary data collection pathway for NTWCs and RTWPs is the Global Telecommunications System of the World Meteorological Organization. The GTS distributes a wide range of earth data observations with standardized data formats and content. Data and information are routed using a message switching system (MSS) consisting of hardware and software systems. An overview of the GTS is given in Figure 4-2.

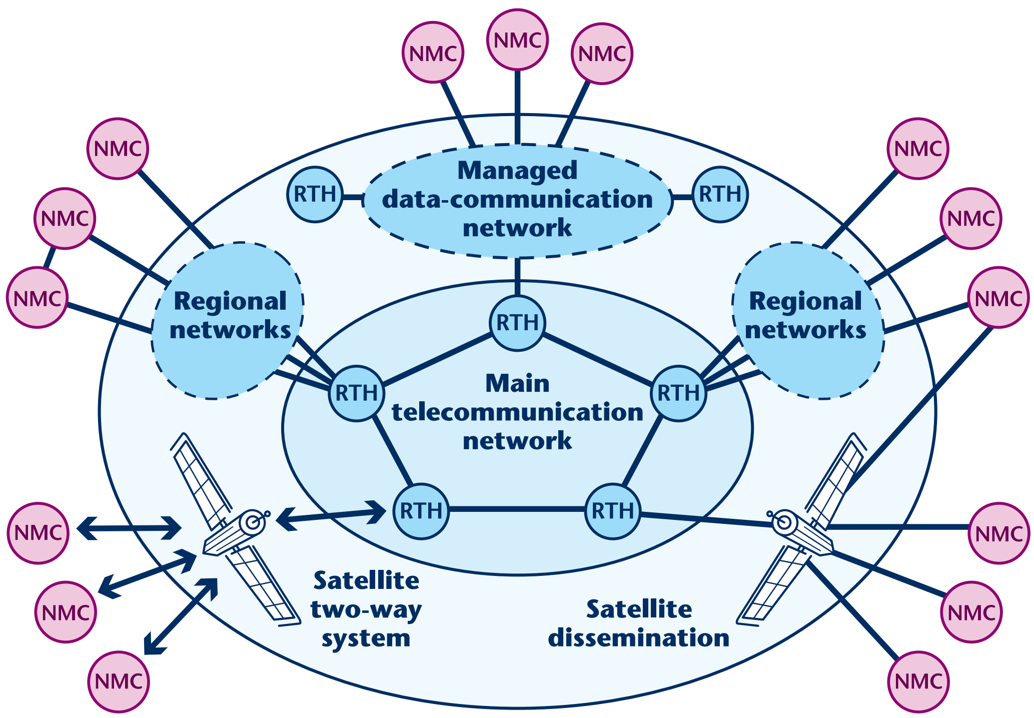


Figure 4-2. Basic Structure of the GTS

The GTS connects meteorological and other centers throughout the world. Its primary purpose is to distribute meteorological, hydrological, and other data, products, alerts, and warnings to the global meteorological community, composed of member nations of the WMO. The structure of the GTS makes use of terrestrial communications circuits to disseminate data, products, and bulletins over a tiered network. The three tiers of the GTS are the World Meteorological Centers (WMC), the Regional Telecommunications Hubs (RTH), and the National Meteorological Centers (NMC).

The three WMCs and the RTHs are interconnected through the Main Telecommunications Network (MTN). The NMCs are connected to the RTHs and other NMCs through numerous Regional Meteorological Telecommunications Networks (RMTN). The NMCs are connected to various in-country points through National Meteorological Telecommunications Networks (NMTN). In addition to the terrestrial network components, several satellite systems provide weather data and bulletins in various regions.

Some NMCs collect various observational data within their territory, such as upper air observations, surface temperature and winds, seismic sensor data, tide gage data, and ship and aviation reports, and produce various forecast and bulletin products. These data and messages are collated for distribution to the RTHs and WMCs via the GTS. Through a distributed set of routing catalogs at each tier (WMCs, RTHs, and the NMCs) of the GTS, data is routed across the GTS to every center requiring each data set and message. The formats and routing procedures are formally defined in WMO Manual 386, *Manual on the Global Telecommunication System*. There are other NMCs that receive data from GTS but do not yet contribute locally generated messages into GTS for distribution. It should be noted that at the present time, while sea level data is handled acceptably by GTS, the transmission of seismic data is probably beyond its scope and is better handled by other communications channels.

Data Formats and Contents

WMO Manual 386 defines the meteorological message format for transfer of information and data on the GTS. Information traversing the GTS may be in alphanumeric, binary, or pictorial form. The messages have a predefined structure consisting of a starting line, an abbreviated heading, the bulletin text, and an end-of-message line. This structure is illustrated in Figure 4-3, taken from WMO Manual 386.

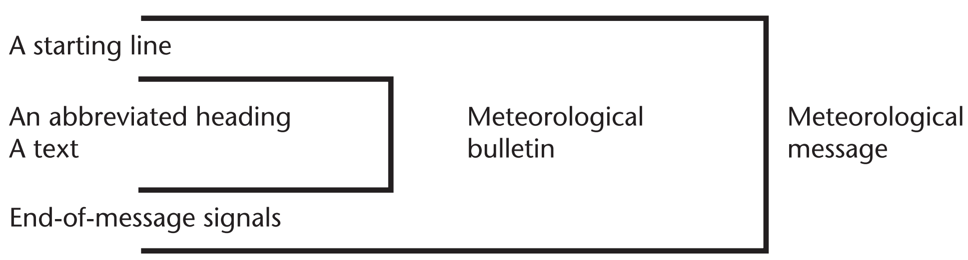


Figure 4-3. GTS Bulletin Structure

The starting line, abbreviated heading, and end-of-message line are alphanumeric using either the International Telegraph Alphabet No. 2 (ITA-2) or the International Alphabet No. 5 (IA-5). Messages containing information in binary representation are required to use IA-5 for these fields.

To the extent that the GTS is retained as the preferred means of transmitting tide gage data from their source (the gages) to the concerned data centers (notably, Permanent Service for Mean Sea Level (PSMSL), University of Hawaii Sea Level Center (UHSLC), and national sea level data centers), the necessary data format is contained in the WMO Manual on Codes at **http://www.wmo.int/pages/prog/www/ois/Operational_Information/ManOnGTS.html.** See Figure 4-10 for an example of a GTS message.

Message Switching Systems (MSS)

At the heart of the GTS routing mechanism reside hardware and software systems called the MSS. These systems are developed and deployed by various commercial firms and governmental agencies worldwide and must comply with the message structure and routing procedures called out in WMO Manual 386.

An MSS is essentially a store-and-forward data filtering application. A constant stream of data available on one or more incoming connections is monitored for the message header information, upon which the MSS makes routing and storage decisions based on user-configurable criteria. Messages are then typically stored in a database as well as forwarded to predetermined destinations, which could include, but are not limited to, local forecasting workstations, local storage devices, other organizations within the NMC's territory such as disaster management centers and national dissemination networks, and other MSSs on the GTS network. Routing of messages can occur several ways on a variety of circuit connections such as point-to-point over a local area network (LAN) or wide area network (WAN), dial-up, fax, email, Very Small Aperture Terminal (VSAT) satellite ground station, internet and file transfer protocol (FTP) services, etc.

Routing of data between RTHs and NMCs is done in accordance with GTS formatted routing catalogs accessed by, or resident on, the MSSs at each center. These routing catalogs consist of American Standard Code for Information Interchange (ASCII) files that can be imported into database applications. Therefore, the structure of the files is such that each line, or record, contains a discrete routing entry consisting of the 11-character abbreviated heading, the 4-character identifier of the GTS circuit from which the bulletin is received, and a series of one or more 4-character identifiers of the GTS circuit to which the bulletin is to be sent. The WMO stipulates that all centers make their routing catalogs available on FTP servers and that they be updated, at a minimum, every 3 months and preferably at least monthly. The prescribed format is a comma-separated value file, with the first record containing the last date of modification in the form YYYYMMDD. The functionality of an MSS varies based on location (WMC, RTH, or NMC) and in-country capabilities and requirements. Many MSSs are far more sophisticated and are linked with other software and hardware systems such as weather display, processing, and forecasting systems and disaster management systems.

Important Points to Remember about Data Collection through the GTS

- GTS can be used to:
  - Collect earth data observations.
  - Share data and information with other NTWCs and RTWPs.
- GTS is a three-tiered system, made up of World Meteorological Centers, Regional Telecommunications Hubs, and National Meteorological Centers.
- GTS uses message switching systems (MSS) to address, prioritize, and route products.
- Product formats required by GTS are specified in WMO Handbook 386.
- Sea level data can be monitored through the GTS, but primary access to seismic data should be via other means, notably the internet and dedicated circuits.

Other Data and Information Collection Communications Channels

Several other communications options, other than GTS, are available to collect data and information necessary for tsunami detection by NTWCs and RTWPs. These options include the internet, dedicated WANs, telephone and broadband links, and satellite systems. International seismic network and sea level network data can be obtained through the internet and GTS, respectively. In many cases, a tsunami warning center must collect national tide gage, buoy, and seismic data by telephone land lines or wireless technologies (such as cellular phone and radio links). Whenever possible, interrogation methods should be automated and capable of being easily modified during events.

Tip

Automate data collection, and make interrogation parameters easily modifiable during events.

Seismic Data Communications—Accessing International Seismic Networks

As noted in Chapter 3, in the section on seismic networks, NTWCs and RTWPs may access international seismic networks to receive crucial seismic data. This section describes methods for gaining access to the Incorporated Research Institutions for Seismology (IRIS) Global Seismic Network (GSN).

Incorporated Research Institutions for Seismology's Global Seismic Network

The IRIS GSN is made up of nearly 130 stations with affiliations to the U.S. Geological Survey (USGS), University of California San Diego's (UCSD) International Deployment of Accelerometers (IDA), GeoForshungsZentrums Potsdam (GEOFON), China Earthquake Administration (NCDSN), Institut de Physique du Globe de Paris

(GEOSCOPE), Germany's Federal Institute for Geosciences and Natural Resources (BGR), U.S. National Seismographic Network (USNSN), Berkeley Digital Seismic Network (BDSN), Air Force Technical Applications Center (AFTAC), and several other national and international networks.

The GSN was conceived as a network of digital seismographs arrayed uniformly around the globe, a configuration that yields a station spacing of about 18 arc degrees, or about 2000 km. Two decades after the birth of IRIS, there are about 126 stations installed and 12 more planned. These stations are distributed over all continental landmasses, several key island sites, and an ocean bottom location between Hawaii and the west coast of the United States. Of the installed stations, the USGS manages 73, and U.S. universities and affiliated institutions operate 53. When the GSN stations are combined with stations from the Federation of Digital Seismograph Networks (FDSN) and the International Monitoring System (IMS) of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization, the number of land-based stations exceeds that called for in the original GSN plan. Although the exact number of stations and their locations will continue to be subject to change due to the installation of a few additional stations and/or the possible closing of some stations, future perturbations to the existing system are expected to be small.

The IRIS GSN stations continuously record seismic data from very broadband seismometers at 20 samples per second (sps), and provide for high-frequency (40 sps) and strong-motion (1 and 100 sps) sensors where scientifically warranted. It is also the goal of the GSN to provide for real-time access to its data via internet or satellite. Most of the IRIS GSN stations meet this goal. Figure 4-4 shows the distribution of stations in the GSN network.

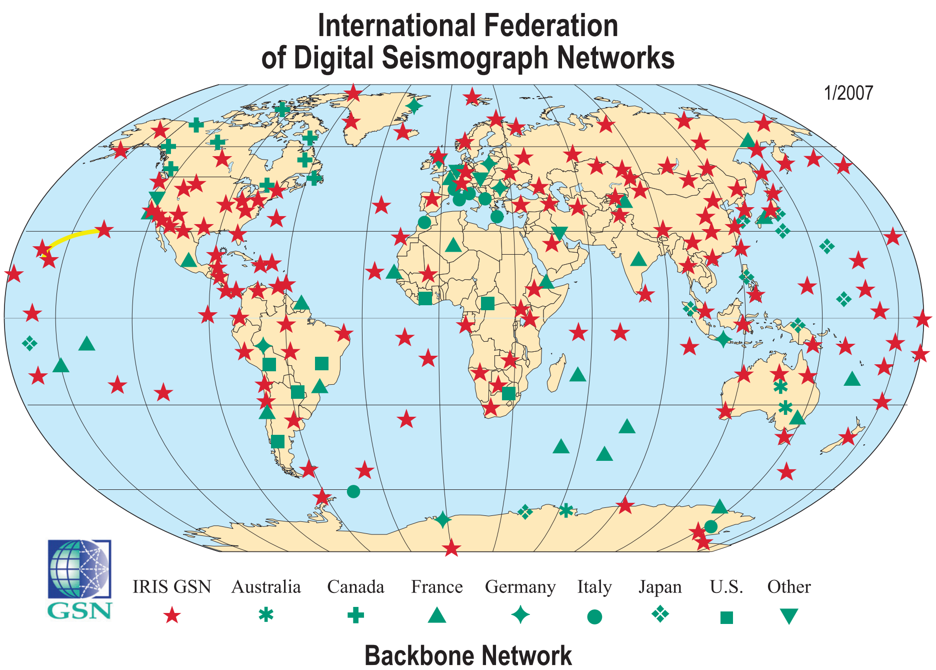


Figure 4-4. Global Distribution of Seismic Networks

Sensors Used in the IRIS GSN

The network uses a suite of sensors to capture the full range of geophysical information in the environment surrounding an IRIS GSN site. The sensors may be grouped into several broad categories:

- **Principal broadband seismometer.** At each IRIS International Deployment of Accelerometers (IDA) station, one of two seismometers (either the STS-1 very broadband seismometer manufactured by *G. Streckeisen AG* or a triaxial KS54000-IRIS manufactured by Geotech Instruments, LLC) is employed to accurately record very-long-period to mid-range seismic data.
- **Auxiliary seismometer.** Because the STS-1 and KS54000-I sensors do not record the higher frequency portion of the seismic spectrum with the sensitivity desired by the IRIS community, an auxiliary sensor is installed at many sites. The auxiliary sensor is either an STS-2, also made by *G. Streckeisen AG*, a CMG-3T by Guralp Systems Ltd., or a GS-13 also by Geotech Instruments, LLC.
- **Strong motion accelerometer.** The above seismometers will behave in a nonlinear fashion when subjected to high accelerations. In order to record acceleration up to 2g with fidelity, a strong motion instrument is installed at most sites. The instrument in use at IRIS/IDA stations is the FBA-23, made by Kinemetrics Inc.
- **Other instruments.** Because of the effect of air pressure on long-period seismic recordings and because geophysical phenomena such as volcanic eruptions generate pressure waves that are of interest to seismologists, it was decided to install microbarographs at GSN stations. The model used at IRIS/IDA stations is the 6016-B made by Paroscientific, Inc.

GSN Communications

Stations of the IRIS Global Seismographic Network are configured as nodes on the internet to facilitate access to the internet and its associated long-haul telecommunications infrastructure. By developing data acquisition and transmission around the internet's Transmission Control Protocol/Internet Protocol (TCP/IP) suite, the task of data collection from remote locations is reduced to one of bringing the internet to the station, a problem for which a multitude of off-the-shelf solutions exist.

Nodes at GSN stations shown in Figure 4-5 are connected to the internet over a variety of circuits including:

- LAN already on the internet
- Dedicated (leased) telecommunications circuit to an internet "point-of-presence"
- Dial-up telecommunications circuit to an internet "point-of-presence"
- Satellite circuit for those stations unreachable by existing telecommunications circuits

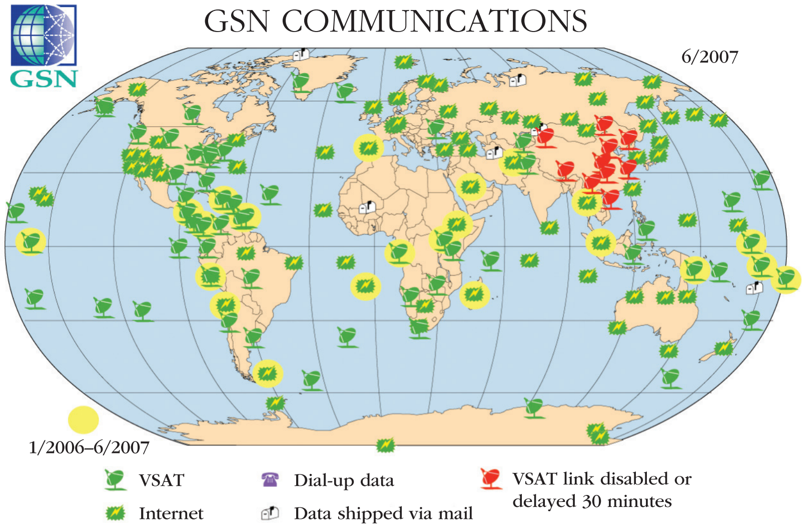


Figure 4-5. Communications Methods Used for GSN Sites

Data acquired via telemetry may be used for such diverse purposes as:

- **Tsunami warning:** Prompt transmission of the seismic data permits experts to locate earthquakes quickly, assess the likelihood they have generated a tsunami, and predict when the destructive wave will arrive. Such predictions have already saved numerous lives.
- **Emergency response:** Prompt and accurate location of earthquakes allows emergency personnel to better plan their response to disasters that occur in remote regions of the world.
- **Monitoring underground explosions:** Seismic methods are used increasingly to monitor adherence to nuclear test ban treaties. When a nuclear device is exploded underground, the resulting shock wave can be detected by seismic instruments over great distances.

In an effort to avoid huge losses in data resulting from an outage in a single network, centers should strive to receive seismic data from several different vendors. For example, the Pacific Tsunami Warning Center's (PTWC) suppliers for teleseismic waveform data are the National Earthquake Information Center (NEIC),Albuquerque Seismic Laboratory, West Coast/Alaska Tsunami Warning Center, IRIS/IDA, USGS Menlo Park, Cal. Tech, the University of Washington, and the University of Puerto Rico, Mayaguez.

Tip

Critical data should be collected from multiple networks via multiple communications methods.

Teleseismic waveform data flows to PTWC via two basic routes. One route is over the dedicated NEIC WAN, and the other is via the World Wide Web (WWW). In terms of programming, these differing routes can be treated the same; they have no differences as far as TCP/IP is concerned. Dedicated lines have a guaranteed bandwidth and are separate from the WWW. Data flowing through dedicated lines should make fewer hops than data flowing over the WWW, resulting in less latency. Furthermore, data flowing along dedicated paths are not as susceptible to WWW outages.

Sea Level Data—Accessing International Tide Gage Networks

As noted in Chapter 3, in the section on coastal tide gage networks, numerous tide gage networks exist around the world. Many of these networks are coordinated by the Intergovernmental Oceanographic Commission (IOC) of the United Nations Education, Scientific, and Cultural Organization (UNESCO).

Global Sea Level Observing System

The most extensive and notable tide gage network is the Global Sea Level Observing System (GLOSS), conducted under the auspices of the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) of the World Meteorological Organization (WMO) and the IOC. The main component of GLOSS is the Global Core Network (GCN) of over 290 sea level stations around the world for long-term climate change and oceanographic sea-level monitoring. The present definition of the GCN (the definition is modified every few years), called GLOSS02, is shown in Figure 4-6.

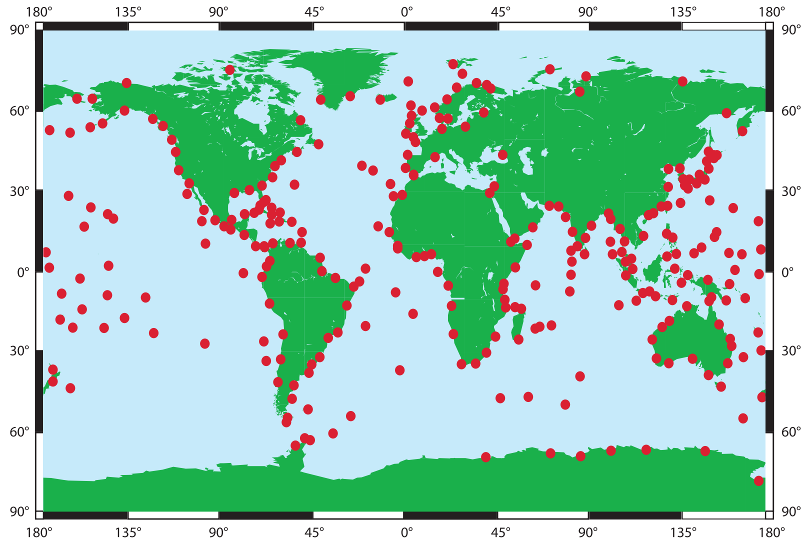


Figure 4-6. GLOSS Core Network Defined by GLOSS02

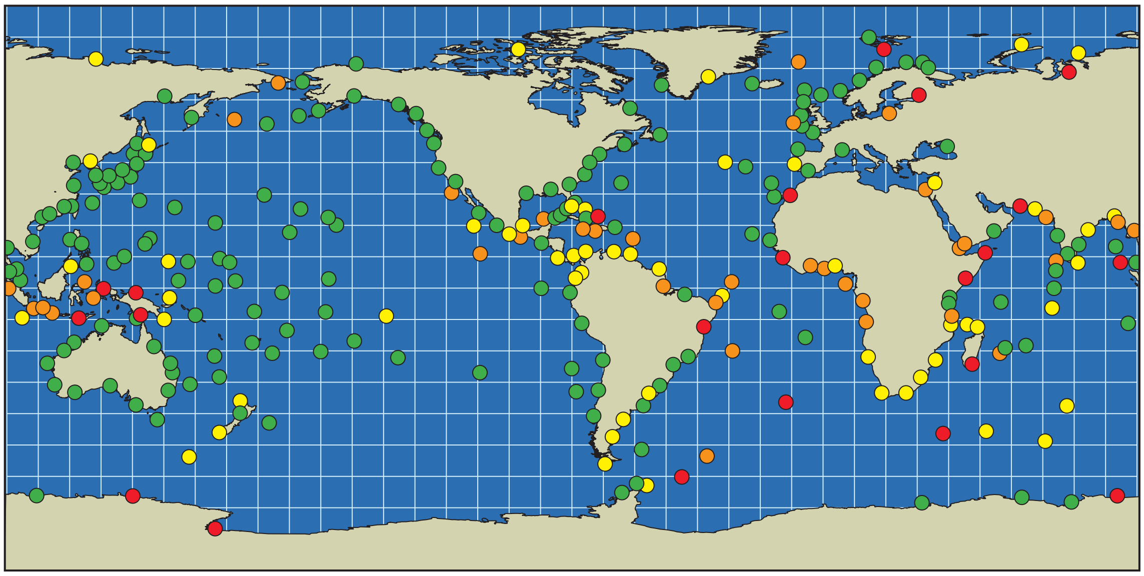
Permanent Service for Mean Sea Level

GLOSS data and data from numerous other networks are archived by the Permanent Service for Mean Sea Level (PSMSL). Since 1933, the PSMSL has been responsible for the collection, publication, analysis and interpretation of sea level data from the global network of tide gauges. It is based in Liverpool at the Proudman

Oceanographic Laboratory (POL), which is a component of the UK Natural Environment Research Council (NERC). The PSMSL is a member of the Federation of Astronomical and Geophysical Data Analysis Services established by the International Council for Science (ICSU). It is supported by the Federation, the IOC, and NERC. Figure 4-7 (a) and (b) shows the types of GLOSS stations in the PSMSL database, along with the Indian Ocean sea level network.

a.

GLOSS status within the PSMSL data set - October 2006



The PSMSL usually provides, each October, a summary of the status of the GLOSS Core Network (GCN) from its viewpoint. An "operational" station, from a PSMSL viewpoint, means that recent MSL monthly and annual values have been received and checked as far as possible, and have been included in the databank. For each of the GCN stations we have used the year of the last data entered into the databank, if any, to place the station into one of four categories:

- **Category 1:** "Operational" stations for which the latest data is 2002 or later.
- **Category 2:** "Probably operational" stations for which the latest data is within the period 1992-2001.
- **Category 3:** "Historical" stations for which the latest data is earlier than 1992.
- **Category 4:** "Stations for which no PSMSL data exist.

b.

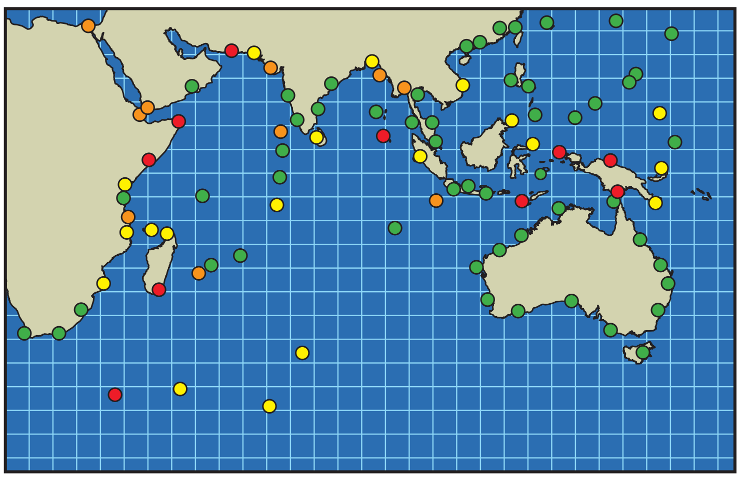


Figure 4-7a. GLOSS Station Status Within the PSMSL Archives as of October 2006
Figure 4-7b. GLOSS in the Indian Ocean Region as of October 2006

Communications

Sea level data acquired by a tide gage may be required in “real time,” “near real time,” or in “delayed mode,” depending on the application. For example, a storm surge or tsunami warning system requires the data to be transmitted to the competent authorities in a very short time. On the other hand, for some scientific research, it is often only necessary to recover the data annually, in which case it can be stored locally and recovered during a site visit, either by downloading the data to a personal computer or by extracting and replacing a memory card. In any case, it is expedient to adopt such a local procedure, even if a communication link is in operation, to prevent loss of valuable data.

The Global Telecommunications System

As noted in the previous section, GTS is widely used by all the meteorological organizations for real-time transmission and interchange of environmental data (see **www.wmo.ch/web/www/TEM/gts.html**; and also **www.wmo.ch/web/www/ois/Operational_Information/WMO386/ManOnGTS.html**, which is the GTS Manual). Given the development by the IOC of an Indian Ocean Tsunami Warning and Mitigation System, GTS is being used more and more by the sea level community. GTS is the future for the GLOSS network, and in particular for the GLOSS Fast Data Center (GFDC).

The Indian Ocean Intergovernmental Coordination Group and other groups have adopted standards for core sea level stations for tsunami detection requiring data transmission within 15 minutes of being recorded at a tide gage (IOC Technical Series 71). A 1-minute sample, 5-minute cycle may be adapted for selected sites close to tsunamigenic source areas. The data would be composed of 1-minute samples to achieve the required resolution and would need to be made available on the GTS. This is in fact the actual recommendation for sea-level data transmitted for tsunami warning systems: making use of the GTS, which works well if geostationary meteorological satellites are used for data transmission. If this is not the case, arrangements with the national meteorological organizations may be needed for including and downloading sea level data from the GTS; automatic transmission by email or FTP will probably be required from the national sea level agency to the meteorological institute, GFDC, or Tsunami Alert System, for including the data in GTS.

Other Satellite Communications for Data Collection

The mission of meteorological satellites is generally twofold: collection of observational data such as infrared and visible imagery, and dissemination of this data as well as other products that are uplinked from the controlling meteorological service. Additionally, some of these satellites receive data from various Data Collection Platforms (DCP), such as tsunami buoys and tide gages. Often gage interrogation frequency can be increased, and time between transmissions shortened when tsunami warning center specified criteria are reached or exceeded.

There are several satellite systems that can be useful in supplementing GTS connectivity. These include:

- International Satellite Communications System (ISCS)
- Emergency Manager's Weather Information Network (EMWIN)
- EUMETCast, the UK Met Office's Satellite Distribution (SADIS)
- India's Satellite (INSAT) Distribution System
- Satellite-based data distribution systems like RETIM-Africa
- Radio and Internet for the Communication of Hydro-Meteorological and Climate-Related Information (RANET)
- Global Marine Distress and Safety System (GMDSS)

The above provide options for alternate and backup communications to ensure receipt of crucial data. The listed satellite systems are also capable of delivering warning and other products. They are discussed in detail in Chapter 8, in the section on dissemination. Overall there are now upward of 30 orbiting satellite systems in operation dedicated to data transmission, some on a global basis. Mobile satellite systems may be classified according to orbit altitude as follows:

GEO – geostationary earth orbit, approximate altitude: 35,000 km

MEO – mid-altitude earth orbit, approximate altitude: 10,000 km

LEO – low earth orbit, approximate altitude: <1,000 km

In all cases, when a tsunami warning center collects local seismic or sea level data via satellite, telephone services, or wireless links, the data should be properly coded and posted to the appropriate international databases for use by all NTWCs and RTWPs. A local gage reading may help the tsunami warning center determine the magnitude of a tsunami in its area of responsibility (AOR). The same data may assist a neighboring tsunami warning center in saving lives in its AOR.

Selecting a Communications System

The selection of a communication system for real time (RT) or near-real-time (NRT) data transmission is always a compromise among a number of constraints. The principal factors guiding a decision in the adoption of a system are:

- Data rate, data-rate profile in different operational modes (if more than one)
- Power availability (power from mains or autonomous/self-powered)
- Guarantee of data transmission (private network or shared data line)
- Location and availability of telecommunication infrastructure (satellites in field of view)
- Land or marine application (fixed or moving)
- Availability of funding.

Two-way communications with a tide gage can be advantageous. It can be used to update software or calibration values at the station, to interrogate the system for faults, to change the sampling rate and to carry out many house-keeping functions that would otherwise wait for a site visit. This allows the system to be flexible and improves overall reliability.

Tip

In the event of an earthquake, the first losses are often the PSTN network, mobile telephone links, and electrical power.

In adopting a communication system for a tide gage installation, one consideration has to be its reliability under severe environmental conditions. For example, for tsunami warning, some of the tide gages may have to be positioned in a tectonically active region to provide an acceptable early warning. In the event of an earthquake, the first losses are often the PSTN network, mobile telephone links, and electrical power. Under such circumstances, satellite links may be the only option. Additionally, some form of uninterruptible power supply (UPS) is necessary. This often takes the form of a battery back-up system with an adequate reserve capacity of several hours. A number of manufacturers, including tide gage and data logger manufacturers, produce relatively inexpensive ready-to-use communications systems suitable for tide gages. For a list, see the websites given on the PSMSL website: **http://www.pol.ac.uk/psmsl**.

The method of communication depends largely on the distance the data have to be transmitted. For short links (such as harbor operations), a radio link is often convenient. For countrywide links, subscriber trunk dialing or dedicated telephone lines of the Public Switched Telephone Network (PSTN) are an effective medium. Where fixed lines are not practical, the growth in the use of mobile phone links using General Switched Messaging (GSM) technology and General Packet Radio System (GPRS) protocols has extended the potential for long-distance communication. Both the fixed and mobile telephone systems give access to the internet through an Internet Service Provider (ISP), which can greatly enhance the transmission of data. For example, many of the GPS stations of the global network of the International Global Navigation Satellite System Service, which has some similarities to the global tide gage network in terms of number of sites and amount of data to be transmitted, report through the internet.

All the forms of telephony are merging into one, with telephone links provided by a supplier for which the connection method is transparent to the user. After the tsunami of December 26, 2004, India implemented a real-time coastal sea level data transmission by means of GPRS with continuous connection to internet, with much lower costs than previous experiments based on Short Messaging Service and Data Call Services.

The advantages of broadband technology are:

- Continuous two-way connection allowing high-speed data sampling and near-real-time data retrieval. Remote gage diagnostics and the ability to reprogram the system remotely are available.
- Timing drift and operator setup error eliminated by having accurate time available from Network Time Protocol servers on the internet.

- Data delivery costs are known up-front, because the subscription costs are paid monthly or yearly.
- Real-time data collection allows malfunctions to be found and fixed, more rapidly.
- Fixed-line broadband systems can also allow backup access through a dial-up modem.

The disadvantages of broadband technology are:

- A LAN interface is required; this is often difficult to add to existing tide gage systems. A land line is necessary for nonsatellite broadband systems.
- Serial port is generally not available, so interfacing is more difficult.
- Power requirement for broadband modems is quite high (~1 amp); this can create problems where main power is not available.

As already noted, for more remote areas, mobile satellite links provide a viable alternative. There are now upward of 30 orbiting satellite systems in operation dedicated to data transmission, some on a global basis.

Real-Time Transmission of Tsunameter Data

The real-time transmission of data from the tsunameter buoy varies depending on the operating mode of the bottom pressure recorder (BPR) (Figure 3-26). Transmission of real-time water level heights occurs when the Tsunami Detection Algorithm triggers a suspected event, when the tsunameter buoy is interrogated by the tsunami warning centers or the National Data Buoy Center,(NDBC) or at prescheduled intervals. The BPR transmits the messages to the surface buoy via underwater acoustics systems. The surface buoy is equipped with duplicate and independent communications systems to transmit data to the Iridium satellite and then on to the Iridium Gateway in Tempe, Arizona, where an Iridium Router-based Unrestricted Digital Internetworking Connectivity Solution (RUDICS) routes the data to the NDBC RUDICS Server at Stennis Space Center, Mississippi. RUDICS then routes the messages to a Data Acquisition Center server located at the Stennis Space Center, where NDBC attaches NOAA header information and message identifiers and sends the data to the National Weather Service's Telecommunications Gateway (NWSTG) in Silver Spring, Maryland for internet distribution via the global telecommunications operation center. The tsunami warning centers and NDBC pick up the data from the NWSTG broadcast. NDBC decodes and reformats the data for real-time web display and database storage. If the buoy is unable to establish the connection to the NDBC RUDICS Server, information does not move from the buoy's communication buffer.

A tsunami warning center or NDBC can initiate an interrogative data retrieval mode, or set the BPR in Event Mode; however, the Iridium receivers on board the surface buoys have a limited amount of receive time. Upon receipt of the command to retrieve high-frequency data, the BPR transmits 1 hour of 15-second pressure and temperature data. The data parameters are in a similar format as that written to the on-board memory card. NDBC will maintain a catalog of these data for possible archiving.

Important Points to Remember about Data Communications Channels

- Broadband interrogation methodology allows for faster real-time retrieval of time-critical data. However, broadband modems have a relatively large power requirement.
- Several satellite systems are available to serve as both primary data collection channels and as backups for GTS and other interrogation methods.
- Interrogation methods should be automated, and easy to modify. An example is two communications with local tide-gage networks where sampling rates can be changed during an event.
- Locally collected data should be properly coded and posted to the appropriate international databases for use by all NTWCs and RTWPs.

Backup Communications for Data and Information Collection

NTWCs and RTWPs should employ backup communications for data and information collection required to detect a tsunami. Two types of backup communications should be employed by tsunami warning centers: alternative communication paths within a center and backup communications by another center.

Alternate communication paths for data collection and product dissemination are needed within an NTWC or RTWP. In the event of the failure of one of a center's primary communication links, information can be rerouted through a secondary connection.

Center functionality backup by another center means that procedures are in place for an RTWP to assume the functions of one of its NTWCs if that national center has lost all communications links. Similarly, each RTWP must have agreements in place for another RTWP to take over in the event of a catastrophic event at the disabled regional center. Typically, a tsunami warning center should have connections to at least two other centers, and RTWPs to another regional provider to provide backup communications.

While commercial satellite systems do not directly support the GTS, it is important to take into consideration all of these systems since they may offer diverse dissemination mechanisms of tsunami warning information that may be able to supplement primary GTS connectivity. In this regard, a suitable commercially provided service could be used as further backup to GTS circuits.

Many other meteorological satellite systems are operated in polar orbits for observational data collection, and many perform additional functions of collecting data from DCPs such as buoys and tide gages. The role of implementing more than one satellite receiving system should be explored by an NTWC or RTWP to provide maximum overall system reliability. Although not common, unexpected outages of satellite systems do occasionally occur and can sometimes result in total loss of a satellite platform. Data reception from more than one satellite system will help ensure very high reliability in the unlikely, but possible occurrence of loss of one satellite service combined with a loss of terrestrial communications at a tsunami warning center.

Important Points to Remember about Backup Communications

- A center should have alternate communications paths to collect crucial seismic and sea-level data, and to disseminate warning and other products.
- To plan for possible total communications outages, each center must make arrangements for another center to take over. This requires careful planning, extensive coordination, and attention to numerous small details.

Data Collection Formats

Earth data observations are collected in a number of different data formats. Data formats from seismometers, tide gages, and tsunameters (DART buoys) vary in the data volume, transmission frequency, and format. NTWCs and RTWPs must be knowledgeable of and capable of handling these data formats.

Seismic Data

The NEIC component of the Advanced National Seismic System (ANSS) acquires data from foreign broadband stations in near-real-time. The NEIC automatically acquires over 2,000 data channels with an aggregate data volume of about 2.5 Gbyte per day. Of these data, about 860 Mbytes/day are archived (two copies each) onto optical storage (an aggregate of nearly 4 Tbytes to date). At the same time, the NEIC distributes data to the research community through an Automatic Data Request Manager (AutoDRM), autodrm@usgs.gov, and the IRIS Data Management Center (DMC). Real-time data are provided to ten Regional Seismic Networks including the Pacific and Alaska tsunami warning centers to augment regional and teleseismic monitoring.

All data, whether through the USGS CrestNet or internet, are transferred between data centers using the USGS Earthworm software, the *de facto* standard for seismic data and hypocenter parameter exchange. Seismic data transfer is quite complicated. The original data format is dependent on the manufacturer of the field equipment. Each brand has a different format, and sometimes multiple formats by the same vendor. The recording network (which is usually the operating network) is responsible for decoding the data. Within the tsunami warning center, data are converted to the Earthworm format and shared with other centers. Earthworm documentation is available at **http://folkworm.ceri.memphis.edu/ew-doc/**.

The primary seismic data archive for the seismic community is through the IRIS DMC. Information on the data and data formats is available from IRIS at: **http://www.iris.edu/manuals/DATutorial.htm**. The Standard for Exchange of Earthquake Data (SEED) manual can be found on the IRIS website at: **http://www.iris.edu/manuals/SEEDManual_V2.4.pdf**.

Tide Gage Data

In general, sea level data are digitized and sampled at the field station. Ideally, the data transmitted for tsunami monitoring will be 1-minute (or better) averaged data values that are transmitted at least every 15 minutes. Currently, many stations transmit every 10 to 60 minutes and data averages are at 1- to 4-minute sampling intervals. Data are transmitted over a number of different satellites to regional telecommunications hubs of the WMO, and onward to customers such as the Pacific Tsunami Warning Center, the Japan Meteorological Agency, and to any requesting national hydrological agency, as depicted in Figure 4-8.

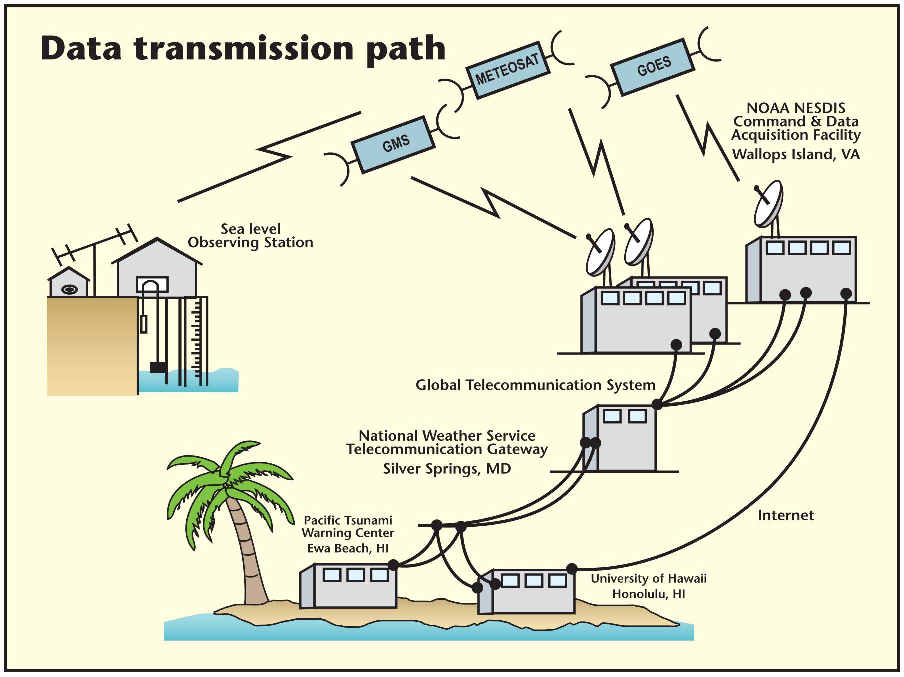


Figure 4-8. Data Transmission from Field Station to Tsunami Warning Centers
*Source. "Display and Decode of Sea Level Data Transmitted over the WMO Global Telecommunications System. Version 1.1, November 2005" (***http://www.ioc-tsunami.org/***).*

Sea Level Data Reported in WMO Code Form

The two primary WMO formats, Binary Universal Form for the Representation of meteorological data (BUFR), and Character form for the Representation and EXchange of data (CREX), offer great advantages in comparison with the traditional alphanumeric codes. The main features of the table-driven codes are self-description, flexibility, and expandability, which are fundamental in times of fast scientific and technical evolution. In addition, BUFR offers condensation (packing). The alphanumeric code CREX provides simple readability but no packing. BUFR has been used mainly, so far, for satellite, aircraft, and wind profiler observations, but also for tropical cyclone information and for archiving of all types of observational data. CREX is already used among meteorological centers for exchange of ozone data, radiological data, hydrological data, tide gage data, and soil temperature data. Ideally, BUFR should always be used to exchange observations internationally. CREX should be used only if binary transmission is not possible. It is thought that these two codes can satisfy all WMO needs for observation coding and are recommended for all present and future WMO applications.

Each station and its data transmission is described by a unique set of parameters, including Satellite Product Headers, Station Platform, method of transmission and transmission time, and file formats. Figure 4-9 shows an example of decoding a tide gage report in CREX format.

TIDE GAUGE DATA EXAMPLE

```
CREX++
T000101 A001 D06025++
RI010 1998 01 23 15 00 2761 00 00 30 -30
01407 1225 01384 1217 01382 1221 01395 1220 01473 1262 01502 1227+
CT010 1998 01 23 15 00 2781 01 00 30 -30
02024 1757 02043 1717 02124 1728 02177 1716 ///// //// 02259 1670++
7777
```

Interpretation of the example:

Line	Group	Meaning
1	CREX	Indicator of a CREX message
2	T000101	CREX Master Table Number 00, Edition 01, Version 01
	A0001	Data type 001: Surface data - sea
	D06024	Tide elevation series
3	RI010	Tide station RI010
	1998	Year: 1998
	01	Month: January
	23	Day: 23
	15	Hour: 1500 UTC
	00	Minute: 00
	2761	Sea/water temperature
	00	Tide station automated water level check: Good data
	00	Tide station manual water level check: Operational
	30	Time increment: time is now hour 1500, minute 30
	-30	Short time increment: increment is applied prior to each replication of two descriptors indicated by the group R02006, thus the time is now hour 1500, minute 00
4	01407	Tide elevation of 1407 mm at hour 1500, minute 00
	1225	Meteorological residual tidal elevation of 1225 mm at hour 1500, minute 00
	01384	Tide elevation of 1384 mm at hour 1400, minute 30
	1217	Meteorological residual tidal elevation of 1217 mm at hour 1400, minute 30
	01382	Tide elevation of 1382 mm at hour 1400, minute 00
	1221	Meteorological residual tidal elevation of 1221 mm at hour 1400, minute 00
	01395	Tide elevation of 1395 mm at hour 1300, minute 30
	1220	Meteorological residual tidal elevation of 1220 mm at hour 1300, minute 30
	01473	Tide elevation of 1473 mm at hour 1300, minute 30
	1262	Meteorological residual tidal elevation of 1262 mm at hour 1300, minute 00
	01502	Tide elevation of 1502 mm at hour 1200, minute 30
	1227	Meteorological residual tidal elevation of 1227 mm at hour 1200, minute 30
	+	End of report for station RI010
5	CT010	Tide station CT010
	1998	Year: 1998
	01	Month: January
	23	Day: 23
	15	Hour: 1500 UTC
	00	Minute: 00
	2761	Sea/water temperature: 276.1 K
	00	Tide station automated water level check: Good data
	00	Tide station manual water level check: Operational
	30	Time increment: time is now hour 1500, minute 30
	-30	Short time increment: increment is applied prior to each replication of two Descriptors indicated by the group R02006, thus the time is now hour 1500, minute 00
	602024	Tide elevation of 2024 mm at hour 1500, minute 00
	1715	Meteorological residual tidal elevation of 1715 mm at hour 1500, minute 00
	02043	Tide elevation of 2043 mm at hour 1400, minute 30
	1717	Meteorological residual tidal elevation of 1717 mm at hour 1400, minute 30
	02124	Tide elevation of 2124 mm at hour 1400, minute 00
	1728	Meteorological residual tidal elevation of 1728 mm at hour 1400, minute 00
	02177	Tide elevation of 2177 mm at hour 1300, minute 30
	1716	Meteorological residual tidal elevation of 1716 mm at hour 1300, minute 30
	/////	Tide elevation missing at hour 1300, minute 30
	////	Meteorological residual tidal elevation missing at hour 1300, minute 00
	02259	Tide elevation of 2259 mm at hour 1200, minute 30
	1670	Meteorological residual tidal elevation of 1670 mm at hour 1200, minute 30
	++	End of report for station CT010; also, end of Data Section
7	7777	End of CREX message

Figure 4-9. Decoded Example of WMO CREX Format

GTS coding requirements for sea level data can be found in the GTS Manual (WMO Publication 386) (**http://www.wmo.ch/web/www/ois/Operational_Information/WMO386/ManOnGTS.html**).

Sea Level Data Reported in Non-WMO Code Form

Sea level data from the GLOSS tide gage network and some other organizations use a non-WMO code form. The following example is the report received from the DCP in Colombo, Sri Lanka, collected via the Geostationary Meteorological Satellite at the Japan Meteorological Agency. The report is the 1-minute observation transmitted every 15 minutes. The message received at the Regional Telecommunications Hub via GTS for the report at 0430 coordinated universal time UTC on 29 March 2006 is shown in Figure 4-10.

```
SWIO40 RJTD 290430
:ENB 1 #1 M 3763 3761 3761 3759 3758 3758 3755 3754 3752 3750 3749
3746 3745 3744 3743 3743 3743 3742 3742 3742 3742 3741 3741 3741 3739
3739 3738 3737 3737 :ENC 0 #2 3269 3265 3263 3263 3260 3256 3250 3246
3247 3246 3245 3243 3244 3243 3242 3239 3237 3234 3233 3233 3232 3230
3232 3232 3233 3233 3232 3228 3229 3230 :BATTLOAD 0 12.83 :NAME=
```

Figure 4-10. Example of GLOSS Non-WMO Sea Level Gage Report Code

The first line of the message depicted in figure 4-10 is the abbreviated header (TTAAii CCCC YYGGgg) of the bulletin for identification and transmission on GTS. The date/time group YYGGgg given in the abbreviated header is 0430 UTC on the 29th of the month. The month and year (March 2006) are not reported in the message.

The latest observation time reported in this message is 0431 UTC, i.e. 0430 + 1 min. Twenty-nine tidal measurements at 1-minute intervals are included in the report, but 14 of the 29 observations have already been reported in the last bulletin. The observations are reported in **reverse** order.

Time	Data Value
0431	3763
0430	3761
0429	3761
0428	3759
0427	3758
.	.
.	.
.	.
0417	3743

(15 new observations)

0416	3743
0415	3743
0414	3742
0413	3742
.	.
.	.
.	.
0403	3737

(14 observations reported in previous bulletin and repeated in this bulletin)

Tsunameters (DART buoys)

DART provides internally stored high frequency data, triggered event data, and lower frequency data for system monitoring. Pacific Marine Environmental Laboratory (PMEL) engineers provide system enhancements through continued research and development efforts.

High frequency data consists of temperature and pressure averaged over 15-second intervals for the entire bottom package deployment period. Observations are stored on a flash card in the BPR until the bottom package is retrieved and the data recovered by NDBC. These data are retrospective and in addition to data transmitted in real time. In addition to internally recorded 15-second data, DART systems report a combination of 15-second data and 1-minute averages when triggered to do so by the detection of an event. These data provide the tsunami community with deep ocean tsunami observations essential for evaluating the potential risk to coastal communities. In addition, each DART system delivers spot pressure observations at 15-minute intervals in near-real-time for system monitoring.

Near-real-time bidirectional communication allows access to internally set system parameters and allows centers to manually trigger event-reporting mode. Additionally, bidirectional communication can be used to retrieve a 1-hour block of internally recorded pressure and temperature frequency counts from the flash storage card. A limited number of these after-the-fact requests are possible, due to battery life considerations. In order to maintain this capability for the deployment life of a given system, the tsunami warning centers must coordinate this activity among interested parties.

Interrogation Protocol

The tsunami warning centers coordinate DART trigger activation during events. Normally, if triggers are not activated by the earthquake or tsunami, a center can initiate an interrogative data retrieval mode, or set the BPR in Event Mode. However, the Iridium receivers on board the surface buoys have a limited amount of receive time. Upon receipt of the command to retrieve high-frequency data, the BPR transmits 1 hour of 15-second pressure and temperature data.

The tsunami warning centers perform after-the-fact interrogation of internally recorded 15-second data. Specific requests by interested agencies should be made no earlier than a day or two following an event, as tsunami warning center personnel will be focused on operations. Tsunami warning centers will advise appropriate agencies when data have been downloaded unrelated to specific requests.

Real-Time Transmission of Data—Iridium Transmissions and Time Series Data Formats

The real-time transmission of messages varies depending on the operating mode of the BPR, as described above. Transmission of real-time water level heights occurs when the Tsunami Detection Algorithm triggers a suspected event, when the buoy is interrogated by the tsunami warning centers, or at pre-scheduled intervals. The BPR transmits the messages to the surface buoy via underwater acoustics systems. In addition to the examples given below, see a slightly different presentation of current codes in the Description of Real Time DART System Messages, Revision 3.01 (2 August 2007), by Marie C. Elbe and Scott E. Stalin (a NOAA/PMEL publication).

Every Iridium transmission begins with a platform header followed by the message formats as described in this document. The format of the header is:

3f 3f 3f ck ck DARTxxxP/S

3f 3f 3f = three bytes to start the transmission (always 3f hex)

ck ck = two byte checksum

DART = Indicates tsunami buoy platform ID follows

xxx = three ASCII digit platform ID

P/S = P indicates transmission from Primary side; S for Secondary side.

Standard Mode Hourly Reporting

Standard-mode hourly reporting consists of water level height data. The reports consist of four discrete 15-minute water column height values, in millimeters, via acoustic modem each hour, and via Iridium every 6 hours if height data are available. In addition, a GPS Position Fix is transmitted once per day, or hourly if height data is not available.

Height Data (Transmitted via acoustic modem every hour, via Iridium every 6 hours if height data available)

<cr>D$1*C/I d*

ate time batv1 batv2 batv3 ht1 ht2 ht3 ht4 tries * checksum

<cr>D$1*C/I date time batv1 batv2 batv3 ht1 ht2 ht3 ht4 tries * checksum*

<cr>D$1*C/I date time batv1 batv2 batv3 ht1 ht2 ht3 ht4 tries * checksum*

<cr>D$1*C/I date time batv1 batv2 batv3 ht1 ht2 ht3 ht4 tries * checksum*

<cr>D$1*C/I date time batv1 batv2 batv3 ht1 ht2 ht3 ht4 tries * checksum*

<cr>D$1*C/I date time batv1 batv2 batv3 ht1 ht2 ht3 ht4 tries * checksum*

<cr> = 0x0D

D$1 = message id

C/I = message status, C = corrupted, I = intact

d*ate* = month day year

t*ime* = hour minute second

batv1 = BPR battery voltage in 10ths of a volt, or error code

batv2 = acoustic modem DSP battery in 10ths volts

batv3 = acoustic modem battery in volts

ht1 ... ht4 = water column height in millimeters

tries = number of tries to deliver BPR data

* = = checksum delimiter checksum = exclusive OR of all characters preceding "*", 1-byte hexadecimal **Example:** D$1I 08/17/2006 12:15:00 1654147 5311813 5311758 5311703 5311652 1* 35 D$1I 08/17/2006 13:15:00 1654147 5311604 5311559 5311516 5311480 1* 34 D$1I 08/17/2006 14:15:00 1654147 5311445 5311414 5311389 5311369 1* 3C D$1I 08/17/2006 15:15:00 1654147 5311352 5311342 5311336 5311336 1* 36 D$1I 08/17/2006 16:15:00 1654147 5311341 5311353 5311366 5311385 1* 3A D$1I 08/17/2006 17:15:00 1654147 5311407 5311433 5311466 5311499 1* 32
GPS Position Fix (Transmitted once per day or hourly if height data not available)
D$0 N/S lat_deg E/W long_deg * checksum D$0 = message id date = month day year time = hour minute second lat_deg = latitude of buoy, DDMM.MMMM N/S = North or South long_deg = longitude of buoy, DDMM.MMMM E/W = East or West * = checksum delimiter checksum = exclusive OR of all characters preceding "*", 1-byte hexadecimal **Example:** D$0 08/17/2006 13:05:05 4857.0556 N 17816.8330 E* 5D

Figure 4-11. Examples of Standard-Mode Hourly Reports

Tsunami Event Mode Reporting

Examples of tsunami event-mode reports are shown in Figure 4-12. They consist of the following types:

First Event Mode Message (Message #0). Reports the water column height that triggered the event mode (in millimeters), along with three height deviations (15-second height values 0.75 minutes prior to the event trigger).

Second Event Mode Message (Message #1). Reports 15-second height values -0.75 to 3 minutes after event trigger.

Subsequent Event Mode Messages (Messages #2-14). Reports 15 1-minute average height values from the detection of the event until event mode has ceased.

First Event Mode Message (Message #0)

D$2 C/I msg# tt time ts begin height dev1 dev2 dev3 tries * checksum
D$2 = message id
C/I = message status, C = corrupted, I = intact
msg# = message number (0 for the first message)
time = time tsunami detected
begin = first data point time stamp
height = first data point water column height in millimeters
dev1...dev3 = deviation from height in millimeters, 2-byte hexadecimal
tries = number of tries to deliver BPR data
* = checksum delimiter
checksum = exclusive OR of all characters preceding “*”, 1-byte hexadecimal
 	
Example:
`D$2I 00 tt 22:53:15 ts 22:52:30 3259892`
`00000044000001* 28`

Subsequent Event Mode Messages (Message #1 - #14(typically))

D$2 C/I msg# tt time ts begin height dev1 dev2 dev3……dev15 tries * checksum
D$2 = message id
C/I = message status, C = corrupted, I = intact
msg# = message number
time = time tsunami detected
begin = first data point time stamp
height = first data point water column height in millimeters
dev1...dev15 = deviation from height in millimeters, 2-byte hexadecimal
tries = number of tries to deliver BPR data
* = checksum delimiter
checksum = exclusive OR of all characters preceding “*”, 1-byte hexadecimal
 	
Example:
`D$2I 01 tt 22:53:15 ts 22:52:30 3259892`
`000000440000fffffffffffffffffffffffffffffffffffffffefffefffe01* 29`
`D$2I 02 tt 22:53:15 ts 22:44:00 3259897`
`fffffffffffefffdfffcfffcfffb000cfffafffafff9fff9fff8fff8fff701* 2C`
`D$2I 03 tt 22:53:15 ts 22:52:00 3259909`
`ffeeffeeffedffedffecffecffebffeaffeaffeaffeaffe9ffe8ffe8ffe701* 22`

Figure 4-12. Examples of Event-Mode Reports

Extended Mode Hourly Reporting

Extended reporting mode consists of 120 1-minute average values, transmitted via Iridium each hour for additional data redundancy. Extended reporting mode transmits data from 1 hour prior to the next top of the hour until the Tsunami Detection

Algorithm is in non-triggered status. Figure 4-13 provides an example of an extended-mode hourly report.

120, 1-minute averages transmitted via Iridium each hour

D$3 C/I tt ts height dev1 dev2 dev3..........dev119 tries * checksum

D$3 = message id
C/I = message status, C = corrupted, I = intact
tt = time tsunami detected
ts = first data point time stamp
height = water column height in millimeters
dev1...dev119 = deviation from height in millimeters, 2-byte hexadecimal
tries = number of tries to deliver BPR data
* = checksum delimiter
checksum = exclusive OR of all characters preceding "*", 1-byte hexadecimal

Example:

```
D$3Itt 22:53:15 ts 23:00:00 3259888
ffffffffffffffffffefffdfffdfffcfffcfffcfffbfffbfffafff9
fff9fff8fff8fff7
fff7fff6fff6fff5fff4fff4fff3fff2fff2fff1fff1fff0ffefffef
ffeeffeeffedffec
```

Figure 4-13. Extended-Mode Hourly Report Example

High-Resolution On-Demand Data Format

The DART High-Resolution On-Demand Data Format consists of 1-hour of high-resolution 15-second data, sent via Iridium on demand by the warning centers. This data is in ASCII-Hexadecimal Data Format. An example is shown in Figure 4-14.

(1 hour's worth transmitted via Iridium)

D$5C/Icafedata…
D$6C/Idata…
D$7C/Idata…
D$8C/Idata…

D$5-8 = message id
I = 2-byte hexadecimal representing the beginning of the data
C/I = message status, C = corrupted, I = intact
To decipher:

1) Remove the message IDs and status (i.e. D$5I, D$6I, D$7I, and D$8I)
2) Remaining data block is decoded as Flash Card data (above)

Example:

```
D$5Icafe4843040a1406110000a707000180b6073fde847<snip…>
D$6I01c388ab014f903a01aa88ab0103903a019388ab00b<snip…>
D$7I003f88ab016d903a006388ab012a903a008888ab00e<snip…>
D$8I011f88ab02bb903a017188ab027b903a01c388ab023<snip…>
```

Figure 4-14. Example of DART High-Resolution On-Demand Data Format

DART Real-time Data Formats - Reformatting Iridium Messages

NDBC reformats the received Iridium messages into SXXX46 messages for distribution via the National Weather Service Telecommunications Gateway.

Raw Standard Mode Message from the Buoy:

D$1I 08/22/2006 18:15:00 1474142 4709825 4709819 4709819 4709824 1* 35
D$1I 08/22/2006 19:15:00 1474142 4709831 4709842 4709862 4709883 1* 07
D$1I 08/22/2006 20:15:00 1474142 4709906 4709933 4709962 4709995 1* 3B
D$1I 08/22/2006 21:15:00 1474142 4710033 4710072 4710115 4710155 1* 7F
D$1I 08/22/2006 22:15:00 1474142 4710198 4710244 4710282 4710322 1* 30
D$1I 08/22/2006 23:15:00 1474142 4710363 4710398 4710431 4710457 1* 01

NDBC applies bulletin header (SXXX46 KWBC) and Date-Time Group (230012 – 23rd day of the month at 0012 UTC). NDBC then applies GOES1 header line (DDDDDDD0 235001256) and *end-message line* (00-0NN 00E) to keep the DART II data message compatible with DART I, so that decoders can process the messages.

```
SXXX46 KWBC 230012
DDDDDDD0 235001256
D$1I 08/22/2006 18:15:00 1474142 4709825 4709819 4709819 4709824 1* 35
D$1I 08/22/2006 19:15:00 1474142 4709831 4709842 4709862 4709883 1* 07
D$1I 08/22/2006 20:15:00 1474142 4709906 4709933 4709962 4709995 1* 3B
D$1I 08/22/2006 21:15:00 1474142 4710033 4710072 4710115 4710155 1* 7F
D$1I 08/22/2006 22:15:00 1474142 4710198 4710244 4710282 4710322 1* 30
D$1I 08/22/2006 23:15:00 1474142 4710363 4710398 4710431 4710457 1* 01
00-0NN 00E
```

Important Points to Remember about Data Formats

- Tide gage data for tsunami monitoring should be transmitted at 1-minute (or better) intervals, with averaged data values transmitted at least every 15 minutes.
- Data are transmitted over a number of different satellites to regional telecommunications hubs of the WMO.
- Two primary WMO data formats are: Binary Universal Form for the Representation of meteorological data (BUFR), and Character form for the Representation and EXchange of data (CREX).
- DART provides internally stored high-frequency data for temperature and pressure averaged over 15-second intervals.