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USA CARTOGRAPHIC RESPONSE TO THE INDIAN OCEAN TSUNAMI OF DECEMBER 26, 2004
PRELIMINARY REPORT

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ABSTRACT

The fourth largest earthquake in the world since 1990 took place in the Indian Ocean on December 26, 2004. The result of that magnitude 9.0 earthquake was a tsunami that claimed approximately 283,000 lives and left homeless more than one million people in numerous countries. In order to respond adequately to this disaster, geospatial data and information of many types were needed. An *ad-hoc* internet group of Federal agency scientists, disaster response practitioners, and remote sensing experts attempted to organize and share data and information among each other and with any other users who needed those data. U.S. Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), the Department of State (DOS), the U.S. Agency for International Development (USAID), the National Geospatial-Intelligence Agency (NGA), the Pacific Disaster Center and the Federal Emergency Management Agency (FEMA) all participated. Independently, the U.S. Navy initiated response activities and began taking reconnaissance aerial photography using P-3 aircraft and helicopters stationed on aircraft carriers nearby. The international geospatial community was also active. Landsat, Spot, MODIS and other satellite imagery were tasked for reconnaissance level planning and response. Commercial satellite imagery and military aerial photography were acquired for detailed disaster assessments and response activities. The

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United Nations began preparing for a Humanitarian Information Center in Banda Aceh, Sumatra, the Indonesian island most affected by the tsunami. Large-scale maps were updated frequently to assist responders and aid workers in the field. Planners and policy makers used small-scale maps to appraise the situation and plan for massive international assistance efforts. The US response, like that of some other countries crossed all sectors with contributions from government, intergovernmental organizations, academia, civil society, and private industry. While such a massive disaster will require a long-term commitment of resources and support, the experience of the immediate response has taught lessons useful to the community of cartographers and related scientists and practitioners.

THE CARTOGRAPHIC AND RELATED SCIENCES RESPONSE

Within ten minutes of the Sumatra-Andaman earthquake event the U.S. Geological Survey (USGS) National Earthquake Information Center (NEIC) began to sound alarms that a large earthquake had taken place south of Sumatra. Within the first fifteen minutes after the earthquake, a tsunami warning was issued by the National Oceanic and Atmospheric Administration (NOAA). Within two hours of the earthquake warnings went out to 25,000 recipients, including all of the coastal nations in the South Asia region. Although the warnings went out, they were either too late for areas closest to the epicenter of the earthquake or not effective in areas with no experience in how to respond. The notifications activated response organizations both within and outside the USA government. Less than twenty and one-half hours after the event its magnitude was estimated to be 9.0 [6]. By then the international community was mobilizing to respond.

Cartographic Response

On December 27, 2004, the USGS Earth Resources Observation System Data Center (EROS) began acquiring Landsat and other satellite imagery of the affected area and initiated analysis of the imagery to identify locations devastated by the tsunami. USGS geologists began preparing shake maps to identify locations of earthquake damage and used an experimental program called PAGER (Prompt Assessment of Global Earthquakes for Response) to overlay shake map information on and other data to help estimate damage and prioritize rescue operations for earthquake affected areas.

USGS geography, tsunami, earthquake, and remote sensing experts attempted to organize an *ad-hoc* internet group of Federal agency scientists and disaster response practitioners to share data and information among each other and with any other users who needed those data. Within twenty-four hours of its inception NOAA, the Department of State (DOS), the U.S. Agency for International Development (USAID), and the Federal Emergency Management Agency (FEMA) were participating. Within a day after that the National Geospatial-Intelligence Agency (NGA), the United Nations, and the Pacific Disaster Center were actively involved.

Independently, the U.S. Navy initiated response activities and began taking reconnaissance aerial photography using P-3 aircraft and helicopters stationed on aircraft carriers nearby.

The United States scientific community worked with scientists from Indonesia, Sri Lanka, India, and Thailand and elsewhere to help produce maps of information critical to response and recovery including regions susceptible to future tsunamis, locations with salt water intrusion and groundwater quality, the effects of the tsunami on coral reefs, earthquake effects, and land cover and vegetation change.

The international geospatial community was not idle. The United Nations (UN) began making geospatial information available and worked closely with the USA and other governments to help share data effectively. Also, the UN, in concert with USAID, began preparing for a Humanitarian Information Center in Banda Aceh, Sumatra, the location hardest hit by the tsunami.

Humanitarian Information Center (HIC)

The HIC in Sumatra, established by the United Nations Office for the Coordination of Humanitarian Affairs (UN/OCHA), provided support to humanitarian response through a range of information products and services. To aid the UN effort, the US provided a considerable volume of raw and processed data, a digital atlas of Aceh province, a manual with UN approved standards for collecting information, and a person to help set up the facility.

Tsunami Humanitarian Information System (THIS)

A disaster of the magnitude and scale of the Indian Ocean tsunami involves many national and international organizations and requires multi-organizational coordination and information sharing. The THIS working group consisted of personnel from over 60 offices and organizations, including the USAID, the DOS, Department of Defense and US Pacific Command, USGS, NOAA, NASA, NGA and several non-governmental partner organizations. The working group addressed and responded to identified needs and requests for data, information, and imagery and established an international network for locating, obtaining, and disseminating data and products. The group identified USG, foreign, and commercial satellite imagery acquired over tsunami-affected areas and publicized access to that information on web sites. The group also set up a geocollaborative workspace for participants to share information, track requests for geospatial information from response agencies and affected countries, and share information on lessons learned and best practices.

Remote Sensing Applications

Landsat, SPOT and other imagery were made available through the USGS, NGA, the Pacific Disaster Center (PDC), and UNOSAT, and other organizations. The greater coverage and availability of Landsat data, including the extensive historical archives and consistency of instrumentation and footprint complimented the higher spatial and spectral resolution commercial imagery and the classified space-based and airborne imagery acquired over small, targeted areas.

USGS, PDC, and UNOSAT provided access to civilian data sets. Initially, USGS services were focused on posting pre-tsunami and noncommercial data, while PDC developed a site to post GIS-ready compressed data products derived from commercial data. As soon as post disaster Landsat data were collected by the satellites they were made available. USGS National Center for Earth Resources Observation and Science (EROS) hosted the commercial data archive and provided the increased capacity required for compression and staging the original and compressed data, as well as some data products. Documentation of content and ease of use of the various sites varied widely.

NGA and FEMA under the auspices of USAID produced imagery-derived assessments depicting the extent of devastation in a number of identified locations. These assessments were made available to anyone with a response need.

Among the uses for the satellite imagery were:

- Base layer for map products,
- Situational awareness and orientation materials,
- Response to incoming requests from representatives of international response partners, affected nations, and humanitarian organizations,
- Damage assessments,
- Diplomatic coordination,
- Logistical planning.

Academic Activities

Researchers at universities and other non-government organizations (NGOs) have extensive analysis capability that was available. Many universities and NGOs responded through their own international collaborations. Landsat data is available through the University of Maryland. They need significant expertise to assimilate into usable products. Acquisition of post-tsunami data from the various portals was possible however there was some delay.

There were noted successes. For example, the Center for Global Change and Earth Observations acquired Landsat data and conducted analysis for Aceh at the request of contacts in the Indonesian government Agency for Technology Assessment (Baden Penerapan dan Pengembangan Teknologi). Although the small footprint of the higher resolution commercial satellites were not as useful for initial assessments as the Landsat views, they were valuable for more detailed analysis and the analysis was provided within 30 hours after acquisition.

Civil Society

As an example of how civil society is taking a role in using geospatial technologies to help with disaster response, Mercy Corps teamed up with over 50 geographic information systems (GIS) and remote sensing (RS) professionals to improve relief efforts in tsunami-stricken areas of Asia. In order to assist in developing effective long-term rehabilitation solutions for coastal communities decimated by the recent Indian Ocean tsunami, Mercy Corps established an integrated GIS/RS Data Center in Seattle, Washington staffed by volunteer GIS/RS experts.

PRELIMINARY LESSONS LEARNED

The many response activities involving geospatial data pointed up a number of preliminary lessons:

- The analysis could not have been accomplished without data from seismic stations near the region of the earthquake. Had there been more seismic monitoring stations and tide gauging stations it is likely more accurate information and a more accurate estimate of the magnitude of the earthquake and the resultant tsunami would have been achieved earlier. Monitoring capabilities must be improved to ensure adequate warning.
- Disasters can occur over extremely large areas and response plans should take this into consideration.
- Training must be improved for nations in harms way and local responders.
- Education is important for the general population. Education must be conducted on the nature of the disasters, appropriate response actions, and the use of geospatial information to aid in their response.
- Timely access to commercial data must be improved.
- Capacity must exist to rapidly acquire, process, and widely disseminate the remote sensing data. Though valuable, the higher resolution data would have been even more beneficial if it had been more rapidly assessed and reformatted to meet such needs as delineate breaches in physical infrastructure, bolster damage estimates, and locate staging areas for relief support.
- Appropriate scale data must be made available. In general, large-scale data are more valuable than small-scale data for disaster response, recovery, reconstruction, and planning for future disasters. Intermediate scale data (1:100,000-scale or larger, 15 meter to 30 meter resolution) are needed for reconnaissance and making regional estimates. Very small-scale data are useful for illustration and briefings. For many response activities page size maps are most practical.
- A historic baseline of satellite imagery must be available so comparisons can be made with post disaster imagery to identify impacted areas.

- Current fundamental geospatial data layers are important (transportation, building stock, topography, vegetation, geographic names, etc.) and, in most cases lacking
- Maps derived from high-resolution imagery showing damage polygons are valuable to responders.
- Expect destroyed infrastructure in disaster areas so use multiple approaches to make data available including physical transport of the data. Often, as was the case in this tsunami, high-speed Internet links are not available in disaster stricken areas.
- Coordination must be improved among Federal agencies, nations, and the various sectors of society (government, private industry, civil society, academia).
- Access to data is critical throughout the disaster cycle. Access should be made as easy and inexpensive as possible. Some minimum agreed upon standards for access and "look and feel" of portals should be established to simplify and move data into the hands of the users.
- Scientific and environmental assessments need to be conducted as soon as possible after the event, before evidence is removed by post-disaster clean-up activities.