PREDICTION AND RISK ASSESSMENT

PAUL F. KRUMPE

Prediction of natural phenomena which have the potential for causing disasters is an extremely difficult proposition both from a scientific and socio-political perspective. Experience has shown repeatedly our inability to predict events leading to disasters. Geophysical predictions, in order to have maximum utility, must specify the date, time, place and magnitude of physical events. In order to meet the minimum criteria for effectiveness and credibility, predictions must be stated within limits which are useful to the public and can be practically applied. Perhaps the best way to deal with the inevitable conflicts and uncertainties associated with the problem of disaster prediction is to either not make such pronouncements or issue forecasts based on the likelihood or probability of event occurrence. In the latter case it is best to provide simplified thresholds for various threat levels and suggest appropriate actions necessary to avert the impacts of an event.

We do not want to overwarn, thereby contributing to a panic. We find it useful for both the scientist and disaster manager to collaborate closely in setting threat parameters and developing contingency plans based on practicality and local experience.

It is in this context that we, in Office of Foreign Disaster Assistance (OFDA), have initiated the use of probabilistic forecasting techniques, and hazards and risk assessment methodologies in lieu of prediction. This is now possible because a considerable amount of time and money has been spent over the last seven years in capturing, compiling and analyzing hard quantitative historical and real-time physical data as inputs to operational national, regional and global early warning systems which are capable of providing significantly increased leadtimes on the likelihood of disaster. We have developed, in concert with many other agencies of Government, such as the USGS, NASA, NOAA, USDA and DOD a technical resources network supported by an impressive variety of ground and satellite-based remote sensing and monitoring systems. The goal has been to access environmental information in order to reduce the uncertainty of disaster occurrence, monitor potentially destructive phenomena, and assist host country disaster managers in identifying and tracking imminent threats to determine when to activate emergency plans, including evacuation, in order to protect populations at risk.

It is obvious that disasters can be avoided if the threats are properly identified and communicated to vulnerable population centers in a timely manner such that appropriate actions can be taken. The goal of disaster preparedness should be to establish the organization and procedures to implement strategic plans based on reliable forecasts and early warning of probable events. In order to accomplish this, we need to produce quantitative risk maps as well as real-time information, and teach disaster managers how to apply the data for decision-making and contingency planning. Assessment of risk—i.e., determining the probability that social or economic and life-threatening consequences of natural physical events will equal or exceed specified thresholds for a particular site or region during a specified exposure time—is the best way to deal with the uncertainty of future disasters. Even more important is the need to define the acceptable risk one is willing to assume and to project the political, economic and social costs associated with over-warning or under-warning. We also have found that risk and hazards analyses provide a sound basis for establishing disaster preparedness priorities at the host country and regional level.

In the past several years OFDA has supported the implementation of disaster forecasting and early warning systems in virtually every region of the developing world. Our applied research effort to date has concentrated on five major disaster types: earthquakes, volcanoes, tsunamis, severe storms and drought/famine.

Earthquakes

The ultimate goal of our earthquake hazard reduction activities is to assist host governments in reducing the death and injury toll caused by geophysical disasters. The starting point for this program several years ago was the need to quantify seismicity both

From the Office of Foreign Disaster Assistance, U.S. Agency for International Development, Washington, D.C.

historically and in real-time, through seismological investigations, the installation of seismic networks, preparation of hazards and risk maps and probabilistic earthquake forecasting. The results of these initiatives today directly support life-saving contingency planning and mitigation priorities at the country and regional levels. We have installed, with contractor and U.S. Geological Survey (U.S.G.S) support, national seismic networks in Guatemala, the Dominican Republic, Peru, Costa Rica, El Salvador, and Fiji. We have provided major support since 1981 to regional seismology organizations in the Andean region and in Southeast Asia. One of our major activities, Seismic Risk in the Andean Region (SISRA), coordinated by the U.S.G.S., has recently concluded with the publication of historical seismicity catalogues, an earthquake loss estimation methodology, and a series of regional earthquake hazards maps suited to disaster planning and reinsurance management. Concurrent with this effort has been the investigation of the probabilistic recurrence of major subduction zone earthquakes in the Circum-Pacific region. This U.S.G.S. effort will lead to the quantification of seismic gaps—regions of high seismic potential—which will greatly facilitate improved strategic planning at the host country and regional level. This activity has already demonstrated its potential utility in forecasting the high probability of a damaging, tsunamigenic earthquake in the Valparaiso region of Chile. The recent event in Mexico also falls within the probabilities (forecast timeframes) developed in this program.

Tsunami

OFDA has been supporting NOAA's Pacific Marine Environmental Laboratory (NOAA/PMEL) in the design, development, testing and installation of a near-shore tsunami (seismic seawave) alert system. The THRUST project—Tsunami Hazards Reduction Utilizing Systems Technology—is a pilot demonstration project in Valparaiso, Chile that utilizes the GOES geo-stationary weather satellite as a telemetry system to confirm tsunami generation immediately following a major offshore earthquake. The satellite transmits telemetry from on-land sensors which are triggered by an earthquake. It has the potential for providing realtime or near realtime evacuation alerts some 10-30 minutes following a major earthquake event. This obviously has significant life-saving potential for those people on or near the beach areas. In addition to the THRUST project, OFDA has worked with subcontractors to model tsunami run-up or inundation along specific coastal areas of the Pacific Ocean where population centers are most vulnerable. We have also supported the comprehensive mapping of historical Circum-Pacific tsunami generation with a view towards educating the public, disaster officials and others about this hazard. In the past 135 years some 70,000 inhabitants of coastal areas have been killed by tsunamis in the Pacific Basin. The Pacific Tsunami Warning Center (PTWC) in Honolulu can provide adequate warning time and notice of far-field tsunami threat to coastlines thousands of miles from the earthquake source zone, but the PTWC system is unable to warn coastal areas close to the tsunami origin in a timely manner.

Volcanoes

A significant portion of the world's population live in the "Ring of Fire" around the Pacific Basin, a region characterized by volcanoes noted for their explosive activity. In addition, many active volcanoes exist on the African continent. Only a few of the more than 500 active volcanoes throughout the world are closely monitored. Inactive, though potentially dangerous volcanoes require monitoring also. Many of these volcanoes could be routinely monitored for precursory seismicity, water and fumarole temperature changes, chemical anomalies, uplift/deformation rates, associated tilt and magnetic field fluctuations prior to eruption by using automatic sensors and data collection and relay platforms linked by telemetry to satellites. Either the polar orbiting, geostationary or an appropriate mix of communications satellites could be used for relay of ground sensor data as well as warning information.

Although such a comprehensive system is technically feasible, its implementation is unlikely in the near future due to budgetary constraints. Other options available for global volcano eruption surveillance include the use of special sensors on the weather satellites as well as possible observations from infrared heat sensors aboard U.S. Department of Defense satellites. To date, OFDA's volcano monitoring activities have concentrated on ground-based *in situ* line-of-sight seismic data collection platforms and electronic distance measuring devices used to monitor changes in volcano eruption precursors. These may indicate immediate threat and require evacuation alerts issued by the host government. Our experience in this field, in cooperation with the U.S.G.S. has centered on monitoring Rabaul volcano in Papua New Guinea, Mayon volcano in the Philippines, La Soufriere in St. Vincent, El Chichon in

Mexico, and most recently Ruiz volcano in Colombia. We are currently conferring with the U.S.G.S. and the Smithsonian Institution on formulating a Latin America and possibly a global Volcano Crisis Assistance Team (VCAT) to assist host governments in immediate systematic technical evaluation of volcanoes posing major threat to vulnerable population centers.

Severe Storms

The U.S. Navy has developed and currently operates for Agency for International Development (A.I.D.) and Department of Defense (DOD) use, an advanced computer-based warning system for determining the strike and wind threat probability of tropical cyclones worldwide. We have supported the U.S. Navy in developing aspects of the system since 1979 because we recognized its potential value in a civil disaster preparedness and warning context. OFDA arranged with the Navy for the promulgation of threat messages for cyclonic storms through the Navy Fleet Numerical Oceanography Center (FNOC, Monterey, CA) military communications network. These threat probability statements are based on forecasts issued by the National Hurricane Center (NHC) in the Caribbean and Gulf of Mexico and DOD facilities at Guam in the Western Pacific.

These severe storm threat summaries are computer-generated messages sent from FNOC directly to U.S. missions in a threatened area. Possible secondary addressees are generated by the FNOC computer on the basis of areas threatened and appear in the text of the message as recommendation for U.S. mission distribution. The FNOC addresses the messages to selected foreign service posts on a computer-generated list with additions and deletions where appropriate, based on level of storm strike and wind threat. This system is not a forecast, but a statistical probability threat estimate. The storm threat is estimated by allowing statistically for forecast errors and is expressed as a threat index. The threat indices are computed on a real time operational basis for 125 populated areas worldwide but are forwarded to posts only when the threat becomes significant. U.S. missions are encouraged to confer with senior officials of the host country's national meteorological agency to provide information about the system and seek the Agency's cooperation in using and evaluating the operational products. This information is maintained within official channels and is shared only at the formal request of the host government. It is not publicly released, since such inadvertent release of storm threat information might undermine confidence in the local warning and forecast system which we would hope to strengthen through training and technology transfer.

A recent evaluation of this program points to the need to further update and refine the statistical data base upon which the system operates as well as the need for increasing the timeliness of threat message distribution to our overseas field missions.

In addition, a cyclone tracking system recently installed in Bangladesh by NOAA and NASA with A.I.D. support has significantly improved the Bangladesh Government's forecasting and monitoring program as well as their disaster preparedness program. OFDA is also supporting a program in the Philippines to upgrade that country's radar cyclone tracking system and institute cyclone risk studies. Since 1984, we have worked with the Philippine meteorological agency on transferring the U.S. Navy wind and strike threat probability forecasting system into their operational monitoring system. This improved capability enables Philippine scientists to better advise Civil Defense Officials on warning the public in coastal areas. Storm warning technology will also be installed in Fiji this summer.

Drought/Famine

Since 1979, OFDA has supported the National Oceanic and Atmospheric Administration (NOAA) Assessment Information Services Center (AISC) in developing, testing and implementing the Global Climate Impacts Assessment System.

This cooperative effort has sought to significantly improve drought disaster early warning in the developing world. Principal results to date include: 1) operational assessments of weather impact on subsistence food supplies in over 400 sub-regions of the world, and 2) rapidly evolving technical assistance to help participating countries implement a similar independent assessment capability to strengthen their own food security through improved agricultural advisories and crop yield/production forecast estimates. The NOAA assessments have been verified against available host country information from 1979 thru 1985 and demonstrate that reliable, 3-6 month alerts on the potential for food shortages and probable famine conditions can be provided at least 30-60 days before the beginning of crop harvest. Moreover, highly reliable qualitative information can be provided on the severity and geographical extent of drought, including its impact on rangelands and human migration. A.I.D. is currently moving rapidly to support NOAA in implementing an upgraded, advanced capability to provide each country in the Sahel region with special quantitative weather/crop impact assessments as well as assist each country in developing national crop condition assessment systems based on rainfall and satellite data. All of this is made possible as a result of dramatic breakthroughs in the uses of NOAA weather satellite systems applications.

A.I.D. is developing a Famine Early Warning System (FEWS) which incorporates the NOAA weather/crop assessment information into a comprehensive geographic information system.

In the FEWS system, data on nutritional status of populations, and other social data such as demographics, health, water supplies, migrations, crime rates and cultural values are cross correlated with other parameters such as soils, cropped area, seed availability, logistics, transport routes, storage facilities and food prices.

The detail afforded in routinely monitoring areas as small as a one square kilometer is unique to FEWS and can provide best estimates, early on, regarding populations at risk. This is now being done with sufficient lead time so as to strategically plan targeted interventions thereby mitigating famine impacts.