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GUEST EDITORIAL

# Addressing resilience to cyclones – a perspective

Cyclone is one of the major natural hazards that threatens human lives, livestock, agriculture, infrastructure, buildings, forest and wild life in coastal areas. As the Bay of Bengal basin is more prone to cyclogenesis compared to the Arabian Sea, the East coast of India has been more vulnerable to cyclones than the West coast. During the last two decades or so, the intensity of cyclones has increased mainly over the North Indian Ocean. It could be attributed to warming of seas among other factors. The stronger winds resulted in higher storm surges and waves, which led to deeper inundation of inland areas and made coastal regions highly vulnerable. We have to live with the hazards of cyclones and prepare ourselves to build resilience, especially to save lives. The impacts of cyclones are through strong winds, storm surges, heavy rainfall and floods. Hence, in order to build effective response mechanism, we need to assess our vulnerability to such events.

There are three main aspects which need to be considered to respond and manage cyclones. First is the quality of our knowledge about genesis and movement of cyclones, and providing forecast of cyclone characteristics. Second is the preparedness of organizations that respond to such a hazard, essentially administration and governance system at the national, state, district and local levels; in carrying out evacuation, providing shelter, food, water, medicine, sanitation, security, rescue and relief. Third is the awareness in the coastal communities about cyclones.

Setting up of an efficient system for detection and monitoring of cyclone, providing timely, accurate and reliable forecast, communicating likely risks and assessment of vulnerability of people to cyclone, are most crucial. The forecast of cyclones has improved significantly during last fifteen years due to better understanding of the physics of cyclone generation, space-time history, observations of oceans and atmosphere including satellite observations and improved assimilation of these datasets into numerical models. Cyclone forecasts provided by the Earth System Science Organisation–India Meteorological Department (ESSO–IMD) have been quite reliable as witnessed during last decade. There has been continuous improvement in forecast accuracy (~30 km for 24 h lead period) and skill over the years. All cyclonic events of the recent past were well predicted, response of the governments and the people to these events was exemplary and thus resulted in the reduction of the number of human deaths to less than hundred as compared to thousands in the past. Just two decades ago, during the cyclone in Orissa in October 1999, about 10,000 people died and thousands of crores worth damage occurred to infrastructure and properties. Therefore, accurate and timely prediction of cyclones has helped to save thousands of lives and thus is a remarkable achievement.

The investments made to improve observations of ocean through satellites, moored and drifting buoys, Argo floats, deployment of Doppler Weather Radars (DWR) and automatic weather stations on coast, etc. have all led to better understanding of conditions of generation of cyclones. INSAT satellites provide images at 15 minutes interval, and have been found to be most useful for detecting formation of cyclones, their areal extent, location, movement and determining their intensity. Atmospheric Motion Vectors derived from multi-spectral imager and temperature/humidity (T/H) profiles from 19 channel sounders have been found to have positive impact on prediction. Global measurements of ocean surface vector wind provided by scatterometers allowed improved prediction of ocean state, ocean dynamics and monitoring of cyclonic systems. Sounder for Probing Vertical Profiles of Humidity (SAPHIR) on-board Megha-Tropique has provided data during cloudy conditions at higher accuracy levels and improved forecast of rainfall and winds. The network of 12 DWRs provides information about the size and intensity of cyclones, at least 4–5 days in advance.

Assimilation of these observations into 12 km resolution global numerical models and meso-scale models (3 km) has resulted in overall improvement of prediction of cyclones. The first forecast of likely cyclone event is now provided almost a week before its impending danger. The estimates of storm surge provided by ESSO-Indian National Centre for Ocean Information Services are very valuable to provide information on areas likely to be affected and assessment of likely damage to infrastructure, crops, human settlements, etc. The recent development of flood forecasting system in Chennai and Mumbai further helps to provide rescue and relief in urban areas. ESSO-IMD as a Regional Specialised Meteorological Centre of World Meteorological Organisation provides

advisories to all countries bordering the Arabian Sea and the Bay of Bengal.

The availability of improved atmospheric wind profiles from Atmospheric Dynamic Mission Aeolus and Cyclone Global Navigation Satellite System, observations of atmospheric thermodynamics structure from Hyperspectral Infrared Sounder on-board METOP satellites, and T/H profiles with high vertical resolution from navigation satellites, will further improve our understanding of cyclone processes and provide insight into the intensification and decay of cyclones.

A web-GIS based dynamical decision support system is being implemented under the National Cyclone Risk Mitigation Project. It aims at acquiring forecasts and observational data visualizing likely impact scenarios, assessing the risk through evaluation of hazard, vulnerability and exposure conditions as well as conveying advisories through web and location-based services. Such a system will enhance our capability to respond to cyclones. The use of AI-based tools will further help in analysing observational data along with input from social media.

The forecast and early warning are not sufficient to mitigate risk from the cyclone hazards. The existing social systems, political, administrative, economic and industrial structures are equally important to provide resilience to society. We have seen that, though cyclone-related information has been provided, in absence of effective communication to people at large, or lack of ability of local administration to respond to an event, cause loss of lives and damage to property. The setting up of the National Disaster Management Authorities at the State and Central levels and National Disaster Response Force (NDRF) has tremendously improved the response mechanism. The development of information system and emergency plans for evacuation, rescue and relief by these agencies, have helped to set up very effective and efficient response mechanism in the country. Shelters have been set up in coastal areas to withstand any hazard and are equipped to meet any calamity. Apart from these shelters, schools, colleges and other public utility buildings are also used for providing temporary housing. Major damage occurs to communication and power networks during such cyclones and it is pertinent to house these networks underground to keep them functioning during a hazardous event. All police stations, fire brigades, government administrative buildings and hospitals should also be made hazard resistant in vulnerable areas. Mock drills and communication tests are most critical, and should be carried out periodically.

The increasing population and development of industries have affected existing habitats and rational land use along the coast. Thus, many times, potentially hazardous areas have been occupied by buildings and industries. Such irregular growth of high density urban areas, make them very vulnerable and 'risk' increases. The availability of vulnerability maps on 1 : 25,000 scale, for the entire Indian coast is useful to plan hazard resilience land use and evolving of safe siting and construction practices for long range planning of cities. Such maps are required to be upgraded to cadaster, to get an idea about population, crops and properties which are likely to be affected. Visualization of likely vulnerable areas in 3D during an event greatly helps administrators, and should be made available.

It has been realized now, that even if we have early warning and responsive organization to address any event, without supportive human system, we can still lose lives. In India, over a period of time, especially on the east coast, trust of local communities in the forecast as well as in the local administration has increased manifold. They are now reasonably well-informed about possible dangers from cyclones. It is desirable to educate people, especially students about the science, risks involved, social impact and rescue measures. It has been observed that many villages have volunteers to inform people about potential dangers as well as assist administration in directing people to safe places and providing necessary relief. The system of volunteers should be put in place all along the Indian coast. After the event, they also provide evidence of damage and assist in providing compensation to affected people. Such people must be trained to carry out their functions and will have to be equipped with a few tools, such as smart phones.

There is need to address anthropogenic activities which have influenced in generating extreme events. Under changing climate, cyclones are persisting for longer time and thus yield heavy to very heavy rainfall. Though it is difficult to relate individual events to climate change, we are experiencing increasing frequency of intense cyclones and associated heavy rainfall events. The rising sea levels further compound the impact of storm surges on coast.

An effective collaboration with neighbouring countries to build observational systems, develop standards for data exchange, networking of required services and preparation of human communities, has to be ensured. Various organizations such as Indian Ocean Rim Countries Association, Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation, Regional Integrated Multi-Hazard Early Warning System for Africa and Asia, etc. are critical in developing resilient response mechanism. Collaboration with international research institutes to addresses science questions and improving understanding of interaction between earth system processes is essential to build improved predictive models. Our capability for responding to cyclones at regional, national, institutional and individual levels needs to be enhanced. We should constantly evaluate and improve performance as well as prepare ourselves to address newer challenges.

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