Myanmar’s deadly daffodil

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Tropical cyclone Nargis wrought havoc in southern Myanmar, with an estimated death toll well above 100,000. Potential future disasters could be alleviated with currently available forecasting skill and effective disaster mitigation plans.

On 2 May 2008, a “very severe tropical cyclone”[1] crossed over southern Myanmar with winds in excess of 65 ms^{-1} (135 mph), similar in intensity to Hurricane Katrina when it struck the US Gulf Coast in August 2005. Cyclone Nargis (Urdu for ‘daffodil’) moved eastwards along Myanmar’s Irrawaddy delta (Fig. 1a). The path of the storm could not have been worse. The delta is densely populated and very low-lying, continuing upriver essentially at sea-level for more than 200 km. The Andaman Sea, immediately to the south of the delta, has an extensive and shallow continental shelf, allowing the cyclone to build up a storm surge of sea water estimated at up to 4 m that inundated some areas 40 km from the coast.

The passage of cyclone Nargis left large sections of the coastal areas of the delta and regions inland along the channels of the Irrawaddy river under water (Fig. 1b,c), which had devastating consequences: over 130,000 lives were lost and buildings, infrastructure, farmlands, livestock and fisheries were destroyed. According to United Nations estimates, 1.5 million people were “severely affected” by the cyclone. Nargis ranks as the deadliest disaster in the recorded history of Myanmar (formerly known as Burma) and is comparable to the damage in South Asia from the 2004 Indian Ocean tsunami. After a disaster on this scale, the question arises whether return times of such catastrophes make it necessary to invest substantially into ways of reducing their impact, and whether strategies that have proved useful elsewhere can be adapted to the region.

TROPICAL CYCLONES IN THE INDIAN OCEAN

Nargis formed in the southern Bay of Bengal during the last week of April 2008. Two periods are conducive to tropical cyclone formation in the North Indian Ocean: before the onset of the South Asian monsoon (April–May) and following the monsoon (October–November). During northern-hemisphere spring, the sea surface temperatures in the North Indian Ocean are the warmest anywhere on the planet. At the same time, the vertical wind shear, which can inhibit the formation of strong cyclones, is relatively low — ideal conditions for the intensification of a hurricane. Nevertheless, Myanmar and other countries affected by North Indian Ocean tropical cyclones have historically seen only infrequent tropical cyclone landfalls.

As a result of the passage of cyclone Nargis over 130,000 lives were lost and buildings, infrastructure, farmlands, livestock and fisheries were destroyed. After a disaster on this scale, the question arises whether strategies that have proved useful elsewhere can be adapted to the region.

Recently there has been an apparent elevated activity in the North Indian Ocean: since 2006, four major tropical cyclones (category 3 to 5 on the Saffir–Simpson scale) have occurred, compared with a total of eight major tropical hurricanes in the previous 25 years. Whether this increase is the result of climate change and the warming sea surface temperatures in the Indian Ocean, and therefore likely to be part of a continuing trend, is difficult to assess because of limitations to data quality and length of record. But irrespective of future trends in the North Indian Ocean, it is prudent to develop and improve forecasting and mitigation strategies to limit casualties and property damage. Vulnerability is increasing as population pressure is forcing more people to live and farm in coastal zones that are easily flooded.

The Irrawaddy delta, once known as the ‘rice bowl’ of the British Empire, is economically very important for the country with its extremely fertile soil that has allowed Myanmar to become a major rice exporter. Beyond the loss of life and instantaneous wind and water damage, Nargis caused extensive harm to Myanmar’s winter rice crop. Whereas people could perhaps have been evacuated to greater effect with more advance warning and more efficient disaster plans, it is even more challenging to protect crops in vulnerable coastal regions. The loss of winter rice due to the devastation from Nargis means that the people of Myanmar face food shortages. The reduction in exports may also further exacerbate the global food crisis that is already affecting the poorest people in the world. In addition, the salination of large areas of the Irrawaddy delta inundated by the seawater surge, and the loss of rice seed as a result of the flooding, pose serious challenges to future rice production. Although subsequent rain flooding has flushed salt from large areas of the delta, 50,000 acres are now unfit for planting[2] and will have to be abandoned.

FORECASTING CYCLONE NARGIS

A tropical cyclone forecasting system is in place in the North Indian Ocean. The Indian Meteorological Department is designated as a Regional Specialized Meteorological Centre by the World Meteorological Organization, and is

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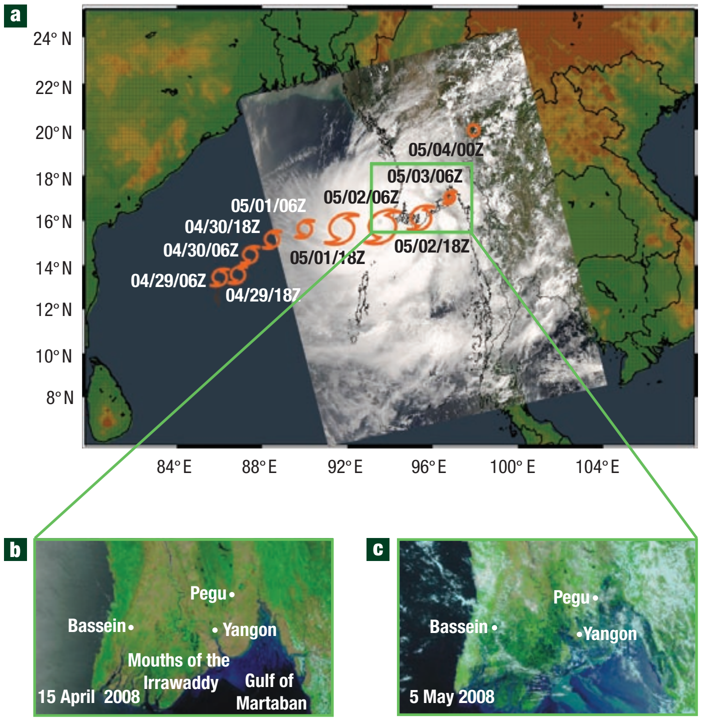

Figure 1 A hurricane emerging. **a**, The track of tropical cyclone Nargis across the Bay of Bengal, by date and universal time. The intensity of the tropical cyclone is coded by symbol size. The storm formed as a tropical depression on 29 April 2008 and moved northeastward before intensifying to a very severe tropical cyclone[1], equivalent to a category 3 or 4 hurricane. At that stage Nargis moved along the Irrawaddy delta coast. The hurricane-force winds ahead of the storm forced a 3–4-m storm surge across the delta. The satellite image was taken on 5 May 2008 at 6.45 UT. **b**, A close up of the Irrawaddy delta on 15 April 2008. **c**, Aftermath of the transit of Nargis. Blue–green areas are flooded and extend inland up to 50 km from the coast. The trajectories were taken from the Joint Typhoon Warning Centre (http://metocph.nmci.navy.mil/jtwc.php). Irrawaddy delta satellite pictures courtesy of NASA/MODIS Rapid Response Team (http://earthobservator.nasa.gov/NaturalHazards)

responsible for issuing the official tropical cyclone forecasts and warnings. This information is then communicated to national meteorological agencies that interpret it for national needs. There is, however, an important gap in the current forecasting system. There is no mandate for the Indian Meteorological Department to provide storm-surge forecasts, and no warnings of impending surge accompanied their tropical cyclone alerts. With Nargis, over 80% of mortality was related to the storm surge[2], which washed away more than 100 villages.

The Indian Meteorological Department identified the system on April 27, upgraded it to cyclonic storm Nargis on April 28, and classified it as a very severe cyclonic storm on April 29[1]. It was therefore clear, days ahead of landfall on 2 May, that a very severe tropical cyclone was approaching the low-lying regions of the Irrawaddy delta. Forecasts and warnings were communicated regularly to Myanmar's Department of Meteorology and Hydrology during the period before and after the landfall of Nargis, although the Indian Meteorological Department noted that there was little response from Myanmar.

Myanmar's utilization of these forecasts is unclear for two reasons: it is difficult to obtain any information from the country, and mixed messages emerge from the scarce information that is available. For example, Myanmar's official forecasts appeared on page 15 in the newspaper *The New Light of Myanmar* from 29 April to 2 May, noting only minimal impact anticipated from Nargis[4]. Specifically, the day before landfall[4], the newspaper noted that "…the severe tropical cyclone NARGIS … is forecast to cross the coast during the next 36 hours … Under the influence of this storm, rain or thundershowers will be widespread …. [regions given] … frequent squalls with rough seas will be experienced off and along the Myanmar coast. Surface wind speed in squalls may reach [50] mph …". It therefore seems that the forecasts and warnings of the Indian Meteorological Department were downplayed in Myanmar newspapers. On the other hand, a post-Nargis assessment by Myanmar's Department of Meteorology and Hydrology and the Asian Disaster Preparedness Centre[3] point to a successful forecast (using traditional non-numerical 'synoptic' techniques) and warning effort by the Department of Meteorology and Hydrology, including storm-surge forecasts (using 'empirical methods'). Documentation of these forecasts has, however, not been uncovered. The report also notes that the warnings were not heeded by the public.

Be it through lack of communication, insufficient warnings or a failure to realize the severity of the threat to the delta regions of the Irrawaddy, the lack of response to the warnings resulted in a far greater loss of life than need have occurred.

FORECASTS FOR THE DEVELOPING WORLD

Developing countries tend to have limited means of communication and few established evacuation routes to prepare for an impending natural disaster, such as that inflicted by Nargis. The most vulnerable people live in the river deltas of Bangladesh, India, Myanmar and Pakistan where population pressure has caused people to farm in coastal regions that are the most vulnerable to surge flooding. Moreover, people in rural areas can only move on foot or by rudimentary transport along minor roads to places of relative safety, and they have to take with them their livestock, belongings and food.

These factors suggest that three main improvements are necessary in order to make forecasts more effective: the time horizon of the forecasts needs to be extended; storm surge forecasts and the use of best practices should be added to the mandate of the Regional Specialized Meteorological Centres, and resilient national disaster plans must be developed.

Tropical cyclone warnings of three days or so, which may be adequate for the developed world, provide insufficient time for the organization and implementation of evacuation in developing countries. Experimental probabilistic forecasts[5] between one and fifteen days in advance, based on the ensemble simulations of the European Centre for Medium-Range Weather Forecasts at 40-km resolution, indicate extended predictability of regions of cyclogenesis and potential cyclone tracks in the North Indian Ocean. Including such extended range forecasts as part of the suite considered by the Indian Meteorological Department would help provide more useful information to the developing

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countries in the region. Given the critical importance of the forecasts issued by the Indian Meteorological Department, it is essential to ensure that they are using the best operational forecasting models available, and that 'best practices', like those of leading tropical cyclone forecasting centres, are carried out.

It is also essential that storm surge forecasts be included as a part of the tropical cyclone warnings that the Indian Meteorological Department disseminates throughout the region. The bathymetry of the North Indian Ocean is known sufficiently well for surge forecasts to be made, and the data as well as the technical methods to produce these forecasts are already available.

Important insights on the development of national disaster plans can be gained from the manner in which Bangladesh has learned to deal with tropical cyclones. Storm surges associated with tropical cyclones hit the river deltas of West Bengal and the Ganges–Brahmaputra delta in 1970 and 1991 respectively, killing hundreds of thousands of people. In November 2007, Sidr — another tropical cyclone of similar strength — made an almost identical landfall in Bangladesh as the 1970 Bhola Island storm. Although Sidr cost over 3,500 lives, this death toll was far less than the previous two storms.

This was achieved through the establishment of a national emergency network and the construction of storm shelters and hillocks as well as dikes and polders along the coast. Extended cyclone forecasts[5] and storm surge forecasts by the Louisiana State University in the US were communicated to the Bangladesh Meteorological Department in addition to the Indian Meteorology Department's forecasts of Sidr's intensity and track. Hence there was ample and timely warning for the Bangladeshi disaster management authorities to take precautionary actions and over two million people were evacuated. Uniquely, forecasts were communicated to the remote coastal areas by cell phone networks that had been established as part of the national disaster plan. This cell phone network had already been used earlier in the season to issue warnings of the two major floods of the Brahmaputra River during August and September 2007[6].

With the aid of international agencies, communication networks can be established in all countries around the North Indian Ocean and in other vulnerable regions in a manner similar to those set up in Bangladesh. The same warning systems, critical for tropical cyclones, can also be used to communicate forecasts of flooding and impending tsunamis. A relatively small investment by the developed world into improved forecasts and warning systems, complemented with places of refuge (storm shelters and hillocks), could hugely benefit public safety and economic stability of the region, minimize catastrophic losses, and reduce the massive cost of after-the-event humanitarian efforts. Of course, the countries involved would have to be willing to accept such help.

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