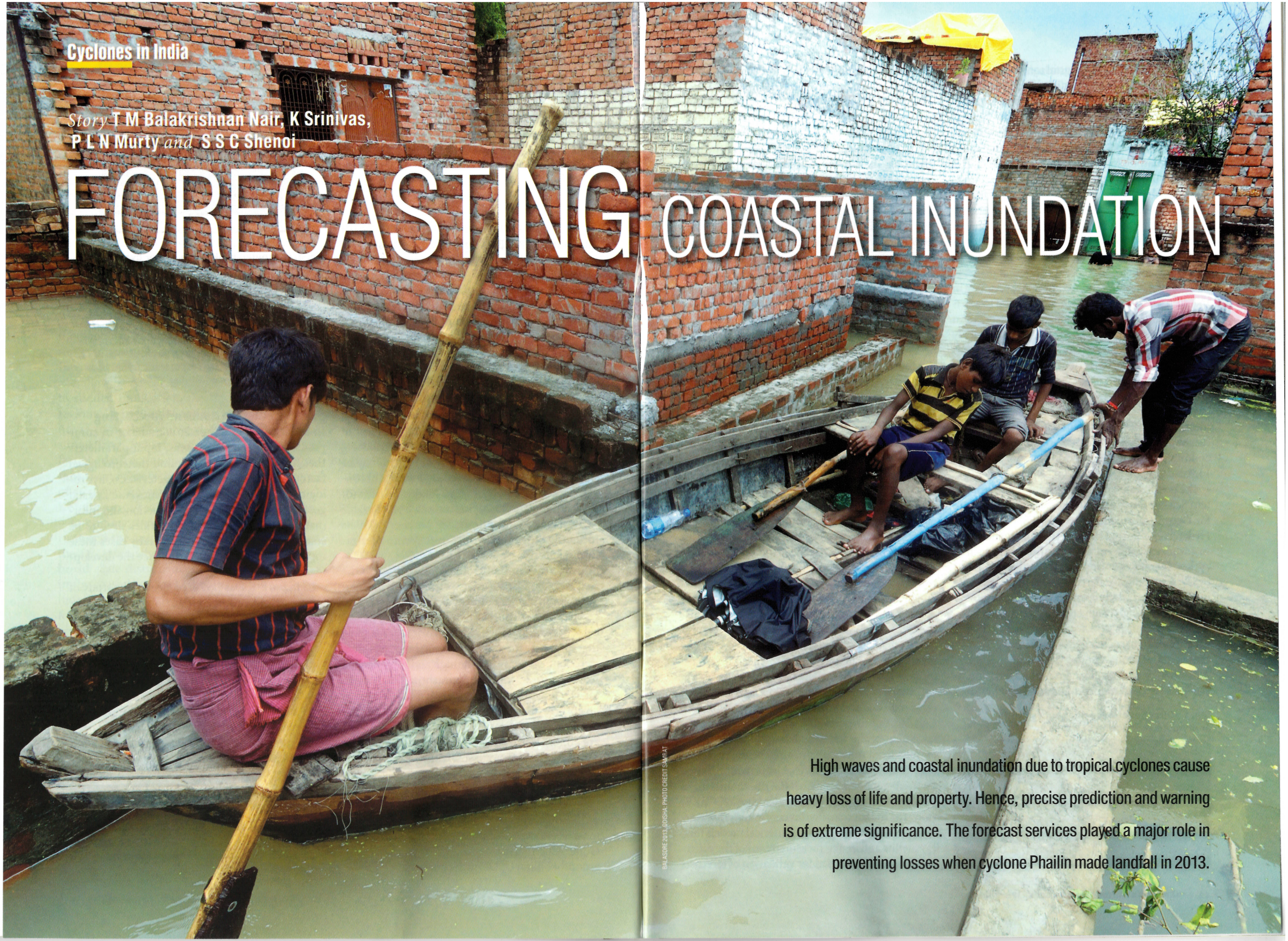
Story T M Balakrishnan Nair, K Srinivas, P L N Murty *and* S S C Shenoi

FORECASTING COASTAL INUNDATION



BALASORE 2013, ODISHA: PHOTO CREDIT SAMRAT

High waves and coastal inundation due to tropical cyclones cause heavy loss of life and property. Hence, precise prediction and warning is of extreme significance. The forecast services played a major role in preventing losses when cyclone Phailin made landfall in 2013.

India has a 7517 km coastal zone—comprising 5423 km of coastal mainland and 2094 km of island coastline. About 25 per cent of India's population is concentrated in the 'coastal zone' with activities that vary from traditional fishing to oil and gas exploration in the 2 million sq km of Indian exclusive economic zone (EEZ). It is thus very important to issue timely and accurate forecasts about the sea state conditions to fishing communities, oil and shipping industries, ports and harbours, navy, coast guard and the general coastal population to support their routine operations as well as caution them about possible hazards. Some users, especially shipping and offshore industries, also seek information about conditions prevailing in the deep seas. Providing such information to a heterogeneous community demands the existence of an ocean state prediction system that would routinely provide accurate forecasts based on numerical ocean models that mimic the actual conditions at sea on a day-to-day basis. Information about surface parameters sought primarily includes winds, waves, tides, currents, and temperature; while the subsurface information on currents, temperature and salinity can be particularly critical during extreme weather conditions like cyclones, which seasonally hit the Indian coasts.

The ocean state forecast system at the Earth System Science Organisation–Indian National Centre for Ocean Information Services (ESSO-INCOIS), Hyderabad is geared to warn the stakeholders well in advance, during extreme weather events such as cyclones as well as during rough weather conditions by issuing high wave alerts. It also provides sea state information on a daily operational basis to a number of users for smooth conduct of their operations.

Ocean state forecast services during tropical cyclones

At landfall, cyclones can cause widespread damage because of sustained high winds, high waves

Fig. 1 : Directional wave rider buoys for the continuous monitoring of waves

PHOTO COURTESY: NIOT

and storm surges. A storm surge is the high sea level caused due to the 'inverted barometer effect', which is the adjustment of the sea level to changes in barometric pressure. Moreover, if the 'eye' (where the barometric pressure is minimum) of the tropical cyclone happens to cross the coast at the local high tide, the net sea level rise would be higher, compounding the danger.

Realising the requirements of the heterogeneous user community dependent on the sea, the Ministry of Earth Sciences constituted INCOIS in 1999 to provide specific ocean information services at various levels. ESSO-INCOIS started the quantitative Ocean State Forecast (OSF) service in 2005 and issues forecasts of ocean parameters such as significant wave heights, remotely generated waves (swells) and ocean surface winds, seven days in advance of an imminent episode and at three hourly intervals, every day. ESSO-INCOIS generates forecasts with inputs obtained from numerical weather prediction (NWP) models in India and abroad. Subsequently, to forewarn stakeholders about impending high waves, ESSO-INCOIS initiated a service called the 'high wave alert'. It is aimed at providing an 'alert' when the wave height is between 2.5 and 3.0 m and a 'warning' when the wave height exceeds more than 3.0 m due to disturbed sea conditions or high swells. These early warnings are validated online using real-time automated observation systems deployed at sea.

The spatio-temporal resolutions of the forecasts, as well as high wave alerts depend on user needs. While fishermen are usually interested in forecasts two days in advance, the navy requires information on coastal seas 10 days in advance for planning operations. The requirements of offshore industries are operation-specific. Coast Guard requires the nowcast or present conditions, for conducting search and rescue operations to check untoward incidents at sea and for controlling oil spills.

The forecasts are issued at various spatio-temporal formats and are location-specific. ESSO-INCOIS has also improved the system by increasing the resolution of the wave models and incorporating outputs from other general circulation models of oceans to generate subsurface information, based on user requests. ESSO-INCOIS maintains a network of directional wave rider buoys (DWRB) along the Indian coastline for continuous monitoring of waves and validating numerical models (Fig. 1). Satellite and in-situ measurements of the different parameters are used for validation of forecasts

Fig. 2: Forecast of wave data for October 12, 2013

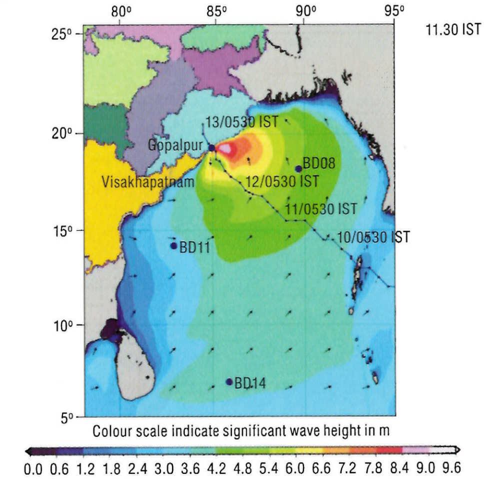
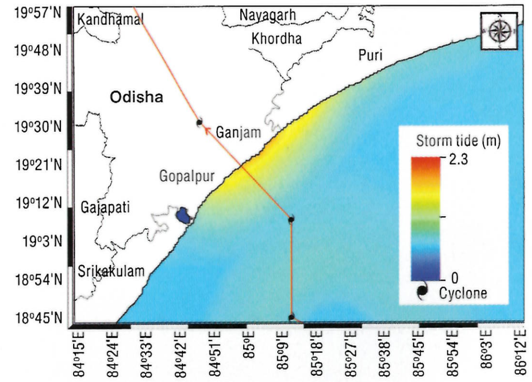


Fig. 3: Predicted maximum storm surge height of 2.3 m above the mean sea level at Ganjam, Odisha



Source: INCOIS, Hyderabad

in real- time and delayed mode. Generally, errors increase with forecast time. However, daily updating reduces the margin of error. The wave heights are compared with observations in real-time from DWRBs and this comparison is available online on the ESSO-INCOIS website (www.incois.gov.in).

Learning from Phailin

An evaluation of the high waves and coastal inundation during very severe cyclonic storm Phailin, 2013, presented a unique opportunity. Unlike the 1999 Odisha super cyclone, when no quantitative ocean state forecasting system was in place to forewarn coastal communities, warnings for Cyclone Phailin were issued five days in advance. This helped maritime communities, administrators and other stakeholders to take maximum precautions well in advance, thereby saving life and property. Specific high wave alerts for the coastal stretch extending from Srikakulam (Andhra Pradesh) to Jagatsinghpur (Odisha) were issued in English as well as in regional languages. The dissemination of this information was done through the ESSO-INCOIS website, mobile phones, emails, and electronic display boards (installed at most fish landing centres along the Indian coastline). Non- governmental organisation (NGO) partners of ESSO-INCOIS were encouraged to issue local warnings through loud speakers, notice boards at village resource centres and voice messages on television and radio. During Phailin (Fig. 2) forecasts on wave data issued by ESSO-INCOIS proved to be accurate. Data from the ESSO-INCOIS DWRB network, including that off Gopalpur, Odisha (at 12m water depth) and wave data obtained from deep sea moored buoys BD08, BD11 and BD14 deployed by the ESSO-National Institute of Ocean Technology (ESSO-NIOT) was used for validating the forecast wave parameters.

The predicted maximum storm surge height was 2.3 m above the mean sea level at Ganjam, Odisha (Fig. 3). This caused a maximum inundation of 430 m near Ganjam and minimum inundation of 50 m near Gopalpur. It was observed that the impact of the storm surge due to Phailin was subdued due to low tide conditions (neap tide–moon at first quarter) during landfall. A field survey using GPS techniques was done within a few days of landfall for obtaining inland inundation data.

Endnote

ESSO-INCOIS continues to upgrade its forecasting system as regards accuracy, spatial and temporal resolution, with newer operational models. Steps towards assimilating observed real-time data in the numerical forecast models are underway; this will significantly improve the accuracy of forecasts. ESSO-INCOIS is also increasing automated coastal and offshore observation systems with real-time data transmission capability. Argo profiling floats, ship mountable real-time automated weather stations, deep sea moored and a coastal wave rider buoy network are components of this observation system in addition to satellite- derived data. The latest information and communication technology is deployed to ensure quick dissemination of weather-related information to users. GY

The authors are Scientists and Director, respectively, from Earth System Science Organisation-Indian National Centre for Ocean Information Services (ESSO-INCOIS).
bala@incois.gov.in